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SCIENTIFIC INTELLIGENCE REPORT

THE SOVIET SPACE RESEARCH PROGRAM

MONOGRAPH IX
SPACE MEDICINE



CIA/SI 33-59

21 August 1959

CENTRAL INTELLIGENCE AGENCY

OFFICE OF SCIENTIFIC INTELLIGENCE

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Scientific Intelligence Report

THE SOVIET SPACE RESEARCH PROGRAM

MONOGRAPH IX
SPACE MEDICINE

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.

CIA/SI 33-59
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PREFACE

This monograph, one of a special series on the Soviet space program, presents intelligence on Soviet research activities and capabilities in the field of space medicine. The information is based on public statements made by responsible Soviet scientists and officials, published scientific reports on Soviet achievements in space medicine research, and intelligence reports on Soviet activities in this field. The cutoff date for the information contained in this report is 1 May 1959.

The complete series of 12 monographs on the Soviet space research program is listed below. Monographs II through XII are designed to support the conclusions found in Monograph I, which is an overall evaluation of significant Soviet space research capabilities. Monograph I will be published last.

Monographs for the Soviet Space Research Program:

- | | |
|-----------------------------------------|-------------------------------------------------------------------|
| I Estimate 1959-74 | VII Telemetry, Communications, and Reconnaissance Instrumentation |
| II Objectives | VIII Ground Support Facilities |
| III Organization, Planning, and Control | IX Space Medicine |
| IV Space Vehicles | X Space Biology and Astrobiology |
| V Propulsion System | XI Astronomical Aspects |
| VI Guidance and Control | XII Current Status of Progress |

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THE SOVIET SPACE RESEARCH PROGRAM

MONOGRAPH IX SPACE MEDICINE

CONCLUSIONS

1. The Soviets have an advanced research program in space medicine that is being aggressively pursued on a broad base. This program encompasses not only the medical and biological aspects of work and survival in a space environment but also the human factors engineering of the environment itself.
2. Soviet space medicine research has been characterized by early exploitation of large-scale rocketry to test animal survival and life-sustaining systems under space and space-equivalent conditions. It is likely that the Soviets by-passed experiments with high-altitude manned balloons.
3. High-altitude rocket research has probably given the Soviets an initial lead in the study of cosmic radiation effects on living organisms. We believe exploitation of their satellite program has provided them with data on the effects of other forms of radiation upon living organisms in outer space.
4. There is evidence of unique physiological research applicable to control of environmental stress factors which might affect functional characteristics of the human operator in space vehicles. This research includes human preconditioning, use of drugs, study and control of human responses to space conditions, and exploration of pertinent aspects of cybernetics (mainly the theory of feedback or automatic control including the working processes of the nervous system and sensory organs).
5. Soviet medical research provides the USSR with a sound basis for the selection and training of candidates for flights into outer space and is now adequate for the realistic development of manned space capsules suitable for re-entry and recovery.
6. There is no known medical obstacle to prevent the Soviets from orbiting a human being for short periods during late 1959 or early 1960. It is believed that the Soviets will take a calculated risk on the combined physical and physiological stresses affecting the astronaut.
7. The wealth of knowledge acquired by the USSR in the field of space medicine, plus the apparent boldness and breadth of Soviet research, should permit continued significant advances in space medicine and related fields during the next 5 to 10 years.

SUMMARY

Soviet research advances in space medicine are the result of a thorough and well-planned program. Although Soviet exploitation of foreign literature was comprehensive, the end

products were largely due to native Soviet conceptual efforts. The space program gained impetus by emphasizing scientific training along with well-coordinated use of Soviet

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civilian and military competencies in the bio-medical and human factors engineering fields.

The exploitation of available large-scale rocketry for animal experimentation made it possible for the Soviets to arrive at an explanation of specific biological phenomena. Although vertical-type launchings with successful animal recoveries were brief rocket flights, the associated bio-medical investigations provided approximate qualitative and quantitative effects similar to those in actual orbiting space vehicles. The "Laika-satellite" combination probably provided the Soviets with undisclosed quantitative data on the combined effect of acceleration, noise, vibration and weightlessness during the launching and orbital flight.

Assessments of statements and voluminous publications by Soviet experts indicate that they are conducting bio-astronautical research under very high priority. As a result, Soviet scientific efforts will be marked in the coming years by demonstrated improvement and sophistication of space suits, ejection devices, parachuting systems and automatic controls for experimental flights necessary for functional manned space flight.

The hazardous effects resulting from radiation is a basic problem which should be determined prior to man's venture into space. Vertical rocket flights to high altitudes have probably provided the Soviets with data on latent biological radiation effects, although no such data have been officially released. No specific data have been released on the characteristics of radiation experienced during the

Sputnik II flight; however, Sputnik II has probably given the Soviets an initial lead in quantitative data from analyses of radiation measurements programmed for this experiment. There are indications that the Soviets will attempt to avoid radiation hazards by orbiting below or above the radiation belt. Whether or not any protection will be gained by moderate but conventional shielding is open to question.

Since 1955, the Soviets have intensified physiological research on the control of environmental stress factors. This important work which concerns the functional characteristics of the human operator in space vehicles includes studies on acceleration, weightlessness, bioengineering, oxygen saturation, development of a sealed cabin, vibration and acoustics, theory of controls including the working processes of the nervous system and sensory organs, and other aspects (human factors engineering) directly and indirectly related to the launching of manned vehicles.

The placing of man in space for extended periods is probably one of the next steps in the Soviet space program. Currently, the Soviets are capable of recovering man from a vertical or near-vertical launching which constitutes a sub-orbital buildup capability. Soviet criteria for personnel selection, the advanced degree of training of specific individuals (test pilots), and Soviet statements concerning intent to put man into space, manifest an intensive and logical program for the accomplishment of their space flight objectives.

DISCUSSION

INTRODUCTION

Soviet determination to place man into space has resulted in focusing attention on the functional characteristics of man as related to external factors which may aid or impede his activities in space.

The stresses (figures 1, 2, and 3) posed by space flight comprise one of the principal

areas of medical research interest in the USSR. The Soviets have intensified their investigations on matters such as (1) physico-chemical problems connected with oxygen deficit, (2) vibration and high-intensity sound, and (3) psychophysiological inquiries into the sensory phenomena by which man is oriented to his surroundings.

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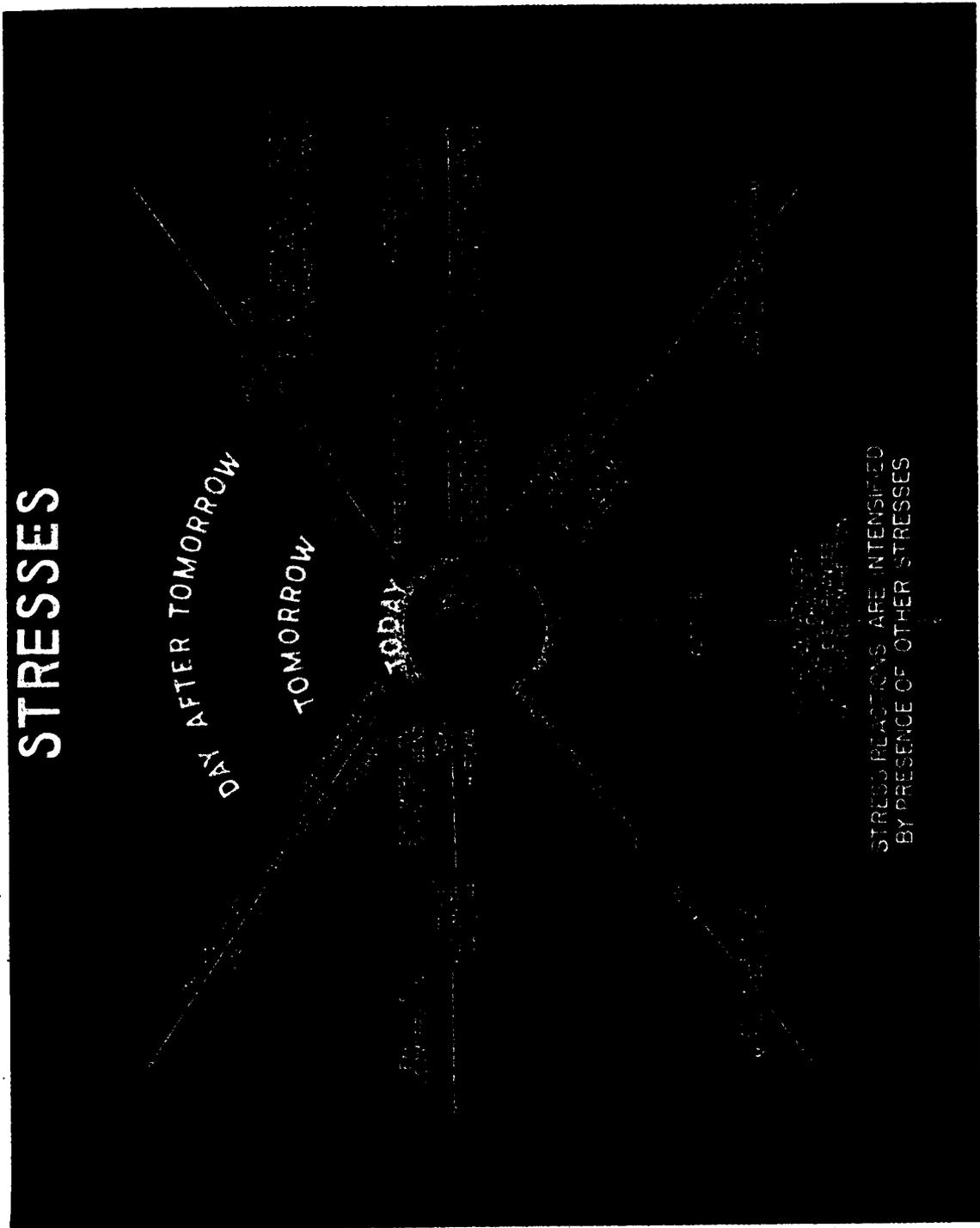


Figure 2. Stresses of space flight from human factors point of view.

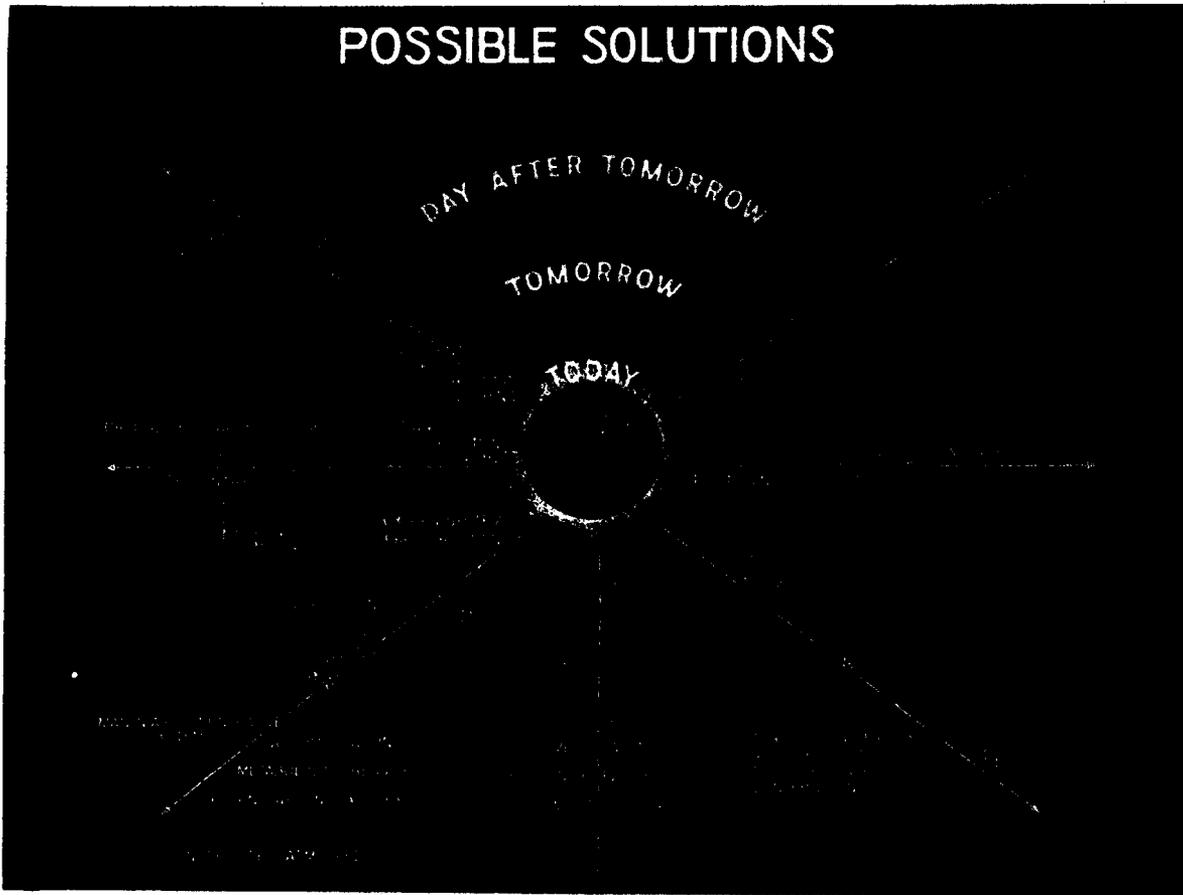


Figure 3. Possible solutions of human factor problems

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The Soviets are also giving consideration to food, oxygen, and water requirements. Micro-organisms and protein derivatives are being studied as potential sources of nutritional requirements for prolonged space travel. The Soviets recognize that certain plants might be ideal sources of oxygen for man in a sealed environment, because they would provide him with the necessary oxygen and also absorb carbon dioxide waste. Distillation of waste products and of involuntary water loss (perspiration, etc.) is proposed as a future source of water supply.

