FOREIGN TECHNOLOGY DIVISION

SOVIET EFFORT TO CONTACT EXTRATERRESTRIAL LIFE

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appeared in 1962, its second edition in 1965. The first edition was revised by the author, translated by Paula Fern, annotated by the U.S. astronomer C. Sagan, and published in the U.S. in 1966 as "Intelligent Life in the Universe" by I. S. Shklovskiy and C. Sagan.

With the First Conference on "Extraterrestrial Civilizations" (Byurakan Observatory, May 20-23, 1964) which included all the leaders in radio astronomy and some optical astronomers, the problem can be said to have obtained the official recognition of the Soviet Union.

Before proceeding to the details of Soviet schemes for the establishment of contact with extraterrestial civilizations it is important to realize that the whole problem hinges on the answers to three general questions:

(1) What is the origin of the solar system? Without knowing this answer it is not possible to decide whether planets are rare or common around the stars.

(2) What is the nature of life?

(3) What is the origin of life on the surface of the earth?

In spite of a very large amount of work, both East and West, no definite answers to these questions are available. We have to fall back on vague arguments such as "with so many stars some of

them at least must have planets," etc. It is impossible at the present time to prove or disprove the existence of planets of the size of the earth even around the nearest stars, let alone life on these planets. Therefore, the existence of intelligent life elsewhere in the universe is at the present time an article of faith rather than a scientific fact. In this respect, scientists are in exactly the same position as their predecessors were in the 18th Century, or even the ancient Greeks 2,000 years ago. The only difference considered extremely significant by the proponents of life in the universe is modern man's possession of radio communication techniques capable of reaching out to 1,000 light years and more. How to utilize this capability is the subject of animated discussion among the radio astronomers in the West and the USSR.

SECTION II

EXISTENCE OF EXTRATERRESTRIAL LIFE

1. General Attitude

The Soviets are emphatic that their materialistic philosophy is in complete agreement with the idea of extra-terrestrial civilizations. According to this philosophy, life is a normal and inevitable consequence of the development of matter, and intelligence is a normal consequence of the existence of life.

Even the best-informed scientists in the USSR, like Oparin and Shklovskiy, must necessarily subscribe to this crude philosophy promulgated more than 100 years ago by Marx and Engels. However, once having stated their materialistic point of view they often introduce reservations. Thus Oparin thinks that the presence of oceans was the necessary factor in the appearance of life on the earth, and Shklovskiy is willing to accept the existence of life only on the earth, but this would be a "miracle."

2. What Kind of Life?

The Soviets seem to be committed to life based on the hydrocarbon compounds, that is essentially the same kind of life that exists on the earth, from bacteria to man. Oparin considers any other basis of life sheer impossibility, and at any rate devoid of any physical meaning. Shklovskiy goes into considerable

detail to show by energy considerations that life must necessarily be based on hydrocarbon reactions.

Speculations common in the West about the possibility of life based on ammonia, or even inorganic compounds (as in Hoyle's novel "The Black Cloud" which appears to be not only alive but even intelligent) do not occur in Soviet literature.

3. Persistence of Terrestrial Type of Life

As conditions on the Moon, Venus, and Mars are known to be severe in terrestrial terms, the problem arises whether even the simplest terrestrial organisms like bacteria can exist there. Experiments to test bacteria and other simple organisms under these conditions are conducted in both the East and West, on a comparable scale. In the USSR, this is done in the Institute of Microbiology, Academy of Sciences, USSR, and probably other places. There is a recent report of the simulation of conditions on Mars for microbial growth by A. I. Zhukova and I. I. Kondrat'yev (1965) of that institute.

The problem has assumed considerable importance as terrestrial bacteria have been shown to possess remarkable endurance and adaptability in planetary conditions. The danger of contamination of planets by terrestrial micro-organisms exists and has required international cooperation since the introduction of space exploration.

4. Search for Life on Mars

Mars is the only planet where conditions remotely approach those on the earth. It was therefore natural that Mars became the focus of attention of astronomers and biologists looking for evidence of life elsewhere in the solar system.

In the U.S., the center of the study of Mars for a long time was the Lowell Observatory, Arizona, where Percival Lowell's work was continued by E. C. Slipher. In the USSR, an indefatigable searcher for evidence of life on Mars was Tikhov.

Tikhov (1875-1960) was a Pulkovo astronomer who had attained considerable international reputation for the excellence of his observational work. In 1909, during one of the great oppositions of Mars, he studied that planet through filters and proved the existence of snow near its poles and clouds in its atmosphere, in spite of the low position of the planet during observations. This work remained little known in the West, and was repeated at the next great opposition in 1924 with substantially the same results by W. H. Wright at Lick Observatory, California.

After his retirement from Pulkovo, Tikhov settled down in Alma-Ata, Kazakh S.S.R., and in 1947 formed there a "Sector of Astrobotany" at the Institute of Physics and Astronomy of the Academy of the Kazakh S.S.R. The idea of this sector (or section) was to study the behavior of plants in conditions approaching those of the Planet Mars, that is the Arctic tundra and high mountains.

Many astronomers and botanists worked at this section which published five volumes of its proceedings (1947-1960). Although this work did not resolve the question of life on Mars, it nevertheless uncovered many remarkable instances of adaptation of plants to extreme climatic conditions. Tikhov's method of obtaining spectra of plants in reflected light to compare with the spectrum of Mars was later employed in the West, especially with the development of the infrared techniques.

With Tikhov's death his section was absorbed by the Institute of Astronomy. Tikhov's works were published in five volumes by the Academy of Sciences, Kazakh S.S.R. They contain 33 of his own papers on the problems of terrestrial plants and existence of life on Mars.

The results of investigations by Tikhov and his collaborators were indecisive so far as the existence of plants on Mars was concerned, paralleling similar results in the West. They simply increased the probability in favor of the existence of such life. The occurrence of intelligent life on Mars is even more difficult to prove than the existence of plants. Shklovskiy's point of view is that Mars once had a civilization which launched its artificial satellites, but is now a dead body.

The question of life on Mars will be resolved only with an actual visit there either of instrumented or manned vehicles.

For this reason, emphasis is being given to the development of techniques for detecting the existence of life on Mars in both the U.S. and the USSR planetary exploration program. The discovery by Mariner 4 of craters on the surface of Mars, however, has little direct bearing on the problem of life there. The same can be said of the presumed absence of the Martian Canals.

Few astronomers believe that there can be any life on Venus or the moon. An exception is N. A. Kozyrev, a Soviet astronomer famous for his observations of the moon, who thinks that the high temperature of Venus refers to its ionosphere, and the surface may be in a condition to allow the development of life.

But even the moon cannot be assumed to be entirely devoid of life. Such is the opinion of A. I. Oparin, the greatest authority on such matters in the USSR. According to the TASS Agency (December 29, 1966), Oparin thinks that organic substances either alive or dead are possible on the moon.

Such an idea would probably be unacceptable in the West, but it was only 30 or 40 years ago that W. H. Pickering, an American astronomer, tried to explain various changes of tint in the moon by colonies of insects appearing and disappearing during the progress of the lunar day.

5. Meteorites and Life

Meteorites are the only bodies of extraterrestrial origin that are available for a study in our laboratories. In connection

with the problem of extraterrestrial life, a large number of mineralogists, physicists, biologists, etc., everywhere are studying meteorites. The proof of the existence of organic substances in meteorites would support the existence of life outside the earth, no matter what the ultimate origin of meteorites might be. But in this problem, as in all other problems concerning extraterrestrial life, there is no simple answer and no convincing proof of the existence of life. The problem has recently been reviewed by A. A. Imshenetskiy (1966), Director of the Institute of Microbiology, Academy of Sciences, USSR, where many investigations of such nature are being carried out.

There are three items in meteorites which must be considered in this connection:

(a) Carbonaceous chondrites are stony meteorites which have some carbon matter (up to five per cent of weight) of possible organic origin. At the present time there are 30 meteorites of this class, which can be divided into three subclasses quite different from each other. At first it seemed that this is indisputable proof of the cosmic origin of organic matter, but later researches proved this improbable. The carbonaceous matter is now considered to be of inorganic origin and similar to matter found in terrestrial rocks.

(b) "Organized elements" in the same meteorites are small

round grains which have been considered as possibly produced by plant spores. The best authority in the USSR on these problems, G. P. Vdovykin, does not think they are of organic origin at all.

(c) Bacteria in meteorites have been reported time and again both in the East and West. In every case they were proved to be introduced into the meteorite after its fall on the surface of the earth.

6. Soviet Attitude Toward Science Fiction

The idea of inhabited worlds naturally evokes in people all sorts of emotions which are not always amenable to scientific treatment. In the Soviet philosophy, scientific fiction occupies an honorable place provided that it is not represented as solid achievements of science. Much of what Tsiolkovskiy wrote, for instance, can be characterized as science fiction, and one of the famous Soviet writers, Alexis Tolstoy was famous for his fantastic stories. Academician Obruchev, the explorer of Siberia, was also a science fiction writer.

