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SPACE

(FOUO 2/81)

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MANNED MISSION HIGHLIGHTS

COMPARISON OF SOYUZ-T AND U. S. SHUTTLE

Paris AIR & COSMOS in French No 841, 3 Jan 81 pp 38-39

[Article by Albert Ducrocq: "Soviet Shuttle"]

[Text] The Soviets do have a space shuttle. It is the Soyuz T, as we had occasion to mention in an earlier article. The year 1980 marked a major step forward in its development with its first two manned flights. This spacecraft is expected to be used more frequently in 1981 at a rate consistent with the adjustment and refinement effort required with all new equipment. The Soviets have, however, very prudently decided to keep the regular Soyuz in service for still some time to come. The basic version is much less efficient than the Soyuz T, but Soviet technicians are admirably familiar with it, having worked with it for more than 13 years, whereas they have just barely started to familiarize themselves with the Soyuz T. Hence it is our opinion that we are now witnessing the very gradual replacement of one by the other.

Such being the case, there is no doubt that the Soyuz T is the Soviet space vehicle of the decade. And the fact of calling it a shuttle does not reflect a linguistic contrivance. This spacecraft does actually meet all the criteria required of a shuttle. For the Russians, it is an answer to the American space shuttle orbiter, or at least a different solution applied to the same basic problem which faced scientists of the two space superpowers, namely how to build a vehicle that can travel regularly between earth and near space as inexpensively as possible and with equipment as reliable and as flexible as modern aircraft.

Two Sizes

The major difference between the American and Soviet solutions clearly has to do with the size of the vehicle. The Soyuz T weighs only about 6.5 tons versus the orbiter's 98 tons. As a result the scale is not at all the same, and this because of a fundamentally different approach by both sides.

a. The Americans have no space station in orbit at the present time. They will not have one for some number of years. In any case, whenever they do decide to build one, they will build it in space with the help of the shuttle which is viewed as the spearhead of their space travel effort. During the next few years, the space shuttle will serve as a transport, space residence, as well as an orbital laboratory.

b. The Soviets took the opposite approach. Since 1971, they have been regularly placing a number of Salyut stations in orbit. The Soviet shuttle has the mission of servicing and supplying these stations under operational conditions. The Soviets have thus adopted the principle of using spacecraft specifically designed to transport men and supplies with maximum cost-effectiveness. They point out that with Soyuz T, the cost of placing a cosmonaut into orbit is scarcely more than the cost of placing 2 tons into low earth orbit, namely about $20,000, whereas with the American system, some 14 tons costing $140,000 are necessary per astronaut. This expenditure is justified when you consider that with their astronaut, the Americans simultaneously launch the equipment that will enable him to live in space. This expenditure would no longer be warranted if the orbiter was viewed as a means of transporting men to a structure already in space. In that case, the orbiter could transport 10 men, but this would still bring the cost up to some $100,000 per man.

This difference in size is what was responsible for the dissimilarity of aspect between the Soyuz and the orbiter. When the vehicle's weight is but a few tons, rapid passage through the dense layers of the atmosphere is possible with a thick-walled compact spacecraft whose outer surface will withstand very high temperatures. Such is the reentry method used by the Soyuz spacecraft. It cannot be employed when the vehicle's weight amounts to several dozen tons. Other conditions being equal, kinetic energy is, in fact, proportional to mass, and a spacecraft's outer surface increases only as two-thirds the power of its volume: a spacecraft similar in construction and position to the Soyuz but 35 times heavier would, therefore, have an outer surface only 10 times greater, thereby making it radiate 3.5 times more energy per unit of surface. That would be extremely difficult. And it would be much worse with the fragility of this large spacecraft that would have very little mechanical strength. Technical experts categorically maintain that "if you want to return to earth with dozens of tons, you have to proceed altogether differently. You must opt for--and this is the orbiter solution--the 'gliding flat-iron' which approaches and enters the earth's atmosphere with a high-lift surface in order to extend reentry over a much longer period so as to reduce the energy dissipated per unit of surface."

Considering the choices made, it is evident, therefore, that the Soyuz spacecraft and the American orbiter are preeminently logical solutions, each in its own size category.

Selective Recovery

The number-one characteristic of a shuttle is to be recoverable. The Americans have carried the principle of reuse to its maximum. Almost everything is or will be recoverable. The solid rocket boosters will be recovered at sea, and the complete orbiter will return to earth. Only the large oxygen-hydrogen tank will be expendable, but even this may not be definitive policy. NASA is known to be giving very serious consideration to collecting the tanks left in space by successive orbiter flights. It would thus have, at no extra cost, structural material that might prove useful when building orbital stations. The Russians, on the contrary, seem to have minimal interest in recoverability, inasmuch as they bring back to earth only what is strictly necessary, namely the capsule carrying the astronauts.

Whose approach is right?

Here again, we must consider the choices that have been made. Space specialists know, in fact, that while space travel, in its initial form, might appear to be an aberration in that it requires sacrificing a rocket and several modules with each launch--imagine an aircraft that would be scrapped after completing its maiden flight--the diametrically opposed solution of wanting to recover everything as a matter of principle, is no more advisable. It is indeed useful to recover whatever is valuable. On the other hand, it is false economy to recover items of equipment whose post-flight reconditioning costs would be greater than their production cost.

The cost of Soviet equipment is undoubtedly quite low when we consider the large number of items of the same type and model produced. For instance, the R-7 launch vehicle, as we have repeatedly mentioned, has been in service since 1957 and will probably continue to be throughout this decade. The R-7's basic vehicle has five 100-ton engines--RD-107 or RD-108--each consisting of four identical components--combustion chamber plus nozzle--thereby representing 20 standard components per launch vehicle. This means that some 16,000 of these components have been expended since the start of the space age. No aerospace production line elsewhere in the world can boast of such an achievement. The initial cost of production facilities was redeemed a long time ago and we imagine that the Soviets are in no hurry to adopt another approach.

Nevertheless, there is no indication that the Soviets have not considered recoveries. It is certain, in fact, that, even when mass produced on a large scale, an engine is still an expensive part of a launch vehicle. The four conical engines that form the R-7's first stage are separated from its main body relatively soon enough to drop to earth under conditions permitting their recovery if they are equipped with parachutes. This inevitably brings one thought to mind: if we consider the flight paths of rockets leaving the two large Soviet cosmodromes--Plesetsk and Baikonur--from which the R-7's are launched, we must conclude that the first stage's reentry points have now become the center of veritable "deposits" in which there should be a total of more than 3,000 engines, unless Soviet technicians have removed them, which seems probable, and we can presume they have certainly thought of reusing them.

In this connection, there is a surprising convergence between the American space shuttle and the Soviet launch vehicle-Soyuz combination. The big item currently expended by the Americans is the external tank for the shuttle's main engines, whereas for the Soviets it is the main body of the R-7, but here again this may possibly change. In the beginning, this main body was placed into orbit. Today it includes a second and third stage with the latter steadily increasing in size. But as it is, this third stage is placed into orbit and nothing would prevent putting it aside in the same way, as we noted above, the Americans are thinking of doing with their shuttle's large tank.

Controlled Reentry

One characteristic feature of the shuttle is its ability to glide in the atmosphere during reentry with the resultant capability of controlling its rate of descent, and even of steering it laterally so as to arrive just exactly where it is expected. The American orbiter touches down on a Boeing runway, landing horizontally like an aircraft.

This sort of landing is most attractive. It is not, however, free of risk, even if the Americans have taken all the precautions to reduce the probability of a bad landing to what must be considered practically zero on the human scale of values. Because of its size and configuration, the orbiter cannot land just anywhere. Only a limited number of landing sites on the earth's surface will be capable of handling it. In addition, the absence of an airbreathing engine precludes a go-around, in other words, making a second approach as an aircraft does when for any reason it cannot use the landing site on its first approach.

Unlike the orbiter, the Soyuz spacecraft's earth touchdown is accomplished vertically. Although this is considered a less luxurious method, it is actually more satisfactory for a small-size vehicle. As a matter of fact, it permits landing almost anywhere on earth, on the ocean as well as on the continent, and with a certain degree of comfort because at 1 meter from the ground, landing retrorockets can reduce the spacecraft's speed to very nearly zero.

The big question is maneuvering capability, in other words, to what extent can the spacecraft's occupants choose their landing site during the vehicle's descent?

In the days of the Vostok spacecraft, this question did not arise. A sphere having zero lift--regardless of its attitude, its reentry trajectory will be the same--it was impossible to change its reentry trajectory by atmospheric means. But the situation has changed with the Soyuz spacecraft whose lift coefficient is above 0.2. With this in mind, the Soviets have given their spacecraft an odd bell-like shape to reconcile mechanical strength, stability when penetrating the dense layers of the atmosphere, and the maneuvering systems in the final part of the flight like the Americans with their Gemini and Apollo spacecraft.

Landing Within 1 Kilometer of Predetermined Touchdown Point

We remember a most interesting conversation between the American astronaut Alan Shepard and the Soviet cosmonaut Vitali Sevastyanov, a conversation whose main topic was a spacecraft's glide capability. This conversation took place in front of an Apollo spacecraft, and Sevastyanov's close attention, the questions he asked the American, and his comments had ultimately convinced us of the major role the Soyuz system was undoubtedly long destined to play in Soviet space travel, particularly in succeeding to change the spacecraft's course in the final part of the flight by exploiting the vehicle's lift.

The regular version of the Soyuz already had an attitude control program which kept the vehicle's reentry trajectory locked onto a theoretical curve. Another step forward has been made with Soyuz T which reportedly can actually be piloted in the atmosphere so as to correct any deviations. According to the Soviets, the spacecraft can now definitely land within 1 kilometer of its predetermined touchdown point. The Russians can be expected to do even better, because their obvious goal is to make their Soyuz shuttle as sophisticated as possible.

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FRENCH COMMENTATOR SPECULATES ON FINAL PHASE OF 'SALYUT 6' FLIGHT

Paris AIR & COSMOS in French No 844, 24 Jan 81 pp 53-54

[Article by Albert Ducrocq: "Descent Begun"]

[Text] An airliner sometimes begins its descent several quarters of an hour before landing, which period of time can represent an appreciable portion of the trip. We are seeing the same scenario with Salyut 6.

Put into orbit on 29 September 1977, the Soviet orbital station spent 3 years at an average altitude of almost exactly 341 km, for reasons known to us. At such an altitude, one revolution actually takes 91.35 minutes and at that rate, 31 revolutions would take 2,831.85 minutes, or two times 1,419.925 minutes. A total of 1,419.925 minutes (24 hours = 24,035 minutes) makes one day for the satellite, at the end of which, considering its precession, the orbit will again pass over the same earth track. In particular, when the orbit has been perfectly adjusted, it results in one regular flight over Baykonur every 2 days. This situation is of obvious interest for earth tracking of the station.

This was the situation until mid 1979, except for the free flight period which Salyut 6 experienced because of an irregularity in its engine system. But Progresses then raised the orbit again. Today, it would appear that the Soviets have decided to allow their station to revolve at a lower altitude. On 9 December, Progress 11 left Salyut 6 at an altitude of 290-374 km, an average altitude of 332 km, which since that time has steadily dropped, indicating that for the final phase of the operations, the Russians have seemingly opted for a new formula. It is easy to understand the reason: It responds to a concern for optimization.

Cost of Duration

Two factors are in fact involved.

The higher the station, the lower the resistance to movement because the density of the atmosphere is very low. We know the effect of this resistance: It results in the descent of the satellite. At 340 km, in order to avoid this natural drop, a total thrust of 0.1 m/s per day must be created, a thrust that requires approximately 0.6 liters of fuel. At 320 km, the price is a little higher, on the order of 1 liter. If the altitude is further reduced, the conformation becomes very costly: It will require 5 liters at 260 km and 30 liters at 200 km.

Naturally, these are only orders of magnitude. As we know, the upper atmosphere is characterized by relatively substantial -- and unpredictable -- variations in density (singularly linked to solar activity). Furthermore, resistance to the progress of a Salyut station varies practically from 1 to 3 times depending on its orientation. The fact remains that these figures constitute a valuable reference, bearing in mind that if a station wants to have a long life and be economical at the same time, it must be very high. Any loss in altitude will result in an increase in the amount of fuel consumed. At any rate, this use of fuel is the price paid for duration: In order to keep a station at a given altitude, one must foresee a proportional expenditure in time.

Price of Altitude

On the other hand, altitude is the source of expenditures in two ways.

The higher a station, the greater the consumption of fuel imposed on any Soyuz wishing to join it. We have pointed this out on various occasions and the statement is also naturally valid for the Progress. In order to attain a circular orbit at 240 km from a low orbit (200 to 220 km), a Progress has to use 40 kg of fuel, while in order to arrive at 340 km, 170 kg would be necessary, meaning 130 kg less being taken to the station. A compromise will not fail to be made, depending on the nature of the mission, for a routine course of operation.

When the end of the operation approaches, another consideration comes into play. It is necessary that the station be thrust into the dense strata of the atmosphere above an unpopulated area (in practice, the Pacific). This requires an engine system in good operating condition. We have already had occasion to describe the reaction which a Soviet Skylab whose reentry could not be controlled would cause. A "clean fall" would require additional fuel depending on the altitude of the station: approximately 600 kg from 350 km, 400 kg from 250 km, 240 kg from 180 km, and so on.

When one brings these elements together, one immediately understands the meaning of the strategy chosen by the Soviets.

If our calculations are accurate, they will continue to use Salyut 6 but with a natural descent that will present the triple advantage of enabling the station to be reached more economically, future Progresses to bring the maximum load and following its service, the reentry of Salyut 6 to be controlled by a reduced mass of fuel.

Four-Month Flight

And the schedule?

At an altitude of 340 km, the gross daily loss of altitude is about 0.2 km per day, or 6 km per month. But during the following month -- and we have already reached that stage -- the drop will exceed 10 km. When the station is under 305 km, it will lose 18 km during the third month, 30 km the fourth and 50 km the fifth. Finally, the splashdown would come during the summer.

At least, this is the situation that one foresees in the absence of any maneuver. If they were not to use Salyut 1 (sic) beyond the middle of 1981, the Russians would have an interest in letting their station come down by itself. If, on the other hand, they wanted to prolong the existence of their station and not bring it down until the fall or even the beginning of 1982, then it is now that they must slow the descent because operation remains possible under relatively economical conditions, while it will be costly if they wait and ruinous if they wait longer. For that reason, we must watch the evolution of the Salyut program with particular interest. If several weeks go by without the Russians trying to take their station back up, then one will be able to conclude that they have definitely decided to make it disappear from space during the year after a final phase of operation that would take place during the descent.

Providing, of course, that there is a final phase of operation.

This in fact appears likely. The Russians have indeed announced the flight of the Mongolian cosmonaut for April and the Romanian cosmonaut should be put in orbit in July. One can therefore imagine that a fifth maintenance team, including a new cosmonaut, would be launched in March shortly before the shuttle so that cosmonaut No 100 will be a Soviet. This maintenance team would successively host the last two teams of the current series of Intercosmos piloted flights and leave the station in July or August, shortly before its splashdown.

The fifth maintenance crew's stay on board the Salyut 6 would be shorter than that of the previous two crews, much closer to the 4-month than the 6-month range. The purpose would not be to take a new step in the length of flights -- we continue to believe that in its current form, the Salyut station is not far from having been used to the maximum with the 6-month flight -- but essentially to close the great Salyut 6 operation, taking advantage of the possibility it offers of completing a program in the black inasmuch as the operations are particularly economical, as we have just seen, when one uses a station in its descent phase.

Naturally, the question will not fail to be asked: Is it wise to continue to use a station that is coming back to Earth? Since the loss in altitude is to a certain extent unpredictable, is it not to be feared that the cosmonauts could be trapped in a station whose reentry might suddenly begin to accelerate?

Such fears scarcely seem grounded. As long as a station is above 200 km, officials know that in no case could the returning vehicle suddenly change speed. There is still sufficient time to meet any eventuality. It is worthwhile to recall that up to and including Salyut 3 -- at a time when operations were not planned for over 6 months -- the stations maneuvered at an altitude of under 300 km.

The real concern of the Soviets is the condition of the station, whose equipment is now more than old. The Soyuz T-3 crew did naturally make major repairs, but it did not restore the station to its original condition. The Russians will launch their maintenance crew only when they have assurance that no risk is involved.

Naturally, the situation could change during the mission. More than ever, in the case of this operation, one must speak about an open mission which officials might order ended at any time. As we know, the Salyut 6 operation program has been largely improvised over the past 18 months. It could continue to be so until the end and the Soviets have reason to be satisfied with the course of events, insofar as if this final phase of operation of Salyut 6 comes during the descent, as we think it will, the balance sheet will show the economy of the station. In fact the, Russians will have managed to put on board Salyut 6 a total of nine Intercosmos cosmonauts whom they had originally anticipated dividing between Salyut 6 and 7.

End of a Tunnel

In addition, the descent of Salyut 6 presents another aspect because precisely as a result of the additional program it will have made possible, the completion of this mission may be considered as marking the end of an era in Soviet astronautics.

Naturally, the Russians will not fail to launch Salyut 7, a station that has long been ready and concerning which we already have many details, a station that will be substantially different from the preceding ones, if not in size, then at least in design. It will essentially be a large "living room," the specialized equipment to be outside the station.

But this launching of Salyut 7 will take place in a different context, with the startup of new programs, some of which promise to be spectacular.

Like the Americans, the Soviets seem to have concluded their trek through the desert. In the United States, the past decade had the "shuttle tunnel" during which time NASA's forces were essentially involved in the creation of a new space vehicle. The Soviet Union had the Salyut tunnel. After all, "Salyut" means "salvo" in Russian. Since the cosmos is the testing bench for technologies with respect to satellites, the Soviets decided to devote the decade from 1970 to 1980 to the launching of a salvo of stations destined to enable them to acquire all the technology necessary for the maintenance of a space house and the connections between that house and Earth.

