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SCIENTIFIC INTELLIGENCE REPORT

THE SOVIET BIOASTRONAUTICS RESEARCH PROGRAM

OSI-SR/62-3
22 February 1962

CENTRAL INTELLIGENCE AGENCY

OFFICE OF SCIENTIFIC INTELLIGENCE

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Scientific Intelligence Report

THE SOVIET BIOASTRONAUTICS RESEARCH PROGRAM

NOTICE

The conclusions, judgments, and opinions contained in this finished intelligence report are based on extensive scientific intelligence research and represent the final and considered views of the Office of Scientific Intelligence.

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PREFACE

Bioastronautics includes the study of all factors that may influence the ability of man and other living organisms to function effectively in space. The major identifiable biological problems that remain to be solved with respect to prolonged and successful spaceflight are the effects of radiation and long-term weightlessness on organisms, animals, and man, and the development of an operational and reliable closed ecological system, which will provide man with a suitable gaseous environment, will permit the production of food supplements, and will balance his respiratory processes. This analysis attempts to identify Soviet research activities in the field of bioastronautics, and to assess the results achieved. [redacted]

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[redacted]

FIGURES

THE SOVIET BIOASTRONAUTICS RESEARCH PROGRAM

PROBLEM

To assess the status of the Soviet bioastronautics research program.

CONCLUSIONS

1. About 1950, the Soviets began a broad, carefully planned, high-priority bioastronautics program that has provided their scientists with extensive and valuable information.

2. A biomedical research program was conducted with vertical rockets through mid-1960. This program was followed by the orbital biological carriers Sputnik V in August 1960, and Sputniks IX and X in March 1961, that gave the Soviets much additional physiological and biological data.

3. The 12 April and 6 August 1961 orbitings of Vostoks I and II enabled the Soviets to be the first to test human survival in space with life sustaining systems, and also during reentry and recovery from orbital spaceflight, and thus advanced Soviet bioastronautics research substantially beyond that of the United States.

4. In support of the long-term objectives of interplanetary travel, the primary or immediate interest of Soviet science is the man-in-space program, which includes the intensive study of man-machine relationships during extended time periods in flight. In addition, the objectives of the Soviet overall spaceflight program will continue to encompass studies of the effects of multiple stressors or stimuli on man and lower forms of biological specimens, the possible origin of life in outer space, and the ecology of outer space. The Soviets will also conduct additional biomedical investigations and exploratory space probes in and beyond the Van Allen radiation belts before manned flight can be conducted in those areas and orbital flight observations with animals, testing the reliability of partially closed ecological systems for periods up to 90 days.

5. The development of miniaturized radio telemetric equipment for use in conjunction with spaceflight helmets eliminates an umbilical cord attachment. This technique permits free movement and is indicative of Soviet progress in deriving biomedical data, although the known Soviet body sensors are inadequate for obtaining the type and amount of information desired. This miniaturized equipment will be highly advantageous in future multimanned space missions, particularly those involving prolonged periods of weightlessness or under artificial gravity states.

6. Soviet theorizing on the physiological effects of extended periods of weightlessness and man's rapid transfer back to natural conditions indicates a modern concept of this problem. The Soviets have a definite lead in the observation of zero-gravity effects on man following brief orbital flights. [redacted] procedures or require extensive changes in spacecraft design (rotation).

7. The Soviets will continue to take advantage of and to emphasize their bioastronautical achievements in the propaganda effort against the West. They have already anticipated the psychological and ideological possibilities that manned spaceflight accomplishments will afford as man is forced to revise his social frame of reference. Studies are probably underway to aid them to derive the maximum benefit from their man-in-space program.

SUMMARY

The systematic, sustained, and extensive Soviet bioastronautics program is directed toward acquisition of basic physiological and biological data, along with the development of "hardware" and life support systems. It is evident that the sum total of Soviet vertical and orbital experiments through Vostok II demonstrates an ability to apply complex scientific systems to bioastronautics problems.

Overall, the Soviet bioastronautics program appears to be a well-planned and well-executed attempt to investigate the effects of space (hostile environment) on biological organisms, as well as to provide background for sustaining man in space. Basic research underlying the man-in-space effort began about 1950 as part of a broad, carefully planned, high-priority program which included extensive biomedical experiments in space, conducted with vertical rockets. In addition to placing man in space, the prime objectives of the Soviet bioastronautics program include studies of the effects of multiple stresses on man and lower forms of life, the possible origin of life in outer space, the ecology of outer space, and man-machine relationships.

Assessments of statements and voluminous publications by Soviet scientists indicate that they are conducting and extending bioastronautical research under very high priority. As a result, during the next 10 years, the Soviets undoubtedly will demonstrate substantial improvement and sophistication of chemical and biological gas exchangers, bioinstrumentation devices (telemetry), conventional radiation shielding techniques, environmental instrumentation, life support systems, and biocybernetical controls necessary for extended manned space missions. The placing of man in space for extended periods will result from the orderly and well-executed Soviet space program. The Soviets demonstrated their capability for recovering man from a brief orbital flight in April 1961 and from multiorbital flight 4 months later.

DISCUSSION

ORGANIZATIONAL CHANGES RELATED TO THE SOVIET BIOASTRONAUTICS PROGRAM

The Soviet Union has made great progress in its overall development of spaceflight and supportive research by adopting a national policy of forced scientific and technological growth. The establishment in April 1961 of the new State Committee for Coordination of Scientific Research represents a move toward more centralized control of the national scientific effort and, at the same time, constitutes a deeper commitment to the principal of directed research in many disciplines. The new Committee has taken over organizations previously subordinated to the State Scientific-Technical Committee, now abolished, and appears to be assuming responsibility for negotiating and arranging scientific exchanges with foreign countries.

The new State Committee is headed by a Deputy Chairman of the Council of Ministers, K. N. Rudnev. The Committee is composed of the President of the Academy of Sciences, USSR, M. V. Keldysh; the Minister of Higher and Secondary Specialized Education, V. P. Yelyutin; the Chairman of the State Committee on Automation and Machine Building, A. I. Kostousov; the Chairman of the State Committee on Chemistry, V. S. Federov; the Chairman of the Committee for Inventions and Discoveries, A. F. Garmashev; one of the deputy chairmen of the State Economic Council; one of the deputy chairmen of the State Planning Committee; and other members from other state committees dealing with research and development work.

On the operational level, the Academy of Sciences, USSR, will delegate some of its former functions in applied research to other agencies. Within the Academy, institutes will be reorganized in such a way as to cope with the complex interdisciplinary and basic research problems, including a very likely increase in the Academy's role in space exploration (that is, basic research in biology). On the consulting and decision-making level the prestige and resources of the Academy will, as in the past, be utilized, although there is now an intermediate link—the Committee on Coordination of Scientific Research—which will in turn exert pressure on the Academy.

A general meeting of the Academy of Sciences, USSR, in conjunction with representatives of the Department of Biological Sciences, was held in 1961 in Moscow. Academician N. M. Sisakyan, newly elected secretary of the biological department, reviewed the following five basic steps in the Soviet development of space biology: (1) determination of the problems of space biology based on scientific prognosis and biological interpretation of data on the physical properties of the upper layers of the atmosphere and of spaceflight characteristics of the rockets; (2) experimental studies of dogs, rabbits, rats, and mice launched in rockets to altitudes of 100, 200, and 450 kilometers. (These studies served to ascertain the effects of basic flight characteristics on various functions of the organism and to develop safe means for returning the animals to earth); (3) experimental studies conducted with the aid of radiotelemetry of data from animals in earth satellites under conditions similar to those of manned spaceflight; (4) biological studies of animals and plant life on spaceships and exhaustive studies upon their return to earth; and (5) manned spaceflight.[10]

At an earlier meeting in 1960 Sisakyan noted that the economic importance of some biological problems, including some in space biology, merits a concentration of effort and material resources. He indicated that "a wide introduction into biological experimentation of electronics, automation, and computer mechanisms will be required for their accomplishments."[11 12]

At present, Soviet biological scientists are concerned with the following three major subjects: (1) the effect of external space factors on living organisms; (2) biological principles for space-crew life support in a medium lacking all necessities for maintenance of life; and (3) life on other planets of the solar system.

The basic problems represented contain areas of potential scientific breakthrough and Soviet achievement of solution to these problems could be of major significance politically, ideologically, economically, and in certain cases militarily. The high priority being given to research in space biology, therefore, has significant implications. It is particularly important that evidence of expanded interdisciplinary attack on priority problems of space biology and bioastronautics be carefully evaluated because of the major contribution that Soviet physicists, chemists, and mathematicians may make to the solution of basic biological problems.[18]

HISTORY AND POSTULATION OF SOVIET BIOMEDICAL EXPERIMENTS IN SPACE

Vertical and Orbital Flights (Animals)

The Soviets have performed a series of remarkable systematic experiments with vertical and orbital vehicles carrying dogs and other animals and plants in their cabins and capsules [redacted]. These biomedical probes, starting about 1950, assisted in solving the complicated problems of reentry and recovery. The data retrieved by the Soviets also helped to improve or modify their vehicle orientation system and life supported equipment. These experiments provided the Soviets with a reasonable assurance that man could survive spaceflight and recovery in sealed cabins.[14, 15] The preparation of animals for biomedical experiments was carried out according to specific conditioning techniques, which excluded the necessity of using narcotics.

[redacted]

Manned Orbital Flights

Since the successful launching of Sputnik II, Soviet scientists and designers have followed a path of developing heavy and large satellites and spaceships in support of manned spaceflight. It was necessary for the Soviets to get as much information as possible concerning the design of space apparatus and their on-board equipment, to retrieve basic physiological and biological data, and to work out the reliability of controlling the various

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life support systems in flight.[18]

The last two controlled test shots of the Vostok-type spaceship with animals aboard were conducted in March 1961 according to the same program that was intended for the first spaceship flight with the cosmonaut aboard. According to the Soviets, both flights corroborated the design and systems reliability of the space vehicle, and the first successful orbital flight by man was made by Yuriy Gagarin on 12 April 1961,[19 20] and the first multiorbital flight by German Titov on 6–7 August 1961. The preliminary information on these manned orbital flights confirms impressive Soviet progress in the field of bioastronautics and commitment to large-scale research and development programs in this area of science.

The major significance of Titov's flight lies in the field of bioastronautics because of the impressive demonstration of the life support system the Soviets have developed and perfected for routine operational use. According to Soviet technical and scientific literature, the system used in the Vostok capsules will support human life for a maximum of 10 days and is a regenerative type of system employing superoxides.

A 10-day life support system as provided by the Soviets would be ample for a quick round trip to the moon. In contrast, the Mercury capsule has a life support system which, including pad time, would make a 24-hour orbital flight a risky experiment and certainly prohibits use of the capsule for any mission deeper into space.

Training of Cosmonauts

No direct evidence is available concerning the training of Soviet cosmonauts at specific locations in the Soviet Union, yet the first Soviet manned spaceflights reflect the result of an intensive and logical program for personnel selection and use in these and future spaceflight experiments. The Soviets are believed to have been training their cosmonauts, which may include women, for more than 3 years. Gagarin and Titov were only members of a group of selectees prepared to make the first orbital attempt.[21]

According to recent Soviet statements, the Soviet cosmonauts were selected and trained following interviews with a great number of pilots who expressed desire to perform cosmic flights. Selected flyers, chosen after these interviews, then underwent initial clinical and psychological examinations to determine their state of health and to appraise their potential reactions under the influence of cosmic flight factors. A general physical examination reportedly was conducted by using a number of biochemical, physiological, and psychological methods as well as special functional tests (altitude and pressure chambers, human centrifuge experiments, and other trainer apparatus) which attempted to simulate the factors of cosmic flight on the ground and in the air.

The Soviets further state that the special training programs were planned in such a way that the cosmonauts acquired the necessary data regarding the basic theoretical problems connected with anticipated flights and practical skills in using the equipment and instruments in the spaceship. The programs included the following technical subjects: basic principles of rocket and space technology, design of the spaceship, specific problems of astronomy and geophysics, and special problems peculiar to space medicine. Specifically, the Soviets indicated that the complex of special training and experiments included the following: aircraft flights producing very short periods of weightlessness; training in mock-ups of a spaceship cabin and on a special trainer; protracted stays in a specially equipped soundproof cabin; experiments (training) on a centrifugal apparatus; and numerous parachute jumps from aircraft from various altitudes. As an adjunct to the whole training program, physical training (calisthenics, games, diving, swimming, and exercises on special training apparatus) was conducted under the constant supervision of physicians.

After the completion of the training program, the preparation of chosen candidates for spaceflight was organized. This preparation, disclosed in open literature, consisted of the study of flying tasks (including maps of the area of landings, piloting instructions, and radio communication), the study of emergency supplies and their use in the landing area, the study of the direction finder systems, functional tests on the human centrifuge in a pressure suit with maximum anticipated weight, and prolonged tests in a mock-up spaceship using all standard systems of life support.

The Soviets further disclosed that a group of cosmonauts, prepared for the flight into space, was finally selected as the result of their intensive educational and training work. Pilot Major Yu. A. Gagarin was chosen from this group to make man's first orbital spaceflight on 12 April 1961.[22] Figure 22, at the back of this report, is a photograph taken at the time of his selection.

Postulated Biomedical Achievements in Space

Postulation of the biomedical achievements and time elements of the Soviet space program follows:

Manned Orbital Flight:

1. Launch a maneuverable spaceship heavier than Vostok II and using conventional propulsion fuels, possibly for a circumlunar mission (1962).
2. Launch an aerodynamic glide-type space vehicle (1963–64).

Unmanned Lunar Flights (Biological Experiments):

1. Soft land a biologically instrumented payload on the moon (1962).
2. Launch biological payload from an orbital satellite to soft land on the moon (1962–63).

Manned Lunar Flight:

1. Land a spaceship on the moon and return (1965–66).
2. Launch a space vehicle from an advanced space station, to surface on the moon and return to space station (1967–68).
3. Conduct lunar "on-site" research and development activities (1967–70).
4. Construct lunar launching sites for deep space astrobiological experiments (1970).

TECHNIQUES RELATED TO SOVIET BIOMEDICAL EXPERIMENTS IN SPACE

Chemical and Biological Gas Exchangers

The Soviets may be catalytically recovering oxygen from "superoxides" to regenerate expended O_2 in the atmosphere of space vehicles. The Soviets reportedly used a regenerative system which utilized highly active chemical compounds, in Vostoks I and II. The feasibility of using lithium peroxide as an adsorbent of carbon dioxide and moisture and as an oxygen-storage medium in chemical oxygen systems reportedly was being studied in Moscow in 1960 at the V. S. Kurnakov Institute of General and Inorganic Chemistry. Such systems could be used for air regeneration in space vehicle cabins occupied by living subjects.

Soviet scientists studying the reactions of lithium peroxide with water vapor and anhydrous carbon dioxide at temperatures up to 300°C found that: (1) within a temperature range of 100° to 200°C, in an atmosphere containing 4 percent carbon dioxide and 2.5 percent water vapor, by volume, lithium peroxide was an excellent absorber with simultaneous liberation of an equivalent amount of oxygen; (2) at temperatures below 100°C there was practically no reaction between the lithium peroxide and the other agents; and (3) at temperatures of 300°C and above, all reactions ceased in a short time because of the formation of an impervious carbonate crust accompanied by decomposition.[23-26]

The maintenance of an operational temperature of 100° to 200°C within the gas-cycling element of an air regeneration system should be within the range of Soviet technological capabilities. However, it must be emphasized that a dominant role is played by power, weight, and space limitations in determining the choice of a particular ecological system for a given flight mission. This Soviet research also implies that the Soviets may have completed testing of a potassium regenerative system for O_2 and carbon dioxide removal and are now studing the feasibility of using a chemical compound with a lower molecular weight, perhaps greater efficiency, and probably a lower weight by volume than potassium superoxide (KO_2)* for extended flight use in manned space vehicles. The Soviet Academy of Sciences reportedly expects to "concentrate and accelerate Chlorella research as vital scientific research for 1961." The objectives of this research are large volume cultivation of Chlorella as a food source and utilization of Chlorella in carbon dioxide-oxygen exchange units in submarines and spaceships. An additional research objective is concerned with determination of the chemical composition of Chorella, especially the protein composition.

Research plans revealed include the testing of different strains of Chlorella having different optimum growth temperatures and the search for and testing of new thermophilic (high temperature) strains of the algae (see figure 3). New strains especially desired are those with higher optimum growth temperatures than those now known. Soviet plans call for research on cultivation methods, both the large volume cultivation as successfully employed in Japan, and the closed system primarily developed in the United States. This latter system would be valuable in closed ecological situations such as is encountered in hermetically sealed space cabins and capsules.

A total of approximately 100 researchers of the Microbiology Institute and the Plant Physiology Institute of the Academy of Sciences, USSR, the Soil Microbiology Institute of Moscow University, and the Plant Physiology Institute of Leningrad University reportedly will participate in this work.

It has been assumed that the Soviets were working on devices employing algae for carbon dioxide-oxygen exchange, but this is the first positive evidence that a model device is being developed and tested for this purpose in the USSR. The Soviet plan calls for development of a device weighing about 50 kilograms (110 pounds) which will supply oxygen "semi-permanently" for two people in a spaceship.

The figure of 50 kilograms for a device to supply oxygen for two men is an indication that something other than the normal strain of Chlorella is being employed. Western computations for a gas-exchange device using the normal strain (comparatively low reproduction and photosynthetic rates) call for 23 kilograms or about 50 pounds of solution and algae per man. This amount, along with the necessary weight of containers, lamps, pumps, and gas exchange units, would come to a much higher figure than Soviet design of 25 kilograms per person. Since no direct evidence is available on the characteristics and source of algae species used for this closed circuit system there is a distinct possibility that the Soviets meant 50 kilograms for the equipment with the solution and algae weight to be added later.

Although available information referred only to Chlorella as being the algae under test, or to be tested, it is probable that the Soviets will not restrict their operations to a single genus of algae. It is more probable that their studies of chemical composition will be made on all algae species which are fast growing and fit all criteria imposed by concepts of use and equipment design. Their final selection of species for use probably will be dependent on consideration of all test results.

The Soviets are cognizant of the comparative high value of the thermophilic strains of algae as far as reproduction and photosynthetic rates are concerned. It is not clear, however, whether the Soviets now have thermophilic strains on which research is being conducted. In 1960, a U.S.-developed high-temperature strain of algae was given to an institute of the Academy of Social Hygiene, Work Hygiene, and Advanced Medical Train-

* $4KO_2 + 2H_2O$ yields $4KOH + 3O2$ (oxygen supply). $2KOH + CO_2$ yields $K_2CO_3 + H_2O$ (CO_2 absorption)

ing of the German Democratic Republic and presumably has been made available to the USSR.

Individual Soviet scientists associated with the Chlorella project are among the most competent biologists in the USSR. This fact and the reported assignment of 100 research workers to this task are both good indications of the importance the Soviets are placing on algae research.[28-30]

Other Soviet biological research concerns variants of closed ecological systems reportedly dealing with plankton (Rotatoria, Copepoda, and others). These studies are undoubtedly concerned with the possibilities of developing accelerated propagation rates and food sources of high protein value to be used in connection with future lunar projects involving landing and prolonged habitation by man.[31 32] This research is very significant as the Soviets are placing great stress on how fast they can make plankton divide (division and propagation rates), whereas the U.S. approach is primarily concerned only with potential use as a food souice.

Radiation Factors

The Biological Problem

Detailed experimental and theoretical study of geomagnetically trapped corpuscular radiation (protons and electrons) has become a major field of investigation during the past two years in both the United States and the Soviet Union. Although knowledge of the trapped radiation is still incomplete, these trapped particles are of biological importance for spaceflight in the near vicinity of the earth. Moreover, it is a reasonable presumption that corresponding radiation exists around all other magnetized celestial bodies.[33-38]

Protection and Recovery Problem (Biophysical)

Orbits below 600 kilometers (360 miles) should prove quite safe for long-term orbital manned vehicles. So-called "avoidance routes" can be plotted to escape most of the two Van Allen bands (see figure 4). As recently as 18 June 1961, Prof. Sergey Vernov, Soviet authority on space radiation, reported on such mapping and launching possibilities.[39] As a result of three orbiting spacecraft (Sputniks IV, V, and VI), the Soviets claim to have found that primary cosmic rays comprised the main part of the radiation dose received inside of the vehicle. All of the measurements were in the range of 100 to 200 nautical miles above the earth, the original perigee and apogee limits of this series of satellites. The perigee and apogee of the first manned orbital flight (Vostok I) fall within these limits, suggesting that the 1960 satellite series was planned for the April 1961 manned flight.

Some U.S. and Soviet space vehicles have already obtained scientific data in and beyond the Van Allen belts, but other space probes and additional biomedical investigations will logically precede manned flight in that area.[40] According to U.S. information, orbiting in or above the outer band will require shielding (of the order of 4 to 10 grams per square centimeter) and also avoidance of solar flare activity. Such shielding will also be adequate for auroral radiation and the solar X-rays. Not enough information was available by mid-1961 for scientists to estimate either dose or shielding requirements for neutrons. For cosmic rays, shielding of 10 g/cm^2 is useless. Shielding at a level of 100 g/cm^2 would reduce intensity of cosmic rays significantly. Less shielding than this may, in fact, lead to an increased dose because the primary cosmics would be slowed enough to permit more frequent stoppage of cosmic rays, resulting in damage to the vehicle or passenger. In addition to passive shielding, there are electrostatic and electromagnetic shielding (referred to by the Soviets); but these impose weight or power limitations of their own. Present U.S. opinion suggests that the biological risk of damage from cosmic rays seems acceptable, and the other space radiation can be reduced adequately by 10 g/cm^2 shielding.* [41-46] (See appendix D.)

* The Apollo (multimanned vehicle) structural and local material should provide 8 g/cm^2 shielding.

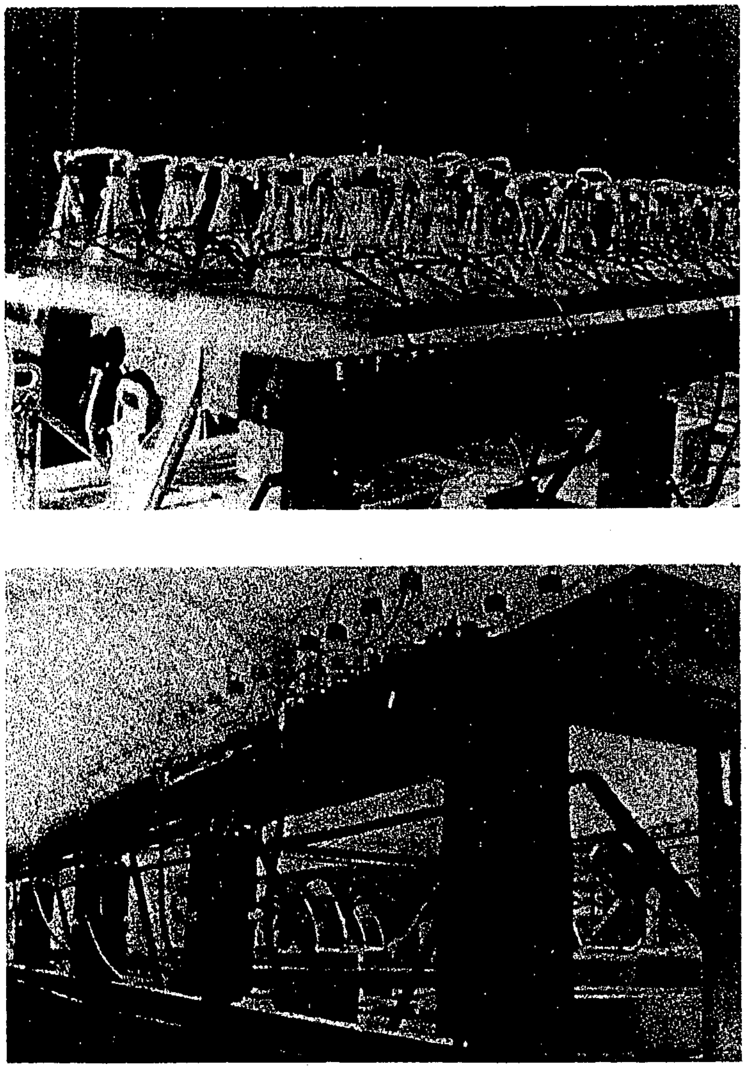

Figure 3. Sterile agal culture units utilizing Chlorella.

