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Through the third, fourth and fifth dimensions in search of...

THE MISSING LINK

James D. Burke

For nearly sixteen years the Soviet Union has been using a deep-space radio link that we have been unable to intercept. This is an account of our intelligence efforts leading, first, to a conviction that the link exists, second, to a knowledge of many other aspects of the Soviet planetary program, and finally to a determined but still unsuccessful effort to find the unknown signal.

Deep-Space Information Systems

To explore the planets, automated spacecraft must return information over distances of tens of hundreds of millions of kilometers. Because of the limits of spacecraft transmitter power and antenna size, the radio signals reaching earth are fantastically weak: many millions of times weaker than the energy collected by a car radio antenna. Deep-space ground stations therefore must have huge antennas and supersensitive receivers similar to the equipment used by radio astronomers. And even then, the rate at which information can be sent is severely restricted. In the early sixties, we and the Soviets received only a few symbols per second from our first planetary probes. Today in U.S. missions the rate has grown to hundreds of thousands per second, enabling the return of images such as those of Mercury from Mariner 10 and of Mars from Viking.^{1 2}

Soviet progress has been less spectacular, but it has also led to a capability for imaging the planets. Figure 1, a picture of Martian landforms returned by the MARS 5 spacecraft in 1973, is comparable to U.S. Mariner imagery. To send pictures such as Figure 1, the Soviet spacecraft must have had some combination of the following:

- a. a large directional antenna pointed accurately toward earth;
- b. a powerful transmitter;
- c. a high transmitting frequency (giving the most gain for a given antenna size); and
- d. on-board data storage so that the picture data could be slowed to a rate that the radio link could handle.

Soviet planetary pictures, having been proved genuine by comparison with data from U.S. missions, show that this design problem has been solved—though not, apparently, in quite the same way or with as high a priority as in the United States. Soviet planetary images have often been inferior in both quality and quantity to those from contemporary U.S. missions; nevertheless it is clear that the Soviets are able to return respectable quantities of data from planetary distances.

¹ Murray, B. C. and Burgess, E., "Flight to Mercury" 1976, Columbia Univ. Press. Lib. Cong. No. LC-76-25017.

² "Scientific Results of the Viking Project," Journal of Geographical Research 82, 28, 30 Sept. 1977.

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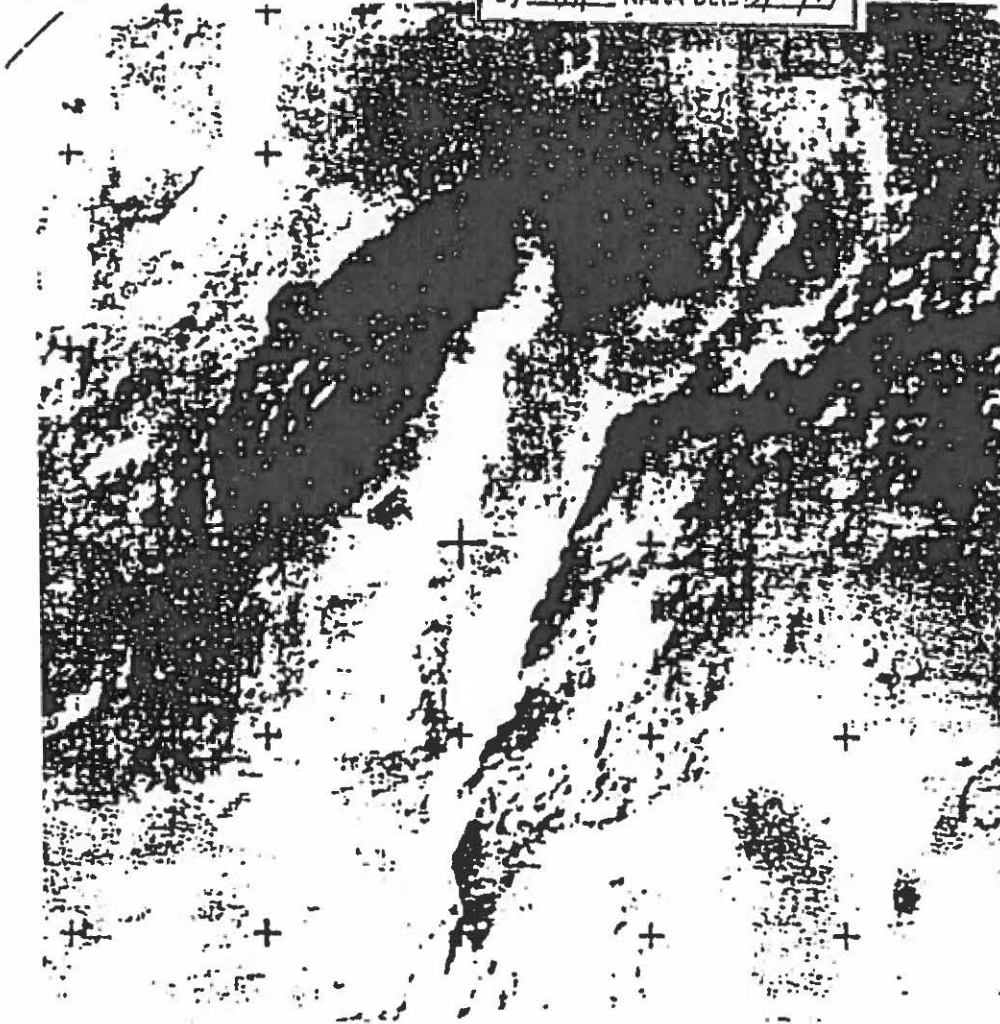
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Fig. 1: Photo of a 100 x 100 km region of Mars, sent to Earth by MARS 5.

