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## Chapter 13

# Major Development Trends of Orbital Space Stations[1]

**K. P. Feoktistov**[2]

First it seems appropriate to recall the development history of present-day Earth-orbiting stations, then to outline how we visualize them in the time to come.

The work on "Salyut" Earth-orbiting stations started in late 1969. It progressed very quickly and intensively, so that by April 1971 a "Salyut" station had already been launched, marking the beginning of the flights of the first-generation orbital stations, as we conventionally describe them. By this we mean stations that operate with supplies of life-support and survival equipment, of fuel, oxygen, food, water and with research equipment, all of which were placed on the stations before launch.

In October 1977, the second-generation stations started operating, and in February 1986, a new-generation "Mir" station was launched. This will be described later.

Within the 15 years (1971 to 1986) we have achieved much in this domain. In the first place, we have proved that man can work and live in orbit for a long time. We proceeded to this understanding cautiously and gradually, as there was at that time no theoretical evaluation of how man could work and live in space. All this has been determined experimentally, and this is one of the substantial achievements of our research.

We have created the technology needed for supporting a prolonged operation of an orbital station in flight. These technological solutions include several docking adapters on the station, the production of manned and cargo spaceships, facilities for delivering propellant, oxygen, water, food and research equipment to the station, plus machinery enabling repair-and-restoration operations to be performed inside and outside the station.

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[1] Presented at the Twenty-Second History Symposium of the International Academy of Astronautics, Bangalore, India, 1988.

[2] National Committee on the History and Philosophy of Science and Technology, Moscow, U.S.S.R.

During that period, the search continued for the most efficient framework in which man can most fruitfully work in orbit. I must say the issue is rather complicated, and up to now we have not decided definitively where it is most efficient to use man under conditions of an orbiting mission. This search is continuing today. Finally, one can assert that in the same years technologically definite stations. What is meant is the establishment of multipurpose orbital laboratories enabling us to carry on astrophysical research in various ranges of electromagnetic radiation, investigations of the Earth and its atmosphere. One can carry out investigations associated with the study of the natural environment in the interest of the national economy, as well as medical, biological and production process experiments aimed at obtaining super pure semiconductor materials and super pure medicinal preparations.

We should point out that the present trend in the construction of multipurpose orbital stations and research laboratories is very much different from the original idea. The image of such a multipurpose laboratory can today be described by a number of characteristics that have evolved during the development of the "Mir" station.

First, a laboratory station should make it possible to conduct a flexible program of research, i.e. allow additional experiments to be included in the program during the period of an orbital flight. This is to prevent being too constrained by the ideas prevailing at the start of the work on the station. The time scale from the conception of the station to its first flight is a long one. During this time there can be many changes in the means of investigation and the direction of the research itself.

Second, all processes on the station should be automated as much as possible. During flights aboard "Salyut" stations, the cosmonauts repeatedly pointed out that they managed to devote only four to six hours a day to the direct execution of experiments, and even that not on a daily basis but for, say, five days a week. They had to spend the rest of their time on communications with Earth, physical training, the maintenance of the station, so their time efficiency was not very high. That is why it is necessary to automate the processes of servicing the station's systems through introducing space-borne computers in various applications on the station.

This also applies to such tasks as the production of low-consumption orientation systems (i.e. requiring little fuel for their operation). The fuel we take into orbit is wanted for keeping the station in orbit, for compensating for the station's deceleration due to atmospheric drag and for orienting the station. Low-consumption orientation systems have been installed on *Salyut-6* and *Salyut-7* stations featuring "Kaskad" systems that need very little fuel.

Another step forward has been made on the "Mir" station. It was necessary to enhance the capacity of the power supply system and the maximum output of the space-borne power supply has been about doubled on the "Mir" station. Naturally, such a supply system was also required to provide for an expansion of communication zones of the crew with the Earth via repeater satellites.

The station makes use of economical systems for supporting the vital activities of the crew, utilizing so-called regeneration (non-expendable) devices for absorbing carbon dioxide. (The "Salyut" station used expendable absorbers, which were regenerative absorbers of carbon dioxide and noxious admixtures; water secreted by human beings in breathing and through the skin was also regenerated there from the atmosphere of the station). Regeneration of sanitary-hygienic water by electrolysis was performed with a view to recovering oxygen.

A modern type station, a laboratory station, is faced with the task of self-control and diagnostics to secure a higher reliability in the functioning of the station and to detect all kinds of failures at an early stage.

Finally, to ensure flexibility in the scientific and expanding research programs aboard such stations, it is very important to build into the station design a modular principle, i.e. a possibility of extending the station. With this end in view, the "Mir" station features, in addition to two axial units, four more docking units to which we can attach modules containing specialized scientific apparatus for a variety of research activities.

What has been said so far refers to the formation of a possible trend in space station development, namely, the creation of multipurpose orbital laboratories, but one can probably conceive of certain other trends as well.

