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The Soviet Space Station: Evolving Objectives, Production Requirements, and Resource Demands

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A Research Paper

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The Soviet Space Station: Evolving Objectives, Production Requirements, and Resource Demands [redacted] 25X1

A Research Paper

This paper was prepared by [redacted] 25X1
Office of Soviet Analysis, with contributions from
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of Scientific and Weapons Research. [redacted] 25X1

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The Soviet Space Station: Evolving Objectives, Production Requirements, and Resource Demands

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Summary

Information available as of 18 November 1988 was used in this paper.

Since March 1987 the Soviets have maintained the first continuously manned space station, the Mir, in orbit. According to the Soviets, it is a prototype of a modular-design space station, already dubbed Mir II in the press, that will be assembled in orbit in the mid-1990s. This continuous presence in near-Earth orbit gives the Soviets the opportunity to perform iterative experiments that could speed scientific breakthroughs applicable to civilian programs, lead to improved intelligence collection systems, and, in the long term, examine phenomena in support of strategic defense programs. The success of the space station program as a showcase for Soviet science and technology could also contribute to Moscow's campaign to develop long-term cooperative agreements with West European countries and Japan. 25X1

Objectives

Soviet spokesmen have said that Moscow's most important economic and technical objective for the program is the eventual industrialization of space. As their literature indicates, the Soviets currently are experimenting with methods to produce materials such as electronic components, superstrength alloys, and ultrapure biological preparations that could have both military and civil applications. These experiments may give way to pilot production when a special materials-processing module is delivered to the Mir in the early 1990s. 25X1

The Soviets probably hope that their extensive and widely publicized program in materials production research will lead to commercial and scientific research agreements with Western governments and firms that currently have no other long-term access to Earth orbit for experimentation. As of late 1988, for example, a US firm and several West European companies had signed contracts for small experiments on the Mir. Further successes would allow Moscow to expand its space-related commercial and scientific relationships with the West. 25X1

[redacted] 25X1

The Soviets clearly view the space station program as a source of international prestige, and they are quick to contrast the "peaceful" nature of their space activities with what they interpret as US attempts to use space for military advantage. Nonetheless, the USSR's program also serves military objectives. [redacted] Soviet publications on space materials experiments indicate that cosmonauts have carried out sensor research and tested equipment for deployment on unmanned space systems. We expect such military-related research to continue. [redacted] 25X1

The Soviet Road to Space

The Soviets have followed a cautious, evolutionary approach to the design of succeeding generations of space vehicles. Most Soviet spacecraft have adapted off-the-shelf components and subsystems where possible and have been built using a modular approach to simplify assembly. This strategy is a product of program history, the limitations of Soviet technology, and management practices that emphasize scheduled production over innovation. [redacted] 25X1

This evolutionary approach has helped the Soviets limit the cost of the program. Our analysis indicates that the manned space program accounted for about 2 percent of overall expenditures for military procurement and operations in 1987 and about 25 percent of the USSR's total space budget, shares that have been relatively constant since the program's inception. Deployment of the next-generation Mir II space station in the mid-1990s will lead to somewhat higher expenditures. If they decided to launch the entire Mir II complex in one year, the Soviets could face a short-term increase of up to 10 percent in annual space program costs. [redacted] 25X1

Prospects

The Mir II space station and its support craft will require more advanced, technologically demanding designs and production practices than the current generation of manned spacecraft. Because of its greater size, as compared with the current station, the Mir II will require, among other things, a more complex attitude control system and more electric power than present Soviet solar cells can supply. [redacted] 25X1

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To support the Mir II, the Soviets have produced a reusable shuttle orbiter and the SL-X-17 Energiya space launcher. A successful shuttle program would allow the Soviets to transport large cargoes to the space station and return complex equipment, experimental products, and manufactured items to Earth. The Energiya can carry either unmanned payloads of up to 120 metric tons or the shuttle with a 30-metric-ton payload—about the same as the US shuttle. In comparision, the SL-13, currently the Soviets' largest operational booster, has a 20-metric-ton capacity [redacted] 25X1 25X1

[redacted]

Soviet successes in developing commercial and scientific ties to Western governments and firms also could give the USSR access to space-related Western technology and research findings not otherwise available or restricted by the Coordinating Committee on Multilateral Export Controls (COCOM) accords. Indeed, Soviet proposals for joint space projects with US scientists have included requests for integrated circuits, computer software, and US scientific equipment. Austrian and French cosmonauts will leave equipment and materials on the Mir, including a panel of composite materials the French are studying for use in their own spacecraft. [redacted] 25X1

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The Soviet Space Station: Evolving Objectives, Production Requirements, and Resource Demands [redacted] 25X1

Program Objectives

For the Soviets, the space station program promises potentially significant economic and scientific benefits. General Secretary Gorbachev also underscored its importance to the USSR's international prestige in 1987, when he described manned space as a triumph of Soviet science and the socialist system, and as proof that the USSR did not have to go abroad, "hat in hand," for advanced technology. We believe that the Soviet leadership is acutely aware that its Mir space station is one technological accomplishment, aside from military hardware, that Moscow can hold up as an example to the world—and one that it will exploit through public diplomacy. [redacted]

[redacted]

The Direct Economic Benefits

Soviet spokesmen say their most important economic and technical objective is the eventual industrialization of space, including materials processing, manufacturing, power generation, and the assembly of large structures in orbit (see table). The Soviets recently announced that, by the early 1990s, a special module would be docked with the Mir station to serve as a "minifactory" for smelting semiconductors. The station already contains an enlarged and improved Korund furnace, which TASS called a "pilot plant" for further research in this area. Thus, current experiments on Mir may mark the beginning of the transition from basic research on materials processing to actual production, with cosmonauts aboard the station performing the periodic servicing required. A reasonable volume of delicate materials or even complete modules that needed refurbishment could be returned using the shuttle orbiter. [redacted]

Several Western companies and scientific experts concur with Soviet assessments of the economic potential of space manufacturing. According to US business publications, at least 20 companies are ready to experiment in orbit on ways to create new alloys, develop thin films for coatings, and grow semiconductor and protein crystals more efficiently than is possible on Earth. Ten US companies are offering payload devices, microgravity research technology, and a commercial space station for the early 1990s. [redacted] 25X1

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Soviet spokesmen and press reports maintain that remote sensing of natural resources from the space station has already saved millions of rubles per year. In the fall of 1988, [redacted] 25X1 [redacted] a Soviet scientist said that the Mir and its 25X1 predecessors contributed to a national Earth resources network that provided data to the fishing fleet. One press report claims that the Central Asian republics had used space photography from Salyut 7 for planning land use and environmental protection measures and that Soviet geologists regularly used other cosmonaut photography in minerals exploration. [redacted] 25X1

Some Soviet critics, however, believe that the economic benefits of the manned program have, to date, been overstated. In the fall of 1987, for example, General Shatalov, chief of cosmonaut training, said that no one had followed up on promising results from experiments on the space station and that significant space manufacturing would not begin until the year 2000 because the pace of development was so slow. V. S. Avduyevskiy, a leading space scientist, said in September 1987 that work on space materials processing was too unfocused. Lt. Gen. Kerim Kerimov, Chairman of the State Commission for Flight Tests of

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Space Station Experiments With Materials Processing

	Civilian Application	Military Application
Gallium arsenide	High-performance semiconductors for ultra-high-speed integrated circuits	Radiation-hardened electronics
Mercury cadmium telluride	Infrared detection and thermal imaging	Missile launch detection and infrared imaging
Cadmium sulfide	Ultraviolet detection and ultraviolet imaging	Missile launch detection and ultraviolet imaging
Organic and polymeric crystals	Optical computers	Optical computers
Superalloys	High-strength materials	Aircraft and spacecraft parts
Ultrapure proteins, enzymes, and hormones	Vaccines and chemical analysis of biological substances	Biological warfare agents

Note: These selected experiments illustrate the range of Soviet materials-processing activities on Salyuts 6 and 7 and on Mir as described in Soviet open publications.