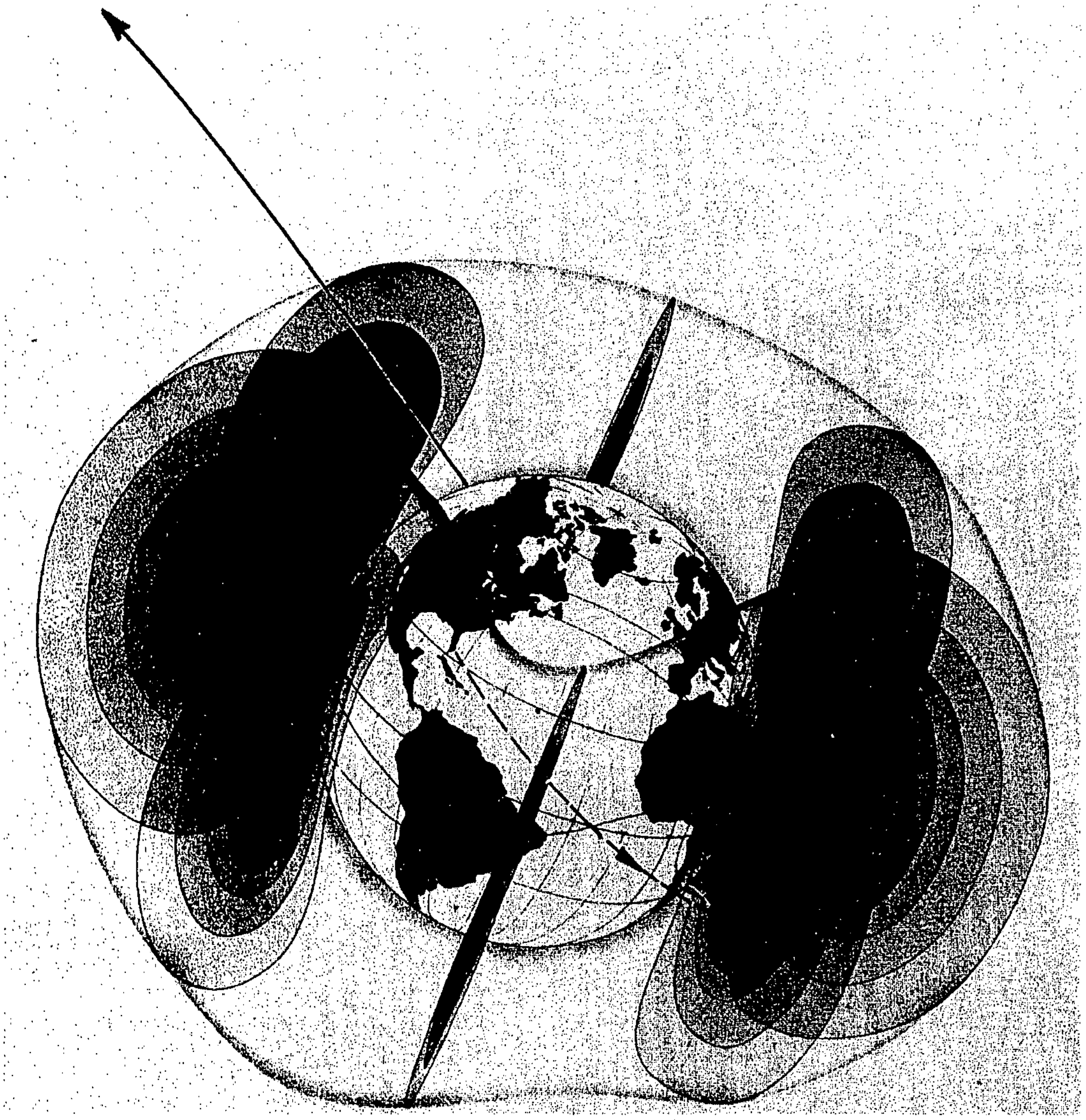

Figure 4. Van Allen radiation belts as conceived in late 1960.

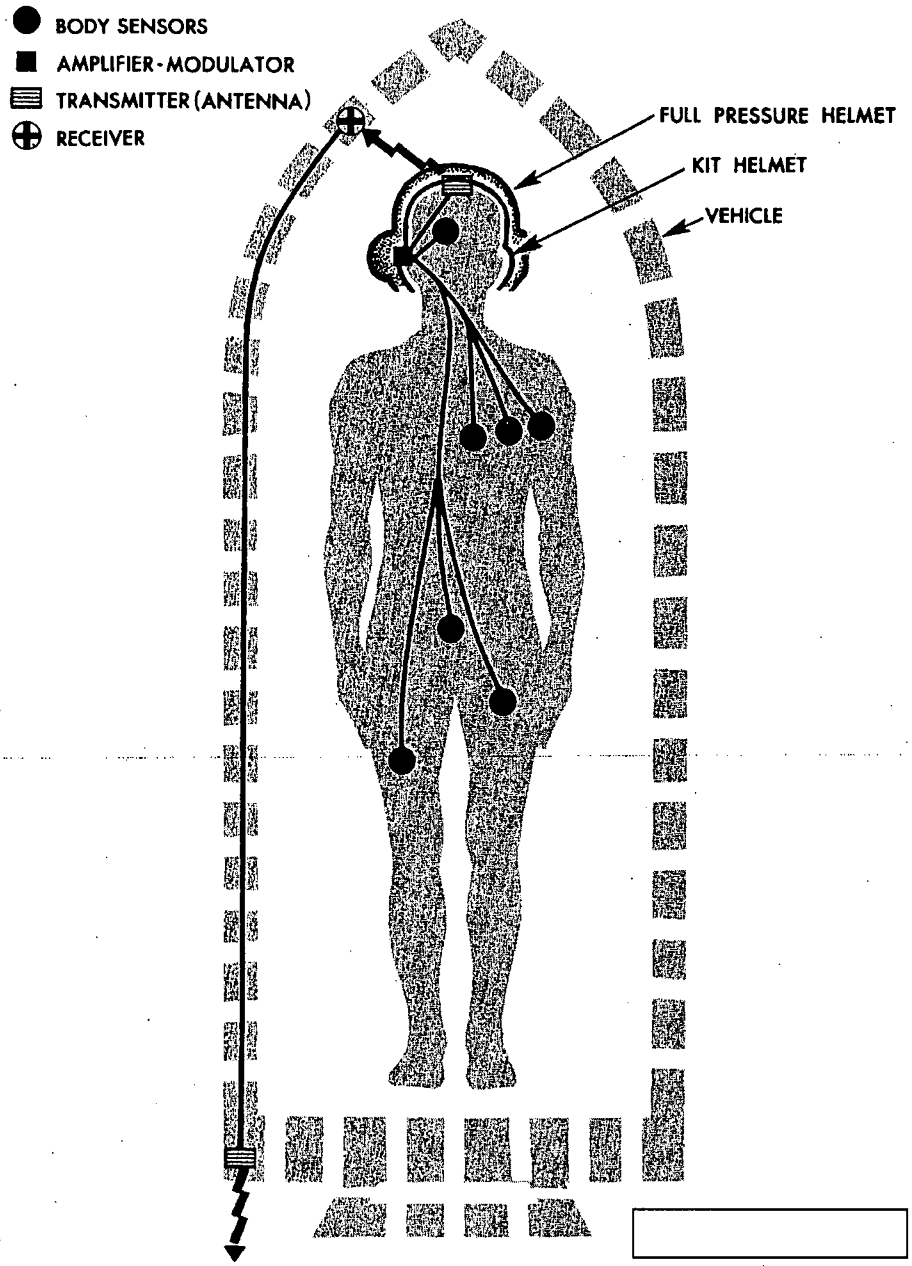

FIGURE 5. ILLUSTRATION OF RADIO - TELEMETRIC SUBSYSTEM WHICH WOULD ELIMINATE NECESSITY FOR UMBILICAL CORD

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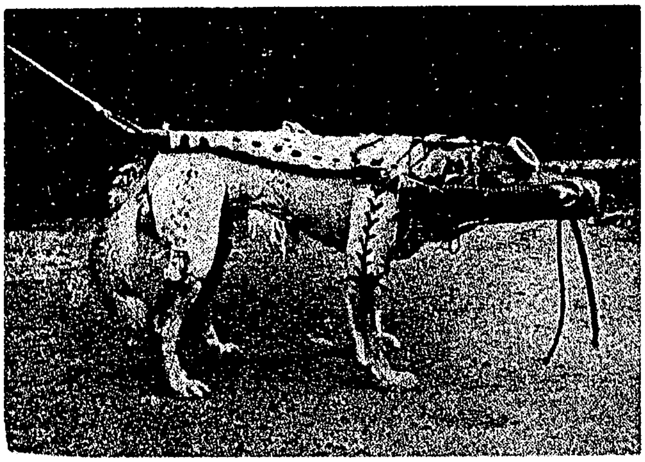

Figure 6. Dog with "free-movement" radio-telemetric kit.

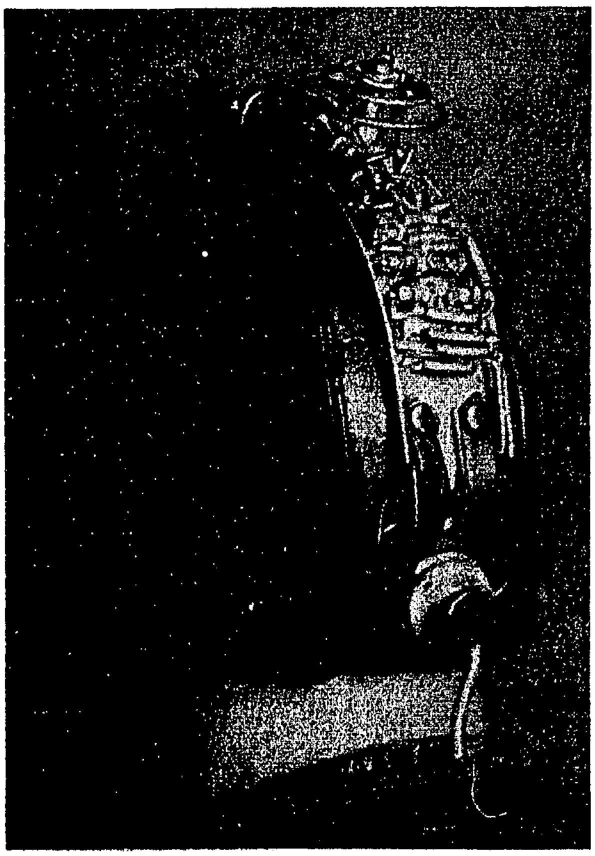

Figure 7. Helmet equipped with telemetric radio kit, designed by L. Shuvatov.

Figure 8. Shuvatov's helmet measuring arm movements.

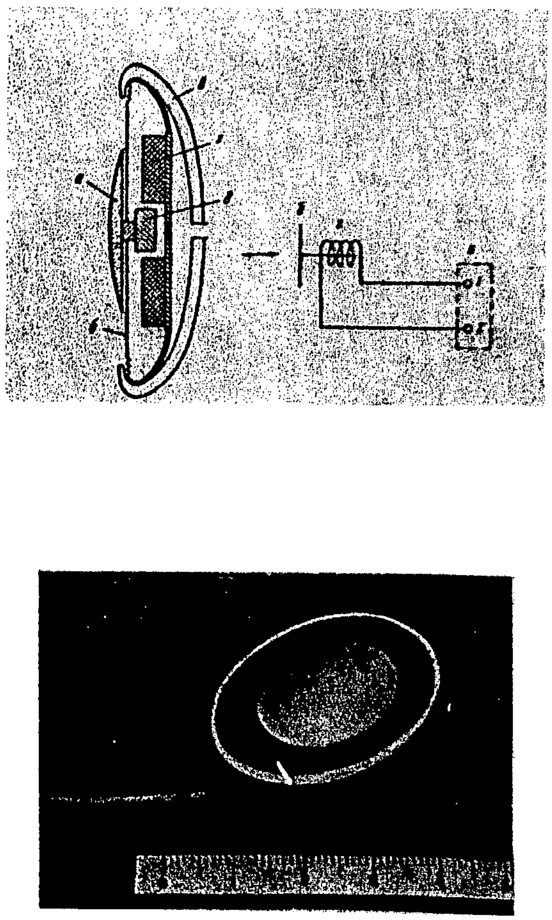

Figure 9. Electromagnetic
pick-up for recording cardiac sounds.

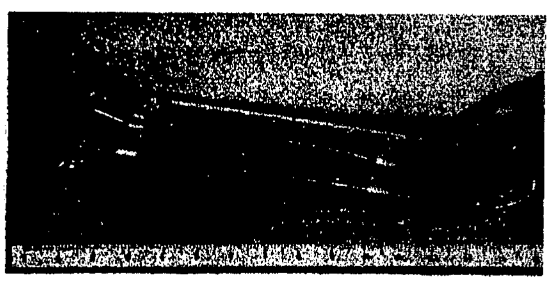

Figure 10. Potentiometer pick-up for mechanograms (limb movement)

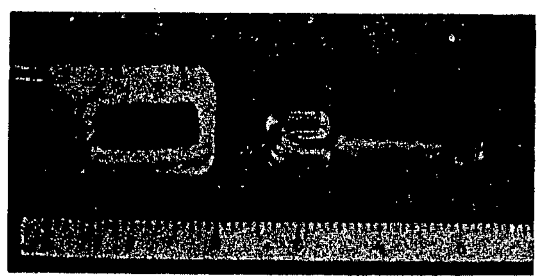

Figure 11. Oxyhemometer (pick-up for oxygen saturation level of blood).

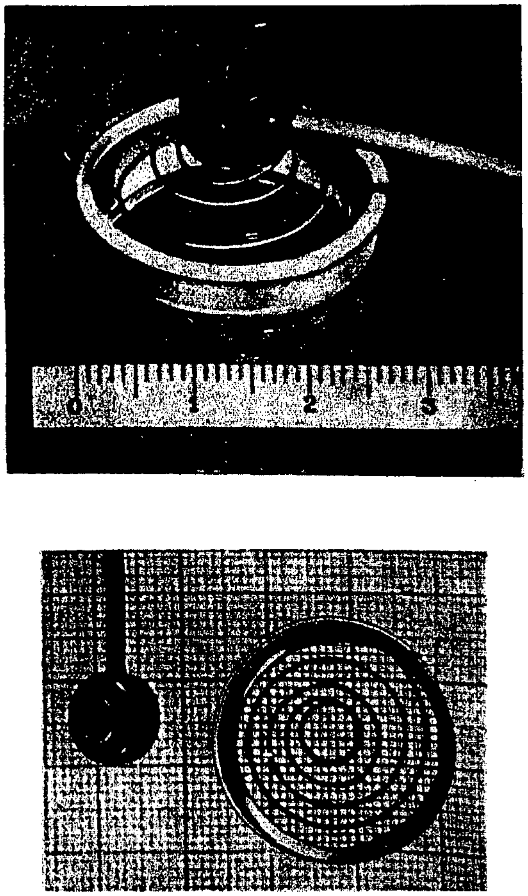

Figure 12. Body temperature pick-up.

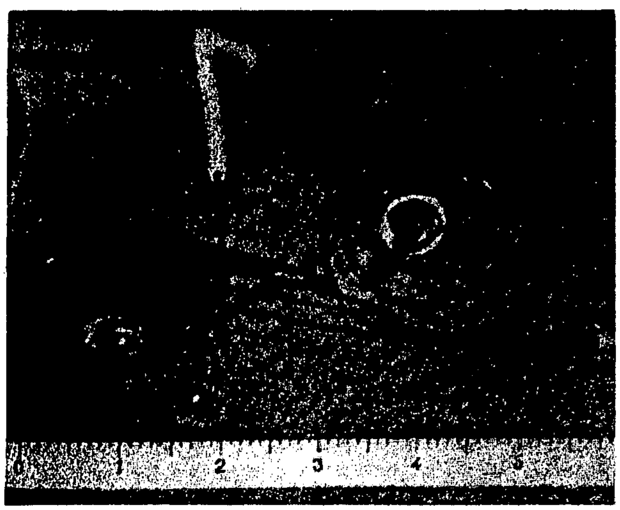

Figure 13. Device for measuring muscle biocurrents.

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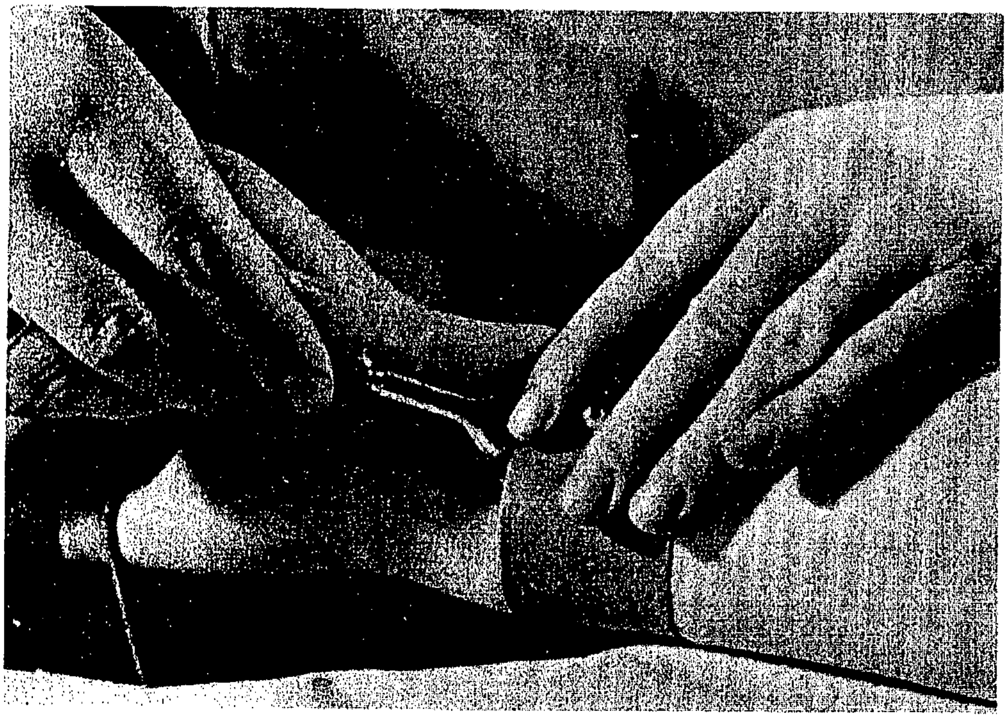

Figure 14. Pulse pick-up device.

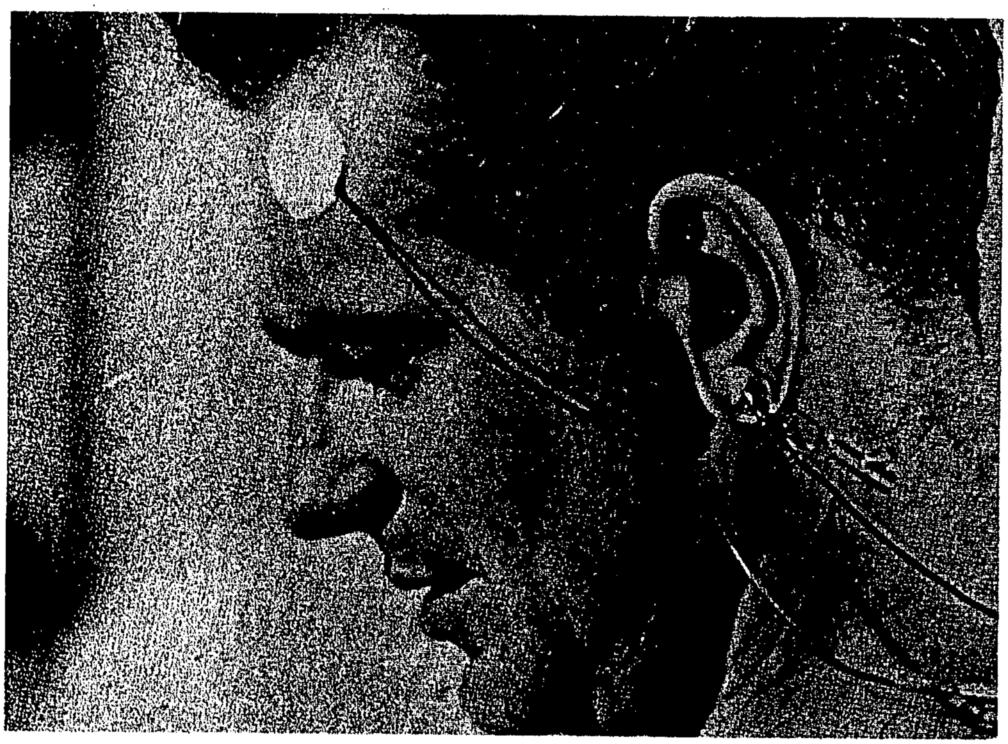

Figure 15. Titov with forehead sensor (brain waves) and ear oxyhemometer (oxygen saturation of blood).

Life Support Equipment Problem

In general, life support equipment is adequately shielded by any measures which will protect man. There are, of course, items which will be exposed externally to direct space radiation. The successful operation of battery sources and transmitters of data in Sputnik III over a period of two years provides the most direct evidence for the survival of electronic support equipment in Soviet space vehicles. The integrated radiation exposures in this early Soviet experiment are still much below the level at which serious deterioration may be expected.[33] Even for such items as plastics, transistors, and solar energy convertors, doses on the order of 10^6 rem are required to produce damage.[33 47–51] Metals are extremely resistant to radiation damage.

Radiation Shielding Technique (Sputnik V)

Analysis of the possible Sputnik V configuration (spaceship and biocapsule) suggests that the USSR is actively investigating specific combinations of radiation shielding techniques for capsule design and personnel protection against radiation. The Soviets reported that the two dogs, Belka and Strelka, wore special clothing for the Sputnik V spaceflight. Over this, the dogs reportedly wore so-called fixed clothing made of capron (a synthetic fiber known generally as nylon 6 made from caprolactam). This clothing reportedly prevented mechanical damage to radiation counters which had been placed in the bodies of the animals.

Previously, the Soviets mentioned the use of a series of metallurgical, alloy, and plexiglass (simulating water) matrices as radiation attenuation techniques. These combinations may constitute the normal physical "make-up" of the inner and outer skin of the spaceship and biocapsule. Further shielding was proposed for the living test subjects consisting of clothing made from capron or nylon 6 synthetic fiber to which lead and tungsten in some suitable form may have been attached, laminated, or mechanically incorporated. Also the added weight of the clothing would be a supplemental "positioning aid" to a restraint harness during the launching and recovery phase but would be nullified during the entire period of the weightless phase.[55–57]

These combined shielding techniques will not solve the primary cosmic ray problem nor that resulting from the bombardment by very energetic protons or electrons. For short missions, however, the maximum biological hazard may be lessened.

Scientific Instrumentation and Use

Biodetectors

A. A. Imshenetskiy, Director of the Institute of Microbiology, Academy of Sciences, USSR, has noted that one of the most important problems of space biology is collecting samples of particles from outer space and analyzing them from a microbiological point of view. There is no evidence that Soviet investigators have developed a device which would permit specific identification of live micro-organisms without culture and biochemical methods. But it is possible that a photoelectric device supplemented by other analytical instrumentation (such as a mass spectrometer) has been rigged to determine concentration, size, and some physicochemical characteristics of captured particles. In addition, micromedia for growth and biochemical analyses may have been included in the arrangement with some design for telemetric monitoring of oxidation-reduction potentials and pH changes. If particles are picked up which lie within parameters identified with known micro-organisms, a signal might be telemetered to a receiving station on earth. Other evidence of metabolism and respiration, as demonstrated in the biological apparatus, might be relayed in similar fashion. Despite evidence of the existence of very reliable Soviet biotelemetry devices, such a remote-controlled complex detection apparatus of necessity would be subject to numerous opportunities for malfunction and probably would be limited to relaying only presumptive information about living organisms in outer space.

