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## Shuttle and Salyut: A Lost Opportunity

*NASA has direct responsibility for any discussions with Soviet officials regarding [joint] compatible docking systems in our respective manned space flight programs.*

Thomas O. Paine, NASA Administrator, July 31, 1970, in a letter to Mstislav V. Keldysh, President of the Soviet Academy of Sciences

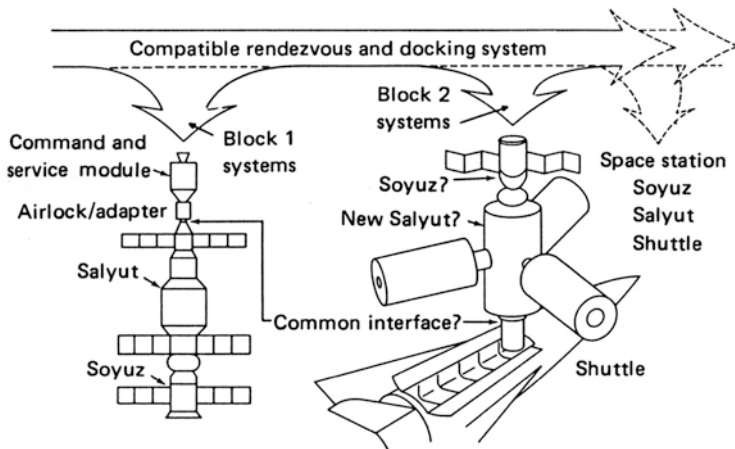
As the Shuttle concept evolved through the early 1970s so did the design of the space station. It was a time of change in the American space program. The Apollo program to the Moon concluded in 1972 and was replaced by three flights in 1973 to Skylab, a space station made by repurposing lunar hardware. Following Skylab, there remained just one confirmed mission and three flight seats for American astronauts, a joint docking mission between an Apollo Command and Service Module and a Soviet Soyuz spacecraft. After that, there would be a hiatus until the Space Shuttle was ready to fly. This was optimistically expected to occur in 1978 or 1979, but in reality NASA faced a six year await between ASTP in 1975 and STS-1 in 1981.

It was during this period that some the first defined plans were created for sending a Shuttle Orbiter to a space station – although not an American one, it was Soviet. In the planning of ASTP there had been discussions about docking an Apollo with a Salyut station, but after 1975 any follow up would necessarily involve the Shuttle Orbiter. It would provide the first indication of the potential of establishing a truly international station.

### THE PROPOSED SHUTTLE-SALYUT DOCKING MISSION

Both official and informal discussions between the United States (NASA) and the USSR (primarily the Soviet Academy of Sciences) occurred throughout the 1960s mainly to exchange a limited amount of information, but also to establish various treaties, including those covering the possible rescue and return of astronauts and cosmonauts from space.<sup>1</sup> By the late 1960s, the concept of a joint US-USSR manned mission was beginning to gain

support and interest, with the potential of a long-term interest in developing a mutually acceptable docking system for future space station under development by both the Americans and the Soviets. In August 1970 the Office of Advanced Developments (OAD) at NASA Headquarters investigated some of the technical issues and published a summary report 'International Cooperation in Space' that reviewed current, albeit American, thoughts on the potential of developing joint equipment and procedures with the Soviet Union.



A sketch for a senior staff briefing on July 12, 1971, at NASA's Manned Spacecraft Center in Houston supporting the development of a universal docking system.<sup>2</sup>

With the Apollo program winding down and NASA anticipating using the Space Shuttle to open up American access to space, it seemed logical to include a common docking system in the Shuttle's design for use on future spacecraft or space stations, be these American or Soviet. The OAD report outlined known hurdles which would have to be overcome, in addition to the language barrier. At this point, the Soviet (Soyuz) and American (Apollo) spacecraft maintained their internal atmospheres at different pressures using different atmospheric gases. Information about the Apollo probe and drogue docking system was in the public domain through press releases from NASA, Rockwell as the manufacturer, and articles in the trade press (notably *Aviation Week & Space Technology*), but very little detail was known about the Russian systems. On the positive side, the Shuttle's docking system was still in the early phase of its design and so it could readily be tailored to suit requirements.

For Apollo, however, the hardware configuration had already been flight proven and its diminished budget gave little room for maneuver. Both the remaining lunar missions and the Skylab program had already been severely trimmed, and while there was back-up Skylab hardware in storage, if this wasn't used there would be no further American manned missions in space until the Shuttle was ready. Still, the case for flying at least one joint docking mission with the Soviets in the middle of the decade, rather than just wasting the existing hardware, was gaining strength.

### Apollo Soyuz

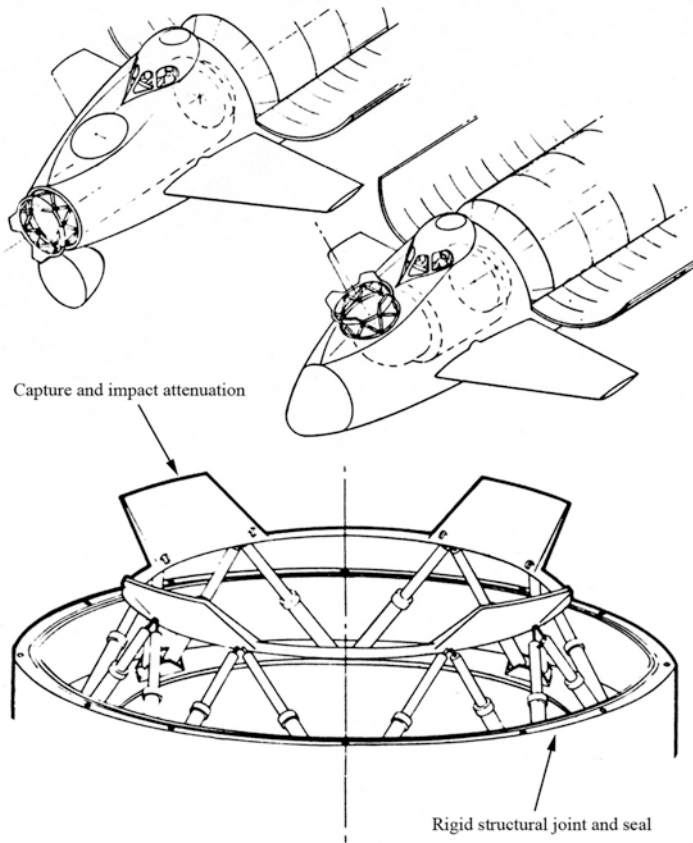
The possibility of an Apollo linking up with a Soyuz emerged from informal talks in New York between NASA's Administrator Dr. Thomas O. Paine and Academician Anatoly A. Blagonravov in April 1970.

According to NASA memos dated September of that year, three possibilities were discussed, two of which were feasible in the timeline available using existing (known) hardware. The first suggestion was for an Apollo to dock with a Soyuz. The second idea was for a Soyuz to dock with Skylab (with the Apollo docking at the radial port reserved on Skylab missions for a rescue vehicle). The third option was longer term, because it envisaged docking a Shuttle with an unspecified Soviet spacecraft. At this point in 1970 there was little evidence in the West of the imminent appearance of the Salyut space station but it was believed that the Soviets, having lost the race to be the first to land men on the Moon, were switching their focus to a space station program.

Docking equipment on US space programs was designed for a specific purpose. On Gemini, that purpose was to develop the basic techniques required in order to carry out rendezvous and docking, so the equipment could be relatively simple. The nose of the two-man spacecraft was simply maneuvered into a receptacle on the nose of an Agena target vehicle, whereupon three latches engaged to establish a rigid connection. There was no requirement for internal crew access or transfer to the unmanned target. In the case of Apollo, several members of the crew would require to transfer between the two spacecraft. In this system, a probe mechanism on the nose of the CSM was extended to engage with a conical drogue on the roof of the LM. After three small latches engaged to establish a soft docking, the probe would retract to draw the vehicles together for a hard docking that required firing a series of 12 latches in the collars to establish a rigid connection. Once the tunnel was pressurized, the hatches would be opened to form an internal tunnel between the vehicles through which astronauts could transfer in a shirt-sleeve environment. As a back-up provision, it would be possible to put on their space suits and transfer externally using the front hatch on the LM and the side hatch on the CM. This latter option was partially simulated during the Apollo 9 mission in March 1969.