[redacted] 25X1

Manned Space Complexes, said in late 1987 that valuable research in materials, biotechnology, and remote sensing of natural resources was not finding practical application for lack of a coherent policy. In our view, these complaints reflect space officials' frustrations with longstanding Soviet difficulties in translating scientific research into successful programs. [redacted]

Building a Market for Space Services

Moscow's unprecedented openness about its manned program has provided opportunities not only to demonstrate Soviet technological accomplishments but also to build long-term relationships with the West. Soviet representatives have offered the Mir space station for international cooperation in many scientific fields. Westerners have visited the Tyuratam launch complex in Central Asia. The Soviets have released extensive technical details about spacecraft missions and capabilities and have invited the United States to join in a long-term project to send a manned mission to Mars. [redacted]

A new organization, GLAVKOSMOS,[1] claims to be responsible for arranging all outside participation in the Soviet space program. It has been offering civilian satellite photography and access to the Mir's research facilities in return for hard currency. As of late 1988, the Soviets had contracted with a US firm and five West German firms to run small experiments on the Mir, and the European Space Agency agreed in July 1988 to fund microgravity experiments. These initial successes could lead, at least from the Soviet perspective, to the sale of more lucrative and technologically promising space services, including satellite launching and the sale or lease of Soviet communications satellites. [redacted] 25X1 25X1

Access to Western Technology

Such commercial and scientific agreements would give the Soviet Union opportunities to obtain space-related Western equipment or research data not otherwise available. [redacted] 25X1 25X1 For example, Soviet scientists have offered the Mir for international research on superconductors. 25X1 In discussions with US counterparts about space cooperation, other Soviet scientists asked their US counterparts to provide an extensive list of items for possible joint projects, including integrated circuits, computer software, and US scientific instrumentation and equipment. French and Austrian cosmonauts will 25X1

[1] Formally the Main Administration for the Creation and Use of Space Technology for the National Economy and Scientific Research. [redacted] 25X1

supply their own equipment, which will remain on the Mir, including a range of composite materials that the French are considering for use in their own future spacecraft. We believe many of these proposed transfers involve items currently restricted by COCOM understandings.

A Propaganda Weapon

General Secretary Gorbachev is also apparently intent on using what he believes is a Soviet lead in civil space activities to compete with the United States on the public diplomacy front. Moscow has been quick to contrast what it regards as US attempts to use space for military advantage with the Mir's alleged peaceful nature. A Novosti news agency analysis released in the fall of 1987 said, for example, that the Pentagon regarded the proposed US space station as a potential platform for repairing and refueling "Star Wars" weapons, converting space debris into decoy targets, and preparing for intelligence operations and battle management in the event of hostilities. In contrast, the Soviets characterize their program as dedicated exclusively to scientific research, international cooperation, and economic activities such as remote sensing and space manufacturing.

The Military Connection

Despite Moscow's propaganda, the space station program serves Soviet military goals as well. The Ministry of Defense, the Air Forces, and the Strategic Rocket Forces participate in every phase of space vehicle production and mission planning. Soviet publications on space materials experiments indicate that the space stations have carried out sensor research and tested equipment for deployment on unmanned intelligence collection systems.

The cosmonauts' long-term research program in areas with potential strategic applications is the product of changing Soviet perspectives on the military potential of manned space activities. Soviet writings from the late 1960s and early 1970s indicate that theoreticians were briefly interested in using manned space platforms for reconnaissance, targeting, and warning to support earthbound military operations in response to alleged US plans to do the same.[2] By the mid-1970s, however, following extensive experience with manned spaceflight and effective unmanned reconnaissance and early warning satellites, the Soviet military leadership came to believe that cosmonauts can be used 25X1 most effectively for systems development and long-term research with potential application to strategic missions, rather than for support of earthbound military operations. 25X1

Evolution of the Soviet Manned Space Program

Since the mid-1960s the Soviets have pursued a cautious, evolutionary approach to the design and production of space stations and their support craft. Using analyses of the technical characteristics of Soviet spacecraft and Soviet publications on spacecraft engineering and production, we have identified some key characteristics:

- Because the design bureaus give first priority to meeting performance standards and timetables, they adapt as many components as possible from 25X1 other spacecraft. Frequently, spacecraft produced at the same time for different missions share many subsystems, such as propulsion or life support.

- Most spacecraft have distinct modular sections for payload, guidance, propulsion, and other support systems. Soviet publications on spacecraft engineer- 25X1 ing claim this modular approach makes subsystems 25X1 interchangeable, simplifies assembly, and holds down costs.

- Most spacecraft are assembled in groups, with 25X1 modifications introduced into successive units until 25X1 the potential of a given design is fully exhausted and technical issues requiring a new design arise.

[2] In the 1960s and early 1970s, Soviet authors frequently quoted US debates over the military potential of the Manned Orbiting Laboratory, canceled in the 1960s, and later over the Skylab space station. As recently as 1983, a Soviet publication accused the United States of setting up a space command to run a manned orbiting weapons platform and to take advantage of space as a future theater of military operations. 25X1

- All new systems and components are thoroughly tested before they become operational and before functioning predecessors are retired. [redacted] 25X1

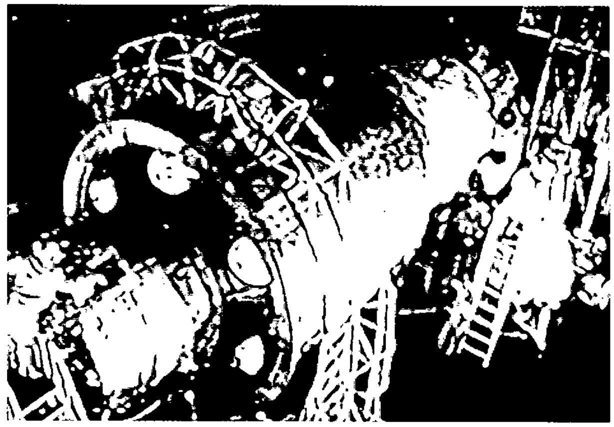
This strategy is a product of program history, the limitations of Soviet technology, and management practices in the defense industries that design and build spacecraft (see inset and figure 1). The Soviets have developed support craft—the Soyuz crew ferry and the Progress cargo ship—and space stations with their expansion modules as two families of vehicles, each with long-term mission requirements. Each new generation of support vehicles or space stations has introduced new hardware designed to meet those requirements progressively (see pocket chart at end of this paper). [redacted] 25X1

