Launch dates of Salyut space stations announced by the Soviets: 1[4]

Salyut 1	Apr. 19, 1971
Salyut 2	Apr. 3, 1973 (failed)
Salyut 3	June 25, 1974
Salyut 4	Dec. 26, 1974
Salyut 5	June 22, 1976
Salyut 6	Sept. 29, 1977
Salyut 7	Apr. 19, 1982

Salyut 1

The first in the Salyut series carried an Orion I telescope for obtaining spectrograms of stars in the *2,000* to *3,000* angstrom region of the electromagnetic spectrum; a gamma-ray telescope, called Anna III, provided observations unattainable from Earth. Several optical and multispectralcameras were used for astronomical and Earth photography. Photo sessions of geological and meteorological phenomena were coordinated with aircraft flights and orbiting weather satellites. Making use of a hydroponic farm, biological experiments centered on the effects of weightlessness on plant growth and nutrition. Long-term implications of the effects of microgravity on the human organism were also studied.

A first attempt to board the station by a three-man crew on *Soyuz* 10 was thwarted by faulty docking equipment on the Soyuz. A second attempt by Soyuz 11 cosmonauts was successful; this three-man crew became the world's first occupants of what some would describe as a true "space station"-i.e., long-term in-space infrastructure that accommodates human beings—residing in Salyut for *23* days. This initial success, however, was followed by an unhappy ending. A valve, intended for equalizing internal and external pressures as the spacecraft descended through the atmosphere during recovery, jerked open at the instant of the explosive separation of the command and orbital modules, permitting the cabin's atmosphere to escape. The cosmonauts, wearing no spacesuits, perished. * From then until the launch of Soyuz T-3 in 1980, Soyuz vehicles were redesigned to allow the crew to wear spacesuits. Crew size was reduced to two to provide sufficient room for the suits and related equipment. Salyut 1 was intentionally removed from orbit 175 days after launch.

Salyut 2

This vehicle did not achieve stability in orbit, began to tumble, and broke up before crews could occupy it.

Salyut 3

Unlike Salyut 1, which had two sets of fixed solar panels fore and aft, Salyut 3 carried two larger panels attached just aft of the centerbody, on the rear transfer module .15 These panels could be rotated so the craft could continue to receive solar power whenever it was in sunlight, whatever its orientation. Salyut 3 was also modified so that its docking port was aft .[16] Other noteworthy modifications included higher efficiency power and life-support systems and more convenient interior design.

Cosmonauts aboard Salyut 3 conducted some 400 scientific and technical experiments, including high-resolution photo reconnaissance and/or Earth resources observation, spectrographic study of aerosol particles in the Earth's atmosphere, the culturing of bacteria, and the recycling of water.

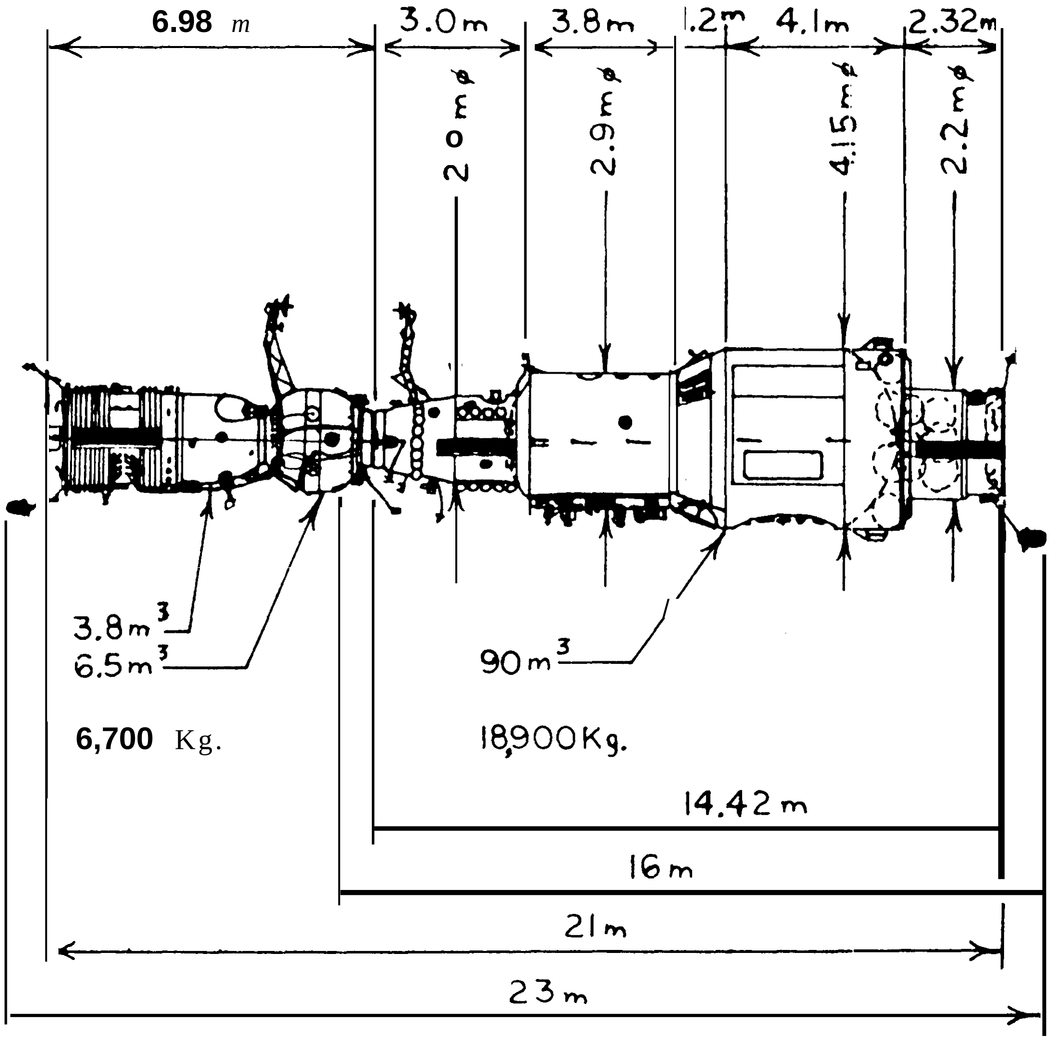
The crew of Soyuz 14 resided aboard Salyut 3 for 14 days, but a follow-on Soyuz 15 crew proved unable to effect docking. Overall, the station remained operational for twice its design lifetime. Some 2 months after Salyut 3's final crew departed, a data capsule was ejected and recovered on Earth. That only a few photographs,

[14]Cosmos *557,* launched *May* 11, 1973, has been identified in Western circles as a successfully orbited Salyut, although the station suffered a propulsion or command-sequencer failure, rendering it useless for human occupation. The vehicle rapidly decayed in orbital altitude, reentering the atmosphere on May 22, 1973. See, "Reception of Radio Signals From Cosmos 557, " The Kettering Group, *Space flight, vol. 16, 1974,* pp. *39-40.*

● The cause of death was embolism, i.e., the formation of bubbles in the bloodstream.

"Although all subsequent Salyuts retained this midship mounting of solar panels, they were placed farther aft on Salyuts *3* and 5 than on Salyuts 4, 6, and 7. See, for example, *AW&ST,* Dec. 4, 1978, p. 17.