By contrast, NASA knew little about Soviet docking systems apart from the probe and drogue used for the joint mission flown by Soyuz 4 and Soyuz 5 in January 1969. As there was no internal transfer tunnel available on this mission, the two cosmonauts who crossed from one ship to the other did so by EVA. It was later revealed that this exercise was also a test of the method the Soviets intended to use on their (canceled) program to send cosmonauts to the Moon, where one man would EVA from the main spacecraft (an enlarged form of Soyuz) to the lunar lander, undock, and descend to the lunar surface. Upon his return, the vehicles would dock and he would make a second external transfer.

The androgynous docking system proposed for the Shuttle was an idea that had been studied by North American Aviation in May 1962 during evaluations of early docking techniques but not pursued by Apollo. During a preliminary tour by NASA officials of Star City near Moscow in October 1970, Caldwell C. Johnson, a leading US spacecraft designer and specialist in docking systems, informed his Soviet counterparts about this androgynous docking system. Reciprocal comments showed that the Soviets also had docking systems with internal transfer tunnels in development and that these would be



October 1970, MSC spacecraft designer Caldwell C. Johnson prepared these Vu-graphs to explain the concept of a ring and cone docking system and its possible future use by the Space Shuttle.<sup>3</sup>

incorporated into Soviet spacecraft “in the near future.” However, the details of these systems were not revealed at that meeting.<sup>4</sup>

Just six months later, on April 19, 1971, the first unmanned 41,675 lb (18,900 kg) Salyut space station was launched into orbit. Four days later, the three-man crew of Soyuz 10 gave chase with a plan to board the station for a residency of 20–30 days. Unfortunately, it proved impossible to achieve a hard docking and they returned to Earth after just 48 hr.

Once the design fault in the new docking mechanism had been remedied, a second mission, Soyuz 11, was launched on June 6 with a late replacement of the entire crew after one member of the prime crew fell ill. This time the docking and transfer into the station was achieved and the cosmonauts spent most of their 24 day mission on board the Salyut. Tragedy struck during their return to Earth, however. At that time, Soviet cosmonauts did

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not wear pressure suits and when a pressure equalization valve in the Soyuz malfunctioned, the evacuation of the capsule's air resulted in the deaths of the three Soyuz 11 crewmen: Georgi T. Dobrovolsky, Vladislav N. Volkov and Viktor I. Patsayev. It was another tragic setback to the Soviet program, coming just four years after Vladimir M. Komarov died when Soyuz 1 smashed into the ground because its parachutes failed to deploy properly.<sup>5</sup>

As a result of the Soyuz 11 accident and subsequent inquiry, all Soviet manned flights were delayed for at least a year. Several subsequent failed attempts to orbit another Salyut-type station meant that no cosmonaut entered orbit until September 1973. Despite these difficulties, the Americans were still keen on the idea of a joint mission, and the best plan still seemed to be to dock an Apollo at one end of a Salyut while a Soyuz was docked at the other end. But the problems of incompatible docking systems and differing atmospheric compositions remained to be resolved. The Soviet spacecraft used an oxygen-nitrogen atmosphere at sea-level pressure, whereas Apollo used pure oxygen at about one-third of that pressure. Any crewmen who attempted to transfer between vehicles without acclimatization would suffer from nitrogen bubbles forming in the blood stream, in the same manner that deep sea divers who ascend too rapidly develop a condition called 'the bends.' To overcome this, the Space Division of Rockwell International proposed a special airlock and docking module that was 10 ft long by 5 ft diameter ( $3.05 \times 1.52$  m). This would house crewmen while the internal atmosphere was adjusted to either the Apollo or Soyuz, depending on which direction they were going, prior to opening the relevant connecting hatches. In order to resolve the problem of the existing vehicles having different docking systems and at the same time evaluate a new compatible system, which was the reason for staging the mission, this module would have an Apollo drogue at one end and the new androgynous system at the other to mate with a compatible system on the Soviet vehicle.

Although NASA had been open about ending the Apollo program, its replacement by the Space Shuttle, and their intentions for large space stations, the Soviets were not so forthcoming about their plans. This made detailed preparations for any joint mission rather frustrating. Although the joint mission was being proposed initially as a one-off opportunity, there were expectations (at least on the American side) of possible future collaborative ventures. The joint docking system would be developed too late for it to be used operationally by Apollo, but NASA would be able to use it on the Shuttle for operations with Soviet spacecraft or space stations.

The approval of the Space Shuttle development in early 1972 was a boost for the continuation of American human space flight, but in April the Soviets dismissed any prospect of an Apollo-Salyut Test Project. During another visit to Moscow by NASA officials the Soviets said, "It was not technically and economically feasible to fly the (joint) mission using Salyut."<sup>6</sup>

By the spring of 1972, only one Salyut had been placed into orbit. Its design was a compromise to ensure that it reached orbit before Skylab for propaganda purposes. It featured only one docking port at the front. To include a second docking facility at the rear would, according to the Soviets, require significant reconfiguration of the station's layout. This would take so long that the project would no longer be feasible within the proposed timeframe of the joint mission. This disappointed the Americans, who were seeking not only to gain experience of research aboard the Salyut, but also an insight into the Soviet space station program and long-term plans. Their own Skylab program was limited to just

one station with three manned missions, and while the American station did have two docking ports, the idea of a Soyuz docking at Skylab was never formally proposed. The first joint mission therefore became an Apollo docking with a Soyuz with Rockwell's new module as the interface. While the acronym remained the same, ASTP now stood for the Apollo-Soyuz Test Project, or, as the Soviets called it, the Soyuz-Apollo Test Project.

After two years of joint technical talks, on May 24, 1972, US President Richard M. Nixon and Soviet Premier Alexei N. Kosygin signed an agreement for the two nations to cooperate on space and technology developments for five years, with ASTP as the highlight. Just over three years later, following the docking of a three-man Apollo with a two-man Soyuz on July 17, 1975, astronaut Thomas P. Stafford and cosmonaut Alexei A. Leonov shook hands in an open hatch. Global media coverage emphasized the spirit of détente of the rival Cold War superpowers working together. ASTP also marked the end of the Apollo era, with the final crew splashing down on July 24. The focus within NASA would now switch to developing the Shuttle.

At that time, NASA was planning to undertake atmospheric tests using a prototype Orbiter in 1977. This series of Approach and Landing Tests (ALT) would be followed by up to six Orbital Flight Tests (OFT), starting in 1979, to put the Orbiter through its paces. Starting in 1980, up to six 'development flights' would evaluate the hardware and procedures to enable the whole system to begin operational missions from 1981.\*

## **The Salyut Era**

Although the first joint mission was merely an Apollo and a Soyuz docking for a few hours, the American desire to dock with a Salyut at some point in the future did not go away. With the Shuttle still several years from its inaugural flight, NASA approached the Soviets with the idea of a Shuttle docking with a future Salyut station.

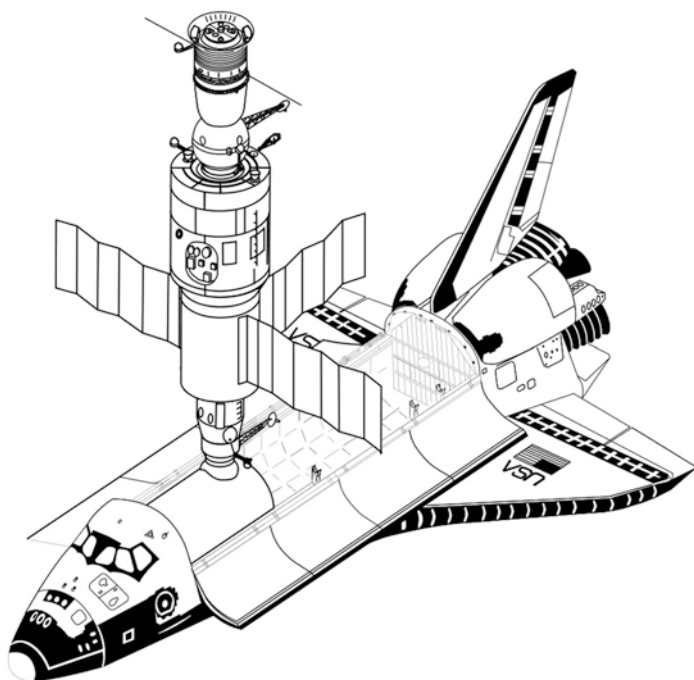
Having lost the race to the Moon, the Soviets turned to one of their cherished plans for space exploration, the establishment of a permanent human presence in space by a succession of space stations. To ensure they beat the American Skylab, the first Soviet station became a compromise of two designs that were being developed by rival design bureaus.