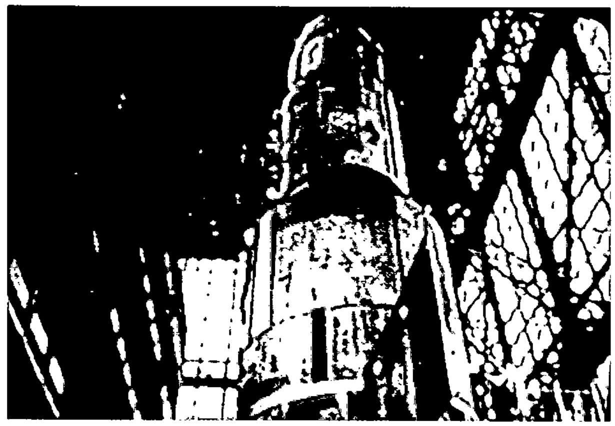
[redacted] the USSR decided to concentrate on space stations after Khrushchev's abortive attempt to engage the United States in a race to send men to the Moon. The United States quickly established a clear lead, while a crash Soviet project to develop the SL-X-15, a heavy launcher needed to send manned spacecraft into lunar orbit, failed. Reports from West European and US journalists indicate that, after the fall of Khrushchev, Sergei Korolev, the space program's founding designer, convinced Brezhnev to back orbital stations as a better approach to examining the feasibility of extended manned space missions. [redacted] 25X1 25X1 25X1

Support Craft

The Soyuz vehicle family was the first step in developing a capability for extended manned orbital missions. According to a Soviet biography, Korolev began to design the original Soyuz for independent three-man orbital missions in 1964. By docking in orbit and exchanging crews in January 1969, Soyuz 4 and 5 demonstrated the capability to perform the basic maneuvers needed to build and resupply a space station. Subsequently, according to Soviet publications, the Soyuz became a crew ferry. The T and TM versions of the Soyuz introduced updated navigation, power supply, propulsion, and guidance systems. In

Managing the Program





Interior views of manned spacecraft assembly line [redacted] 25X1 25X1

With oversight from the armed forces and requirements from the Ministry of Defense (MOD), the Soviet Union's defense-industrial ministries design and manufacture all craft for the space station program. The Politburo determines space policy, but the Military Industrial Commission (VPK), a committee of the Presidium or inner cabinet of the

Council of Ministers, has the final say on space-related production issues. The VPK staff resolves any differences that may arise among the MOD, the armed services, and the defense-industrial ministries. Once the basic vehicle becomes operational, GLAVKOSMOS coordinates the requirements of Soviet scientific institutions and foreign customers for mission profiles and instrumentation packages. [redacted]

The armed forces and the MOD have the same oversight role for space as they have for other aspects of Soviet research and development. According to press reports, the military also plays a direct role in flight-testing and mission planning. Soviet press articles indicate that Air Force Lt. Gen. Kerim Kerimov is head of the State Commission on Flight Tests of Manned Space Complexes—the organization responsible for approving ground tests, flight plans for manned missions, research projects on the space stations, and cosmonaut selection. [redacted]

Senior management controls production through a highly structured process—the Unified System of Design Documentation—which prescribes how projects move from applied research through production and deployment. Because these procedures are similar throughout the defense-industrial complex and take approximately 10 years to complete, we can use fragmentary information to forecast when a system will be deployed or to determine when development began. [redacted] *the major milestones for the development of a new manned craft are:*

- *Project approval, which initiates the design of a prototype.*
- *Completion of subscale and full-scale prototypes, which are probably used to check the overall design and plan the production line.*
- *Factory testing of a prototype craft at the Chelomey Design Bureau's facilities at Reutov and Faustov outside Moscow.*
- *Unmanned flight-testing.*
- *Initiation of regular production of craft.*
- *Initial operating capacity, followed by the progressive introduction of improvements until the full capabilities of a design are realized.* [redacted] 25X1 25X1

The Chelomey and Glushko Design Bureaus, operating under the First Chief Directorate of the Ministry of General Machine Building, one of the nine defense-industrial ministries, design and build all space-station-related craft except the shuttle. [redacted] 25X1 [redacted] *the two design bureaus operate like US aerospace companies, serving as integrating contractors and frequently sharing responsibility for a final product.* [redacted] 25X1 25X1

[redacted] *the two bureaus have complementary roles. The Glushko Design Bureau is apparently the senior organization for manned spacecraft, with particular responsibility for life-support systems under former Cosmonaut Konstantin Feoktistov, identified in Soviet publications as Chief of the Life Support Division and one of the creators of the Salyut.* [redacted] 25X1 25X1 *Chelomey assembles the Salyut and Soyuz families of spacecraft, probably at the Fili 23 plant in the Fili suburb of Moscow. One emigre report, however, also points to Chelomey's Reutov complex as the final assembly point.* [redacted] 25X1 25X1

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1978, designer P. K. Feoktistov, a former cosmonaut, developed the Progress unmanned resupply vehicle from the Soyuz by replacing the crew compartment and life support systems with cargo space and propellant tanks. [redacted]

Space Stations

[redacted] the Soviets began to design their first station, the Salyut, in the mid-1960s in parallel with work on the Soyuz. By the late 1960s the Soviets were designing and testing a space station life support system and were training cosmonauts. In 1968 they completed a yearlong ground test of the Salyut's life support system, as shown in a Soviet film released in the early 1970s. A team of cosmonauts using the first Soyuz configured as a crew ferry visited Salyut 1 in near-Earth orbit in 1971. [redacted]

The Soviets have used three mission profiles to develop their design for a space station. Salyuts 1 and 4 pursued primarily civilian research, while Salyuts 3 and 5, with a somewhat different design, conducted primarily military research using all-military crews. Salyuts 6 and 7 and the Mir are a civilian/military series with mixed civilian and military crews and a correspondingly diverse research program. Salyut 2, which had the military design, was never manned. Valentin Glushko, the leading Soviet spacecraft designer, says that Salyut 6 was the first fully operational space station because its forward and aft docking ports could accommodate Progress and Soyuz craft simultaneously for periodic resupply and crew rotation. [redacted]

Expansion Modules. The Soviets introduced the multipurpose Cosmos 929 series spacecraft in 1977. This series can serve as an expansion unit for a space station; a space tug for interorbit transfers; a means to return cargo and, possibly, a crew to Earth in its reentry module; and, possibly, an independent manned or unmanned freeflying vehicle. The reentry capsule on the freeflying version could be shielded to enable it to fly manned at higher latitudes or altitudes where radiation is more intense. We believe the series became operational in 1982 when a cargo version docked with Salyut 7. [redacted]

Mir, the Prototype Modular Station. According to the Soviet press, the Mir, launched in February 1986, is a prototype modular space station. Mir's core unit consists almost entirely of the onboard computer and control section, living quarters, and docking adapters 25X1 capable of receiving up to five specialized expansion units in addition to the Soyuz and Progress support vehicles. Modules for additional crew accommoda- 25X1 tions, power, remote sensing of natural resources, 25X1 space manufacturing, and biomedical studies will be docked with the core unit or maintained in nearby orbits (see figure 2). [redacted] 25X1

The Next Generation of Spacecraft: Crossing a Technical Rubicon

The next-generation space station and its support craft require more advanced, technologically demanding designs and production practices than does the 25X1 current generation of manned spacecraft. A reusable Soviet shuttle orbiter is now entering intensive flight-testing. It will be needed to support Mir II's bigger crew and the new station's larger scale research and space manufacturing by delivering and returning delicate cargoes. Given its more demanding mission profile, the shuttle orbiter probably requires production methods more typical of advanced aircraft, such as rigorous quality control and precision manufacturing. Its similarity to its US counterpart indicates the Soviet orbiter probably incorporates advanced technologies such as computer-driven control systems and special alloys (see figure 3). [redacted] 25X1

We will not be able to determine how successfully the Soviets have adapted their design to the capabilities of 25X1 their defense industries until the shuttle orbiter has made several space missions. The aircraft industry has failed dramatically with advanced designs in the past. An early version of the Flanker fighter disintegrated in the air, and the TU-144 supersonic airliner was grounded after serious weaknesses in its titanium structure remained uncorrected. [redacted] 25X1