'*Ibid,

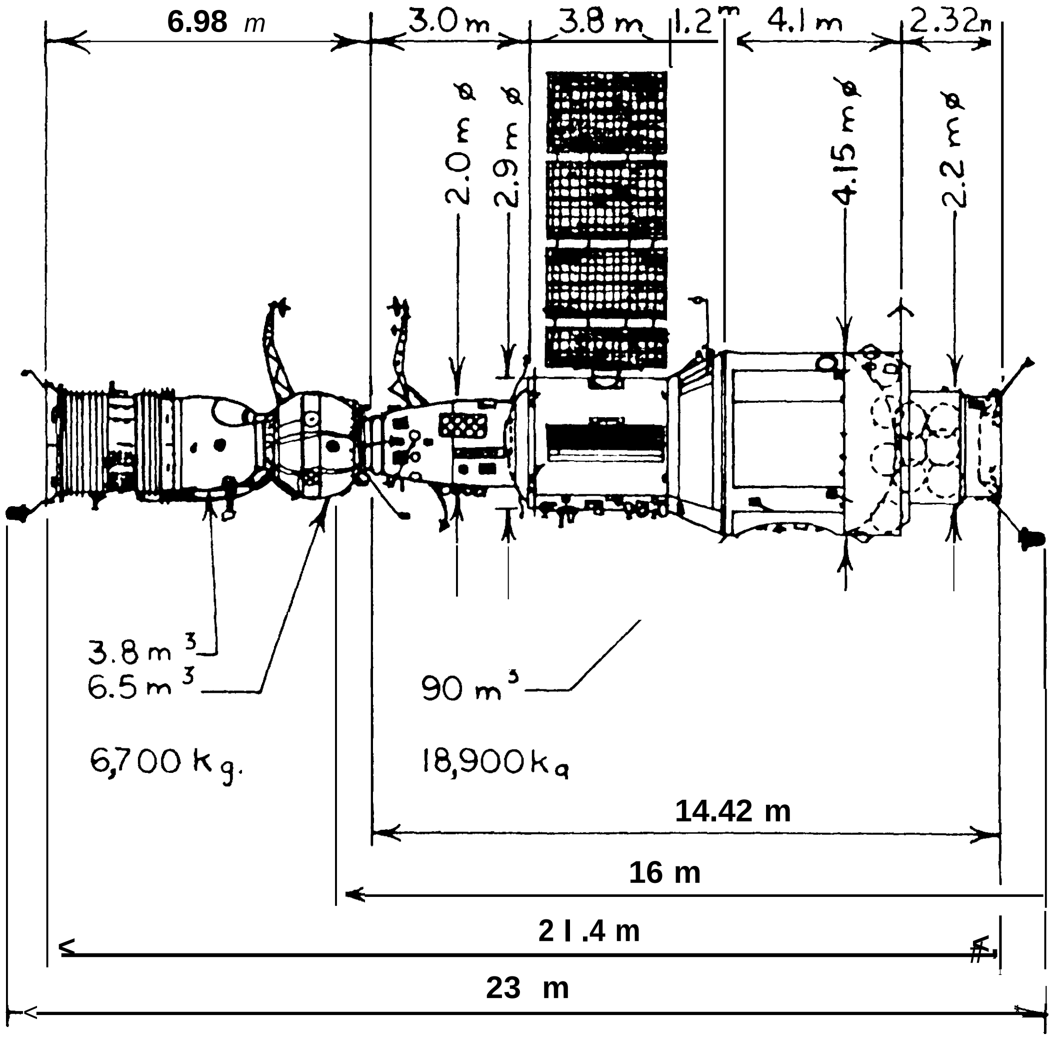


Soyuz 1 1/Salyut 1. Total volume: 100.3 m³. Total weight: 25,600 kg. Total solar panel surface area: 42m²

showing noncritical interior equipment aboard Salyut 3, have been released encourages speculation that its primary mission was probably military.

Salyut 4

The design of this station, seemingly primarily civilian in character, allowed the crew more ready access for repair and replacement purposes. Two navigation systems for the station's automatic control were evaluated, as was a new teletype system. Onboard scientific equipment, weighing about *2.5* tonnes, was of much greater variety and capability than that carried on previous stations. The cosmonauts' time was devoted each day to a specific area of investigation-astronomical, Earth resources, or biomedical. X-ray, solar, and infrared spectrometric telescopes were among the host of instruments employed. Making repeated observations of agricultural patterns, forests, and maritime areas, the crew collected a large body of data on Earth resources. They also studied micro-organisms, higher plants, and the human cardiovascular system, measuring the tone of blood vessels and the circulation of blood to the



Credit: C P Vick, 1983

Soyuz 18/Salyut 4: Total volume: 100,3 m³. Total weight: 25,600 kg. Total solar panel surface area: 60 m²
Solar panel span: 17 m

brain, The cosmonauts also evaluated the effectiveness of various exercise and diet regimes for counteracting the reconditioning effects of microgravity,

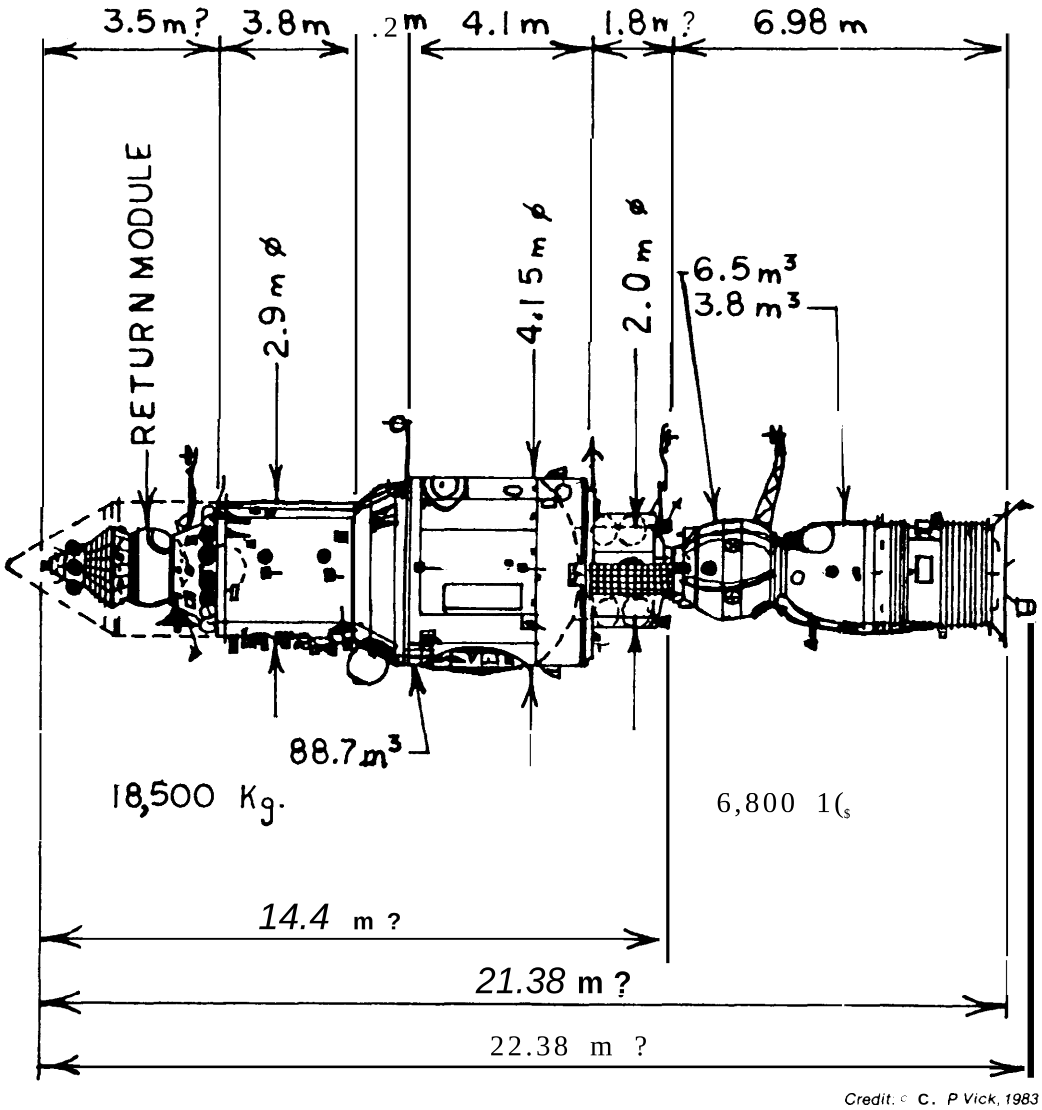
The first crew to board Salyut 4 arrived on Soyuz 17; they remained for *29* days. The mission of their scheduled successors, the crew of Soyuz 18A,[17] was aborted during ascent, Next aboard were the Soyuz 18B team; they remained on the station for 62 days. Soyuz 20, a vehicle without crew, carried biological specimens; it docked and remained at the station for 89 days before returning to Earth. Part of its mission *was* to determine whether Soyuz could remain without power for a relatively long time before restarting its power supply without mishap—an important consideration in planning for one crew to remain aboard a Salyut for a lengthy mission. Salyut 4 was purposely taken out of orbit after 770 days of flight.