However, the Soviets have attempted to draw a line separating science fiction from deliberate fraud and distortion of facts well established by science, and some Soviet scientists, principally astronomers, are busy refuting and criticizing sensationalism by writers who exhibit more exuberance than knowledge. One such writer is Kazantsev, the author of a fantastic

tale, "Guest Out Of Cosmos" (1959), which has had its repercussions abroad also. The main idea is that the Tunguska meteor, which landed in Russia in 1908, was in reality a spaceship from Mars supplied with a hydrogen bomb. This ship blew up over Siberia thus saving the earth from conquest by the Martians. Astronomer Yu. G. Perel' (1959) concedes that a fiction writer may invent anything he pleases, but Kazantsev represents his wild surmises and ignorant theories as scientifically established facts. Kazantsev, however, proceeded to attack official science as concealing from the public the true situation, etc., thus closely paralleling the UFO enthusiasts in the U.S. who accuse the Air Force of suppressing evidence supporting flying-saucer visitations.

Another line of pseudo-scientific effort is directed toward the discovery of traces of contacts of higher civilization with the earth. In the USSR, M. M. Agrest in 1959 put forward an idea that classical myths and biblical stories contain in them vague reminiscences of visits by extraterrestrial highly civilized beings. These are gods coming down to earth, angels flying through the air, destruction of Sodom and Gomorra (evidently by an atomic bomb), kidnapping of people (the biblical Enoch) by the intruders, etc.

The search for information, however, is not restricted to the Bible. Anything is good if it points toward the existence of extraterrestrial civilizations; crude images on rocks in the

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Sahara, mythical small men in China, Peruvian fairy tales, are examples. More recently, in the Soviet popular magazine, "Sputnik," 1967, Nr. 1, there is an article by Vyacheslav Zaytsev, "Visitors from Outer Space" which is full of such stories. It is stated that the author spent 30 years of his life collecting this information.

To the credit of Shklovskiy (second edition of his book, Chapter 23) he refutes many of the ridiculous stories which have been propagated very assiduously in the West, particularly in the U.S., where they have been adopted by the adherents of the UFO cult. Other serious Soviet writer-scientists like V. N. Komarov ("Man and Mysteries of the Universe," 1966) also exhibit an exemplary caution.

In general, it appears that the problem of sensationalism in science is exactly the same both in the USSR and the U.S. There are scientists interested in the problem of extraterrestrial civilizations and there are writers who want to publish a breath-taking book. There are even combinations of the two. In the USSR, Shklovskiy is not averse to publicizing his own wild ideas. In the West, there are F. Hoyle and George Gamow of the same type. Modern science is so fantastic that the boundary between possible and impossible is fairly indistinct. Some people, sometimes even bona fide scientists, simply cannot discern this boundary and mix up

solid science, their unconscious desires, and fairy tales into a nightmarish whole. The Soviets cannot escape this situation any more than the Americans and West Europeans.

SECTION III

POSSIBILITY OF ESTABLISHING CONTACT

In view of the complete absence of concrete data on extraterrestrial civilizations the only possible formulation of the problem is this: Assuming that there are extraterrestrial civilizations, what would be the best way of getting in touch with them? This problem is twofold: (1) How can understandable signals be transmitted and (2) how can signals from outer space be detected and interpreted?

Radio signals from other civilizations, no matter how clear and strong, would have had no significance 50 years ago, since nobody on earth could intercept them, let alone interpret. According to modern astrophysics the development of stars is a continuous process and they certainly were not all created at the same time. If there are planets around them, and if there is life on these planets, and if there are civilizations, they must be in various stages of development. The extraterrestrial civilizations obviously must be in a similar or higher state of development than our own in order to make a contact possible.

On the earth, life has existed for something like two or three billion years. Written documents can be traced for some 6,000 years, while in contrast the use of radio for interstellar

communications is less than 20 years old. In other words, the time during which a civilization like ours is in a position to communicate with other civilizations is infinitesimally short in comparison with the duration of life on the planet, and age of the stars.

The next question is how long shall we have this ability to communicate with other civilizations, that is, how long is our civilization likely to endure? The answer to this can be based only on faith and temperament. Shklovskiy thinks that a civilization cannot last longer than 10,000 years for which he is taken to task by his Soviet colleagues. According to the Communist conception our civilization, once reorganized by the adherents of Marx and Lenin, will go on forever as all sources of internal friction will be removed. Therefore, the duration of a civilization should be put down as 10^9 rather than 10^4 years. Western writers would tend to the longer time scale. It is, however, clear that the duration of a civilization is something that cannot be decided a priori. Our own civilization may be said to be 6,000 years old, and whether it will survive for another 4,000 years, or 400 years, or even 40 years is anybody's guess. Some thinkers, notably H.G. Wells and O. Spengler, were very pessimistic in this respect. It is well known that our

civilization has had its ups and downs. The ancient Romans, for instance, were much more highly civilized than their descendants a thousand years later. Therefore, there is no need to postulate a complete destruction of our civilization in order to lose our ability for interstellar communication.

The duration of any civilization is accordingly a guess, and this factor makes all discussions about interstellar contacts very nearly a pure exchange of verbage. Shklovskiy, for instance, develops a formula for the average distance between civilizations, d, depending on the time, T, of the duration of the existence of stars and, t, the duration of civilization:

$$d = 5.2 \left(\frac{T}{t}\right)^{1/3} \text{ parsecs}$$

If we put $T = 10^{10}$ years as commonly accepted, and $t = 10^{4}$ years we compute the average distance between two civilizations in our galaxy to be 520 parsecs or about 1,700 light years. Shklovskiy is evidently afraid of his own result and is willing to take $t = 10^{5}$ to 10^{6} years. Even in this case the distances come out on the order of 100 parsecs or 300 light years.

Similar calculations by L.M. Gindilis, reported in an article entitled, "The Possibilities of Communication with Extraterrestrial Civilizations (Zemlya I Vselennaya, No. 1, 1965) are summarized in Appendix I. Although the assumptions used in Gindilis's calculations are different from Shklovskiy's, Gindilis concludes

that the distance between civilizations in a galaxy is not less than several hundred light years and is probably more than a thousand light years.

Although the results of these two calculations differ, the important feature is that both calculations indicate the extremely large distances involved in attempting to establish communications with extraterrestrial civilizations.

The tremendous distances between the stars is another serious difficulty; they average out to about 3 parsecs or 10 light years, not to speak of the millions of light years separating us from other galaxies. The situation is thus not very encouraging even with the most favorable assumptions about the frequency of the planets and a simultaneous existence of highly developed civilizations on these planets. (Some of the planetary requirements for civilizations to evolve are given in Appendix II.) Soviet radio astronomers such as Troitskiy and Kotel'nikov think that 1,000 light years is the maximum distance at which interstellar communications have any meaning at all, and at this distance the existence of only one civilization similar to ours can be expected.

As is well known, Project Ozma in the US was based on a much greater restriction of the problem. Only the nearest stars were considered and among these only those that were more or

less in the same physical class as our sun. Only two stars τ Ceti and ϵ Eridani about 11 light years distant were tried. Signals in the hydrogen line 1420 Mc were sent to these stars from the National Radio Observatory in May-July 1960, and characteristics of the radio emission from these stars analyzed. No evidence of any artificial signals was discovered, and the answer to our own signals, if any, cannot be expected until 1982.

It is not known whether the Soviets ever attempted a similar experiment. They all quote the Ozma project, and the book "Interstellar Communications" published by the NASA in 1963 (in which the Ozma project is described) appears to be one of their fundamental information sources, although, the Soviet expert Khaykin considers Ozma a waste of time and resources (Byurakan Conference, p 90). The inference in most of the Soviet papers, however, seems to be that the Soviets have nothing to offer in the experimental line comparable even to the modest Project Ozma. Experience, however, with Soviet scientific practice, notably their withholding of information on recent scientific activities for several years as was the case with their radio telescope development, makes it advisable to exercise caution in ascertaining their status from published literature alone.

How can the existence of civilizations like ours be discovered? Shklovskiy points out that at least one indication of intelligent activity is available, i.e., the generation of electromagnetic energy by planets which, of course, at stellar distances would merge with their stars. He notes that there are several thousand radio and television stations on the earth, and taking their power into consideration concludes that the brightness temperature of the earth in television wavelengths is some millions of degrees. Moreover, this temperature started rapidly increasing since about 1940. He speculates, therefore, that if a similar situation can be associated with one of the nearest stars it would be prima facie evidence of existence of intelligent life there. He cautions, however, that this possibility requires a long and careful survey of all sources of cosmic origin, something that is not very easy to organize.

