Green light for Soviet space?

The USSR's long declared aim to develop orbiting space stations has been dogged by failures with its Salyut space laboratory. But the safe return of the Soyuz-17 crew last week, after their successful month in Salyut-4, should signal the start of a new period of activity

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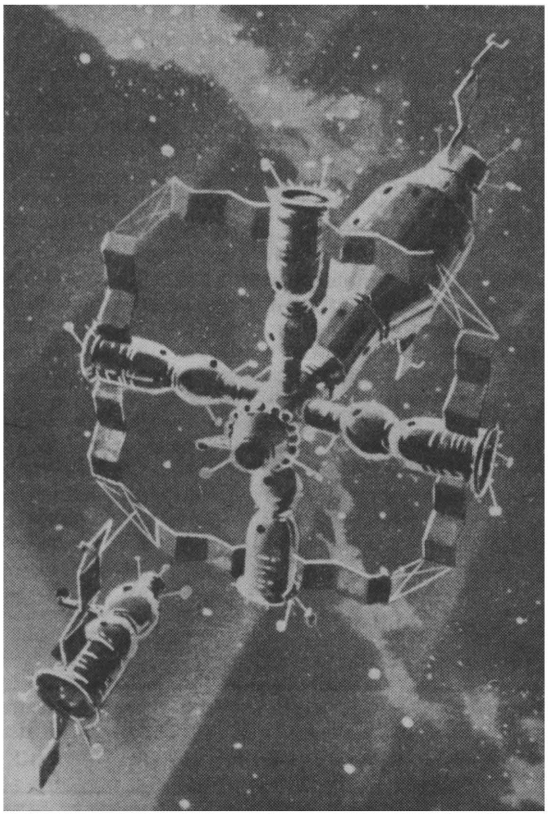
Although the Soviet Union had many early space successes—first Sputnik, first man in space, first photographs of the back of the Moon, and so on—civilian space exploration was not the top priority at this time. Since the end of the Second World War, the Soviet government had been extremely nervous about the American presence in Europe. From its bases in Germany, the US was in a position to bomb any of the large cities in the west region of the USSR, while the Soviet Union could not reach any American city. As a result, the development of strategic missiles received the highest priority. These, it was hoped, would also serve the space programme. In the event, however, they turned out to be unsuitable for manned exploration of the Moon. And by the time this was realised, the US Apollo programme was well underway. The Soviets gracefully indicated that they were not interested in racing to the Moon . . .

Plans to build orbital space stations, however, were not something they could leave so easily to the Americans. They had always professed that this anyway was one of the important long-term aims of their space programme—and had, of course, been working in this direction all the time. By the end of the 1960s, the Americans started making preparations for Skylab. And, as a result, the Soviets had to accelerate their whole orbital space station programme. They appear to have gone too quickly. Failures followed.



Model of Salyut docking with five Soyuz craft

A number of factors militated against them. First, although the Soviet Union had by then achieved a certain parity status with the US in strategic matters, its civilian space research was only just beginning to move up the priority ladder. Secondly, the space design team had lost many of its most important and experienced members—the men who had been responsible for the successes of the late 1950s and early 1960s. Korolyov, Isaev, Yangel, Babakin and some others were all dead. And then there was the actual level of technological culture in the Soviet Union. Anyone who has compared the nuts and bolts of the TU-144 with Concorde, or Soviet space vehicles with American ones, will know that Soviet workmanship still lacked the sophistication of that of the West. This was a problem, the Soviets appreciated, which would only be overcome with time and experience.

Salyut-1 space station was developed in a hurry and proved a tragic lesson. Its design was simple, being basically a three-stage cylinder, but it had certain structural weaknesses. When the Soyuz-11 spacecraft was undocking for its return flight to Earth, the docking mechanism was damaged in such a way that the hatch could not withstand the pressure difference when the spacecraft reentered the Earth's atmosphere.

Workmanship, rather than a design fault, was responsible for the loss of Salyut-2 in April 1973. While modifying the Salyut-1 design, the engineers also decided to improve some of the internal units. These included up-rated electrics and electronic systems which worked well, but somehow caused the pressure to build up inside the spacecraft in excess of its design limits.

Both the Salyut-1 and Salyut-2 setbacks were followed by angry postmortems in the Central Committee. Tremendous political pressure was put on the space designers. After the second failure the emphasis was to produce fewer things but better. This coincided with the period of detente. Contact with the West no doubt assisted the design thinking of the Soviets, and they were now receiving large if not unlimited funds. The new vehicles—Salyut-3 launched in June 1974 and Salyut-4 launched in December—have so far worked successfully and the previous shortcomings appear to have been corrected.

The space stations incorporate a number of modifications, most important of which are improvements in the internal life support systems and in the positioning of the solar panels. These have been enlarged and placed at an angle to the spacecraft as a self-orienting system. This means that the solar batteries can receive energy from the Sun, whatever the position of the ship—this was not the case before.