One can now consider that this is a fait accompli and that the Soviets have developed "their" space transport system, a system in which the rocket complex + Soyuz is the counterpart of the American shuttle and in which Salyut represents something without any equivalent in the American program, in this case, a living module that can be operated anywhere, just as the Soyuz T can itself claim to go anywhere, inasmuch as it has navigational systems with which the Zond could not be equipped.

It would be logical -- and it is in this sense that one must speak of a new epoch in Soviet astronautics -- that in this way, Russian piloted vehicles will go far in the cosmos. At the present time, let us recall that no cosmonaut has yet gone 500 km from the Earth. In the USSR, there will definitely be a desire to get revenge for the 1960-1970 decade, a decade that came to a close with the spectacular leap of the Americans to the moon, while the Soviets had to face the opposite situation. Now, with the shuttle, the Americans are going to remain in circumterrestrial space -- no piloted vehicle will enable astronauts to get far from Earth in the foreseeable future -- the Russians now have instruments that will allow their cosmonauts to embark upon the path of distant space.

We must understand that all their thoughts run in that direction: While Salyut 6 descends, the Soviets are dreaming of nothing but that great leap.

[Editor's note: The "Progress-12" transport ship docked with "Salyut-6" on 26 January 1981. On 28 January a "Progress-12" engine burn raised the orbit of "Salyut-6" to 359 by 307 kilometers with a period of revolution of 90.9 minutes.]

[5-11,464]

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INTERPLANETARY SCIENCES

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MONOGRAPH ON INTERPLANETARY FLIGHTS

Moscow MEZHPLANETNYYE POLETY in Russian 1979 pp 1, 270-271

[Annotation and table of contents from book "Interplanetary Flights", by V. N. Kubasov and A. A. Dashkov, Izdatel'stvo "Mashinostroyeniye", 272 pages]

[Text] Annotation. The book discusses methods for solving the problems involved in selecting the trajectories of space vehicles. Methods for computing the optimum dates of launching from the earth and flight approach to the planets are outlined. Methods for correcting the trajectories and controlling the motion of interplanetary space vehicles are described. The problems involved in autonomous navigation are considered.

The book is intended for scientific and engineering technical workers engaged in the development of space technology.

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RADAR OBSERVATIONS OF MARS, VENUS AND MERCURY ON THE 39-CM WAVELENGTH IN 1980

Moscow DOKLADY AKADEMII NAUK SSSR in Russian Vol 255, No 6, 1980 manuscript received 4 Sep 80 pp 1334-1338

/Article by Yu.N. Aleksandrov, A.S. Vyshlov, V.M. Dubrovin, A.L. Zaytsev, S.P. Ignatov, V.I. Kayevitser, Academician V.A. Kotel'nikov, A.A. Krymov, G.M. Petrov, O.N. Rzhiga, A.T. Tagayevskiy, A.F. Khasyanov and A.M. Shakhovskiy, Institute of Radio Engineering and Electronics, USSR Academy of Sciences, Moscow/

/Text/ In the period from February to April 1980 at the Center for Long-Range Space Communication in the Crimea, the USSR Academy of Sciences' Institute of Radio Engineering and Electronics and a number of other organizations conducted radar observations of Mars, Venus and Mercury. During these observations a new, fully rotatable parabolic antenna with a dish diameter of 70 m was used to study and receive the radio signals. The use of this highly efficient antenna, as well as an increase in the transmitter's power and an improvement in the receiver's sensitivity, made it possible to increase the energy potential of the planetary radar by a factor of 50 (while retaining the previous wavelength of 39 cm), which enlarged the possibilities for radar investigations of the planets substantially. In particular, the maximum radar observation range was increased by a factor of more than 2.5.

The observations made in 1980 encompassed significant sections of the planets' orbits: 82° for Venus near the elongation, 139° for Mercury in the region of its inferior conjunction, and 29° for Mars in the area of its opposition; in connection with this, the greatest distances to Venus, Mercury and Mars were, respectively, 161, 139 and 135 million km (these distances are not the maximum possible ones). As a result of the observations we obtained highly accurate astrometric information that made it possible to ascertain the actual accuracy of the theories of the inner planets' motion. New information was also obtained about their relief and the reflective properties of their surfaces.

The distances and velocities of the planets were measured by techniques explained in /1,2/.

Over the entire interval of the 1980 observations, the deviations in the theoretical distances to Venus (as predicted on the basis of the numerical theory /3/) from their measured values did not exceed 6 km (as was the case in the 1977 and 1978 observations). In connection with this, the root-mean-square values of the equipment-methodological errors in the measurements were 300-500 m at distances of up to 140 million km and 1-1.5 km at greater distances. A graph of the measured

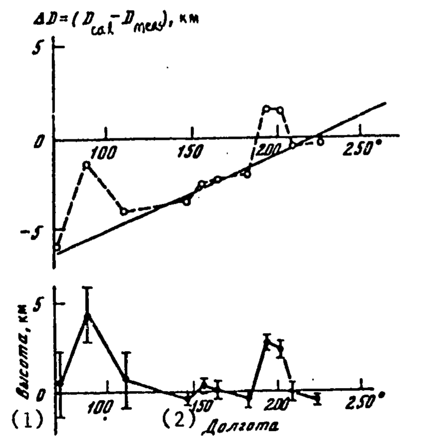

Figure 1. Deviations in the distances to Venus (as calculated on the basis of /3/) from their measured values (above), as a function of longitude, in the coordinate system adopted by the MAS in 1976. The trace of the point being observed moves from 1° S. Lat. (left) to 3.°7 S.Lat. (right). Below is the profile of the heights of Venus's surface as obtained from these measurements. The vertical segments indicate the root-mean-square errors in the measurements.
Key: 1. Height, km
2. Longitude

deviations, as functions of the longitude of the point being observed, is shown in the upper part of Figure 1 in the system of coordinates adopted by the MAS /International Astronomical Union/ in 1976. A straight line approximating the regular component of the deviations caused by inaccuracy of the prediction has been drawn through the points that were obtained. In connection with this, three points at longitudes 87, 193 and 201° were eliminated; according to /4/ these points are located in mountainous areas.

Variations in the deviations relative to the approximating line, as shown separately in the lower part of Figure 1, can be regarded as the profile of the heights of Venus's surface along the trace of the point being observed, the latitude of which changed from 1.°0 S.Lat. at longitude 70° to 3.°7 S.Lat. at longitude 230°. As is obvious from Figure 1, the trace intersects a hilly plain about 8,000 km long at longitudes 110-185° and two extensive mountainous areas about 4,000 and 2,500 km long at longitudes 70-110° and 185-210°, respectively. The first is the higher of the two, reaching a height of about 4 km at longitude 90°, while the second area achieves a height of 2.5 km at longitude 195°.

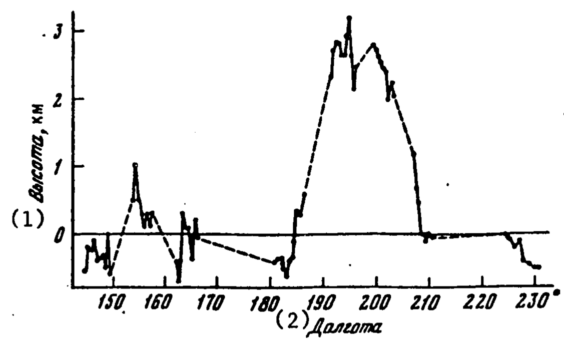

Figure 2. Profile of heights of Venus's surface, as obtained by simultaneous measurements of the distances to different points on the apparent equator on the basis of frequency-temporal selection of the return signals. Longitudinal resolution is 0.°4, or 40 km along the equator.
Key: 1. Height, km 2. Longitude

The profile of the heights of Venus's surface at longitudes 145-230° (see Figure 2) was also investigated in more detail by another method [2] that was based on the simultaneous measurement of the distances to different points on the planet's apparent equator, the return signals from which were separated according to lag and Doppler frequency shift during processing. In this case the surface resolution was about 0.°4 with respect to longitude (or 40 km along the apparent equator), which made it possible -- as is obvious from Figure 2 -- to derive the structure of the profile in more detail in the vicinities of the eight points used in Figure 1, and to distinguish some smaller details in the relief. Measurements made on different days are joined by broken lines in Figure 2.

In the 1980 observations the prediction of the distances to Mars was based on the numerical theory presented in [5]. During the time of the observations, the measured distances' deviations from their predicted values changed within limits of 3-21 km and were caused to a considerable degree by the effect of surface relief; in this case the root-mean-square errors in the measurements were 0.6-1.5 km, depending on the distance to the planet. An analysis of the deviations showed that during the time of the observations, the regular component caused by the inaccuracy of the prediction changed monotonically from 13.5 to 21 km. Such a match can be regarded as completely satisfactory if we consider that the actual interval in the prediction was 9 years, since the latest radar information used in formulating the numerical theory in [5] was obtained in 1971. The change in the prediction error during the nocturnal cycle of observations (less than 8 h) did not basically exceed 100 m, which is significantly less than the measurement error. Therefore, it was assumed that the variations in the deviations of the measured distances from the prediction in each separate cycle were caused only by variations in the heights of the sections of surface passing through the point being observed as Mars rotated. The lengths of the traces along which the point being observed moved in 8 h averaged 117° of longitude. Since Mars and the Earth have different (in both magnitude and direction) velocity vectors for their intrinsic rotation and their revolution in orbit, as time passed the traces shifted with respect to both longitude and latitude. During the observations, this displacement was 8.5-9° of longitude and 1.5-3' of latitude per day, which means that the latitudinal change did not exceed 1' in 8 h. From 15 February to 15 April the widths of the traces varied within limits of 20°01' and 21°12'.

The profiles of the surface heights along the individual traces were processed by the method of least squares in overlapping sections, so as to obtain an overall profile of Mars's surface heights in the full interval of longitudes from 0° to 360°.

The profile that was produced is shown in Figure 3. In order to correlate the profile that was obtained with the average (zero) surface level, we used the topographic map of Mars that was compiled on the basis of television pictures transmitted from the "Mariner-9" spacecraft [6]. The correlation was carried out for equal sections in the longitudinal intervals 160-190° and 230-260° that lay on the surface of an ellipsoid with axes A = 3,394.6 km, B = 3,393.3 km, C = 3,376.3 km.

The most noteworthy section of the profile was that obtained by the passage of the point being observed along the northern slope of the mountain Olympus Mons, where a maximum height of 17.6±1.5 km was observed at latitude 20°44'±20'. The average steepness of the mountain's slopes, as estimated from the ratio of its height to

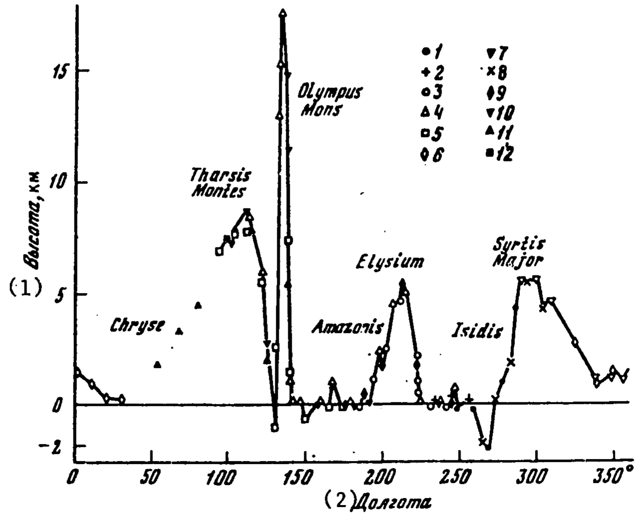

Figure 3. Profile of Mars's surface heights along 20°44'±20' N.Lat. Resolution was about 3° and 4° with respect to latitude and longitude. The area in the interval 120-150° was analyzed with a longitudinal resolution of about 1°.5 (90 km). The small number of measurements in the 32-95° interval made it impossible to obtain a continuous profile of heights in this area. Depending on the signal level, the accuracy of the height measurement ranged from 0.6 to 1.5 km. The measurements were made on different days during the observations: 1. 15-16 February; 2. 19-20 February; 3. 21-22 February; 4. 26-27 February; 5. 28-29 February; 6. 18-19 March; 7. 21-22 March; 8. 25-26 March; 9. 2-3 April; 10. 8-9 April; 11. 11-12 April; 12. 15 April 1980.

the half-width of its base at the zero level, is 3°.6. This mountain, along with a comparatively deep depression to the left of it at longitude 130° and a longer depression 2 km deep at longitude 270°, was not previously recorded on the profile diagram of Mars produced by the American investigators in 1967 [7] for the same interval of latitudes. The depression that were measured are not seen on the topographic map of Mars mentioned above.

During the 1980 radar studies of Mars, we also measured the reflective properties of its surface. The variations in the effective scattering area (ESA), as related to the area of the planet's cross-section πR^2_{σ}, as a function of the longitude of the point being observed, are shown in Figure 4. Because in these measurements we took into consideration only the signals reflected by the part of the planet representing the surface of a spherical segment with a diameter of 730 km (height of the segment = ~20 km), the data obtained correspond to the lower boundary of the planet's ESA.

As is obvious from Figure 4, Mars's ESA changes by more than an order of magnitude, from 0.01 to 0.12. The anomalously low ESA values in the area of the mountainous formations Olympus Mons and Elysium can be related to the special structure of the surface in these regions, which results in a reduction in the area of the sections

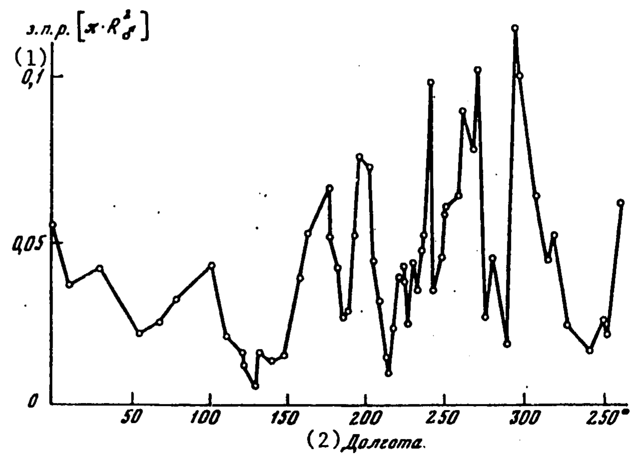

Figure 4. Variations in Mars's ESA in units of cross-section $\pi R^2_♂$ along $20^{\circ}44' \pm 20'$ N.Lat. Measurement error did not exceed 30 percent.
Key: 1. ESA 2. Longitude

oriented perpendicularly to the radar beam. The highest ESA value is seen on the plateau in the Syrtis Major area, where a strong, mirror-type reflection is seen from large-scale smooth areas.

The first radar observations of Mercury were made in the USSR in the summer of 1962 /8/. At that time, the reflective properties of its surface were investigated and its rate of motion was measured. The sensitivity of the original planetary radar was inadequate for making precise measurements of the distance to Mercury, so there were no attempts to study it with radar in the USSR in the intervening years.

In the 1980 observations of Mercury (from 1 March to 5 April), the distance to it was measured with an accuracy of 1.2 km, and its rate of motion with an accuracy of 5 cm/s. In this case the distance to Mercury was 97-139 million km, while its rate of motion relative to the Earth ranged from -27.3 to +26.3 km/s. The distances measured during the observations proved to be 120-420 km more than the figure provided by the analytical theory /9/ constructed on the basis of optical observations. As should have been expected, the accuracy of the classical analytical theory of Mercury's motion turned out to be 1.5-2 orders of magnitude worse than the accuracy of the numerical theories for Venus and Mars /3,5/.

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PRELIMINARY RESULTS OF MEDICAL STUDIES CONDUCTED DURING MANNED FLIGHTS OF THE 'SALYUT-6' PROGRAM

Moscow IZVESTIYA AKADEMII NAUK SSSR: SERIYA BIOLOGICHESKAYA in Russian No 1, Jan-Feb 81 p 5-20

[Article by Ye.I. Vorob'ev, O.G. Gazenko, N.N. Gurovskiy, A.D. Yegorov, A.V. Beregovkin, V.A. Degtyarev, V.V. Kalinichenko and I.I. Kas'yan, submitted 26 May 80]

[Text] Physiological displacements were observed during space flight which corresponded, on the whole, to preflight estimations and reflected the phasic course of adaptational processes. The displacements were seen in changes in circulatory patterns, variation in basic indices for hemodynamics at rest within the limits of physiologic norms, increase of blood flow to the head and decrease of blood flow to the tibia. The nature of changes in circulation, caused by physical stress and the addition of negative pressure, varied and, in a number of studies during flight, were more marked than on earth.

Changes were observed after flight during the period of readaptation. These reactions were of a functional nature, qualitatively not different from reactions observed after other flights. After the 140 day flight they were less marked, on the whole, than after the 96 day flight.

During the post-flight period, in order to accelerate the process of readaptation, a complex of rehabilitative-therapeutic measures was conducted, including regulation of motor activity, rehabilitative muscle massage, therapeutic sports and water procedures.

Results from the 140 day flight did not suggest any kind of contraindications for future planning of longer periods of space flight and once again demonstrated the possibilities for management of health in flight and preparation of the organism for return to the forces of earth's gravity.

Introduction

In the USSR, from 1977-1978 during the orbital program "Salyut-6"--"Soyuz", manned flights of 96 day duration (the first main crew: CC-1 [commander of crew-1] Yu. V. Romanenko, FE-1 [flight engineer-1] G.M. Grechko) and of 140 day duration (the second main crew: CC-2 V.V. Kovalenok, FE-2 A.S. Ivanchenkov) were carried out. The basic landmarks of each of these flights of unprecedented duration were: exit and work of the crew outside of the orbital complex; the joint work during each flight with two visiting crews as well as the first main crew's work with one transport freight ship and the second crew's work with three; completion of a multitude of scientific, scientific-technical, medical-biologic experiments and observations.

During the flight, the first main crew (MC-1) carried out joint work with two visiting expeditions (EC-1 and EC-2): personnel in the first, V.A. Dzhanibekov and O.G. Makarov, personnel in the second, A.A. Gubarev and citizen of the Czechoslovak Socialist Republic V. Remek. The second main crew (MC-2) worked together with the second international visiting expedition, the personnel for which included P.I. Klimuk and M. Hermaszewski (Polish Peoples Republic), V.F. Bykovskiy and S. Jaehn (German Democratic Republic).