Soviet Deep-Space Communications

In their large program of flights aimed toward the Moon, Venus, and Mars since 1970,³ the Soviets have consistently used and improved a few basic communication links, most of which have been described in public and confirmed by U.S. intercept. The known links and their functions are listed in Table 1. One link remains unknown and we are now confident that this is no accident, for it is the one that carries prime, high-rate science data including orbital imagery such as Figure 1.

Soviet announcements from 1962 onward have acknowledged that this link exists. The most explicit description of it appeared in *Pravda*, 19 December 1971, in connection with the MARS 2 and 3 missions:

Two radio channels—one narrow-band and one broad-band—are utilized for communication between the orbital apparatus and the Earth. The narrow-band channel is designed primarily for making trajectory measurements and transmitting telemetry information; it operates in the decimeter waveband. The broad-band radio channel, which functions in the centimeter waveband, permits

³Sheldon, C. S. II, "United States and Soviet Progress in Space: Summary Data through 1976 and a Forward Look" Lib. Cong. Document 77-99 SP, 5 April 1977.

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Table 1

SOVIET DEEP-SPACE DOWNLINKS

Wavelength (cm)	Frequency (MHz)	Use
163	183.6	Lunar telemetry
32	922.76	Lunar telemetry and imaging
32	928.4	Planetary narrow-band data (including some imaging)
8	3691 or 3713.6	Coherent 4x multiple of 32-cm carrier, for dual-frequency plasma and occultation experiments
5?	?	Planetary broad-band data including orbital imaging and science

the transmission of large volumes of information from the television assemblies and scientific instruments.

Since all statements about the narrow-band channel were proved correct by intercept, we have tended to give some weight to similar statements about the broad-band channel. Given such a clear target, one may well ask why this signal has never been intercepted. To answer this question, we must consider some technical matters and also the intelligence environment within which deep-space SIGINT collection occurs.

Early U.S. Deep-Space Collection Efforts

Twenty years ago both the United States and the USSR began trying to reach the Moon. The Soviets succeeded first and then, in the decade 1959-1969, were overtaken by the massive U.S. response that put Apollo astronauts on the Moon and caused the Soviet manned lunar program to collapse. During the great lunar contest, both parties also were active in automated exploration of the planets. The Soviet planetary exploration effort was much larger than that of the United States, but its successes were few.

At the outset of both programs in 1959, we had no capability for intercepting Soviet signals from deep space, and there was some debate over the need to do so in the absence of any evident security threat. In the end it was decided to build a multipurpose station which could collect deep-space signals and also those from high altitude communications satellites, the latter being, of course, of possible military importance. Because the Soviets normally transmit only to stations on their own territory, our station had to be in the Eastern Hemisphere. The site selected for it was near Asmara, Ethiopia, in the vicinity of other existing U.S. facilities. From 1965 to 1975 this deep-space station, named STONEHOUSE (Figure 2) functioned with increasing competence, recording signals from Soviet lunar missions, comsats, and planetary spacecraft. Before its successful career was ended by political unrest and terrorism in Ethiopia, STONEHOUSE—with the aid of several collaborating sites—gave us a fairly full understanding of the Soviet lunar and planetary program.⁴ We learned how the known data links listed in Table 1 were used, and we came to understand much of the information that they carried. We even obtained some scientific data superior to any released by the Soviets, indicating that STONEHOUSE

⁴ (SECRET) Burke, J. D. "Seven Years to Luna 9" *Studies in Intelligence*, Summer 1966, X/3, pp. 1-24.

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Issuing Link

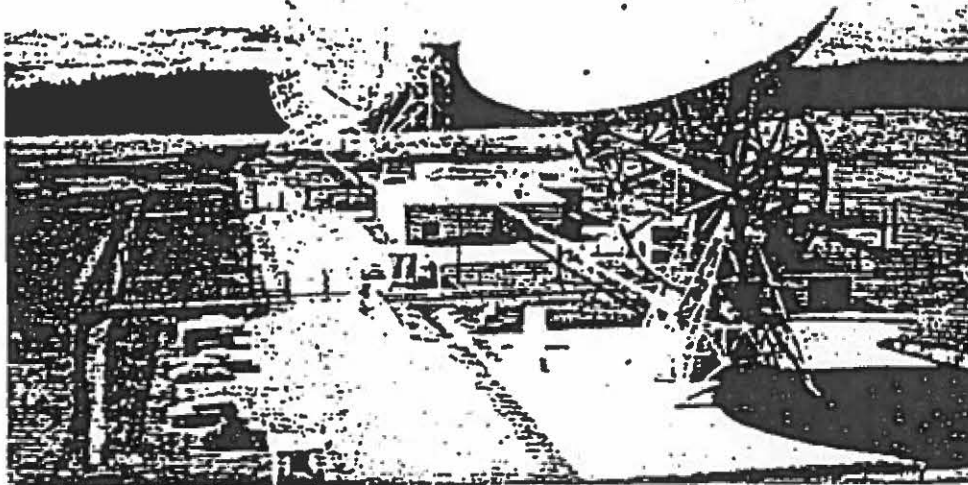


Fig. 2: STONEHOUSE deep-space receiving station near Asmara, Ethiopia. The antenna in the foreground was 26 meters in diameter; the one in the background was 46 meters in diameter.