The effects of partial vacuums, cosmic rays and other types of electromagnetic radiations that are likely to be encountered by man in space have also been considered. The Soviets have approached these problems by subjecting man and animals to experimental situations in an attempt to induce adaptation to these conditions through the process of conditioning.

Although the chronic effects of certain environmental factors, such as zero gravity, are not known, there is little doubt that Soviet scientists can alter animal and human responses in order to adapt to the extended or temporary stress conditions that are experienced in launching, brief orbital flight, and re-entry.

SOVIET EFFORT IN SPACE MEDICINE

Objectives and Magnitude of Effort

The Soviets have not stated or released an official time schedule or their specific objectives or motivations for manned space flight. However, repeated assertions, opinions, and predictions* of Soviet scientists, engineers, and military experts indicate a Soviet intention to place and sustain man in space, with deliberate re-entry and recovery.

Early Soviet experiments using dogs as test subjects during vertical rocket flights are the forerunners of animal recovery experiments in orbital flights.^{1,2} Their present parachute-type recovery system from vertical flights gives reasonable assurance of the preservation of the animal's life. However, a need for additional work to insure better stabilization

* See Appendix C — Quotations.

and favorable deceleration during the nose or forward section's fall from high altitude is indicated.

Placing man in space is one of the next steps in their program and it is probable that Soviet scientists will accomplish this shortly after the preliminary experimentation related to orbital flight recovery is successfully completed.^{3,4}

In general, the successful results of operational safety systems employed under varied environmental conditions of vertical flights demonstrate improvement, if not sophistication, of Soviet space suits, ejection devices, parachuting systems, and automatic controls for experimental flights necessary for the achievement of manned space flight.⁵

Probable Soviet Goals

An assessment of hundreds of statements by Soviet experts indicates that Soviet space-flight efforts will be intensified in the coming years. Our postulation of the bio-medical goals and time elements of the Soviet space program are given in table 1.

TABLE 1
POSTULATED BIO-MEDICAL GOALS OF
SOVIET SPACE PROGRAM

Manned Flight

1. Develop, test, and launch IGY and IGC satellites. (1957-59)
2. Develop, test, launch, and recover life-carrying (animal) satellites. (Orbital) (1959-60)
3. Develop, test, launch, and recover life-carrying (man) rocket. (Vertical) (1959-60)
4. Develop, test, launch, and recover life-carrying (man) satellites. (Orbital) (1960-61)
5. Develop rocket-powered manned vehicle. (1961-63)
6. Develop and orbit a large manned conventional space station. (1964-65)

Manned Interplanetary Flight

1. Develop, test, and fire a lunar-impacting rocket. (1959)
2. Develop, test, and fire an instrumented soft-landing lunar rocket, including instrumented bioastronautical experimentation. (1960)
3. Develop, test, and launch a satellite around the moon. (1959)
4. Develop, test, and launch a satellite around the moon, returning to earth. (Recoverable) (1963-64)
5. Develop, test, and launch a manned lunar rocket from space station. (Recoverable) (1970 at earliest)
6. Astrobiology "on-site" activities. (1970 at earliest)

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An authentic manned space vehicle must be designed around the biophysical and psychological requisites. Compromises and specialization of human-factors engineering design, however, will have certain advantages for longer trips (interstellar flight), because there are weight-saving refinements (algae photosynthetic process, inert gas dynamics, etc.) that can be made.

Radiation presents one of the basic problems which must be solved prior to man's venture into space. Vertical rocket flights to high altitudes have probably provided the Soviets with data on latent biological radiation effects although serial blood counts and extensive follow-up examinations of the experimental animals within one day following recovery revealed no immediate harmful effects. No specific data have been released on the nature and intensity of radiation experienced during the Sputnik II flight. There are indications that the Soviets will attempt to avoid radiation hazards by orbiting below or above the radiation belt in an appropriate trajectory. Whether or not any protection will be gained by moderate but conventional shielding of the subject is open to question.

Major Achievements to Date

The Soviets have emphasized research related to stress factors, such as extremely high altitudes, through the evolution of basic research applicable to aeromedicine. Included in this research is significant work in acceleration, weightlessness, bioengineering, oxygen saturation, the development of a sealed cabin, and many other aspects directly related to the launching of manned missiles or satellites.⁶⁷ To date, the Soviets have achieved some notable results. (See tables 2 and 3)

Trends and Estimated Capabilities

Bio-Medical Implications — Exclusive of material achievements, accelerated Soviet exploratory research in aeromedicine and space medicine will result in an increased understanding of the fundamental mechanisms that underlie human performance and behavior in space and will encompass the broad

range of space environments and space equivalent conditions in civilian and military operations. Soviet investigators will increase their observations on biological effects of radiation, artificial environment, orientation in space, optical factors, gravity zero, as well as on temperature and pressure tolerances.

During the next few years, the Soviets will continue to use animals for extremely high altitude research, employing primates such as monkeys and chimpanzees. The orbiting of a human being for a period of hours to days will depend on the perfection of an ejectable "sealed capsule" for re-entry and/or the re-ignition of reserve fuel for re-entry of a manned rocket.

It is expected that the Soviet investigators will modify animal and human responses so that space travelers may adapt themselves during launching, orbital flight, re-entry and recovery.

The USSR will make significant advances in establishing the effects of physical factors (temperature, motion of the air, atmospheric and barometric pressure, radiation, ionization of air) on biological systems.

The Soviets will continue to emphasize achievements in space medicine in their propaganda effort against the Free World.

Military Implications — The USSR is currently (1959) training military airmen to tolerate the adverse conditions which they may meet in space flight. A member of the Soviet delegation to the Eighth International Astronautical Congress, held during August 1957 in Barcelona, Spain, pointed out that Soviet studies on the effects of space travel on human beings already are far advanced. These studies, simulating extremely high altitude conditions, were devised following space explorations using animal subjects. Scientists of the USSR and all other countries now have confirmation that living creatures can survive in a space vehicle for extended periods.

Space research programs in the Soviet Union will include the military medical sciences, giving researchers new substantive ways to resolve old problems and new opportunities for experiments in environments,

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TABLE 2
SOVIET BIO-MEDICAL SPACE PROGRAM 146
 Vertical Rocket Flights

DATE OF VERTICAL FLIGHT	No. of Dogs	ALTITUDE	DATA RECEIVED				No. of Flights	TRAINING	
			Pre-Flight	Vertical Flight	Post-Flight	RECOVERY			
1949-1982 (Used pressure suit without sealed cabin)	9	60 miles	(1-3 days before launching) 1. Electrocardiograms 2. Blood analyses 3. Pulse rate (95-180/min.) 4. Urinalysis	1. Partial & complete weightlessness (3.7 min.) 2. Maximum & minimum blood pressure values 6. Pressure variables inside compartment. (640 mm. Hg down to 18 mm. Hg until separation of rocket nose section, 188 seconds or 3 minutes)	8. Stabilisation 9. O ₂ feed in pressure suits, 8 liters per min. (2-3°C temperature variance) 10. Safety reserve of pressure suit not less than 2½-3 Psi 11. G-Load (a) Acceleration (transverse). 5G, 100 seconds (b) Deceleration (variable axis). 5G, 40 seconds 12. Ascending trajectory speed, 1.72 km/sec 13. Descending trajectory, 1.76 km/sec	(1 day after flight) 1. Electrocardiograms 2. Blood analyses 3. Pulse rate (normal) 4. Urinalysis	(Descent in catapult cradle) 1. Radius, 3-70 km (18-42 miles) from launching site 2. 3-8 hours after launching 3. Parachuting (a) Increase or decrease of 2-5 respirations per minute	6-12 9-18 5-12(?) 1 Total: 21-42	(Conducted daily for several months) 1. Two hour stay in pressure suit (attitude, behavior, and neurological) 2. Twice daily feeding schedule 3. Catapulting of carriage with dogs under ground condition 4. Pressure helmets 5. Vibrastand 6. Hermetically sealed cabin 7. Absolute and excessive pressure in regard to the suit 8. Acoustics 9. Capsule space (0.28 m ³)
1960-1967 (Used pressure suit without sealed cabin)	12	65 miles							
1967-1968 (Used sealed cabin at 1 atmosphere)	5	60-130 miles							
27 Aug 1968	2	270 miles							

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TABLE 3. SOVIET BIO-MEDICAL PROGRAM¹⁴⁶ Sputnik-II Orbital Flight (Laika) — 3 November 1957

	PRE-FLIGHT ORBITAL TRAINING AND BIOLOGICAL DATA	BIOLOGICAL DATA (ORBITAL) — QUALITATIVE REFERENCE REPORTED BY SOVIETS	BIOLOGICAL DATA AND INSTRUMENTATION
Perigee — 140 miles (18,000 m.p.h.)	1. Gradual training of dogs for protracted and confined trip in small cabin.	[REDACTED]	1. Cylindrical sealed container — 640 mm (diameter) and 800 mm (length) with removable cover and inspection hatch.
Apogee — 1,038 miles (15,000 m.p.h.)	(a) Accustomed to laboratory furnishings.		2. Food and water supply — 3-liter metal container.
Orbit Time — 103.75 minutes	(b) Confined in special cages.		3. 7-day ration — gelatinous material containing necessary amount of water and nutritive ingredients (automatic feeder trough and water dispenser).
Remarks:	2. Size of cages gradually diminished, finally approximating that of airtight satellite cabin.		4. Measurement of respiratory rate using strain-gauge indicators with resistance from 0.3 to 25 k. ohm.
Number of Dogs Selected for Complete Training — (a) 10 dogs selected (weight about 6 kg.) (b) "Laika" selected from this initial group for Sputnik II Orbital Flight (female, 2 yrs. old, wt. 6 kg.).	3. Confinement increased from hours to 15-20 days.		5. Amplifier-commutation unit with 3000 as coefficient of amplification.
	4. Animal adaptation to accoutrement for registering physiological functions.		6. Restraining cloth suit for actual flight.
	5. Training of animal for defecation and urination during 20-day confinement.		7. Rubber sanitary arrangement attached to airtight "latrine" reservoir. Activated carbon and specially dried moss for deodorization and absorption.
	6. Tolerance to noise of operating assembly.		8. Sealed cabin constructed of aluminum alloy (interior and exterior).
	7. Caloric measurements and general food composition.		9. 7-day programming of air regeneration system.
	8. Measurement of energy requirements (varied within limits of 400-850 cal. per day).		10. Ventilation (small electric motors).
	9. 100 grams per day of pressed food (40% bread crumbs, 40% powdered meat, and 20% beef fat) during initial experimental feeding period of 20 days.		11. Controlled animal body heat (special heat-conducting screen).
	10. Measurement of water consumption (average 120 ml. and not more than 200 ml. per day).		12. Controlled pressure relay (no rise above 765 mm Hg permitted).
	11. Selection of final gelatinous food mixture (basic nutrients, water and agar-agar).		13. Control of cabin temperature above 15°C. (twin thermo-relay).
	12. Combined effect of acceleration, noise and vibration.		14. Temperature indicators and checks for ventilation (wire rheostats and potentiometers).
	13. Tolerance to vibration loads up to 10 g. (Vibration caused greater functional changes than did sound.)	15. Radio apparatus for ground relay.	
	14. Acceleration (chest-spine direction) — 2 to 10 g "overload" for 6-15 minutes:	16. Instrument for study of ultraviolet and X-rays from sun.	
	(a) Increased saliva excretion	17. Protracted laboratory testing of instrumentation under vibratory and accelerative conditions.	
	(b) Pulse rate increased 1.5-2 times normal		
	(c) Respiratory rate increased 1.5-3 times normal		
	(d) Arterial pressure increased 50-80 mm Hg.		

"Laika" apparently died of anoxia.

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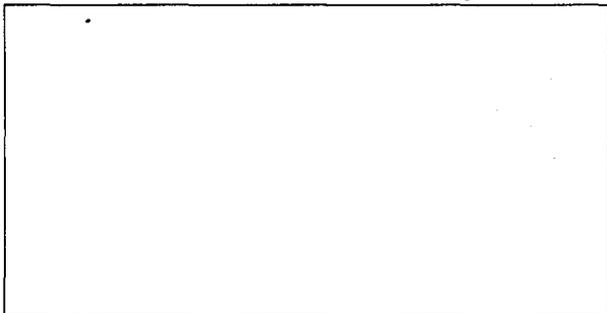
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such as a near-perfect vacuum, intense solar exposure, or bombardments by cosmic and other radiations. Problems of major military significance in space medicine will continue to be attacked with considerable success by Soviet scientists.