One, officially known as Almaz ('Diamond') but cloaked under the generic Salyut family name, was to address military objectives. The second, originally called Zarya ('Dawn') but changed shortly prior to launch to Salyut ('Salute'), had more scientific (or civilian) objectives. In the compromise to accelerate the development, an Almaz was stripped down and a Soyuz propulsion unit was fitted at its rear where a docking system was to have been. Instead, a simple docking system was installed at the front, where the Almaz crew capsule was to have been situated. This redesign precluded the inclusion of a second docking port, so the follow-on first generation Salyuts (the lost Cosmos 557 and then Salyut 4) also featured a

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\* What transpired was that the Shuttle development encountered many unexpected hurdles, delaying the first orbital flight by several years. Nevertheless, the ALT phase occurred in 1977 and there were extensive ground tests in 1978 and 1979. The OFT phase was subsequently reduced to four missions, with the first flying in April 1981 and the last in June 1982. The objectives of the 'development flights' were incorporated into the first few 'operational' missions, starting in November 1982.





A NASA illustration of the proposed Shuttle-Salyut docking.

single docking port at the front. For the second generation Salyut 6 and Salyut 7, an engine unit similar to that intended for the Almaz was installed at the rear instead of the borrowed Soyuz propulsion system. This had two engines, set off-axis to accommodate a docking system and transfer tunnel on the axis. The highly secret military Almaz stations (Salyut 2, 3 and 5) had already used this arrangement. Consequently, although the Soviets had told the Americans it wasn't "technically feasible" to add a second docking port to Salyut, they were already doing so. They simply did not wish the Americans, familiar with the early civilian Salyut, to know that there was a different configuration for the secret military version.

Ironically, in 1973, the year after they refused the suggestion of an Apollo-Salyut docking, the Soviets began work on the second generation Salyut space station with a docking port at each end. This new Salyut could also support EVA (the first time that the Soviets could conduct spacewalks since 1969) and be refueled and resupplied by automated freighters. These Progress ships, introduced in 1978, were based upon an unmanned version of Soyuz. Salyut 6, the first of the second generation stations, was launched in September 1977 and became one of the most successful by remaining in operation through to 1981. Salyut 7 was launched the following year and served until 1986, by which time a third generation station had been placed on-orbit and given the name of Mir ('Peace').

While the Soviets focused on the longevity of human space flight using the Salyut stations, with missions lasting up to six months, the Americans doggedly pursued the

development of the Shuttle. The inaugural orbital flight was in April 1981, and by the end of 1985 there had been twenty-three missions. Of course there had been setbacks, difficulties and cancellations, due primarily to processing and reliability issues on the ground as well as changes to the manifest, but on the whole the Space Transportation System was very capable. It had its flaws and was neither as reliable or as economical as first envisaged, but NASA was confident that with experience the situation would improve.

By the early 1980s, the Shuttle and Salyut programs were following their separate paths. While Shuttle and Mir would eventually meet on-orbit in the mid-1990s, there had in fact been detailed proposals to achieve this feat much sooner.

## THE 'ORIGINAL' INTERNATIONAL SPACE STATION

On June 6, 1974, Academician Mstislav V. Keldysh, President of the Academy of Sciences of the USSR, wrote to NASA's Deputy Administrator, George M. Low, on the subject of further cooperation in space research. Low's reply indicated that that definite interest remained at NASA for such cooperation. A joint meeting between Low and Keldysh was planned for October or November of that year, and Low suggested that talks be held in advance to "direct our respective studies to some candidate projects which appear at an early time to have possible mutual interest."<sup>7</sup>

A meeting of NASA staff in Washington DC in August 1974, supported by a teleconference from JSC in Houston, included a discussion on the "international aspects of a space station." A presentation given on August 29 reported upon the knowledge that the USSR was interested in continuing manned space activities in Earth orbit and was "contemplating an 110,250 lb (50,000 kg) class space station, with associated launch vehicles [i.e. Proton and eventually Energiya] and logistics systems [which became Progress]." The discussions also noted that the European Space Research Organization (ESRO, a forerunner of ESA) had expressed interest in entering manned space activities, but was seeking cooperative ventures rather than designing its own launch vehicle or manned logistics craft. The meeting reaffirmed NASA's commitment to manned orbital activities with the Shuttle, although it had no plans to develop a heavy lift launch vehicle in the Saturn V class. Finally, it was noted that Japan had no interest in taking on its own major manned space program but had instead expressed a desire to "participate with other nations, if some national purpose were identified."<sup>8</sup>

Virtually predicting the later development of Mir, the presentation also included the forecast that whilst the facilities seen aboard Soviet space stations to date (Salyut 1 and Salyut 3) were limited, "several Salyut [modules] would be joined together on-orbit to form a multi-manned station." Cooperative and equal partnership between nations could result in the establishment of one or more permanent orbital stations if "substantial funding becomes available by 1980." The meeting suggested that such a station would comprise a central core module to which a number of service modules would be either temporarily or permanently attached, with "a 30-man crew selected to allow specialization without extensive cross-training." Laboratory modules could also be attached as necessary. The complexes would receive visits by short-duration sortie craft, host unmanned facilities such as free-flyers which would be serviced by these craft, and be resupplied by



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logistics craft, including a “*shuttle-class [vehicle] for transporting personnel, cargo, and all orbital elements, except the core module, in either direction between their orbits and Earth*” [author emphasis]. This was an early suggestion that the Space Shuttle would play a major role in the construction and subsequent occupation of a modular space station. All of this would require an international cooperative venture that included at least Europe and Japan, and possibly the Soviet Union. Such a partnership might have conceived a truly ‘international’ space station by 1990.

The timeline suggested in the meeting (which depended upon final approval and provision of adequate funding by 1980) was:

- 1975: Multi-lateral discussions; unilateral concept studies.
- 1976: Joint concept discussions; preliminary management considerations.
- 1977: Final concepts and management agreements.
- 1978: Technical studies and interface definitions.
- 1979: Study review and special preparations.
- 1980: Contract for design and development.

Launch of the core module would be by Proton or perhaps a modified unmanned Shuttle concept (similar to what became known as Shuttle-C during post-Challenger studies) and would include the European Sortie Module (which became Spacelab).

The data was passed to the Soviets for consideration later that year, with NASA hoping for a positive response to enable them to establish a framework timeline in the spring of 1975. It would then be followed by a series of meetings to move the project forward once ASTP was completed.

### US Concerns Raised

By late June 1975, barely a month before the ASTP mission was to fly, concern was being raised about potential US-USSR space station studies. During a visit to JSC by George Low earlier in the month, former flight director and now technical director for ASTP at JSC, Glynn S. Lunney, raised some concerns about the joint proposal. While Low agreed that there were valid issues that would have to be raised with the Soviets, he did not necessarily agree with Lunney conclusions. A meeting was organized to discuss the matter.

Lunney’s concerns highlighted the problem of discussing an *International* Space Station with other [unidentified] countries when the US lacked direction for its own planning beyond the Shuttle. There were no defined goals, objectives or proposals for the US space program in the 1980s. Lunney also raised concerns about how the US might approach such countries to invite their participation, in particular the timing of any approach in view of US government approval cycles, and the degree to which it should be a partner. He offered a range of options for a joint definition study, ranging from postponing any decision on a space station to suggesting that each side complete their own integrated studies with specific focus on certain elements, highlighting any potential problems they could foresee. While current proposals for follow-on missions after ASTP included having a Shuttle dock with a Salyut as the preliminary to a fully international long-term space station, Lunney questioned the ability of the Soviets, or indeed their interest, in supporting a Shuttle-Salyut study and the International Space Station proposal alongside its own domestic space program.