Moscow is also flight-testing the SL-X-17, or Energiya, its first space launcher to use a high-energy cryogenic propellant combination—liquid hydrogen

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Figure 2
Projected Completed Mir Space Station

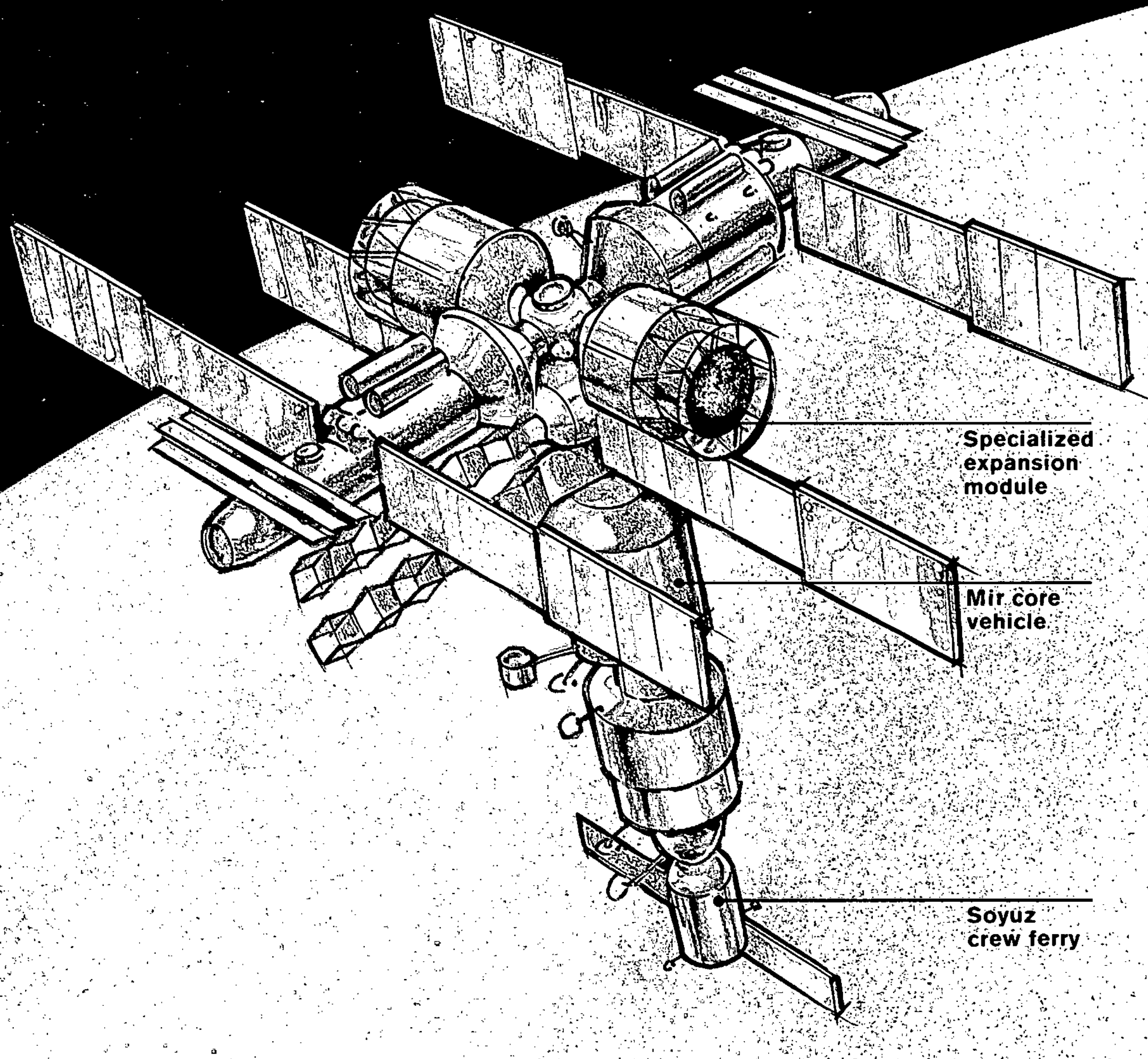

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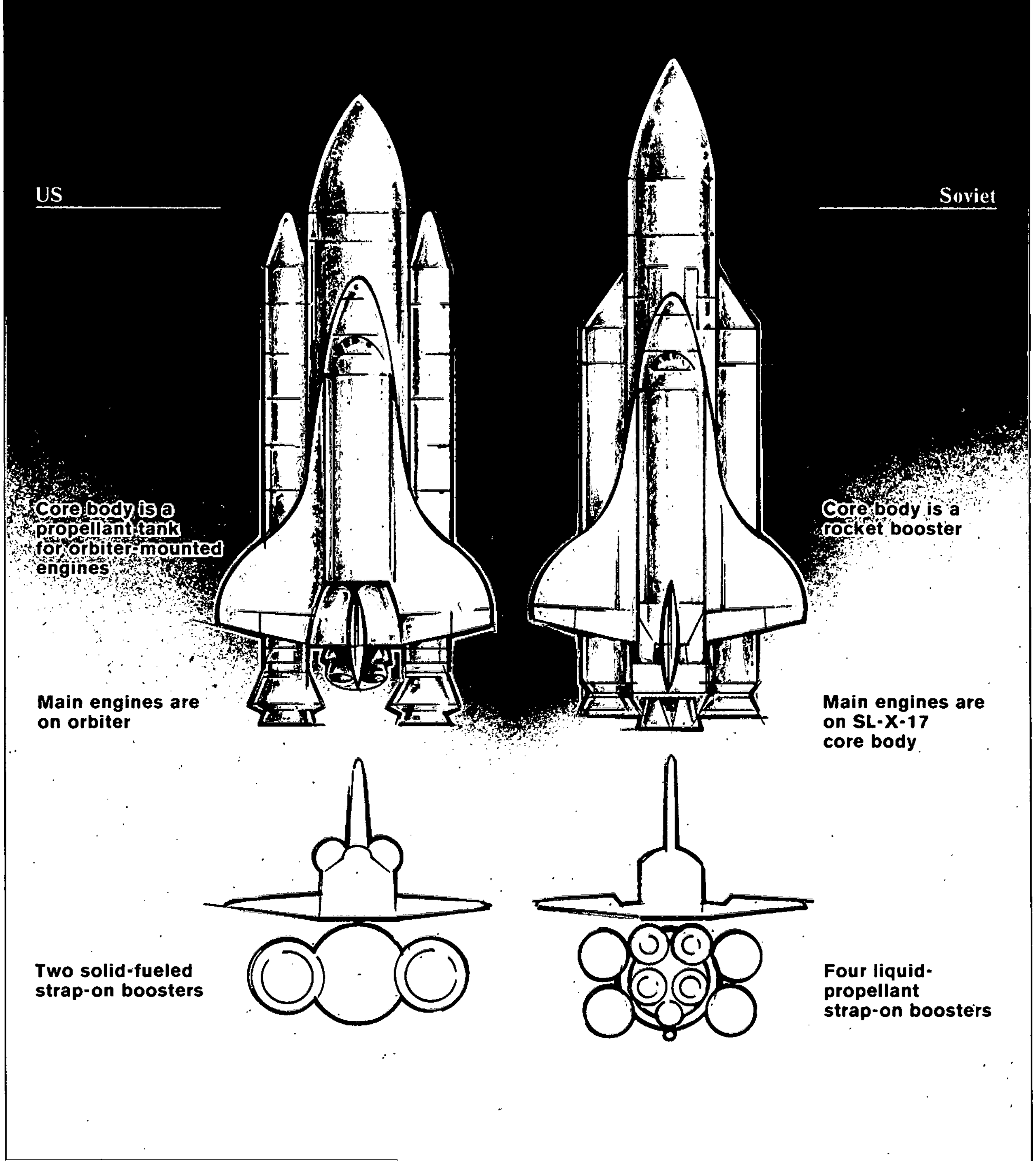
Figure 3
Comparison of US and Soviet Space Shuttles