A 1961 Hungarian article based on an interview with the microbiologist V. D. Timakov, Vice President of the Academy of Medical Sciences, USSR, notes that Sputnik V, which was launched on 19 August 1960, was equipped with a biodetector. Although the biodetector was reported to be especially designed for vehicles which are not to return to earth, Sputnik V was, in fact, successfully recovered. Other public statements made in February 1960 about the need for designing such micro-organism detection devices, suitable for cosmobiological studies indicates a possibility that the biodetector was still under development when used in Sputnik V. This instrument reportedly could transmit radio signals which would alert the receiver to "evidence of life, such as unknown microbes" encountered in space. When the biodetector passes through a "danger zone," it is designed to flash a warning signal back to earth.

A number of air sampling devices produced or under development in the USSR are applicable to the problem of extremely high altitude sampling. Several scoop, suction, and impinger devices could be applied to initial recovery of samples outside Soviet vehicles. Scoop and vacuum bottle devices have been used by the Soviets for evaluating bacterial profiles of the upper atmosphere, possibly up to 100 kilometers (62 miles). However, the biodetector within a vehicle going beyond 60 miles may be a version of the devices developed by B. V. Deryagin, M. A. Fuchs, and others for determination of particle concentration in highly dispersed aerosols utilizing photoelectric methods.

The problem of extraterrestrial life and potential microbiological hazards is a matter of serious concern to Soviet biomedical investigators from a theoretical, as well as a public health, point of view. Despite weight limitations and collection priority of the astrophysical information, it is possible that a version of the biodetector will be installed in future space vehicles.[70 71]

Instrumentation of Peripheral Interest

The Soviets have been experimenting for 9 years with electric devices to induce sleep in animals and man, and to produce a condition similar to that existing under the influence of anesthetics.[72] Such research is only of peripheral interest to bioastronautics but their clinical work and its applications could possibly aid Soviet researchers in simulation studies for planning work-rest cycles (shifting, reversing, lengthening, shortening) and in scheduling the future activities of selected crews for vehicles making extended flights. The device's adaptability to variations in length of a simulated sleep period on humans would be very helpful in determining possible effects of sleep cycles and the possible operation of biological timing mechanisms involved in manned spaceflight. Although there is no direct evidence of such research being applied to space activities this Soviet device could aid studies oriented toward relationship between brain functions and behavior, especially under emotional responses and changing levels of consciousness, such as sleep, parabiotic states and wakefulness. The test of the Soviet portable unit at a U.S. institute resulted in a dog going to sleep, but the test was not conclusive.

Thermoelectric Methods for Analysis of Metabolism Rate

Some significant Soviet research related to manned spaceflight, as well as obvious clinical use, reportedly being done at the Department of Hygiene, Military-Medical Academy, Leningrad, is devoted to the determination of heat loss from human skin due to radiation, convection, and conduction. According to Soviet description this is a new thermoelectric method for the analysis of metabolism rate based on the principle of direct calorimetry.

Eleven calorimeters consisting of round cellophane discs, into which a battery of serially connected thermoelements is mounted, are attached to various parts of the human body. Simultaneous readings of thermoelectric potentials of all calorimeters permits an estimate of the mean heat loss from one unit of skin during one unit of time. Studies on heat loss by evaporation (under ordinary conditions of thermal comfort the Soviets constitute this as meaning approximately 25 percent of all lost heat) is not registered during these studies but is determined at other institutes. To ensure conditions of thermal comfort, the Soviet determinations were made at an average skin temperature of 34°C. In 90 percent of the 74 test subjects examined the difference of values obtained by this Soviet method and the values obtained by Western methodology (Douglas-Haldane) did not exceed 6 percent and in the remainder of the subjects did not exceed 10 percent.[73 74]

Other Soviet researchers describe their investigations of heat exchange in eight men between 25 and 35 years of age during exposure to temperature of 40°C, 50°C, 70°C, and 75°C. Values of heat production, heat emission, and heat accumulation in the organism were determined. These heat exchange studies make it possible to determine the heat load on man at various temperatures and to calculate the time during which the greatest loads studied may be endured, depending on the speed of heat storage and the limiting permissible values of heat accumulated in the organisms.[75 76]

This Soviet indirect method of determining the fundamental metabolism rate by measuring the rate at which heat is given off by the human skin may lead to development of new techniques for maintenance of adequate internal environments of space vehicles traveling at high speeds, particularly during the decelerative and re-entry phase. This important research at the Military Medical Academy could be significant to the Soviet biotelemetry requirements and capabilities. Adaptations of telemetering equipment to transmit quantitative data related to energy levels (basic to maintenance of cellular activity, respiration and adequate peripheral circulation) of cosmonauts during active and passive periods of spaceflight would demonstrate a high degree of capability in instrument development for bioengineering problems. In addition, the studies at other institutes on elucidation of mechanisms involved as well as knowledge of unusual heat losses and reactions are necessary as re-entry heating and other thermal stresses may make it necessary for Soviet cosmonauts to withstand extremes of temperature. The failure of the human subject under heat stressors is precipitous and seems to involve autonomic failures.[77]

Human Factors Engineering

Important Soviet work which concerns the functional characteristics of the human operator in space vehicles includes studies of vibration effects on the human body, air contamination in confined areas, recovery techniques, post-flight observational phases, role of cybernetics in manned spaceflight, and other aspects directly and indirectly related to orbital and inter-planetary spaceflight.

Role of Cybernetics in Manned Spaceflight— According to recent statements of A. I. Prokhorov, member of the the Presidium of the Scientific Council of Cybernetics of the Academy of Sciences, USSR, the science of cybernetics will become increasingly important in the conquest of space.

Cybernetical tools (self adaptive) will help man when he is unable to operate quickly enough the complex processes and equipment involved. The means of applied cybernetics are fast electronic computers and different automatic machines. For this reason, the role of cybernetics is important in the Soviet conquest of space. This type of bionics research also helps in checking the design of a spaceship before it is built as well as in choosing the most heat-resistant and durable alloy for the re-entry phases and successful recovery of man in space vehicles.

Prokhorov further stated that it is certain that future spaceships will have several cybernetical machines, each of which will solve its own special task. In any case, according to Prokhorov, future cosmonauts assigned to extended missions will be accompanied in the spaceships by different cybernetic devices which will help them carry out many of the tasks involved.[78]

Western scientists consider it important, however, to realize that limited endurance is not likely to be confined to the human subject in the competition between man and machine. Machines, too, suffer from serious shortcomings; and the failure of such cybernetical devices in space vehicles is likely to be more rapid than the failure of any human passengers. This is particularly probable as the machines and devices become more complicated and involve very large numbers of individual components. It may well be that one of the most important requirements of man in space will be to maintain the machines.[79]

Soviet hypothesis agrees in general with the U.S. postulation on this problem but they concede that the way out of the predicament (increased number of elements reduce reliability of system) is to increase the reliability of each element individually as well as devising new principles of building a system whereby damage to individual elements would not affect the work of the machine as a whole. The Soviet scientist, V. A. Trapeznikov (Chairman of the National Committee of the Soviet Union on Automatic Control and Director of the Institute of Automation and Telemechanics), states that nature provides an example of such a foolproof system in living organisms which follow the principle of transfer of function. When some cells are damaged their functions are performed by other cells. The same principle, according to the scientist, should be followed in building automatic systems, that is, self-adaptive systems.[80]

Post-Flight Phase of the Soviet Space Program — At a February 1, 1961, meeting of the Department of Biological Sciences, Academy of Sciences, USSR, Academician N. Sisakyan, a biochemist of the Bakh Institute of Biochemistry and the Secretary of the Department of Biological Sciences, reported on some post-flight observations of living objects successfully launched and recovered from Soviet spaceships, satellites, and high-altitude rockets. (See figure 16.) [81 82] He mentioned prior Soviet claims that flight below known radiation belts is reasonably safe.

Sisakyan's statements disclose, however, that some of the living organisms are affected by spaceflight conditions. This member of the Academy of Sciences as well as other Soviet observers said that the space dogs have developed "highly refined" changes in nuclear structure of cells, but apparently there is no evidence yet of adverse effect on physiological functions. Examination of bone marrow of mice sent into orbit shows that a number of blood cells do not reproduce normally, but it is not yet possible to say whether the blood-forming function of marrow is impaired.[83] A transitory increase in the amount of serum globulin and total serum protein, and a decrease in the serum cholinesterase activity were noted in Belka and Strelka a few days after their successful recovery from orbital flight.[84 85] The nucleic acid studies have also proven to the Soviets that apparently no lasting disorders of metabolism are induced by such short spaceflights. Decreases in serum cholinesterase levels may have resulted from stresses of combined flight factors and exposure to toxic substances produced by the normal operation or to malfunction of the internal equipment of the sealed cabin. Progressive decreases in subject's serum cholinesterase activity for longer periods than 16 orbits could lead to difficulties, although there is the possibility of reparative processes during sleep.

The probable significance of including 14 ampules of fungi strains (actinomycetes) was to study the significance of genetic effects of radiation. Any changes in the two strains (radioactive sensitive and radioactive resistant) can be measured and utilized further for the production of more strains which might be beneficial but could just as well be harmful.[83 86 87] Soviet observations are considered valid in view of the altitudes and durations of their vertical and orbital missions. It is also recognized that Soviet scientists can trace possible future effects of past exposures to spaceflight during the remaining life period of these experimental objects.

Vibration (Ground Simulators) — Soviet research on oscillatory resonance of the human body while subjected to vibrations is conducted for the purpose of studying the resulting influence on physiological functions, regularity of vibrations, and evaluation of shock-absorbing devices.[88 89] Following an orbital shot with animals suggestions were made by the Soviets for the use of various shock absorbers in order to reduce future vibrational effects on the human body.[90]

This research is most likely designed to determine thresholds of performance deterioration under conditions of specific vibrational amplitudes (simulating powered flight and re-entry phases) at or near the frequencies of human bodily resonance. It appears that Soviet research tasks on resonance phenomena within the 1 to 60 cycles per second range are initially concerned with impairment of perceptual vision (nystagmus), speech monitoring, and psychomotor performance. These Soviet studies, which have been performed on ground simulators, will enhance information about physiological tolerance to operational stresses of vibration.

In the Soviet experiments on head resonance, an accelerometer was bound firmly to the human head by rubber tapes. Simultaneous registrations were also made of the accelerative movements of the vibration stand. The Soviets found that the acceleration of the oscillatory motions of the human body were much higher than those of the vibrating test stand, particularly during experiments within the 3.2 cycles per second and plus or minus 10 millimeters. Their results also established frequencies of 5 to 8 cps and 17 to 25 cps as the resonance regions for the human body, 20 to 25 cycles per second being the critical resonance for the head.[91] These Soviet findings apparently confirm U.S. data on the vibrational problems of manned spaceflight to the effect that certain frequencies, that is 3 to 9 cycles per second, rather

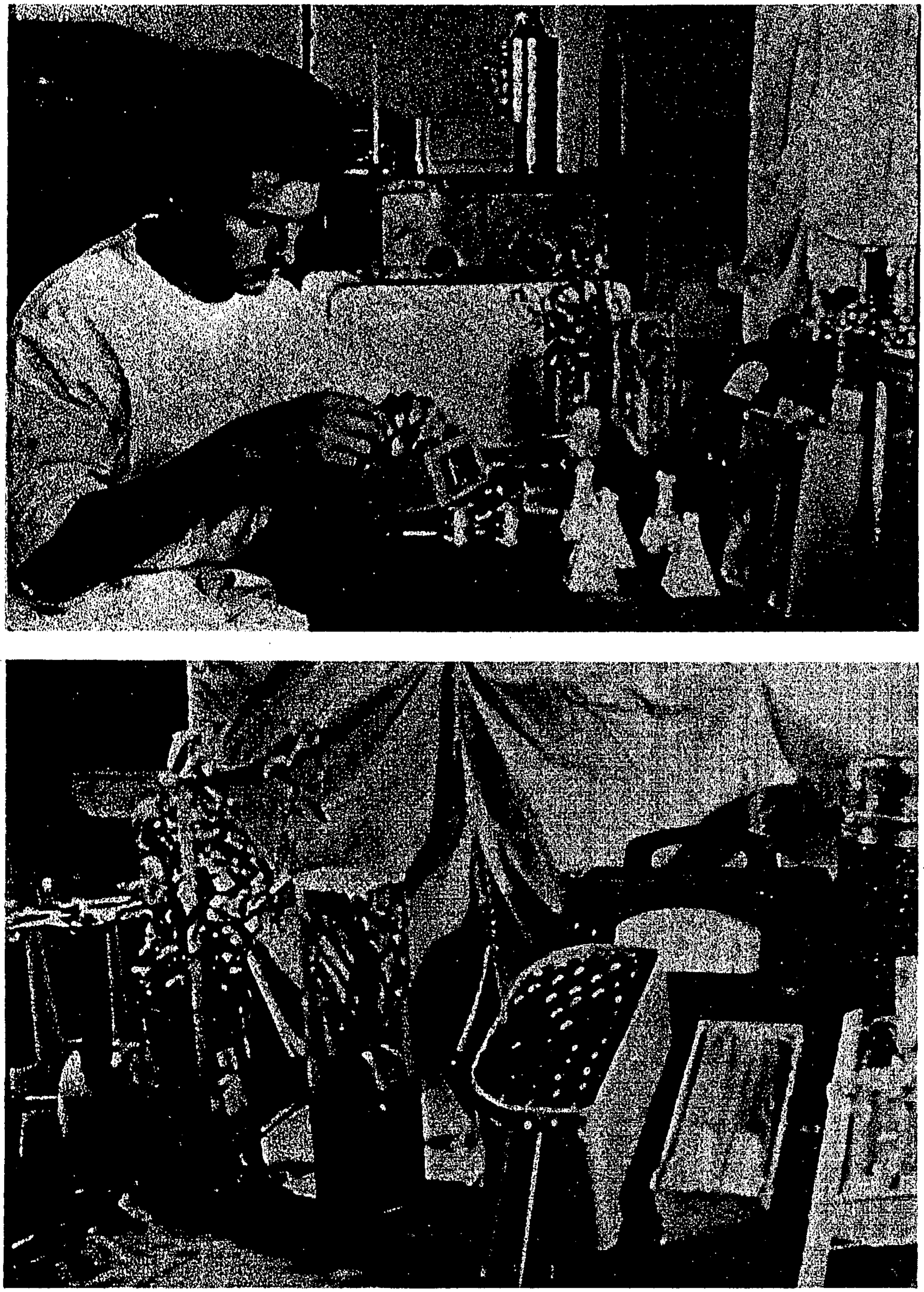

Figure 16. Bioelements of space zoo used in Sputnik V.

than amplitudes cause mental dissociation and other transitory disturbances. Other potential problems which may arise if U.S. or Soviet space candidates are subjected to low frequency vibrations during launch or re-entry are lack of speech intelligibility (no control of air flow in trachea) or the possibility that the human subjects might be forcibly lulled to sleep, in a manner reminiscent of cradle rocking.

Air Contamination in Confined Areas — The Soviets recently reported their study of contamination of the air resulting from exhaled carbon monoxide (CO) in confined rooms. Carbon monoxide is not burned to carbon dioxide (CO_2) in the body, and is only gradually eliminated from the lungs as air is inhaled. Test subjects (smokers and non-smokers) were confined in groups of three in test chambers with a volume of 24 cubic meters of air for several days. All possible external sources of CO contamination were carefully checked and eliminated. The air-purification system in the chamber was the peroxide type and could only reduce the CO concentration. Calorimetric determination of the CO concentration was made with a Swedish device. After 9 to 10 days, the air of the testing chamber with the three confined subjects contained 0.023 to 0.027 milligrams per liter of CO. The smokers exhaled alveolar air containing CO at an average rate 0.22 milligram per liter more than the non-smokers.[92-94]

These Soviet studies on formation and exhalation of alveolar air containing CO from the human organism during confinement appears to be of importance to problems of controlled air purification and toxic effects of CO in vehicles for manned spaceflight. Such data also aids in determining the physiological tolerance of man in confined areas without ordinary ventilation or exchange of air. The peroxide-type air purification system reported by the Soviets indicates further support of Soviet trends using superoxides for the development of chemical-oxygen systems. This information on CO rates could also aid Soviet feasibility studies related to capsule and vehicle design (size), reliability of sealed cabins against leakage, optimum control systems pressure and oxygen levels, and integration of safety features for CO detection and quantitative estimates (toxicities).

Recovery of Gagarin from Orbital Flight — The Soviets, in successfully recovering man from orbital flight, were guided by the results of animal experiments carried out between 1950 and 1961. The successful completion of such a large portion of their vertical and orbital experimental work clarifies the Soviet use of parachutes as the most practical method for recovery of the space cabin (housed life support equipment and landing system) and the cosmonaut, separately. Such ejection systems have been reliably tested for many animal recoveries from vertical and orbital apogees as high as 270 miles. Within the cabin of the spaceship, Gagarin sat in a catapult chair which served as his working place as well as an emergency escape apparatus during the powered flight phase. The cosmonaut's chair included a special back for holding his body during ejection and parachuting, and that contained a parachute system; catapulting and pyrotechnical equipment; emergency equipment including food, water, radio for communications and direction-finding after landing; ventilation system for pressure suit and parachute oxygen gear; and other automatic equipment. It is likely that Gagarin ejected from the heavy cabin between 22,000 and 9,000 feet and continued the descent by a conventional parachute.[95-97] The Soviets have never confirmed the method of Gagarin's recovery from orbital flight, but it appears that the Soviet ejection technique is more practical than the recovery of the spaceship containing the man. However, if Gagarin did eject, he most likely experienced before ejection the stress of the spaceship's "braking phase" and a momentary rotation of the "ship" during the descent trajectory into atmospheric levels.

Sterilization of Space Probes — At the Darwin Centennial Celebration, 24 to 28 November 1959, held in the United States, Dr. G. F. Gauze, Director of the Institute for the Search for New Antibiotics, mentioned that to avoid possible contamination of the moon by microorganisms from terrestrial materials, a group of microbiologists at the Institute of Microbiology of the Academy of Sciences, USSR, was attempting to maintain the sterility of materials actually reaching the moon, to include a thorough sterilization of the rocket, the capsule, and all parts of it while on the moon.[98 99]

This statement by one of the most prominent Soviet microbiologists supports previous indications that Soviet interests include possible infectious disease problems of space travelers, microorganisms on other planets, and "super-clean" factors associated with the development of space vehicles. It substantiates previous reports that laboratory investigations under A. A. Imshenetskiy, Director of the Institute of Microbiology, include studies of microorganisms under simulated space vehicle flight conditions. Previous press, radio, and public statements by Imshenetskiy, Iyerusalimskiy, and others have indicated space microbiological projects in Moscow and Leningrad.

Soviet origin-of-life laboratory research, theoretical study, and discussion are and probably will continue to be dominated by A. I. Oparin, who is Director of the Bakh Institute of Biochemistry, a member of the Academy of Sciences, USSR, and the recognized Soviet leader in discussions and experimentation on the origin of life. Experimental data published since 1957 indicate that some other Soviet scientists, by concentrating their experimentation in the appropriate fields, could probably add considerable valid experimental data concerning the origin of life. On the other hand, a considerable amount of worthwhile biochemical research indirectly related to the origin of life is done in the USSR.

Some Soviet leaders realize the propaganda and ideological value of success in this research as it relates to the field of bioastronautics, and increasing support for the use of the physical, mathematical, and chemical sciences and scientists in bioastronautical experimentation is evident.

Potential disturbance of the ecological environment of the earth or other planets from outside sources is cause for modest debate in the United States as well as in the USSR. It is likely that the Soviet space microbiological group is one facet of a larger program intended to estimate, by experimentation, the conditions of macro- and micro-forms of life on other planets. In view of the emphasis on decontamination of component parts, it is probable that this program at the Institute of Microbiology also is closely coordinated with the Central Institute of Disinfection, Moscow, where actual decontamination research and development for earthbound projects and investigation is carried on. The Soviets intend to incorporate countermeasures into space probes against factors which might prejudice the health of the astronaut or harmfully disturb the flora and fauna of the astral body under investigation, as well as that of the earth.

THEORETICAL RESEARCH RELATED TO SOVIET BIOASTRONAUTICS

Maximum Utility of Oxygen

The availability of oxygen has long been known to be one of the prime limiting factors in the ability of man to exist and to function effectively at high altitudes. For some time, scientists throughout the world have been studying this high priority problem and seeking methods to alleviate it. Solution to this important problem would be a marked advance in the physiology of respiration.

A recent Soviet article reports that the pharmacological laboratory of the Minsk Medical Institute, Byelorussia SSR, is testing the ability of a pharmacological preparation to increase animal (rabbits and mice) resistance and survival rates in an oxygen-deficient atmosphere at a simulated altitude of about 34,000 feet in hermetically sealed vessels. The Soviet preparation, Bas,* is administered for 5 days in doses of five milligrams per kilogram of weight. On the sixth and following days, the experimental animals undergo hour-long confined exposures at simulated high altitudes. The Soviet laboratory's data indicate that the survival time of the experimental animals was increased 2.4 times over the control animals.[105 106]

This study indicates Soviet interest in using chemical compounds to extend the time limits at which a living organism may function at high altitudes. This type of data is expected to be of considerable value to the space sciences because of the practical value of extending the usefulness of life support equipment and because controlled use of this or similar agents may assist test subjects in neutralizing the effects of oxygen deficiencies during launching and re-entry phases of space missions.

Simulation of Human Responses to Parachute Recovery

A Soviet scientist, L. P. Grimak, reports on a study of the "cardiovascular and neurological changes that take place in all stages of parachuting" in which five parachutists participated. This study was carried out by simulating the emotional state of parachutists through verbal suggestion while under hypnotic sleep. Grimak further states that it was possible to form a good picture of the various reactions of a parachutist from the time he leaves the aircraft until the time he reaches the ground. This study showed that there was a rise in arterial blood pressure, pulse, and respiration, which reached a maximum just prior to jump. These physiological changes tended to return to normal after the parachutist leaves the airplane and the parachute opens.[107]

The significance of this unique experiment is that it provides Soviet scientists with a way to simulate the emotional and physiological responses which a parachutist or future cosmonaut will undergo during recovery. This technique should be useful in the selection of cosmonauts who show the most stable and predictable reaction to the stresses of recovery. It should also provide future cosmonauts with experience in adjusting to the stresses of re-entry in the laboratory and without the physical risk involved in actual parachute descents.

Molecular Biology

Deoxyribonucleic acid (ampules) aboard Sputnik V was observed by the Soviets in spaceflight because of its possible role in relaying hereditary factors from generation to generation and because the acid is an important component of cell nuclei. Soviet postflight observations are also extremely valuable for future man-in-space flights, particularly from the standpoint of possible cell mutations and other genetic studies.[108-113]

REACTIONS, FUNCTIONS, AND RESPONSES OF GAGARIN (VOSTOK I)

A period of significant, but apparently not critical, vibration was experienced by Gagarin (and also by Shepard) in the period 70 to 85 seconds after launch. The periods of transonic flight and the period of maximum dynamic pressure (the points in the exit trajectory at which the spacecraft and launch vehicle are subjected to the largest aerodynamic

* 1 benzyl-2, 5-dimothyl serotonin is a benzyl analog of serotonin.

load) occur close together, and general vibration is usually associated with them.

[redacted] Maximum vibration for Shepard began about 70 seconds after launch and lasted for 15 seconds. Shepard reported that his head vibrated, blurring his vision for a few seconds.[115] Although this vibration was expected, it is not completely reproducible in wind tunnel tests of the vehicles, on pilot trainers, or in flight simulators. Modifications such as more head support padding and more streamlined fairing for the spacecraft-to-booster adapter ring can be expected to reduce this problem for future U.S. flights.

[redacted]

Gagarin reportedly ate, drank, floated in his space cabin, wrote notes, read instruments, transmitted by voice and key to the ground, recorded observations on a tape recorder, and performed secondary tasks incidental to the automatic control of the space vehicle. Also for the first time, Gagarin experienced the rapid transition of dark entry into the earth's shadow and the abrupt emergence therefrom.