[17] 18A is the U.S. designation. The Soviets refer to this event as the April 5 anomaly,

Salyut 5

Salyut 5, the second station thought by Western analysts to be primarily military, was the last in the Salyut series to carry only one docking port, a design characteristic which effectively prevents a resupply vehicle from docking when a crew of cosmonauts is already aboard. * Salyut 5 demonstrated a high-resolution camera, similar to that on Salyut 3, that was used to study mineral deposits, seismic areas, environmental damage caused by mud streams and railway construction paths. A device for smelting certain metals—bismuth, tin, lead, and cadmium-and a crystal growth experiment were evaluated in the station's microgravity environment. As in previous Salyuts, biological experiments on fish, plants, and fruit flies were also conducted; algae and higher order plants were cultivated to examine the effects of the spaceflight environment on their development and growth.

*It is technically possible, but too risky, to back off one spacecraft and then dock another while the crew is on board the station.



"Military" Salyut Conceptional Design: Total volume: 99 m³. Total mass: 25,300 kg. Total solar panel surface area (estimated): over 50 m². Total mass: over 25,000 to 25,300 kg. Only a few written descriptions, a few movie film segments, and a few photographs of the internal and external design layout of the Military Salyut 3 and 5 vehicles have been released

Over the course of Salyut 5's stay in orbit, Soyuz 21 brought a two-man crew, who remained on the station for 49 days; the crew of Soyuz 23 failed to dock; and the crew of Soyuz 24 remained aboard for 16 days.

Like Salyut 3, this station ejected a recoverable pod to Earth after its last crew departed, and, as with Salyut 3, the Soviets have released only internal photographs of limited interest. The station remained in orbit for 412 days before it was commanded to reenter.

Salyut 6

By far the most productive of Soviet space stations, this "second generation" Salyut included two docking ports, fore and aft; the station was fashioned to support a new propulsion system capable of being refueled in orbit. A water-regeneration device became a standard feature of the life-support system, supplying crewmembers with wash water; fresh drinking water was stored. Many of the experimental systems tested on earlier stations became operational on Salyut **6.** A new multispectral camera (which had been flight-tested on Soyuz 22) and astronomical telescopes were flown. During its mission, cosmonauts assembled and deployed from Salyut's aft end a dish antenna used in mapping radio emissions from the Sun and the Milky Way, although the ultimate success of this experiment is in doubt.[18] Several materials processing furnaces were appraised, and infrared-sensitive semiconductors were produced. Other experiments produced superconductors, eutectics, alloys, pure metals, glass, ionic crystals, and metal oxides. Salyut **6** cosmonauts also tested newly designed extravehicular spacesuits.

Cosmonauts routinely worked as in-orbit repairmen, enabling the station's design life of 18 months to be greatly surpassed. Because of the longevity of Salyut 6, perhaps to the surprise even of the Soviets themselves, its crews registered an impressive list of accomplishments. Space applications and Earth observations each accounted for about one-third of the cosmonauts' work schedule; the final third was split between biomedical studies and astrophysics.

The two docking ports permitted 33 successful dockings using vehicles with and without cosmonauts. At least two crews tried but failed to dock with the station. Five long-duration cosmonaut crews and 11 visiting crews accumulated a total of 676 days of operation. New duration records for human spaceflight were successively established: 96, 140, 175, and 185 days. During Salyut 6's lifetime, eight cosmonauts from the Soviet bloc resided in Salyut for short periods; Soyuz 33, carrying a non-Soviet crewmember, along with a Soviet pilot, failed to dock. * Salyut 6 operations introduced the use of Soyuz T and Progress vehicles, multiple-crew dockings, refueling in orbit, and the Cosmos 1267 module. * *

Cosmos 1267 docked with Salyut 6 in June 1981 for a long series of what were described as checkouts of automated systems and "dynamic tests" of the overall response of the structure to maneuvers while docked with another vehicle. According to Soviet space planners, Cosmos 1267 represented a "prototype space module, " built to expand the operations of future stations; such modules could be dedicated to materials processing and astronomical or other scientific pursuits, or they could be outfitted as living quarters. They could also be undecked from Salyut, flown alongside the station and reconnected. This configuration would be particularly useful for the conduct of experiments in materials processing, because it could avoid perturbations caused by the station's reactions to movements of the cosmonauts.[20]

The Soviets apparently were undecided about using their long-lived Salyut 6 for future missions,

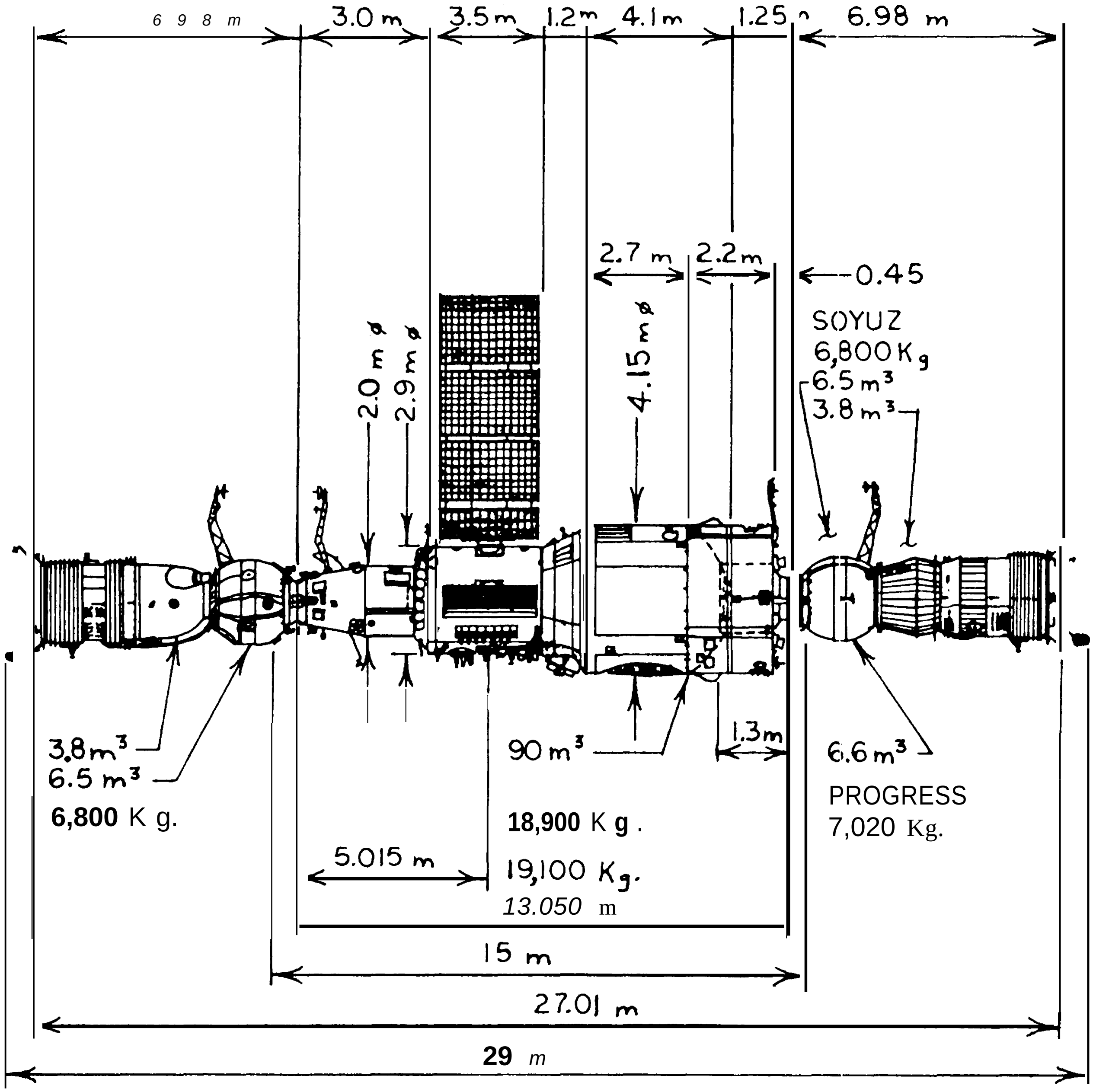
[18] Craig Covault, "Radio Telescope Erected on Salyut 6," *AW&ST*, Aug. 13, 1979, pp. 54-55 See also "Soviets Ready Salyut 6 Crew Return, " *AW&ST*, Aug. 13, 1979, p. 21.