These might include the establishment of specialized orbital stations for solving particular problems: for instance, a specialized orbital station for investigating natural resources. In principle, natural resources can be studied by automatic apparatus, and this is being done, but at the same time requests have been made for special orbiting stations to investigate natural resources. The best orbit for such a station would be at an inclination of 97°, approximately. Such a station would then pass over each latitude under the same conditions of solar illumination, which would ensure similar observation conditions and enable regular observations of the atmosphere and the ocean surface to be conducted.

Another plausible evolution in the development of orbital stations is the establishment of bases for servicing space vehicles in orbit. This would include repair, refueling, unfolding of antennas, installation of large structural members. This kind of servicing could be made available to space vehicles for investigating natural resources, low-orbital spacecraft sent to a geostationary orbit, interplanetary spaceships, and towing spacecraft from a low working orbit to a high geostationary orbit or to an interplanetary trajectory.

One can visualize still another trend: setting up a "construction site," where it would be possible to assemble large radio telescopes. The views of contemporary radio astronomers and engineering calculations show that it would be desirable and feasible to establish a system of space borne radio telescopes with mirror diameters on the order of 100 m or more. According to present thinking, one of the telescopes would be placed in low Earth orbit, while the other would be positioned in circumsolar orbits. Then, by using radio interferometry methods, one can achieve very high resolution and get a notion of the remotest objects of our universe. To set up such a system of telescopes, a "shipyard" in orbit is wanted, where one could build, unfold and install those telescopes, striving for the required surface precision, and then sending them to their working orbits upon completion. The same shipyard could be used for assembling manned interplanetary spaceships and preparing them for flights. Sooner or later this problem will be tackled and solved. In such a shipyard we could build reusable spacecraft tugs, whose electric jet engines would be solar-powered for inter orbital flights, for example, to a geostationary orbit. The construction of orbital solar power stations could also come out of such shipyards, if in the future it is decided that these are required.

Another use of orbital stations could be associated with production problems. Already present-day experiments carried out on Soviet orbiting stations and American space vehicles have shown that it is advantageous to produce super pure materials and medicinal and biological preparations under conditions of weightlessness. Much work remains to be done, and a lot of experiments need to be conducted to solve these problems. But in the future we may count on the creation of factories in orbit, and such factories will be "production" orbital stations.

What can be said concerning the equipment on board an orbital station? We have already discussed the content of present day orbital stations. A future orbital station will probably be an extendible structure, which means there will be certain heavy frames on which various portions of orbital stations can be mounted. One can predict the availability of a large number of docking ports for manned and cargo ships, space vehicles, etc. Included on such an orbital station would be hangers for the maintenance of space vehicles, both outside the station and in sealed compartments. There may also be refueling depots for priming the spacecraft with propellant, but it is probable that the filling stations will be separated mechanically from the main base of the orbital station. Such stations need large power supplies, whose output is rated not in kilowatts, but in hundreds of kilowatts. Uninterrupted communications with the Earth should be provided, and remote-control manipulators are going to be widely used. A great deal of maintenance will have to be performed on the station, especially outside. There, operations are labor-intensive and hard, and they involve complex manipulations. Very careful and prolonged preparation precedes each spacewalk of a cosmonaut. As extravehicular activity involves fairly sophisticated operations, we need to solve the problems of producing telecontrolled manipulators with grips, processing tools of every kind, tentacles, as well as telemanipulators, that can be controlled both from the space station and from Earth. Actually we embarked upon that path long ago, when we started building automated space vehicles and cargo ships. Beginning with the first mission, we tried to introduce automatic operation modes for manned spacecraft. Properly speaking, mankind has been following this path for a long time by adopting all kinds of mechanization and remote control at ground facilities. We should say that this path takes us rather far, for from primitive instructions like "serve, turn," we shall have to proceed gradually to more and more complicated ones. In the end, apparently, an artificial entity will be created, which will be able to execute the work program as well as a human being, to work without difficulties in space, and for which outer space will not be a hostile medium. Such an entity (in our understanding) is solid-state, on an inorganic basis. In principle, there is nothing to preclude the creation of an entity no less sophisticated than a human being, at any rate in terms on the intellect level. To be sure we will tackle this problem at some time or other. Perhaps it is this path that will lead us to a further broad conquest of circumsolar space and maybe to star flights.

While on the subject of orbital stations, one more peculiarity should be mentioned. Many users of orbital stations are incompatible with each other. For instance a large optical telescope requires a pointing accuracy of 0.1 or even 0.01 arc seconds. If mounted on a space station, such a telescope could not be operated successfully if the crew were moving around and carrying out other operations. The same can be said of certain production processes. Therefore, the idea has been conceived of an "Oblako" orbital station consisting of several (possibly three to four or up to ten) objects flying at a distance of a few kilometers from one another and keeping that distance stable. This prevents collisions, while properly supporting flight in a compact group, so that the crew of the central base, where the pilots are stationed, might fly over to an automated portion of the facility, for example, to the refueling depth or the telescope, to perform some work there.

This seems to be one of the most plausible versions of orbital space stations to come.