Gagarin served as a "backup" to the autopilot* in event of a one orbit malfunction; whereas, Shepard actually assessed his own capability to operate manual control of flight altitudes during a few minutes of his downrange flight. The Soviet claim to new space records was adequately documentated for acceptance by the official keeper of the world's flight records, the Federation Aeronautique Internationale; and Gagarin officially earned three world records for manned orbital flight—weight, altitude, and time duration.[116-119]

[redacted]

Vostok I presented the Soviets with the opportunity to study the combined responses of Gagarin to a combination of flight factors which cannot be fully simulated under laboratory conditions; that is, weightlessness, noise, vibration, and re-entry dynamics.

One of the principal tasks of the biomedical experiment derived from Gagarin's orbital flight in Vostok I was a complete observation of his response to the transition of G forces acting on him within a period of 108 minutes. This transition, in combination with other extreme and brief flight factors, involved: 1G (ground launch pad); increased G (6–8G during acceleration to escape velocity); zero G for 67 minutes (orbital flight); increased G (10G during re-entry to atmosphere); 1G (ground recovery area).[120]

The most critical phase of this whole transitional period, as noted by the Soviets, is from extended weightlessness back to 1G. Here the increase in the force of gravity will be endured with far greater difficulty than at the beginning of the flight, because the prolonged absence of weight may cause a weakening in the appropriate mechanisms of blood circulatory control and other physiological processes.

REACTIONS, FUNCTIONS, AND RESPONSES OF TITOV (VOSTOK II)

According to Soviet scientists, the data from Titov's flight are being processed. However, their preliminary reports indicate that during the entire orbital flight the cosmonaut retained a sufficient level of working capacity. He oriented the spaceship manually and carried out a number of other maneuvers necessary for scientific measurements. At the beginning of the second orbit, Titov took pictures with a motion picture camera, and reportedly the results of the filming in orbit are of definite scientific interest.

No pathological indexes were observed in Titov's main physiological functions although discussions of U.S. experts with Professor Peter K. Anokhin, Director of the Sechenov Institute of Neurophysiology, Moscow, indicated that the Soviets had recorded the electroencephalogram of Titov during his alleged sleep and that the brain-wave recordings were very interesting and unusual and had occasioned much discussion. Apparently the erratic signal bursts evident in measurements recorded disclosed to the Soviets that Titov had slept only fitfully and was very restless. Corroborative evidence that electroencephalographic records were taken on Gagarin and Titov during their orbital flights came from discussions with other Soviet scientists.

Other Soviet scientists publicly reported some pronounced changes in the function of Titov's "vestibular apparatus" (inner ear) during the flight period. Although the loss of balance caused by this change apparently had no effect on his ability to carry out the assigned work schedule aboard Vostok II, Soviet scientists believe that subsequent experiments will be necessary to determine whether the vestibular disturbance under conditions of weightlessness is peculiar to Titov or if it will be common among all space travellers. Subsequent elicitation from Soviet scientists attending international conferences and governmental meetings indicate that the Soviet scientists involved in the bioastronautics program are concerned about the disturbance of Titov and are interested in training techniques which could help compensate for the physical reactions in flight or in the development of flight maneuver techniques which would reduce the physiological reaction. Before the I.A.F. meeting in Washington, D. C. (October 1961) Professor V. I. Yazdovsky, Soviet space medicine expert, stated that "what values of artificial gravity (if necessary) should be recommended are problems requiring further experimental solution."

According to the statements of Titov and other available data, the transition from the condition of weightlessness to re-entry overloads and recovery by parachute, separately from the spacecraft, was smooth and did not lead to any kind of unpleasant consequences or functional disturbances.

PSYCHOPOLITICAL IMPLICATIONS OF SOVIET BIOMEDICAL EXPERIMENTS IN SPACE

Impact of Manned Space Flight

The Soviets are keenly aware of the psychological impact which successes in their man-in-space program have on all peoples of the world. They have anticipated some ideological-philosophical possibilities of their program and will undoubtedly continue to exploit further successes in order to secure the maximum psychopolitical benefit.

A 1958 publication, representing the composite and interdisciplinary opinions of Soviet scientists, implies Soviet awareness and anticipation of future social impacts resulting from each new step in the manned spaceflight program.[121] They consider this present social period as the beginning of the era of Cosmic Man. They concede that this transformation will have little effect on man's normal life for the next few years but consider the prospects unlimited.

Significantly, the Soviets refer to "tactical" achievements rapidly becoming part and parcel of life and that these developments bring much that is useful but do not change the nature of man's social existence. In contrast, the Soviets consider "strategic" achievements as not affecting the individual directly. These "strategic" achievements of a scientific nature—such as cosmic flights and nuclear and thermonuclear energy—make themselves felt slowly, they contend, but then they radically change all the relations and attitudes of human society and its environments. These attitude changes mean that technological advances, evolution of man in space, and policies encouraging the growth of science must be viewed or anticipated in terms of their effect both on direct military power and on the struggle for world leadership in political, psychological, and cultural terms. Should the West or the Soviets achieve success with a man-in-space program to a degree that the scientific and technological achievement is applied to the development of manned space vehicles with a weapon delivery capability or other military uses, then new attitudes may develop from a world-wide realization of common vulnerabilities to space hazards and threats.

Soviet Views Regarding Man's Exploitation of Outer Space

As man becomes increasingly involved in space travel, the legal aspects of such missions become increasingly complex for all involved nations. Thus far, the Soviet Government has shown little disposition to collaborate on specific plans for alleviating the legal problems attendant upon such space explorations.

The problems of space law were widely discussed in the Soviet Association of International Law at its sessions in 1958 and 1959. In the Academy of Sciences, USSR, a group of lawyers under the chairmanship of Professor Ye. A. Korovin of the Legal Science Institute has been formed to study the legal problems of space activity. On several occasions, the Soviet newspaper, *Sovetskaya Rossiya*, which is published primarily for the guidance of Party and Government officials within the RSFSR, has published major articles suggesting the establishment of a new Party position on this important facet of space sciences.

Professor Doctor G. P. Zodorozhniy, Soviet international law specialist, delivered a lecture on "Legal Problems of Outer Space" on 9 November 1960 at Stuttgart, Germany. The Soviet legal expert's views on outer space, presented to a body of scientists and professors within a non-Bloc area, are extremely important because of his current position at the Legal Science Institute of the Academy of Sciences. His discussion centered around problems of outer space and emphasized Soviet ability to alter positions in reference to legal aspects, such as regulation of space station orbits and functions; exploitation of extraterrestrial resources; occupation, ownership and use of the moon or other planets, and political aspects, such as linking of the neutralization of outer space with the elimination of U.S. overseas bases and total atomic disarmament. He pointed out that the USSR takes the position that individual states should be granted sovereign rights on the matter of their extraterrestrial installations, spaceships and satellites, unless international agreements are concluded in each individual case. However, the USSR agrees that it is still too early to establish a general applicable code for such matters. He reminded the group that the USSR does not recognize the International Court established by the United Nations, adding that the United States described its recognition of the Court as voluntary. In answer to a question which postulated an analogy between the neutralization of the Antarctic and control of outer space, he stated that the Antarctic is a continent; whereas outer space is an unimaginably larger and non-homogeneous entity, which gives rise to much greater problems. The USSR, he continued, favors banning the use of outer space for military purposes.

It should be noted that the "Soviet man" first on site could be a force for military purposes as well as for peaceful possession. Soviet foreign policy is reflected in Khrushchev's statement at the National Press Club in Washington on 16 September 1959, "We regard our sending a rocket into space and putting our flag on the moon as our victory." To the world listening, Khrushchev then qualified "our" as belonging to all nations of the world.[123-127]

The legal Sciences Institute of the Department of Economics, Philosophical and Legal Sciences, Academy of Sciences, USSR, may be the decisive policy organization for determining the legal objectives of Soviet exploitation of space as well as the extent of their participation in the United Nations General Assembly, the International Committee on Space Research (COSPAR), and the International Academy of Astronautics.

Soviet Propaganda Drive

Yuriy Gagarin's successful spaceflight on 12 April 1961 touched off a Soviet propaganda orgy unprecedented in its volume and extravagance. For 4 days, more than 90 percent of the monitored Soviet radio broadcasts were devoted to the event, covering such themes as "Soviet superiority; Gagarin, the hero; worldwide acclaim; peace and power" and other Bloc reactions. For the world population a unique propaganda souvenir is available—a phonograph record of "Yuriy Gagarin in Space." The record begins with a report on the landing of the rocket. The voice of the first astronaut is accompanied by a commentary in English, French, German, Chinese, Spanish, and Arabic.[128 129]

SOVIET BLOC SUPPORT TO BIOASTRONAUTICS RESEARCH

There are recent indications that Czechoslovakia and Poland plan to increase their capabilities for supportive space research. In 1961 these two countries were accepted as active members of the International Committee for Space Research (COSPAR). Furthermore, in early 1960, Czechoslovakia, having been accepted as a member of the International Federation for the Study of Outer Space of the United Nations Organization, in New York, agreed to intensify and improve the quality of research for the spaceflight fields. At the present time Doctor Rudolf Pesek is a member of the preparatory committee of the newly founded International Astronautical Academy.[130-137]

The limited and generalized program disclosed by the Bloc areas appears to negate the need of their launching any satellites or high altitude rockets but to direct supportive research toward physiological, psychological, hygienic, and technical problems of manned spaceflight. Of particular significance to Bloc coordination are Czech proposals to study oxygen systems, utilizing biological (algae) and chemical (lithium) methods. Such Bloc research would support the Soviet emphasis on studies related to the development of "superoxide" systems for extended flight missions.

Other than minimum service support from other European Satellites and Communist China, the Soviet spaceflight research effort may benefit to some extent from the overall coordination of the Sino-Soviet Bloc scientific and technical effort achieved through agreements concluded between the Soviet Academy of Sciences and the national academies of the Bloc countries and through the organization of special scientific-technical cooperation commissions. A 5-year agreement on scientific cooperation was signed in Moscow on 21 June 1961 by representatives of the Academy of Sciences, USSR, and the Chinese People's Republic. The agreement makes provision for the further expansion of joint research in the main spheres of knowledge.[138]

APPENDIX A

MAJOR SOVIET PERSONALITIES DOING RESEARCH APPLICABLE TO BIOASTRONAUTICS

ANOKHIN, Peter K. -- Prof. Dr. Neurophysiology. Director of Sechenov Institute of Neurophysiology, Moscow. Research on processes of physiological monitoring of cosmonauts in training and orbital flight as well as development of telemetering equipment for transmission of electroencephalograms by radio; interest in studies involving the problem of halluciations and disorders of psychic function arising in the state of weightlessness. Leading representative at International Conferences.

ARSENIEVA, M. G. -- Located at the Institute of Biological Physics, Academy of Sciences, USSR, Moscow. Fields of interest -- Cytological studies on recovered mice (Sputnik V); other environmental flight factors (i.e. vibration).

ASRATYAN, E. A. -- Alternate Member of Academy of Sciences, Director of Institute of Higher Nervous Activities and Neurophysiology. Fields of interest -- Remote control (physiological); biotelemetry (radiotelemetering); physiology and cosmic acceleration; knowledge of first manned flight (Y. Gagarin).

AYRAPET'YANTS, E. Sh. -- Candidate of Biological Sciences. Physiology. Head, Laboratory of Interoceptive Conditioned Reflexes, Institute of Physiology imeni I. P. Pavlov, Academy of Sciences, USSR. Research on reaction of enteric organs to hypoxia, mechanism of inner analyzers in higher nervous activity under conditions of rarefied atmosphere, and physiological principles of interoception.

BALAKHOVSKIY, I. S. -- Member, Central Scientific Research Institute of Aviation Medicine, 1956; Physiology, Biochemistry. Biological problems of interplanetary flight, mechanism of production and physical and chemical characteristics of gas from blisters in emphysema of high altitudes, chemical analysis, and photometric determination of oxygen saturation of blood.

BARANOVSKIY, Valentin V. -- Associated with the Central Scientific Research Institute of Aviation Medicine, Moscow -- a physiological optics specialist who has made studies of the absolute distance of objects; research possibly related to space perception, spatial orientation and distortion, i.e. factors affecting man in space.

BORISENKO, I. G. -- Sports commissioner of Chkalov Central Aeronautical Club of USSR. Particularly important as a possible "policy-maker" for training of cosmonauts. Congratulated Y. Gagarin on recovery site. Officially recorded, on the spot where VOSTOK I landed, -- the three world records (weight, altitude, and time) for orbital space flight.

BRESTKIN, Mikhail Pavlovich -- Major. Physiology. Head, Department of Military Labor (Chief, Barolaboratory), Military Medical Academy imeni S. M. Kirov (1955). Awards: Stalin Prize Second Class. Specialty: Aviation Medicine. Studies: Role of oxygen in high altitude flights and low pressure chamber experiments.

CHERNIGOVSKIY, Vladimir N. -- Prof. Dr., Physiology. Research on vital activities of animals during rocket flights to high altitudes. Chernigovskiy did original work with test dogs (conditioning and pre-conditioning) at the Laboratory of Physiology of Receptors, Institute of Physiology imeni I. F. Pavlov, Leningrad and is presently director of that Institute. He is also interested in the athermal effects of radio frequency exposures.

DEDYULIN, I. M. -- Physiology. Department of General Physiology and Department of Biochemistry, Institute of Experimental Medicine, Academy of Medical Sciences, USSR. Specialty is high-altitude physiology. Research on effect of low temperature on circulatory system and metabolism at high altitudes.

DEMENT'EV, Petr V. -- Chairman of the State Committee on Aviation Engineering of the Council of Ministers of the USSR, since its establishment in 1957. Aviation Engineer; graduate of Zhukovskii Air Engineering Academy in 1931. Born in 1907.

DORODNITSIN, Anatole A. -- Head of Computer Center, Moscow. Possible optimum command and control systems for life support of man-in-space vehicles.

DRUZHININ, G. V. -- Cybernetics. Position unknown. Studies: Relationship of redundancy efficiency to performance time of the system implies associated electronics for capsule attitude control; manned recovery; communications; systems reliability; subjective probability in decision theories.

EL'PINER, I. Ye. -- Doctor of Biological Science. Chief of the Laboratory of Ultrasound or the Ultrasonics Group, Institute of Biological Physics (1958), Academy of Sciences, Moscow; Acoustics Commission of the Academy of Sciences, USSR. Specialty: Physiological Acoustics. One of the foremost Soviet authorities in the application of ultrasonics to medical research. Studies: Biological action of ultrasonic waves. Oxidation and reduction of biological substances under the action of ultrasonic waves.

FRANK, G. M. -- Doctor of Medical Sciences. Director of Institute of Biological Physics (1958), Academy of Sciences, Moscow. In charge of subordinate Laboratory of Living Structure and Deputy Chief Editor of the journal Biophysics. Considered by Western authorities to be one of the outstanding Soviet biophysicists. Studies: Molecular structure of oriented proteins in tissues, changes in the mechanical properties of a nerve during its stimulation, and phosphorous metabolism in bones. Born 1904.

GAVRILOV, M. A. -- Cybernetics (1958). Possibly located at the Remote Control Institute of the Institute of Automation and Telemechanics. Studies: Principal problems of the theory of telemechanical devices; communication between remote control devices and a human monitor; theories for operating capabilities of complex devices, reliability requirements, optimal design and analysis.

GAZENKO, Oleg G. -- Lt. Col., Candidate of Biological Sciences; Member, Barothermic Lab., Chair Physiology, Military Medical Acad. imeni S. M. Kirov. Space Medicine and Bioastronautics. Understudy of Dr. V. I. Yazdovskiy, space medicine expert. Research on the effects of lowered partial oxygen pressure on higher nervous activity, physiological analysis of fatigue, physiological reactions to space flight conditions.

GERSHUNI, Girgory Viktorovich -- Professor-Doctor. Head, Laboratory of Physiology of the Auditory Analyzer, Institute of Physiology imeni I. P. Pavlov, Academy of Sciences, USSR. Specialty is physiology of sense organs. Research on quantitative investigations of the range of action of imperceptible sound stimulations, physiological acoustics, auditory thresholds, and biomechanical analogies (cybernetics).

IMSHENETSKIY, A. A. -- Director of Institute of Microbiology, Academy of Sciences, USSR, Moscow (sterilization of space probes).

ISAKOV, Petr Kuz'mich -- Col. Candidate of Biological Sciences: Member, Soviet Air Force Institute of Aviation Medicine 1956-57 (Laboratory Headquarters 1957,) Member, Science Technical Commission and Chairman, Cosmic Biology Commission, Astronautics Section, DOSAAF, 1957. Since 1956, he has been identified as the person responsible for research on designing anti-g equipment at the Soviet Air Force Scientific Research on Testing Institute of Aviation Medicine. Research on possible use of Chlorella for provision of oxygen during space flight, effect of cosmic radiation on animals, effects of acceleration and gravity on man, safe space flight clothing, ejection seats, behavior of animals launched in rockets, problems of living in outer space, and problems of returning satellite crews from the cosmos.

KALABUKHOV, N. I. -- Institute of Microbiology and Epidemiology, Saratov, USSR. Field of Interest--outstanding Soviet expert in hibernation (comparative ecology of hibernating animals;) hypothermia.

KANAVETS, O. L. -- Physiology, Biophysics. Laboratory of Photobiology, Institute Biological Physics, Academy of Sciences, USSR. Specialty: Physiological Optics. Studies: Investigation of depth perception under varying light conditions and adjustment of blinking source of light at certain brilliances of background, increasing depth perception.

KELDYSH, Mstislav V. -- Newly elected President of the Academy of Sciences, USSR (19 May 1961). Born 1911. Applied mathematician and expert in aerodynamics and rocket development. Prior to election to Academy's presidency was director and leader of research of "several research institutes conducting work in mathematics and mechanics and charged with the solution of major scientific and engineering development problems in the area of special technology"; this refers to the group of research and development centers for missiles and space vehicles managed mainly by the State Committee on Aviation Engineering, Ministry of Medium Machine Building (weapons development), and Ministry of Defense.

KOBRINSKIY, A. -- Possibly the Central Research Institute for Prosthetics, Moscow. Heads interdisciplinary team (doctors, electrophysiologists, engineers) which develops devices with a bioelectrical control system.

KRISS, A. Ye. -- Head of the Laboratory of Electron Microscopy, Biological Science Division, Academy of Sciences, USSR, Moscow, (space probe sterilization).

KUKH, Erich -- Geobotanical and Plant Taxonomy Chair, Tartu State University, Tartu, Estonskaya SSR (oxygen mediums for space vehicles).

KUZIN, Aleksandr Mikhaylovich -- Doctor of Biological Sciences. Biochemistry. Director of Institute of Biological Physics, Academy of Sciences, USSR. Specialty is biophysics. Research on (1) harmful effects of radiation, (2) metabolism, and (3) nutrition.

KUZNETSOV, A. G. -- Candidate of Medical Sciences. Head, Physiology Department, Soviet Air Force Scientific Research Testing Intitute of Aviation Medicine (1957). Production of oxygen-respiration instruments and altitude-compensating clothing, study of vapor formation phenomena in organisms at high altitude.

LIVSHITS, N.N. -- Candidate of Biological Sciences, Biophysics. Senior Scientific Associate, Institute of Biological Physics, Academy of Sciences, USSR (1957). Awards: Medal for Labor Valor (1954). Studies: Laws of binocular color mixture; theoretical research on UHF magnetic fields.

MAYSKIY, Ivan -- Director of Institute of Experimental Biology, Academy of Medical Sciences. Fields of interest -- Effects of space factors on biological substances; extreme limits of survival of living cells in outer space.

MENITSKIY, D. N. -- Professor. Physiology. Institute of Experimental Medicine, Academy of Medical Sciences, Leningrad. Specialty is electrophysiology. Research on (1) cybernetics in biology and medicine, and (2) methodology of simultaneous recording of respiratory movements and bioelectric processes.

NIUBERG, N. T. -- Director of the Laboratory of Biophysics of Vision, Institute of Biological Physics -- electrophysiological and psychophysical methods in studies of the eye mechanisms. Also interested in applications of information theory to problems of vision (space navigation); photosynthesis; biochemical actions and psychology.

PARIN, V.V. -- Director of Institute of Normal and Pathological Physiology imeni I. P. Pavlov, Moscow. Observed Y. Gagarin after his return to earth.

PLATONOV, K. K. -- Author of "Psychology of Flying", published by the Military Publishing House of the USSR Ministry of Defense, Moscow (1960). Fields of interest -- Psychological singularities of space flight;) aviation psychology;) pilot and possibly "cosmonaut" selection.

POKROVSKIY, Aleksey Vasil'yevich -- Col. Doctor of Medical Sciences. Associated with Soviet Air Force Institute of Aviation Medicine (1957); Member of USSR National Committee IGY (1957). Earth satellite research, study of vital activities of animals during vertical rocket flights, influence of ultraviolet and cosmic rays on living organisms and ways of eliminating it, effect on animals (weightlessness), high acceleration, and heavy radiation. Born 1903.

PROKHOROV, A. I. -- Member of the Presidium of the Scientific Council of Cybernetics of the Academy of Sciences, USSR. Fields of interest -- Self-adaptive systems (cybernetical tools); optimum control systems (including life support).

SERYAPIN, Aleksandr Dmitriyevich -- Doctor of Medical Sciences, Chairman, Scientific Technical Committee on Biology of Cosmic Flight, Astronautics Section (space satellite research, space physiology).

SHPIL'BERG, P.I. -- Doctor of Medical Science. Physiology, Laboratory of Electrophysiology, Institute of Psychiatry, Academy of Medical Sciences, USSR. Research on the biophysics of escape and electroencephalographic investigations of man under normal and abnormal conditions.

SIROTININ, N. N. -- Reportedly Director of Institute of Physiology imeni A. A. Bogomolets, Kiev. Directed space medicine research such as: Studies on plants and organisms suitable for use in providing a closed ecological system for space vehicles; acceleration studies, hypoxia; protection against cosmic rays; nutritional problems of prolonged space flight.

SISAKYAN, N. M. -- Academician and prominent Soviet biologist, Academy of Sciences, USSR, Moscow. Fields of interest -- Biological problems of space flights; environments of hermetically sealed cabins (pressure, temperature and gas composition of Sputnik XI).

SLONIM, A.D. -- Institute of Physiology imeni I. P. Pavlov, Leningrad USSR. Field of interest -- physiological thermoregulation which has speculative possibilities for space flight, extended submarine voyages or as a possible solution to survival of radiation.

SOBOLEV, S. L. -- Cybernetics (1958). Location unknown. Studies: The theory of information, basically a statistical theory of processing and transmitting information; the theory of automatic electronic computing machines as a theory of self-organizing logical processes similar to the processes of human thinking; and the theory of systems of automatic control, mainly the theory of feedback which includes a functional study of the working processes of the nervous system, sensory organs and other organs of living organism.

SOKOLOV, Y.N. -- Prof. Dr., Psychology, Physiology. 41 years of age. Member, Moscow State University imeni M. V. Lomonosov. Research in electroencephalography and transmission of cosmounat's brain-wave measurements over longdistances. Had much to do with analysis of such recordings made on Gagarin and Titov. Studies on interaction between parts of visual analyzer and galvanic skin reaction in man in response to indifferent and conditioned stimuli.

TERSKAYA, N. -- Director of Laboratory of Biophysics, Krasnoyarskiy Institute of Physics. Fields of interest -- Control of biological processes; cybernetics and Chlorella; closed respiratory systems for spaceships.

TIMAKOV, V. D. -- Vice President of Academy of Medical Sciences. Fields of interest -- Origin of life; biodetector (bacterial and viral profiles at high altitude) used on Sputnik V.

TROSHIN, A. S. -- Dr. Biological Sciences. Corresponding Member of the Academy of Sciences. Director of the Institute of Cytology, Academy of Science, USSR, Leningrad. Responsible for setting up the Laboratory of Cosmic Biology within this Institute. Research on behavior and adaption (or adjustment) of organic cells in various environmental conditions (extreme high and low temperatures; radiation).

TRAPEZNIKOV, V.A. -- Chairman of the National Committee of the Soviet Union on Automatic Control and Director of the Institute of Automation and Telemechanics. Fields of interest -- Optimum control systems (including life support); biodetector (form and color of environmental contaminants and known or unknown organisms).