Lunney proposed that any meeting in the fall of 1975 should first concentrate on the ongoing compatibility studies of the Space Shuttle with Salyut to define the objectives, scope, and schedule of any such mission and examine the capabilities required for any future systems beyond that. The International Space Station proposal should remain a suggestion for joint consideration at some specified date in the future, with continuing exchanges of information keeping a range of configuration options open for later study. This would also be the occasion to define the level of participation by other nations, as well as to approach "sensitive" subjects such as the details of any large booster that the Soviets might possess.<sup>9</sup>

Despite the concerns raised by Lunney and others, planning for the joint meeting in November 1975 between NASA and the Academy of Sciences proceeded. Part of this planning was based upon a letter of August 13, 1975, from Arnold W. Frutkin, NASA Deputy Director for International Affairs, to Vladlen E. Vereshchetin, Vice Chair of the Academy of Sciences' Council for International Cooperation in the Exploration and use of Outer Space,<sup>10</sup> outlining the primary agenda items. Those pertaining to the Shuttle-Salyut and the early ISS proposals were itemized as:

- *Joint projects which would involve the Shuttle-Salyut-Soyuz spacecraft.* The formation of a Manned Flight Operations Joint Working Group made up of members from both sides was suggested. This would be able to recommend special projects, objectives and planning scenarios, including schedules and milestones. Frutkin explained that NASA was seeking a partnership that was similar to that for ASTP, preferably engaging the same personnel from both sides in order to continue the cooperative momentum.
- *The possible Soviet use of the STS for various payloads.* From 1976, NASA would be willing to furnish the Soviets with pertinent information on flight opportunities, user requirements, terms, and other considerations. Frutkin asked whether similar opportunities could be extended to American payloads and experiments during a future Salyut or other Soviet program. His letter also mentioned "consideration for flight opportunities for crewmembers of the two sides, on an approximately reciprocal basis, where mutual project interests and objectives warrant."
- *A future [international] Space Station.* Any such project would begin with both sides agreeing not to make a firm commitment to develop future space stations, either jointly or independently at this point. It was hoped, instead, to establish mutual agreements under a new Space Station Joint Study Group. If this group were to be established, then its first task would be to define the parameters of initial concept studies and a schedule for those studies to be undertaken. Each side would undertake its own independent studies, then the Joint Study Group would meet to try to "harmonize the concepts of the two sides." This would be submitted to the respective principals to resolve any differences and proceed with those aspects that were agreed upon.

It was hoped the upcoming meeting would resolve the first phase of cooperation and determine whether a more advanced program was practicable. If so, it was expected that this second stage would result in preliminary designs for a large space station, either by dividing the work equally or by blending the efforts of both sides and perhaps including other international partners. It would be easier to draw in further partners if

the US and the USSR could work in harmony together over the long-term. Frutkin's letter enquired whether any of the topics listed were of interest to the Soviets for the next meeting, and concluded, "We believe that it would be very desirable, with respect to Shuttle-Salyut-Soyuz prospects, if accelerated discussions regarding the compatibility requirements for the Shuttle docking mechanisms could be prioritized now that ASTP has been completed."

The meeting between NASA and the Academy of Sciences expected by the end of 1975 was delayed several times until October 19–22, 1976. The Soviet delegation at the meeting in Washington DC was headed by Chairman of the Interkosmos Council, Academician Boris N. Petrov, with the NASA team headed by Deputy Administrator Dr. Alan M. Lovelace. The meeting set up a Joint Working Group (JWG) to "study the appropriate scientific objectives, and the operations required thereby, to optimize the Shuttle's flexibility and Salyut's long stay time, and study the flexibility and objectives of an international space station."

Despite general consensus and the apparent readiness of the Soviets to draft and even to sign an agreement, it was NASA that was reticent. The lengthy delay in arranging the meeting had placed it barely a month ahead of the November 1976 national election in the United States, so NASA, not wishing to pre-empt a possible new Administration in the White House, declined to draft or sign anything. NASA suggested that the Soviets should propose a draft agreement *after* the election had taken place. Jimmy Carter won the election. The Soviets duly submitted their draft on November 27. This move on the part of the Americans had a political rationale, because it meant the idea for a Shuttle-Salyut project looked like a proposal by the Soviets for a continuation of the ongoing ASTP program instead of a 'new' extension to the Shuttle program. This was a ploy to make it easier to 'sell' the idea to the politicians. The space agency discussed the draft proposal with the State Department and the newly appointed National Security Council (NSC) and then the agreement was signed in May 1977.<sup>11</sup>

### The May 1977 Agreement

Details of the agreement signed on May 11 were released by NASA on May 17.<sup>12</sup> This confirmed the continuation of the very successful ASTP partnership. It called for three Working Groups, two for "orbital manned flight activities" and the third for a "possible international space station."

The first Working Group was to assess the scientific and applications programs that could be conducted during joint operations between the Shuttle and a Salyut in the early 1980s. The second Working Group would define the relevant flight plans. These studies were to last 18–24 months, with recommendations from both sides and an obligation to put "science first." It was assumed that the first flight of a Shuttle would occur in 1979 and that the docking with a Salyut would occur in 1981. The particulars of the mission program would be defined over the course of the joint studies. The third joint Working Group would make a series of phased studies related to an international space platform or station. If a consensus of objectives for future space station activities emerged from these initial studies, then further studies would be undertaken to explore the potential design configurations of such a station.

### NASA's Tentative Expectations

The next step was to organize a joint meeting of all the working groups, possibly by late July. A proposed agenda from the Soviets had been received, indicating their interest in pursuing the topic. Having initially just reiterated the points that had been agreed upon, NASA would soon propose a less detailed, more flexible agenda to be submitted to the Soviet Academy of Sciences. This was in part due to the fact that operational flights by the Shuttle were still some way off. The initial areas which NASA proposed for study were covered in the broadest terms: infrared interferometry; life sciences; atmospheric chemistry and climatology. The Soviet proposals were then to be cross-matched by sub-groups to identify potential areas of joint research that would benefit from the combined capabilities of the Shuttle and Salyut.

Right from the start, NASA emphasized that it was willing to exchange information and any developments necessary to plan the Shuttle-Salyut operations and to refine the program of research objectives. NASA said that all the information that they provided would be based entirely on previously published data and documents widely available under the agency's openness policy. The only truly 'new' information was expected to come from the Soviets and relate to their Salyut station whose detailed design and composition was still generally unknown in the West. Information concerning the Soyuz had, of course, been revealed to the Americans out of necessity via the ASTP project.

The always important issue of funding was a potential stumbling block, but NASA believed the costs were not incremental to the existing development of the Shuttle. It would probably have been necessary to provide funding for some kind of a "docking capsule" earlier than the broader Shuttle program might otherwise have required, but even the development of a program of science experiments was in line with what the agency anticipated for the 'typical' Shuttle mission profile. There were no indications than any 'extra' flights would be required in order to test or demonstrate procedures or hardware in advance of an operational docking mission. This suggests that (as was the case with Shuttle-Mir later) the docking system might not be tested on a mission prior to the first attempt to dock with Salyut.

NASA noted that this joint cooperative relationship must reflect "political judgment as to the desirability of these cooperative programs." In addition, regular reporting and analysis would be required to ensure that the program was adhered to at all times. If the initial program proved to be a success, there were recommendations in place to plan for further Shuttle-Salyut missions during the 1980s; a statement that was an early foresight of what was to come.

### Hopes for the Future?

As the November 1977 meeting approached, the prospect of further cooperative efforts between the Americans and the Soviets was drawing favorable comments from several sources. During the 28th Congress of the International Astronautical Federation held in Prague, Czechoslovakia in September, its Chairman, Professor Marcel Barer of France, reminded delegates they were present to celebrate the 20th anniversary of the launch by the Soviet Union of the first artificial satellite, and to look forward to a possible Shuttle-Salyut joint mission.

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Other reports indicated that the Soviets were fully supportive of such a program and were eager to promote and highlight the work being done on their Salyuts as being “for the benefit of all on Earth.” The Americans appeared to be viewing ASTP and Shuttle-Salyut as just the first stage of cooperation. This was revealed in a letter dated October 20, 1977 from Frank Press, who was the Science and Technology Advisor to the White House, to Academician Vladimir A. Kirillin, Chair of the State Committee on Science and Technology, and Deputy Chairman of the USSR Council of Ministers. Press wrote, “Our delegation intends to put forward certain suggestions...of considerable importance for the future of our total cooperation in space. In general, they mean to propose a more extensive exchange in the planning [of] planetary investigation over the next decade.”<sup>13</sup> Clearly, the Americans were seeking to expand the cooperation far beyond the Shuttle-Salyut docking and ongoing life sciences cooperation, and indeed beyond any potential international space station; they were thinking about long-term joint exploration of the rest of the solar system.