The basic medical tasks consisted of maintaining the good health and adequate work capacity of the crew in flight, carrying out medical examinations, managing a complex of prophylactic measures to prevent the non-beneficial effects of space flight on the human organism and preparing the main crews for the effect of return to the forces of earth's gravity. This report presents results of medical observations of the cosmonauts during and after flight, as well as results of studies on body weight and tibial and cardio-vascular system capacity after a 140 day flight.

Characteristics of flight conditions in a orbital complex

The atmosphere in the living quarters of the orbital complex during the flights of the first and second main expeditions was similar to the earth's atmosphere. Basic indices for the environment in the living quarters were: general pressure 733-847 mm Hg; partial pressure of carbon dioxide 158-229 mm Hg; partial pressure of water vapor 7.0-16.4 mm Hg; air temperature 19.0-24.5°.

The cumulative dose of irradiation received during the flight of MC-1 was 2.1 Rem, MC-2--approximately 3.0 Rem. Nourishment during flight consisted of a six-day menu comprised of 70 designated products. The caloric value of the food ration was 3,100 Kcal (on the "Salyut-4" station--2,800 Kcal). The content of the basic food and mineral ingredients was: protein 140 g, fat 100 g, carbohydrates 385 g, calcium 800 mg, potassium 3.0 g, phosphorus 1.7 g (norm 1.2-1.5 g), sodium 4.5-5.0 g (norm 4.0-6.0 g), magnesium

0.4 g (norm 0.3 g), iron 60 mg (norm 15 mg). A vitamin pellet, Airovit, was added daily to the food ration.

During flight, the visiting expeditions and cargo ships delivered fresh products in accordance with the desires of the crew. Water requirements were, on the average, for MC-1--1.2-1.4 liters and for MC-2 --1.4-1.7 liters/day per person.

Conforming to a program for work and rest (PWR), nine hours (from 2300 to 0800 hours in the morning according to Moscow time) were allocated for sleep, 2.5 hours for physical exercise, 2.5 hours for four meals, about eight hours for conducting experiments and other work, two hours for personal time of which one hour, as a rule, was for an after-dinner rest. Days off for MC-1 were allowed after five to six days and for MC-2--every Saturday and Sunday (with certain exceptions). On the whole, the PWR was adhered to. Departures from the routine were related to conducting the docking operation with the transport ships and with unloading the "Progress" ships, to joint work with the expeditionary convoys and to completion of operation "Exit". In a number of cases, especially during the flight of MC-1, deviation in PWR was related to the initiative activity of the crew.

Prophylactic measures included: activities for physical training on a veloergometer and running track (MC-1 completed training 30-40 percent of the planned time and MC-2 to a significantly greater extent; on an average, in a ten day period of flight, the total time of training for MC-2 was for CC 42-87 minutes and for FE 51-82 minutes every day); the wearing of weighted suits which insured constant weight on the motor apparatus: for MC-1 10-12 hours and for MC-2 15-16 hours/day; training by application of negative pressure to the lower parts of the body; administration of water-salt supplements at the day of flight completion; wearing before re-entry and after flight of prophylactic anti-overload suits.

During the flight, showers using the cleaning agent, catamin, were taken twice by MC-1 and three times by MC-2.

To insure psychological balance, leisure activities were arranged such as radio contact with interesting people (artists, commentators, scholars) and the families of the cosmonauts. Relay of musical accompaniment during radio contact sessions, as well as special concerts and informational transmissions were provided.

General condition of the cosmonauts

The change to weightlessness was accompanied in all six crews (two MC and four EC) by the development of sensations of increased blood flow to the head, nasal congestion and puffiness of facial skin. Certain cosmonauts, during this period, experienced transitory spatial illusions, decrease in appetite, and discomfort with head and trunk movement. The extent of manifestation of these reactions varied with each individual. Some cosmonauts experienced vomiting after eating. Usually, autonomic disturbances disappeared after four days. In MC-2, vestibular-autonomic reactions were not observed, but sensations of increased blood flow to the head and nasal congestion were noted to some degree (on the first through sixth day of flight). Sensations of increased blood flow to the head decreased towards the end of the first week of flight, but as a rule, MC-1 experienced fatigue during the whole flight. Their fatigue increased at the beginning of physical work and they required larger quantities of fluids. Fatigue which developed during the work day was usually resolved completely after a night's sleep.

During the flight, mild illnesses developed. In the course of the 96 day flight, one of the cosmonauts on the 50th day became ill with a common cold. He was treated with drugs from the flight pharmacy. During this flight, by the third month, both cosmonauts experienced headaches and discomfort in the area of the heart. For FE-1, these sensations were related to hunger. Dental problems also developed during the 96 day flight.

During the 140 day flight, on the 21st day CC-2 developed paronychia of the middle finger of the left hand after blood was drawn. Therapy consisted of antibiotics, sulphamides and local application of sintazol ointment. On the 49th day of flight, CC-2 reported intermittent discomfort in the area of the heart without radiation to other areas. These sensations disappeared independently and did not return. FE-2 was diagnosed retrospectively as having had left-sided otitis of the middle ear manifested by ear pain on the 112th day of flight. Warm alcohol compresses were used as therapy.

Mild, everyday traumas occurred such as a bruised onychia of the right thumb of FE-2 on the 39th day and bruises of the left talocrural joint of CC-2 on the 47th day of flight during work on the veloergometer. Treatment was not required for these problems. Both cosmonauts of MC-2 experienced headaches on the 29th, 39th and 53rd day of flight, related, in their opinion, to increased CO_2 in the atmosphere of a value greater than 5 mm Hg (up to 6-7 mm Hg). Subsequently, increase of CO_2 content to levels greater than 5 mm Hg in the atmosphere was not allowed.

During the 140 day flight, periodic selective decrease of appetite for certain products was observed, mainly in FE-2.

MC-1 slept well as a rule. They fell asleep quickly and sometimes had dreams. The length of sleep for MC-1 was, on the average, 7.5 -8.0 hours. However, during joint work with EC and during their own independent work, the duration of sleep was shortened. During the 140 day flight, the sleeping habits consisted of early awakening of CC-2 (especially at the beginning of the flights) with subsequent difficulty falling back to sleep and wakefulness in FE-2. In general, these sleep habits were aggravated in flight, but also occurred on earth. This sleep pattern did not interfere with work capacity. On the average, duration of sleep in the first seven weeks of flight was four to six hours for CC-2 and eight hours for FE-2. A subsequent tendency for normalization of sleep and even lengthening of its duration was noted in CC-2. However, CC-2 sometimes retired early. As a sleep aid, CC-2 once took eunoctin (it caused headache and malaise) as well as the tranquilizer, phenibut.

During prolonged flight, essential changes in the nervous-psychological sphere did not arise. However, in certain periods of flight, signs of asthenia were observed (fatigue towards the end of the work day, sleepiness, restlessness during sleep and rare emotional outbursts in the form of inaccurate transmission of information) which were somewhat more marked in MC-1. After touchdown (at the landing site) the cosmonauts noted weakness, fatigue, a feeling of increase in body weight and surrounding objects, an uncomfortable displacement of internal organs in the direction of the vectors of gravitation and vertigo. Sharp movements of the head during evacuation at the landing site caused vestibular discomfort in CC-2 and FE-1.

Examinations, conducted immediately after flight, revealed pallor of the skin and puffiness of the face, limitation of locomotive function, and decrease in orthostatic stability (after two to three minutes of standing in a vertical position, the commander of MC-2 became faint). The inflated anti-overload suit did not provide adequate protection on the day of landing.

Subsequently, the condition of the crew improved progressively and motor activity was increased. Also, on the first day after the 140 day flight (that is, after a night's sleep) vestibular discomfort disappeared in CC-2, walking became more steady and the crew was able to walk unassisted to a meeting with the director.

Results of studies during and after flight

Change in body weight and leg mass

During the 140 day flight, body weight, measured in flight with the aid of the massmeter, decreased in both cosmonauts (figure 1). In CC-2, a clear relationship of decrease in body weight to length of flight was not evident. The greatest loss of weight (2.3-3.4

kg) was observed in him in the 44-59th days. In other periods of flight, the weight loss in CC-2 did not exceed 1.7 kg. In FE-2, weight decreased progressively up to the 86th day of flight (-5.4 kg) but after providing a larger selection of ~.od products, the weight deficit was decreased by the 122nd day and was reduced to a loss of -3.8 kg. After the flight, the decrease in body weight was: in CC-1 -3.6 kg, in FE-1 -4.4 kg, in CC-2 -2.1 kg, in FE-2 -5.4 kg. CC-2 regained the lost weight in the course of three days, FE-1 in the course of four to eight days, in CC-1 and FE-2 in the course of about two weeks.

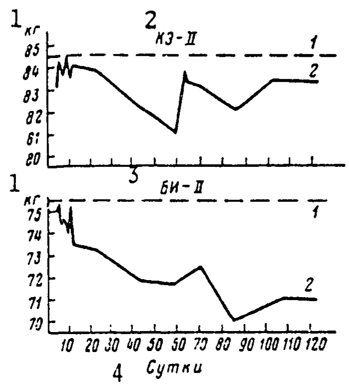

Рис. 1

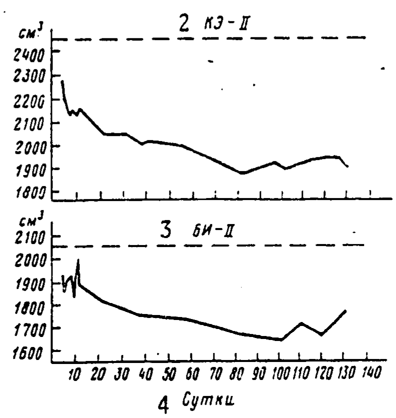

Рис. 2

Рис. 1. Динамика массы тела второго основного экипажа в полете: КЭ-2 — командир экипажа: БИ-2 — бортинженер экипажа; *1* — средняя величина показателя до полета; *2* — величина показателя в полете

Рис. 2. Динамика объема голени второго основного экипажа в полете: КЭ-2 — командир экипажа; БИ-2 — бортинженер экипажа; *1* — средняя величина показателя до полета; *2* — величина показателя в полете

Figure 1. Dynamics of body weight of the second main crew in flight: CC-2--commander of crew; FE-2--flight engineer of crew; 1--average value of indices before flight; 2--value of indices during flight

Figure 2. Dynamics of leg mass of the second main crew in flight: CC-2--commander of crew; FE-2--flight engineer of crew; 1--average value of indices before flight; 2--value of indices in flight

Key:

1. kg	3. FE-2
2. CC-2	4. Days

During the flight, periods of increased physical activity and emotional tension (physical exercise, operation "Exit", re-entry) as well as the limitations of the manner of eating, resulted in loss of body weight. However, the loss of fluid in the organism as a result of its redistribution at the inital period of weightlessness, as well as loss of muscle mass as a result of underuse of the muscular system, were significant. A decrease in leg mass also occurred (figure 2). Thus, in the 140 day flight, leg mass in both cosmonauts was decreased in the first 11 days of flight by not more than 11-13 percent. By the 80-100th day, leg mass was decreased progressively in CC-2 by 23.0 percent, in FE-2 by 19.6 percent and was stabilized subsequently. On the 96 day flight, decrease in leg mass did not depend on length of flight--the deficit in CC-1 was 17-20 percent, in FE-1--9-16 percent.

Study of the cardio-vascular system
During flight, the frequency of cardio-vascular contraction in three of the four cosmonauts exceeded the pre-flight frequency and, in a number of cases, at the end of flight a tendency towards progressive increase of this index was noted (figure 3). However, in CC-1, the frequency of cardiac contraction during flight was, as a rule, lower than the pre-flight frequency or not different from it.

The indices for arterial pressure (terminal and peripheral systolic, diastolic, cardiac and pulse) were altered slightly and their dynamics were different for each cosmonaut. Generally, changes in arterial pressure developed at several stages of flight, with a tendency for decrease in all or several related indices. Thus, in CC-1 and CC-2, all the indices for arterial pressure decreased by the second month and several indices (terminal systolic, diastolic, pulse pressure) in CC-1 decreased by the third month of flight. Pulse pressure in FE-1 and FE-2 was lower than the preflight levels (figure 4).

Changes in the dynamics of contraction of the left ventricle of the heart became apparent during the 140 day flight. These included a shortening of the isometric contraction phase, less constant relative and absolute lengthening of the ejection time, acceleration of diastole and isometric relaxation, diastasis and lengthening (only in CC-2) of relative and absolute index values for rapid filling.

Changes in flight of central hemodynamics, based on rheographic data, were characterized by initial (on the fourth to seventh day) increase in the pulse volume of the heart (PV) in three of the four cosmonauts (by 20-32 percent) and a slight tendency for increase relative to pre-flight levels, of momentary circulation volume (MCV) throughout the entire course of the flight (figure 5). In both crews, the indices for PV and MCV to the head, which reached a maximum by the 50-85th day, were lowered to pre-flight levels towards the end of the 140 day flight but increased throughout the entire course of the 96 day flight (figure 6). Indices for tonus of small cranial vessels were decreased in three cosmonauts. Several studies during flight revealed asymmetry of indices for blood supply to cranial vessels. This resolved towards the end of the flight. Indices for blood supply to the leg decreased given simultaneous increase or absence of changes in indices for blood supply to the forearm.

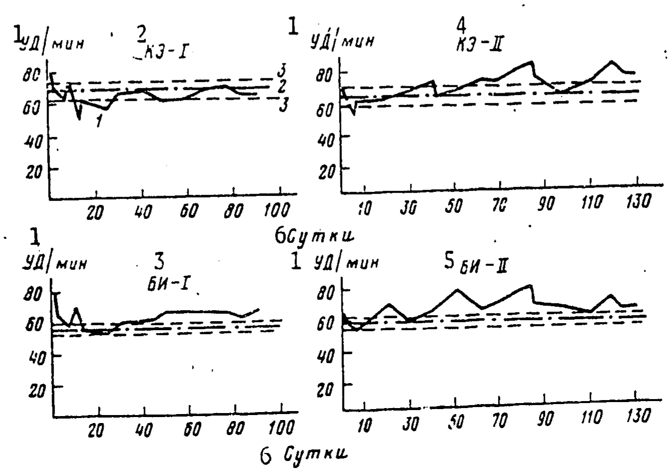

Рис. 3. Динамика средних величин частоты сердечных сокращений в полете: *1* — фактические средние величины показателя в разные периоды орбитального полета; *2* — средние величины показателя в предполетном периоде; *3* — пределы колебаний показателя в предполетном периоде; КЭ-1 и КЭ-2 — командиры первого и второго основных экипажей; БИ-1 и БИ-2 — бортинженеры первого и второго основных экипажей

Figure 3. Dynamics of average frequency of cardiac contraction in flight: 1--average value of indices in different periods of orbital flight; 2--average value of indices in the pre-flight period; 3--extent of variation of indices in the pre-flight period; CC-1 and CC-2--commanders of first and second main crews; FE-1 and FE-2--flight engineers of first and second main crews

Key:

1. Beats/minute
2. CC-1
3. FE-1
4. CC-2
5. FE-2
6. Days

During the 140 day flight, venous pressure, determined by phlebogram of the jugular vein during application of negative pressure to the lower parts of the body, increased initially by 1.5-2 times, normalized by the 85th day of flight and subsequently increased again. In the 96 day flight, the level of venous pressure was increased to a still greater degree and did not decrease (figure 7).

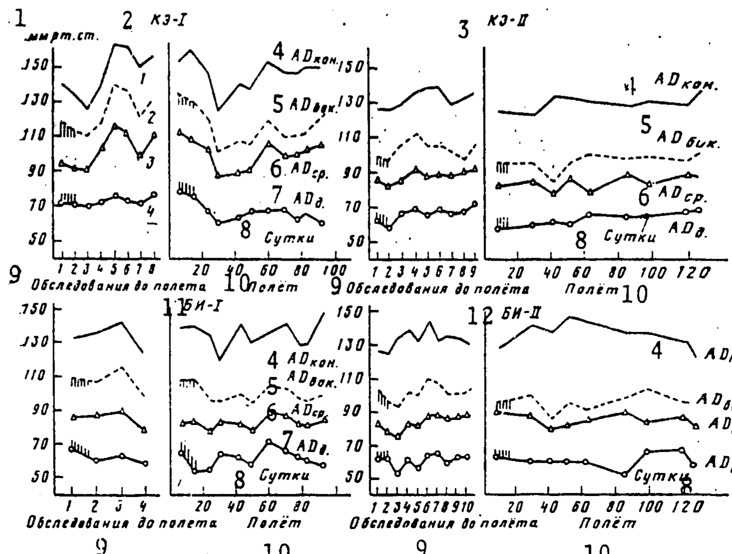

Рис. 4. Динамика показателей артериального давления в полете: 1 — конечное систолическое артериальное давление (АД$_{кон}$); 2 — боковое систолическое артериальное давление (АД$_{бок}$); 3 — среднее артериальное давление (АД$_{ср}$); 4 — диастолическое артериальное давление (АД$_{д}$); направлениями штрихов обозначено пульсовое давление. КЭ-1 и КЭ-2 — командиры первого и второго основных экипажей; БИ-1 и БИ-2 — бортинженеры первого и второго основных экипажей

Figure 4. Dynamics of indices for arterial pressure in flight: 1--terminal systolic arterial pressure (AP_{ter}); 2--peripheral systolic arterial pressure (AP_{per}); 3--average arterial pressure (AP_{aver}); 4--diastolic arterial pressure (AP_{dias}); direction of strokes, marking designated pulse pressure. CC-1 and CC-2--commanders of first and second main crews; FE-1 and FE-2--flight engineers of first and second main crews

Key:

1. mm Hg
2. CC-1
3. CC-2
4. AP_{ter}
5. AP_{per}
6. AP_{aver}
7. AP_{dias}
8. Days
9. Examined prior to flight
10. Flight
11. FE-1
12. FE-2

Based on data from plethysmographic studies, venous pressure in the lower extremities in flight (studied only in MC-2) was on the 130th day approximately 8 mm Hg in CC-2 and on the 125th day approximately 6 mm Hg in FE-2. During exit from the spaceship the plethysmographic curve showed a maximum increase in the tibial venous pressure, which, evidently, indicated a decrease in tonus of the vein and an increase in elasticity. The volume rate of

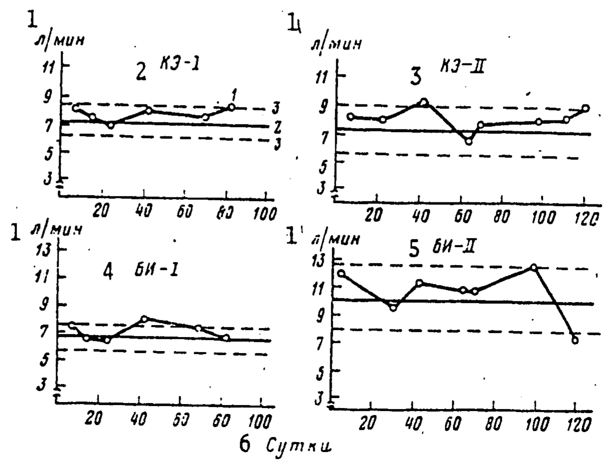

Рис. 5. Динамика минутного объема кровообращения в полете: 1 — фактические величины минутного объема кровообращения в разные периоды орбитального полета; 2 — средняя величина минутного объема кровообращения в предполетном периоде; 3 — пределы колебаний минутного объема кровообращения в предполетном периоде; КЭ-1 и КЭ-2 — командиры первого и второго основных экипажей; БИ-1 и БИ-2 — бортинженеры первого и второго основных экипажей

Figure 5. Dynamics of momentary circulation volume in flight: 1--level of MCV in different periods of orbital flight; 2--average level of MCV in the pre-flight period; 3--extent of variation of MCV in the pre-flight period; CC-1 and CC-2--commanders of the first and second main crews; FE-1 and FE-2--flight engineers of the first and second main crews

Key:

1. Liters/minute
2. CC-1
3. CC-2
4. FE-1
5. FE-2
6. Days

blood flow to the tibia was decreased.