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(see figure 4). Energiya can carry either the shuttle orbiter with about a 30-metric-ton payload or unmanned payloads of up to 120 metric tons, compared with the 20-metric-ton capacity of the largest operational Soviet booster, the SL-13.[3] A published Soviet description of the SL-X-17 launcher claims that new materials, such as special aluminum and titanium alloys and thermal protection coatings, make up more than 70 percent of the Energiya's unfueled weight. The first shuttle flew unmanned in mid-November 1988, one month after an unsuccessful attempt [redacted] 25X1

According to Soviet press reports, the Mir II station will be launched in the mid-1990s and assembled in orbit from one or more 100-ton core modules. We believe that this project will also probably require the use of more advanced technology and production practices. Because of its greater size, as compared with the current Mir, the new station will require more electric power than current Soviet solar cells can supply and a more complex attitude control system (see figure 5). The Soviets' experience in operating the current Mir space station could also lead to design changes requiring more advanced materials, operating subsystems, or electronic components. [redacted] 25X1

The Resource Commitment

The evolutionary approach to spacecraft development and deployment has helped the Soviets hold down the costs of the program. Our analysis indicates that the space station program accounted for about 2 percent of overall expenditures for military procurement and operations in 1987, and about 25 percent of the USSR's total space budget (see figure 6). Since the inception of the space program, this share has remained, on the average, fairly constant.[4] Moscow will probably not face any major increases in the cost of

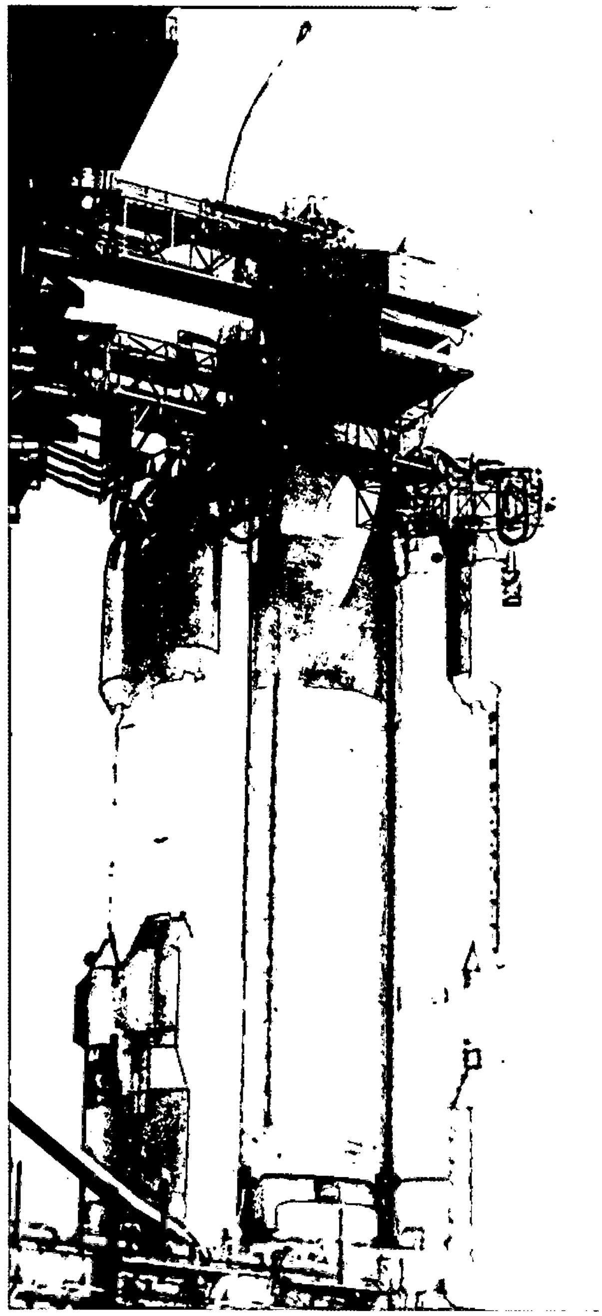

Figure 4. SL-X-17 launch vehicle (Energiya). [redacted] 25X1

[3] The US shuttle can carry approximately 30 metric tons into near-Earth orbit, while the Titan IV expendable launcher, being developed for the Air Force, will have a payload capacity of approximately 18 metric tons. [redacted]

[4] All references to costs and spending in this paper refer to ruble outlays, which reflect Soviet resource scarcities and indicate the burden on the Soviet economy [redacted] 25X1

Figure 5
Conception of the Large Modular Space Station (Mir II)