### The November 1977 Meeting

The next meetings between the Soviet Academy of Sciences and NASA took place in Moscow, November 14–17, 1977. The American delegation was led by Dr. Noel W. Hinners, Associate Administrator for Space Science at NASA Headquarters, and the Soviet delegation by Dr. Boris Petrov, Chair of the Interkosmos Council of the Soviet Academy of Sciences. A NASA press release described these as exploratory meetings designed to identify “candidate areas for study to define a possible joint experimental program in the 1980s, using the Shuttle and Salyut-type spacecraft.”<sup>14</sup>

The Science and Applications Working Group (SAWG) would be chaired by Dr. Hinners while the Operations Working Group (OWG) was chaired by Dr. Glynn S. Lunney, currently the manager of the Shuttle Payload Integration and Development Program Office at JSC. Together, these groups were to define scientific areas for the proposed joint flight, exploiting both the vast payload capacity and flexible delivery capability of the Shuttle and the extended orbital duration of a Salyut.

Almost lost behind the news about the meeting in Moscow, was a second event mentioned in the same press release. This was hosted by the NASA Wallops Flight Research Center, Virginia, during November 19–25. The eighth annual meeting of a NASA-Soviet Space Biology and Medicine Working Group was the latest event in an ongoing program initiated in 1971 by a Science and Applications Agreement between NASA and the Soviet Academy of Sciences. Prior to this formal meeting, a workshop on simulated weightlessness was held over November 16–18 in Bethesda, Maryland. This program focused upon the biomedical results from Cosmos 936 (an unmanned satellite that included US experiments), a briefing by the Soviets on the recent long-duration flights by the Soyuz 21 and Soyuz 24 crews on board Salyut 5, and a NASA briefing on the third Spacelab Mission Demonstration Test (SMD-III). Delegates also discussed space sickness, its impact on the health of astronauts, and the prospects for future such research as the duration of missions increased.

The summary of these two meetings was released by NASA in January 1978.<sup>15</sup> The Joint Working Groups (JWG) agreed to further meetings in both the USA and USSR in

1978 and that the next (ninth) conference of the Space Biology and Medicine Working Group would be held in the USSR later that year. As a further measure of cooperation, the Soviets invited American participation in two Biosatellite missions that were to be launched in 1980 and 1981.

By the Moscow meeting, the JWG for Basic and Applied Scientific Experiments had progressed in reviewing fields of scientific investigation that could be carried out within the framework of the Shuttle-Salyut program:

- Radio astronomy experiments using an aperture synthesis system.
- Infrared interferometry.
- X-ray astronomy.
- Gamma-ray astronomy.
- Cosmic-ray research.
- Research on physical conditions on active regions of the Sun.
- Space biology and medicine.
- Laser absorption spectroscopy for studying pollution of the upper atmosphere.
- Radio sounding for radio geophysical studies of the 'astrosphere' of Earth.
- Space processing.
- Active (controlled) experiments in Earth's magnetosphere and ionosphere.
- Space meteorology and studies of Earth resources.

Common ground was identified in most of these fields, and both sides proposed further studies to be carried out ahead of the next planned meeting in the US in the spring.

The OWG agreed that experiments conducted on the separate vehicles during the joint mission might require a degree of interaction and mutual orientation between the two spacecraft in addition to any docking operations. The Shuttle could deliver bulky scientific apparatus to be mounted either inside or outside the Salyut, whilst smaller experiments could be launched aboard the Salyut. The group defined three possible modes of operation, any of which might require coordination between the vehicles in order to conduct some of the proposed scientific experiments:

- Mode A: The Salyut and Shuttle as two mutually orientated but separate spacecraft.
- Mode B: During the time the Salyut and Shuttle were docked together.
- Mode C: The Salyut operating scientific experiments that were delivered by the Shuttle.

Basic specifications and preliminary information regarding the capabilities of both spacecraft were exchanged. Each side would also "prepare a handbook with technical specifications and operations parameters for their spacecraft, including sketches and block diagrams." These were to be exchanged by January 1, 1978. In addition, there was a list of US requirements on the spacecraft systems that could be imposed by the potential scientific equipment and experiments, and a similar Soviet document which was entitled 'Preliminary Technical Proposals of Program Accomplishments.' All of these documents would be reviewed at the next meeting in the spring, while the main topic of the next round of talks would be compatibility of systems, including: mission phases; docking systems;



joint flight dynamics; equipment installation (including the utility of a robotic manipulator of the Shuttle); on board electrical compatibility; radio communications; and life support. Unsurprisingly, all of these subjects were revisited twenty years later when preparing for Shuttle-Mir and Shuttle-ISS operations.

### Next Steps

The two sides agreed that in the spring of 1978 the JWG's should concentrate upon defining possible scientific programs and identify any requirements which might be placed on either the Shuttle or Salyut to support those activities. The OWG was to exchange the materials and discuss any technical requirements for inter-spacecraft compatibility, while liaising with the SAWG about the feasibility of supporting any proposed scientific program.

By July 1978, it was presumed that the groups would have agreed the preliminary selection of experiments and a division of work on scientific material and apparatus to facilitate a more accurate costing of the science program. The OWG would present its findings on the feasibility of the hardware necessary for the intended science program, and would continue to work on compatibility issues relating to the systems of the two vehicles. Recommendations for a scientific program were expected to be finalized by October 1978, along with a technical feasibility report. A management plan to execute the joint program would follow and the appropriate technical documentation would be developed.

### A SOVIET SPACELAB?

An interesting, albeit largely overlooked development was reported in the summary of the Space Biology and Medicine meetings at Wallops Island and Bethesda, "The US side informed the Soviet side about the general characteristics of the Shuttle-Spacelab system, including the Life Science Module, Common Operations Research Equipment, Spacelab Payload Accommodations, and the possibility of conducting medical and biological experiments in these systems." Was NASA opening the way for Russia to install experiments on a future Spacelab Life Sciences mission? It appeared so. Dr. David L. Winter, the US co-chairman, "invited the Soviet side to participate in these experiments and informed the Soviet side of the procedures...to submit proposals for consideration for flight."

At the next meeting, planned for the second half of 1978 in the USSR, all of the items listed for discussion were for "joint flight experiments in Space Biology and Medicines." This could have led to a joint biomedical program to be performed in a Spacelab as part of the payload for the proposed Shuttle-Salyut mission, but it could equally have led to a dedicated Spacelab Life Science mission, equivalent to the two Spacelab D (German) and single Spacelab J (Japanese) missions flown on the Shuttle. A third Spacelab Life Science (SLS) mission was considered for the French (Spacelab F), but never pursued. Had events turned out differently, it is conceivable that the mid-1980s Shuttle manifest could have included a Spacelab R (Russian) SLS mission. There is evidence in the form of a letter in March 1978 from astronaut Joseph P. ('Joe') Allen, then Director of Legislative Affairs Division in Washington, to US Senator E. William Proxmire (D. Wisconsin), the Chair of

the HUD-Independent Agencies Appropriations Subcommittee. Summarizing the meetings held in November 1977, Allen pointed out that a reciprocal offer to the Soviets in return for their flying American experiments on Biosatellite missions in 1980–1981 was “to propose experiments for a Spacelab when the Shuttle becomes operational.”<sup>16</sup>

### **NASA’s Organization of the Shuttle-Salyut Study Activity**

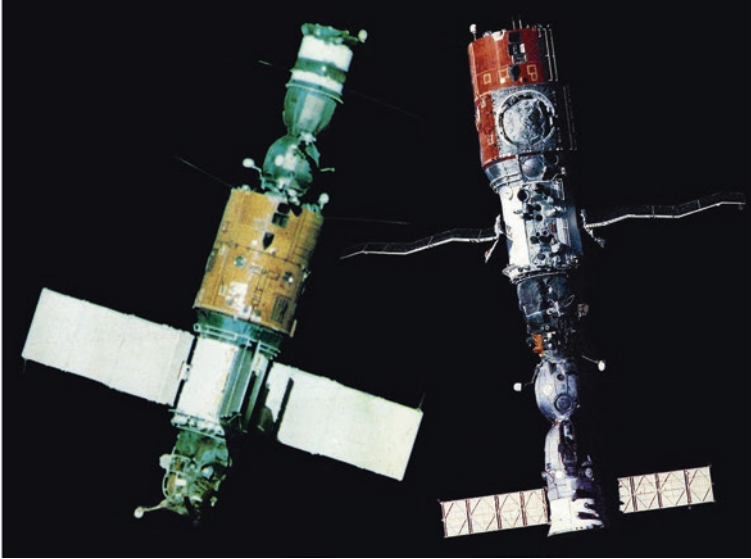
As well as being Chairman of the SAWG, Noel Hinners was the overall lead for the American study of candidate payloads under the Shuttle-Salyut Payload Activities Program. This study was conducted through the Astrophysics Division (Code SC) and the Office of Space Sciences at NASA Headquarters. It was managed by Dr. Franklin D. Martin (also Code SC). The Goddard Space Flight Center in Greenbelt, Maryland, was responsible for supporting mission management requirements for payloads, with JSC in Houston having managerial responsibility for all US operational Shuttle-Salyut requirements and ORI, Inc., acting as support contractor for the study activities. It was presumed that, as the program developed, other NASA field centers would sign up as payload or instrument developers, each with its own technical support and scientific support teams and coordinating efforts via the appropriate program offices at NASA Headquarters.