Electrocardiographic examination (12 separate EKG tests) revealed no essential changes in bioelectrical activity of the myocardium during flight. Minor variations in indices, not exceeding the normal limits were noted. Comparison with data, obtained at the first EKG examination in flight (MC-1--seventh day, MC-2--21st day) showed that during the 140 day flight, the amplitude of the QRS complex and the T waves did not change towards the end of the flight. The R/T interval in comparison with pre-flight data

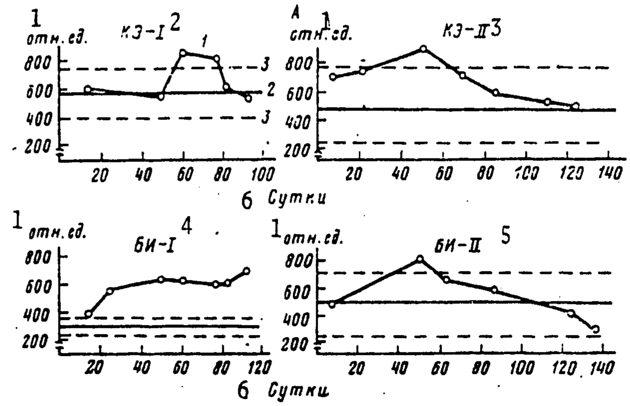

Рис. 6А. Динамика показателя пульсового кровенаполнения сосудов головы в полете: *1* — фактические величины показателя пульсового кровенаполнения сосудов головы в разные периоды орбитального полета; *2* — средняя величина показателя пульсового кровенаполнения сосудов головы в предполетном периоде; *3* — пределы колебаний показателя пульсового кровенаполнения сосудов головы в предполетном периоде; КЭ-1 и КЭ-2 — командиры первого и второго основных экипажей; БИ-1 и БИ-2 — бортинженеры первого и второго основных экипажей

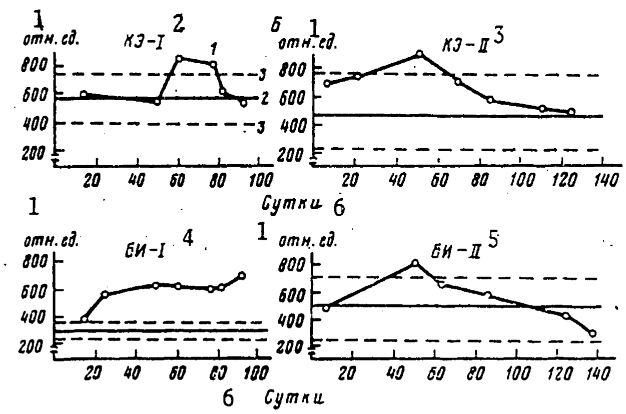

Рис. 6Б. Динамика показателя минутного кровенаполнения сосудов головы в полете: *1* — фактические величины показателя минутного кровенаполнения сосудов головы в разные периоды орбитального полета; *2* — средняя величина показателя минутного кровенаполнения сосудов головы в предполетном периоде; *3* — пределы колебаний показателя минутного кровенаполнения сосудов головы в предполетном периоде; КЭ-1 и КЭ-2 — командиры первого и второго основных экипажей; БИ-1 и БИ-2 — бортинженеры первого и второго основных экипажей

Figure 6A. The dynamics of indices for blood supply to cranial vessels in flight: 1--value of indices for blood supply to cranial vessels during different periods of orbital flight; 2--average value of indices for blood supply to cranial vessels in the pre-flight period; 3--extent of variation of indices for blood supply to the cranial vessels in the pre-flight period; CC-1 and CC-2--commanders of first and second main crews; FE-1 and FE-2--flight engineers of first and second main crews

Figure 6B. Dynamics of indices for momentary blood supply to cranial vessels in flight: 1--value of indices for momentary blood supply to cranial vessels in different periods of orbital flight; 2--average value of indices for momentary blood supply to the cranial vessels in the pre-flight period; 3--extent of variation of indices for momentary blood supply to the cranial vessels in the pre-flight period; CC-1 and CC-2--commanders of the first and second main crews; FE-1 and FE-2--flight engineers of the first and second main crews

Key:

1. Reference units
2. CC-1
3. CC-2
4. FE-1
5. FE-2
6. Days

increased, although during flight specific dynamics were not observed as a rule. After flight, decrease in T waves was noted on EKG.

Tests for physical stress, using a veloergometer (five minutes with a stress of 750 kg-m/min) during the course of the 140 day flight (the test was conducted on the 29th, 41st, 62nd, 97th and 119th day) showed good or satisfactory results in both cosmonauts. The frequency of cardiac contraction in flight at the time of completion of the test reached a somewhat higher level than prior to the flight: in CC-2 prior to flight 116-120 beats/min, in flight 117-135 beats/min; in FE-2 prior to flight 103-107 beats/min, in flight 108-115 beats/min (figure 8).

During the 96 day flight, the absolute and relative increase in the frequency of cardiac contraction at several examinations was more marked than prior to flight. This was especially apparent on the 24th day of flight when other hemodynamic indices were altered essentially as well. The greatest increase in frequency of cardiac contraction in response to physical stress occurred during a series of studies, especially marked in MC-1. These shifts together with other hemodynamic changes, can be attributed to a definite decrease in the functional capacities of the cardiovascular system in flight. The more marked changes in MC-1 are related, possibly, to the fact that the recommended amount of physical exercise was carried out to a lesser extent, than the amount undertaken by MC-2.

Post-flight tests for physical stress were conducted on the seventh day (three minutes with a stress of 600 kg-m) and revealed

Рис. 7. Динамика показателя венозного давления в полете: *1* — средняя величина показателя в предполетном периоде; *2* — величина показателя в полете; КЭ-1 и КЭ-2 — командиры первого и второго основных экипажей; БИ-1 и БИ-2 — бортинженеры первого и второго основных экипажей

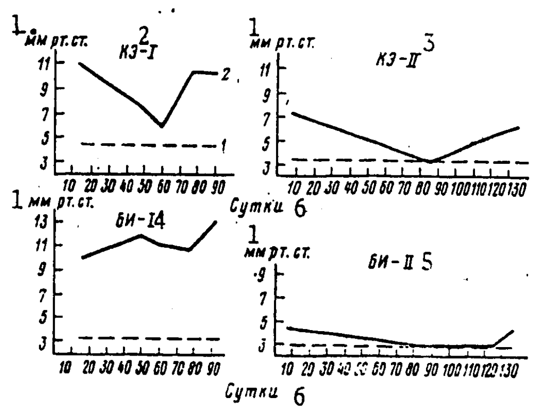

Figure 7. Dynamics of indices for venous pressure in flight: 1--average value of indices in the pre-flight period; 2--value of indices in flight; CC-1 and CC-2--commanders of first and second main crews; FE-1 and FE-2--flight engineers of first and second main crews

Key:

1. mm Hg	4. FE-1
2. CC-1	5. FE-2
3. CC-2	6. Days

changes in the regulation of the cardio-pulmonary system (table). For MC-1, the frequency of cardiac contraction and systolic and arterial pressure were increased at the time of the test in comparison with pre-flight data. These indices (the so-called cardiac stress index of I.K. Shkhvatsabaya (1978)) were increased in the commander by 10 percent and in the flight engineer by 28 percent. This level of strength of cardiac activity insured an adequate supply of oxygen not only for the commander but also for the flight engineer. In fact, the oxygen requirements were 11 percent less than the pre-flight level, which, evidently, reflected the extent of lack of conditioning for physical stress. In MC-2, an increase in the strength of cardiac activity was noted even at rest: the cardiac load index exceeded the pre-flight level in CC-2 by 44 percent and in FE-2 by 75 percent. However, this reaction to physical stress, in comparison to the initial level, was altered to a lesser degree: the cardiac load index in CC-2 increased at the time of the test by 20 percent and in FE-2 by 34 percent in comparison with pre-flight levels. Although the strength of cardiac activity was also increased, an adequate supply of oxygen was obtained, reflecting the change in regulation of cardio-pulmonary function. After five weeks of readaptation, the reaction to physical stress was completely restored.

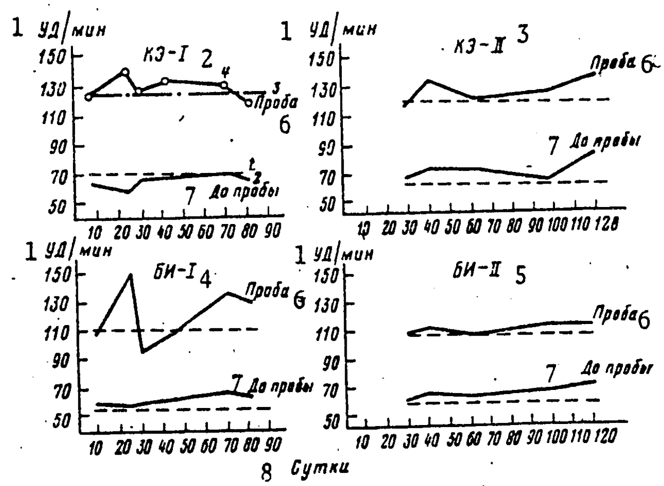

Рис. 8. Динамика частоты сердечных сокращений при проведении пробы на велоэргометре в полете: *1* — средняя величина частоты сердечных сокращений в предполетном периоде перед пробой; *2* — максимальная величина частоты сердечных сокращений в предполетном периоде во время пробы; *3* — средняя величина частоты сердечных сокращений в полете перед пробой; *4* — максимальная величина частоты сердечных сокращений в полете во время пробы; КЭ-1 и КЭ-2 — командиры первого и второго основных экипажей; БИ-1 и БИ-2 — бортинженеры первого и второго основных экипажей

Figure 8. Dynamics of frequency of cardiac contraction during veloergometric tests in flight: 1--average frequency of cardiac contraction in the pre-flight period before the test; 2--maximum frequency of cardiac contraction in the pre-flight period at the time of the test; 3--average frequency of cardiac contraction in flight before the test; 4--maximum frequency of cardiac contraction in flight at the time of the test; CC-1 and CC-2--commanders of first and second main crews; FE-1 and FE-2--flight engineers of first and second main crews

Key:

1. Beats/minute
2. CC-1
3. CC-2
4. FE-1
5. FE-2
6. Test
7. Before test
8. Days

A function test applying negative pressure to the lower parts of the body (NPLB), carried out four times in the 140 day flight and five times in the 96 day flight, caused a circulatory reaction, similar to the pre-flight reaction to the same test. However, in flight, the increase in frequency of cardiac con-

Некоторые показатели кардио-респираторной системы у членов экипажей орбитальной станции «Салют-6» на 3-й *мин* ступени физической нагрузки 600 *кгм/мин* за месяц до полета и через неделю после его окончания (по данным В. В. Щиголева и др.)

1 Показатели	2 Время исследования	3 96-суточный полет: 5 командир, 7 фон	3 96-суточный полет: 5 командир, 8 нагрузка	3 96-суточный полет: 6 бортинженер, 7 фон	3 96-суточный полет: 6 бортинженер, 8 нагрузка	4 140-суточный полет: 5 командир, 7 фон	4 140-суточный полет: 5 командир, 8 нагрузка	4 140-суточный полет: 6 бортинженер, 7 фон	4 140-суточный полет: 6 бортинженер, 8 нагрузка
11 Частота сердечных сокращений, *уд/мин*	9 До	75	114	58	109	64	105	58	103
	10 После	80	119	66	119	82	118	86	120
12 Период изгнания, *мс*	До	253	220	283	235	261	230	271	220
	После	240	200	255	170	250	207	245	170
13 Потребление кислорода, *мл/мин*	До	254	1206	238	1445	297	1350	313	1221
	После	264	1209	254	1335	296	1349	313	1320
14 Кислородный пульс, *мл/уд*	До	3,4	10,6	4,1	13,3	4,6	11,8	5,4	11,9
	После	3,3	10,2	3,8	11,2	3,6	11,4	3,6	11,0
15 Артериальное давление систолическое, *мм* рт. ст.	До	140	170	135	140	115	150	110	160
	После	140	180	120	165	130	160	130	180
16 То же, диастолическое	До	70	95	75	90	70	90	60	75
	После	75	90	80	80	85	95	70	90
17 Сердечный нагрузочный индекс, усл. ед.	До	105	194	78	153	74	158	64	165
	После	112	214	79	196	107	189	112	216

Table. Several indices for cardio-pulmonary function in crew members of the orbital station "Salyut-6" given a three minute interval of physical stress at a rate of 600 kg-m/min for the month prior to flight and at the week after its completion (based on the data of V.V. Shchigolev and others)

Key:

1. Indices
2. Time of examination
3. 96 day flight
4. 140 day flight
5. Commander
6. Flight engineer
7. Background
8. Load
9. Before
10. After
11. Frequency of cardiac contraction, beats/min
12. Ejection phase, ms
13. Need for oxygen, ml/min
14. Oxygen pulse ml/beat
15. Systolic arterial pressure, mm Hg
16. Diastolic arterial pressure
17. Cardiac load index, standard units

traction was more marked, in the majority of cases, and was slightly increased in some of the cosmonauts in relation to the length of the flight (figure 9). Rheographic investigation, given a vacuum, showed different degrees of decrease in indices for circulation to the cranial vessels (figure 10). This phenomenon was accompanied by marked vaso-constriction.

In the post-flight period, a study was conducted to determine the reaction of the organism to ortho- and anti-orthostatic effects according to the following plan: horizontal position--30 min, 70°--10 min, horizontal position--6 min,--150°--6 min, --30°--6 min.