YARBUS, A. L. -- Physiology. Institute of Biological Physics. Academy of Sciences, USSR. Specialty is physiological optics. Research on fixation points of visual apparatus and spatial perception.

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YAZDOVSKIY, Vladimir Ivanovich -- Prof. Dr., Col. SAF Medical Service (1961); Head of Cosmic Physiology Course, Moscow State University imeni M. V. Lomonosov; associated directly with the Academy of Sciences, USSR, Moscow and directly responsible for the physiological training of cosmonauts. Studies of interplanetary flight medicine; study of vital activities of animals during rocket flights 1951-1958; telemetric studies of animals and men 1957-1961; studies on weightlessness and other parameters of manned space flight. Probably responsible for complete life support system used during Titov's flight. Seems to be the organizing and managing type in the Soviet space program, and to be an energetic, authoritative, and capable organizer.

YUROV, Sergey G. -- Candidate of Technical Sciences. Electrical Engineering. Director, All-Union Illumination Engineering Institute (Moscow ISI) (1955). Specialty: Optical Instrumentation. Studies: Variations of the spectral sensitivity of the eye under great intensities, spectral sensitivity of the eye at a given level of brightness, effect of temperature on the spectral transmission of colored glass, variations in the spectral sensitivity of the eye, spectral sensitivity of conditions of adaptation; and equivalence of photometric dimensions.

ZHIKAREV, S. S. -- Medical Sciences. Institute of Experimental Medicine. Specialty is bioclimatology. Research on changes in blood at various altitudes; reaction of skin to solar radiation at different altitudes.

ZVORYKIN, V. N. -- Physiology. Barothermic Laboratory, Chair of Physiology, Military Medical Academy imeni S. M. Kirov. Specialty is aviation medicine. Research on changes in higher nervous activity in rarefied areas and on anoxia and hypoxia (oxygen deprivation).

Other personalities associated with the Soviet bioastronautics program

AGADZHANYAN, N.A.
ALIFANOV, V.N.
ALTUKHEV, G.V.
ANNENSKIY, F.D.
BABKIN, B.P.
BARBASHOV, N.F.
BAYEVSKIY, R.I.
CHISTOVICH, L.A.
CHUDAKOV, A. Ye.
ENGEL'GARDT, V.
FEDEROV, Ivan, Y.
FESENKOV, V.G.
FRADKIN, M.I.
GLEKIN, G.B.
GLEZER, V.D.
GRASHCHENKOV, Nikolay
GUREVICH, B. Kh.
KAZAKOV, A.I.
KHIL'KO, V. M.
KOGOZIK, V.A.
KRIMSHTEYA, A.F.
KUBANSKIY, A.
KUCHEROV, N.I.
KURNOSOVA, Lidiya V.
LIPSKIY, Yu.N.
LOROVIN, Ye. A.
MARENINA, A.I.
MIROLYUBOY, G.P.
NIKOLAYEV, A.
OPARIN, A.I.
PELGEV, Petr I.
PETROVICH, G.V.
PODOGORETSKIY, M.I.
RUDNIY, H.
SANILEYKO, V.I.
SARYCHEV, S.
SHAPOSHNIKOV, Vladimir
SHARONOV, V.V.
SHUVATOV, L.P.
SMORODINTSEV, A.A.
STRELICHUK, I.V.
TSUKHERMAN, I.I.
VAKAR, M.
VAZIN, V.P.
VERNOV, S.R.
VORONIN, Leonid G.
YAKOVLEV, V.G.
YEFREMOV, A.I.
YUGOV, Ye.
ZHDANOV, V.M.
ZHUKOV-VEROZHNIKOV, N.N.

APPENDIX B

MAJOR ORGANIZATIONAL UNITS DOING RESEARCH APPLICABLE TO BIOASTRONAUTICS

Acoustics Institute, Academy of Sciences, USSR.

Astrobiological Institute, Department of Astrobotany, Academy of Sciences, Kazakh SSR, Alma-Ata. Prof. Gavriil A. Tikhov, Director (1958). [redacted] This institute was directed by the Academy of Sciences to exploit its full resources to studies of the biology of Sputniks and space flight and to studies of how to set up laboratories that will support human beings in Sputniks. [redacted]

Astronomical Council of Academy of Sciences, USSR.

Central Aero Hydrodynamic Institute, imeni N. Ye. Zhukovskiy (Tsentral'nyy Aerogidrodinamicheskiy Institut (TsAGI) Zhukovskiy Air Field (formerly Ztakhanova, 60 kilometers south of Moscow and 15 kilometers north of Ramenskoye). Director unknown. This institute is working on decelerator studies, flight clothing, oxygen equipment, and other problems involved in high-altitude flights. May be connected with "LII" (Flight Research Institute).

Central Institute for The Advanced Training of Physicians (Tsentral'nyy Institut Usovershenstvoyaniya Vrachey), Ploshchad'Vosstaniya 16 1/2, Moscow. This central institute is the headquarters of a system of postgraduate medical institutes located throughout the country. Established primarily as a training organization, the institute, nevertheless, conducts a considerable amount of research. Some of the recent research includes visual perception studies, anoxia, physical stress, and respiratory functions under varying climatic conditions.

Central Psychophysiological Laboratory for the Study of Flight Work, Moscow.

Central Research Institute for Prosthetics, Moscow.

Central Scientific Research Institute of Aviation Medicine (Tsentral'nyy Nauchno-Issledovatel'sky Institut Aviatsionnoy Meditsiny (TsNIIAM), Petrovskiy Park, Moscow. S. I. Zubbotin, Director. The most modern aeromedical research equipment probably located here. An underground pressure chamber and a human centrifuge have been reported at this facility which was established by directive in 1946-1947. This establishment is also believed to be the newest and most important center for aeromedical research in the Soviet Union. It has an estimated staff of 80 doctors, 12 aviation engineers, and 5 test pilots. Research has been done on pressure suits, designing of laboratory and other aeromedical equipment, acceleration, high-speed flight, cabin pressurization, G-suits, and pilot fatigue. This institute is believed to be similar in function to the Aeromedical Laboratory at Wright Field.

Central Scientific Research Institute of The Air Force Hospital (TsNIAG), Moscow. Director unknown. This institute is mentioned frequently as an important research center. It has a large staff which has been doing research on flight personnel. The type of research done by this institute would be comparable with that of the School of Aviation Medicine, Randolph Field.

Computer Center (directed by Anatole A. Dorodnitsin), Academy of Sciences, USSR, Moscow.

Cosmonaut Training Centers (probable)

Krasnovodak, on southeast shore of Caspian Sea.

Bratsk, north of Lake Baikal on Angara River.

Unidentified, northwest of Chelkar near the Emba River.

Unidentified, near Kzyl-Orda, east of Aral Sea.

Unidentified, north of Tashkent, near Alma-Ata.

Department of Biological Sciences, Academy of Sciences, USSR, Moscow.

Flying Research Institute (LII), Ramenskoye, southeast of Moscow. Director unknown. This center, under the Ministry of Aircraft Industry, which is located next to the Central Aero Hydrodynamic Institute (TsAGI), is equipped with a linear decelerator and an ejection seat tower. The decelerator is somewhat comparable with that used by the USAF at Holloman Air Force Base. It can be used to determine specifications in designing ejection capsules, aircraft seats, restraining devices, and to establish human endurance limits for deceleration, wind blast, tumbling, and parachute opening shock incurred simultaneously during escape from very high-speed aircraft at high altitudes. The ejection seat tower was designed by Meinkel in Germany and moved to Ramenskoye. This center probably is engaged in research similar to that done at the Aeromedical Laboratory and at Holloman Air Force Base.

Institute of Astrophysics, Alma-Ata.

Institute of Biological Physics, (Institut Biologicheskoy Fiziki), Academy of Sciences, 33 Bol'shaya Kuluzhskaya Ul., Moscow. Professor Doctor G. M. Frank was director in 1958. This important facility was organized in 1953 under the Department of Biological Science, Academy Sciences. [redacted] Coordinates the biophysical research of other institutes and laboratories of the various academies in pursuing the following problems: in vivo studies of nerve and tissue changes; effects of high-frequency, electromagnetic, and other radiations on the human organism; studies of physiological, optical, and acoustical effects of light and sound irritants; studies of biological action of ultrosonic waves; correlative studies on the optic and acoustic analyzers; structural and physical-chemical basis of living processes; polarigraphic studies; and spectroscopic and infra-red studies.

Institute of Biophysics, Academy of Medical Sciences, USSR (Institut Biofiziki) Moscow. A. V. Lebedenskiy, Director. Organized by P. P. Lazarev in 1919 until 1952, specific research of a biophysical nature was concentrated in this institute. In 1952, other strategic biophysical research was assigned to the newly organized Institute of Biological Physics, and other scientific institutes of both Academies in the USSR.

Institute of Evolutionary Physiology imeni I. M. Sechenov, Academy of Sciences, USSR, Leningrad.

Institute of Experimental Biology, Academy of Medical Sciences, Moscow. Director unknown. Soviet published material indicates this institute is especially active in the study of human biological rhythms. This work could deal with cancer biology. However, it also has application for determining proper schedules for day-night cycles and in the preparation of man for space flight. A subordinate laboratory of this institute, Laboratory of Chemical Immunology, reports production and testing of a number of drugs (sedatives; circulatory stimulators; preparations affecting lung and skin respiration) for humans traveling in space.

Institute of Experimental Medicine, (Institut Eksperimental'noy Meditsiny) Academy of Medical Sciences, Moscow, Leningrad. Academician D. A. Biryukov, Director. Most of the basic research of this Institute is done in Leningrad, but the administrative office is located in Moscow. Some significant research is concerned with high-altitude studies. Other studies embrace individual variabilities in relation to external environment, a strategically important problem. A group headed by G. Ye. Vladimirov, who is also associated with the Military Medical Academy imeni Kirov, has been engaged in high-altitude studies since 1948. This important group has published on brain reactions to oxygen deficiencies and cortical-chemoreceptor investigations.

Institute of Experimental Pathology and Therapy, Academy of Medical Sciences USSR, Sukhumi. Utkin (fnu), Director in 1958. This institute was formerly the Sukhumi Medical and Biological Station, which was organized in 1927. The institute with fully equipped laboratories, currently conducts extensive experimental animal work comparable with research on human beings such as latent anthropology, behavior dominance, natural occuring diseases, higher nervous activity, conditioning, neuroses, hypertension, and effects of day-night cycles. For the experimental work the institute has 1,000 monkeys, baboons, and crosses between various species of animals, chelata, apes and some beasts never seen before. Sixty percent of these animals are born in captivity.

Institute of Higher Nervous Activity and Neurophysiology, Academy of Sciences, USSR, Moscow.

Institute of Labor Hygiene and Occupational Diseases (Institut Gigiyeny Truda i Professional'nykh Zabolevaniy), Academy of Medical Sciences, Moscow. Professor A. A. Letavet, Director. The predecessor All-Union institute by this name dates back to 1924; its title as a Central Institute dates from 1933, and its present title from at least 1946. The major research of this institute is devoted to basic toxicological studies, which entails experimental research on the toxicity of new chemical substances appearing for the first time in industry; the mechanism of the effect of chemical substances and the means of rendering them harmless to the organism; and on the oxygenating-restoration processes in the occupational intoxications, with special heed paid to enzyme systems as a direct point for affixing the effect of the poisons. Corollary projects included an elaboration of the physiology of muscular activity, microrhythm of workers in high temperatures, water loss in man during rest at different air temperatures, and correlation of morbidity and working ability. Furthermore, specific techniques were formulated for personnel using ultrahigh frequency impulse oscillators and other hazardous equipment.

Institute of Microbiology, Academy of Sciences, USSR, Moscow. Sterilization of space probes.

Institute of Normal and Pathological Physiology imeni I. P. Pavlov, Moscow.

Institute of Phychology, Leningradskoe Shosse, Moscow.

Institute of Physical Problems, Academy of Sciences, USSR, Moscow.

Institute of Physiology imeni A. A. Bogomolets (Institut Fiziologii imeni A. A. Bogomol'tsa), Ukrainian Academy of Sciences, Kiev. Prof. N. N. Sirotinin reportedly director in 1958. In April 1953, the Institute of Clinical Physiology and the Institute of Experimental Biology and

Pathology combined to form this new institute. The major fields of research interest are physiology and correlative problems in psychiatry and high-altitude studies. Recent information indicates directed space medicine research such as studies on plants and organism suitable for use in providing a closed ecological system for a space ship; acceleration; hypoxia; protection against cosmic rays; and nutritional problems of prolonged space flight.

Institute of Physiology imeni I. P. Pavlov (Institut Fiziologii imeni I. P. Pavlova), Academy of Sciences, Pavlova (suburb of Leningrad). Academician Konstantin Mikhaylovich Bykov, former director. Deceased 1958. One of the major Soviet centers for research in neurophysiology, enzymology, and hematological research. Considerable neurophysiological work has been done on electroencephalography, on the evolution of brain activity, hypnosis, and on interoceptive and exteroceptive conditioning, which is a unique line of investigation for man-space vehicle systems. These experiments have also produced the functional characteristics of localized and general interoceptive reflexes, the gradients of interoception in the gastrointestional tract, the afferent impulses in interoceptor effects upon the skeletal muscles, the effects of carbon dioxide and oxygen inspiration upon interoceptive reflexes, and interoception in the bone marrow. The biophysical work of this institute on reaction of tissues to the local effect of microwaves is significant to bioastronautical activities.

Institute for The Protection of Labor, (Institut Okhrany Truda), Leningrad. Director unknown. This institute, under the jurisdiction of the All-Union Central Council of Trade Unions, has laboratories equipped with the latest apparatus, including atmospheric and soundproof chambers and light engineering and noise abatement equipment. The staff, which includes biologists, chemists, physicists, and engineers, has developed numerous instruments and appliances for measuring noise, light intensities, and toxic concentration of gases and vapors. Such instrumentation is applicable to research on manned space-flight.

Institute of Radiation and Physical-Chemical Biology (directed by V. Engel'gardt), Academy of Sciences, USSR, Moscow.

Institute of Virology imeni Ivanovskiy, Academy of Medical Sciences, Moscow.

Interagency Commission for Interplanetary Communications, Moscow.

Laboratory of Biophysics (Krasnoyarskiy Institute of Physics), Krasnoyarsk.

Laboratory of Chemical Immunology, Academy of Medical Sciences, Moscow.

Laboratory of Electron Microscopy, Academy of Sciences, USSR, Moscow, Microbiological testing and control procedures related to payload sterilization.

Laboratory of Physiological Chemistry (Laboratoriya Fiziologicheskoy Khimii), Academy of Sciences, Moscow. Director unknown. There is a paucity of material published by this installation; research is apparently concentrated on theoretical aspects of fatigue.

Laboratory of Pressure Chamber Studies, Central Clinical Hospital, Civil Aviation Fleet, Moscow.

Legal Sciences Institute, Academy of Sciences, USSR, Moscow.

Leningrad Sanitary Hygiene Medical Institute (Leningradskiy Sanitarnogigiyenicheskiy Meditsinskiy Institut), Leningrad. Director unknown. Founded in 1908 as the Second Leningrad Medical Institute, this facility took its present name in 1947. The more significant research involves the biophysical effects of vibrations on the human organisms and the electromyographic investigation of muscles and nerves.

Medical Radiology Institute, Moscow.

Military Medical Academy imeni S. M. Kirov (Voyenno-Meditsinkaya-Akademiya imeni S. M. Kirova). Chief Medical Administration of the Armed Forces of the USSR (Glavnoye Voyenno Meditsinskoye Upravleniye Vooruzhennykh Sil SSR) Klinicheskaya Ul., Leningrad. Brigadier General Professor P. P. Goncharov, director in 1954. This school is considered by the Soviets to be the highest rated medical institution in the USSR because of its relative standing, tradition, and prestige. It is primarily a training institution, but important research is conducted by its numerous outstanding faculty members. Equipment includes refrigerated research chambers simulating artic conditions in which frostbite and other cold phenomena are studied, pressure chambers for simulating high-altitude conditions, one of the world's best medical libraries, and an excellent anatomical museum. Most of the basic research in physiology has been devoted to the mechanisms of the central nervous system. The applied research includes studies on the changes in blood circulation encountered when the human body is subjected to varying "G" stresses, the physiology of anoxia and hypoxia at high altitudes, the effects of high and low environmental temperatures, the respiratory apparatus and physiological optics.

Military Research Institute of Aviation Psychology, Moscow.

Moscow State University imeni M. V. Lomonosov.

National Committee of the Soviet Union on Automatic Control.

P. F. Lesgaft Institute of Natural Science, under the Academy of Pedagogical Sciences, Leningrad. The late L. A. Orbeli, former member of this institute, commented in 1956 before a high-level conference, on the possibility of reorganization of this institute into an Institute of Cosmic Biology.

SECRET

Red Banner Scientific Testing Institute of Soviet Air Force. Located at Chkalovskaya Airfield, 40 kilometers northeast of Moscow. Pressure chambers, centrifuges, accouterment.

Remote Control Institute of the Institute of Automation and Telemechanics, Moscow.

Scientific Research Institute of Physical Culture and Sports, Leningrad.

Scientific Technical Committee on Biology of Cosmic Flight, Moscow.

Soviet Air Force Institute of Aviation Medicine, (NIIAM-VVS) Moscow. Directed by Col. K. Palatonov. Biophysics and human engineering; also horizontal sled work (deceleration and ejection bailouts).

Soviet Air Force Scientific Research Testing Institute of Aviation Medicine at Chkalovskaya Airfields, 40 kilometers northeast of Moscow. Director unknown. This center, probably the second most important aeromedical research center, is equipped with two pressure chambers, two human centrifuges, and an ejection seat catapult probably of German World War 11 origin. Research has been done on pressure suits, preflight oxygen breathing, flight indoctrination and anti-G suits. The work of this institute probably compares with the ASAF Proving Ground, Eglin Field.

State Astronomical Institute imeni Shternberg, Kazakhstan.

State Committee of the USSR Council of Ministers for Coordination of Scientific Research.

V. S. Kurnakov Institute of General and Inorganic Chemistry, Laboratory of Peroxide Compounds, Academy of Sciences, USSR, Moscow.

APPENDIX C

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APPENDIX D

PARAMETERS OF SPACE RADIATIONS

Primary Cosmic Radiation

This radiation consists of stripped nuclei of low atomic number from two sources--galactic and solar. Solar usually consists of 10 percent of total except during flares when it may exceed galactic.

Total Energies 139-141/

Galactic - 10^2 to 10^{12} Mev

Solar - 10 to 10^5 Mev

Dose (under non-flare conditions) 142-144/

Altitude	Dose
Sea level	1 mr/hr
2000 mi	15 mr/24 hr

Under flare conditions, the unshielded free space dose may range up to 10^4 m/hr. "Thin down" events are thought not to contribute major damage to large organs, but may be capable of producing detectable damage to such structures as the eye.

Geomagnetically Trapped Radiations (Van Allen Bands and Auroral Soft Radiation) 140-150/

The inner band lower edge is at 400-1300 km (240-780 miles) depending on longitude; upper edge is about 5000 km (3,000 miles) with peak intensity at 3,500 km (2,100 miles). Less than 1 percent of the particles in this zone are protons; these protons provide the chief contribution to radiation dose from this band. Composition is shown below.

Flux at Heart of Inner Zone

Component		Energy		Intensity
Electrons	$>$	30 Kev	$\sim$	$2 \times 10^9/cm^2$ sec steradian
Electrons	$>$	600 Kev	$\sim$	$1 \times 10^7/cm^2$ sec steradian
Protons	$>$	40 Mev (up to 700 Mev)	$\sim$	$2 \times 10^4/cm^2$ sec steradian (omnidirectional)

Flux at Heart of Outer Zone

Electrons	> 30 kev	~	$1 \times 10^{11}/cm^2$ sec steradian (omnidirectional)
Electrons	> 200 kev	≤	$1 \times 10^{8}/cm^2$ sec steradian (omnidirectional)
Protons	> 60 mev	≤	$10^{2}/cm^2$ sec steradian (omnidirectional)
Protons	< 30 mev		?

The outer band extends roughly from 12,000 (7,200 miles) to 30,000 km (18,000 miles, or as high as 50,000 km (30,000 miles) during solar flare activity. Peak intensity at 16-18,000 km. Radiation dose contributed primarily by electrons. The flux of electrons in this band may vary by factors of 10^2 to 10^3.

Dose rates are as follows:

Radiation	Surface (no shield)	~ $1g/cm^2$ shield	~ $4g/cm^2$	$10g/cm^2$	$100g/cm^2$
Inner Zone Protons	~100r/hr	10-20r/hr >	10r/hr ≥	10r/hr ~	1r/hr
Electrons	> 10^6 r/hr	? low* ~	0	---	---
Outer Zone					
Electrons	> 10^6 r/hr	50-200 r/hr**	0.1 r/hr	0	---
Protons	?	? low	0	---	---

*Chiefly from bremsstrahlung. To reduce a high (atomic number) inner liner and a low Z outer shield should be used.

**Some bremsstrahlung will occur here also.

Total Integrated Dose with Various Shields*

Shield	Dose
$10 g/cm^2$	100 rem
$16 g/cm^2$	25 rem
$30 g/cm^2$	3 rem

X-Rays

Present at all levels above atmosphere. Source is the sun. Energy ranges up to 90 kev, but most is below 10 kev.

Neutrons

Present from atmosphere up to inner Van Allen belt. Present concepts suggest neutrons resulting from decay of primary cosmics are the source of the inner belt radiation. No information on dose levels.

*No time interval stated. Includes dose from cosmics.

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APPENDIX E

PICTORIAL SUPPLEMENT

Propaganda Motion pictures on the orbital flights of Yuriy Gagarin and German Titov were released by the Soviets in November 1961. Selected photos from these films are included in this appendix.

17. Major Yuriy A. Gagarin, First Man in Space, 12 April 1961
18. Gagarin Being Fitted to Contoured Couch
19. Positioning of Some Physiological Sensors on Gagarin
20. Gagarin on Centrifuge
21. Preparation of Gagarin for Spaceflight
22. Selection of Gagarin for First Manned Orbital Flight
23. Biomedical Conference, Reportedly Following Gagarin's Orbital Flight
24. Interior View of Soviet Aircraft Used for Simulation of Weightlessness
25. Display of Squeeze Tubes and Other Space Foods
26. Unidentified Subject with Surface Electrodes for Recording Brain Waves and Other Physiological Measurements
27. Unidentified Subject in Oscillator Chair for Recording of Brain Waves, Blood Pressure, Possible Ballistocardiogram (Waist Girdle), and other Measurements not Identified
28. Unidentified Subject on Tilt Table
29. Soviet Television Reception of Gagarin in Flight
30. Major German Titov. Made First Multiorbital Spaceflight 6 and 7 August 1961
31. External Views of Vostok Space Ship
32. Sensor (Biotelemetry) Placement on Titov's Body

33. Titov Preparing for Flight
34. Titov Ready for Orbital Flight
35. Titov on Bus, Sampling Squeeze Tube Food
36. Rear View of Titov's Full Pressure Helmet
37. Soviet Television Reception of Titov in Orbital Flight
38. Post-Flight Removal of Respiratory and EKG Sensors from Titov
39. Vostok Instrument Panel, Showing Globe Reference Instrument
40. Interior of Vostok II
41. View of Cosmonaut in Vostok II
42. Interior View of Vostok II
43. Unidentified Optical Device Used in Vostok II
44. Prof. Dr. Valdimir I. Yazdovskiy, Soviet Space Medicine Expert, Apparently in Charge of all Soviet Cosmonaut Training and Life Support Activities
45. Titov Checking Out on Swing-Type Simulator
46. Titov Riding Rotation Simulator
47. Titov Orientation on Trampoline
48. Monitoring of Physiological Indices During Various Positions on Carousel
49. Disorientation Chair or Capsule
50. Vertical Accelerator
51. Titov in Isolation and Confinement Chamber Before Orbital Flight
52. Titov and Equipment Used For Conventional Parachute Recovery
53. Soviet Analogs (Biotelemetry) of Manned Space Flights

Figure 17. Major Yuriy A. Gagarin, first man in space, 12 April 1961.