SOVIET RESOURCES

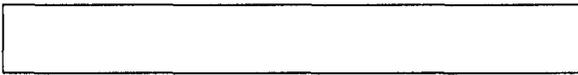
Organization, Planning, and Control

The permanent Interagency Commission on Interplanetary Communications was established in 1955 under the Astronomical Council of the Academy of Sciences, USSR. The Commission (figure 4) which coordinates and directs all research concerned with space problems, is headed by Academician L. I. Sedov and is composed of outstanding scientists of diverse specialties, including medical scientists within subordinate Scientific Councils. The membership of this Council has included such outstanding medical scientists as the late L. A. Orbeli and K. M. Bykov.

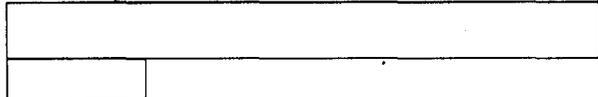


The Soviet space medical program is apparently centralized instead of being divided among branches of the armed forces. The Soviets consider research and production work on the "Sputniks" to be complementary to their efforts in military ballistics.¹⁶ (See figure 5 for the schematic dual relationship of the scientific program to military organizations and the many fields allied with certain developmental features of the Soviet space flight program).

Aeromedical requirements are believed to be established by the Aeromedical Section of the Learned Medical Council attached to the Chief of the Main Military Administration



of the Ministry of Defense and the successor to the 7th Main Administration of the Ministry of Aircraft Industry. When a research problem has been established, it is sent to the Academy of Sciences, and the directors assign the project on a priority basis to a research establishment or to an individual scientist. The capabilities of all research establishments are considered in meeting the needs of aviation and space medicine. Military medical institutes, medical councils, and scientific councils attached to the Academy of Sciences, and ministries throughout the USSR work together to coordinate the research.



Nature, Extent, and Adequacy of Facilities for Present and Future Research, Development, and Testing

Advanced investigations on space problems ** are underway at the Institute of Biological Physics, Academy of Sciences, Moscow; the Central Scientific Research Institute of Aviation Medicine, Moscow, and at least 25 other major institutes. An unknown number of subordinate laboratories are engaged in problems related to space flight. At least 100 Soviet scientists have published significant papers related to basic and applied aspects of space travel.¹⁹⁻²¹

The ambitious Soviet space program indicates a broad scientific base in aviation and space medicine, both in terms of the immediate research experiments conducted on the Sputniks and Mechta and in terms of long-range fundamental investigations. In some instances, the application of basic space programs through active participation of various research facilities is explicitly stated; in others, it is only a matter of conjecture. The successful launching and instrumenting of three satellites and Mechta provide ample evidence that the Soviet facilities and personalities are, thus far, adequate to support the space flight program.



"Lalka" apparently died of anoxia.

3 times normal
(d) Arterial pressure increased 50
-80 mm Hg.

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SPACE AND UPPER ATMOSPHERE MEDICINE

Functional Areas

Acceleration and Deceleration — New concepts on the biological effects of acceleration, if confirmed and extrapolated from current animal experimentation, will enable the USSR to simulate and eventually solve many bioengineering problems associated with rocket and space flight. The Soviets probably will lead in the study of acceleration effects on both peripheral sensory nerve functions as well as motor behavior, thereby increasing the efficiency of various techniques for postponing or reducing the adverse physiological effects of acceleration under space flight conditions. (See figure 6.) Soviet scientists have drawn special attention to transverse accelerations by vertical rocket recoveries and their launching and orbiting of the Sputnik II dog, Laika. The horizontal positioning (figure 7) of the dog (perpendicular to the direction of acceleration) minimized substantial displacement of blood from vital organs such as the brain and increased the resistance of the living animal to overloads by a large factor. The Soviets claim that a 10- to 12-fold acceleration overload is fully permissible for man. The Soviets point out that only the involuntary delay in breathing, produced by rocket acceleration limits the permissible time of action of an overload.²³

Also in overcoming the acceleration problem the Soviets may be using preliminary oxygen-saturation techniques to saturate not only the red cells but the plasma. By such a method, the Soviets claim that during the launching phase of perhaps 4 to 8 minutes man could presumably go without breathing.

Some other desirable effects of this "no-breathing" technique could be postulated:

- 1) Counteraction of any tendency toward hyperventilation.
- 2) Help in counteracting overload of the right side of the heart during the rapid acceleration.

Weightlessness — Soviet studies of man in the weightless state (high-speed aircraft maneuvers) were reported in 1956.²⁵ The So-

viets may well intend to alter or modify normal vestibular function by drugs or surgery, substituting visual and touch receptors in order to prevent serious physiological disturbances of circulation, digestion, respiration and mental function, which ordinarily accompany weightlessness and tumbling.²⁶ (Symptoms of sickness caused by weightlessness normally appear in 40 seconds or less, whereas the stress effect from motion sickness takes 15 to 20 minutes to develop.) As early as 1955, Soviet studies in exposures to sub-gravity were unique in that they isolated stimulus-sensation relationships, as physiological and illusionary responses to disorientation in space, adaptation to difficult meteorological conditions, etc. This research solved some biophysical problems associated with weightlessness in space.²⁷⁻²⁹ Adaptation to altered sensation was generally prompt and effective and, therefore, these findings could point the way to the solution of some of the more important problems of space medicine.

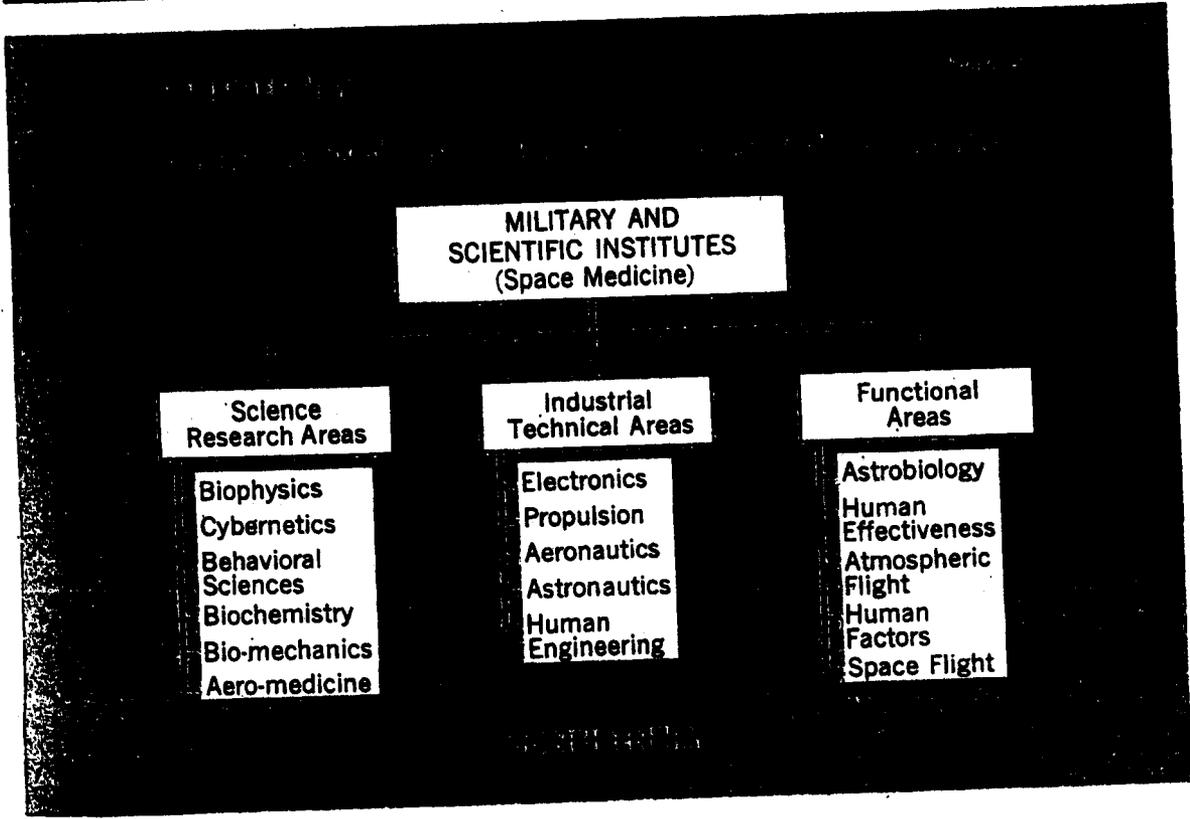
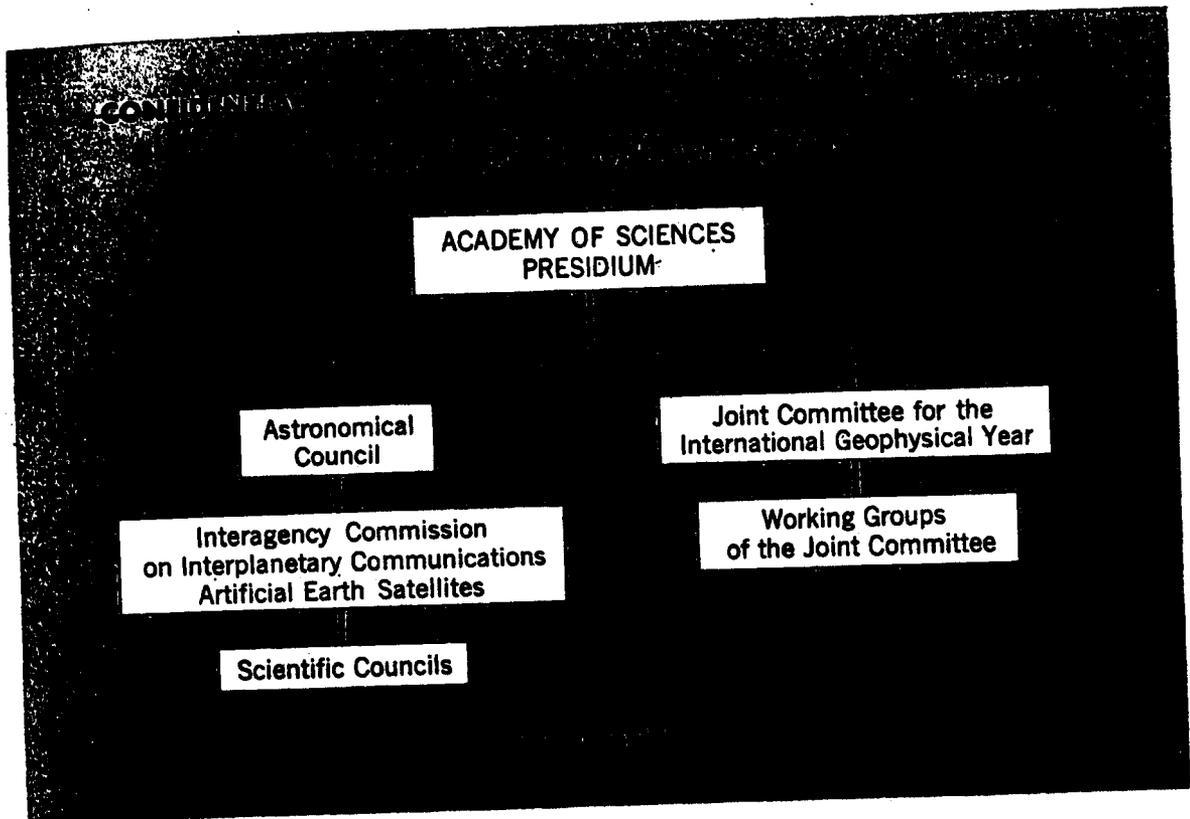
The Soviets have made functional tests of the semi-circular canals (inner ear) in a state of zero gravity on animals under rocket flight conditions.²³ The longest space flight to date by an animal was that of the dog in Sputnik II. The vehicle was under zero gravity, but the acceleration force actually experienced by the animal was dependent upon the rotation rate of the satellite and her location relative to the axis of rotation — and these factors are not known with certainty at present.²⁴

Other Soviet research discusses anti-gravity devices which could possibly diminish side effects such as red-outs or black-outs during violent stresses. Vehicles incorporating such devices would generate their own gravitational field, which would be quite independent from any external gravitational or non-gravitational field.³⁰⁻³³

Spinning During Launching Phase — The Soviet ability to stabilize their animal-carrying rockets, thereby eliminating or reducing spin to tolerable levels during the launching phase, demonstrates an appreciable lead in space biological experimentation over the United States. Rocket flight stabilization was of primary importance in safeguarding ani-

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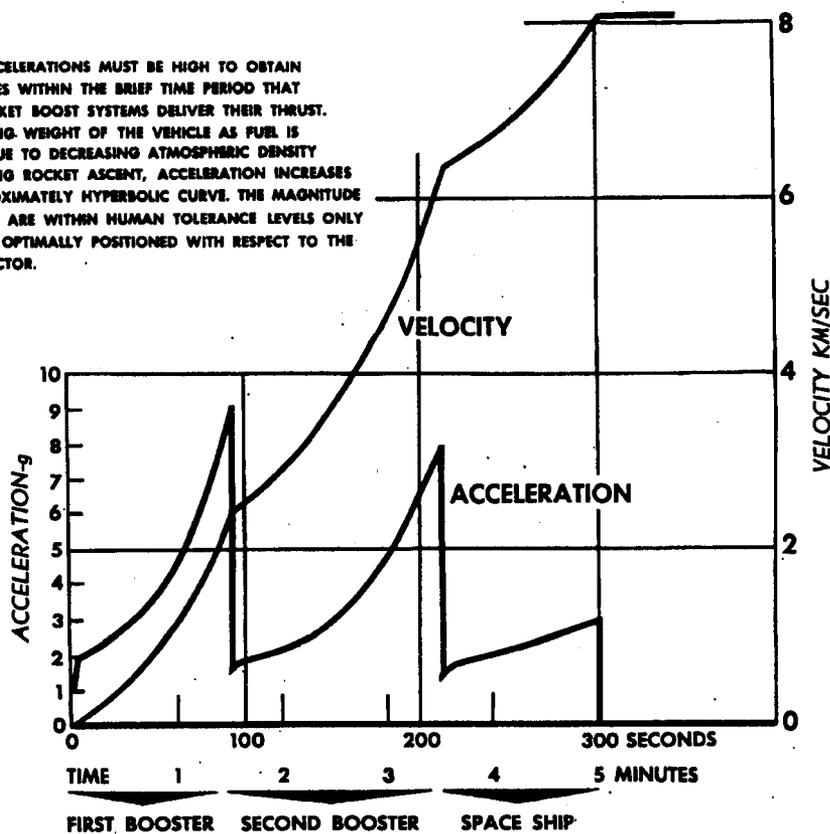


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Figure 6

ACCELERATION TIME CURVE

PEAK VEHICLE ACCELERATIONS MUST BE HIGH TO OBTAIN ORBITAL VELOCITIES WITHIN THE BRIEF TIME PERIOD THAT PRESENT DAY ROCKET BOOST SYSTEMS DELIVER THEIR THRUST. DUE TO DECREASING WEIGHT OF THE VEHICLE AS FUEL IS EXPENDED AND DUE TO DECREASING ATMOSPHERIC DENSITY ENCOUNTERED DURING ROCKET ASCENT, ACCELERATION INCREASES ALONG AN APPROXIMATELY HYPERBOLIC CURVE. THE MAGNITUDE OF THESE STRESSES ARE WITHIN HUMAN TOLERANCE LEVELS ONLY IF THE SUBJECT IS OPTIMALLY POSITIONED WITH RESPECT TO THE ACCELERATION VECTOR.