Developing the idea of energy criterion, Kardashev points out that the earth civilization is currently utilizing 4×10^{19} ergs/sec and this quantity is rapidly increasing in an exponential way. By extrapolation he concludes that by the year 5000 A.D. humanity will consume 4×10^{33} ergs/sec, which is equal to the output of the sun and by the year 8000 A.D. to the energy output of the whole galaxy, that is 4×10^{44} ergs/sec.

Obviously such possibilities require the harnessing of the whole energy of the sun of which the earth intercepts now only one part in two billion. Projects of this sort are in existence, one of them being Dyson's Sphere to capture and retain the energy of the sun. The utilization of the galaxy will then be the next problem.

Kardashev sets up a classification of civilizations according to the energy criteria as follows:

(1) Technological level approaches that of terrestrial civilization; consumption of energy 4×10^{19} ergs/sec.

(2) Civilization utilizing the whole energy of the star, that is, of the order 4×10^{33} ergs/sec.

(3) Civilization, having at its disposal the energy of its galaxy, is about 4×10^{44} ergs/sec.

Further, Kardashev, basing his argument on our own experience, thinks that Stage 1 is reached in a few billion years. Stage 2, according to him, should develop within several thousand years after Stage 1 had been reached. Stage 3 should be developed in not more than 10 million years after Stage 2. Thus indicating that the 10,000 years postulated by Shklovskiy for the existence of a civilization is not satisfactory to at least some Soviet astronomers.

The evidence of the existence of a civilization of Type 3 would consist of radio phenomena which could not be explained in any

rational way. All this setting up of criteria is highly arbitrary as it presupposes complete understanding of radio astronomical processes which is hardly the case.

An illustration of this humble truth is the controversy produced by Soviet astronomers over STA-21 and STA-102, that is, Nrs. 21 and 102 in the California Institute of Technology Catalogue of Cosmic Radio Sources. They were hastily declared as satisfying the requirements of civilizations of Type 3, and some more of such, LHE-210, LHE-459, and LHE-523 were found at GAISh.

So far as the situation with STA-102 is concerned much doubt has been thrown on Kardashev's claim that its period variation in radio frequency should be considered as an artificial signal with a period of 100 days, drawing our attention to this galaxy. Astronomers in the West failed to confirm its periodic variation and it is generally considered now of the quasar type, that is, a perfectly natural, although not yet perfectly understood, object.

Yu. N. Pariyskiy investigated, on Kardashev's request, sources STA-21 and STA-102 with the great Pulkovo radio telescope (Byurakan Conference, pp 54-60), but his conclusions are hardly in favor of the artificial origin of the radio emission from these two sources. He finds that their radio properties

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are similar to those of some other cosmic sources and the strength of the signals under the most favorable assumption exceeds by several orders of magnitude the strength that we can reasonably expect from civilizations of Class 2 or 3.

The criteria which an artificial signal from another civilization should satisfy, according to Kardshev, are:

(1) The small angular size of the source. This he considers an extremely important if not a decisive indication of the artificiality of the source.

(2) Maximum intensity of signal in the range 3-10 cm.

(3) Variability of the signal in time.

Much of the discussion at the Byurakan Conference was centered on these criteria, some participants declaring that many natural objects could satisfy them. V.I. Slysh (Byurakan Conference, pp 61-67) thinks that a simultaneous fulfillment of these criteria by a cosmic source would constitute a presumption (but not a proof) of its cosmic origin. The question whether a cosmic radio source is artificial or not can be settled according to Slysh only by a systematic survey of the whole sky by means of a radio interferometer with a resolving power 0.1". This at least would eliminate all sources that are clearly natural, so that attention could be concentrated on a few suspicious objects. He does not indicate whether the Soviet technical capacity is

adequate to meet this challenge.

1. Means of Communication

Assuming that there are extraterrestrial civilizations willing to communicate, consideration must be given to how this may be accomplished. There are three possible ways of doing this:

(a) Direct contact, that is, interstellar travel, seems to be excluded from serious consideration despite the fact that this mode of communication is the most appealing to human imagination. Even assuming that physiological requirements of inhabitants of various planets are identical, the problem of travel, aggravated by tremendous distances, still remains. The various proposals of photon rockets, etc., (for which Dr. Stanyukovich is famous in the USSR) taking advantage of the relativity dilatation of time will not be of much use even when they are technically possible. According to Sagan the flight with acceleration of 10 m/sec^2 would allow a trip to the Andromeda galaxy in 28 years so far as the passengers in the rocket are concerned. However, for the home civilization that sent them this would be equivalent to 1.5 million years. A round trip taking three million years is of doubtful value. The information returned may have been made obsolete by better systems developed after the mission departed.

(b) Radio contact is a method for exchange of signals which is now technically possible but the distances at which it is effective are very small in comparison with the size of the universe.

Only one way radio contact, of course, is not limited by distance. We may imagine a civilization in the Andromeda galaxy that sent out signals "to whom it may concern" a million and a half years ago. We would just now be receiving them.

(c) Possible contact by means of masers, lasers, and other modern electronic means.

L.N. Gindilis (1965) in his survey of the problem gives a tabulation summarizing the present situation. This tabulation is shown in Table I, where d denotes the distance between civilizations in light years, and t_c the life time of a civilization. This t_c, as has already been remarked is of a highly speculative nature. Shklovskiy takes it to be of the order of 10,000 years, Gindilis thinks it should be billions of years, that is, comparable to the life-time of the planets themselves.

The bulk of discussion in the USSR (as well as in the West) is on the selection of suitable radio frequencies and other characteristics of radio waves for interstellar communications. The hydrogen wavelength 21 cm originally proposed as having a

TABLE I

TYPES OF CONTACT BETWEEN CIVILIZATIONS

Distance Between Civilizations, light years	Possible Types of Contact
$d < 100$	All types are possible.
$100 < d < 1{,}000$	(1) One-way radio communication (2) Two-way radio communication possible (3) Direct contacts by bodily visits possible but unlikely
$1{,}000 < d < t_c$	(1) One-way radio communication (2) Direct contacts, if possible, will be only one way
$d > t_c$	Only one-way radio communication possible.

universal meaning and actually used in the Ozma project is objected to by many scientists both East and West. The reason for this is the abundance of interstellar hydrogen which places the high threshold of radio noise exactly in this line.

The choice of the wavelength for communication is, of course, badly restricted by the known properties of the earth's atmosphere. Moreover, it is equally restricted by the unknown properties of other bodies' atmospheres. It is easy to imagine a planetary atmosphere suitable for life having argon instead of nitrogen which would radically change its transmission properties.

Perhaps the most thorough discussion of this problem was given by Kotel'nikov in the Byurakan Symposium (pp 113-120). The hydrogen wavelength 21 cm is assumed to be impractical for the above-mentioned reasons. He proposes a multi-channel receiver containing a large number of narrow-band filters. If a monochromatic signal of a certain frequency reaches the antenna it will be automatically recorded and an appropriate channel tuned to that frequency.

Even with this device the coverage of the whole sky is not an easy undertaking. Assuming a limiting distance of 1,000 light years, the number of stars in this space will be of the order of 10 million. To cover the whole sky including all these stars will take exactly one year utilizing antennas and recorders recommended by Kotel'nikov. Further, what guarantee is there

that the signal will be detectable on exactly the date programmed for observation? Kotel'nikov's final conclusion is that it may be possible to discover a civilization of our type by our present radio means if it exists on one star out of 10^6. If this figure is one star out of 10^7 the discovery will be almost impossible, and if a civilization exists only on one star out of 10^8 its discovery will be impossible unless the radio apparatus becomes much more efficient. The criteria of one civilization per 10^6 stars corresponds statistically to the limiting distance of 500 light years. Thus a distance of only 500 to 1,000 light years must be considered as the limiting distance for interstellar communications.

V.S. Troitskiy (ibid., pp 97-112) by an entirely different line of reasoning comes to the same conclusion that even with a narrow direction signal the limiting distance of a civilization detectable by radio is about 1,000 light years. He estimates a power requirement for this distance on the order of 1.6×10^{16} watts. A brief discussion of power requirements from a Soviet reference is contained in Appendix III.

The problem of what to transmit to stellar civilizations and how to interpret signals received from them was only briefly treated at the Byurakan Conference. A.V. Gladkiy (pp 145-146)

expressed only general ideas as to the form a language can take under different conditions. He is a member of the Institute of Mathematics, Siberian Section of the Academy of Sciences, USSR, and being a mathematician he declares that it should not be assumed that mathematics of our stellar correspondents will be the same as ours. A short discussion of the artificial language Lincos developed by the Dutch mathematician Hans Freudenthal does not indicate any Soviet originality in this direction. The attempt to unravel the meaning of the Mayan inscriptions of Yucatan by a mathematical analysis carried out by the same Mathematical Institute of Siberia was not well received in the West, and the Mayan language is probably much simpler than the language of a planet X attached to star Y in galaxy Z. The understanding of stellar language may possibly turn out to be a harder problem than sending or receiving stellar communications. Resolutions of the Byurakan Conference emphasize the importance of linguistic studies in this connection.