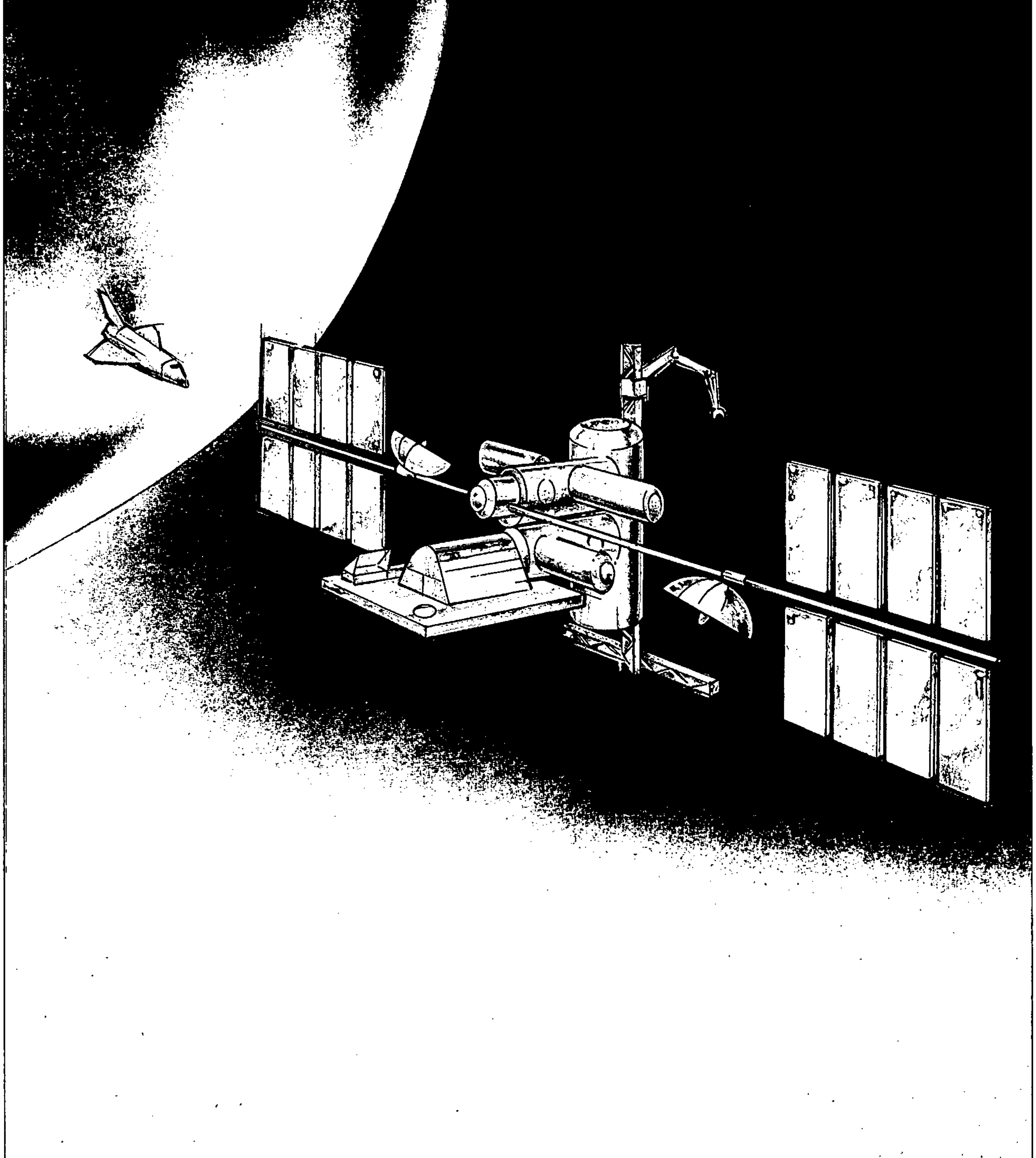

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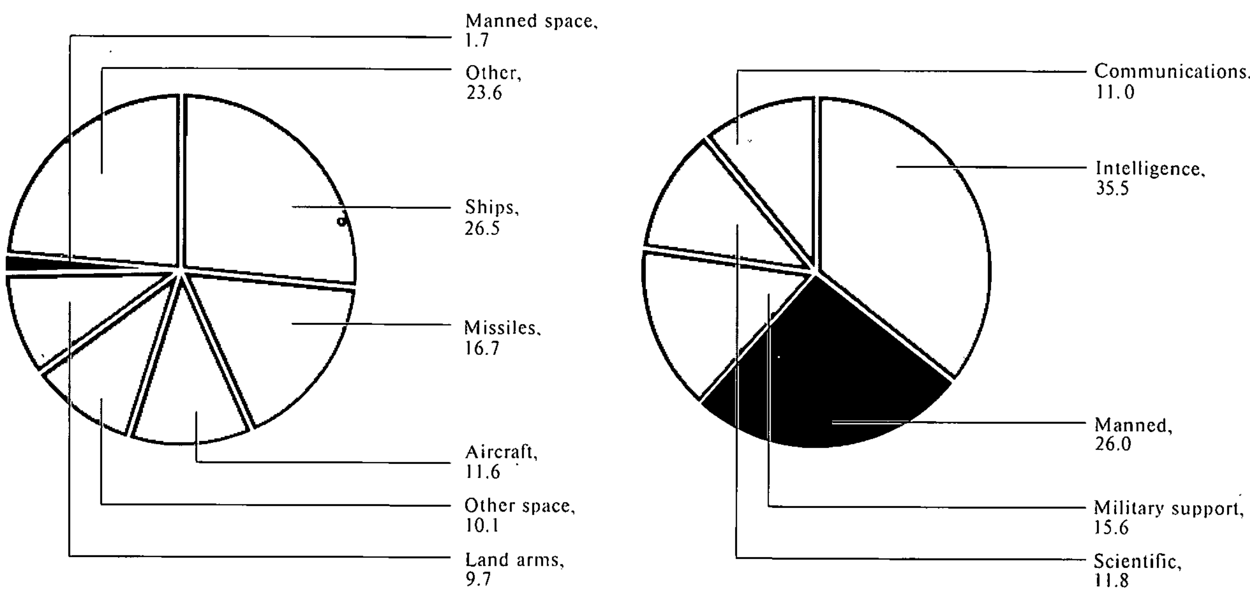
Figure 6
Estimated Soviet Space Program Outlays, 1987

Costs compared with outlays for military procurement, operations, and maintenance[a]

Percent of defense budget

Expenditures as share of total space procurement

Percent



[a] Excludes research, development, testing, and evaluation costs.

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the program until it deploys the Mir II space station in the mid-1990s because it has already made major investments in launch vehicles and the shuttle orbiter. By the mid-1990s the Soviets will have to choose between accepting a short-term increase of up to 10 percent in annual manned space costs by deploying the Mir II quickly or holding annual cost increases to a more modest level by deploying the station components gradually. [redacted]

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Research and Development

We estimate that R&D costs for the space station program will remain fairly constant until the mid-1990s. Increased spending on the large Mir II modular space station and on a possible follow-on to the shuttle orbiter will probably offset spending declines in current programs. Using contractors' estimates for the development costs of each craft and our reconstruction of the project management process, we found that R&D spending for the Soyuz and Salyut peaked in the mid-1970s, while spending on the shuttle orbiter and the SL-X-17 launcher peaked in the mid-1980s. Between 1965 and 1987, space-station-related craft accounted for 25 percent of total space program R&D spending. The SL-X-15, the abortive bid to develop a launcher in the 1960s for the manned lunar program, and the SL-X-17 are the two most expensive development programs in the history of Soviet manned space. [redacted]

R&D spending on newer programs will probably increase, but we have too little information to estimate future levels. Mir II, the large modular space station, will be the first of the new systems to be deployed. We believe the overall design will be an evolutionary development from current hardware, but Mir II's greater size, as already indicated, will require improved power supplies, attitude control systems, onboard computers, and other subsystems. [redacted]

Beyond Mir II, we can only speculate on projects in early stages of development. The Soviets could follow growing US and West European interest in a transatmospheric vehicle capable of flying a payload into orbit from a conventional runway. A manned mission to Mars early in the next century, also mentioned repeatedly in Soviet forecasts, will require extensive R&D, but program engineers are probably just beginning to examine preliminary design concepts. [redacted]

Procurement Costs

In 1987 the space station claimed about 25 percent of the USSR's total spending on the procurement of space vehicles and launchers, second only to intelligence collection satellites. Manned spacecraft cost more than unmanned satellites on a per-unit basis because they must be built to greater precision, are more complex, and have additional subsystems for life support and safety. Annual Soviet spending on unmanned satellites is higher, however, because more are built. Soviet unmanned systems generally have short lifetimes and are frequently deployed in multisatellite networks. [redacted]

We believe that production of the Salyut- and Soyuz-class spacecraft has kept pace roughly with the frequency and duration of the cosmonauts' missions, with a few additional spare crew ferries and cargo carriers provided for safety. Our analysis indicates that between 1965 and 1987 the Soviets launched 189 Soyuz and Progress vehicles but probably built a total of 196. They also launched 16 space-station-class vehicles, including the Cosmos 929 series craft, but probably built one additional spare. [redacted] 25X1

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Our analysis also indicates that the Mir II could make the space station program the single most expensive item in the Soviet space budget by the 1990s. The Soviet shuttle orbiter is probably several times more expensive per unit than the original Soyuz crew ferry because it is larger, reusable, and based on more advanced aerospace technology. Its booster, the SL-X-17, is far more expensive than the SL-4 used for Soyuz because it is much larger, more complex, and uses cryogenic propellants. Depending on the number of core units it contains, the Mir II large modular space station and its requisite SL-X-17 launch vehicles could account for as much as 10 percent of annual Soviet spending on space-related procurement in the middle-to-late 1990s. [redacted] 25X1

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Operations Costs

We estimate that the space station accounted for approximately 25 percent of Soviet space operations costs in 1987, which include expenditures for launching and maintaining space systems in orbit. For the manned program, these costs include not only the actual launches of spacecraft but also the costs incurred during missions, the costs of the supplies carried on Progress cargo craft, and ongoing expenditures to replace parts and to maintain the Mir space station in orbit. In 1988, for example, the cosmonauts replaced elements of the station's guidance system after a failure caused the Mir to tumble uncontrollably for a short period. [redacted] 25X1

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The growing length of manned missions accounts for the fact that operations costs have been equivalent to approximately 75 percent of procurement costs since

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the late 1970s. These costs will probably increase once the reusable orbiter begins flying regular missions during the 1990s. More extensive use of the SL-X-17 will raise costs because the system is more expensive to use on a per-launch basis than the older SL-4 and SL-12/13 launchers, which are currently the mainstays of the manned program. 25X1

Facilities

The space station program apparently did not require continuing investments in design and production facilities until the shuttle orbiter program began.