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mals in the vertical rocket flight launched in August 1958, to a calculated altitude of 240 nautical miles.²²⁻²⁵ Adequate stabilization also enabled the Soviets to use animals to test life sustaining systems in space and under space equivalent conditions to a greater degree than has been possible in the United States. The United States, however, has conducted more prolonged space equivalent experiments using manned balloon flights.

Nutrition — Soviet interest in exploring and exploiting space has stimulated nutritional research. The Soviets have emphasized research on problems related to substantial supplies of conventional food, as well as to water and oxygen for space flights lasting as long as two years. They consider that the weight of these essentials for a crew of four men will approach 11 tons, which accounts for their search for methods of diminishing such a tremendous payload for any future cosmic flight.²⁶⁻²⁷ The Soviets are aware of the possibility that green algae could be placed in capsules or concentrated and, along with the required water supply, might fulfill minimal nutritional requirements for prolonged survival in space. The Soviet choice of the algae group of *Chlorella* is important because it contains most of the essential food substances (such as proteins, carbohydrates, fatty acids, vitamins and minerals) and can be readily assimilated.

Other Soviet laboratory research on nourishment under conditions of prolonged space-flight has included cultivation of both special seaweed, containing a large quantity of protein, and mollusks, from which a nutritious fat can be extracted. According to the Soviets, approximately 200 liters of seaweed — enough to nourish a man for 6 months — can be raised inside a space vehicle. They have concluded that the plants not only solve the nourishment problem of spacemen, but also help to create normal atmospheric conditions.²⁸⁻²⁹

In addition to the problem of dietary sustenance, the Soviets have also been concerned with the stress effects of fatigue which are important in determining the best diet for maintenance of efficiency.

High-Frequency Magnetic Fields — Since 1955, Soviet biophysicists have emphasized the problem of investigating the functional effects exerted by alternating magnetic fields on the human organism.⁴⁰⁻⁵¹ With the continuing development of rocket, missile, and satellite capabilities, the objectives of this medical research may tie in with magnetic acceleration of matter for possible space flight propulsion. The Soviets have made reference to this and other ionic propulsive phenomena; also, some evidence of this development has recently come into view, for example, the production of high-energy particles in intense pitched sparks as related by I. V. Kurchatov (Nucleonics, 14, 37/1956).

Recent Soviet data have been reported on the effects of magnetic fields on 128 persons who were exposed routinely to such fields set up by high-frequency currents. The Soviets made the following conclusions concerning this stress hazard:

a) Functional changes in the central nervous system appeared in people who worked near high-frequency currents.

b) Changes were transitory and not inclined to be progressive.

c) Women apparently are more sensitive than men to the action of a high-frequency induced magnetic field.

Extraterrestrial Environments — In December 1956, a multidisciplinary conference was held at the State Astronomical Institute imeni Shternberg under the auspices of the Interagency Commission on Interplanetary Communications, Academy of Sciences, USSR. A. G. Karpenko, scientific secretary of this Commission, noted that this was the first time such a gathering had been held in the Soviet Union. The conference approved a research plan for the Institute of Biological Physics of the Academy of Sciences, USSR and also passed a resolution on the necessity of forming a special Institute of Cosmic Biology.^{52-59 150} The research plan included basic aspects of supportive biological research.

New evidence from Polish astronomer Jan Gdamski indicates that at least four other suns are better equipped to support human life on their respective planets. This scientist

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has analyzed the living conditions surrounding the 59 stars lying within 17 million light years of earth. Gadowski found that 16, or 27 percent, were similar to our sun in terms of such "life potential" factors as heat and light. Also, he estimated that four actually surpass the sun in liveability bands where planets could support human life.⁶⁰⁻⁶¹

The nature of this space research and medical evidence also support the view that the Soviets' ultimate goal is interplanetary flight rather than a more limited objective.

Infection — Two prominent Soviet microbiologists, in a discussion on the possibility that terrestrial microorganisms might acquire extraordinary pathogenic characteristics for man under space-travel conditions, have indicated that Soviet scientists are indeed studying the possible role of pathogens under simulated and/or actual space-travel conditions. Such studies might include the course of latent or acute infection in passengers on space vehicles, changes in the characteristics of microorganisms when exposed to extra-terrestrial environments, and the possible existence of human pathogens on other astral bodies.⁶² Soviet virologists Zhdanov and Petersen claim that space selectees will not suffer from heightened pathogenicity of saprophytes or of viruses present in the human organism. New horizons are opening up in Soviet studies on viral disease morbidity of would-be human and animal space travelers.
63 64

Radiation • — Vertical rocket flights to high altitudes (approximately 270 statute miles), together with successful recovery of the experimental animals, have probably enabled the Soviets to derive data on latent biological radiation effects, although no such data have been officially released. However, serial blood counts and extensive follow-up examination of the experimental animals within one day following recovery revealed no harmful effects. Sputnik II has probably given the Soviets an initial lead in quantitative data from analyses of radiation measurements programmed for the experiment.

* For more extensive discussion (Van Allen data) see Monograph IV of this series.

The Soviets have not released any quantitative data on the nature and intensity of known or unknown radiation sources. There are indications that the Soviets will attempt to avoid the radiation hazard by orbiting below or above the radiation belt in an appropriate trajectory. However, the hazard of cosmic radiation remains an open question, since there is no known effective way of shielding against it. Still unknown also is the relative biological effectiveness (RBE) of cosmic radiation as compared with other known forms of radiation. Results from Sputnik II, which did not travel quite so far out in space but went to higher northern and southern latitudes, should be roughly compatible with Explorer IV results. Physical measurement indicates that dosage from unshielded cosmic is low, and most researchers feel there will be no measurable adverse effects for short exposure times, although genetic or local tissue effects for prolonged exposures are possible. In terms of dosage, cosmic provide at most about 25 mr per 24 hours, up to about 10,000 miles. As one approaches the sun this dose should increase slowly, since the 10 percent due to solar activity will be increasing on the basis of the $1/r^2$ law, except for sudden variations from solar flares, etc. For all practical purposes, however, the rate of 25 mr per 24 hours should be a satisfactory figure for voyages no closer than half-way to the sun. One other possible radiation hazard should be mentioned. There have been many observations indicating the presence of neutrons in space. To date, no data have been obtained to permit any evaluation of this hazard.

Preconditioning — One unique feature of the Soviet space medical program is perhaps the degree to which space animals are preconditioned. It is quite possible that the vestibular apparatus of the Sputnik test dog was altered or modified by surgery or drug prior to its prolonged space flight in order to study the positioning sense of the animal through other sensory organs. Since the sensory vestibular apparatus is responsible for signaling the position of the body in the space environment, disruption of this apparatus could provide significant data for fu

Figure 11

BIO-HANDS

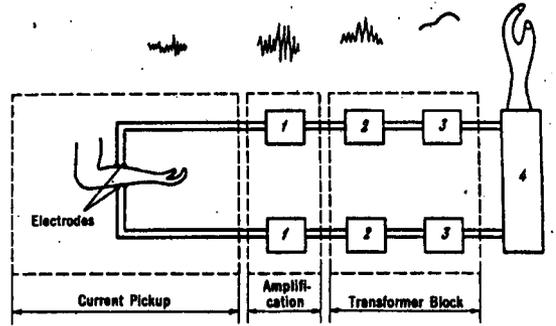
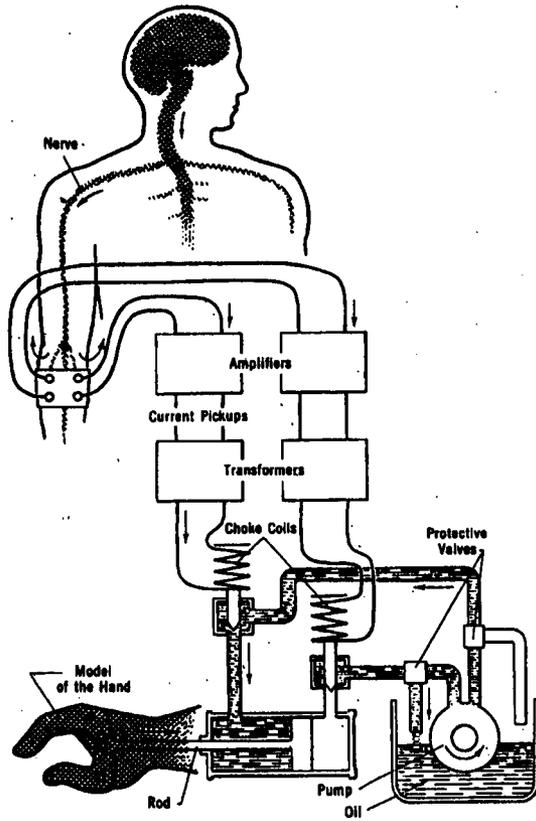
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Figure 11

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BIO-HANDS



BLOCK-DIAGRAM OF THE BIOCURRENT MANIPULATOR
 1. AMPLIFIER 2. RECTIFIER 3. INTEGRATOR 4. MANIPULATOR

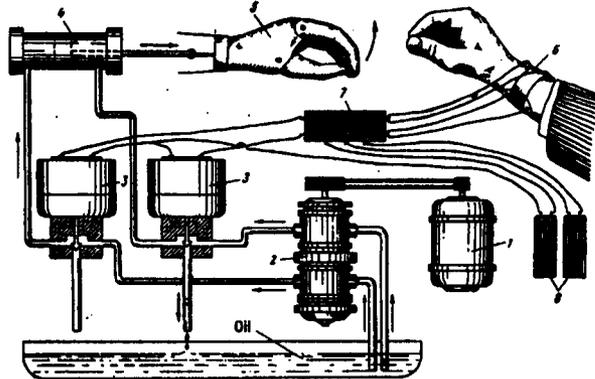


DIAGRAM OF AN OPERATING MODEL OF THE MANIPULATOR
 1. ELECTRIC MOTOR 2. DUAL PUMP 3. ELECTRIC AUTOPILOTS WITH HYDRAULIC VALVES
 4. CYLINDER WITH PISTON 5. PROSTHETIC HAND MANIPULATORS 6. BRACELET WITH TERMINALS
 7. ELECTRONIC TRANSFORMER 8. POWER SOURCE

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ture studies on problems of weightlessness. In the past Soviet scientists have meticulously followed prescribed regimens of compensating for altered position sense by adapting test animals to new types of coordinations and by conditioning animals to other orienting senses, such as sight and touch. Presumably, if an animal could be oriented through use of sight and touch without vestibular assistance, it would not have much difficulty in a weightless state and would not be liable to motion sickness and accompanying digestive and circulatory disturbances. However, this technique of altered responses cannot be extrapolated directly to humans, and further research along these lines is undoubtedly in progress.

Selection of Animals in Vertical Rocket Research—An April 1958 interview with Anatoly Karpenko, Scientific Secretary of the Interagency Commission on Interplanetary Communications of the Academy of Sciences, USSR, revealed the following three reasons for the Soviet preference for dogs in space flight experimentation:

- 1) acceptably high order of neurological system.
- 2) easily and quickly trained for a passive role.
- 3) readily taught to be content with unusual environments.

The use of trained dogs provides the Soviets with many answers about the emotional reactions resulting from the stresses of rocket flight and orbital weightlessness. Also, to some extent, these experiments indicate the permanency of original infrahuman conditioning and the degree to which the dogs were conditioned spontaneously by the forces of the vertical rocket flights.⁶⁵

Space vehicles are subjected to vibration and acoustic excitation, the magnitude and frequencies of which are primarily determined by the power plant used. Highest magnitude of vibrations occurs during boost or launch and lasts about 10 seconds. As a vehicle reaches altitudes where air density is very low, the aerodynamic acoustic energy decreases and the power plant acoustic energy is not propagated by the aid of the rest of the vehicle.