As to the other than radio communications with stellar civilizations, the only promising means is an apparatus of the laser type. Shklovskiy discusses it in considerable detail (second edition, Chapter 20), but he cautions that it requires space platforms for its use which are not yet available. As Shklovskiy notes in the introduction to his book, the present

rapid development of radio astronomy, gamma-ray astronomy, X-ray astronomy, etc., indicates possibilities never dreamed of just a few years ago. What is said about stellar civilizations today may become obsolete tomorrow.

The fundamental question whether extraterrestrial civilizations (or even life in general) exist at all has not been answered in these papers nor in similar papers in the West. Nor the next question, whether man-kind is willing to put so much effort into a search which may well prove futile likewise has not been settled.

The Soviets have something to say about this. They rationalize by noting that the development of methods for interstellar communications will be of the greatest advantage to radio technology in general regardless of what the radio technology was originally designed for.

There is also a curious utilitarian streak running through Soviet discussions. In the Soviet periodical ("Sputnik") (1967, Nr.1, p. 179), e.g., the Nobel prize winner, Physical chemist, N. Semyonov, declares that the present knowledge and technology makes possible the regeneration of the atmosphere of Mars which could make Mars a suitable home for humans. Also, some Soviet writers are optimistic that the more advanced civilizations are very anxious to communicate their knowledge to us, even though the Soviets are at times quite unwilling to reveal many of their scientific advancements.

2. Associated Programs, Facilities and Personalities

The only solid basis for the estimate of the Soviet effort in establishing interstellar communications is the book "Extraterrestrial Civilizations" published by the Armenian Academy of Sciences in 1965. It consists of 13 papers delivered on this problem at a conference on May 20-23, 1964, at the Byurakan Observatory. The titles of these papers, in many cases self-explanatory, are given in Appendix IV. There are other indications of the Soviet activity as noted in the text of this report but the total amount of information is very small. The Conference was titled the "First All-Union Conference devoted to the Problem of Extraterrestrial Civilizations." The second Conference was to be called in 1965 but there is no further reference to it in available Soviet scientific literature.

A condensed translation of the resolutions of the Byurakan Conference is given in Appendix V. In it there are a number of institutions in the USSR mentioned as suitable centers for the development of various problems connected with contacting extra-terrestrial civilizations. Appendix VI shows two of the large radio antennas in the USSR.

One of the centers listed by the Byurakan Conference is GAISh (Shternberg Institute) where one of the most influential of the workers on these problems, I.S. Shklovskiy, is located. In a

citation in connection with his election to the corresponding membership of the Academy of Sciences and award of the Lenin prize it is stated that he is in charge of a large theoretical and experimental section of the GAISh. Members of this section carry out astrophysical investigations utilizing the largest optical and radio telescopes, cosmic rockets, and artificial satellites ("Zemlya i Vselennaya," 1966, Nr 5, p 3).

Research at the GAISh of interest in the present connection is carried out by N.S. Kardashev, G.B. Shalomtskiy and other associates of Shklovskiy. They are observing radio galaxies of the quasar type with radio instruments of FIAN (Physical Institute of the Academy of Sciences) on the wavelength 32.5 cm with a view of locating artificial sources.

Quasars are very small objects appearing like stars but with masses approaching those of galaxies. All this is not certain at all and there is no agreement in the interpretation of the observations. The smallness of the apparent size of quazars, which is of the order of 1", is according to Kardashev, a good indication of the possibility of their artificial origin.

It is impossible to say just what practical results of a program like this could be. Kardashev's attempt to explain the periodic fluctuations in the radio emission of source STA-102

Purpose

To review Soviet scientific efforts relating to the problem of contact with extraterrestrial civiliations.

Conclusions

1. There is a comparatively high level of theoretical discussion in the USSR concerning the existence of extraterrestrial civilizations and the problem involved in detecting these civilizations.

2. Participation of many influential astronomers, radio experts, physicists, etc., in these discussions indicates a considerable importance attached to these problems in the USSR.

3. There is no evidence that practical steps on any large scale are being taken in the USSR to contact or to decipher messages from other civilizations, although there exist small projects, of the size of Ozma in some institutions, notably the Shternberg Astronomical Institute in Moscow.

4. The Soviets have available a number of radio telescopes suitable for an integrated search program, if they choose to begin such a program.

5. Considerable emphasis was made at the Byurakan Conference (1964) on the necessity of a systematic survey of the whole sky in order to locate artificial cosmic radio sources.

(as has already been mentioned) as a communication signal has not been accepted in the West. At any rate, this research may be expected to shed some light on the nature of quasars.

Also, Kardashev and Pashchenko at GAISh (Shklovskiy-Sagan, p 478) will be attempting to detect artificial signals on the 21 cm hydrogen wavelength. The anticipated power of the signals should be relatively great. A negative result from this search would indicate that in our galaxy there are not civilizations with power resources of the order 10^{33} ergs/sec. The investigations on the Andromeda galaxy, M31, will also be conducted. It is perhaps noteworthy that nothing of this can be found in the second edition of Shklovskiy's book, and Sagan inserted this paragraph evidently from direct contact with Shklovskiy. Also, an equivalent to this program does not exist in the West.

Nothing is known of the research programs in this connection at the Pulkovo Observatory or at any other institution named in the resolutions of the Byurakan conference.

In a book "Radio for 70 Years" (1965), Siforov (pp 11-23) in an article titled "Radio Role in Space Exploration" fails to include in his scheme of five steps in the development of radio communications the problem of interstellar communication where it logically belongs. He devotes to this problem exactly two lines:

> "It is not impossible that by radio electronic means the problem of contact with intelligent beings elsewhere in the Universe will be solved."

Pariyskiy and Khaykin of Pulkovo in their review of the development of radio astronomy (ibid, pp 140-153) do mention the problem of interstellar communications in a few lines, but put their faith in the international radio telescope discussed at a meeting of International Radio Union (Tokyo, 1963). No concrete program at Pulkovo or any other place in the USSR is mentioned.

Also nothing is said about observational programs in the detailed review article by L.M. Gindilis (1965), although the picture of the Pulkovo (see Appendix VI) radio telescope is given with a caption:

> "Certain peculiar sources of radio emission that are suspected to be artificial have been investigated with this instrument."

This probably refers to sources STA-21 and STA-102, which were investigated on request from Kardashev (as discussed above), but not to any particular program of investigation.

The only practical approach to this problem would be the organization of a continuous radio survey of all objects within a certain distance, such as 1,000 light years, as indeed is recommended by the Byurakan Conference. This will be a gigantic program requiring monitoring some 10 million objects. Obviously an international cooperation is called for, especially so in the southern hemisphere,

part of which is inaccessible to the Soviet astronomers. As the Soviets are already doing astronomical work in Chile this would be the logical place for the establishment of such a radio telescope for the purposes of such a survey.

Nothing illustrates better the importance of the subject of extraterrestrial civilizations in the USSR than a list of attendants at the Byurakan Conference of 1964 who either delivered papers themselves or participated in the ensuing discussion:

*1. V.A. Ambartsumyan, President, Academy of Sciences Armenian S.S.R.; Director, Dyurakan Observatory.

*2. I.S. Shklovskiy, GAISh.

3. G.A. Gurdzadyan, Byurakan.

4. Ya. B. Zel'dovich, Member Academy of Sciences, USSR.

*5. V.A. Kotel'nikov, IRE, Member Academy of Sciences, USSR.

6. B. V. Kukarkin, Astronomical Council, Academy of Sciences, USSR; GAISh.

7. D. Ya. Martynov, GAISh.

*8. N.S. Kardashev, GAISh.

9. E.G. Mirzabekyan, Byurakan.

10. G.M. Ayvazan, Armenian Academy of Sciences.

11. P.M. Geruni, IRE, Armenian Academy of Sciences.

*12. Yu. N. Pariyskiy, Pulkovo.

13. I.D. Novikov, Mathematics Institute, Academy of Sciences, USSR.

14. Ye. Ya. Boguslavskiy, NII 885.

*15. V.I. Slysh, GAISh.

*16. L.I. Gudzenko, FIAN.

*17. B.N. Panovkin, Council for Radio Astronomy, Academy of Sciences, USSR.

18. A.A. Pistol'kors, Corresponding Member, Academy of Sciences, USSR.

*19. V.I. Siforov, Corresponding Member, Academy of Sciences, USSR; IRE.

20. V.A. Razin, NIRFI.

21. L.M. Gindilis, GAISh.

22. G.S. Saakyan, Byurakan.

*23. S.E. Khaykin, Pulkovo.

*24. G.M. Tovmasyan, Byurakan.

*25. V.S. Troitskiy, NIRFI, Director.

*26. N.A. Smirnova, Pulkovo.

*27. N.L. Kaydanovskiy, Pulkovo.

28. E. Ye. Khachikyan, Byurakan.

29. A.V. Gladkiy, Institute of Mathematics, Siberian Section, Academy of Sciences, USSR.

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*Denotes authors of the reports read at the Conference.