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Outlook

The Future of the Space Station Program: Three Scenarios

In the mid-1990s, policy and technological considerations will be more important than cost in determining how the Soviet Union's manned space program evolves. Gorbachev's statements indicate that the leadership assigns high priority to the program because of its political, technological, and economic potential. At Tyuratam in 1987, Gorbachev cited manned space as an example of technological leadership for the entire economy, and particularly for the critical machine-building sector. GLAVKOMOS's energetic campaign to sell space services aboard the Mir and the relentless optimism of the Soviet press about the program's benefits are other indications that the leadership believes the space station is a net economic plus. Moreover, space is a relatively modest item compared with weapon programs, such as land arms or missiles, or the overall Soviet military budget.

Nonetheless, we believe the Soviet leadership will take cost into account in planning the future pace of the space station program. Mir II, which includes the shuttle orbiter and the SL-X-17 booster, will be the single most expensive space project in the 1990s. The annual rate of growth in that cost will, we believe, be a function of technical developments and policy choices. To assess the factors that will probably influence the leadership's decisions, we have constructed three scenarios for the deployment of this new and larger space station, each resting on the following assumptions:

- The Soviets have not fixed a deployment schedule for the Mir II. Our scenarios represent general courses of action they may adopt, on the basis of technical, political, and economic considerations.

- The Soviet leadership will attempt to match resource commitments to potential benefits in making decisions on the space station program. The program has strong support but no "blank check" because the leadership's overall commitment to industrial modernization places all procurement activity, except the most essential military projects, under scrutiny.

- To reduce the risk of introducing a new system, the Soviets will continue to rely on their existing space station and its support fleet until Mir II and the shuttle orbiter, which they need to maintain it, are fully proved.

- We have assumed the largest possible size for the Mir II in order to measure the project's greatest potential impact on resource allocation and spending. The Soviets, however, have probably not determined the final design because they want more experience in operating the current Mir, which they have described as a prototype for future large modular space stations. According to Soviet statements as of the fall of 1988, the larger station could consist of one to three core units, each weighing as much as 100 tons.

- The launch vehicles would be built over a three-year period and the payloads over a two-year period in keeping with the normal practice in the Soviet space program. 25X1 25X1

Evolutionary Deployment Scenario: The Most Likely Choice. The Soviets will probably assemble the Mir II in orbit gradually by launching one core unit per year beginning in the mid-1990s. They will probably keep the current space station operational until its replacement is certified for manned operation. This approach would continue the Soviet practice of not replacing a current generation of manned spacecraft until the successor is fully proved. The Soviets would have more time to practice operational missions with their shuttle orbiter before the vehicle becomes essential to maintaining the next-generation space station. 25X1

Delayed Deployment: An Alternative. Unexpected technical problems could delay the program. Mir II core units must be launched with the SL-X-17 booster, which has made only one partially successful flight. If the shuttle orbiter developed serious problems during its spaceflight testing program, it might not be operational in time to assist in the assembly in orbit of the new station, or to ferry the products of space manufacturing and other delicate payloads. The Soyuz TM and the Cosmos 929 reentry modules are not capable of making sufficiently soft landings and can carry only small payloads. We will obtain our first indication of the Mir II's schedule from the timing of the shuttle orbiter's first attempt to deliver a payload into space: the later this mission takes place, the later the deployment schedule will be for the Mir II

If the Soviets encounter difficulties in developing pilot production processes for space-based manufacturing, they might have less of an incentive to deploy a larger space station rapidly. Space scientists' critical statements about the slow pace in commercializing space-based manufacturing as well as an increasingly indefinite timetable for delivering a materials-processing module to the current space station suggest the Soviets may already be having problems with industrial processes or equipment design

Early Deployment: The Least Likely Choice. Several factors could convince the Soviets to accelerate the deployment of the Mir II space station by launching as many as three core units in a single year, possibly in 1993. Moscow might decide it needs a larger space station to provide a platform for expanding its military-related research or hardware development programs, possibly in response to US actions. A new orbital station might also provide a space spectacular to compete with a revived US program. The Soviets might also want to accelerate space manufacturing or take advantage of opportunities to sign up Western participants in commercial and scientific ventures. We believe the Soviets will have enough SL-X-17 launchers to respond to any of these imperatives.

Soviet development practices and statements indicate that early deployment is unlikely. Soviet statements about the schedule for delivery of specialized modules to the Mir also suggest that the current station will be operational at least through the mid-1990s. The Soviets have generally preferred to evaluate performance data on prototype systems, such as the Mir, before designing or building the next generation. 25X1

Cost Implications. Each of these scenarios implies a different profile of the annual costs of the space station program in the 1990s (see figure 9). In the long term, program costs for each of the options are the same, but, in the short term, the burden will vary:

- Early deployment of Mir II, which in the extreme case could involve launching all three core units in one year, could increase annual spending on space by 10 percent and spending on the space station program by more than 50 percent during 1991-93. 25X1

- Evolutionary deployment would lead to fairly small annual increases in the total cost of space spending and of the space station program.

- Delayed deployment, which could involve one launch per year after 1994, would simply shift a small annual increase in space spending and space station program costs into the future. 25X1

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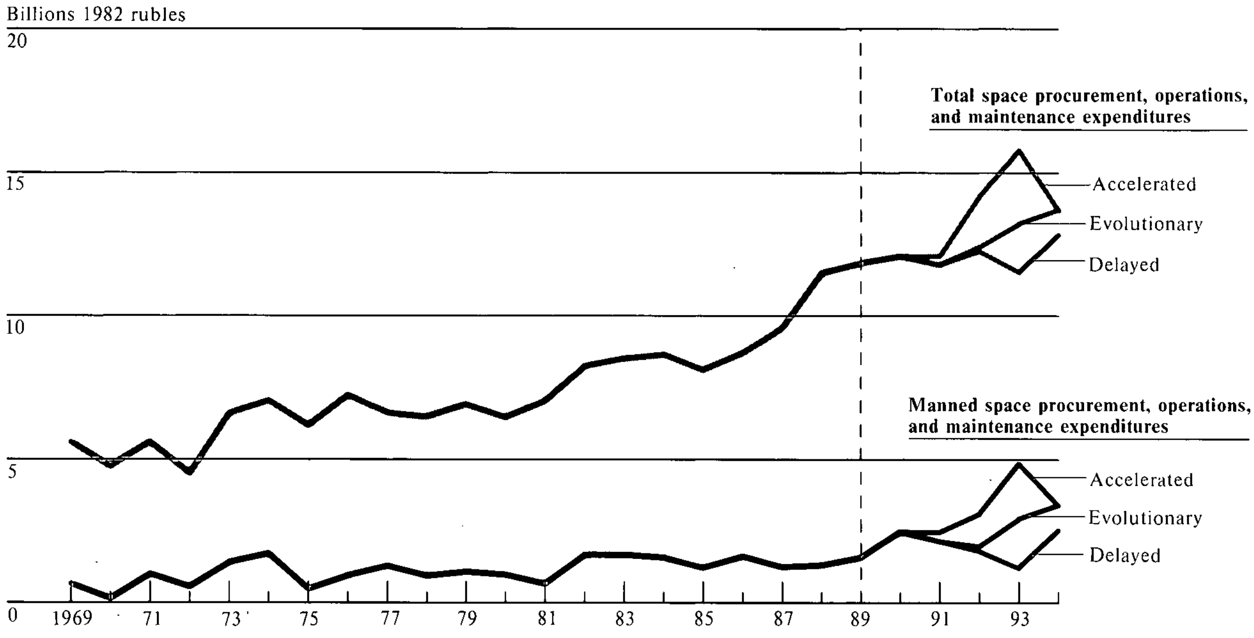
Implications for the United States