The Shuttle Salyut Payload Study Group (SSPSG) consisted of eight panels, each looking at potential experiments in a specific field of scientific study, namely: high energy astrophysics; astronomy; space plasma physics; solar physics; life sciences; atmospheric research; materials processing; and Earth observations. The panels also drew up the scientific rationale and objectives of each study, the typical investigations and instrument operating modes, and the requirements of each experiment. The first meeting of the SSPSG was at Goddard on January 16, 1978.<sup>17</sup> Coincidentally, this was the day on which NASA announced its first group of Shuttle-era astronaut candidates. This group included Robert L. (‘Hoot’) Gibson, who would command the first crew to dock with Mir over seventeen years later, as well as Norman Thagard and Shannon Lucid, who would become the first two American astronauts to live aboard the Mir complex, albeit on different missions.

## **THE DEMISE OF SHUTTLE-SALYUT**

By the time of the meeting at Goddard to discuss the prospects for Shuttle-Salyut, the Soviets had been operating the first dual-ported Salyut for four months.

Launched in September 1977, Salyut 6 was to have received its inaugural crew that October, but Soyuz 25 failed to achieve a hard docking at the forward port and so was ordered home. It fell to the next assigned crew to demonstrate the maturity of the Soviet space station program. Soyuz 26 docked at the rear port on December 11. On the 20th, the two cosmonauts, Yuri V. Romanenko and Georgi M. Grechko (using the call sign ‘Tamyr’) performed the first Soviet EVA since 1969. Their inspection of the forward port confirmed that the aborted docking by Soyuz 25 had not caused any damage. On January 12, four days before the NASA meeting, Soyuz 27 confirmed this assessment by docking at the port. After a week aboard the station, the two Soyuz 27 cosmonauts returned to Earth in Soyuz 26, leaving the residents with a fresh craft to continue their long-duration mission.



The dual port Salyut 6 (1977–1982) was the first truly International Space Station. The view on the left shows a Soyuz at the rear port and the upper side of the station. The view on the right shows a Soyuz at the forward port and the lower side, including the apertures for the instruments that view through the floor. It was this class of Salyut which could have performed a joint mission with a Space Shuttle in the early 1980s. (Courtesy SpaceFacts.de)

The following month, Progress 1, the first of the unmanned freighter variant of the Soyuz, docked at the vacant rear port of Salyut 6. While the Salyut was being refueled using an automated system, the crew unloaded fresh supplies and then filled the ship with miscellaneous rubbish that would be destroyed when the craft later burned up in the atmosphere. This flight set a routine for replenishing space stations that continues today with the ISS. Updated over the years, Progress has had remarkably few failures.

In March 1978, Soyuz 28 delivered Vladimir Remek of Czechoslovakia to Salyut 6 as the first space explorer not to be a citizen of either the USSR or the USA. His one-week ‘visiting’ mission marked the start of the Interkosmos program where the USSR flew ‘guest cosmonauts’ for fraternal socialist states. One week later, the Tamyr crew returned to Earth having established a new endurance record of 96 days, surpassing the 84 days of the final Skylab crew in early 1974.

In just three months, the Soviets had proved that they had overcome the teething troubles of their earlier stations and verified the potential suggested during the early planning for Apollo-Soyuz and later for Shuttle-Salyut. The operational procedures would be repeated in the next twenty-two years by further long-duration expeditions, visiting crews and Progress freighters. In addition, an ambitious program of EVAs would be conducted from Salyut 6, Salyut 7, and then Mir. Interestingly, although Soyuz were exchanged regularly, usually to have a fresh vehicle docked for the recovery or rescue (if required) of a resident crew, the first in-space exchange of a crewmember was not achieved until 1985 in the case of Salyut 7.

This impressive program also proved that the Soviets were capable of conducting and supporting both long-duration crews and short visiting missions to a station, and resupplying it to achieve several years of productive activity. This experience, which could have been supplemented by visiting Shuttles during the mid-1980s, was called upon by the partnership that adapted Space Station Freedom to support the transition via Shuttle-Mir to the International Space Station. Soyuz and Progress missions have sustained the ISS since 2000.

However, the first 'international space station' was Salyut 6, launched in 1977. It hosted five long-duration missions (the longest for 185 days) and eight Interkosmos visiting missions through 1981.<sup>18</sup>

Meanwhile, NASA continued to work on the proposal to send a Shuttle either to Salyut 7 or its successor. On March 1, 1978, an internal review of NASA's Shuttle-Salyut experiments was conducted. The next day Noel Hinners, Frank D. Martin and Norman Terrell gave a briefing on the results to the Interagency Group in which, at least in principle, the group agreed to accept the Soviet proposal to hold the next joint working group meeting on May 22. This required senior management approval within the agency by April 5 and formal Presidential approval by April 26. It would be tight, but it seemed, at last, that progress was being made by the joint working groups, and that formal authorization for the project would be forthcoming. However, suddenly everything went remarkably quiet concerning developments towards a Shuttle-Salyut docking.

On July 17, 1978, *Aviation Week & Space Technology* reported in its round-up of Washington News that the Shuttle-Salyut joint mission was "in deep trouble, if not already dead, because of increased US concerns over technology transfer to the Soviets and the current abrasive political climate between the two powers."<sup>19</sup> It also reported that the Interagency Committee of the National Security Council had spent the previous six weeks re-evaluating the idea of a joint mission. A planned trip to the USSR by the President's science adviser Frank Press that same week had been canceled because of disapproval of the manner in which the Soviet government was dealing with those who opposed its official views.

The changing political backdrop, various international events, and delays within the Shuttle program (not least to the first orbital flight) all contributed to a rapid and rather subdued end to discussions concerning the Shuttle docking with a Soviet space station. The possibility of a Soviet-dedicated Spacelab mission was also quietly forgotten.\* In fact, the suspension of joint flight discussions would last for the next fifteen years!

### A Congressional Review in 1982

The 1982 *US Senate Report on Soviet Space Programs 1976–1980*, compiled by the Committee on Commerce, Science and Transportation which was chaired by Senator Harrison H. Schmitt, an Apollo astronaut and the only professional scientist to walk upon the Moon, explained the difficulties of dealing with the Soviets at that time and the strained international situations that contributed to the suspension of the Shuttle-Salyut project.<sup>20</sup>

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\* Seventeen years later, during STS-71 in July 1995, the first Mir docking mission, the two outgoing Mir-19 cosmonauts participated in a range of medical evaluations in the Spacelab module that was carried in the payload bay of Atlantis, re-kindling those early suggestions for a dedicated Soviet Spacelab mission.

The report cited a number of evident trends in Soviet-American relations between 1976 and 1980. Most notable was the fact that the Soviets were now able not only to sustain their Salyut program, but had increased their space station operations with an improved second generation design and its support infrastructure. This advance was in marked contrast to the perceived lapse of the American effort in the same period, with the distinct absence of anything with which to fill the long hiatus between Apollo and the Shuttle. Establishing a balance between competition and cooperation in space also remained an issue, even after the end of the race to the Moon. However, the down turn in relations was primarily due to the political differences between the two superpowers at that time, and particularly the invasion of Afghanistan by Soviet forces in December 1979.