[19] James C. Brown, ***Materials processing on the Soviet Salyut 6 Space Station*** **Memorandum SWN481-1OO4I, Central Intelligence** Agency, National Foreign Assessment Center, Apr. 1, 1981. Soviet research in the materials processing-in-space arena appears extensive. According to MIT professor Harry Gatos, before a House space subcommittee review of space processing, a large new Soviet research institute employs several hundred full-time scientists working on space materials processing. Other countries involved in this institute Include Poland, Hungary, Czechoslovakia, and France, See ***Astronautics and Aeronautics***, September 1979, p. 9.

*Soyuz 25 with two Soviet crew also failed to dock with Salyut 6.

* *There was no crew aboard either Cosmos 1267 and Salyut 6 during their docking of 40 days, after which both were deorbited.

[20] *From* ***Sputnik to*** *Salyut:* ***25 Years of the Space Age***, Novosti Press Agency Publishing House, 1982, passim.



Credit: C P Vick, 1983

Salyut 6 and attached transport vehicles Soyuz and Progress in various combinations; diagram shows, left to right, Soyuz, Salyut and Progress: Total mass with two Soyuz: 32,500 to 32,600 kg. Total mass with one Soyuz and one Progress: 32,720 to 32,770 kg. Total mass with one Soyuz: 25,700 to 25,750 kg. Total volume with two Soyuz: 110.6 m³. Total volume with one Soyuz and one Progress: 106.9 m³. Total volume with one Soyuz: 100.3 m³. Total solar panel surface area: 60 m². Solar panel span: 17 m and twice had Cosmos 1267 boost the complex into a higher orbit. After Salyut 7 was launched, Cosmos 1267 propelled Salyut 6 into a destructive reentry on July 29, 1982. The stay of Salyut 6 in orbit lasted **4** years and 10 months.[21] [22]

Salyut 7

Currently, the Soviet Union is maintaining Salyut 7 in orbit. Soviet space officials indicate it is similar in size and shape to its predecessor.[23] [24] Two docking ports are again provided, one of which has been modified to handle larger spacecraft. The standard station control system on Salyut 7—the result of experiments conducted on other stations—allows its crews to operate the facility in more automatic modes.[25] Recommendations from cosmonauts who had lived aboard Salyut **6** led to an interior "modernization program" to make Salyut 7 more livable. Designers have taken special care to protect certain observation windows, shielding both inside and outside panels with removable covers, because contaminants from propulsion unit firings, as well as impacts from micrometeorites, degraded the windows on Salyut **6.** The color scheme was changed to improve the residential and working environment, and a refrigerator was installed.

Salyut *6* carried a submillimeter wavelength infrared telescope; Salyut 7 contains a complex of X-ray equipment, The first long-duration crew

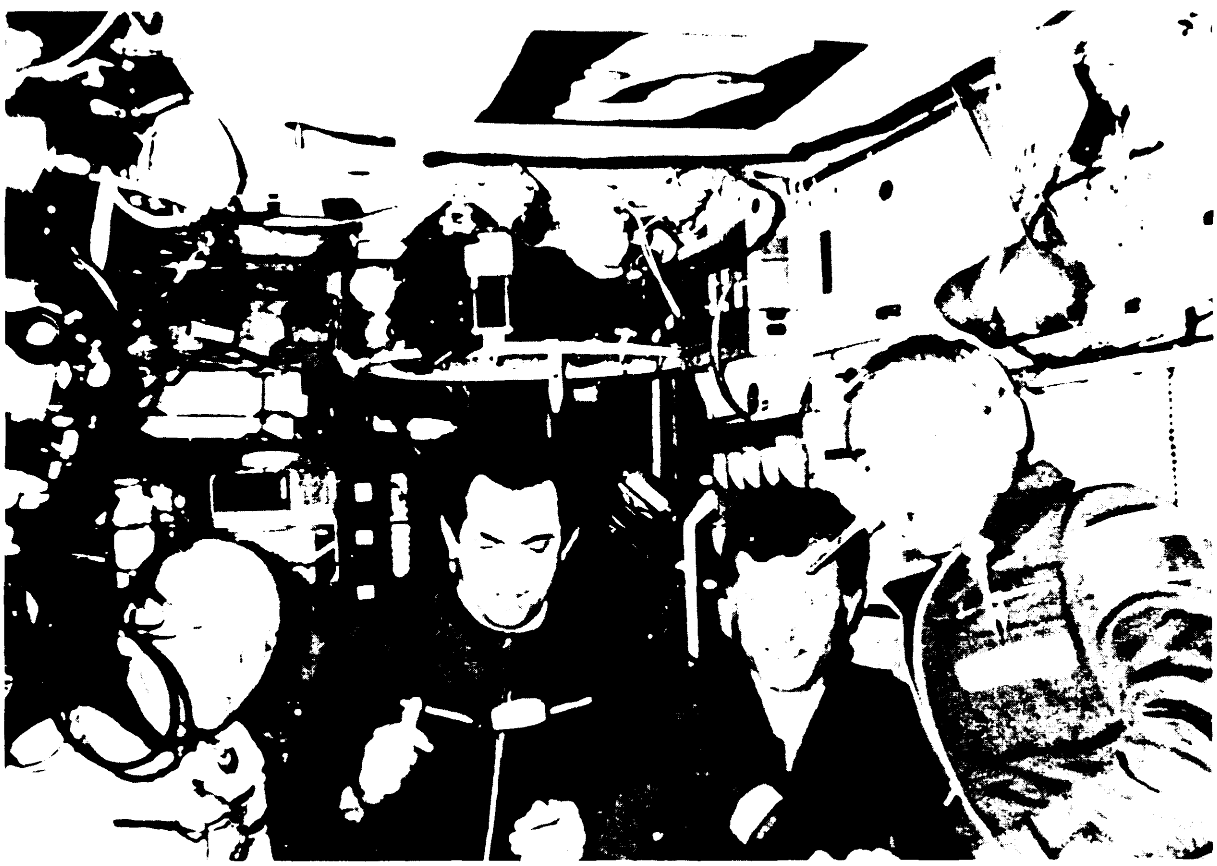
[21] Peter Smolders, "Saluting Salyut's Space Record," *New Scientist*, Oct. 11, *1979*, pp. *118-121*.