By the early or middle 1990s, the Soviet space station program could well attain a number of its objectives, with varying effects on US national security and foreign policy:

- Research aboard the Mir could lead to breakthroughs in technologies with civilian and military applications. A continuous presence in space gives the Soviets a unique capability to perform long-term research. Researchers with minimal cosmonaut training could work more easily on Mir II than on the current space station. Space-based experiments and pilot materials production could lead to improved sensors for intelligence collection or for countermeasures to a US strategic defense system. As their own literature indicates, the Soviets are attempting to make materials such as 25X1

Figure 9
Estimated Cost of Projected Mir II Deployment



Note: Delayed deployment indicates that launches will not occur until after 1995. Evolutionary deployment represents launches at a rate of one per year, beginning in 1994. Accelerated deployment represents three launches occurring in 1993.

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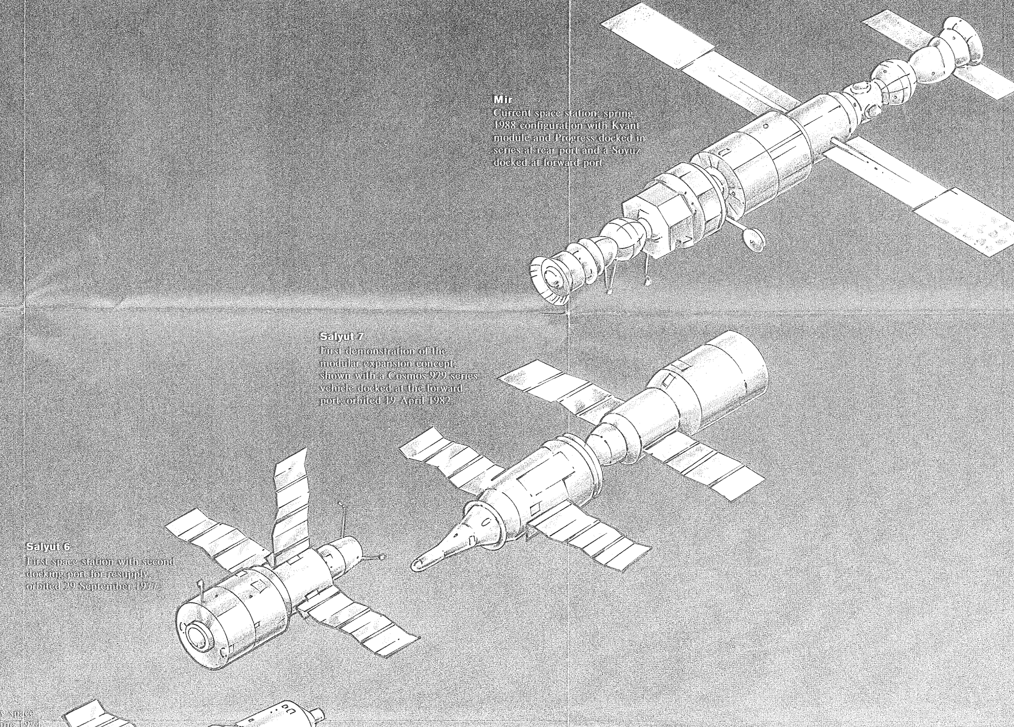
high-capacity, radiation-hardened electronics; materials for infrared and ultraviolet imaging devices; superstrength alloys; and ultrapure, highly valuable biological preparations that have both military and civilian applications. They will not be able to attempt pilot production, however, until the Mir's materials processing module is delivered in the early 1990s. Mir II will be needed for volume production.

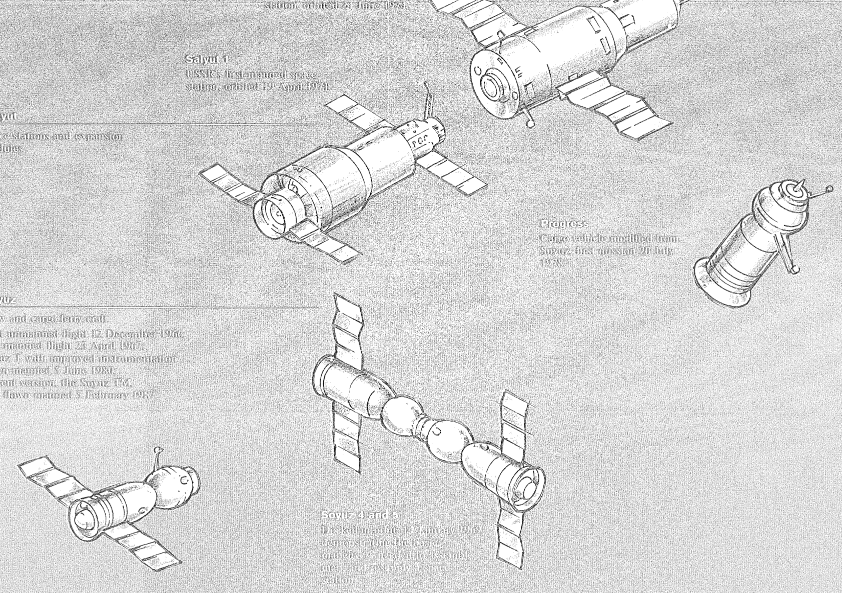
- Lured by the unique capabilities of the Mir, West European countries and Japan could develop long-term scientific or commercial relationships with the Soviet Union. GLAVKOSMOS is ardently seeking such arrangements. Under Gorbachev, the Soviet Union's image has improved, and with it West European and Japanese willingness to engage in commercial and scientific relations. Commercial and scientific cooperation between Western countries and Japan and the USSR could give Moscow access to technology currently restricted under COCOM arrangements. The Soviets might also use a long-term partnership with West European countries and Japan to strengthen their lead over the United States in the commercialization of space manufacturing.

- The Soviets will also continue to use what they believe is a lead in civilian space activities to compete with the United States on the public diplomacy front. Moscow will continue to contrast the "peaceful" nature of its space station with alleged US attempts to militarize space. 25X1

USSR

EVOLUTION OF THE SOVIET SPACE-STATION PROGRAM





Since the mid-1960s, the Soviet Union has pursued a cautious evolutionary approach to its space station program. The Soyuz crew ferry was the first to fly. A series of space stations beginning with Salyut 1 (at lower left) introduced progressively more advanced features, such as dual docking ports to permit resupply and expansion modules to add specialized capabilities. The cosmonauts' missions also grew longer and more complex. At upper right is the current Mir space station, a prototype for a still more advanced modular station the Soviets say will be launched in the mid-1990s.

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