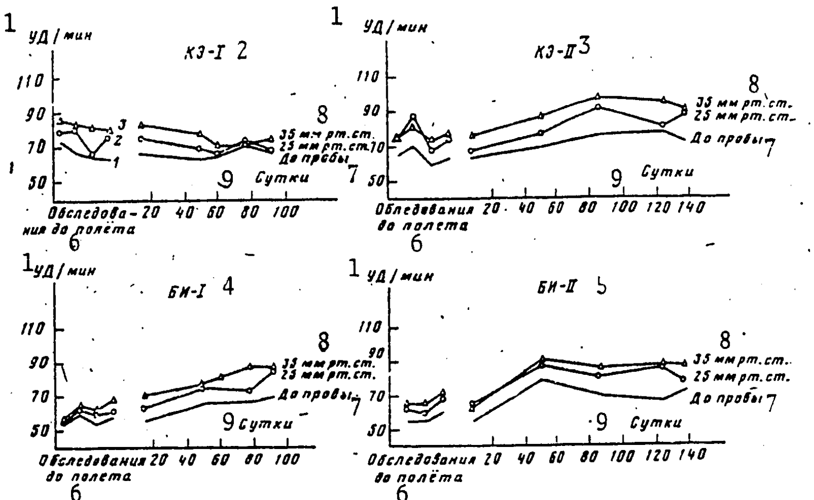

Рис. 9. Динамика частоты сердечных сокращений при проведении пробы с приложением отрицательного давления к нижней части тела в полете: *1* — средняя величина частоты сердечных сокращений перед пробой; *2* — максимальная величина частоты сердечных сокращений при разрежении — 25 *мм* рт. ст.; *3* — максимальная величина частоты сердечных сокращений при разрежении — 35 *мм* рт. ст.; КЭ-1 и КЭ-2 — командиры первого и второго основных экипажей; БИ-1 и БИ-2 — бортинженеры первого и второго основных экипажей

Figure 9. Dynamics of frequency of cardiac contraction after application of negative pressure to the lower parts of the body in flight: 1--average frequency of cardiac contraction before test; 2--maximum frequency of cardiac contraction in a vacuum--25 mm Hg; 3--maximum frequency of cardiac contraction in a vacuum--35 mm Hg; CC-1 and CC-2--commanders of first and second main crews; FE-1 and FE-2--flight engineers of first and second main crews

Key:

1. Beats/minute
2. CC-1
3. CC-2
4. FE-1
5. FE-2
6. Examined before flight
7. Before test
8. mm Hg
9. Days

In all cosmonauts, decrease in orthostatic stability occurred (figure 11), which was more marked than before flight. An increase in frequency of cardiac contraction, acceleration of ejection time and decrease in pulse and cardiac indices were also noted. The decrease in orthostatic stability in MC-2 was more resistant (seven weeks) than in MC-1 (three weeks). The characteristics of the orthostatic reactions after these flights deserve attention. Following the 96 day flight, after three and

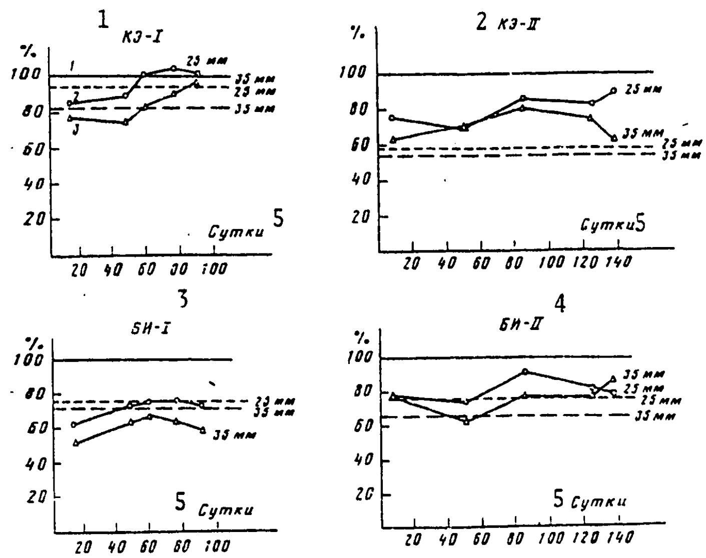

Рис. 10. Динамика показателя пульсового кровенаполнения сосудов головы при проведении пробы с приложением отрицательного давления к нижней части тела в полете: *1* — величина показателя до пробы: *2* — величина показателя при разрежении — 25 *мм* рт. ст.; *3* — величина показателя при разрежении — 35 *мм* рт. ст.; КЭ-1 и КЭ-2 — командиры первого и второго основных экипажей; БИ-1 и БИ-2 — бортинженеры первого и второго основных экипажей

Figure 10. Dynamics of indices for circulation to cranial vessels during tests of applying negative pressure to the lower parts of the body in flight: 1--value of indices before tests; 2--value of indices in a vacuum--25 mm Hg; 3--value of indices in a vacuum --35 mm Hg; CC-1 and CC-2--commanders of first and second main crews; FE-1 and FE-2--flight engineers of first and second crews

Key:
1. CC-1
2. CC-2
3. FE-1
4. FE-2
5. Days

five weeks, hypertensive reactions were observed, but following the 140 day flight, the opposite tendency was noted. This may be a sign of the greater resistant force of anti-gravitational function of the circulatory system in a more prolonged flight.

After the flights, all cosmonauts could better endure, subjectively, anti-orthostatic loads, noting the decrease of its "burden" by approximately 15°. An integral analysis of data for the cardiac cycle showed that arterial pressure, tonus of the main arteries and anti-orthostatic stability were increased in all cosmonauts

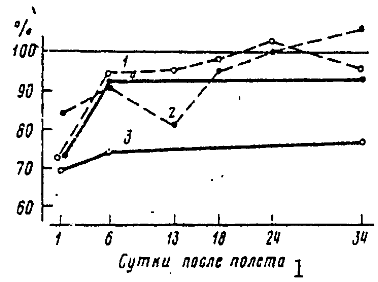

Рис. 11. Динамика интегрального показателя ортостатической устойчивости в послеполетном периоде: 1 — КЭ-1, 2 — БИ-1; 3 — КЭ-2; 4 — БИ-2

Figure 11. Dynamics of integral indices for orthostatic stability in the post-flight period: 1--CC-1; 2--FE-1; 3--CC-2; 4--FE-2

Key:
1. Days after flight

(figure 12) and, gradually, over a course of five weeks of observation, returned to the initial level.

Thus, in prolonged flights, the circulatory system can adapt to weightlessness as seen in increased ability to counteract the redistribution of blood to the cranial area. The manifestation of adaptive changes depends on the plasticity of the individual circulatory system and its resistance to the effects of prolonged space flight.

Рис. 12. Динамика интегрального показателя антиортостатической устойчивости в послеполетном периоде: 1 — КЭ-1, 2 — БИ-1; 3 — КЭ-2, 4— БИ-2

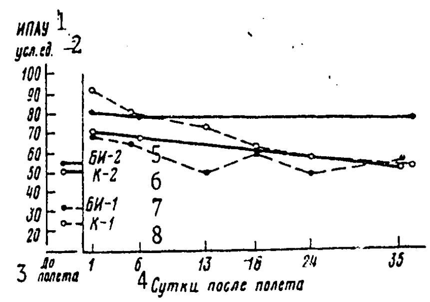

Figure 12. Dynamics of integral indices for anti-orthostatic stability in the post-flight period: 1--CC-1; 2--FE-1; 3--CC-2; 4--FE-2

Key:

1. Integral indices for anti-orthostatic stability
2. Standard unit
3. Pre-flight
4. Days after flight
5. FE-2
6. CC-2
7. FE-1
8. CC-1

Based on echocardiographic data (O.Yu At'kov, G.A. Fomina), after the 96 day flight on the day of landing and on the first day after flight, a decrease in the capacity of the left ventricle and cardiac ejection was noted, as well as a decrease in mass (estimated method) of the left ventricle. The dimensions of the left atrium were somewhat increased. In the first three days after flight, a paradoxical movement of the inter-ventricular wall was recorded in FE-1. This phenomenon is usually observed when a small circulatory region is over-loaded. After the 140 day flight, a decrease in the dimensions and capacity of the left ventricle was noted. A decrease in the pulse volume by 33 percent was observed in CC-2. These changes were not observed on the seventh day after flight. The indices for contraction function of the myocardium did not differ, for all practical purposes, from the pre-flight levels.

Weightlessness is currently thought to be the basic factor which determines the qualitatively unique and specific physiologic shifts which occur in an organism during space flight (Gazenko, Yegorov, 1976; Gurovskiy, Yegorov, 1976). The mechanism for the effect of weightlessness is, evidently, a decrease in the functional load on a number of systems combined with the absence of weight and the resulting mechanical stress on the body structures (Gazenko, Yegorov, 1976; Gurovskiy, Yegorov, 1976; Kovalenko, 1973).

During weightlessness, a redistribution of fluid in an organism towards the cranial direction occurs. This process is reinforced during the flight (chart 1). Studies conducted during the "Skylab" program revealed relocation of the center of body mass (Thornton, 1977) as well as a tendency towards an increase in cardiac ejection, venous pressure and indices for circulation to the cranial area. Such data were also recorded during flights of the "Salyut" program.

Chart 1. Over-view of mechanisms for changes in physiological functions which cause relocation of fluids towards the cranial area

--increase in transmural absorption of tissue fluid;
--lowering of tissue pressure in the lower extremities (decrease in mass of lower extremities);
--increase in transmural pressure and filtration in the capillaries of the upper part of the body (edema of the tissues at the upper regions of the heart);
--increase of venous return, tension on the central and pre-cardiac veins and increase in cardiac ejection;
--increase in indices of circulation to the cranial and jugular veins;
--increase of venous pressure (pressure in jugular veins recorded during flight) which is regulated to the level of central venous

or right arterial pressure (Thornton, 1977);
--decrease of the pressure gradient in the venous system;
--increase of the role of active diastole in hemodynamics;
--development of a phasic syndrome in load capacity;
--increase of pressure in the cardio-pulmonary area and inhibition of the vasomotor centers (Shepherd, 1979);
--increase in tonus of the vagus nerve and activation of relief reflexes (Parin, Meyerson, 1965; Kitayev, 1931; Dexter, Dow, 1950) for receptors of the pulmonary vessels which limit the flow of blood to the heart and which decrease the tonus of vessels of the large chamber (tendency towards decrease of arterial pressure and peripheral resistance);
--elimination of fluid according to the Henry-Gauer mechanism (loss of weight and certain electrolytes) and increase of sanguineous deposition as a result of stimulation of the receptors of the pre-cardiac and pulmonary vessels (Parin, Meyerson, 1965; Ganer, 1974; Chernigovskiy, 1960; Dickinson, 1950), which partially compensate for the manifested shifts (decrease of facial edema and sensations of increased blood flow, etc.);
--stabilization of a new functional level of circulation because of activation of compensatory mechanisms for the carotid sinus (Shepherd,1979; Marshall, Shepherd, 1968).

This redistribution of fluid, possibly, is the basis for the activation of a number of mechanisms which cause changes in physiological functions (chart 2).

Chart 2. Mechanisms for changes in certain functions of an organism during weightlessness

1. Sensation of increased blood flow to the head:--relocation of fluid towards the cranial direction.
2. Edema of body tissue, distributed to the upper areas of the heart:
   --increase of transmural pressure in the capillaries, distributed to the upper areas of the heart.
3. Weight loss:
   --pressure from fluid on the organism;
   --partial loss of muscle mass;
   --increased physical activity and emotional stress;
   --restriction of types of food.
4. Decrease of lower extremity mass:
   --relocation of fluid in the cranial direction;
   --increase in transmural absorption of tissue fluid and decrease in tissue pressure;
   --decrease of muscle tonus and some loss of muscle mass.
5. A tendency for increase in cardiac ejection;
   --relocation of fluid in the cranial direction;
   --increase of venous return.

6. Increase of venous pressure and circulation to the jugular vein;
   --relocation of fluid in the cranial direction;
   --development of general venous stasis because of decrease in the pressure gradient in the venous system and, possibly, because of decrease in the activity of the intra-muscular peripheral heart;
   --Tendency for increased cardiac ejection.
7. Increase of elasticity of the tibial veins:
   --decrease of muscular tonus;
   --decrease of tissue pressure.
8. Reconstruction of the phasic structures of the cardiac cycle (increase of strength and effective length of cardiac contraction, increase in rapid filling time, shortening of the hemodynamically non-effective isometric phase and decrease of the time for cardiac muscle rest):
   --stress on the heart capacity (increase of the role of the indraft function of the heart and of active diastole) and changes in hemodynamics because of decrease of pressure gradient in the venous system.
9. Marked reaction to the tests which apply negative pressure to the lower parts of the body:
   --greater relocation of blood to organs of abdominal cavity and to lower extremities, leading to decreased activity of the receptors in the cardio-pulmonary area and increased activity of vasomotor centers (Shepherd, 1979) with strengthening of the adrenal influence;
   --increased elasticity of the veins of the lower extremities.
10. Decrease of orthostatic stability after flight;
   --increase of elasticity of veins in lower extremities;
   --decrease of venous return.
11. Decrease of endurance to physical stress:
   --development of general deconditioning of the organism because of inadequate load on the muscular system;
   --difficulty in venous return (after flight).

During the last stages of residence in weightless conditions, because of constant physical underloading of the organism (especially given inadequate physical training) and decrease in position-related tonic function of the muscle (no need for the body to resist the forces of gravity), the muscular system, to a greater or lesser degree, becomes deconditioned. As a result, the activity of the intra-muscular peripheral heart is decreased. Blood is moved by this part of the heart from the artery through the capillaries of the skeletal muscles to the veins, thus decreasing the work of the heart and enabling the return of venous blood to the right heart (Arinchin, Nedvetskaya, 1974). The decrease in intra-organ pumping function of the skeletal muscles also promotes the development of venous stasis and increased venous pressure.

Post-flight medical studies revealed a number of more or less clearly outlined syndromes. These included:
--general fatigue and asthenia (rapid physical and psychic exhaustion, irritability);
--deconditioning of the organism to orthostatic and physical effects;
--residual phenomena of redistribution of blood (pastiness of the face and upper half of the chest in MC-1, dilatation and overflow of the venous network with peri-capillary edema, decreased respiratory capacity);
--statokinetic disturbances. Based on data collected by I.B. Kozlovska and co-workers, the cosmonauts developed disturbances in co-ordination of movement and regulation of the verticle position, increase in sensitivity to muscular afferent input and disturbances in inter-extremity reflex interaction, increase in electromyographic indices for muscular strength and decrease in the maximum level of reflex response;
--atrophy of the muscles of the lower extremities (decrease of the perimeters of the tibia and femur, body weight, decrease of tonus and muscle strength);
--anemia in the form of decrease in general volume of hemoglobin (in MC-1 by 24 percent), decrease in the number of erythrocytes (in MC-2 the most marked decrease was observed in CC-2 on the 20th day after flight, in FE-2, on the 34th day) and the content of hemoglobin. After the 96 day flight, changes in the dimensions and form of erythrocytes were observed (aniso- and poikilocytes--15-20 percent of them were abnormal);
--changes in electrolyte metabolism;
--changes in immunologic reactivity.

The complex of rehabilitative measures included functional exercises to regulate motor activity, therapeutic-rehabilitative muscle massage, therapeutic sports and monitored walking, water procedures and psycho-emotional therapy. The effectiveness of these measures was evaluated according to subjective perceptions, the dynamics of pulse and arterial pressure during the procedure and results of clinical-physiological studies.

After the 140 day flight, the rehabilitative measures were carried out in two stages: the first stage (two weeks) at the space port and the second stage (four weeks) in the central mountains (Northern Caucasus).

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SPACE ENGINEERING

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ASTROORIENTATION METHODS AND INSTRUMENTATION EXAMINED

Moscow SISTEMY ASTRONOMICHESKOY ORIYENTATSII KOSMICHESKIKH APPARATOV in Russian 1980 (signed to press 24 Mar 80) pp 2-4, 144

[Annotation, foreword and table of contents from book "Space Vehicle Astroorientation Systems", by Valentin Ivanovich Kochetkov, Izdatel'stvo "Mashinostroyeniye", 950 copies, 144 pages]

[Text] This book presents the basic questions of the theory and principle of constructing space vehicle orientation-control systems with the help of star-tracking sensors which sight on single stars in the star field.

Equations are introduced which relate the orientation parameters to astronomical measurements. Laws of reorientation control are synthesized which are optimal with respect to response time and energy expenditure. Considerable attention is devoted to the design and the statistical analysis and optimization of parameters of astrosystems which are subject to random perturbations.

This book is intended for senior technical personnel engaged in the design of space vehicle control systems.

Foreword

A space vehicle flight-control system is designed to control the movement of the vehicle's center of mass and to control its orientation (its movement around the center of the mass). For the majority of space vehicles, orientation control is the basic mode of movement control and is carried out continuously or periodically during the operation of onboard scientific apparatus requiring a specific attitude for the space vehicle.

The accuracy of orientation control can vary and is determined by the vehicle's purpose. For example, an accuracy of 10-20° [28] is sufficient for the orientation of solar batteries and antennas with a wide aperture of directivity. The majority of space vehicles require an accuracy of orientation on the order of a few degrees or a little more. There are, however, a number of missions, such as the study of space and the trajectory correction for interplanetary space vehicles, which require an accuracy of orientation control no worse than a few degrees or even fractions of angular minutes [2, 28].

Various means can be employed for orientation control. Optical means based on the use of solar, planetary and astral sensors are the most widely used. At the present time, the accuracy of solar and planetary sensors is limited to tens of angular minutes [15].

Star sensors (astrosensors) can, in essence, offer very high accuracy (up to a few angular seconds [28]), since stars are point-sources of light and their coordinates in the celestial sphere are known with very great accuracy. This is explained by the fact that experts in recent years have devoted a great deal of attention to the problems of constructing highly accurate astronomical systems for space vehicle orientation control.

At the present time, various types of star sensors have been created which can be successfully employed on space vehicles. A number of books and articles [5, 11, 13, 17, 19, 24, 30, et al.] are devoted to questions of employing star sensors for navigation on aircraft and space vehicles.

This book is an attempt to summarize and systematize certain data. Along with the theoretical aspects (the derivation of the basic equations relating celestial measurements to the parameters of orientation, the synthesis of laws of reorientation control, etc.), data are presented on the selection of functional arrangements for the various types of astroorientation systems. Examples of solutions to problems of statistically optimizing their parameters are also cited.

The book is logically structured in the following manner:

- principles for the construction and classification of astroorientation systems are presented; data for celestial reference points and the characteristics of practicable instruments for their direction finding are cited (chapters 1 and 2);

- basic astroorientation equations are derived and optimal laws for reorientation (turn) control of space vehicles are synthesized (chapters 3 and 4);

- different versions for the construction of functional arrangements realizing the astroorientation equations are proven to be valid; steps are proposed for the statistical optimization of the parameters of the arrangement selected; the criterion of "maximum probability" and the method of "statistical points" are substantiated for this purpose (chapters 5 and 6).

The application of astronomical devices which insure a high degree of accuracy to orient space vehicles is expedient only on those segments of the orbit where high accuracy is necessary, for example, during the operation of the scientific apparatus. This is explained by the fact that highly accurate orientation demands a higher than usual expenditure of energy (propellant). For this reason, when a high degree of orientation is not required, the space vehicle, as a rule, is oriented in an economical mode with reduced accuracy and the use of simpler methods and instruments, without calling upon complicated computer equipment.

A number of the astroorientation equations presented in the book belong to the "accuracy" stage of dual-mode space vehicle angular movement control. With the aid of other equations (when using star sensors that sight on the star field), one can determine the space vehicle's attitude with great accuracy, even when it is grossly disoriented in space; that is, when its prior attitude is not known. After determining the attitude of such a space vehicle, it is necessary to reorient the craft in the required attitude by turning it about its center of mass.

The author expresses gratitude toward his reviewer, Candidate of Physicomathematical Sciences P. A. Barankov, for his valuable advice and notes which contributed to improving the book.