The large number of radio astronomers from Byurakan Observatory may be explained by the fact that the Conference was held there. Otherwise, the largest number of representatives (6) was from the GAISh, that is, the Shternberg Astronomical Institute of Moscow University, which is an important organizational and observational center of all astronomical

work in the USSR.

A few remarks can be made about these people.

(1) V.A. Ambartsumyan is the best known theoretical astrophysicist in the USSR, highly respected at home and abroad. He is the past president of the International Astronomical Union, and a member of the Academy of Sciences, USSR. This is the first intimation of his interest in the problem of extraterrestrial civilizations, and his remarks at the meeting were of a general character, apparently made in his capacity as the host of the conference. As a serious worker in the problem he can probably be dismissed.

(2) I.S. Shklovskiy is the most picturesque figure in the above list. He is highly respected abroad for his contributions to theoretical astrophysics and radio astronomy, yet there is a streak in his make-up that baffles observers.

He enthusiastically accepted the idea of extraterrestrial civilizations, criticizing his predecessors Oparin and Fesenkov for their lack of imagination and "pedestrian" attitudes. His work is generally brilliant with a few odd ideas here and there.

One of these was his theory that the Martian satellites are artificial hollow bodies put up by the Martians some half a billion years ago before the Martian civilization expired. This reasoning is based on so many wild assumptions that some astronomers were

convinced that it was a deliberate hoax to see how much nonsense they could swallow. Such hoaxes have occurred now and then in the history of science.

Anyway, Shklovskiy cannot ever claim priority in this idea. In 1950, a book was published in the US by Gerald Heard under the title "Is Another World Watching?" The author believes the UFO's are coming from Mars, and its satellites are platforms for launching Martian flying saucers. There is more than one contact between the world of UFO's and scientific discussions of extraterrestrial civilizations.

But Shklovskiy's reputation apparently has not been damaged in spite of violent criticism of some of his work both at home and abroad. Last fall he was elected corresponding member of the Academy of Sciences, USSR. It is known also that he heads a large research group at the GAISh.

(6) and (7) are well known astronomers at the GAISh. Both, and especially Kukarkin, are political figures who get into everything in the way of astronomy at home and abroad.

(8) N.S. Kardashev, a pupil of Shklovskiy, is one of the ablest men at GAISh and is particularly interested in the problem.

(4) Ya. B. Zel'dovich is a theoretical physicist who has been connected with the FIAN and later with the Institute of Chemical Physics.

(5) V.A. Kotel'nikov is the Director of IRE (Institute of Radio Technics and Electronics) of the Academy of Sciences, USSR. He is known for his radar measurements of the planets. V.I. Siforov (19) is Director of the laboratories of IRE.

(25) V.S. Troitskiy is Director of NIRFI (Radio-Physics Institute at Gor'kov University). He is the author of many papers on radio astronomy, and especially on the moon.

(12) Yu. N. Pariyskiy, (26) N.A. Smirnova, (23) S.E. Khaykin, and (27) N.L. Kaydanovskiy are Pulkovo radio astronomers.

(16) L.I. Cudzenko at the FIAN (Physical Institute of the Academy of Sciences, USSR) is prominent in radio astronomy work.

To the above mentioned persons we can add K.P. Stanyukovich, a rocket expert, who frequently writes on interstellar travel by means of photon rockets; V.I. Krasovskiy, an upper atmospheric specialist; V.A. Bronshten, and some others. The total number of scientists in the USSR actively interested in the problem of interstellar communications and extraterrestrial civilizations is probably in the neighborhood of 50.

Of special significance is the participation of Kotel'nikov and Siforov of IRE both of whom are not only radio scientists of considerable standing but also (especially Siforov) influential political figures. Their activity in the problem of extraterrestrial civilizations indicates the degree of importance that the Soviet

government attaches to it. If recommendations of the Byurakan Conference in regard to construction of new instruments, establishing special sections for the study of the problem at various specified institutes, establishment of a special commission to deal with it, etc., are to be implemented (about which no recent information is available), Siforov and Kotel'nikov will play key roles. The presence of participants like Boguslavskiy, connected with Research Institute Nr 885, and a strange reference (in the resolutions) to P. Ya. 2427 may be indicative of a military interest in this topic.

APPENDIX I

CALCULATIONS BY GINDILIS*

The possibilities of communication with other civilizations depend upon the distances between them. This distance in turn is a function of the size of the universe and the number of civilizations in it.

Restricting himself to our own galaxy, Gindilis (1965) attempts to calculate the number of civilizations coexisting in time with our own. The following equation is used:

$$N_c = Nk_1k_2p_1p_2f(t_c) \qquad (1)$$

Where N_c = number of civilizations in our galaxy coexisting in time with our own.

N = total number of stars in our galaxy.

k_1 = factor that specifies the presence of planetary systems (therefore, Nk_1 is the number of planetary systems in the galaxy).

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* "The Possibilities of Communication with Extraterrestrial Civilizations," by L. M. Gindilis. Foreign Technology Division translation number FTD-HT-66-517/1+2+4 dated 27 September 1966.

**k_2 = factor that specifies the planetary systems with conditions that are suitable for life to begin.

p_1 = probability that life will begin on a planet with suitable conditions.

p_2 = probability that in the process of evolution of living matter on a given planet intelligent beings will develop that are capable of congregating into a society and creating their own civilization.

t_c = lifetime of technologically developed civilizations.

According to Gindilis only the factor k_1 can presently be evaluated more or less reliably. The evaluation is based on a study of the rotational velocity of stars of different spectral classes.

** Gindilis apparently has not defined this term accurately. In his calculations this term k_2 also includes a factor of the probability of how many planets within a planetary system have conditions suitable for life to begin. This second factor is not necessarily equal to one as is discussed in Appendix II.

6. Such plans, if consistently carried out, would involve the southern hemisphere, possibly Chile, where the Soviet astronomers already have a foothold.

7. International cooperation in such a large undertaking seems unavoidable. Accordingly, Soviet steps to establish such cooperation may be anticipated at the next meeting of the International Astronomical Union in Prague, in August 1967.

8. As in most Soviet scientific activities, there is noticeable emphasis on the practical benefits to be obtained from a systematic effort to contact other civilizations.

"As we move along the spectral sequence from stars of type O to stars of type M the temperature of the surface layers changes continuously. Other characteristics of stars, for example, their mass, their luminosity, etc., also change continuously. But the rotational velocity changes continuously only for stars of the early spectral classes from O to F2. Around the F2 class the rotational velocity changes sharply, almost stepwise. The equatorial regions of those stars that are hotter than the F2 class rotate with a velocity greater than 100 km/sec. Stars of the later spectral classes G, K and M practically do not rotate at all: their equatorial velocity is several km/sec. We have the impression that, for some reason, in the process of their development the stars of these spectral classes have lost their initial angular momentum, due to which their velocity is significantly reduced. It is curious that the magnitude of the lost momentum for the stars of the same type as the sun corresponds to the angular momentum of our planetary system. From this we can make a very plausible conclusion that the loss of angular momentum is connected with the formation of planetary systems around the stars in a definite stage of their evolution. One possible mechanism for transferring the angular momentum from a star to the forming planets, in which the role of the transfer agent is played by a magnetic field, was proposed by the English astrophysicist Hoyle. If these

presentations are valid, then we can assume that there are planetary systems around all stars whose spectral classes are later than F2. The overwhelming majority of the stars of the galaxy satisfy this condition, i.e., the k_1 factor in formula (1) must be close to unity."

Gindilis also points out that another important argument in favor of a large number of planetary systems in the galaxy results from observations of "Barnard's Flying Star." Because this star is very close to the solar system, (closest to us after Proxima and Alpha Centauri) it moves rapidly along the celestial sphere in comparison with other stars. Barnard's Flying Star is a red dwarf of the M5 spectral class with a mass of 0.15 that of the sun. Van de Kamp (American) observed that the proper motion (path across the celestial sphere) of this star has periodic oscillations caused by the presence of an invisible dark satellite. The satellite is dark because its mass is only about 1.5 times that of Jupiter and therefore cannot be self-luminous. This could be a giant planet rotating around its star along a strongly elongated orbit.

Professor B. V. Kukarkin (USSR) has noted that wobbling could also be caused by a system of several planets similar to our planetary system, provided the periods of rotation of the planets are approximately comensurate. Kukarkin suggests that the proper

motion of our sun would appear to another civilizations's astronomers to be satisfied by the presence of one giant dark satellite with a period of about 60 years. This is explained by the approximate commensurability of the periods of rotation of the two largest planets of our solar system: five periods of Jupiter correspond to 59.3 years, two periods of Saturn correspond to 58.9 years.

Gindilis continues, "These arguments are not, of course, strong proof of the existence of planetary systems around many stars. However, they indicate that there is a weighty basis for such an assumption. Most investigators consider that planetary systems are well spread throughout the galaxy and that their number can attain one hundred billion ($k_1 \sim 1$)."