The report also highlighted matters of internal politics on both sides which were interfering with the desired depth of cooperation, sometimes to the point where the obvious advantages of cooperation were not fully explored and an opportunity was simply wasted. The report concluded, "Whether Soviet-American space relations will improve depends upon conditions at the political level." There seemed little chance of such an improvement in the short-term. But a degree of cooperation did continue with the ongoing exchange of biomedical life science data and regular, cordial meetings at international events and congresses. Some people pursued informal talks in relation to technical issues, but there were no meetings between those who drew up the agendas, defined projects, and approved the funding for collaborative projects.

It would take the better part of a decade for things to change, at least on the space front. The collapse of the Soviet Union in December 1991 led to Russia inheriting the Soviet space program at a time of economic crisis, and for a time it appeared that Mir would simply have to be abandoned. Certainly plans to develop Mir-2 were out of the question.

Meanwhile in the USA there was an urgent need to address the spiraling costs and complexity of Space Station Freedom, which as yet was still a paper project. It would clearly benefit both sides to collaborate in space, but achieving this wouldn't be plain sailing.

The success of Salyut 6 surprised many international observers, not least in America where the mood was that the nation was once again falling behind the Soviets in space, a runner-up status that NASA thought it had left behind the early 1960s. On the eve of STS-1 in April 1981, an unidentified agency spokesperson said a successful inaugural mission for the Space Shuttle would "give us a lift and bring our supporters out of the woodwork." Sure enough, shortly after that two day Shuttle mission was completed, a poll taken by Associated Press-NBS established that Americans were indeed generally supportive of the space program. The poll suggested that 60% did not feel enough was being spent on the program, and 66% said the money spent on the Shuttle was a good investment.

Back in 1978, with proposals for Shuttle-Salyut maturing, the effort made a lot of sense because both parties could contribute something useful and expect benefits from cooperation, although perhaps not in equal amounts. It was evident that the Shuttle and Salyut were mutually complementary, and that a joint scientific program was justified. Notably, it was the Soviets who were the more enthusiastic and apparently anxious to

conduct such a mission. NASA had been more cautious, careful to ensure there would be solid scientific and space applications results and wary lest it be regarded as a dead-end project. NASA was still hoping to push for more than one Shuttle-Salyut docking mission during the 1980s.

But the political differences that became evident in 1978 and 1979 made any such mission impossible. It was not just Afghanistan. There were also difficulties with the relationship between the US and China as well as delays in establishing the Strategic Arms Limitation Talks (Salt II) agreement, the publicly stated aims of the USSR in Cuba, anger concerning the treatment of political detainees within the Soviet Union, and considerable public and political pressure inside the United States.

On February 29, 1979, Dr. Robert A. Frosch, the NASA Administrator, updated Congress on the Shuttle-Salyut mission. But he had very little to report. NASA had postponed all the meetings of Joint Working Groups planned for the previous year, pending further inter-agency reviews. When Dr. Frosch next reported to the Senate in February 1980, all of the working groups had been in abeyance for a year and a half. The proposed Shuttle-Salyut docking mission was “simply at a state where we are in between activities.” Whilst some thought was given to holding a meeting in October 1979, this was not pursued. At the time, the status was described as “an arm’s length agreement that will more or less continue.” The Soviet view of the stalemate was that the postponement of the inaugural launch of the Shuttle from 1979 to 1981 meant the joint mission could not be scheduled until the middle of the decade.

Having started with much promise in 1977, the proposal quietly slipped out of the limelight. It would be another fifteen years before the idea resurfaced. Although much could be speculated about the program had it developed as planned, the slippage in the Shuttle program would have pushed any joint missions beyond the operational life of Salyut 6 and probably beyond Salyut 7 to its successor. When *that* was launched into orbit in February 1986 it was to act as the core of the modular Mir station...and that is where this story comes full circle.

As for the dedicated Spacelab mission with Russian cosmonauts and experiments, perhaps that, too, might have emerged intact had international and political events of the late 1970s not intervened.

## A RETURN TO SKYLAB?

At the same time that discussions with the Soviets were officially progressing (but in reality had stalled) over a joint Salyut-Shuttle mission, NASA was also reviewing the option of returning to the Skylab orbital workshop.

### Leaving the Keys Under the Mat

On February 8, 1974, the Skylab 4 astronauts Gerald P. Carr, Edward G. Gibson and William R. Pogue, floated into their Apollo at the end of a record breaking 84 days in space. With the hatches closed, the last crew to occupy the space station left behind a “bag of



items” that served as “a time capsule” for any future visitors to the OWS. It was one of the unused white urine stowage bags, tied close to the hatch. Inside were photos and a checklist, among other items. Commander Jerry Carr informed Mission Control that they had left the “keys to the station under the front door mat.”<sup>21</sup> No formal return mission was planned, but the SL-4 crew had closed, but not locked, the airlock hatch to permit entry to Skylab.

### **Marshall’s Skylab-Shuttle Plans**

At the time, it was expected that the unmanned workshop would stay on-orbit until at least 1983, whereupon the slight but incessant drag would erode the orbit sufficiently for it to fall into the atmosphere and burn up.

On June 10, 1977, John H. Disher, the former Skylab Deputy Director and now NASA’s Director of Advanced Programs, asked the Marshall Space Flight Center (MSFC) in Huntsville, Alabama, which had built Skylab, to undertake an in-house study into the feasibility of reusing it. The engineers analyzed the condition of the station and the possibility of its being renovated in the early 1980s. On November 16 the results were presented to Associate Administrator for Space Flight John F. Yardley.

The proposal was for a four-phase plan to reactivate the station. Phase-I required an immediate decision to re-boost the station to a higher orbit in order to extend its orbital life until about 1990. This would be followed by a ground-initiated reactivation test that would be conducted on the OWS between June 1978 and March 1979. If these actions were successful, it was intended that the fifth (of six) orbital flight tests planned for the Shuttle would rendezvous with Skylab in February 1980. After finishing a fly-around to inspect the condition of Skylab close up, the Shuttle crew were to deploy an unmanned vehicle from the payload bay. Controlled from the flight deck of the Shuttle, this would use an Apollo-type probe to dock at the axial port on the vacant station, fire its thrusters to raise the orbit of the OWS, then undock to clear the port for further use.<sup>22</sup>

### **Shuttle-Skylab Phase-II**

Phase-II of the reactivation plan would involve using special refurbishment kits to bring Skylab back on-line. This hardware including a 25 kW Power Module (PM) which had solar arrays, and a Docking Adapter (DA) 10 ft (3.48 m) in length to enable a Shuttle to dock. Since Skylab had an Apollo-type drogue, the DA was to have an Apollo probe at one end and an ASTP-type androgynous docking unit at the other end to accommodate the Shuttle.<sup>23</sup>

Two Shuttle missions were planned for Phase-II. The first, in January 1982, was to carry the initial refurbishment kits and the DA. Shuttle astronauts would perform EVAs in order to stow two of the four solar arrays on the Apollo Telescope Mount to improve the docking clearance for future visiting Shuttles. They would also retrieve a meteoroid experiment left on the ATM eight years previously by the SL-4 astronauts. The second Shuttle mission would bring more refurbishment kits and the crew would make repairs to the damaged Skylab cooling system. The astronauts were to do some “simple passive experiments,” although exactly what those might be was not defined. The plan was also to retrieve samples of the station’s structure for analysis on Earth to study the effects of

spending a decade in low Earth orbit. A detailed analysis of these samples would, it was suggested, help the designers of future spacecraft better understand the deterioration of materials over a period that equated to 58,400 day/night cycles.

All of this work would have provided valuable information for future programs and in advance of any follow on stations. For example, Mir completed some 87,600 cycles during its fifteen years on-orbit. Similarly, the Hubble Space Telescope had, by the time of its final servicing mission in May 2009, completed over 110,900 day/night cycles since its deployment in April 1990. This work is ongoing with the ISS. Since it was launched in November 1998, the Zarya module had endured over 102,000 day/night cycles in the seventeen and a half years to May 2016 (when this chapter was written).