Many space travel problems remain unsolved by Soviet and Western scientists, and the biological data acquired from Sputnik II clearly indicate the need for continued and expanded research to minimize hazards of space flight.

Toxicological Hazards (Fuels)—The evolution of high-heat fuels and Soviet development of the boron hydrazine compound, pentaborane, are important from a toxicological standpoint. The Soviets plan to produce large quantities of borane compounds, and the increasing availability of these materials, along with the high toxicity of borane hydrides may lead to a considerable number of accidents resulting from the Soviets' handling of these compounds during their industrial development and end use.⁶⁷⁻⁷¹

Vibrations—Some unusual physiological studies which indirectly apply to acceleration are underway in the USSR. It appears that humans and dogs are undergoing vibrational testing (figure 8) to determine the effects of vibration as a receptor irritant of visceral organs.⁷²⁻⁷⁴ According to the Soviets, a number of new facts have been discovered as a result of the experiments on humans. The subjects usually were placed in a reclining or

* Weightlessness affecting the nerve centers was suggested as the cause of the accelerated heart rate and respiration on 27 April 1958.

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transverse position and vibrations * of single frequencies (100 cycles) with amplitudes ranging from the very low of 0.1 millimeter (.004 inch) to a high of 1.5 millimeters (.04 inch) were employed. It was tentatively concluded that the local action of vibration has a generalized but different functional effect on the internal organs, the motor analyzer, and the response mechanisms of each test subject.

Acoustics Research—The USSR has a well-qualified group of scientists and technicians engaged in infrasonic, sonic and ultrasonic research and development. Active programs exist for studying wave diffusion through some types of biological and physical media; they include work on medical acoustics, psychological acoustics, signal analysis, and information theory.

It is believed that until recently a serious deficiency in Soviet laboratory instrumentation existed, which, together with a more rigorous classical education, tended to stress basic theory. It is not believed that backwardness in instrumentation development is any longer deterring progress. The Soviet program in this area is comparable to that of the advanced nations of Western Europe and is capable of producing original contributions in selected areas.⁷⁵

Physiological Acoustics—Some of the Soviet basic physiological studies, using specific experimental techniques (table 4), may lead to improved design in space vehicle equipment.⁷⁶⁻⁷⁸ These studies included fundamental research on auditory conditioned reflexes (table 5). For example, the Soviets described simple reflex responses to sound stimuli weaker than those to which verbal responses can be obtained, which indicated a need for revision of the differential and absolute auditory thresholds as established in the West. The Soviet use of different reflex responses, divided into basic groups, makes it possible to discriminate certain character-

* Acceleration by vibration increases logarithmically with the amplitude at a constant frequency. For example, vibration at 100 cycles per second with an amplitude of 0.12 inches will produce 10⁶ G's. G forces produced by vibration are different at different points within the body.

istics of a sound signal. These responses may have important application to man-vehicle systems and feed-back mechanisms involved with information theory. Because of man's potential as an instrument, a data processor, and a computer, along with high reliability, the human operator may prove to be a vital, versatile and economical part of the most complex space vehicle system.

TABLE 4

PHYSIOLOGICAL ACOUSTICS

Laboratory of Physiology of Hearing,
Institute of Physiology imeni I. P. Pavlov, Academy
of Sciences USSR,
Leningrad—1958 (Director—G. B. Gershuni)

ASPECTS OF HEARING

1. Threshold Measurements on Humans
2. Electrical Measurements on Animals
3. Psychophysiological Studies of Dynamic Behavior

TABLE 5

PHYSIOLOGICAL ACOUSTICS

Six Methods Studied and Intercompared for Absolute and Differential Threshold Measurements on Human Hearing

1. Direct "Verbal" Response
2. Non-Verbal Response
3. Electroencephalogram (EEG)
4. Galvanic Skin-Resistance Response
5. Conditioned Eyelid Response
6. Conditioned Finger Response

Pathological Acoustics—Soviet studies on the cumulative effects of noise on the human organism appears to be many sided. As early as 1955, such investigations were accorded a priority by the Academy of Sciences, USSR.⁷⁹ Currently, the Soviets point out the detrimental effects of noises upon the central nervous system and arbitrarily refer to the reaction of the organism to noise as "noise disease".⁸⁰⁻⁸³

The Soviets state that noises of greater magnitude (120-130 decibels) are harmful. However, they also indicate that noise of 90-100 decibels, depending upon its spectral composition, can lead to functional breakdown in the gray-matter (cortical) dynamics, thereby exerting an influence upon the psyche, weakening attention, and causing clinical symptoms (fatigue, insomnia, fear).

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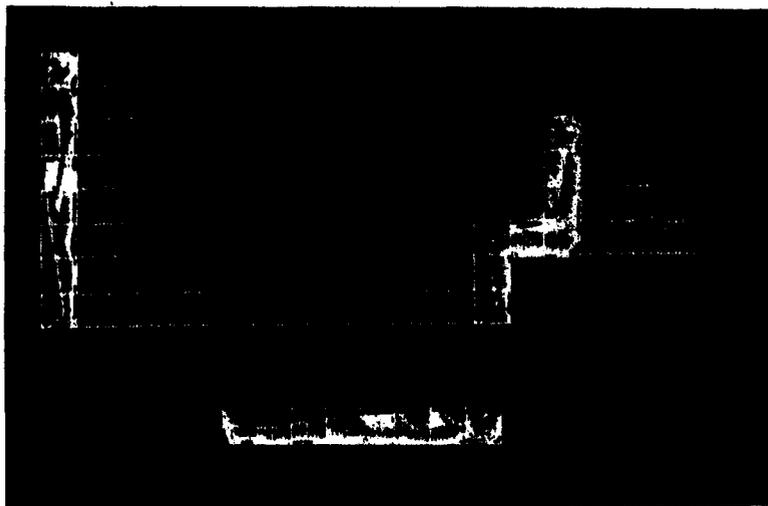


Figure 7. Overload factors (positioning.) "The most comfortable position of the body during ascent is the "lying position". In this position fatigue will be minimal. The hatched area shows the rate of loading within every cube."



Figure 8. Vibrastand (vibrator studies.)

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This Soviet research directly bears upon space medicine since it helps to explain the fundamental mechanisms undergoing physiological alterations which occur in ground maintenance crews and test subjects during the phases of launching and flight up to orbital and escape velocities.

Biomedical Observations in Space (Sputnik II) — Soviet use of an artificial satellite for biological experimentation (1957) provided them with physiological data from a highly trained dog in an orbiting space vehicle. From the biomedical point of view, the Soviets created orbital satellite conditions which approach, if not duplicate, those which will be experienced during interplanetary flight.

Soviet bioastronautical research with a satellite provides important types of information: firstly, the development of a sealed cabin system for regulating its functioning which will satisfy conditions required for sustaining life of an animal at all stages of the orbital flight; and secondly, the study of the biological effects of the stress factors of orbital space flight.

The adequate study of biological influences of certain other stress factors (radiation and re-entry) will be realized only with the launching of satellites which permit equipment and animals to be safely recovered.

Sealed Cabin Equipment and Experimental Apparatus — Soviet demands for economy in weight and size influenced the construction of an aluminum, airtight cabin for "Laika" in the Sputnik II experiment. The sealed cabin, reinforced by a sturdy frame, was a cylindrical container 640 millimeters in diameter and 800 millimeters in length provided with a removable cover and inspection hatch.

The animal cabin contained equipment for air regeneration (highly active chemical compounds), temperature regulation (small dimensional electric motors; special heat-conducting screens), food troughs and automatic feeders, a sanitary arrangement (deodorization and absorption reservoir containing activated carbon and specially dried moss), and electronic medical apparatus,

commutation units, amplifiers and pick-ups for registering the physiological functions and motor reactions of the animal.

A supply of gelatinous material containing the necessary amount of water and basic nutritive ingredients adequate for a 7-day ration was contained in a 3-liter metal container.

Laika wore a light, woven garment attached to small restraining metal chains which restricted the animal's mobility while permitting her to stand, sit, or recline, and to move back and forth along the longitudinal axis of the cabin. See table 3 for other qualitative data.

Training of Experimental Animals — Ten dogs were selected for the preparatory training period of several months. From this group, "Laika" was chosen for the final orbital experiment. The Soviets considered the initial phase of training complete when the animal had spent 20 days in its confining cage without undue signs of agitation and exhibited no general or local ill effects. The final training phase consisted basically of conditioning and influencing the resistance of the animals to various environmental factors experienced in a sealed cabin (noise, acceleration, vibration, positioning, etc.). A detailed breakdown of the Soviet training schedule is available in table 3.

Results of Satellite Research with "Laika" — The Soviets divided this experiment into three basic periods: the pre-flight period, the launching and escape into orbit and the orbital flight of the satellite. During the pre-flight period, Laika's condition in the Sputnik II cabin was completely satisfactory and was essentially the same as that observed during previous laboratory experiments.

The Soviet qualitative analysis of the electrograms (7 separate recordings) during the launching of the satellite (3 November 1957) revealed no pathological deviations from the normal. The period of orbital flight produced complete weightlessness with no essential change in the physiological functions of the animal. No clear biological effect of the action of space radiation on Laika was observed.

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Human Factors Engineering

Deceleration Devices — As early as 1957, a Soviet writer reported the construction of a so-called aerodynamic or rocket "carriage" which simulates the physical conditions of flight velocities and aerodynamic forces. This horizontal device, as reported, does not refer to any known Western sled. The physical description includes a special railroad path of 3 to 7 kilometers length (1.8 to 4.2 miles) with some auxiliary mechanisms. According to this report, devices of existing design can reach a speed up to 1500 meters per second (about 3600 miles per hour) with acceleration forces up to 100 g.⁸⁴⁻⁸⁵ Soviet utilization of such a vehicle would aid them in determining the performance limits of their present ejection seats and to obtain physiological data for establishing human tolerance to deceleration from extremely high speeds. Such experimentation could also lead to the development of new escape techniques and radically changed protective equipment for advanced Soviet space vehicles.

Space Flight Equipment — In order to maintain an adequate environment for short manned space flight, the Soviets are experimenting with a hermetically sealed cabin with oxygen provided from pressure tanks.⁸⁶⁻⁸⁸ These cabins include an air conditioning and circulatory system, temperature control devices, and sensitive equipment for measuring the internal environment of the cabin. Devices for the measurement of physiological data from the test subject, including pulse, blood pressure, respiration, and temperature are in use.⁸⁹⁻⁹³

Excess CO₂ is removed from the cabin atmosphere by the use of chemically absorbent lime; excess water is removed by hydroscopic silica gel. Ventilated space suits with attached sealed plastic helmets are worn by experimental animals. Soviet vertical rocket data support the conclusion that their present system is completely adequate for maintaining a habitable atmosphere in a cabin containing two dogs for at least 6 hours. Temperatures recorded from the experimental animals and the cabin were within normal

ranges. No physiological disturbances were noted in the experimental animals as a result of their cabin environment.

Living alga, suggested already as a potential partial food source, could also serve as an O₂ source during prolonged flights.

Bio-Energetics and High Temperature Effects — Some Soviet research is devoted to the analysis of human adaptation and tolerances to the increased temperatures that occur in flight vehicles traveling at high speeds. Relative humidity, barometric pressure and other environmental conditions are being studied as important stress factors.⁹⁴⁻⁹⁶ In orbit, a potential vehicle skin temperature of from 300° to 100°C below zero exists. Internal temperatures should be maintained between 10° and 30°C for human habitation. In the quest for higher speeds and the recovery of man, Soviet scientists may have encountered a number of operational temperature problems such as heat transfer and the high temperatures of present and future propulsion mediums (figures 9 and 10). Important aerodynamic heating effects occur, of course, on re-entry. The vehicle skin temperature increase during ascent is only about 600°F, but it is a major design problem to keep the skin from actually melting, vaporizing, or burning away during re-entry.