"Of course, not all planets are suitable for the evolution of life. Evaluating the number of planets with conditions suitable for life is a rather difficult problem, if only because we know nothing about the life forms that can develop on other planets. We shall not consider this question. The reader can find details about this in the exceptional book of I. S. Shklovskiy 'Universe, Life, Intelligence,' in the books of A. I. Oparin and V. G. Fesenkov, 'Life in the Universe' and Kh. Shepli, 'Stars and People.' The limits for the factor k_2 given there lie in the range from 10^{-6} to 0.06. From this the number of planets in the galaxy with conditions suitable for life is from 10^5 to 10^{10}."

If the element of randomness is excluded, and it is assumed that life must arise in the presence of the necessary conditions (according to Gindilis many scientists think so) then $p_1 = 1$.

Even with the above assumption there is no guarantee that once life has begun it will necessarily evolve into intelligent life. According to Professor A. A. Neyfakh (USSR) even insignificant difference in the physical conditions on different planets in comparison to terrestrial conditions can cause difference in the period of evolution by one or two orders of magnitude.

Because intelligent life developed on earth, the factor p_2 is greater than zero, but from the above discussion not necessarily equal to unity. Thus there is a definite probability that on a planet where some life has developed, this life at sometime in the future will have evolved into intelligent thinking beings. As evident from the preceding discussion, it is not possible to determine this probability p_2.

As described in the main text there is no agreement as to the time span of a civilization. One view is that the lifetime of a civilization t_c is limited and regardless of its length (hundreds, thousands, or millions of years) is small when compared to the cosmic time scale T. Another view is that the lifetime of a technologically developed civilization is indefinitely large and can be only compared with the age of the oldest objects in the universe.

The form of the function $f(t_c)$ depends upon the point of view with regard to the time span of a civilization.

If $t_c << T$,

then $f(t_c) = \frac{t_c}{T}$

If $t_c \sim T$,

then $f(t_c) = \frac{T - To}{T}$

where T_o is the time between the formation of a planetary system and the appearance of a technologically developed civilization on it.

Assuming the lifetime of a civilization is limited, the following variables may be substituted into equation (1):

Nk_1k_2 = between 10^5 and 10^{10}

P_1 and P_2 unknown but greater than zero and less than or equal to one.

$f(t_c) = \frac{t_c}{T}$ where T is generally accepted as 10^{10}

Upon substituting into equation (1) under the premise that one wishes to calculate the maximum number of civilizations, the following result is obtained:

$$N_c \sim t_c \qquad (2)$$

Therefore in the most favorable case the number of civilizations coexisting with ours in the galaxy is equal in order of magnitude to their lifetime t_c in years.

Gindilis then quotes two evaluations of the number of civilizations, the first evaluation is that there are not less than one per 10^{12} stars (not less than one civilization in five neighboring galaxies). The second evaluation, more optimistic, is that there is one civilization per 10^6 stars or on the order of 10^5 civilizations in the galaxy.

Gindilis then calculates the average distance $\underline{d}$ between civilizations in the galaxy by using the following formula:

$$d = d_o \left(\frac{N}{N_c}\right)^{1/3}$$

where d_o is the average distance between neighboring stars, then assuming $d_o = 7$ light years one may calculate the average distance d, given values of N and t_c. These results are shown in Table II.

Based on Table II and his discussion about the possible number of civilizations in the galaxy, Gindilis concludes that the distance between civilizations is not less than several hundreds of light years, and it is probably more than a thousand light years.

TABLE II

Distance between civilizations as a function of the number of civilizations.

N/N_c	N_c	d (in light years)
10^2	10^9	32
10^3	10^8	70
10^4	10^7	150
10^5	10^6	320
10^6	10^5	700
10^7	10^4	1500
10^8	10^3	3200
10^9	10^2	7000

APPENDIX II

PLANETARY REQUIREMENTS

If one assumes that the process of the beginning and evolution of life on other planets must be similar to the Earth's (as maintained by Soviet astrophysicist I. S. Shklovskiy). The following series of planetary requirements must be met.

1. "Planets on which life may begin and develop may not evolve too close to or too far away from their star, and their surface temperatures must be favorable to the development of life. However, taking into account that a comparatively large number of planets, say about ten, can originate simultaneously with the star, it may be reasonably expected that at least one or two of them may rotate at distances at which the temperature range remains within the required limits. It is very unlikely that the red dwarfs of the spectral class M, and even later subclasses K, would sustain life on their planets since their radiation energy is insufficient.

2. The mass of an inhabitable planet must be neither too large nor too small. If the gravitational field of a planet is too strong, the original hydrogen-rich atmosphere will not be able to evolve (by a process involving the escape of hydrogen into space) into the oxygen-containing air on which the advanced terrestrial type of life depends; if the gravitational field is too weak, the

atmosphere will escape into space early in the planet's history (Mercury is such an example).

3. A highly organized life may be found only on planets circling sufficiently old stars whose ages may be estimated at several billion years, since enormous intervals of time are necessary for the appearance of any intelligent species on a suitable planet.

4. The star must not vary significantly in its brightness for several billion years. During this time it must reliably and continuously pour forth a steady stream of light and energy, never once pulsating or altering its output to any significant degree. Most stars meet this condition.

5. The star must not be of multiple type, otherwise the orbital motion of its planets would be substantially different from the circular, and the resulting sharp, if not catastrophic, temperature variations on the planet's surface would prelude the possibility of life developing."*

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*The quotation taken from ATD Report 66-57

Not all Soviet scientists completely agree with the listed requirements. F. A. Tsilsin (of the State Astronomical Institute), for example, does not agree that only single stars are capable of having planets which fulfill the other outlined requirements. Tsilsin goes on to point out three instances where a binary star system could have an inhabited planet. In the first of these the two stars are very close together and the planet rotates around their common center of gravity. In the second instance the two stars are far apart and one or both have a planet rotating around them in the favorable temperature zone. In the last case a planet is considered to be in the libration point of the binary star.

Although it's not agreed that each factor listed must be met for intelligent life to develop, as evidenced by the preceding discussion. The list does serve to indicate some of the considerations necessary in trying to accurately determine the probability that intelligent life exists elsewhere.

SECTION I

HISTORY OF THE PROBLEM

The idea that intelligent beings might exist outside of the earth was debated in antiquity (Anaxagoras, Plutarch, Lucian, etc.). This speculation was frowned upon by the Catholic Church as contradictory to the Christian dogma of the uniqueness of man and his relation to the universe. During the Renaissance the idea of habitable worlds was again revived (Nicolaus Cusanus, Giordano Bruno, Kepler, etc.).

The telescope showed many details on the surface of the planets which generally favored the idea of habitability. It was assumed that man was the goal to which all creation moves and consequently, the celestial bodies did not have any reason to exist unless they served as homes for intelligent beings. In the 18th Century, such scientists as Huygens, Fontenelle, Swedenborg, and others wrote elaborate treatises on the supposed inhabitants of other planets, and even the great philosopher Kant thought that at least some of the planets besides the earth might be inhabited.

Further development of this idea occurred in the early 19th Century. Sir William Hershel, perhaps the greatest observational astronomer of all times, deduced from his own observations that the sun was really a dark body which very well might be inhabited.

APPENDIX III

POWER REQUIREMENTS

In considering a radio communication link between our civilization and another civilization, it is of interest to determine the power which must be radiated in the direction of the other civilization.

The power requirement can be calculated by the following equation:

$$W = I_v \left(\frac{\lambda}{d_1}\right)^2 {}_2 \left(\frac{\lambda}{d_2}\right)^2 {}_2 R^2 \qquad (1)$$

where d_1 = diameter of the transmitting reflector

d_2 = diameter of the receiving reflector

R = distance between reflectors

Equation (1) reduces to:

$$W = I_v \left(\frac{\lambda}{d_1}\right)^2 {}_2 \left(\frac{\lambda}{d_2}\right)^2 {}_2 R^2 = 10^{-24.2} \frac{R^2}{d_1^2 \, d_2^2} \text{ Watt/cps} \qquad (2)$$

under the assumption that the hydrogen radio frequency line is used and that the other civilization is at a rather high galactic latitude where the level of interference (determined by the cosmic radiation background) is much smaller. Two types of interference which have to be considered are radio emissions from the star around which the inhabited planet revolves and background cosmic radiation. The intensity of this interstellar interference in the

radio-frequency line is not greater than that of the continuous galaxy radio-frequency emission in the same spectral range, which is equal to $10^{-21.5}$ cw/m^2 ster/cps for comparatively large angular distances from the Milky Way band. In the Milky Way the intensity of the hydrogen radio-frequency line is several dozen times greater than the magnitude at the higher galactic latitudes.