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CALCULATING SPACECRAFT HEAT EXCHANGE

Moscow RASCHET TEPLOOBMENA KOSMICHESKOGO APPARATA in Russian 1979 (signed to press 28 Sep 79) pp 2, 5-6, 207-208

[Annotation, introduction and table of contents from book "Calculating Spacecraft Heat Exchange", by Vasiliy Mikhaylovich Zaletayev, Yuriy Vasil'yevich Kapinos and Oleg Vladimirovich Surguchev, Izdatel'stvo "Mashinostroyeniye", 1,330 copies, 208 pages]

/Text/ ANNOTATION

The authors discuss typical problems of the theory of heat exchange that are related to the calculation of the thermal conditions of spacecraft and the planning of temperature control systems. They devote particular attention to the specific nature of a spacecraft's heat exchange with the surrounding medium in space.

This book is intended for engineering and technical personnel who are engaged in rocket building and cosmonautics.

INTRODUCTION

One of the necessary conditions for the reliable functioning of a spacecraft and its systems and, consequently, the justification for significant expenditures for its creation, is the provision of the necessary heat conditions for all its elements.

However, this problem has its own specific factors under the conditions encountered in outer space: a spacecraft that is outside the limits of the Earth's atmosphere is itself -- figuratively speaking -- a tiny planet, wherein the temperature distribution is determined by the field of external heat flows, the properties of the spacecraft's surface and the ship's orientation in space (in space, when the same surface is oriented differently relative to the field of external heat flows it will have different temperatures), the power consumption of the on-board equipment, the thermal relationships inside the ship and a number of other factors.

At the same time, many elements and instruments in a spacecraft are capable of working only in strictly defined temperature ranges. Therefore, a modern spacecraft is unthinkable without a special on-board system: a temperature condition control system (SOTR).

The creation of a SOTR for a specific spacecraft takes place in three mutually related stages:

a theoretical, calculative analysis of the heat exchange processes in the spacecraft and the thermal conditions in it as a whole, a comparison of the possible ways of solving the temperature condition control problem, and a final calculative test of the selected SOTR variant;

experimental testing and development of the SOTR under terrestrial conditions, primarily on the basis of modeling of the actual thermal conditions under which the spacecraft will function;

final testing and development of the SOTR on the basis of the results of full-scale tests.

In view of the fact that experimental development requires the creation of a unique experimental base, and because development under full-scale conditions entails considerable material expenditures, the calculative-theoretical methods for analyzing and testing thermal conditions and the effectiveness of a SOTR play an extremely important role in the solution of the problem of controlling the thermal conditions in a spacecraft. They are needed not only during the SOTR planning stage, but also during the stages of experimental and full-scale testing of the technical decisions that have been made.

The optimum path for the solution of the spacecraft temperature condition control problem is, obviously, a combination of the calculative-theoretical methods of analysis with ground-based experimental development and a final check with full-scale tests.

The design of a spacecraft is quite complicated as far as the precise theoretical calculation of its thermal conditions is concerned. The special features of heat exchange inside a spacecraft and with the space surrounding it complicate the calculations even more. This makes clear the urgency of the development and systematization of those calculative methods that would make it possible to make the entire series of necessary evaluations and produce a sufficiently complete representation of a spacecraft's thermal conditions with a degree of accuracy adequate for practical engineering and minimal expenditures of effort.

Approximative engineering methods for analyzing the particular problems of spacecraft heat exchange are not only necessary, but are irreplaceable at the most critical stage of SOTR development, which is that of selecting the general plan for the system. During the stage of test calculations of the thermal regime of individual spacecraft elements and the craft as a whole, as well as during the stages of ground-based experimental development and full-scale testing, they are used as an auxiliary method, and sometimes as the basic one. With rare exceptions that are basically the result of attempts to maintain consistency in our explication, the materials presented in this book only supplement works that are already known. Therefore, many of the known solutions for particular problems are not presented, but references are made to them in the appropriate sections.

To some degree or another, all of the particular solutions allow for the specific nature of heat exchange processes in a spacecraft and, in particular, the periodicity of the changes in spacecraft temperatures with respect to time and spatial coordinates that are related to a spacecraft's design. Special attention is given to this feature. In the appendix we present a method of periodic integral transformations that was developed especially for the analysis of such processes and the use of which leads to a substantial simplification of the solution of many applied problems.

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THEORETICAL PRINCIPLES OF DEVELOPING SPACECRAFT

Moscow TEORETICHESKIYE OSNOVY RAZRABOTKI KOSMICHESKIKH APPARATOV in Russian 1980 (signed to press 26 Mar 80) pp 2-4

[Annotation and table of contents from book by G. Yu. Maksimov, Izdatel'stvo "Nauka", 1800 copies, 320 pages]

[Text] A discussion is presented of the physical-mechanical principles of developing automatic spacecraft. The prerequisites are presented for selecting the parameters of the basic on-board systems which include the radiotelemetric system, the electric power supply system, the orientation control system and the on-board antennas. The principles of the development of the composition and structural design are discussed. In particular, the peculiarities of developing unsealed compartments with equipment are analyzed. Significant attention has been given to the problems of in-flight spacecraft control. In the last chapter a version of an algorithm for efficient spacecraft design is presented. The book is intended for engineers and scientific workers involved with the development of spacecraft and also for students studying the fundamentals of space engineering.

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SOME PROBLEMS OF ASSEMBLING AND SERVICING OBJECTS IN SPACE

Moscow NAUCHNYYE CHTENIYA PO AVIATSII I KOSMONAVTIKE 1978 in Russian 1980 (signed to press 5 Mar 80) pp 94-99

[Paper by I.T. Belyakov and Yu.D. Borisov: "Problems of Assembling and Servicing Objects in Space"]

[Text] A real expansion in the mastery of the space near the earth in conjunction with the mastery of the planets of the solar system requires that cosmonauts execute diverse technological operations related to the assembly of space stations, the building of special structures in near-earth space, on the Moon and other planets, as well as the servicing of orbiting and interplanetary ships in space and other space facilities.

The unique properties of outer space at the same time create the prerequisites for the organization of production and engineering complexes in space.

Thus, the following major types of human activity in outer space are ascertained:

1. The control of spacecraft.
2. The performance of scientific research.
3. The technical servicing of spacecraft, including repair.
4. The assembly, installation and construction of space facilities.
5. Production activity.

As is well known, the first manned flight into space took 108 minutes. The crews of modern orbital stations are now remaining in space for several months each. Years will be required for flights to the nearest planets of the solar system. With such timeframes, it is very difficult to provide for reliable long term operation of the numerous systems of a spacecraft or station. The probability of failure of individual units increases and various systems and subsystems can disrupt their operation. Under these conditions, it is essential to restore the operability of a system or instrument, replace them in flight with spares or repair them. There is a third way of increasing reliability: this is system duplication. However, this approach entails a sharp increase in the weight of the system and the spacecraft as a whole.

For long term manned flights, serviceable systems are preferable, since they are less expensive and more reliable than unserviceable ones. Moreover, the capability of repairing a system, is also of psychological importance in addition to the engineering significance, in imparting confidence in the crew in their own abilities and in the successful completion of the flight.

The necessity for technical servicing and repair of space facilities during flight follows directly from experience with their operation, while the performance of such work is a new direction in the field of efficient utilization of space facilities.

Three variants are possible for the technical operation of facilities:

1. Insertion in orbit without returning to earth.
2. Launching and return to earth for repair and repeated utilization.
3. Launching and periodic servicing and repair in orbit.

It is more expedient from an economic viewpoint in a number of cases to perform the technical servicing of objects in orbit during operation, rather than to return them to earth for repair and repeat utilization.

Technical servicing of objects from the outside can be accomplished by means of a special auxiliary module or directly by the cosmonauts going into open space.

Analysis shows that the requirements for constantly increasing the efficiency and minimizing the economic expenditures for the operation of space facilities govern the necessity for the performance of preventive and repair work.

Technical servicing and repair are included in that work. the execution of which is practically impossible to fully automate. For this reason, the performance of such work is incorporated in the functional obligations of the crew, because of which, its part in providing for the normal functioning of facilities increases considerably.

To provide for the technical servicing and repair of systems and plants, it is essential to design into the complement of facilities a sophisticated and technically sound on-board system for preventive maintenance and repair, which has not been included in the complement of such facilities up to the present time.

The following problems are to be solved in the development of this kind of system: Work planning and organization; the development and realization of specialized technology; providing the tools for preventive and repair work; special training of the crew; and experimental debugging of the work performance procedures and technology.

During the process of technical operation of facilities, the following two types of work are performed by the crew: technical servicing and restorative repair.

Such an organizational engineering system provides for three work categories: routine, emergency repair and experimental.

Attention is to be devoted to the advanced expansion of experimental and research work, a result of the performance of which is the replenishment of the routine and emergency repair work categories. This approach will promote an improvement in the engineering and technical level of the servicing, as well as a reduction in the weight of the spare parts and the delivered loads.

The primary method of routine work is the replacement of units, modules and assemblies with the execution of the installation and removal operations inside and outside the facilities.

The replacement of components in units can be carried out as emergency repair work, as well as the execution of mechanical machining operations, soldering, welding and cutting, which are matched to the actual conditions.

The design of the equipment, as well as the creation of the technology and procedures for preventive and repair work makes it necessary to develop them under conditions approaching actual conditions, specifically, in airborne laboratories, under conditions simulating the combined action of factors in vacuum test stands installed on board a flying laboratory, as well as under conditions of water simulated weightlessess, something which is especially important for training crews.

The same attention should be devoted to the development of systems for preventive and repair work as to other systems which provide for normal functioning of the units of a complex.

Technical work can be classified by function as work to preserve, renew, rebuild or eliminate products. Preservation work is performed for the purpose of maintaining a specified level of reliability and service life and is of a preventive and prophylactic nature. Renewal work involves the restoration of the reliability and service life characteristics of the products. Reconstruction work has the purpose of eliminating obsolescence by means of modernizing or replacing units. Work to eliminate products (partially or completely) consists in removing valuable equipment in the case where further operation and return to earth is not expedient for technical or economic reasons.

Depending on the nature and complexity of the operations, the requisite technological equipment and the kind of crew, the following servicing level can be established: automated elimination of defects; simple adjustments, manual changeover to a standby, manual servicing operations; the replacement of a failed unit with a spare (using tools and employing repair instructions); the repair of a failed unit in a specialized work position with technological equipment and tools; the replacement of mechanically secured components in a unit with its partial disassembly; the replacement of components with non-disconnectable connections, as well as resoldering components, preparation, machining, welding and restoring coatings.

The specific features of servicing and repair are found as a function of the functional principles for the systems, subsystems and units of the spacecraft. The equipment subjected to repair and servicing is broken down into the following groups on this basis: modular equipment; mechanical equipment; electromechanical equipment; radioelectronics and electrical systems; chassis and metal structures.

An analysis of repair and servicing facilities makes it possible to ascertain the nomenclature of the technological processes. Such technological operations are: resetting and adjustment; cleaning, washing, lubrication and filling; securing and check operations; installation and demounting operations; assembly and disassembly work; load transportation; gluing; hermetic sealing; soldering; monitor and measurement operations and fault detection; mechanical processing (drilling, cleaning, cutting, bending, straightening); welding and cutting; restoring coatings by spraying.

The nature and content of technological servicing and repair operations set the conditions for the necessity of outfitting a crew with the means of performing this work: tools and accessories, specially designed for the specifics of the execution of the work activity under space flight conditions, taking into account both the technical and organizational engineering as well as the ergonomic aspects.

Based on theoretical research and experimental test studies, as well as the results of operation under full-scale conditions, we have formulated a set of requirements for the design of special tools.

The following requirements can be formulated based on the ergonomic aspect:

1. The basic structural design of the tool should assure the possibility of its convenient layout, taking into account ergonomics and esthetics.

2. It is essential to strive to use cutting tools (such a drill, milling cutter, etc.) with automatic feed or automatic clamping of the tool in welding and assembly operation. In this case, the application of large energy reserves on the part of the cosmonaut is not required.

3. Fastening components (screws, bolts, nuts) and the tools should take the form of a unified, mutually related, easily fitted together "screw--tool" system with a rigid mechanical connection between them. A coaxial configuration should be structurally provided for the fastening elements and the tool, without the application of effort on the part of the cosmonaut and without the necessity of monitoring.

4. During the process of executing an operation, a tool should require the application of force by the operator in only one profile, for example, a torsional moment or an axial force.

5. Transitions in an assembly operation, such as the setting of a tool, backing off, setting a component in a holder, removing a tool, etc., should be simple, have a minimal number of work movements and where necessary, be performed with one hand.

6. It is essential to strive for maximum mechanization of a cosmonaut's labor, giving preference to mechanized tools over manual nonmechanized ones.

In considering the technical aspects, yet another series of requirements can be sited.

1. Avoid using mechanisms with reciprocating motion. It is necessary to replace them where possible with less energy intensive mechanisms with rotorary motion, since the reaction to a torsional moment is more easily neutralized than the reaction to a reciprocating motion.

2. The reactive effect on the hand of the working cosmonaut should be either absent or minimal. It is essential to use a closed system of forces, including the main working force and the reaction to it.

3. Strive to minimize the weight and power consumption. The preferable form of energy is electrical.

4. A structure should have high reliability in operation, an adequate service life, operational reliability, reparability and servicing simplicity.

5. The construction of a tool should provide for a minimum number of adjustments during the operational process; it is essential to provide for ease and speed of insertion and removal of attachments and preclude the possibility of their incorrect insertion.

6. It is necessary to provide for an efficient structural design and production process articulation breakdown of the structure into modules, which makes it possible to test the modules in parallel, and where necessary, replace them during the process of modernizing the modules as well as during the operational process (for example, a drive, handles, tool heads).

7. It is essential to provide for the maximum degree of universality of a tool and its modules, as well as the fastening components in the structural design of a spacecraft and all of the technological equipment.

The principles treated here should not be considered final. They are subject to further improvement, correction and possibly, some of them will be dropped in the future.

Taking the necessity for complete work safety into account, a number of requirements can be formulated by working from the technical-organizational aspect:

1. It is essential to equip tools with mechanical and electrical interlocking, which prevents actuating or turning mechanisms off without authorization;

2. A tool should provide for holding a fastening before and after the completion of the operation to preclude its free drifting in weightless;

3. Machining tools (especially when they are used inside a spacecraft) should be equipped with highly reliable shaving trapping devices;

4. It is essential to provide for a means of securing a tool in the hand, in the clothing of the operator or in the work position.

5. The structural design of a system should be rigid, since vibrations and even elastic deformations within the tolerances allowed make it difficult to hold, something which can lead to the loss of the tool, and this, in turn, can produce the undesired feeling of danger for the cosmonauts.

In analyzing the group of problems confronting space technologists, the conclusion must be drawn that the structural design of the space facility (and possibly also the equipment for experiments) should be linked to its servicing and repair technology, i.e., it should be suitable for repair. A more general conclusion is that the structural design should be technologically feasible.

The realization of this principle first of all presupposes the standardization and matching of fastenings (under conditions of mechanical assembly) and tools (manual and mechanized). This will also be of no small significance with possible efforts to render mutual international assistance in space. It must be noted that the design of a space facility should provide for convenience in the execution of repair and servicing operations for practically all of its assemblies and units, provide access for the cosmonaut to all of the vitally important points in the spacecraft, to the equipment and units, for which there is a probability of failure. In step with the increasing operational life of space facilities in orbit as well as the number of them, the necessity arises for creating specialized "repair spacecraft", as well as "assembler spacecraft". Only the creation of a "repair spacecraft", outfitted with all of the necessary equipment and tools, fastening facilities, work positions, etc. will make it possible to resolve the entire set of problems involving the servicing and reapir of objects in space.

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SPACE APPLICATIONS

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ON THE POSSIBILITY OF THE REMOTE OPTICAL REGISTRATION OF THE PARAMETERS OF INTERNAL WAVES ON THE BASIS OF THEIR MANIFESTATIONS ON THE OCEAN SURFACE

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/Text/ The authors examine the mechanism of the formation of the sea surface's image during observation of the solar track and a section of the surface that is free from patches of sunlight. They derive relationships connecting the average values of signals and the dispersion of the surface's slopes. They determine the level of the signals' fluctuations and evaluate the minimum magnitude of the subsurface disturbances caused by an internal wave for which changes in the surface's images can be observed (for wind velocities above the surface that are less than 10 m/s).

The measurement of the parameters of internal waves by contact methods is a traditional question in oceanography (see, for example, survey /1/ and the literature cited there). At the same time -- as is demonstrated by the results of measurements made on board ships simultaneously with photographing of the sea surface from airplanes and spacecraft /2-4/ -- internal waves can be observed on the basis of their manifestations on the surface. The possibility of observing internal waves from space is extremely tempting, primarily from the viewpoint of determining their two-dimensional spatial spectra, since only the frequency or unidimensional spatial spectra can be determined by contact methods /1/. However, for the correct interpretation of data obtained by aerospace photography (without enlisting contact measurement methods) it is necessary to have information, in the first place, on how an internal wave changes the structure of the surface wave action and, in the second place, on how and under what conditions these changes are manifested in the image of the sea surface. Actually, what we are talking about is constructing some "transfer function" for the system internal wave-agitated surface-measuring instrument. Works /5-9/ are devoted to a theoretical investigation of the first (hydrodynamic) part of this problem, while /10-12/ describe the results of experimental research performed in the laboratory and under natural conditions. The most significant work in this respect is /12/, in which the authors describe a cycle of investigations of the interaction of internal and surface waves that was carried out in a bay on the west coast of Canada. In this work, in particular, the authors establish a relationship between the parameters of internal waves and the dispersion of the slopes of the surface wave action. The existence of this relationship makes it possible to proceed to the solution of the second (optical) part of the problem and, in the end, construct the desired transfer function for some typical observation conditions, which is the subject of this article. We are discussing the properties of the sea surface's image during observation of the solar track and a section of the surface that is free from patches of sunlight. For these cases we evaluate the level of noise in the image that is caused by wave action. In the final part of this article we present relationships that make it possible to evaluate the minimum level of subsurface wave disturbances at which an internal wave can cause noticeable changes in the surface's image.