The Soviet development of microthermistors, with dimensions amounting to fractions of a millimeter is very significant. The Soviets claim great precision for this device in measuring skin temperatures of living organisms. With these devices, temperature-time curves are recorded with a lag of less than one second. By using this method of measurement, the Soviets also claim the existence of hitherto unknown characteristics in the physiology of respiration and transpiration.⁹⁷

Bio-mechanics in Space Flight — A Soviet radio-broadcast recently claimed development in the USSR of an "iron arm" run by the brain.⁹⁸⁻¹⁰⁰ Photographic evidence (figure 11) does not indicate that this specific device operates as the result of brain-wave transmissions. The described technical advance is probably the mechanical translation of elec

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Figure 9

PROPULSION TEMPERATURES

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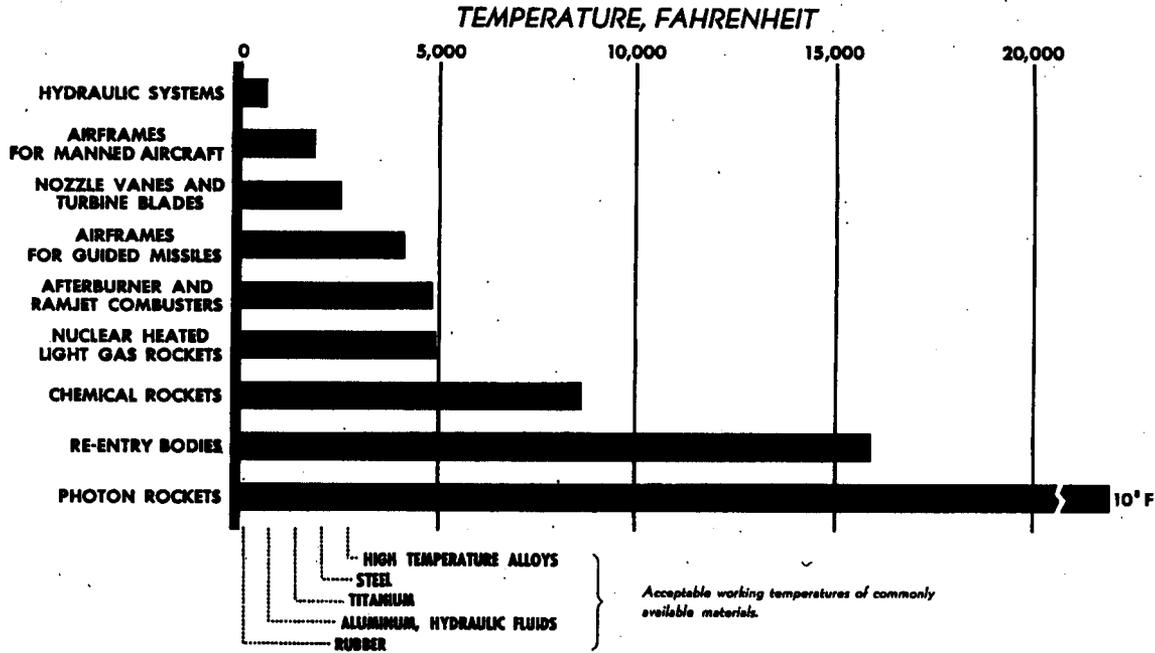
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Figure 10

OPERATIONAL PROPULSION TEMPERATURES

"HIGH TEMPERATURE" PROBLEMS START AT 200° FAHRENHEIT

(MAY AFFECT INTERNAL VEHICLE TEMPERATURE)



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impulses generated by the operator's forearm and hand muscles, thereby imitating human hand motion.

Such a apparatus could open up new prospects for man to operate flight vehicles without gross muscular effort by the pilot, dependent to the human and not to manual control. Also, such an instrument, when used in space vehicles, would enable Soviet scientists to conduct experimental operations which, at present, can be performed only by a well-trained human hand. Soviet scientists are also reported to be investigating models of "hands," controlled electrically as well as by radio at great distances, which are capable of sensitively determining changes in temperature, hardness, and irregularities of handled objects.

In late 1958, the Soviets stated that the development of cybernetics makes it possible to build equipment which, without human intervention, will be able to calculate physical measurements (navigational programming; bio-mechanics; ground relays).¹⁰¹ The implications of Soviet work on artificial muscle actions would be of importance to cybernetics, mathematical logic and systems biology as supportive links between the sort of biological systems that are actually used by humans and the machine analogies to be exploited for future research.

Hermetic Cabin of Soviet Space Vehicle. The Soviets suggest an atmosphere composed of equal parts of oxygen and helium for future space cabins,^{102 103} and have considered its thermal conductivity, ability to form isotopes, proneness to spontaneous combustion, and other physical and chemical properties. According to the Soviet findings, helium possesses considerably greater thermal conductivity than nitrogen, thereby providing normal temperature maintenance in the cabin.

The disadvantage of using helium is its tendency to escape from imperfectly sealed capsules. However, such an inert component of the air in a space vehicle is preferable for weight and other considerations. The weight of the air of a space station of 18,400 m³

volume would be about 25 tons. Of these 25 tons not less than 20 tons would be nitrogen. The volume of helium exerting the same pressure would have a weight of only 2.3 tons, a saving of more than 16 tons of transport weight. Furthermore, as the solubility of helium in blood is only one-fifth that of nitrogen, the risk of bubble formation (embolism) in the event of an explosive decompression would be almost negligible.

Superclean Environments—Soviet research on supercleanliness is only of peripheral

* For further information see Monograph VII of this series.

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medical interest, but it is a primary factor (contamination of delicate mechanical and electrical systems by minute particles of dirt, dust or airborne micro-organisms) and indicator of the fabrication of high precision components (space vehicle flight control; radar detection; information control; inertial navigation systems). The Soviets appreciate the importance of supercleanliness and have worked out the theoretical aspects of contamination, even in very small particle-size ranges. There is some evidence of Soviet dust-free rooms. Also, they have developed some equipment which is suitable for maintaining superclean conditions, and their standards are comparable to those prescribed in the West.¹⁰⁷

Radiation Shielding Technique (Sputnik III) — Analysis of the excess weight (over 800 lbs.) in Sputnik III suggests the possibility that the USSR is actively investigating specific radiation shielding techniques. Previously, the Soviets have claimed that they know the quantity and quality of radiation in space (to the limits of Sputnik's flights) and its radiochemical effect on internal gas mixtures of hermetic cabins.^{108 109} In addition, the Soviets mention the possibility of using a series of thin layers as a radiation shielding technique.¹¹⁰ Their recent research on boron derivatives is possibly relevant to the synthesis of materials suitable for shielding, such as the use of boron-10 (non-radioactive isotope) in various matrices. Laboratory tests on neutron absorption indicate that a given thickness of this isotope is slightly over 5 times more effective than natural boron, 20 times better than lead, and 500 times better than concrete. By the use of such materials, the danger of neutron-induced vehicular contamination and the resultant biological hazards can be lessened. This would not, however, solve the primary cosmic ray shielding problem nor that for the bombardment by very energetic protons or electrons.

Systems Biology — The study of cybernetics may give the Soviets new means of making accurate investigations of many biological problems resulting from environmental factors. This Soviet research has possible appli-

cations in space medicine from the standpoint of the statistical characteristics (pitch, amplitude, and frequency) of speech.¹¹² These approaches lend value to the development of telemechanics and the operation of mechanisms at a distance through spoken and tone signals.¹¹³

Recovery Techniques — Vertical Rockets (Animal Bearing) — Soviet animal recovery experiments differ from those of the United States. In the United States, animal experiments using vertical rocket flights have not been carried out for several years and emphasis has been given to experiments using sealed gondolas attached to high flying balloons. Soviet recovery studies also differed from those carried out in the United States in the following respects:¹¹⁴

- a) The dogs were not anesthetized as were the monkeys used in the United States.
- b) Pressure suits were used on experimental animals for the first time.
- c) The dogs supplied with an ejectable recovery apparatus were exposed for about one hour to the environmental stress of the upper atmosphere.

Recovery of Soviet Man from Space — It is believed that the problem of recovery is one remaining major obstacle to the Soviets' placing a man * in space. In attempting to solve this problem the Soviets are guided by the results of animal experiments held between 1949 and 1958. The Soviets detail the following steps for safely recovering a man from space:^{115 116}

- a) At an altitude of 330,000 feet the rocket head containing the man separates from the rocket. The rocket head then free-falls to 115,500 feet in 116 seconds.
- b) At some altitude above 115,500 feet, a small stabilization parachute (possibly a nozzle-valve type) is deployed to reduce tumbling and to orient the rocket head in a desired attitude during descent.
- c) From 115,500 feet to 92,000 feet the stabilization parachute sharply decreases the

* See appendix A (Biographic Data), II, for four possible candidates.

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of descent and the man is subjected to 5.3 g's for 10 to 12 seconds.

From 92,000 feet to 16,500 feet the g forces are less, and in the range of 16,500 feet to 9,000 feet the man can eject from the capsule (figure 12), and continue the descent by conventional parachute.

The successful completion of such a large portion of their experimental work suggests that the Soviets consider recovery by parachute as their most practical method for early recovery of a manned space capsule. In conjunction with these recovery techniques the Soviets also call attention to the sudden changes in metabolism and the unknown human effects of transition from weightlessness to terrestrial conditions. According to the Soviets, such recoveries will possibly require a certain intermediate conditioning period of limited physical stress and thorough medical observation.¹¹⁷ The cardiovascular system, accustomed during weightlessness to transport the blood column without the force of gravity, might need a certain time for adaptation after re-entering a gravity field.

Water Impact Area — In the latter part of 1958, the Soviets proclaimed Lake Baikal a state nature reserve for furtherance of scientific research and biological achievements.¹¹⁸ Because of the proximity (East, down-range) of this vast lake to rocket launching areas, this disclosure suggests an attempt to cover-up and control restricted areas, possibly for a future water impact recovery. This technique would constitute a decided safety factor for human recoveries.

Theoretical Research

Fundamental Understanding of the Cytochrome System and Oxygen Activation — In the field of biochemistry, the Soviet scientists have been studying the cytochrome system (porphyrins and other iron complexes), which is essential to oxygen activation in cellular respiration. The degree to which this basic research can be applied to the stress problem of oxygen activation in space flight is open to question at this time.¹¹⁹⁻¹²² Possibly through understanding these enzymes, the

Soviets may hope to alter the metabolic processes of living organisms in those situations involving extremely high altitude.

Vapor Formation Phenomena — As early as 1950, the Soviets considered that the phenomenon of mass vapor formation in tissues of the organism represented a little-explored domain of high altitude physiology. At the present time, world literature reveals little research on this space flight problem. The beginning of this type of Soviet research in 1950 was related to determining the peculiarities of the development of vapor formation in the living organism at various altitudes, times, and locations. The Soviets termed this phenomenon a "decompression tissue emphysema." They attach particular significance to this problem as the phenomenon can cause not only temporary, reversible physiological changes but also leaves traces of deep, irreversible pathological damage in the structure of internal organs and tissues.¹²³

The 1954 Soviet claim of lowering body temperature artificially (hypothermic techniques) by 5° to 12°C for complete protection against vapor-formation phenomena is of considerable importance when considered with other Soviet research on mild hypothermia, effects of cold acclimatization, and ventricular fibrillation.¹²⁴⁻¹²⁷ This Soviet high altitude research may be revelant, primarily, to preorbital flight rather than longer orbital flight periods.

Psychophysiological Basis of Visual Sensations — Major Soviet emphasis continues to be assigned to research and development in the areas of optics and vision.¹²⁸⁻¹³² The Soviets are concentrating their visual studies on depth discrimination, spatial perception, and sense organs as well as on artificial information-handling devices.¹²⁹

These studies, important to active surveillance in space flight, indicates an attempt to identify basic visual mechanisms. Comprehensive data on the organism's capability to recognize multiple objects in a spatial field of decreased luminance existing at extreme altitudes have not hitherto been compiled. (See table 6 and figures 13-16 for hypothetical situations.)

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TABLE 6
MEASUREMENTS OF SKY LUMINANCE
AT SELECTED ALTITUDES

<u>EQUIVALENT FOOT CANDLES</u>	<u>ALTITUDE (feet)</u>
1,140	10,000
910	20,000
760	30,000
490	40,000

(Sun elevation of 45°, a point in the sky at 45° azimuth to the sun and 30° elevation above the horizon)

The biomedical objective of Soviet investigations on visual systems at various altitudes appears to be related to spatial transparencies (space perception, spatial orientation, distortion) i.e. factors affecting man in space. The determination of transparencies is of major strategic significance to manned interplanetary flights.

"To see" has several distinct meanings to the Soviets, depending on whether lighted or non-lighted objects are intended. To see such an object (differentiate its presence from its absence), it must be differentiated from its surroundings or background. As altitude increases, luminance (lux) decreases and distant or close objects "appear" out of place or not at all to normal vision (lack of substantial frame of reference). In dark outer space, external objects brightened by the solar rays cannot be determined accurately by the human eye, thereby inhibiting accurate perception of objects in the navigational areas of orbital and interplanetary space vehicles. Also, the probability of misleading sensory information arising from weightlessness may be an added visual problem.

If men in Soviet space vehicles require a current status display of position and motion, it appears to be within Soviet capabilities to make a device which, together with conventional data handling components, can provide accessory visual information within the extreme time and resolution requirements of space navigation.

UHF Electromagnetic Radiation — Astronautical operations will subject personnel to hazardous environmental conditions such as various electromagnetic radiations. Modern

radar beams have achieved power densities which have not been adequately appraised in determining the parameters of human tolerances and biological effects hazards. A study by N. N. Livshits on the role of the nervous system in reactions to UHF electromagnetic fields shows that the biological effects induced are other than simple thermal induction.⁴⁴ Recent U.S. experimentation tends to confirm this particular Soviet finding, yet the nature of the changes in the reticulo-endothelial system (RES) and the mechanism through which this radiation acted is completely unknown. Thermistor temperature measurements indicate that there is no physiological temperature rise in a live animal.

We are aware of only a few U.S. scientists who are working in the same general field as Livshits. These U.S. scientists speculate from their data that electromagnetic energy of appropriate frequency and appropriately used might cause a variety of mental effects, including obliteration of memory, stimulation of memory, possible selective recall, and hallucinations. These experimental data tend to corroborate the type of phenomena being cursorily described in Soviet literature on biological effects of ultra-high frequency (UHF) magnetic fields. The fact that the Soviets are interested in this whole field is highly significant to astronautical activities (communication, radar, ground crews) as well as to its possible applications to genetic processes (mutagenic effects).