[22] "TASS Reports Termination of Flight of Salyut **6** Station," *Pravda*, July **30, 1982, p. 1**

[23] B. Konovalov, "A Trip Through the 'Salyut 7,' " *Izvestiya*, May 18, 1982, p. 3

[24] "The New Salyut 7 is a Modernized Station," *Air and Cosmos* No 910, June 5 1982, p 43

[25] "Salyut 7 Incorporates State-of-Art Upgrades," *AW&ST*, July 26, 1982, pp 26-27,



Crewmen on Station Aboard Salyut 7

used a new computer-controlled 300-lb materials-processing furnace to produce several pounds of semiconductor monocrystals. This furnace operates automatically when the station is unoccupied. New systems for medical examination and diagnosis have improved the range of biomedical parameters that can be monitored, either onboard by the cosmonauts or remotely from the ground. For example, a thorough electrocardiogram can be obtained automatically. Measurements of blood circulation in the cerebral cortex, an important parameter in near-weightless conditions, are receiving particular attention.

Performing about 300 experiments, the station's first long-term crew worked to meet orders from 500 national economic and scientific centers. Soviet officials stated that, for the first time, a Salyut space station undertook "direct research production tasks."[26] Some 20,000 photographs of the Earth's surface were reportedly taken during the first phase of this operation.

Initial operations of Salyut 7 relied on Progress vehicles for resupply and refueling.[27] The Soyuz T-5 transported a crew of two to the Salyut in May 1982. Subsequently, a Soyuz T-6 with three aboard, including a French spationaut, and a Soyuz T-7 with three, including the world's second woman cosmonaut, visited the primary crew on separate occasions. The primary crew set a new world endurance record for spaceflight: 211 days.

On March 2, 1983, "a modular transport ship," Cosmos 1443 (a Cosmos 929-class module), was launched, and docked with Salyut 7 on March 10 in a configuration similar to the Salyut-6/Cosmos-1267 complex.[28] Although a Soyuz craft with

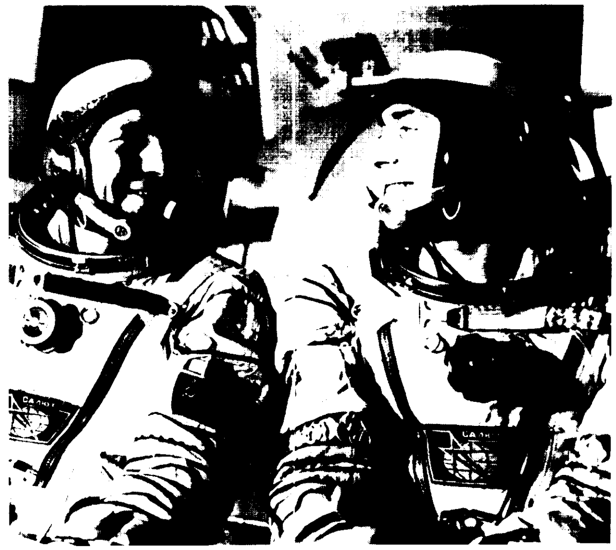


Photo credit. Novosti

Members of the Soyuz-9 space mission

a crew of three aboard failed to dock with the complex in April 1983,[29] a two-person crew boarded the station on June 28, 1983, and remain aboard as of this writing.

The Salyut-7/Cosmos-1443 orbital complex was thought capable of housing as many as six crewmembers.* Stationing of that many people aboard the complex would have born out earlier Soviet pronouncements that this configuration was a prototype for future larger scale space stations. On August 14, 1983, Cosmos 1443, along with its descent module (with a capacity for returning one-half tonne of cargo, but not a crew member) was undecked from Salyut 7.** Then on September 19, 1983, Cosmos 1443 was inten-

[26] "Kuznetsov Presents Awards to Salyut 7 Cosmonauts," Moscow Domestic Service, LD291458, Dec. 29, 1982.

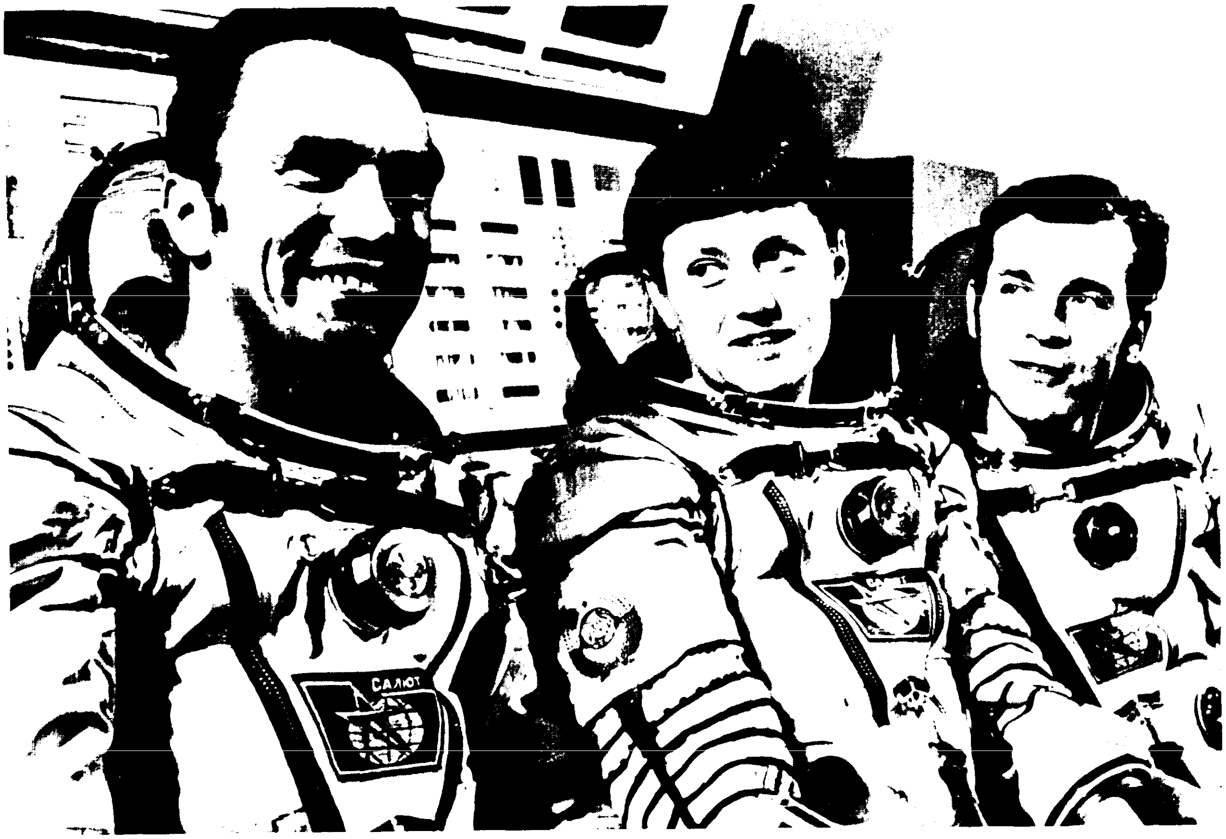
[27] In the early phase of Salyut 7, two small "subsatellites" were launched from the station by its first long-duration crew. These satellites, Iskra 2 and Iskra 3, were constructed by students of a Moscow Aviation Institute and served as communications satellites for amateur radio enthusiasts, The two satellites were "launched" from the station's airlock. For a detailed account of early work on Salyut 7, see: "Salyut Mission Report," by Neville Kidger, *Spaceflight*, January 1983, pp. 28-29.