Figure 18. Gagarin being fitted to contoured couch.

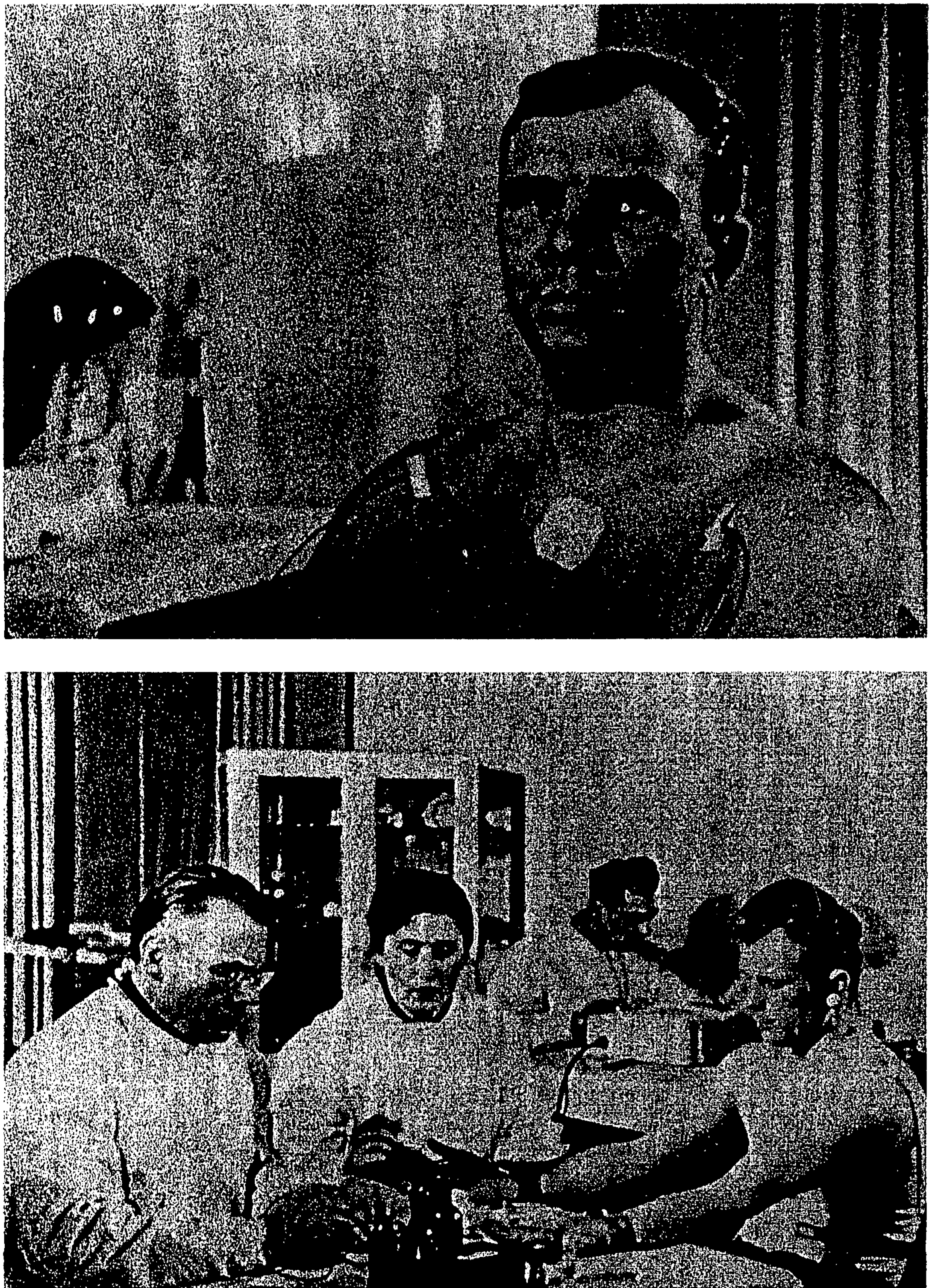

Figure 19. Positioning of some physiological sensors on Gagarin. Note abdominal binder (possible ballistocardiogram sensor).

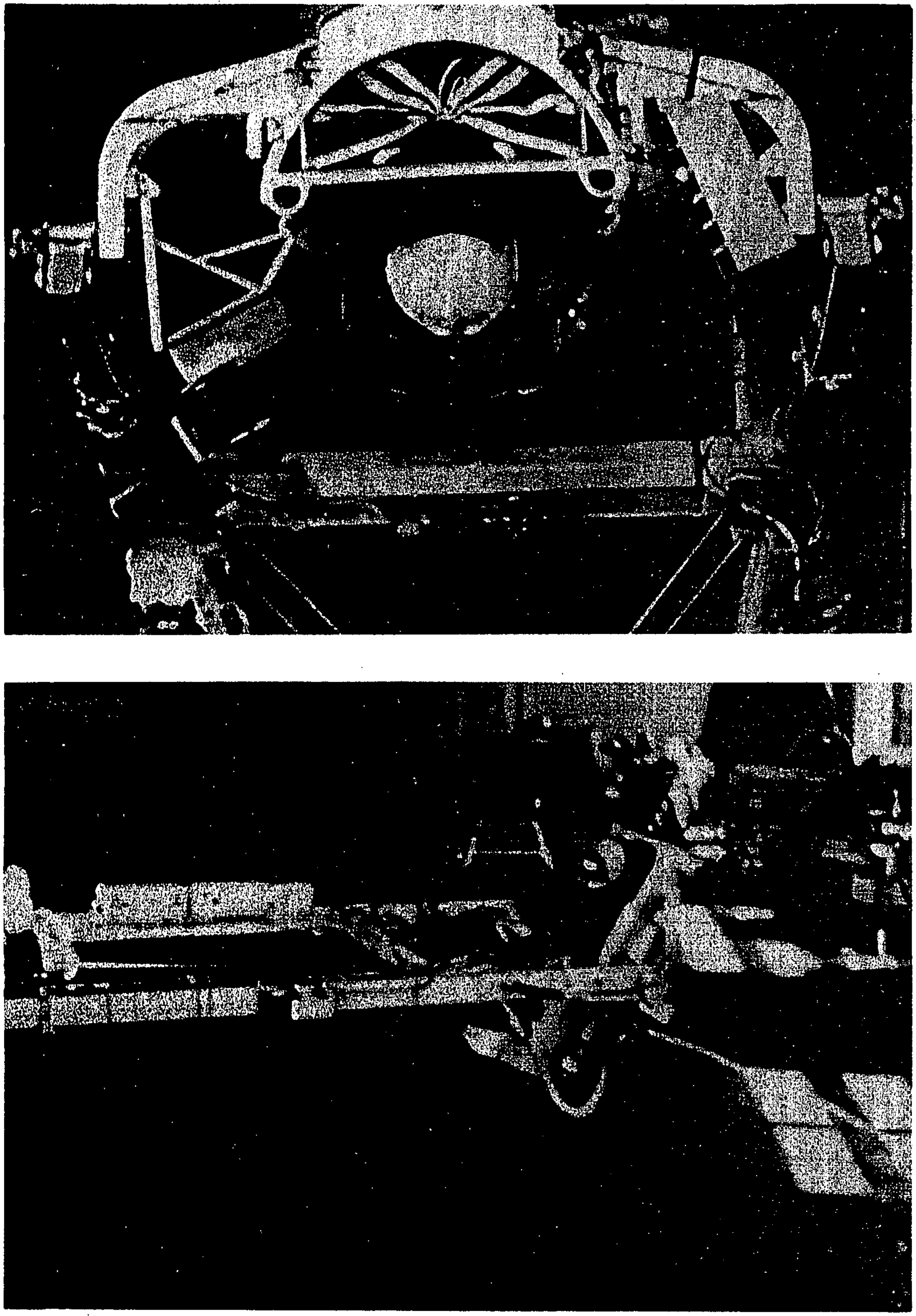

Figure 20. Gagarin on centrifuge.

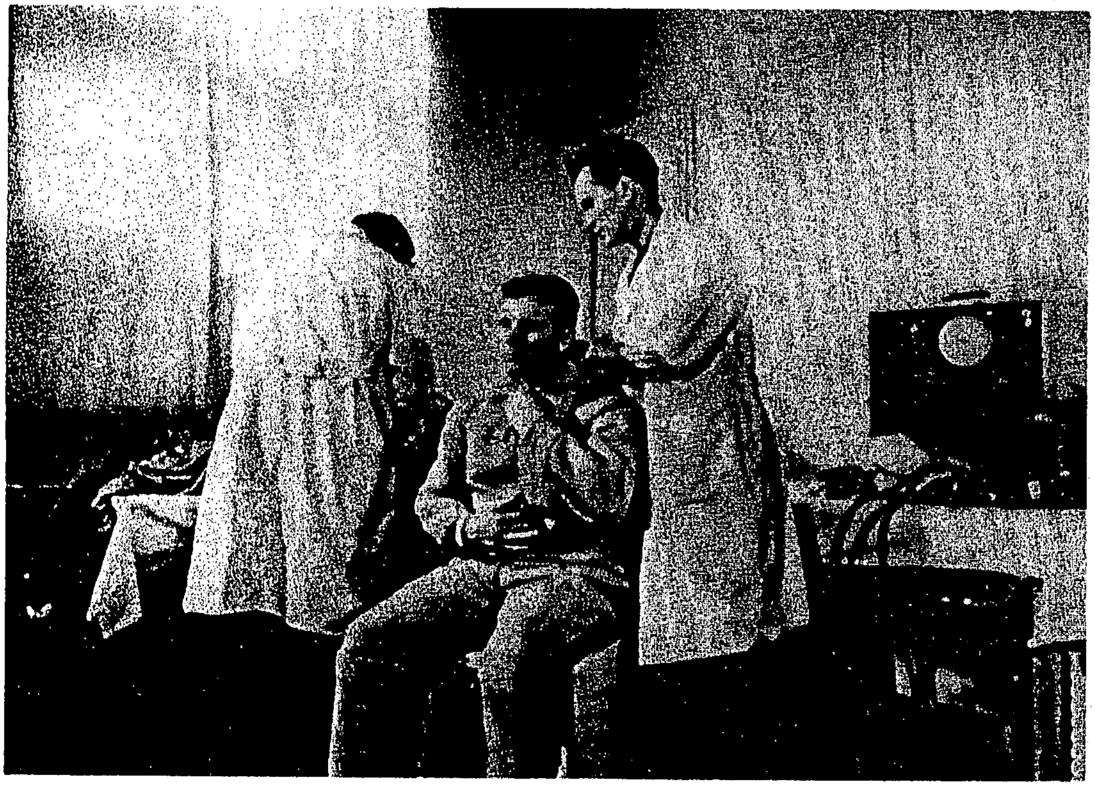

Figure 21. Preparation of Gagarin for spaceflight.

Figure 22. Selection of Gagarin for first manned orbital flight. Prof. Dr. V. I. Yazdovskiy, apparently in charge of all cosmonaut training and life support activities, to right of Gagarin. Second man to right of Yazdovskiy is probably Admiral Sergey G. Gorshkov. Man at the head of table is Marshall Kirill Moskalenko, head of the Strategic Rocket Forces until his election as a Member of the Communist Party Central Committee in November 1961 at the 22nd Party Congress.

Figure 23. Biomedical conference, reportedly following Gagarin's orbital flight. Facing the camera right to left, Prof. Dr. V. I. Yazdovskiy, V. V. Porin, and N. M. Sisokyan. Other participants are unidentified. Note biotelemetry analogs in the rear.

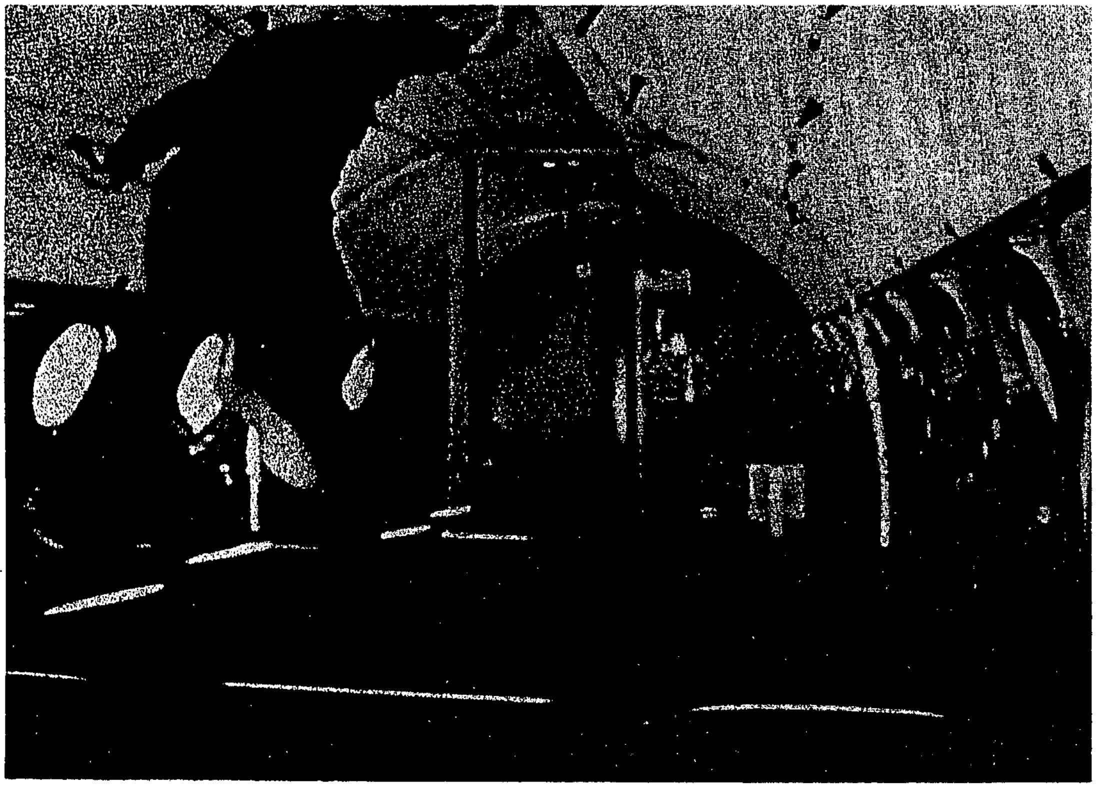

Figure 24. Interior view of Soviet aircraft used for simulation of weightlessness. Note netting at the rear.

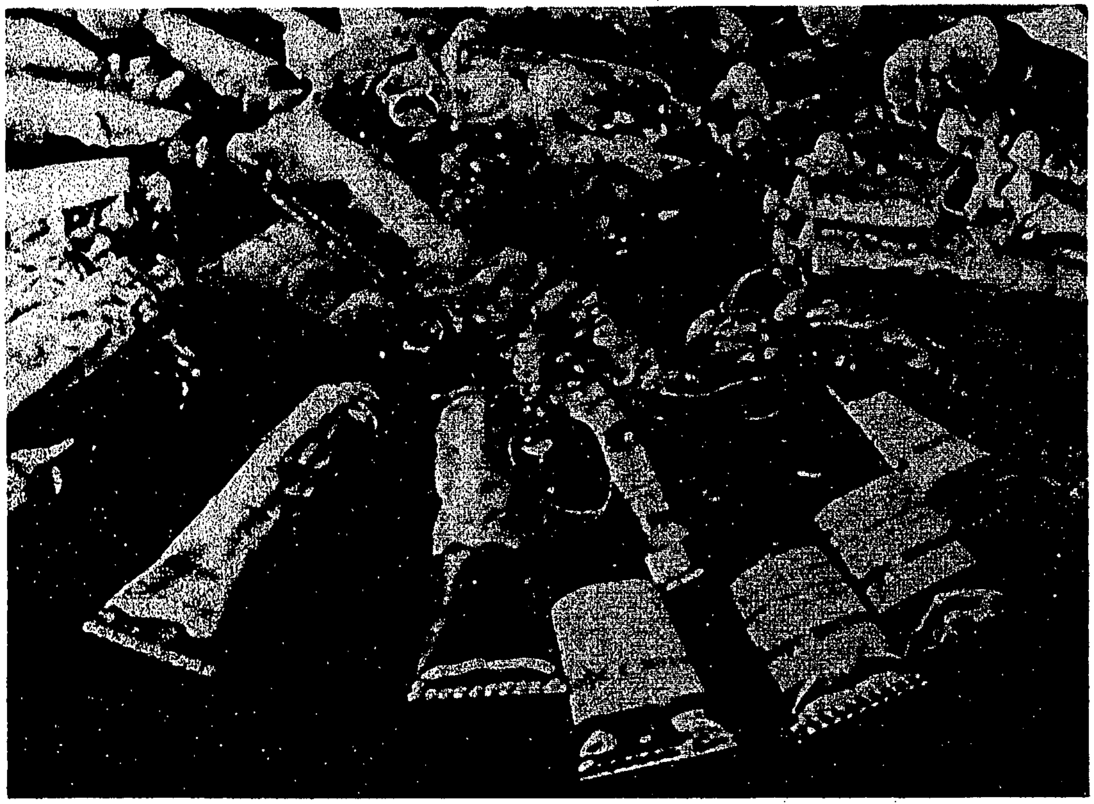

Figure 25. Display of squeeze tubes and other space foods. The three tubes in the forefront contain coffee, milk, and meat.

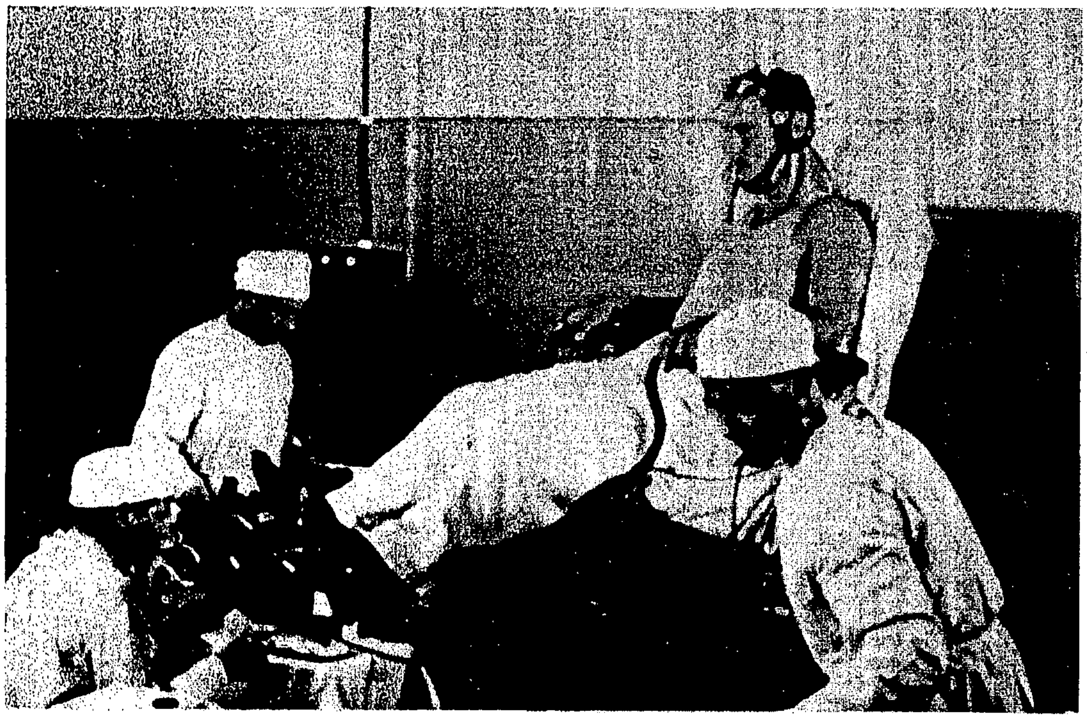

Figure 26. Unidentified subject with surface electrodes for recording brain waves and other physiological measurements. Subject is sitting in vibration chair.

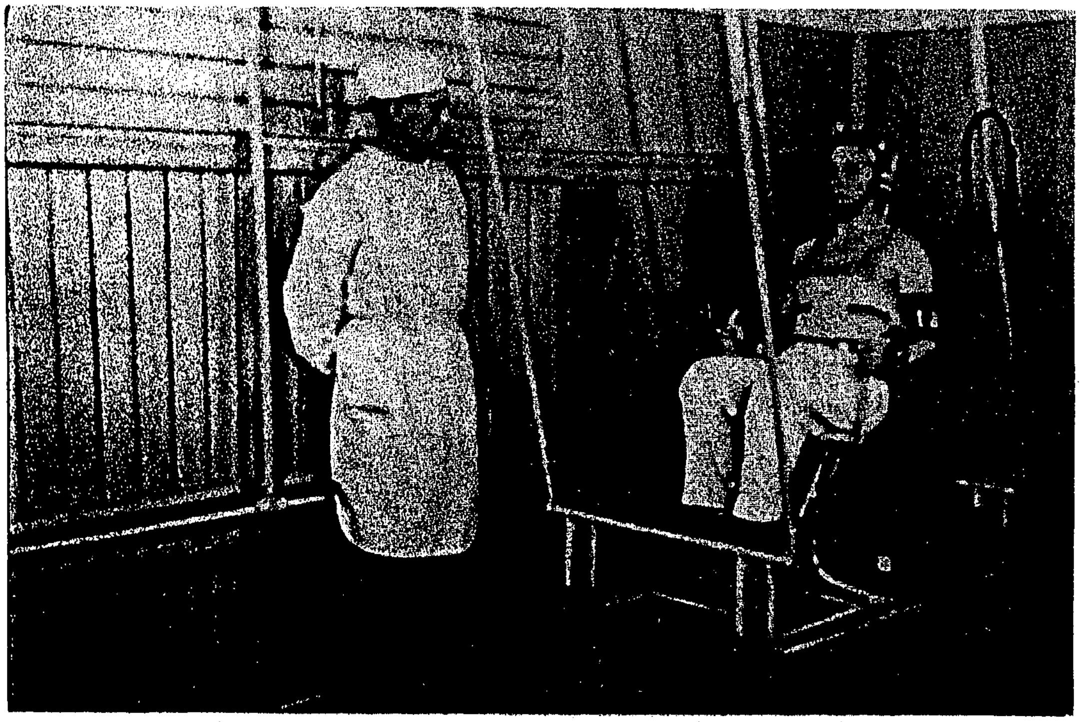

Figure 27. Unidentified subject in oscillator chair for recording of brain waves, blood pressure, possible ballistocardiogram (waist girdle), and other measurements not identified.

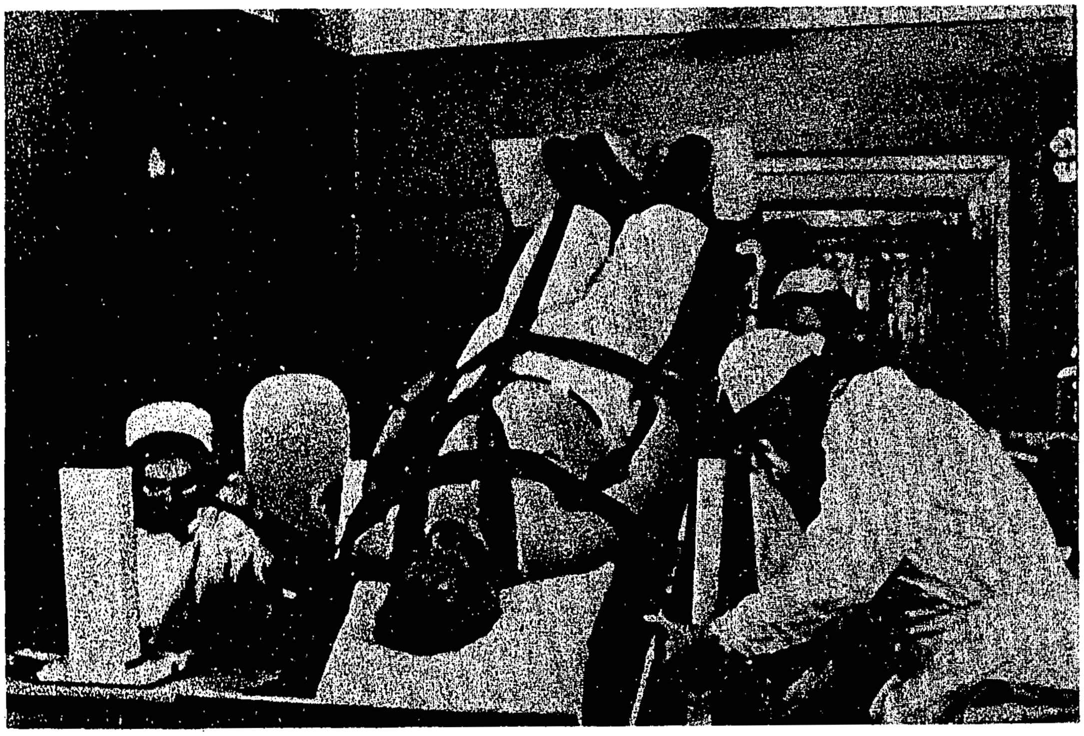

Figure 28. Unidentified subject on tilt table.