Biophysical Exploration of Cerebral Functions — The Soviets report the use of polarographic procedures for determination of the oxygen tension in the brain under conditions of chronic stress. Such research indicates Soviet interest in new analytical electrode combinations of stimulating and analytical electrodes, and use of electrochemical phenomena to record key events in cerebral metabolism.¹²²⁻¹²⁵ Because the depolarization rate of a polarographic cathode is dependent upon the applied potential used, it also provides a means of studying the presence of electro-reducible substances other than oxygen in the brain.

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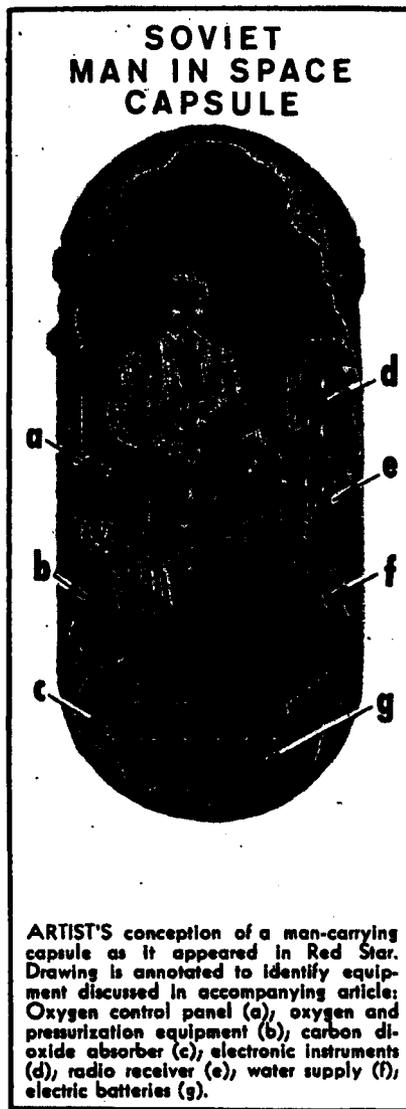


Figure 12

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VISUAL IMPRESSION
OF UNLIT SATELLITE IN A PLANETARY SHADOW



Figure 13. The only cue to a hypothetical satellite's presence is a gap in the stars. Even if discerned at all, it is impossible to estimate its size, distance or velocity from its appearance alone. Approach or recession could be inferred from changes in apparent size.

VISUAL OBJECTS (HIGH ALBEDO) SHOWN IN FULL SUNLIGHT.

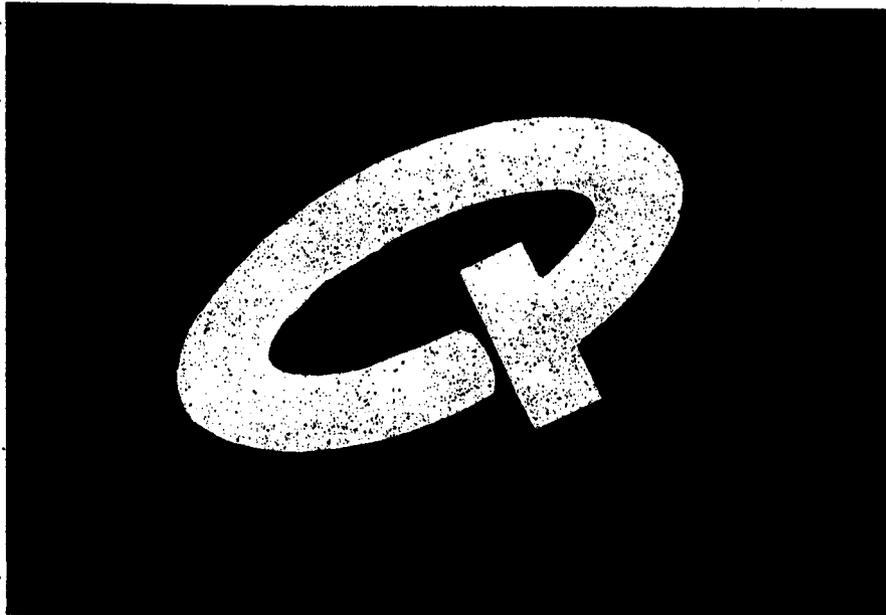


Figure 14. Because of glare, the background of stars is largely lost to the eye. From its shadow, we can see that the cylinder is near the ring. But how far are they? How are they moving relative to the observer?

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VISUAL OBJECTS (ALMOST "NEW") AGAINST PLANETARY SEGMENT

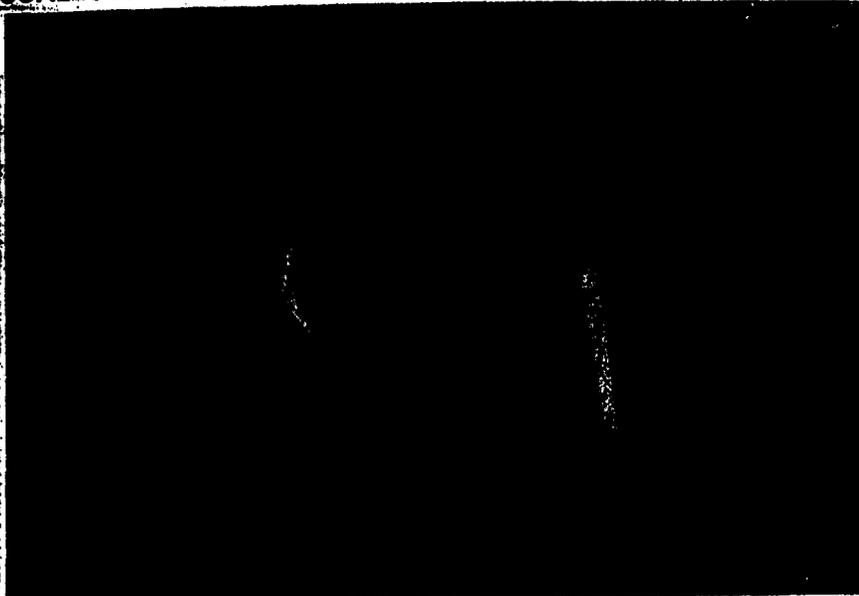


Figure 15. There are no cues from surface detail on the vehicle. Manifestly, the cylinder is nearer to us than the ring. How much nearer?

VISUAL IMPRESSION OF AN ILLUMINATED SYSTEM

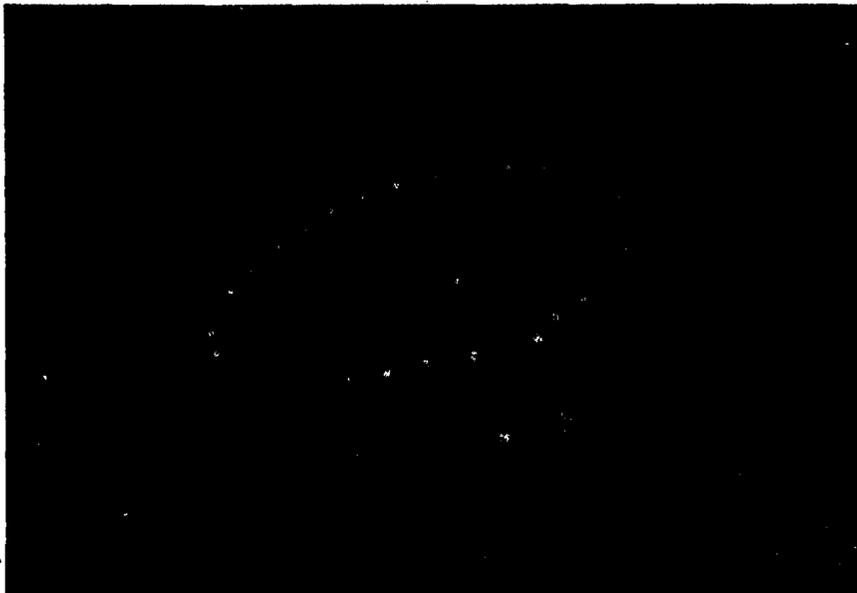


Figure 16. The prominence of background stars will depend upon the brightness and color of the lights. If all consecutive contour lights were a known, standard distance apart, the experienced observer could infer the altitude, size, distance and displacement of the two bodies.

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that Soviet polarographic procedures are adapted to measure not only oxygen availability in the brain, but also oxygen consumption and flow rate. Further, it appears that Soviet polarographic systems could be used for the measurement of the rate of metabolism in a small volume of living brain. A number of factors, such as fear or anxiety, which increase the metabolic rate of brain cells, or hypoxia, which lowers the rate, would tend to decrease the slope of an oxygen consumption curve. Perhaps prolonged stresses with concomitant increased oxygen utilization in specific segments of the brain coupled with the inability of the body to compensate by increasing pressure or dilating cerebral arteries could cause permanent physical damage to the brain. Perhaps changes in the arousal state, such as increased awareness and alertness, are the result of adequate homeostatic mechanisms for increasing oxygen supply to areas having increased demand. These phenomena may be the basis of Soviet polarographic studies and also could provide the basis for resolving some fundamental physiological problems related to the space flight program, such as the influence of prolonged absence of gravitational stimuli to the homeostatic centers of the brain.

Psychology and Sensory Deprivation — These subjective factors have not received very much published attention by the Soviets although their animal conditioning and tolerance tests show real awareness of these problems.¹³⁸ Drugs will probably be used by the Soviets to reduce anxiety, discomfort, and other adjustment problems that cannot be solved by selection, training, and conditioning.

The actual conditions under which the first human test subjects will be required to operate must be, to some extent, conjectural until the design and performance of the man-carrying vehicle is known. It seems certain, however, that the test subject will be deprived of many of the normal sources of sensory stimulation resulting from weight factors requiring his confinement in a small compartment.

Western experimental evidence and the evidence of former prisoners indicate that there is a level of sensory deprivation below which the sequelae may be psychologically serious. This level naturally varies between individuals and seems to depend on a number of factors, such as whether or not the test subject will be required to adopt a passive role. As in the past, Soviet selection of personnel will be based on the established ability of the subject to withstand extreme environmental conditions.

SINO-SOVIET BLOC SUPPORT

The USSR has received a minimum of service support from the European satellites and Communist China during the IGY and IGC programs. However, there are indications that Czechoslovakia, Poland and Communist China intend to increase their capabilities for supportive space research.¹³⁹⁻¹⁴⁰

The new astronomical commission recently established by the Czechoslovakian Academy of Sciences has agreed to coordinate and establish certain branches of research related to the space flight field. This commission will participate at future International Astronautical Federation meetings. The Chairman of the Commission, Rudolf Pesek, reports that Czechoslovakia will not take an active part in the launching of satellites or high altitude rockets in the foreseeable future, but that conditions already exist for research in branches closely connected with astronautics.

There have been a number of reports of questionable validity that claim the existence of an active space program in Communist China.¹⁴¹⁻¹⁴⁴ According to these reports, an effort is going forward to launch a satellite, or even a Moon rocket, from the territory of Communist China, probably with Soviet assistance. The objectives behind any such work, if it is actually taking place, are matters of speculation, but Communist China's desires for prestige and international recognition would probably be a large factor. The Communist Chinese are apparently cooperating with the USSR in the program of observation of Soviet satellites.¹⁴⁵

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NEXT 12 PAGES

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APPENDIX C

QUOTATIONS

1. Aleksandr NESMEYANOV, President of the USSR Academy of Sciences, delivered the following statement before the annual meeting of members of the Academy on March 26, 1959. "There is no doubt", he declared, "that such gigantic tasks as the attainment and exploration of the moon and, subsequently, of the nearest planets will be accomplished before the current seven-year plan ends. The latest accomplishments of Soviet scientists will contribute to the solution of this problem." 151/

2. Academician A. NESMEYANOV, President of the Academy of Sciences, USSR, announced that, "The Seven-Year plan (1959-1965) for the development of science devotes considerable attention to elaborating new means of astronomical investigations with the aid of new powerful optical and radio-technical instruments and with the use of space rockets and artificial satellites." 152/

3. Prof. Dr. B. Kanysh I. SATPAYEV, Director of the Academy of Sciences, Kazakh SSR, stated, "We look upon the launching of the sputniks, and the connection of all the sciences associated with it, as the beginning of a new era - in the life of the human being." 153/

4. Prof. Leonid Ivanovich SEDOV, speaking at the Ninth International Astronautical Federation Congress in Amsterdam, 25-30 August 1958, said, "Animal experiments were a national issue to the Soviets. The nation which is first in solving space navigation problems will be the first to launch a manned satellite, and ... the Soviet Union was resolved not to lose its chance to be first in this." 3/

5. An article entitled "Man Before the Start Into the Cosmos" by Candidates of Medical Sciences, Ye. YUGOV and A. SEROV, published in Izvestia, 5 Oct 58, includes the statement, "Science at present can see no principal difficulties it is necessary to overcome in order to insure man's sojourn into cosmic space." 154/

6. A. ALEKSANDROV, in an article entitled "Man and Cosmos", published in Meditinskiy Rabotnik, 31 Dec 1957, states: "The importance of astrobiology is gaining momentum. Astrobiology is a theory of adaption of a living organism to new, cosmic dimensions of technology and new methods of travel; it concerns itself with organic life in astral domains."

He further stated that: "The ultimate aim of all rocket launchings of all explorations of upper regions of atmosphere, stratosphere, and interplanetary space is to have humans travel safely from one point to another at some future time."