[28] "Soviets Launch Module to Enlarge Salyut 7," *AW&ST*, Mar. 7, 1983, p. 19.

[29] "Soviet Docking in Space Fails; Mission Aborted," *Washington Post*, Apr. 24, 1983, pp. A-1, A-12.

*It is not clear that docking arrangements allow more than one Soyuz T to dock with a Salyut 7/Cosmos 1443-type combination at a time; such a provision would be expected in the future.

**A rather complex sequence of events occurred during August 1983. Cosmos 1443 undecked on August 14. Then on August 16, Soyuz T-9 undecked, the Salyut was rotated through 180, and the



The crew of the Soyuz T-7 spaceship (from left to right) –crew commander Leon id Popov, Pilot-Cosmonaut of the U. S. S. R.; researcher engineer Svetlana Savitskaya; and flight engineer Novosti

tionally deorbited, perhaps because of a serious malfunction affecting its operation .30 More recently, Salyut 7 itself has experienced a serious propellant leak, leaving it with two of its three oxidizer tanks empty and 16 of its 32 attitude control thrusters unusable. Because of the difficulty of making repairs, it is less likely that Salyut 7 will become a major component of a large modular station.

Military Utility of Salyut

Salyut space stations serve both military and civilian needs.[31] Through the mid-1970's, each station could be distinguished as military or civilian by its design, communications frequencies, orbits, onboard equipment, and crew composition. Such distinctions are virtually impossible to draw for the Salyut 6 and 7 stations. Indeed, now that 6 years have passed since the last Salyut clearly identifiable as military was used, a separate military Salyut program may no longer exist.

Civilian Salyuts (1 and 4) were flown in higher orbits, increasing their value for astronomical observations. Telemetry was typical of Soviet nonmilitary spacecraft, and the crew commander, although usually from the Soviet military, was accompanied by a civilian flight engineer.

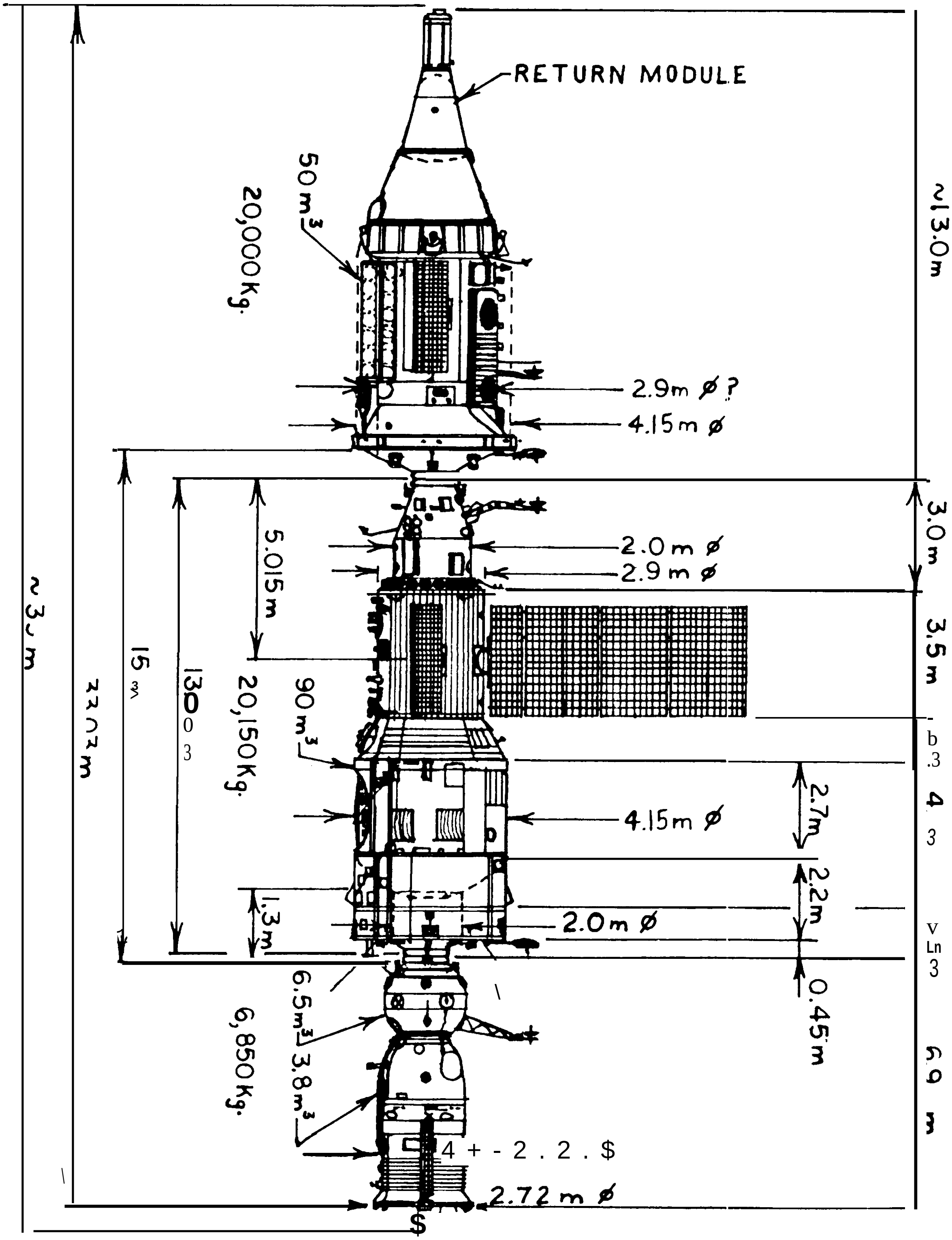
In contrast, military Salyuts (3 and 5) were flown in lower orbits, presumably to get the most out of the capabilities of onboard photo reconnaissance assets and activities which replaced the astronomical activities of civilian flights. * Flights of these Salyuts, typically using radio frequencies

Soyuz was redocked at the "front" end of the station. On August 17, Progress 17, bringing additional fuel, air, and water was docked to the "back" end of the station. On August 19, the descent module from Cosmos 1443 landed in Kazakhstan, U.S.S.R. Since the undocking of Cosmos *1443* and Salyut *7*, the two spacecraft went out of and (through firing of the motor of the Progress attached to Salyut) came back into orbital phase, but apparently no attempt was made to redock prior to the intentional deorbiting of Cosmos 1443.

[30] *Aviation Week & Space Technology*, Oct. 10, 1983, p. 25

[31] Johnson, op. cit., pp. 213-217

*In order to maintain such a low orbit for very long, large quantities of propellant must be expended.



Credit: - C P Vick, 1983

Cosmos 1443/Salyut 7/Soyuz T: Total mass: about 47,000 kg, Total solar panel surface area: '[00 m^2. Total power output: 7 kW. Total volume: 150.3 m^3. Solar panel span: 16-17 m associated with other Soviet military space missions, were conducted by all-military crews. They remained in orbit for shorter periods than their civilian counterparts and ejected capsules for recovery on Earth.

Of course, there must be some military interest in scientific programs. For instance, astronomical investigations completed by Salyut crews maintained the orientation of certain equipment to an accuracy of a few arc-seconds, a capability related to what might be needed to aim directed-energy weaponry. The materials processed in microgravity could range from electronic components to new pharmaceuticals,

Many activities aboard Salyut might be described, in the United States, as civil, but others might well have military implications. Whether military activities aboard these stations pose a serious, near-term threat to the United States cannot be determined from the open literature. Certain military operations may have been turned over to automated spacecraft: Soviet advancements in satellite photo reconnaissance may have reduced the need for crewmembers to gather these data.