Measuring the Dispersion of the Slopes During Observation of the Sea Surface

1. It is a well known fact that on the basis of the characteristics of the solar track observed on the surface of the sea, it is possible to form an opinion about the distribution function of the surface's slopes and, in particular, on the dispersion of this distribution. This fact was used in the work of Cox and Munk, where they studied the dependence of the slopes' distribution function on the wind velocity above the surface /13,14/ and which has already become a classic. On the other hand, in /15/ the author investigated the mechanism of light-spot signal formation and evaluated the level of the wave-related noise for optical scatterometers, in which the radiation source and the receiver are collocated. The analysis performed in this work is also correct for signals registered during observation of the solar track; the slight difference consists only of the geometry of the observation setup. Therefore, we will omit all the intermediate calculations in our description of the properties of the solar track's image.

Let the image of the solar light spots on the sea surface be formed in a receiving device that is placed at height h above sea level and consists of a large number of elementary receivers with narrow radiation patterns that, as a whole, form the instrument's field of view (this can be a camera, a transmitting television tube and so on). For the purpose of simplification in the calculations, we assume that the distribution of brightness on the solar disk and the elementary receiver's input parameters can be approximated by Gaussian functions[1] and that the size of a resolution element on the sea surface is much greater than the size of the receiving aperture. In this case, the random realization of the power striking an elementary receiver can be described by the following expression /15/:

$$P=\frac{E_0\Omega^2}{\pi(\omega^2+\Omega^2)}\iint\limits_{-\infty}^{\infty}\exp\left\{-\frac{(\mathbf{r}-\mathbf{r}_0)^2}{\beta^2h^2}-\frac{(\mathbf{r}_0-\mathbf{r}+3\eta h-\varkappa_{1\perp}-\varkappa_{2\perp})^2}{h^2(\omega^2+\Omega^2)}\right\}d\mathbf{r}, \qquad (1)$$

where E_0 = intensity of illumination of the sea surface by direct solar rays; ω and Ω = angular dimensions of the solar disk and the receiving aperture from the surface; β = width of the radiation pattern; $\varkappa_1$ and $\varkappa_2$ = unit vectors characterizing the direction of the solar rays and the receiving pattern; $\varkappa_{1\perp}$ and $\varkappa_{2\perp}$ = their projections on the horizontal plane; $\mathbf{r}_0$ = the vector describing the receiver's position in this plane; η = the projection on it of the local normal to the surface.

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[1]Such an assumption for larger (in comparison with the correlation distance of wave action) dimensions of a resolution element does not affect the final result of the calculations.

Apart from the assumptions indicated above, expression (1) is correct when $|\varkappa_{1\perp}|$, $|\varkappa_{2\perp}|$, $|\eta|\ll 1$ and the height of the surface waves is much less than the height of the receiver's position. Averaging (1) with respect to the ensemble of realizations of the surface and assuming that its slopes are distributed according to the normal law and the wave action is anisotropic[1], we obtain:

$$\bar{P}=\frac{E_0\Omega^2h^2\beta^2}{8\sigma_\theta^2}\exp\left\{-\frac{(\varkappa_{1\perp}+\varkappa_{2\perp})^2}{8\sigma_\theta^2}\right\}, \tag{2}$$

where σ_θ^2 = dispersion of the surface's slopes. In writing (2) we assumed that the inequality $8\sigma_\theta^2 \gg \beta^2 + \Omega^2 + \omega^2$ has been fulfilled. Thus, the average power in a single element of the image, as a function of the angle between the direction of the incident rays and the radiation pattern's direction, repeats the distribution function of the surface's slopes. From expression (2) it also follows that a change in the slopes' dispersion can be judged by the magnitude of the change in the average power. In particular, for the central part of the solar track the following formula is correct:

$$\overline{\Delta P}=-\bar{P}\Delta\sigma_\theta^2/\sigma_\theta^2, \tag{3}$$

where $\overline{\Delta P}$ = magnitude of the change in the average power when the slopes' dispersion changes by the amount $\Delta\sigma_\theta^2$.

In order to evaluate the minimally registerable magnitude of changes in dispersion, it is necessary to determine the level of the fluctuations in the received signal, as the observation is conducted for a limited section of the surface and for a limited time interval. The calculation of the signal's dispersion, which was made on the assumptions that a resolution element on the surface is much larger than the wave action's correlation distance and that the time for obtaining a frame is much shorter than the surface's characteristic lifetime (the case of a "frozen" surface), leads to the following result:

$$\overline{\Delta P^2}=\overline{P^2}-\bar{P}^2=\frac{2\sigma_\theta^2\rho_0^2}{h^2\beta^2(\omega^2+\Omega^2+\beta^2)}\bar{P}^2, \tag{4}$$

where ρ_0 = the effective correlation distance of wave action, as introduced in [16]: $\rho_0^2 = 2\sigma_\xi^2/\sigma_\theta^2$; σ_ξ^2 = dispersion of the prominences.

Assuming that the threshold change (that is, the minimally registerable change in the average signal $\overline{\Delta P}_{min}$) is determined by the equality $|\overline{\Delta P}|_{min} = \sqrt{\overline{\Delta P^2}}$, from (3) and (4) it is not difficult to derive the expression for the minimally registerable relative change in the slopes' dispersion. In the case of $\beta^2 \gg \omega^2 + \Omega^2$ it has the form

$$\left|\frac{\Delta\sigma_\theta^2}{\sigma_\theta^2}\right|_{\text{мин}}=\frac{2\sigma_\xi}{\beta^2 h}. \tag{5a}$$

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[1]It stands to reason that real wave action is anisotropic, and it is not difficult to derive a corresponding expression that allows for the anisotropy. However, for the sake of brevity we are not doing this, since the final result -- the signal's noise level -- is not very sensitive to this factor (see formula (5)).

Let us state, without derivation, that for anisotropic wave action, as well as for cases where the change in the slopes' dispersion with respect to different directions is not the same, expression (5a) is modified:

$$\left|\frac{\Delta\sigma_{\theta x}^2}{\sigma_{\theta x}^2}+\frac{\Delta\sigma_{\theta y}^2}{\sigma_{\theta y}^2}\right|=\frac{2\sigma_t}{\beta^2 h}, \tag{5b}$$

where $\sigma_{\theta x}^2$, $\sigma_{\theta y}^2$ = dispersions of the wave action's slopes in two mutually perpendicular directions.

Thus, the accuracy of the measurement is related comparatively simply to the observation system's parameters and an integral parameter of the wave action: the root-mean-square height of the waves.

2. Let us discuss in detail yet another method for registering the state of an agitated sea surface. Let the observation be done on a clear, sunny day, with a section of the sea surface free from patches of sunlight falling into the instrument's field of view. We will assume that the approximations used in the preceding section are correct. Here the computation techniques remain the same, with the basic difference being that in this case radiation scattered by the atmosphere strikes the receiver. If the angular distribution of the brightness of the radiation striking the surface is described by the function $I(\varkappa_{1\perp})$, for the random realization of the signal at the photoreceiver's input it is not difficult to derive the following expression:

$$P=\int_{-\infty}^{\infty}\ldots\int I(\varkappa_{1\perp})F(\mathbf{k},\mathbf{p})\exp\{-i(\mathbf{p}+\mathbf{k}z)(\varkappa_{1\perp}-2\eta)\}\times\exp\{i\mathbf{k}(\mathbf{r}_0-\mathbf{r})-i\mathbf{p}\varkappa_{2\perp}\}d\mathbf{k}d\mathbf{p}d\mathbf{r}d\varkappa_{1\perp}, \tag{6}$$

where F(k,p) = Fourier spectrum of the receiving radiation pattern and the input aperture.

If, as before, we approximate the distribution F(k,p) with a Gaussian function, after averaging (6) with respect to the ensemble of realizations of the surface, for the average power $\bar{P}$ we obtain:

$$\bar{P}=\frac{\pi\beta^2\Omega^2h^2}{8\sigma_\theta^2}\iint_{-\infty}^{\infty} I(\mathbf{u}-\varkappa_{2\perp})e^{-u^2/2\sigma_\theta^2}d\mathbf{u}. \tag{7}$$

It is clear that, in this case, for the change in the average power resulting from a change in the slopes' dispersion we cannot derive a formula similar to (3), since for the distributed source in the subintegral part of (7) we cannot assume that $u^2/2\sigma_\theta^2 \ll 1$. In order to obtain a simple relationship between the average power value and the slopes' dispersion, let us make use of the fact that the brightness distribution $I(\varkappa_{1\perp})$ is quite smooth in comparison with the slopes' distribution function over a broad area of angles[1]. Expanding function $I(u - \varkappa_{2\perp})$ into a series of

[1]The area of angles close to the direction of the Sun's rays, where the sky's brightness changes most abruptly, is an exception. During observations of the sea surface in this area, however, it is more essential to allow for spots of light caused by direct solar rays, and the formulas in the preceding section are correct for this.

powers of variable u and limiting ourselves to the quadratic terms in the expansion, we obtain

$$\bar{P}=(\pi\beta\Omega h)^2[I(-\varkappa_{2\perp})+2\sigma_0^2\Delta_{\varkappa_\perp}I(-\varkappa_{2\perp})], \tag{8}$$

where $\Delta_{\varkappa_\perp}I$ = Laplacian of the function $I(-\varkappa_{2\perp})$.

Thus, the average power is represented in the form of two components. The first of them (strictly speaking, to it we must add a component related to the radiation that is scattered by the water layer and emanates from under the surface) equals exactly the power received in the absence of wave action. The second component is caused by wave action and is proportional to the dispersion of the slopes. Under identical observation conditions, the average signal's variability (as follows from (8)) is caused by the wave action's variability:

$$\overline{\Delta P}=(\pi\beta\Omega h)^2 2\Delta\sigma_0^2\Delta_{\varkappa_\perp}I. \tag{9}$$

In passing, let us mention that in the case of completely diffused irradiation of the surface (I = constant), $\overline{\Delta P}$ = 0 and the received signal contains no information about the state of the surface.

Let us evaluate the magnitude of the signal's dispersion so as -- as before -- to determine the minimally registerable level of change in the dispersion. Without presenting here the full expression for signal dispersion, we will only point out that, as has been shown by calculations carried out with the help of a number of empirical formulas that describe the energy spectrum of wave action /17,18/, as well as experimental distributions of the sky's brightness /19,20/, the signal dispersion component caused by the linear terms of the expansion of function $I(\varkappa_{1\perp})$ is negligibly small at wind speeds $V<10$ m/s. Therefore, we have

$$\overline{\Delta P^2}=\frac{4(\pi\beta h\Omega)^4}{S}\iint\limits_{-\infty}^{\infty}(q_{xx}^2B_{xx}^2+q_{yy}^2B_{yy}^2+2q_{xx}q_{yy}B_{xy}^2)\,d\rho, \tag{10}$$

where $q_{ij}=\partial^2 I/\partial\varkappa_i\partial\varkappa_j$; B_{ij} = correlation functions of the slopes; $S_0=\pi\beta^2h^2$. Using the relationships

$$\iint\limits_{-\infty}^{\infty}B_{ij}^2(\rho)\,d\rho=(2\pi)^2\iint\limits_{-\infty}^{\infty}G_{ij}^2(\mathbf{k})\,d\mathbf{k},\quad G_{ij}=k_ik_jG_\xi$$

(where $G_\xi(k)$ = energy spectrum of the prominences) for the isotropic spectrum, we reduce expression (10) to the form

$$\overline{\Delta P^2}=\frac{4\pi^3(\pi\Omega\beta h)^4(3q_{xx}^2+3q_{yy}^2+2q_{xx}q_{yy})}{S_0}C. \tag{11}$$

The value of C, as determined by the formula

$$C=\int\limits_0^{\infty}k^5G_\xi(k)\,dk,$$

is some integral characteristic of the wave action and, consequently, a function of the wind speed V above the surface.

Assuming, as before, that the threshold value of a change in the signal is determined by the condition $|\overline{\Delta P}|_{min} = \sqrt{\overline{\Delta P^2}}$, from (9) and (11) we obtain:

$$|\Delta\sigma_\theta^2|_{min} = \frac{2\pi}{l_0}\sqrt{\frac{3q_{xx}^2+3q_{yy}^2+2q_{xx}q_{yy}}{(q_{xx}+q_{yy})^2}C}, \tag{12}$$

where ℓ_0 = linear dimension of a resolution element in the area.

Generally speaking, for specific evaluations of the value of $|\Delta\sigma_\theta^2|_{min}$ it is necessary to have available quantitative data on, in the first place, the values of the second derivatives of the sky's brightness and, in the second place, on the wave action's energy spectrum (in order to determine the value of C). However, here we will make use of the fact that the distribution of the sky's brightness in directions perpendicular to the solar vertical is of a smoother nature, so that we can assume that $q_{xx} \gg q_{yy}$ without any particular loss of accuracy. Formula (12) then takes on the form

$$|\Delta\sigma_\theta^2|_{min} = \frac{2\pi}{l_0}\sqrt{3C}. \tag{13}$$

As far as the value of C is concerned, for the sake of determinacy we will assume that the energy spectrum of the surface prominences is described by the (Pirson-Moskovits) formula /17/. In this case,

$$|\Delta\sigma_\theta^2|_{min} = \frac{\sigma_\xi}{l_0}\sqrt{\frac{3}{2}a_0}, \tag{14}$$

where a_0 = a dimensionless numerical coefficient equal to $\sim 4\cdot 10^{-3}$; $\sigma_\xi^2 = a_0 V^4/1.48g^2$, where g = gravitational acceleration.

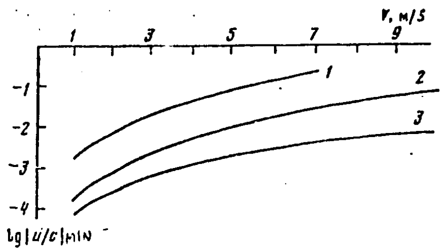
The formulas that have been derived ((3), (5), (9), (14)) make it possible to relate changes in the power of the received signal to wave action parameters (more precisely, to the dispersion of the slopes) and to evaluate with what accuracy these changes can be registered under different surface illumination conditions and under different degrees of wave action intensity.

Effect of an Internal Wave on the Surface's Image. Minimally Registerable Level of Wave Disturbances

According to data published in /12/ there exists a relationship between the parameters of an internal wave and the dispersion of the slopes that is expressed by the formula

$$\sigma_\theta^2 = \sigma_{0\theta}^2 e^{Ru/c},$$

where $\sigma_{0\theta}^2$ = dispersion of the slopes of a surface "undisturbed" by an internal wave; u = orbital velocity of particles in an internal wave under the surface; c = = phase velocity of the internal wave; R = some dimensionless coefficient that depends on wind speed, the internal wave's phase velocity and, probably, a number of other factors that have not been accounted for. However, it is important to mention that as the wind speed increases, as a rule the value of R decreases. On the basis of a statistical analysis of the results of measurements (for $V \leqslant 10.9$ m/s), the authors of /12/ obtained the relationship of the linear regression of the value



Dependence of parameter $|u/c|_{min}$ on wind speed for c = 1/ms, $l_0 = 10^2$ m. Curves 1 ($h = 10^4$ m) and 2 ($h = 10^3$ m) are calculated for the case of observation of an internal wave in the zone of the solar track, curve 3 for observation in scattered light from the sky.

of R to the variable lg(V/c):

$$R=-5{,}1\lg(V/c)+6{,}47. \tag{15}$$

Knowing the value of R, it is not difficult to find the change in the slopes' dispersion in the internal wave's field. For $Ru/c \ll 1$,

$$\Delta\sigma_0^2=\sigma_{00}^2\cdot 2Ru/c. \tag{16}$$

Having available expression (16) and the relationships connecting the received signal's parameters with the observation conditions, it is not difficult to formulate a "direct" relationship between these parameters and the internal wave's characteristics. For observation of an internal wave in the zone of the solar track we have

$$\frac{u}{c}=-\frac{1}{2R}\frac{\overline{\Delta P}}{\overline{P}}. \tag{17}$$

In this case the level of the signal fluctuations is such that the minimally registerable value of parmaeter $|u/c|_{min}$ is determined by the formula

$$\left|\frac{u}{c}\right|_{min}=\frac{4\sigma_\xi h}{Rl_0^2}. \tag{18}$$

The corresponding expressions for observation of an internal wave in scattered light from the sky have the forms

$$\frac{u}{c}=\frac{\overline{\Delta P}}{2R[\overline{P}-(\pi\beta\Omega h)^2 I(-\varkappa_{2\perp})]}, \tag{19}$$

$$\left|\frac{u}{c}\right|_{min}=\frac{\sigma_\xi}{2R\sigma_{00}^2 l_0}\sqrt{\frac{3}{2}a_0}. \tag{20}$$

The results of the calculations of the value of $|u/c|_{min}$, as performed with formulas (19) and (20) using relationship (15), as well as the linear relationship between the slopes' dispersion and the wind speed, as derived by Cox and Munk [13,14], are presented in the above figure. Let us mention here that the curves in this figure make it possible to form an opinion only about the possibility of observing internal waves under some conditions or other on the basis of a change in the signal being received. It goes without saying that spatiotemporal nonuniformity of the signal can be caused not only by internal waves, but also by other factors (an oil film on the water's surface, large-scale nonuniformity in the wave action, currents and so forth). Therefore, the conclusion that registerable variability in the signal is caused just by internal waves can be reached only on the basis of an analysis of the spatial structure of the surface's image. In particular, congruence of the image's spatial period with an internal wave's characteristic length for a known or presumed vertical distribution of the water's density in the area under observation can serve as confirmation of this fact.

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THERMAL AERIAL SURVEYING IN THE STUDY OF NATURAL RESOURCES

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[Annotation, preface and table of contents from book "Thermal Aerial Surveying in the Study of Natural Resources", by Boris Vladimirovich Shilin, Gidrometeoizdat, 1,200 copies, 247 pages]

/Text/ ANNOTATION

The author explains the basic principles of a new remote method for studying the environment: thermal (or infrared) aerial surveying. He discusses the physical principles of the method and describes modern airborne thermovisors and their operating principles. Recommendations on choosing optimum surveying conditions are made. The author also discusses special features of the utilization of thermal aerial surveying in the solution of a number of geographic, geological and geophysical problems.