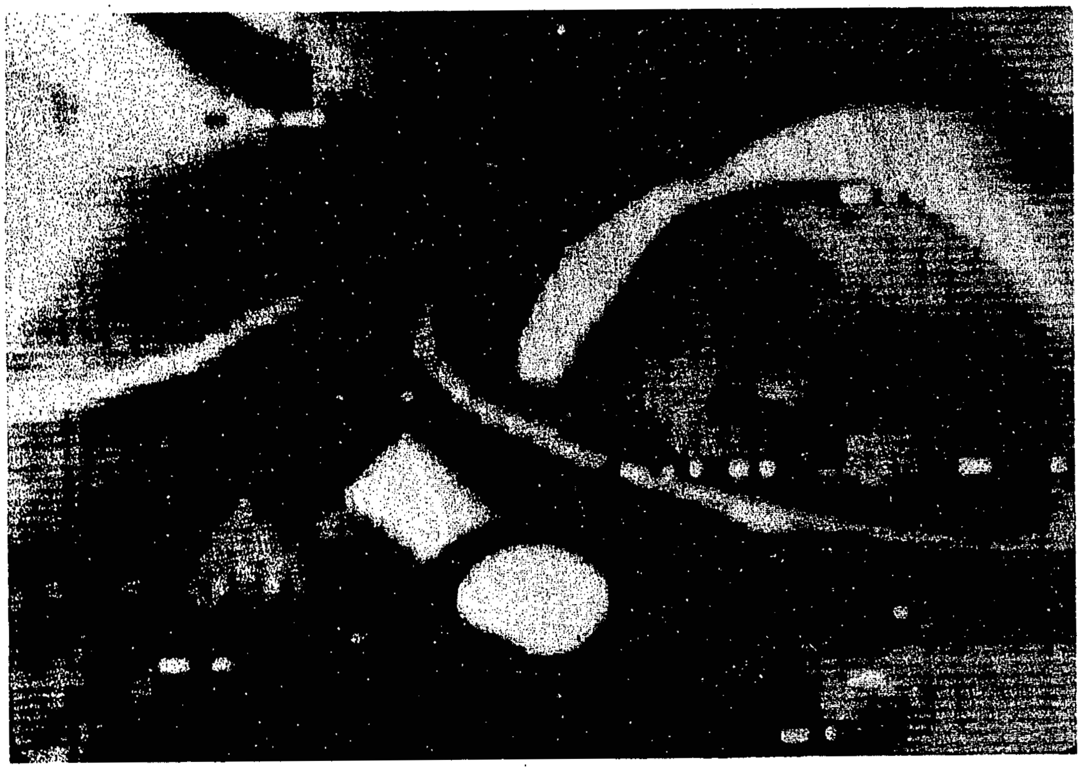

Figure 29. Soviet television reception of Gagarin in flight.

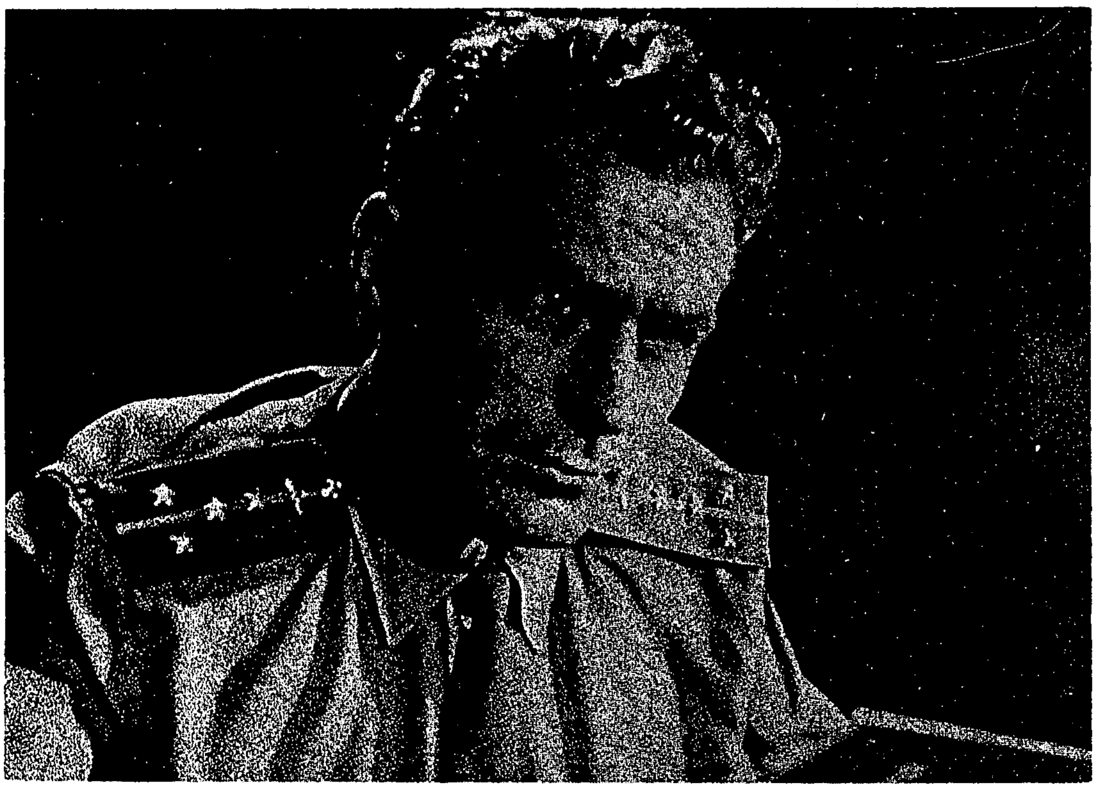

Figure 30. Major German Titov. Made first multiorbital spaceflight 6 and 7 August 1961.

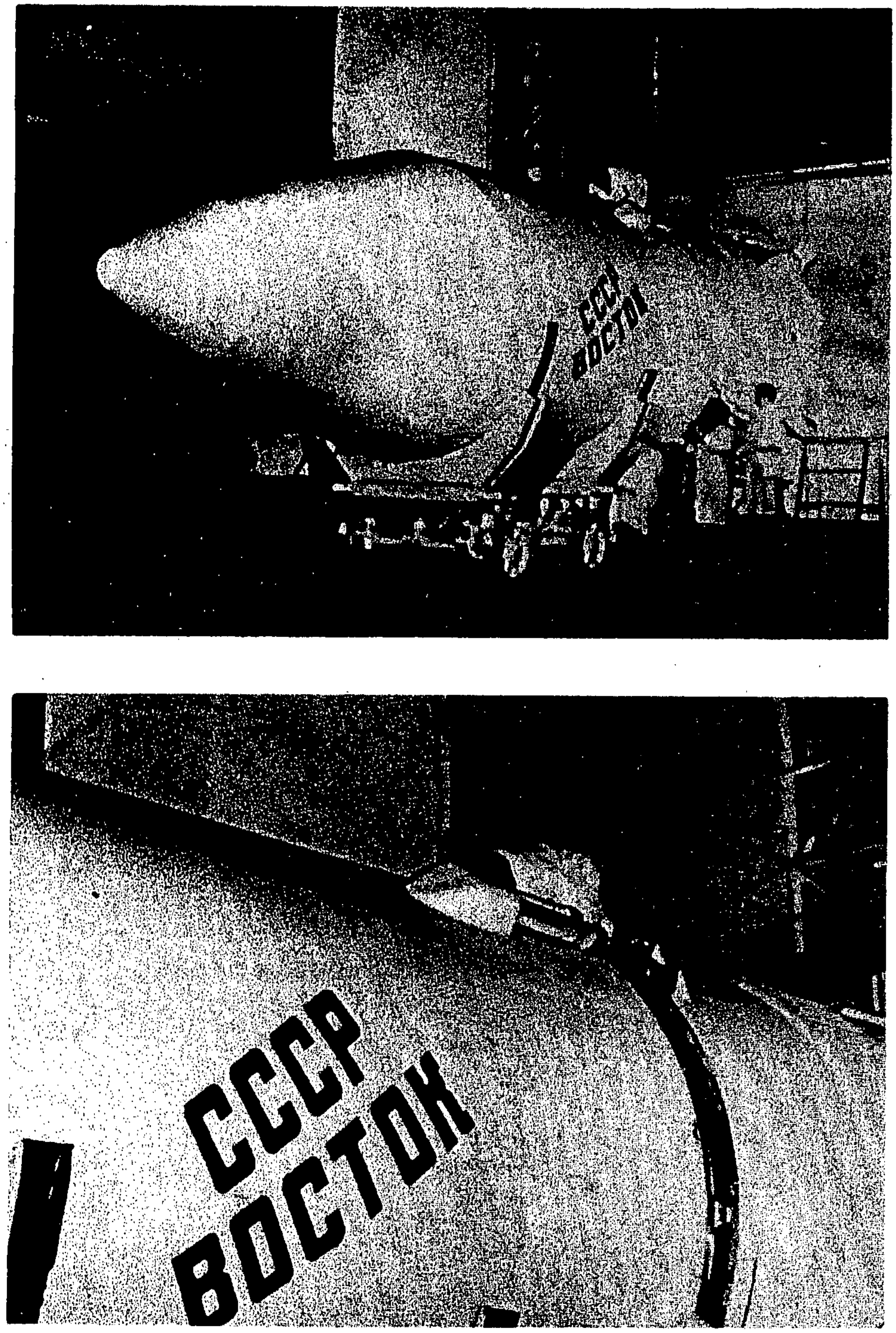

Figure 31. External views of Vostok Spaceship. Note fairing ring attachment.

Figure 32. Sensor (biotelemetry) placement on Titov's body. Note waist girdle which could include sensor for ballistocardiogram.

Figure 33. Titov preparing for flight. Inner suit worn under space suit.

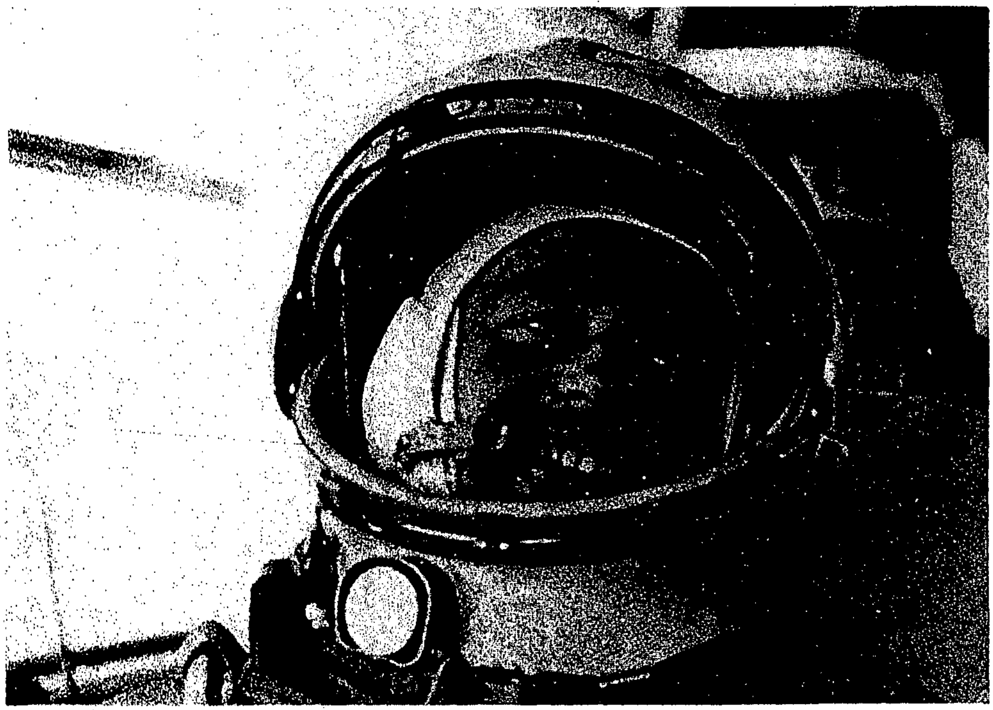

Figure 34. Titov ready for orbital flight.

Figure 35. Titov on bus, sampling squeeze tube food.

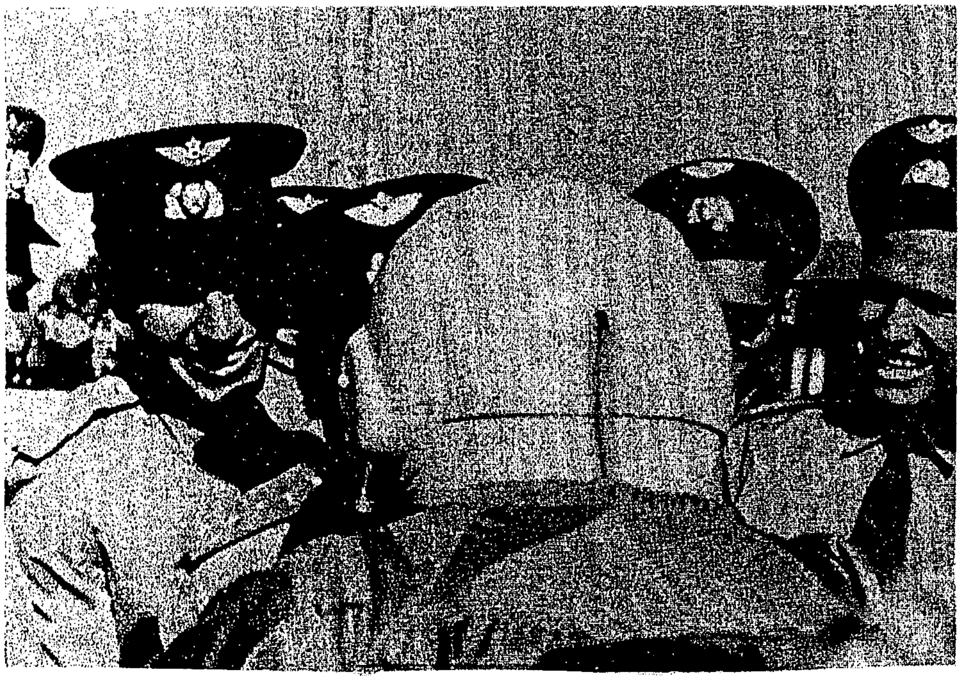

Figure 36. Rear view of Titov's full pressure helmet. Note cable or wire channel to suit.

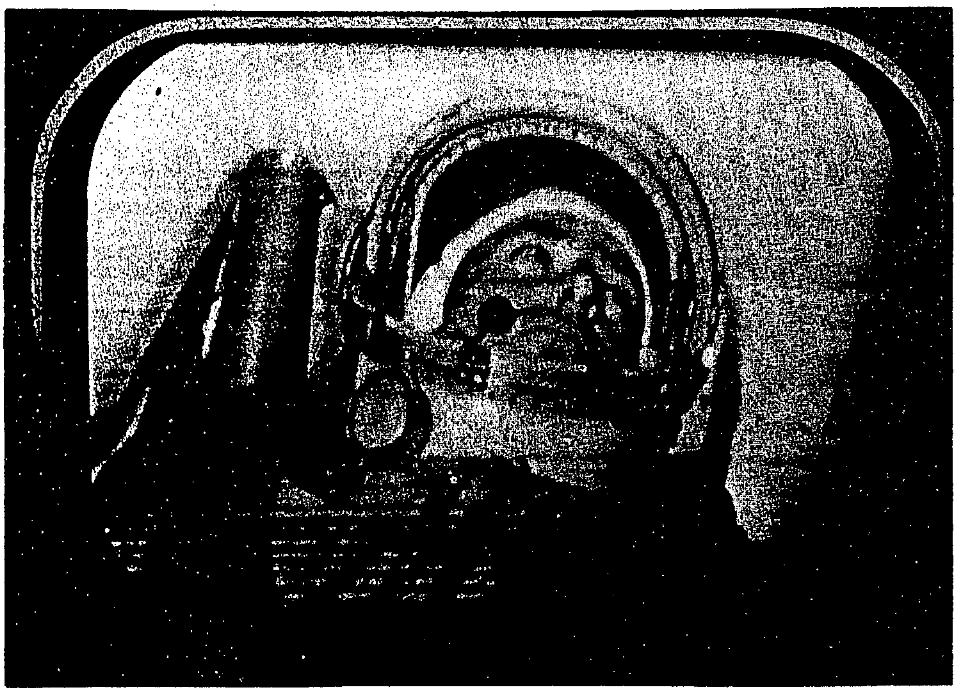

Figure 37. Soviet television reception of Titov in orbital flight. Some pictures show him supposedly asleep. Helmet is open in all TV reception released.

Figure 38. Post-flight removal of respiratory and EKG sensors from Titov.

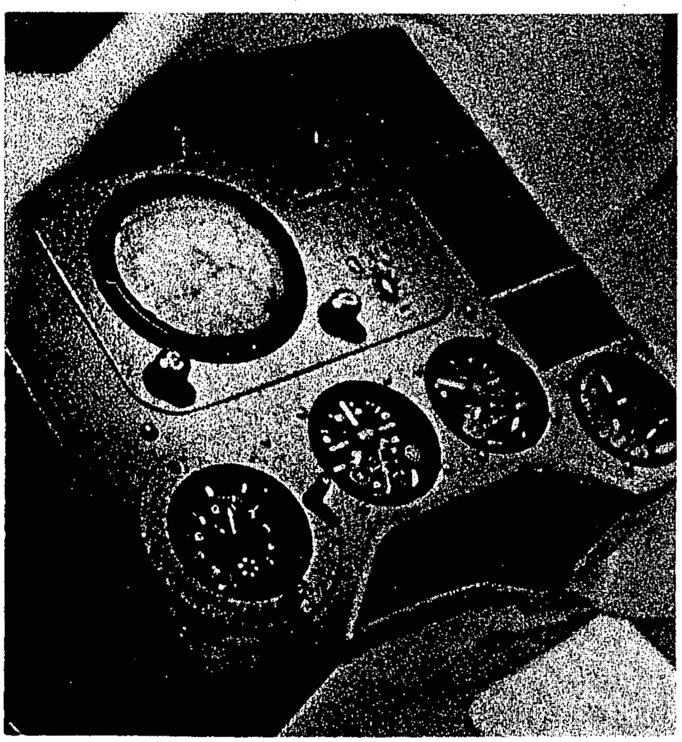

Figure 39. Vostok instrument panel, showing globe reference instrument.

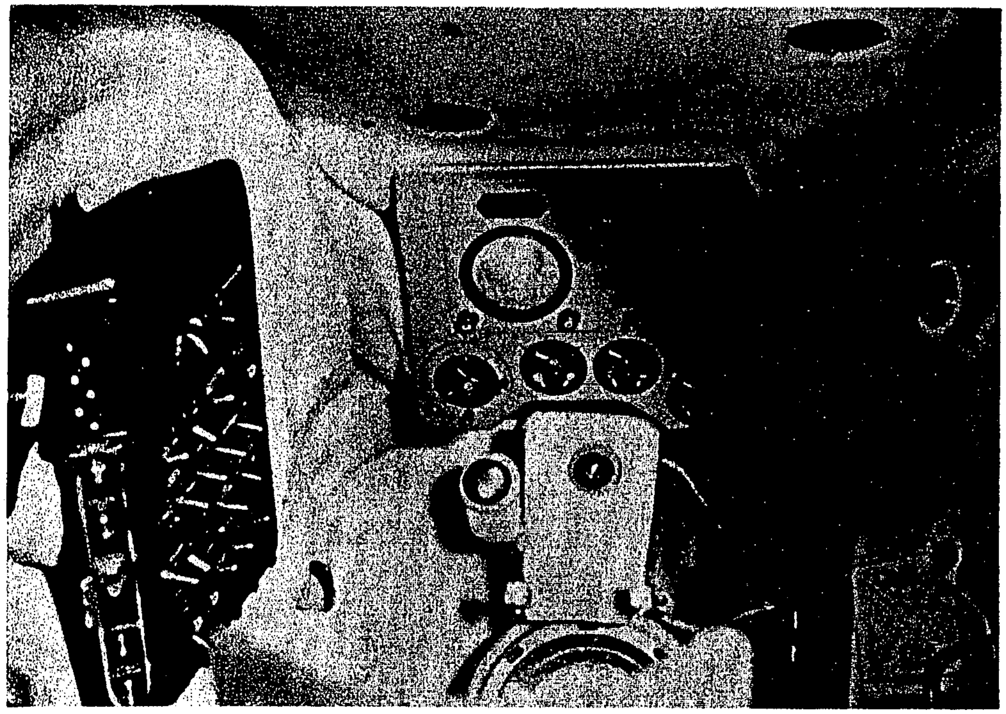

Figure 40. Interior of Vostok II. Instrument panel in center of photo and pilot control panel at left.

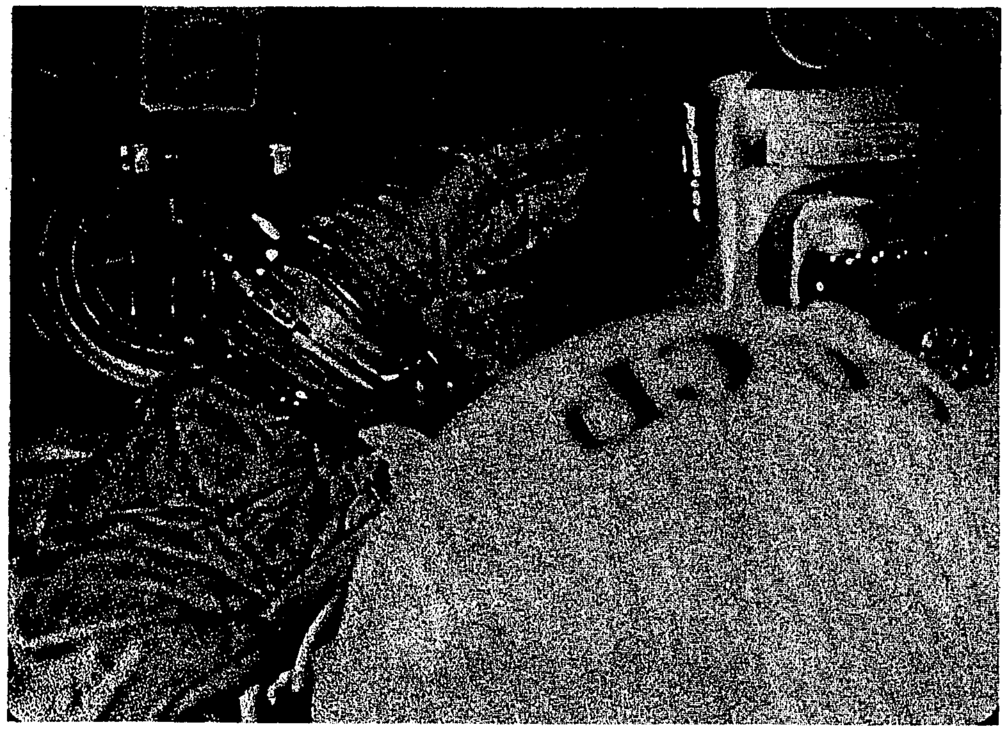

Figure 41. View of cosmonaut in Vostok II showing glove seal mechanism.