As an example, assume that $d_1 = d_2 = 80$ m and that the other civilization is 10 light years away (R = 10). Substituting these values into equation (2), W must be greater than or equal to 100 watts/cps, which is already feasible. It is quite possible that the other civilizations could have a much greater transmission capability and much larger antenna systems than does our civilization. Either or both of these conditions would allow communications over larger distances. Much larger reflectors are being considered which could also increase the radius of communication possibilities. The calculation has shown that communications with other civilizations can be accomplished with modern equipment.

APPENDIX IV

PAPERS READ AT THE BYURAKAN CONFERENCE

1. V. A. Ambartsumyan, Introduction, pp 7-11.

2. I. S. Shklovskiy, "Multiplicity of Inhabited Worlds and the Problem of Establishing Contacts Between Them," pp 15-34.

3. N. S. Kardashev, "Transmittal of Inormation by the Extra-terrestrial Civilizations," pp 37-53.

4. Yu. N. Pariyskiy, "Observations of Peculiar Radio Sources STA-21 and STA-102 in Pulkovo," pp 54-60.

5. V. I. Slysh, "Radio Astronomy Criteria of Artificiality of Radio Sources," pp 61-67.

6. L. I. Gudzenko and B. N. Panovkin, "On the Problem of Reception of Signals From Extraterrestrial Civilizations," pp 68-61.

7. S. E. Khaykin, "On the Problem of Contact With Extraterrestrial Civilizations," pp 83-94.

8. G. M. Tovmasyan, "Ring Radio Telescope for the Establishment of a Contact With Extraterrestrial Civilizations," pp 95-96.

9. V. S. Troitskiy, "Some Considerations on the Search of Intelligent Signals From the Universe," pp 97-112.

10. V. A. Kotel'nikov, "Contact With Extraterrestrial Civilizations in the Radio Range," pp 113-120.

11. V. I. Siforov, "Some Problems of Search and Analysis of Radio Emission From Other Civilizations," pp 121-128.

12. N. A. Smirnova and N. L. Kaydanovskiy, "Influence of Conditions of Radio Wave Propagation in Cosmic Medium and Atmosphere of the Earth on the Angular Size of the Source," pp 129-135.

13. A. V. Gladkiy, "On Possible Languages for Contact Between Different Civilizations," pp 145-146.

APPENDIX V

RESOLUTIONS OF THE BYURAKAN CONVERENCE
May 20-23, 1964

1. Although materialistic philosophy favors the existence of intelligent extraterrestrial life, at the present time there is no valid proof of such life. However, there are strong indications that such life might exist and might develop civilizations.

A contact with extraterrestrial civilizations would be of the highest importance and interest but until very recently such a contact was clearly impossible. At the present time, however, there is a possibility of establishing interstellar communications by means of electromagnetic waves. The best range for this purpose are frequencies 10^9 to 10^{11}, that is the region of centimeter and decimeter waves.

The present-day technology allows the registration of radio signals across stellar distances. A rapid development of cybernetics makes it possible to formulate the problem of cosmic linguistics. The rapid growth of scientific literature on these subjects, and the first practical steps made in the U.S. to contact extra-terrestrial civilizations clearly show that interstellar communication is an actual scientific problem.

2. It is therefore necessary to undertake the development of an experimental as well as theoretical approach to this problem.

A. Experimental work should be conducted along the following two lines of effort:

(a) A systematic survey of the sky in order to detect signals from objects within 1,000 light years, and sending signals within that distance to possible cosmic correspondents.

(b) A search for signals from the substantially more developed civilizations than our own by applying a careful analysis to discrete cosmic radio sources suspected to be of artificial origin.

To carry out these projects, it is necessary to utilize the already existing apparatus and set up radio interferometers with long base lines of the order of 10^6 to $10^7\lambda$'s, in the centimeter wavelengths.

B. It is necessary to continue and intensify optical investigations having a bearing on the above-mentioned programs. This would include work on planetary and stellar cosmogony, a search for planetary systems, identification of radio sources, and an organization of special investigations outside the atmosphere of the earth.

C. Along with these programs there should be organized studies in adjacent fields:

(a) A theoretical study of statistical properties of artificial radio sources, that is, the establishment of criteria

for the artificiality of signals and the development of methods for the discovery of artificial signals. Further, it is necessary to develop methods of analysis of the statistical properties of radio signals and apply these methods to cosmic sources of suspected artificial origin.

(b) Development of methods of establishing contact and of a cosmic language on the basis of the general theory of linguistics. Also, the development of the theory of decipherment and of the basic principles of the theory of learning.

3. To carry out these programs it is desirable to establish in a number of scientific organizations special working groups. The institutions recommended for this purpose are:

GAISh (Shternberg Astronomical Institute, Moscow University)

GAOAN SSSR (Pulkovo Astronomical Observatory)

BAO AN ArmSSR (Byurakan Astronomical Observatory)

NIRFI (Radio-Physical Institute at Gor'kiy University)

IRE (Institute of Radio Technology and Electronics, AN SSSR)

Siberian Section of the Academy of Sciences, USSR

Mechanical-mathematical Faculty of Moscow University

P. Ya. 2427 (Post Office Box 2427, of some unidentified radio institute).

4. For coordination of research work in various organizations the Astronomical Council and the Council for Radio Astronomy of

the Academy of Sciences, USSR, are asked to organize a special Commission for Interstellar Communications. This Commission should be empowered:

(a) Using the available optical and radio astronomy information to work out for the next conference a program of search for the artificial cosmic sources. A possibility of international cooperation in this task should be considered.

(b) Paying attention to the recommendations of the present conference to work out during 1964-1965 a plan for technical and financial assistance in the problem of interstellar communications. This plan should include the construction of appropriate radio telescopes and of receiving and analyzing apparatus.

The personnel of the proposed commission is recommended as follows:

I. S. Shklovskiy, GAISh, MGU

V. S. Troitskiy, NIRFI, Gor'kiy University

G. M. Tovmasyan, Byurakan Observatory, Armenian AN

Yu. P. Pariyskiy, GAO AN SSR (Pulkovo)

N. S. Kardashev, GAISh, MGU

L. M. Gindilis, GAISh, MGU

B. N. Panovkin, Council for Radio Astronomy, AN SSSr

5. It is considered desirable to call the next conference on the problems of extraterrestrial civilizations and interstellar communications in 1965.

6. It is proposed to ask the Academy of Sciences, Armenian SSR, to publish the proceedings of the present conference as a separate book.

APPENDIX VI

DESCRIPTION OF SELECTED ANTENNAS

Presented in this appendix are photos of two of the more advanced radio telescopes used in the USSR for receiving interstellar radio transmissions. The two telescopes are the 22 meter diameter, RT-22 (Shown in Figure 1) and the Pulkovo segmented plate reflector antenna (Shown in Figure 2).