This book is intended for specialists in geology, geophysics and geography, as well as planners, who are concerned with questions relating to the study of natural resources and the environment with the help of the newest remote aerospace methods.

PREFACE

At the present time a great deal of attention is being devoted to the development of new, long-range aerospace methods for IPRZ /investigation of the Earth's natural resources/. One of the basic directions in this area is the development of equipment and methods for studying the Earth's surface in bands of the electromagnetic spectrum that were previously not used in aerial and space research. This primarily means the infrared (IK) or thermal (-emission) band, where the intensity of the radiation and the energy distribution by wavelength is determined by the degree of heating (or temperature) of objects.

The practical and scientific importance of the development of equipment and techniques for the investigation of infrared radiation from aerial and space carriers (infrared -- or thermal -- aerial and space surveying) is predetermined by the fact that the state of a large number of natural and manmade objects and phenomena on the Earth's surface and at shallow depths beneath it depends on changes in the temperature field. The possibility of obtaining, within a short period of time, information on temperature distribution in the form of an image (aerial photograph) with high sensitivity and local resolution opens new prospects for the solution of a number of

IPRZ problems where traditional aerial methods (primarily aerial photographic surveying) are not effective or require significant expenditures of time and equipment. Among these problems we should include the study of regions with active volcanism and hydrothermal activity, hydrogeology and engineering geology, geological mapping, land reclamation and irrigation, the investigation of the aqueous medium and snow and ice covers, environmental protection and so on. At the present time the necessary conditions for the practical introduction of thermal aerial surveying in the listed areas of IPRZ already exist. This fact, as well as the great interest in thermal aerial surveying manifested by specialists in the most diversified branches of the national economy, has predetermined the importance and timeliness of the creation of manuals on the use of thermal aerial surveying in the solution of the enumerated IPRZ problems.

For a complete representation of thermal aerial surveying as a new method for IPRZ, the following fundamental points require explanation:
1) the basic physical laws of IK radiation;
2) thermal aerial surveying equipment;
3) the basic features of the formation of the temperature field of objects on the Earth's surface, in order to evaluate the effectiveness of thermal aerial surveying;
4) the basic propositions of the techniques of aerial surveying and the interpretation of its results for the solution of the most important specific IPRZ problems.

The physical laws of IK radiation and its transmission by the atmosphere (the medium between an object on the Earth's surface and the receiver in an aerospace carrier) have been studied extremely thoroughly in a large number of monographs, such as V.Ye. Zuyev's "Propagation of Visible and Infrared Waves in the Atmosphere" (Izdatel'stvo Sovetskoye Radio, 1970), R. Smith, F. Jones and R. Chesmer's "Detection and Measurement of Infrared Radiation" (Izdatel'stvo Inostrannoy Literatury, 1959), R. Khadson's "Infrared Systems" (Izdatel'stvo Mir, 1972) and M.A. Bramson's "Infrared Radiation of Heated Bodies" (Izdatel'stvo Nauka, 1965).

The technical aspects of thermovision have also been explained quite fully (see J. Lloyd's "Thermovision Systems" (Izdatel'stvo Mir, 1978), M.M. Miroshnikov's "Theoretical Principles of Opticoelectronic Instruments" (Izdatel'stvo Mashinostroyeniye, 1977, and others), although there has been no detailed description of specific airborne thermovisors for IPRZ.

In view of this, in this book the physical laws of IK radiation are explained very briefly, and in the section on thermal aerial surveying equipment, the primary focus is on a description of specific modifications for airborne thermovisors.

Most of the book is concerned with an analysis of the special features of the temperature field of objects on the Earth's surface, aerial surveying techniques, and the interpretation of aerial surveying results in connection with the study of natural resources. This is based mainly on materials gathered during many years of research by the Aeromethods Laboratory on the use of thermal aerial surveying in the solution of IPRZ problems in different regions of the USSR: the Kamchatka Peninsula and the Kurile Islands (1967, 1968, 1972, 1973, 1975, 1977), Sakhalin Island (1973), the Baykal-Amur Railway (1976), Kazakhstan (1973, 1976-1978), the Central Karakum Mountains and Uzbekistan (L973, 1975-1977), Kara-Bogaz-Gol Gulf (1975-1977), the Bashkir ASSR (1976, 1977), the northern part of Western Siberia (1976, 1977), and others.

This book also reflects a number of theoretical and methodological propositions developed by the author in collaboration with colleagues from the Aeromethods Laboratory. I would particularly like to mention the contributions made by G.S. Vypritskiy, V.I. Gornyy and N.A. Gusev. During the review and discussion of the manuscript, useful observations and advice were offered by A.V. Dolivo-Dobrovol'skiy, V.F. Mel'nikov and T.A. Popova, to whom the author wishes to express his sincere gratitude.

In conclusion, the author considers it necessary to mention that the research reflected in this book could be performed only due to great scientific achievements in the creation of modern airborne thermovisors, and he wishes to express his deep gratitude to the creators of these unique instruments: V.L. Denisman, M.M. Miroshnikov, Ye.Ya. Karizhenskiy, D.N. Krasnikov and the collectives led by them.

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SPACE POLICY AND ADMINISTRATION

FRENCH COMMENTATOR VIEWS SOVIET SPACE PROGRAM

Paris FUTURIBLES in French No 38, Nov 80 pp 129-136

[Article by Alain Dupas, of the Interdisciplinary Program for the Development of Solar Energy, 282 Bd Saint Germain, 75007 Paris: "Space Policy of Soviet Union and Socialist Countries"]

> [Text] From Yuriy Gagarin's first flight to Nikita Khrushchev's bluff, from the failed rendezvous on the moon to manned flights in orbital stations, Alain Dupas is retracing for us the main stages of the USSR space programs. He leads us to the discovery of the strengths and weaknesses of the Soviet space power, now the first in the world in terms of total activity, especially in the field of military experiments, although its technology is considerably behind that of western powers.

Almost exactly 20 years ago, on 12 April 1961, the Soviet Union reached its space apotheosis: for the first time, a man, Yuriy Gagarin, was travelling in the cosmos. At the time, the space program of the USSR was clearly the largest in the world, as it is again in 1980, at least in terms of total activity.[1] Every year, the Soviets are making some 100 space launches, i.e. 5 times as many as the United States. Their program is said to employ over 500,000 people, compared with hardly more than 100,000 involved in space programs in America. Their cosmonauts total twice as many hours in flight as the NASA astronauts who have remained grounded since the end of the Apollo experiments in 1975, pending the first flights of the U.S. space shuttle (scheduled for 1981). True, the cosmic technology of the USSR is still much behind its western rival. The efficiency of the U.S. program certainly makes up for its reduced volume. But certain observers worry that, in the long run, the United States space supremacy of the years 1965-1975 will appear to have been an epiphenomenon compared to a much stronger will on the part of the Soviets to establish themselves in space, for political and military reasons.

Nikita Khrushchev's Bluffs

Space became of paramount importance to the USSR at the height of the cold war, during the years 1957-1965. Thanks to Sputnik, Lunik, and the first cosmonauts, the Soviet Union all of a sudden took on the appearance, in the eyes of the whole world, of a great scientific and technological power, one that could rival the United States. Thanks to these spectacular "firsts" in space, Nikita Khrushchev could make people believe his claims of military superiority based on intercontinental missiles.

There is little doubt that, at the time, this brand new international prestige deeply rejoiced the mass of the Soviet people who were suffering from a double complex as they were technically inferior and strategically surrounded. It also made a profound and durable impression on emerging Third World nations and it worried western powers. Therefore, the political consequences of the impressive start of the USSR into space appeared to be very positive. In fact, they were very negative for a long time. The Soviet Union was not as powerful as Khrushchev would have us believe, despite its space successes. It did not have hundreds of intercontinental missiles, but only a few, and very vulnerable at that. Its technology lagged far behind even if, intelligently used by the academician Sergey Korolev, it could fool people and launch satellites and space capsules. The result of this bluff, which Andre Fontaine has very justly called "Sputnik diplomacy," has been to launch the United States into a formidable arms race and a fantastic lunar challenge which the USSR was not in a position to accept.

The result was the huge military lead taken by the United States at the end of the 1960's. And the landing of the NASA astronauts on the Moon in 1969.

Ten Years of Steady Efforts

One often hears the question: did the USSR really try to reach the Moon before the United States? Today, the official Soviet answer is no. But this would not be the first time that the USSR were attempting to rewrite history. And, in fact, a detailed analysis of the programs and statements of the years 1965-1969, not to mention revelations in the United States, leaves little doubt as to the existence of a Soviet program to send men around, then on the Moon. It being so, this program must have been a sequel of Khrushchev's bragging, and it had little chance of success if one considers the level of Soviet technology at the time. Khrushchev's successors aborted the program as soon as it appeared that the United States had won the race.[2]

In space, as in the field of arms, the whole problem facing the new Soviet leaders was to catch up progressively and rationally with the time lost because of Nikita Khrushchev's bluffs. The success which this method appears to have had in the military field, at the cost of huge investments, is well known: most western experts agree that the tactical and strategic arsenal of the USSR has now achieved parity (if not superiority). The situation is the same in the space sector: after 10 years of steady and systematic efforts, the Soviet space program has become the first in the world, as we mentioned at the beginning of this article, at least as far as military experiments and manned flights are concerned.

Two Thirds Of Experiments Are Military

The launching of military satellites represents approximately 70 percent of the Soviet space activity. The most important sector is that of reconnaissance satellites, the importance of which the USSR soon learned at its own expense: it was the photographs taken by the first space spys that, in 1962, convinced Kennedy of the actual strategic weakness of the USSR and enabled him to remain very firm during the Cuban crisis.[3] Today, the Soviet Union is launching many more reconnaissance satellites than the United States, to watch the latter and their allies, and China as well of course, and the various theaters of military operations in which it is directly or indirectly involved. In addition, the USSR maintains in space a complete panoply of satellites intended for military uses: telecommunication, navigation, missile-launching surveillance spacecraft. Contrary to the United States, it has also experimented with interception satellites which could be the precursors of a disquieting arms race in space.

Besides, the military play an important role in all of the Soviet space program. They control almost all of the launching equipment and sites (the Baikonur and Plesetsk cosmodromes in particular), and the Yuri Gagarin training center for cosmonauts (the famous "city of stars") is placed under Air Force control. In this respect, it should be noted that civilian space activities in the USSR are not placed under the control of a single agency, like the U.S. NASA, and that they are probably not formally separated from military activities. As far as we can judge, the Soviet space program is controlled by a secret state commission, placed next to the Central Committee of the Communist Party and to the Council of Ministers, and which coordinates the activities of many institutions (Ministry of Defense, Experimental Design Bureaus, arms factories, Academy of Sciences, etc.).

Priority For Orbital Stations

In the field of manned space flights, for the past 10 years, the USSR has been stressing the placing of stations into orbit. These are spacecraft which remain for months or years in space and where cosmonauts--carried back and forth on spaceships--are working occasionally or continuously. Because orbital stations can operate for a long time, it has become profitable to use heavy scientific equipment (cameras, telescopes, etc.) in space; in addition, since the stations do not have to come back to earth, they can be larger and offer comfortable living space to the cosmonauts.

The Salyut orbital station program undertaken by the Soviets in 1971 is relatively modest if one considers the scale of the means used: the Salyut station proper weighs only 20 tons and its permanent crew is limited to 3; as for the spaceship Soyuz which shuttles between Earth and the Salyut stations, it weighs only 7 tons and its useful load is small. This being said, the objective of the Soviets after they had difficulties with the moon was not, as we have already stressed, to undertake spectacular projects, but to master a number of technologies. From this point of view, the Salyut program, in 1980, appears to have been a full success: after 3 years in operation, the Salyut-6 station, launched in 1977, has made possible the longer flights (96, 140, 175, 185 days) which are necessary if a space base is to be operated rationally, and the total mastery of orbital rendezvous techniques (over 20 successfully completes) and of the resupplying of orbital stations (with automatic Progress spaceships derived from Soyuz).[4]

Flights of Cosmonauts From Socialist Countries

The success of the Salyut-6 orbital station experiment has enabled the USSR to resume prestige space operations with a strongly political character: between 1977 and 1980, 7 socialist bloc countries have sent cosmonauts to spend a week aboard Salyut 6 with a Soviet companion. The countries involved are: Czechoslovakia, Poland, the GDR, Bulgaria, Hungary, Vietnam, and Cuba. Rumania and Mongolia will soon join them; their aspiring cosmonauts are now in training at the city of stars.

In the case of highly developed industrial nations, such as Czechoslovakia and the GDR, it is obvious that collaboration with the USSR does not work only one way. On the contrary; the Soviets can benefit from the contribution of the advanced technology of these countries, for instance in optics, electronics and data processing. In most other cases, however, the launching of foreign cosmonauts is not of obvious scientific interest, either for the USSR or for the countries involved, the modest degree of technical development of which gives them little use for a manned space flight. The only justification for these operations is political. In the case of East European countries, what is at stake is to illustrate how the activities of the various socialist bloc nations can be integrated in the advanced prestige field of space. In the case of Cuba and Vietnam, the message is more probably intended for Third World countries, as the USSR still wishes to be thought of as their one and only support.

Intercosmos and Cooperation With France

International manned flights are organized by the Soviets as part of a program called Intercosmos, started in 1967. Some 20 scientific satellites and many rocket probes have already been launched by the USSR in connection with this program, and it can even be assumed that almost all of the Soviet geophysical space research is now covered by Intercosmos.

Independently from the ever closer cooperation with socialist countries of Soviet allegiance, the USSR maintains important connections, in the field of space, with one western nation, France. On both sides, these connections are probably not free from ulterior political motives: they demonstrate a common desire for detente. But, mainly, they rest on shared scientific and technical interests: for France, to have access to important space equipment (e.g. interplanetary probes), for the USSR to receive very high-level scientific expertise. It is in this spirit that a French cosmonaut is going to work one week in a Soviet orbital station in 1982, and that France will take part in the study of Venus's atmosphere using balloon satellites in 1985.

Applications Stressed

Apart from military missions and manned flights, a third category of space activities has been given priority in the Soviet Union during the 1970's: that of applications.

Because of the size of its territory, the USSR soon became interested in the possibilities offered by telecommunication satellites. As early as 1967, it was the first country to give itself a national system of satellite links, the Orbita network. It connects several tens of small stations to Moscow through Molniya moving (i.e. non-geostationary) satellites. Nevertheless, it was only in 1975 that the Soviets started accelerating considerably their space telecommunication program by launching heavy platforms (about 2 tons) into geostationary orbits. These platforms are of several types: there are the Raduga satellites (USSR domestic links), Ekran (broadcasting of TV programs), Gorizont (international telecommunications). These considerable developments show that in the 1980 the USSR might realize to a certain extent the international Intersputnik network to which the socialist bloc countries have adhered and which is supposed to be the counterpart of the Intelsat system. However, one may wonder whether this attitude would be realistic in view of the technical, political and economic success achieved by the Intelsat organization to which some 100 nations have adhered. More probably, the Soviet Union and its allies will merely develop their space telecommunication systems independently from the rest of the world, and without competing with western countries either in the field of equipment or in that of service. In this domain, as in many others, the socialist bloc market will be fully protected and isolated.

The launching of heavy telecommunication platforms requires the USSR to use considerable technical means. In particular, it involves using the most powerful Soviet launcher, the Proton rocket with a 1,500-ton thrust, which is also used to place the Salyut orbital stations into orbit. As a comparison, the Atlas-Centaur or Ariane launchers, which can launch satellites of a capacity similar to that of the Soviet platforms, are 5 times less powerful (and therefore less costly) than the Proton rocket. In this instance, the USSR is paying the price for lagging behind in the field of electronic miniaturization. Since it produces only a limited number of Proton launchers (about 5 each year), it has reduced some of its other space activities to make up for the acceleration of its telecommunication program. Experimental programs for lunar and planet exploration appear to have suffered most.

Next to telecommunications, another sector of space applications is in full development in the Soviet Union: the observation of earth resources. This uses both recoverable photo-satellites and Salyut orbital stations. Both solutions are much more costly than that used in the United States (high-resolution images transmitted via radio by Landsat) or in France (Spot satellite project). But the Soviets probably have not yet acquired the technology required to build the equivalent of Landsat or Spot.

Very Important Projects

Sustained by an unquestionable political will, the Soviet space program is expected to achieve considerable development during the beginning decade. The trends which we have attempted to describe: considerable military activities, association with socialist bloc countries, importance placed on applications, will certainly become more evident. However, it is on the future of the Soviet orbital station projects that observers concentrate their attention. According to U.S. sources,[5] the USSR has resumed the construction (interrupted in 1971) of a giant rocket which, around 1985, would place into orbit a large station capable of receiving a crew of 12. This station would be used for in-depth studies of the feasibility of space industrialization and also, the United States fears for military testing (e.g. high-power lasers which could be used in anti-satellite or anti-missile actions). It would be supplied by a reusable space glider carrying about 5 cosmonauts and a few tons of freight. The construction of this hypersonic space glider is said to be in an advanced stage. It would be entirely different from the U.S. space shuttle which is a plane-rocket hybrid, and would represent a considerable progress over Soyuz. Pending the implementation of these projects, the Soviets will continue and expand their Salyut orbital station program.

In the longer range, considering only prestige experimental programs, the USSR appears strongly interested in manned interplanetary missions. According to certain sources, it is contemplating a flight to Mars in association with the socialist bloc countries.

FOOTNOTES

1. The most complete reference on the Soviet space program is a report to the Congress of the United States: "Soviet Space Program 1971-1975," staff report prepared for the use of the Committee on Aeronautical and Space Sciences, United States Senate, U.S. Government Printing Office, 1976.

2. Alain Dupas, "La Lutte pour l'Espace" [The Struggle For Space], Editions du Seuil, 1977. This book also contains a general analysis of Soviet space.

3. Philip Klass, "Secret Sentries in Space," Random House, 1971.

4. Alain Dupas, "Soviet Space Revival," LA RECHERCHE, July-August 1978, p 673.

5. AVIATION WEEK, 16 June 1980, p 26.

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