Comparisons with the U.S. program are also complicated by the fact that no operational requirements for U.S. military missions aboard a space station, particularly those requiring crewmembers, have been formally stated. 32 However, in view of President Reagan's speech in March, 1983, on the subject of defense against ballistic missiles, this assessment may be changing. [33] In any case, the military value of the Soviet space station remains open to question.

Capability Base for Salyut Program

The Soviet technology base must inevitably affect its space program. A thorough appraisal of this base cannot be obtained because the Soviets tightly control what information about the program is made public. Observers, however, have noted these characteristics: [34]

- *Simplicity.* —Compared with similar Western systems, Soviet components are, in general, relatively less complicated.
- *Commonality.* —Once a basic system or subsystem is developed, it is used as much as possible thereafter. With this approach, a relatively narrow technological base can serve much broader needs.
- *Gradual Change.* —This principle derives from the other two. Because each system is closely related to its predecessor, the risks attendant on innovation are reduced.

In sum, the Soviets prefer to use a single, reliable basic design over a relatively long time in order to provide several generations of systems for similar or related uses.

Professional surveys of industrial technology in the U.S.S.R. suggest that the Soviets are generally unwilling or unable to undertake rapid innovation. In some cases, however, a few critical suppliers and supporting industries have been able to set priorities that led to rapid change.

[32] At the Space Station Symposium held in Washington, D.C., in July 1983, Richard DeLauer, Undersecretary of Defense for Research and Engineering, reiterated this position. For an earlier discussion, see: Joel Levy, et al., "Potential Military Applications of Space Platforms and Space Stat ions," *Eascon 82, 15th Annual Electronics and Aerospace Systems Conference, IEEE Conference Record 82 CH1828-3,* Sept. 20-22, 1982, pp. 269-276. This paper states: "It is apparent that, at this time, the DOD has not defined any firm requirements for space platforms or space stations. " The military utility of a manned space station, say for photo reconnaissance, requires detailed tradeoff studies, " . in order to evaluate whether the increase in system performance due to man's presence warrants the increase of approximately an order of magnitude in the cost of the program. Any increase in system performance achieved by such means would be measured by some, as yet undefined, weighing of factors such as cost, risk, survivability, reliability, threat recognition and the time to respond. "

[33] "President Seeks Futuristic Defense Against Missiles, " *Washington Post*, Mar, 24, 1983, pp. A-1, A-13. See also, "Reagan Plans New ABM Effort, " *Science, vol. 220,* Apr. 8, 1983. More recently, the Defensive Technologies Study Team, headed by former NASA Administrator James C. Fletcher, has been reported as concluding that "a space-based [ballistic missile defense] system may also require a continuous manned space presence **Both cost and effectiveness** may justify manned systems . Development of a repair and refurbishment system may be fie key to operational and economic viability of space-based ballistic missile defense. " *A W'&ST*, Oct. 24, 1983, p. 50.

[34] Herbert P. Ely, "Impact of the Technology Base on Soviet Weapon Development ," ***Army Research, Development & Acquisition Magazine,*** May-June 1982, pp. 12-13. For a broader look at conditions of Soviet technology see: ***Industrial** Innovation in the Soviet Union*, Ronald Amann and Julian Cooper (New Haven, Corm.: Yale University Press, 1982). The authors discuss Soviet military technologies in detail, and conclude that they do not have the quality and level of sophistication that those of the United States have. In general, although Soviet industry is slow to respond to new R&D initiatives, the technology lag is smallest in the defense and space sectors.

Hampered by a lack of precise instrumentation and sophisticated engineering techniques, Soviet space designers frequently take a "brute-force" approach to problem-solving .35 Although this approach has obvious drawbacks, it does tend to impose—in contrast to the U.S. system of single-unit production—an economy of operation through the exploitation of continuing production of less complex hardware. Lastly, there is a consensus that an uneven research and development base, poor quality control, and poor quality assurance has impeded Soviet space development on many fronts.[3b]

Evidence for these evaluations is provided by the mixed results from lunar probes and interplanetary exploration. Crossing the relatively short distance to Earth's neighboring Moon, Soviet vehicles were generally successful in achieving soft landings, trekking across the lunar terrain, and returning samples of the Moon's surface directly back to Earth, Four-month dashes to the planet Venus resulted in significant Soviet success in landing vehicles and-operating their sensors for brief periods on the surface of that extraordinarily inhospitable world.

By contrast, 9-month journeys to Mars have met with repeated failure, and no attempts have been made to probe Mercury, Jupiter, and Saturn. The outer planets in particular, the subject of intense scrutiny by U.S. space vehicles, have so far remained beyond the reach of Soviet probes. The rather limited time during which important systems aboard Soviet spacecraft remain operational is still a major limitation. This weakness also appears in spaceflights with Soviet crews, who have been able to keep Salyuts operational by undertaking unscheduled maintenance and repair.

As these operations of Soviet spacecraft are reviewed, certain limitations become apparent:

Salyut.—Although Salyut is smaller than currently proposed U.S. concepts, it has accommodated Soviet crews for as long as 211 days. Attachment of a Cosmos 929-type module should markedly improve living conditions.

Salyut cannot communicate via line-of-sight circuits directly with Ear-t h stations (in the Soviet Union) during every ore of its 15 or 16 daily orbits. On those orbits when communication is not possible, the cosmonauts sleep, and telemetry, communicated *via* shortwave circuits, is sometimes used to monitor basic onboard systems. Even during the in-contact orbits, the crew can communicate with Earth stations on Soviet territory for only **25** minutes out of every **90.**

Compared with scientific equipment proposed for any future U.S. "stations," Soviet scientific equipment is low in weight and used sporadically; just a small portion of it is replaceable. The station itself can generate 4 kW of power, Cosmos 1443 contributed 3 kW from its own solar panels while it was attached to Salyut, and additional modules may be expected to do likewise. The low return-weight of equipment transported back to Earth via Soyuz T is one constraining factor; because of the delay in returning photographic film to Earth, its use, rather than reliance on advanced electronics, for remote sensing of the Earth is another (although the installation of live television transmission equipment aboard the latest Salyut has partially overcome this limitation). * The life-support system requires regular deliveries of drinking water and supplies for purifying the cabin atmosphere. * * The current configuration requires that Salyut be refueled through its aft docking port.[37]

Soyuz T.—This vehicle, like the original Soyuz, is a reliable, though relatively unsophisticated, spacecraft. Its onboard computer has no backup. The latest mission of cosmonauts aboard Salyut 7 demonstrated an operational lifetime of Soyuz T, while attached to the station, of *150* days. Be-

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"Ursula M. Kruse-Vaucienne and John M. Logsdon, *Science and Technology in the Soviet Union–A Profile* (Washington, D. C.: Graduate Program in Science, Technology and Public Policy, The George Washington University, **1979)**, pp. 3-7,

[36]Even though impediments exist, can they be circumnavigated by a concentrated scientific thrust? See, for example: John W. Kiser, 111, "Technology: We Can Learn a Lot From the Soviets, " *The Washington Post*, Aug. 14, 1983, pp. Cl, C4. See also: Malcom W. Browne, "Soviet Science Assessed as Flawed But Power ful, " *The New York Times*, May 20, 1980, p. C-3, which describes the buildup of the Soviet science work force and its potential for scientific surprise.

*App. A.

* *Some water is recycled aboard Salyut, a capability that U.S. spacecraft do not possess.