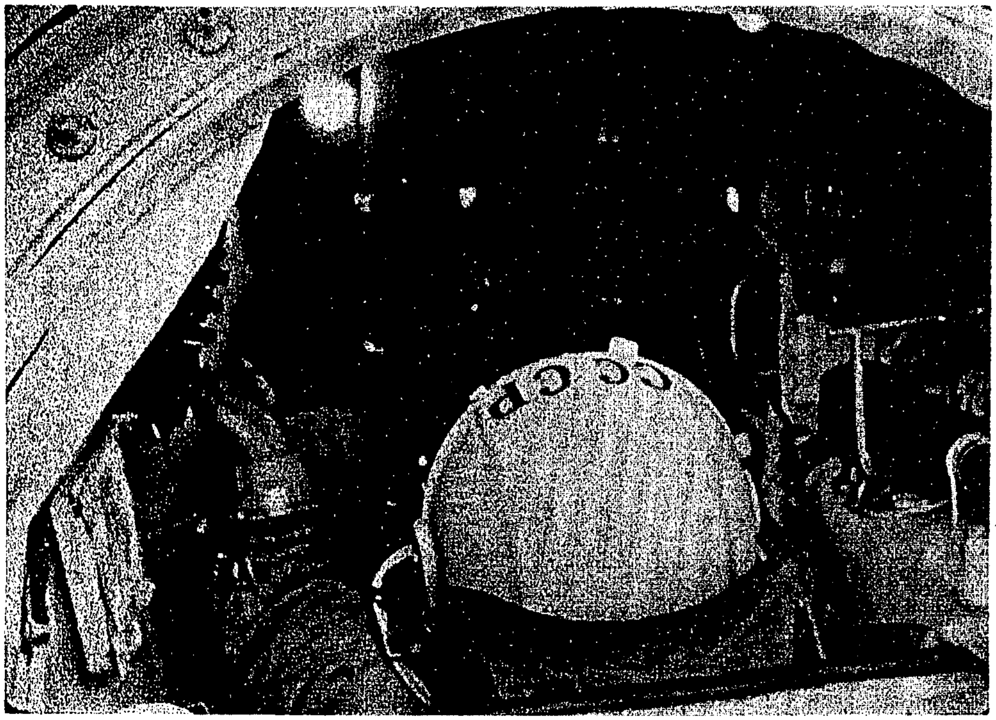

Figure 42. Interior view of Vostok II. Rear "fairing" apparently removed.

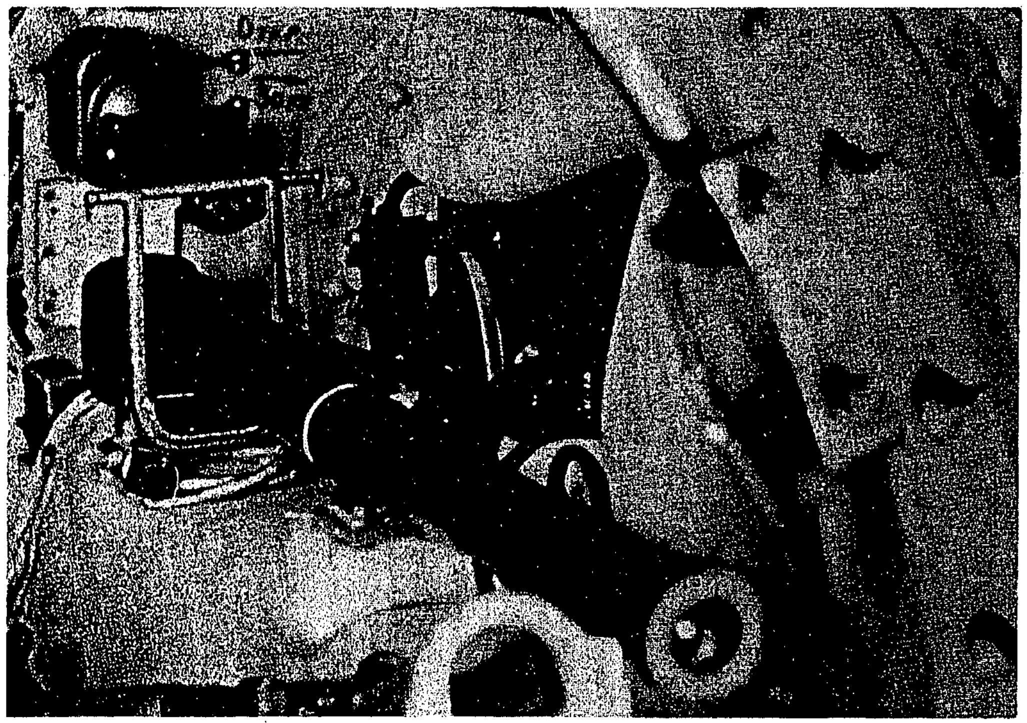

Figure 43. Unidentified optical device used in Vostok II. Not apparent in Vostok I photos.

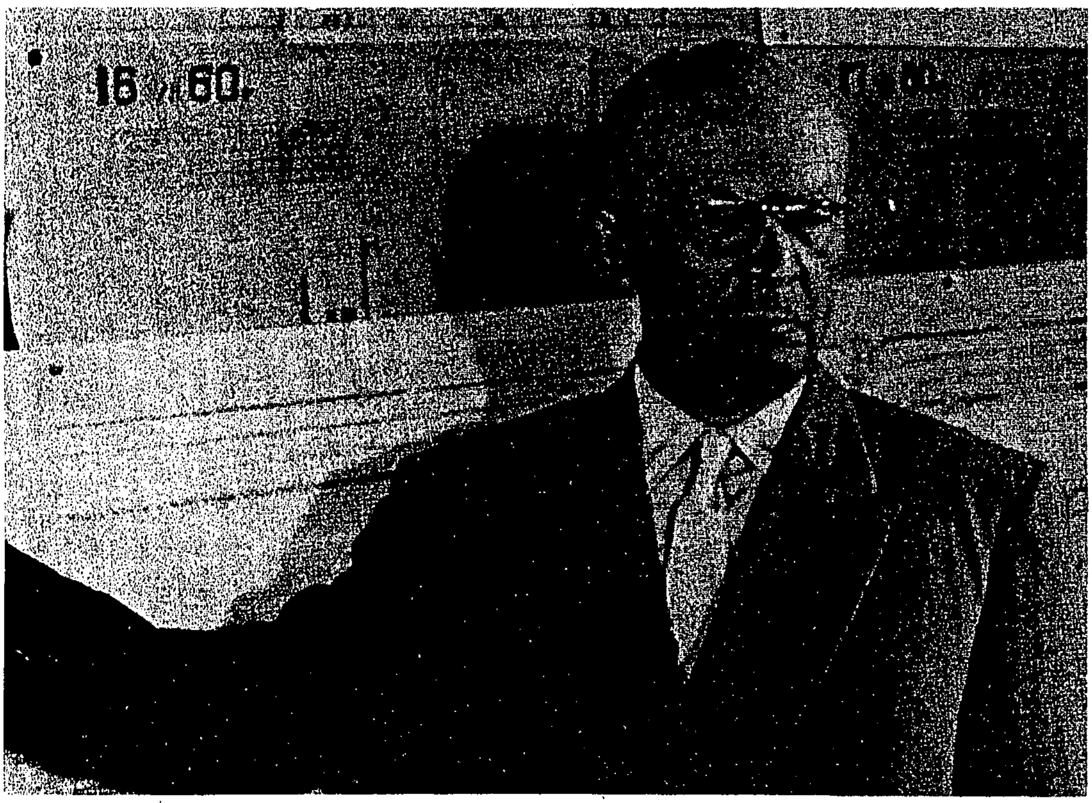

Figure 44. Prof. Dr. Valdimir I. Yazdovskiy, Soviet space medicine expert, apparently in charge of all Soviet cosmonaut training and life support activities.

Figure 45. Titov checking out on swing-type simulator.

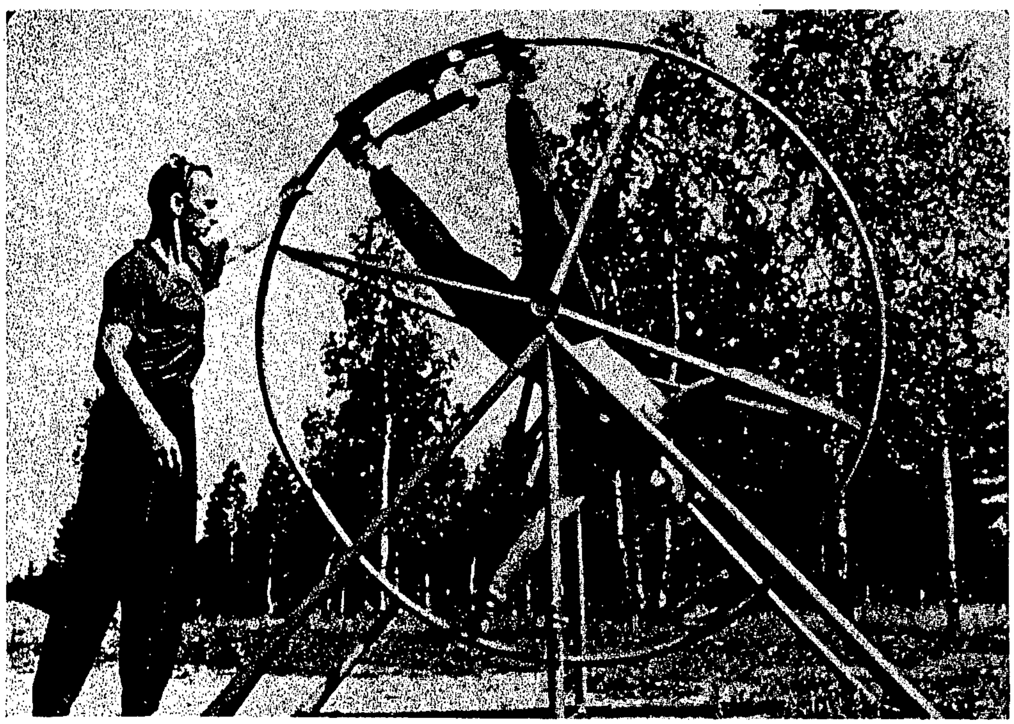

Figure 46. Titov riding rotation simulator.

UNCLASSIFIED

Figure 47. Titov orientation on trampoline.

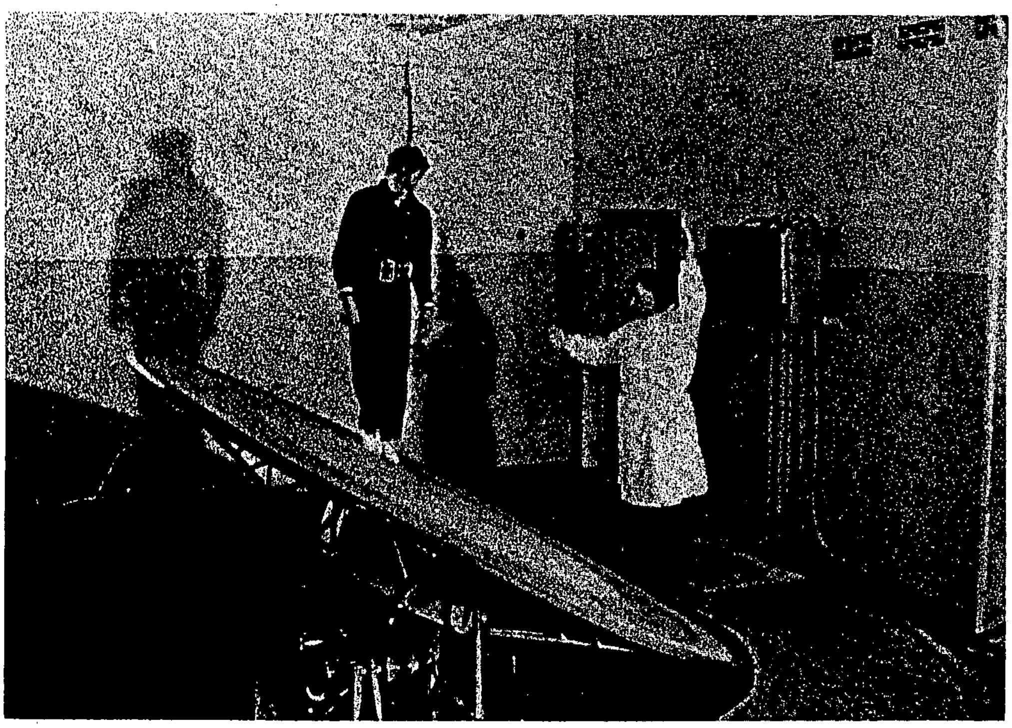

Figure 48. Monitoring of physiological indices during various positions on carousel.

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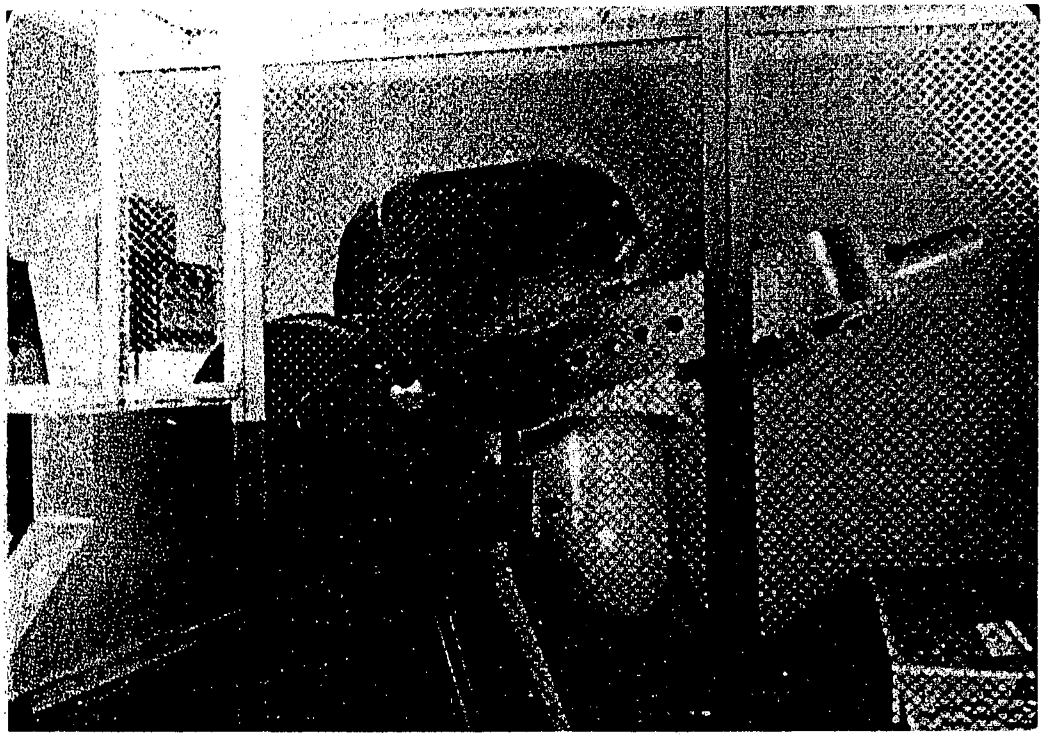

Figure 49. Disorientation chair or capsule.

Figure 50. Vertical accelerator.

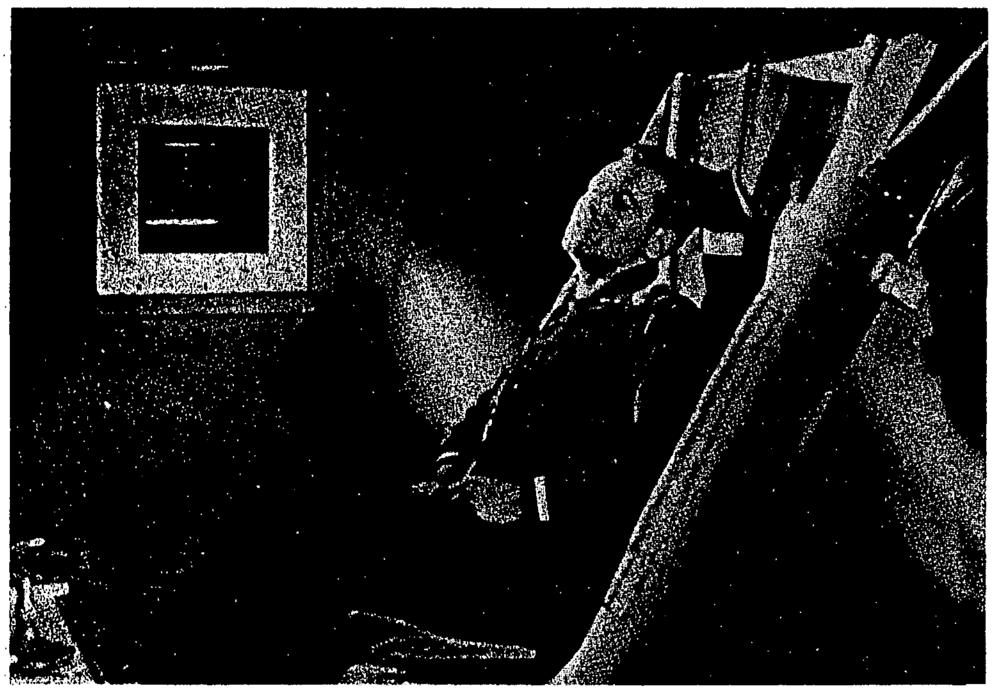

Figure 51. Titov in isolation and confinement chamber before orbital flight.

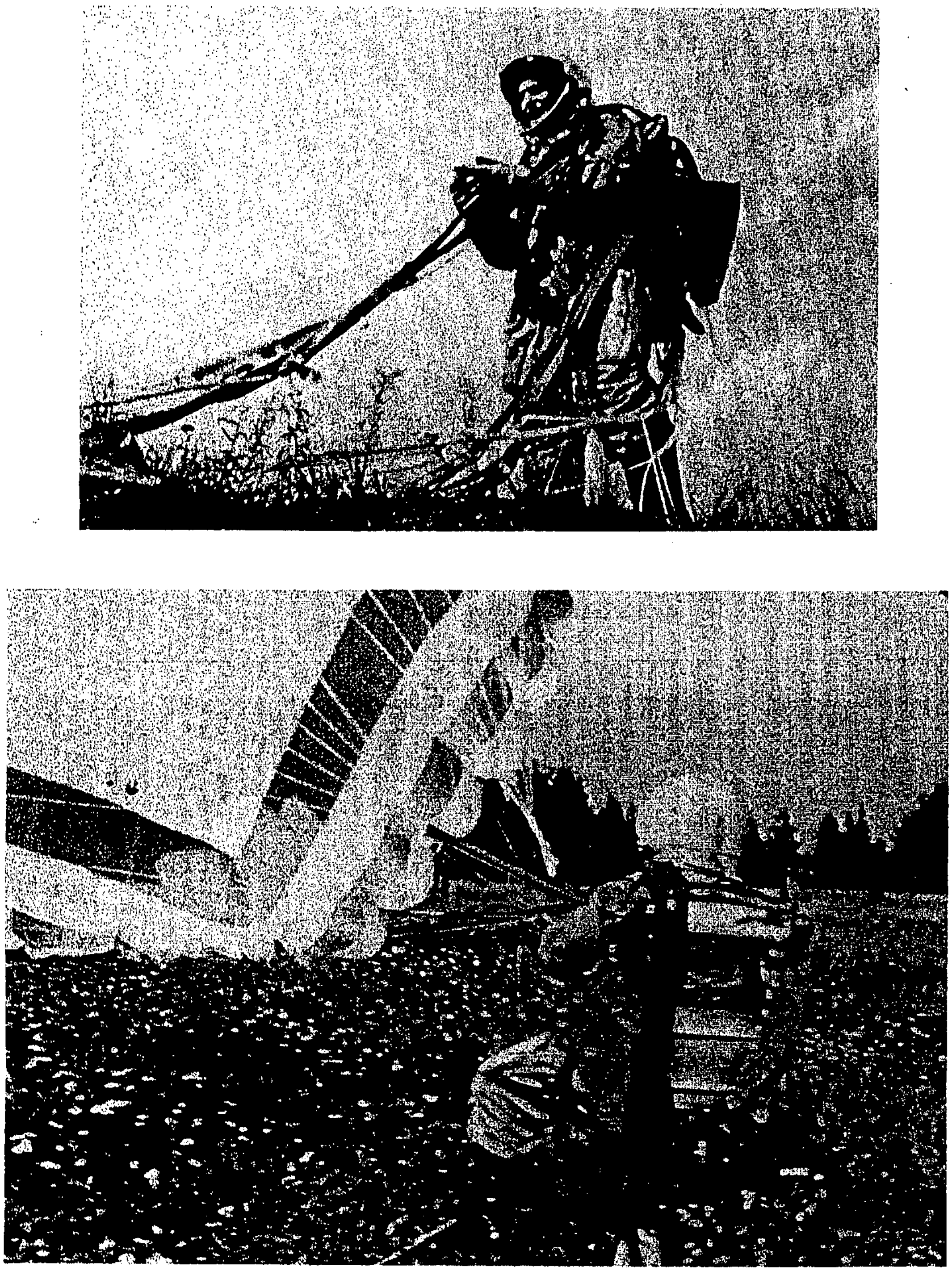

Figure 52. Titov and equipment used for conventional parachute recovery.

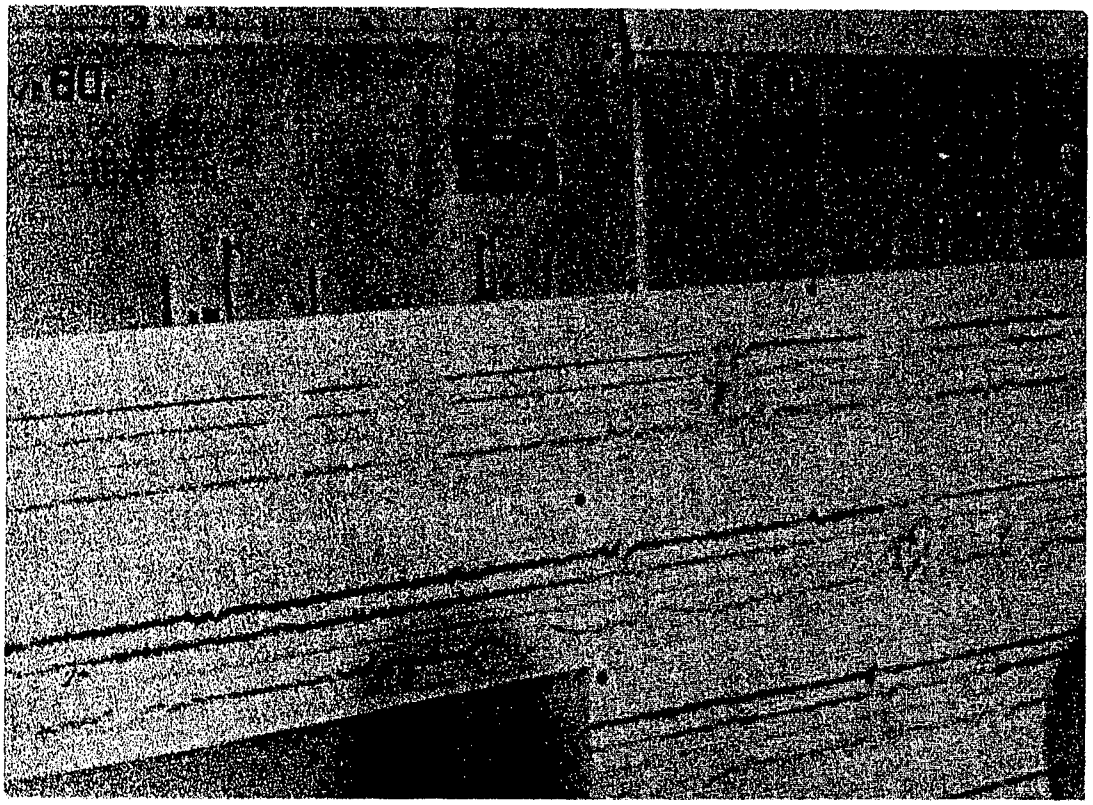

Figure 53. Soviet analogs (biotelemetry) of manned space flights.