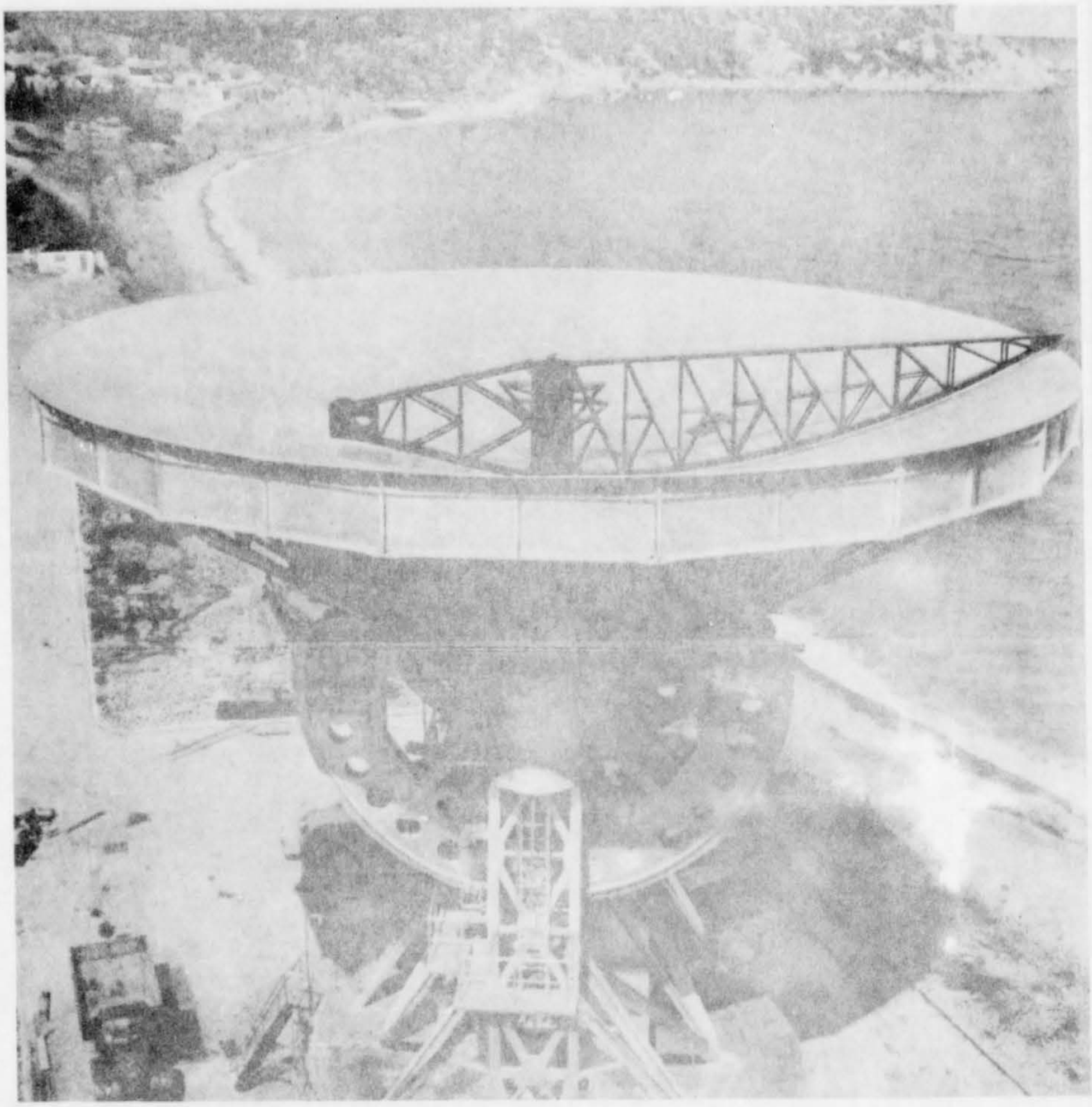

Figure 1. RT-22 Radio Telescope.

He theorized that the brilliant surface of the sun was actually its atmosphere and the so-called sunspots were simply the solid dark surface showing through the rifts of the atmosphere. The very influential French astronomer Arago, as late as 1850, could not find anything wrong with this theory.

In 1832, Von Littrow accepted the idea of J. Lambert (1750) that comets were undoubtedly inhabited and their extensive atmospheres had the purpose of mitigating and preserving the heat of the sun which must vary greatly along the eccentric orbits of those bodies. Both men were leaders in the mathematical theory of comets.

On the moon the German astronomer Gruithuisen could see cities and railroads, and other astronomers speculated what function the rings of Saturn might have to make conditions there more comfortable for the intelligent beings which were undoubtedly there.

In the second half of the 19th Century the science of astrophysics was born and quickly showed that the conditions on the sun, moon, comets, and the majority of the planets were such as to preclude the existence of any life there. The only possibly habitable planets were Venus and Mars, and life on these was highly problematical. It became unfashionable to talk about inhabitants of other planets, and Lowell's ideas about the artificial origin of the canals

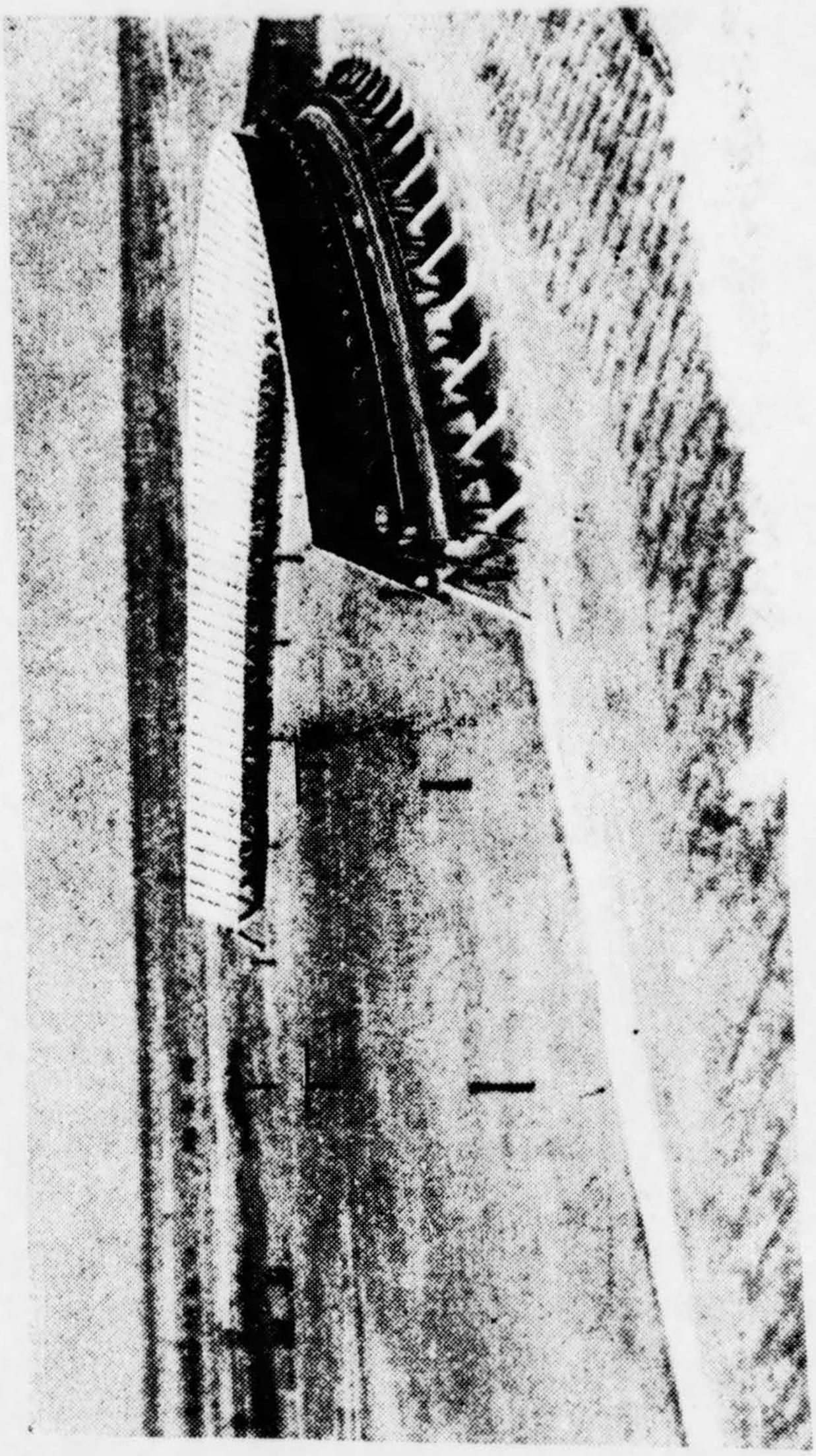

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Figure 2. Pulkovo Radio Telescope.

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* Bibliography from PWS Task Response which is essentially Sections I, II, and III.

on Mars was generally ridiculed.

A few hardy souls here and there continued to maintain that Mars must be habitable regardless of what scientists' observations indicated. In the U.S. such were E.C. Slipher and W.H. Pickering, in the USSR, G.A. Tikhov and especially K.E. Tsiolkovskiy. Tikhov remained essentially a scientist and only tried to prove that terrestrial plants can adapt themselves to the conditions on Mars. Tsiolkovskiy was a dreamer who threw caution to the winds. One of his books, constantly quoted by Soviet astronomers, has the revealing title "Dreams about the Earth and the Heavens." With the development of rocket technology Tsiolkovskiy became in the USSR an almost infallible authority to be quoted along side Lenin and Marx.

The novelists, as usual, were years behind the scientists. H.G. Wells' "The War of the Worlds," appeared in 1905. It was (and still is) extremely popular throughout the world, and many remember the panic in 1938 when this story was dramatized on the radio. Millions of people believed the Martians were landing in New Jersey and marching on New York City.

However, the scientists were rather cool toward the possibility of life on Mars or elsewhere outside the earth. Perhaps the lowest point in the belief of extraterrestrial life was reached in the

1920's when Sir James Jeans showed that the collision of two stars, according to him the only possible mode of the formation of a planetary system, is an extremely improbable event, and it may well be that the earth is a cosmic freak with some kind of mold on it called life.

Doubts were soon thrown on Jeans' theory of the origin of the solar system, and quiet investigations on the origin of life on the earth and other celestial bodies continued. In this respect, A. I. Oparin's work deserves to be mentioned. He is still Director of the Institute of Biochemistry, Academy of Sciences, USSR, and is the author of many articles and several books on this problem.

The situation changed radically with the postwar development of radio astronomy when it became possible to think of a direct contact with extraterrestrial civilizations by means of radio. The beginning of the new approach was sharply marked by the appearance in the British periodical "Nature," of a letter by two U.S. scientists, G. Cocconi and P. Morrison, "Searching for Interstellar Communications" (1959). This letter fired the imagination of many people including one of the remarkable Soviet scientists, I. S. Shklovskiy, the author of numerous articles and several books on the subject.

Shklovskiy's first book, "The Universe, Life, and Intelligence,"