[37]For a discussion of rendezvous and docking techniques involving Soyuz T and the Salyut stations, see: *A viatsiya i Kosmonautika, 1979*, pp. **36-39, translated** in JPRS 74805 Space No. 1, Dec. 20, 1979,

cause the Soviets are reluctant to land Soyuz T in the water or at night, they impose strict constraints on the duration and scheduling of its flights. Yet, they have repeatedly demonstrated the ability to deviate from these conditions when necessary. No spacecraft, of course, can land without restrictions. Indeed, the U.S. Space Shuttle Orbiter operates with even greater restrictions than Soyuz. Major modifications of the U.S. craft would be required if its staytime in orbit were to approach that of Soyuz T.

General

In order to minimize one of these deficiencies, the Soviet Union, according to a plan lodged with the International Frequency Registration Board in 1981, intends to operate a system called the Eastern Satellite Data Relay Network (ESDRN), which will employ radiofrequencies similar to the U.S. Tracking and Data Relay Satellite System (TDRSS). The Soviet system would allow reliable, nearly continuous communication with Salyut stations and other spacecraft in low-Earth orbit, commencing perhaps as early as December 1985.

Despite the fact that the Soviet technology base advances more slowly and still remains, in most instances, less sophisticated than that of the United States, it is not suggested that these factors seriously inhibit what appears to be a continuing and expanding set of objectives for productive operations in space, made possible, in part, by people aboard Salyut-class facilities, and determined by what the Soviets consider valuable. Resupply, repair, and service functions, for example, are often performed by cosmonauts, who were a key factor in the longevity of Salyut *6*. The Soviets regard the adaptability of human beings as a form of insurance that permits continuous and variegated space station operations.[38]

Whereas the U.S. program from its inception was heavily influenced by the high visibility of the Apollo program and the continuing presence of test pilots, who insisted that astronauts be "in the loop" whenever possible, the Soviet program at the outset was heavily influenced by the Institute for Automatic Control, which obviously had a different orientation. However, the same unreliability of automated equipment that has plagued the Soviets' long-duration planetary probes has made the human presence an essential element in the Salyut program. As a result, the Soviets have gone far in discovering how the attributes peculiar to human beings may be put to effective use in conducting unforeseen as well as planned activities in the course of maintaining and operating a space station.[39] Their growing fund of experience supports and in turn is supported by two related requirements of their ideology and their judgment of their national security interests: that they begin "the inevitable socialist expansion into space," and that they maintain and enhance their national prestige. These factors have resulted in what should be appreciated as the cultivation of the human presence in space.

The Soviets have claimed that people stationed in space can improve the effectiveness of Earth observations. After a period of adjustment of a few weeks, cosmonauts report both improved visual acuity and enhanced perception and differentiation of color, making it possible for them to identify land features and ocean phenomena (e. g., the presence of schools of fish) that were not expected to be visible from low-Earth orbit. These findings have been pursued in real-time aboard Salyut space stations.[40] [41]

In support of the human presence, the Salyut stations have served as medical laboratories in which the occupants have completed comprehensive programs of biomedical and life-science research. Much of this data-gathering is dedicated to answering the following questions: Do long spaceflights result in unacceptable psychological effects and produce harmful physiological alterations of the human body? If so, can these effects be countered? In search of answers, the Soviets

[38] G, T Beregovoy, et al, *Experimental Psychological Research in Aviation and Cosmonautics* (Moscow Navka Press, 1 978).

[39] G. T. Beregovoy et al, 'Research in Space Psychology," *Psikhologicheskiy Zhurnal*, 3(4), July-August 1082, pp 1(30-167 (In English, JPRS *Space*, Nov 19, 1982 pp. 17-so,)

[40] Jerry Grey, *Beachheads in Space: A Blueprint for the Future*, New York, 1983, p. 42.

[41] Personal communication from Chris Dodge, Science Policy Research Division, Congressional Research Service, Washington, DC., *re* U, S.-U.S.S.R. Working Group on Space Biology and Medicine, meeting of November 1981, Uniformed Services University of the Health Sciences (USUHS), Bethesda, Md

are planning in-flight missions that would entail stays up to 1 year for cosmonauts.

Special exercise and diet regimes are being employed to counter changes in cardiovascular tone and muscle systems during flight and to facilitate the subsequent readaptation to gravity. Some changes such as the loss of red blood cells have been found to be self-limiting and subsequently reversible. Others, although decreasing in rate over time, may not entirely level off. In particular, osteoporosis, the loss of calcium from bone, may pose a formidable problem in the context of flight durations of a year or more in the absence of gravity.[42,43] Extensive ground-based studies employing simulations of weightlessness (including bed rest and water immersion) are augmenting inflight research.[44]

Medical studies of the cosmonauts, supplemented by onboard diagnostic equipment to monitor their overall health on long flights, continue to be given a high priority aboard Salyut. Certain countermeasures have been designed to maintain good health and high performance during prolonged spaceflight. The most demanding of these is exercise, which consumes an average of 2.5 hours during each day in space and involves the use of specialized gear as well as conventional exercise devices.

The Soviets have devised a comprehensive psychological support program, including the transport of letters and news to Salyut crews and frequent two-way video communication with families and research counterparts on the ground. These measures have been instituted to counter the cosmonauts' isolation and heavy workload.

One challenging goal is a closed life-support system aboard Salyut that would generate water and air and produce food, independent of external supply.[45,46] A complete growing cycle of higher order plants has been evaluated aboard Salyut, as has control of plant diseases and use of vegetables and herbs as food for human consumption.* Creation of partially closed ecological systems may conceivably lead to completely closed systems, suitable for flights of 2 years or more. Designed in accordance with biomedical information derived from past Salyut flights, these closed systems could be implemented for eventual flight to the Moon and neighboring planets; such systems might also lead to substantial cost reductions in Earth orbit operations.

[42] Arnauld E. Nicogossian and James F. Parker, Jr., *Space Physiology and Medicine,* Biotechnology Inc., NASA Headquarters contract NASW-3469, Washington, D.C., September 1982, pp. 20-24.

[43] The Soviets themselves seem undecided about whether very long-term weightlessness will be a general problem. Cosmonaut Georgi Gretchko is quoted (in "Soviets Unveil Space Station Plans," by Peter Smolders, *New Scientist,* June 30 1983, p. 944) as saying of a possible trip to Mars: 'Your heart and entire organism would have become so accustomed to living in space that you would never be able to stand life on Earth again." On the other hand, see Grey, op. cit., pp. 41-42: "One of the cosmonauts, Valery Ryumin, spent a full year in space (he served on the 175-day and 185-day flights aboard Salyut 6), and was in excellent physical condition after both flights. He walked comfortably only one day after returning to the oppressive *[sic]* gravity of Earth, and was jogging happily on the third day. After exhaustive studies of the returned cosmonauts, the Soviets' bioastronautics mentor Oleg Gazenko concluded, 'I believe that humankind can be as happy in space as on Earth.'"

[44] Arnauld E. Nicogossian and Courtland S. Lewis, *A Critical Review of the U.S. and International Research on Effects of Bedrest on Major Body Systems,* Biotechnology, Inc., NASA Headquarters contract No. NASW-3223, Washington, D. C., January 1982.

[45] I. I. Gitelson, et al., *Closed Ecosystems as the Means for the* Outer Space Exploration *by Men (*Experimental Results, *Perspectives),* IAF-81-164, presented in Rome, Italy, Sept. 6-12, 1981.

[46] Y. Y. Shepelev, "Biological life-Support Systems," ch. 10 of *Foundations of Space Biology and Medicine, vol.* 111: Space Medicine and Biotechnology, M. Calvin and O. G. Gazenko (eds.), NASA, 1975. NASA SP-374, pp. 224-308.

*Borage was grown from seedlings to leaf stage, and spring onions from bulbs to maturity.