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In discussing space flight problems to be solved, he said, "The most important problem is re-entry. Humans will be sent into outer space only when this problem is solved." 155/

7. An unidentified member of the USSR Academy of Sciences stated, in May 1958, that the Presidium had established a new Biophysics Society in recognition of the increasing importance of biophysics. He further commented that physics had been the most important science of the last generation, but that biophysics will be the most important science for the next twenty to forty years. 156/

9. Prof. K. PLATONOV, Doctor of Medical Sciences, recently wrote an article entitled, "Man on the Road to the Cosmos" in Soviet Aviation for 30 June 1958, in which he stated, "The main role in the accomplishment of manned interplanetary flight belongs to the Scientists and engineers ... but, in the solution of the psychological problems of man's flight in the cosmos, the important role is played by the investigations of medical workers." 158/

11. Anatole Alexevitch DORODNITSIN, Chief, Physical Sciences Institute in Moscow, said, at the First International Congress of Aeronautical Sciences in Madrid, Spain, 8-13 Sep 58, that: "There is no question that the Soviets have the capability to perform manned ballistic flight or manned satellite flight. Lack of confidence in survival prevents them from doing it, not a lack of hardware capacity. When they do put one up, it will probably be a two-man vehicle." 160/

12. Academician Leonid SEDOV, quoted in an article about the launching of Sputnik III in Pravda, 18 May 1958, said, "The launching of a satellite carrying a human being will be preceded by a number of biological experiments in the cosmos. The main obstacle for this experiment is not of biological nature, but is the complexity of the task of making the satellite return to earth." 161/

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13. Viktor Borisovich (Bartsev?), candidate of medical sciences, in an interview reported on Moscow radio, 3 Sep 58, stated, "The research made on the second artificial earth satellite was aimed at insuring normal conditions for man during flights both to the higher strata of the atmosphere and beyond." 162/

14. Academician A. N. NESMEYANOV, President of the Academy of Sciences, USSR, wrote a report entitled "A Biological Experiment in Space", Pravda, 4 Oct 58. In this he discussed the biological experiment in Sputnik II and concluded that "The principal value of the biological experiment is the fact that the data obtained will serve as the basis for man's penetration into the interplanetary space." 163/

15. Chernigovsky, Member of the USSR Academy of Medical Sciences, in an article in Komosomolskaya Pravda in July 1958 discussing the results of the observations made by means of Sputnik II and its biological experiment writes, "Unfortunately the data relating to the action of cosmic radiation on a living organism are still unreliable. This phenomenon may be judged only after an animal has been successfully returned from the cosmos. This is essential because the action of cosmic radiation may appear not at once but after the lapse of some time." 164/

16. At a press conference celebrating the launching of Sputnik III on 15 May 58, Fedorov, a member of the Soviet IGY Committee and a corresponding member of the Soviet Academy of Sciences, said, "The tasks of this satellite do not include the studies of biological phenomena. In the future, such research using animals will continue." 165/

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19. V. PARIN, member of the Academy of Medical Sciences USSR, author of an article entitled, "Prior to Incursion of Man into Outer Space," published in Izvestia, 2 Nov 58, says, "Long range plans for flights into outer space consist of the development of devices which will guarantee return of animals to earth. Experiments to develop such devices are important, because if animals can be returned to earth, evaluation then will be possible of harmful effects of cosmic radiations not only on the animals themselves, but also on their descendants." 168/

20. An article on the results of the research carried out by the three Soviet sputniks, in the 27 April 1958 issue of Pravda, includes the statement that "Thorough and prolonged examination of an animal after its flight" into space would be needed to determine the effects of cosmic radiation. "The purpose is to insure safe flight of man in cosmic space." 169/

21. In an article in Nauka i Zhizn', May 1958, dealing with satellites and future manned cosmic flights, Fedorov said that "Physiologists consider it necessary to conduct repeated and more detailed experiments on animals before undertaking a flight by man." 170/

22. In the 5 September 1958 issue of Meditsinskiy Rabotnik, V. Malkin, Candidate of Medical Sciences, in an article entitled "Physiological Investigations in the Upper Atmosphere" said that the launching of the research rocket containing two dogs to an altitude of 450 km on 27 August 1958 was one of a series of achievements which are the result of systematic Soviet research in the fields of medicine and biology carried on in rockets during the past 10 years. He explains, "Medical and biological experiments with animals are important, because discoveries can be made which may help find ways by means of which a man can be sent in a rocket into space, both into the upper atmosphere and beyond its limits, with safety and without impairing his normal vital activities." 171/

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APPENDIX D

TERMS AND DEFINITIONS

Adaptation - Change in sensitivity to a stimulus following continuous exposure to the same stimulus.

Aeroembolism - The formation of gas bubbles (principally nitrogen) in body tissues after exposure to conditions of low atmospheric pressure, as in high-altitude flying without benefit of a pressure suit or pressurized cabin; the illness brought on by the presence of these bubbles.

Aeropause - An upper region of the atmosphere in which the atmosphere ceases to function for manned or unmanned flight.

Anoxia - An absence of oxygen in the blood, cells or tissues of the body. Often confused with hypoxia.

Astrobiology - A branch of biology concerned with the discovery or study of life on other planets.

Astronaut - One concerned with flying through space, or one who navigates through space.

Astronautics - (1) The art, skill, or activity of operating space vehicles. (2) In a broader sense, the art or science of designing, building, and operating space vehicles.

Binocular Parallax - The effect whereby an object viewed against a more distant background is seen in slightly different positions by the right and left eye. The fusion by the brain of the two not quite identical pictures underlies our appreciation of depth, or "solidity".

Bioacoustics - The branch of science that deals with the perception of sound and the effects of sounds on living organisms.

Biodynamics - The study of the motion of the forces acting upon bodies in motion, or in process of changing motion, as these motions or forces affect life.

Biosatellite - A satellite designed to carry an animal or plant, or a satellite that carries an animal or plant.

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Blackout - Disappearance of vision with accompanying sensation of blackness that may end in unconsciousness.

Central nervous system - The brain and spinal cord, exclusive of the peripheral (sensory and motor) nerves.

Complex reaction time - Discrimination of motor response from different sensory stimuli.

Conceptual advances - Recognition of unperceived relationships between natural phenomena, which opens up new vistas for research.

Cosmic ray - Any ray of high penetrative power produced, according to tentatively accepted theory, by transmutations of atoms in interstellar space.

Cytochrome - a chemical compound that plays a major role in intracellular oxidations and oxygen activation.

Dark Vision - scotopic or night vision. In darkness, the sensitivity of the eye gradually increases many million-fold over its daylight level. This adaptation also involves a qualitative change, resulting in the effective loss of central vision. Increased sensitivity is obtained at the price of detail and color discrimination.

Depth perception - Direct appreciation of the distance of a given object or objects from the observer, or of the relative distance from front to back in the perception of solid objects.

Electrodynamics - Phenomena of electricity in motion; also the science treating of the action of electric currents on themselves and on one another.

Exosphere - The outermost fringe or layer of the earth's atmosphere where collisions between molecular particles are so rare that only the force of gravity will return escaping molecules to the upper atmosphere.

Fatigue - A scientifically inexact term referring to the various effects of physiological exhaustion, boredom, loss of motivation, and whatever else may be present as an explanation of loss of efficiency following prolonged exertion.

Hyperventilation - The process of breathing rapidly to produce an excess of oxygen and a lack of carbon dioxide in the bloodstream.

Human factors engineering - The art or science of designing, building, or equipping an aircraft or space vehicle to the anthropometric, physiological, or psychological requirements of a person.

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Hypersonic - Of or pertaining to the speed of an object moving at mach 5 or greater speed in relation to surrounding medium.

Hypoxia - Oxygen deficiency in the blood, cells, or tissues of the body in such a degree as to cause psychological and physiological disturbances. Hypoxia may result from a scarcity of oxygen in the air being breathed, or from an inability of the body tissues to absorb oxygen under conditions of low barometric pressure. In the latter case, water vapors from body fluids increase in the sacs of the lungs, crowding out the oxygen.

Illusion - A misinterpretation of certain elements in a given experience, so that the experience does not represent the objective situation, present or recalled, when compared to another standard.

Inertial guidance - A kind of guidance for a missile or pilotless aircraft, effected by means of mechanisms that automatically adjust the missile after launching to follow a given flight path, the mechanisms measuring inertial forces during periods of acceleration, integrating the data obtained with already-known position and velocity, then signaling the controls to effect the desired direction and altitude.

Interplanetary space - That part of space conceived, from the standpoint of the earth, to have its lower limit at the upper limit of translunar space, and extending some several billion miles beyond the limits of the solar system.

Ion engine - A projected species of reaction engine in which thrust is to be obtained from a stream of ionized atomic particles supplied by atomic fission, atomic fusion, or solar energy.

Laika - The name of the female dog carried as a passenger in Sputnik II. Laika, of the Husky breed, approximately 45 pounds in weight, about 20 inches high, survived alive in the satellite from the 3rd to the 10th or 11th of November 1957. The Russians announced that she was alive on the 10th, and dead on the 11th.

"Mechta" - Russian word meaning "dream". Artificial planet No. 1, launched on 2 January 1959.

Movement time - Time elapsing between the beginning and completion of a movement; it includes primary and secondary movement times but not reaction time.

Negative g - physiologically, g forces are defined as "positive" if they act from head to foot and "negative" if they act from foot to head (A man hanging upside-down experiences 1 g negative).

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Neutral density filter - a filter which produces equivalent attenuation of illumination throughout the visible spectrum so that, although the brightness of the scene viewed is reduced, its color values are unaltered.

Orbital velocity - The average velocity at which an earth satellite or other orbiting body orbits.

Outer space - (1) In contexts of currently developing practical zero space activities, the space above the earth's atmosphere, or above its effective atmosphere. (2) Space beyond the limits of the solar system, as in "an intruding meteor from outer space."

Payload - That which is carried in a rocket vehicle to obtain the results for which the vehicle is launched. In a guided missile, the payload is the warhead intended to damage or influence the enemy; in a sounding rocket the payload comprises the instruments, animal, or mechanisms sent aloft to obtain data; in a satellite rocket carrier, the payload is the satellite.

Pressure breathing - Methods of producing passive inhaling and active exhaling (reversing normal process) by increasing pressure exerted on the lungs by an external respirator-type device.

Pressure cabin (comparable to U.S. cockpit and/or cabin pressurization system) - A pressure cabin, in which the necessary pressure of the air and its exchange is maintained by means of boost from the atmospheric air.

Pressure cabin of regeneration type (comparable to U.S. development "sealed cabin") - A pressure cabin, in which the necessary pressure of the air and its exchange are maintained by regeneration appliances, not using the surrounding atmospheric air.

Psychophysical methods - Standardized procedures for presenting stimulus material to subject for judging, and for recording his reactions; originally developed for determining functional relationships between physical stimuli and correlated sensory responses, but now used more widely.

P. s. i. - pounds per square inch (environmental pressures)

Receptor - Sensory ending of a neuron leading from the periphery toward the central nervous system or a specialized cell in connection with a neuron, which is so specialized as to have a low threshold for other sorts of stimuli, and which when stimulated initiates an impulse or impulses in the associated nerve.

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Redout - In negative (foot to head) G-forces, the motion of blood is toward the head. Above 3 G the retinal vessels become engorged and vision is lost because of obstruction of light path to the retina by the excess blood. The light filtering through the blood gives a sensation of redness so the phenomenon is called redout. (Some researchers believe that redout is caused by the dragging of the lower eyelid up over the eye so that the light is filtered through the eyelid tissue.)

Redundancy system - manual or automatic control mechanism (component for component) ensuring successful recovery.

Re-entry - The action involved when an object comes back into the atmosphere after being rocketed to altitudes above the atmosphere.

Space biology - A branch of biology concerned with life as it may exist in space.

Space cabin - A pressurized and climatized cabin for use in space flight.

Space laboratory - (1) A space vehicle carrying sensing and measuring instruments, recording equipment, radio-transmitting equipment and other related instruments, used as a means of obtaining scientific data on conditions in the upper regions of the earth's atmosphere or in outer space. (2) A vehicle that simulates the conditions of a space vehicle.

Space medicine - A new field of medical science that studies the human factors involved in space flight and provides, for the first time, a link between medicine and those branches of science that deal with matters of an extraterrestrial nature. Medical problems in space flight stem, in the first place, from the environment of space itself and from the process of movement through this environment.

Space vehicle - A contrivance that carries something into or through space, either returning to the earth or not. A space vehicle may be manned or unmanned, but is considered to be under man's control in at least a part of its flight. The term is broad enough to include objects otherwise called guided or ballistic missiles if they are being considered to be carrying something through space.

Sputnik - A Russian word meaning "satellite." If capitalized, a manmade moon launched by the Russians, the first on 4 October 1957, the second on 3 November 1957, and the third on 15 May 1958.

Telemeter - A remote control device for quantitative measurements, such as blood pressure or respiration.

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Terrestrial space - Space comparatively near the earth in which the attraction of the earth is predominant.

Vestibular organs - the organs of balance in the inner ear. They are the utricle and saccule, containing the otoliths, which respond to linear g, and the semicircular canals, which are stimulated by angular accelerations of the head.

Zero gravity - A condition existent when the centripetal gravitational attraction of the earth or other spatial body is nullified by inertial (centrifugal) forces.

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