The Soyuz spacecraft has also been modified and now has a redesigned docking mechanism, an improved guidance system, solid-state batteries and better communications. This has been made possible since the spacecraft is now used to ferry just two men instead of the three it carried on earlier missions.

There is, however, still some confusion over what really went wrong with Soyuz-15 last August, when it failed to dock with Salyut-3 and returned to Earth after just two days in space. General Shatalov, the Soviet cosmonaut chief, claimed that it was testing an automatic docking system being developed for Soyuz's "tanker" spacecraft (these will rendezvous with manned or unmanned Salyut stations to replenish their supplies and prolong their useful life in orbit). The system apparently worked to within 30 or 50 metres of the Salyut, but then each time something started to go wrong. According to Shatalov, the crew continued to use the automatic system so as to collect as much information on its malfunctioning as possible. Western space officials are dubious that this is the whole story.

The two Soyuz-17 cosmonauts, Georgi Grechko and Alexei Gubarev, who have just returned after their 28 days in Salyut-4, are both experienced in problems of spacecraft design. Grechko has worked on the problems of landing automatic stations on the Moon. It seems likely that they had been chosen for their ability to appreciate and criticise the

Welding in space comes down to Earth

Metallurgical techniques will be vital to the development of giant orbiting stations—and they also have their earthly spin-offs

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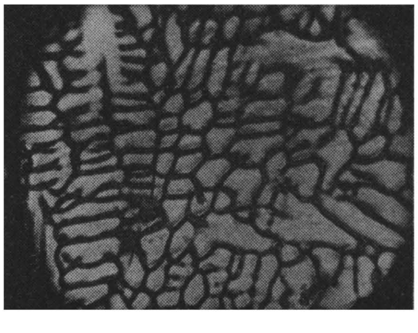
Metallurgy has received a powerful impetus from the exploration of space. Today no one is in any doubt that we will soon have to carry out operations such as the heating and melting of metals directly in space. The main reason why there is such keen interest in this kind of work in both the United States and the Soviet Union is because it is simply impossible to reproduce the same conditions exactly on Earth. Going into space complicates the technology, but promises new and as yet unknown scientific and technological possibilities.

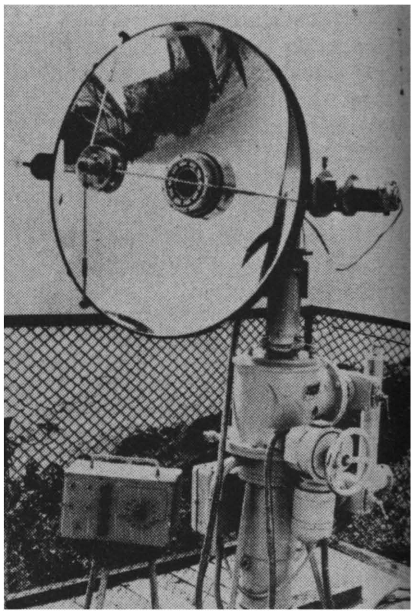
At present, there are three main lines of development in space metallurgy. First, there is detailed scientific research into the behaviour of liquid metals—how molten metal cools and crystallises, the process of its phase transition, the effect of surface tension, the occurrence of wetting with different combinations of phase and materials. Here it is important to study both liquid-only systems and those where the liquid contains solid or gaseous inclusions. And all this requires special research equipment.

Second, there is the development of instruments and techniques for carrying out construction jobs and repairs in space. Experience over the past few years has shown that space vehicles may occasionally need quite serious on-the-spot repairs, involving cutting materials and joining them together—either by welding, soldering or cementing. The same techniques will be needed when space stations or other vehicles are erected from modules launched individually into the orbit. Apart from the special tools and methods that need to be developed, two primary questions concern the ergonomic and physiological capabilities of the cosmonaut himself—how to make it as easy as possible for him to do the job and ensure his safety.

The third main line of research in space metallurgy is the actual production of various metals and articles. We can already see that it should be feasible to produce in space various composite materials (light alloys reinforced with high strength threads or whiskers), monocrystals for the semiconductor industry, and special castings with properties very different from those produced in Earth-based factories.



Microstructure of crystallised copper in gravity (left) and under weightlessness (right)



Compact solar power plant for carrying out metallurgical processes in space. It is mounted on the spacecraft and an optical system directs the required amount of radiant energy on to the surface to be heated.

Members of the Soviet and Ukrainian Academies of Science are tackling together the primary problem of developing the tools specifically for working in space. The work we have done over the past eight years at the E.O. Paton Institute of Electric Welding has emphasised the absolute need for a high degree of working reliability. The tools have to be light, small and of low energy consumption. It is also important that they should working and design of the space station in orbit, including the modifications in its control system that have been introduced on this flight. Their scientific programme did contain some novel experiments. The cosmonauts grew plants, analysed the ozone and water vapour in the upper atmosphere, and regenerated water from the condensate of the atmospheric moisture and their own urine. Reports say this was drinkable. Other experiments in the programme included solar observations, studying X-ray emissions, testing a miniature cryogenic unit for keeping the infrared telescope spectrometer cool, operating a new heating system, and medical experiments.