### **Shuttle-Skylab Phase-III**

The third phase of the program would see the delivery of the PM in March 1984. This featured three androgynous docking units. In a procedure similar to that which would eventually be used with the Unity Node of the ISS, the robotic arm would lift the PM off its payload bay supports, flip it end over end, and mate it with the androgynous unit located in the front of the payload bay. The crew would maneuver the Orbiter to mate the docking system at the far end of the PM with the DA on the orbital workshop. The RMS would then deliver the final refurbishment kits. The astronauts would deploy the two PM solar arrays and its thermal radiators and link up the new arrays to the Skylab power system either by passing cables through open hatches or externally by an EVA. Finally, the Control Moment Gyros (CMG) of Skylab were to be powered up and the faulty attitude control system replaced. When the Shuttle departed, the PM would be left on the DA, which would still have two docking ports available for future visiting craft. At this point, NASA would proudly declare the OWS open for business again a decade after the SL-4 residents had departed in their Apollo spacecraft.

Phase-III would continue with a series of 30–90 day missions docking at the DM. Each of these Shuttles would carry a Spacelab module in its payload bay and would require the Orbiter to draw electrical power from Skylab. It was not intended for the astronauts to live entirely in the OWS, since they would retreat to the comfort of the Orbiter when off duty, but they would use the cavernous OWS in which to carry out experiments, test new EVA equipment, or evaluate ways of performing construction tasks in weightlessness. Additional supplies would be delivered by successive visitors to accumulate reserves and stores, new experiments would be installed and, whenever feasible, selected originals would be revived. Between Shuttle visits, the OWS would be operated in an unmanned mode.

In their report, the Marshall engineers offered no specific plans for Phase-IV, other than the installation of externally mounted modules and pallets (very likely resembling the pressurized European Columbus and Japanese Kibo laboratories and unpressurized stowage platforms which were later developed for the ISS). Future ideas to expand the all-new Skylab included an OWS robotic arm, larger power modules, and attaching an expended Shuttle ET that would be pressurized in order to expand the habitable volume to accommodate more ambitious space construction tests. The study also suggested that an additional floor could be installed in the upper part of the OWS to provide a second

wardroom to allow up to nine astronauts to live and work aboard the station. Perhaps a manned residency *without* an Orbiter in attendance might be possible. The exact details were not forthcoming, but this would have required devising a method of rescuing the crew in an emergency, as there would likely be no stock of Apollo spacecraft available. Of course, a rescue would be simpler if the international situation had permitted Soviet participation because their Soyuz would have been able to serve that role, as it would later do with the ISS.

In addition to detailing the refurbishment and reuse of Skylab, the Marshall study included preliminary costing for Phase-II and Phase-III. The prediction was for a six-year program of funding between FY 1980 and FY 1985, the closeout year. Phase-II would cost around \$14 million and Phase-III \$41.2 million; a total of \$55.2 million. This was without the first and final phases and, significantly, without the cost of the Shuttle flights to transport apparatus and crews to the station. As space writer David S. F. Portree stated in an article on the MSFC proposal, the engineers perhaps gave “an optimistic price tag” for the program.

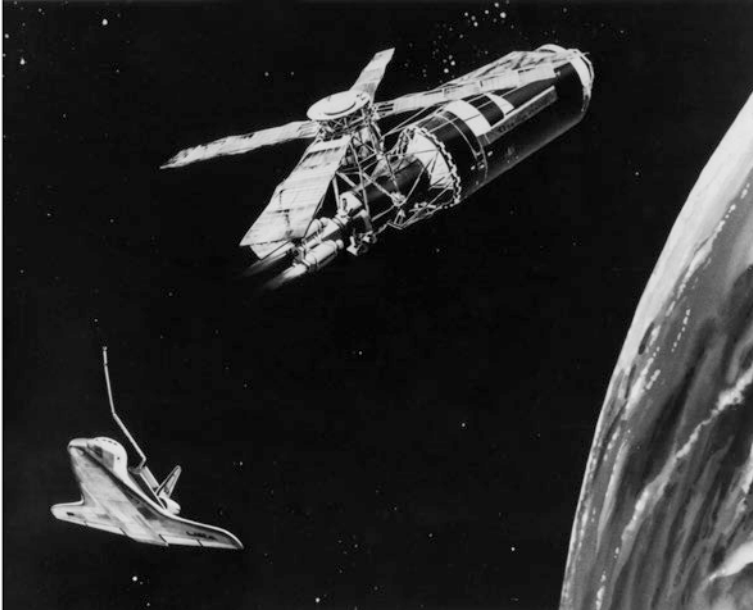
After seeing the results of the study on November 16, 1977, John Yardley ordered further in-house and contractor studies in FY 1978 by McDonnell Douglas under the supervision of JSC and by Martin Marietta under the supervision of MSFC, with each contact worth \$125,000 across nine months.<sup>24</sup>

On March 31, 1978, NASA issued a supporting Fact Sheet about the Teleoperator Retrieval System that was to either re-boost or de-orbit Skylab in 1979.<sup>25</sup>

### Teleoperator Retrieval System

The NASA Administrator ordered development of the Teleoperator Retrieval System (TRS) in October 1977, with Marshall assigned to manage the project. Martin Marietta was hired the following month to design the device. The idea had been under study by NASA since the mid-1960s and its projected long range applications included payload survey, stabilization, and retrieval and delivery. The proposed design featured a central core structure that had its own propulsion systems and attachments for as many as four ‘strap-on’ motors for additional propulsion as required. It would also have a 24-nozzle attitude control system to provide six degrees of freedom, with control through either pre-programmed instructions or by a Shuttle crewmember on the aft flight deck of the Shuttle. The astronaut would use dedicated controls and monitors to remotely operate the unit manually via a TV system located next to the docking equipment.

For the Skylab re-boost mission, the Shuttle would rendezvous with the OWS and the TRS would be deployed from the payload bay. It would flown across to the station and docked at the axial port using an Apollo probe. Then the TRS would return Skylab to its correct attitude so that the four strap-on motors could fire either to re-boost or de-orbit it. The analysis estimated that two burns of 13.5 min would be required for a re-boost mission and one long burn of 27 min for de-orbit. Following the burn, the TRS would undock from the OWS and be put into orbital storage until it could be retrieved by a subsequent Shuttle mission. One possible future use of this vehicle was to install robotic arms on its core element in order to enable it to assemble large structures in space.



An artist's impression of the Skylab re-boost proposal using a Teleoperator Retrieval System deployed from a Space Shuttle.

### Abandoning Skylab

By late 1977, engineers at NASA JSC had reviewed the condition of Skylab on-orbit and the current status of the Shuttle, and had decided that it would not be practical to attempt any type of rendezvous prior to the fifth orbital flight test, which at that time was expected in late 1979. The Shuttle had yet to fly in space, but good results were coming from the ALT flights that year. At this point, no serious studies of docking a Shuttle with an inert space station had been undertaken.

When official approval of the mission was given in September 1977, the Sun was more active than predicted. When the SL-4 crew left Skylab in 1974 the peak of solar activity, which would cause the upper atmosphere to inflate, was predicted to occur in 1980–1981. The consequence of this new data meant that the total drag on the OWS would increase much sooner, advancing its re-entry if no action was taken to prevent that. The entire program was now in a race against time and on a very tight schedule.<sup>26</sup>

In March 1978 NASA named the two-man crews to fly the first four of the planned six OFT missions. The third mission, which was the one most likely to be assigned to visit Skylab, would have Fred W. Haise as Commander with Jack R. Lousma as Pilot. They would be backed up by Vance D. Brand and C. Gordon Fullerton. The plan was for the two astronauts to fly Columbia (the only Orbiter that would be available) on a four day rendezvous with Skylab. But the development of the Shuttle was running very late and as time

### 34 Shuttle and Salyut: A Lost Opportunity

passed there was only a 50:50 chance that the mission would be able to meet the proposed launch date of September 28, 1979; or indeed that Skylab would still be in space. Further development problems slipped the inaugural launch into 1980 at the earliest and that of the third mission to later that year, perhaps even into 1981.

In December 1978, after new NORAD predictions estimated that Skylab would re-enter the atmosphere in July–August 1979, clearly placing the re-boost mission beyond reach, NASA announced that there would be no attempt to revisit it and suspended the development of the TRS.

On July 11, 1979, after completing 34,981 orbits and traveling 930 million miles during 6 years 1 month and 27 days, Skylab re-entered the atmosphere and broke up.

By the end of the year, all thoughts of having a Shuttle dock with a Salyut station in the middle of the decade were in abeyance, and the Shuttle, which was still to make its first orbital test flight, would have to wait another sixteen years to visit a space station.

### NOTES

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