Unless Grechko and Gubarev have anything untoward to report, it is likely that a second crew will soon be launched for a longer stay in Salyut-4. Grechko and Gubarev switched off the on-board systems when they left, to prevent any unnecessary heat or pressure build up in the Salyut, and sealed the hatch in readiness for a new crew.

If all the systems continue to work reliably, we shall probably see a multiple docking of several Soyuz with one Salyut sometime in the not too distant future. A major part of any future space flights is likely to be experiments in welding techniques in preparation for the day when space stations will be welded together from modules in orbit (see article below). But this will depend on whether the technical and design faults of the earlier Salyuts and Soyuzes have in fact been eliminated satisfactorily.

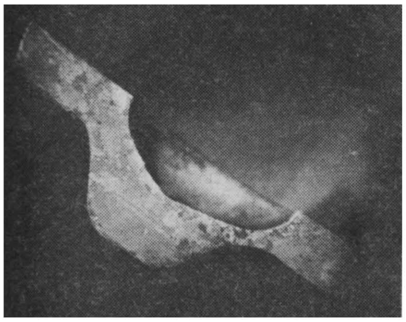
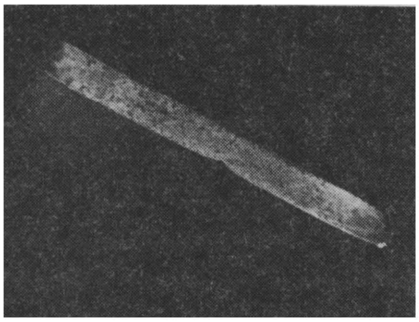
be as universal as feasible; it must be possible to adapt one tool for all the jobs that have to be done on board the spacecraft or outside it.

Since experiments carried out in space itself are very expensive, our institute has developed equipment for studying technological processes in simulated space conditions on Earth. The most successful tests we have carried out so far have been performed in an aircraft fitted out with special experimental rigs containing vacuum chambers capable of being evacuated to 10^{-6} torr. Here we have heated and welded metals in weightless conditions using a variety of heat sources—electron beam, plasma arc, and solar. It is particularly difficult to study the melting, fusion and free crystallisation of metals when the molten metal is in the weightless condition for only a very short time—as in our aircraft laboratory. In such circumstances, we have been able to use no more than 10 to 15 cu.mm of metal.

Nevertheless, we have managed to compare welded joints formed with and without gravity. We have found that samples of aluminium welds made in weightless conditions contain more porosity than could be explained just by the deterioration in the boundary line between the gaseous and liquid phases under weightlessness. We have also observed fairly considerable changes in the microstructure of the metal that has been remelted in space.

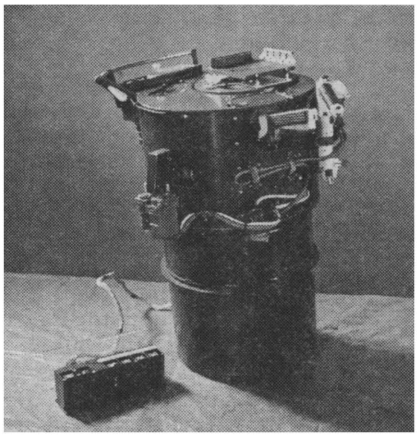
The process of electron beam cutting has not lead to any particular complications either. The molten metal does not move away from the cutting line, but crystallises along the edges. These experiments have made us conclude that it will be quite possible to weld and cut metals during short periods of weightlessness. We have also used the flying laboratories to study man's direct participation in such jobs—by using a special experimental stand incorporating equipment imitating man working in a space suit.

For actual experimentation in space, the institute developed the Vulcan unit. This was a complex automated structure which could cut and weld metal by a variety of methods—electron beam, compressed ray, and fused electrode. It was used on Soyuz-6 in 1969 for the first experiment in welding and cutting metals in space, and carried out both operations successfully. The experience we gained from building and operating Vulcan's miniature welding equipment has been the basis for our further development of metal working space tools. We can expect additional welding and cutting experiments in the near future which will make a definite practical contribution to both space flight reliability and to the production of new materials.

Microstructure of formation of a tin melt in gravity (left) and under weightlessness (right)

The creation of techniques and equipment for heat treating metals in space not only influences the construction of future space vehicles direct, particularly long-term ones, but it is also important for other research fields. For example, the work with electron beam equipment has led to new ways of constructing high voltage supplies and of accelerating electrons; this, in turn, has led to the development of small powerful electron accelerators for sounding the near Earth plasma.



Vulcan welding unit

New methods of metal welding, cutting and soldering that have emerged during the research into space techniques have been taken up by the metal-working industries. Finally, the requirements of space tools—high reliability, safety, small size, low weight, little energy consumption, and the ability to work in a deep vacuum—are all extremely valuable on Earth. If we can succeed in lowering their cost, then these tools could become widely available and beneficial to numerous industries.

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