was performing as well as or better than the Soviet Crimean deep-space stations, at least for the decimeter-wave, narrow-band telemetry. In all this time, however, we never acquired the centimeter-wave, broad-band signal. We came to know exactly where to look and when to expect it to be on the air; we thought we knew its approximate frequency; we searched and did not find it.

The problem in such searches is that one seeks a small needle in a large haystack. The search dimensions are space, time, and frequency. In space, one must point the receiving antenna precisely toward the signal source. We had to determine the trajectory of each outbound spacecraft soon after it left Earth, so that we would know where to point the antennas during the months of interplanetary flight. This was done with the aid of radar tracking from Diyarbakir in Turkey and sometimes with angle tracking, either radio or optical, from sites in Iran and California.

In the time dimension, one could try to search continuously whenever the spacecraft is in view, but this would be very costly and frustrating because Soviet planetary spacecraft transmit only for occasional short periods. We therefore had to devise schemes, based on the behavior of other observed signals, to concentrate our searches at the right times. STONEHOUSE was greatly aided in this task by information from another site, in ██████████ which intercepted Soviet deep-space command uplink transmissions from the Crimea.

As we went on trying, we thus developed reliable means for telling where and when to look. The overseas sites were tied into a real-time system using NSA

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computers and secure communications centered in DEFSMAC. Though often plagued by communications problems, this system essentially solved the space and time search problems. This left the frequency dimension, which was and remains the chief obstacle.

In a deep-space mission the expected radio signal power within any small frequency interval is minute. If the receiver bandwidth is widened to admit more signal power or to cover a larger search region, it also admits more cosmic radio noise masking the desired signal. But to search a broad frequency band a little at a time takes forever, and the Soviet signals are typically turned on only for an hour or two. Unless there is some clue as to where to look in frequency as well as in space and time, the search may be hopeless.

Clues

Apart from the Soviet announcement quoted earlier, what clues do we have for the frequency search? Over the years we have accumulated quite a few. Until the signal is found, of course, we have no way to evaluate their validity. We could be the victims of a prolonged deception—but we wonder if the Soviets would really deem such an effort worthwhile. In other parts of their deep-space enterprise they seem to have followed a fairly consistent pattern: reluctance to release information before launch, lack of candor about failures, and accurate but incomplete information about successes. Outright lies appear to have been rare. Therefore, in planning our searches for the hidden signal, we have tended to give some weight to Soviet-released circumstantial evidence.

The first announcement of our target was made in 1962, during the unsuccessful MARS 1 mission. That spacecraft, the only survivor of six launched in that year for Venus and Mars, was said to be transmitting on wavelengths of 1.6 meters and 32, 8 and 5 centimeters. Though we had no way to confirm these numbers at the time, on later missions we found and identified the 1.6-m, 32-cm, and 8-cm signals as described in Table 1. Therefore, we have always thought it likely that the remaining signal would be in the 5-cm region of the radio spectrum. This belief was reinforced by the next clue, presented to us in 1967 at Montreal. The Soviet EXPO-67 exhibit included a spacecraft (Figure 3) purporting to represent ZOND 3, a camera-carrying planetary spacecraft that had returned test photos of the Moon.⁴ The ZOND 3 camera package apparently contained a centimeter-wave transmitter whose output was conveyed to the spacecraft's directional antenna by a waveguide. A waveguide is a pipe for carrying radio waves, somewhat analogous to a speaking tube for sound, and its outer dimensions give a rough indication of the design frequency. We measured the EXPO-67 waveguide and found that it could indeed handle a 5-cm signal.

Over the next several years we pursued the subject of Soviet waveguides as shown in various hardware exhibits and design handbooks, and we even found some (on Molniya comsats) that could be clearly correlated with intercepted signals. On the planetary spacecraft exhibits, however, the hardware varied and at times we suspected a spoof; in the end we decided that the designs had been evolving and the exhibits were just pieced together from available, perhaps partly obsolete, items. After wondering about this problem with exhibits in Paris and Moscow in 1974, we finally got a good look at a full-scale and obviously genuine spacecraft representing Venera 9 and 10 at Los Angeles in December 1977, where the waveguides and antenna hardware appeared at last to be self-consistent. Figure 4 is a photo of this craft and Figure 5 is a closeup of its antenna feed structure showing the waveguide and two coaxial cables. Pride of place in the feed structure (on the antenna axis) is given to the

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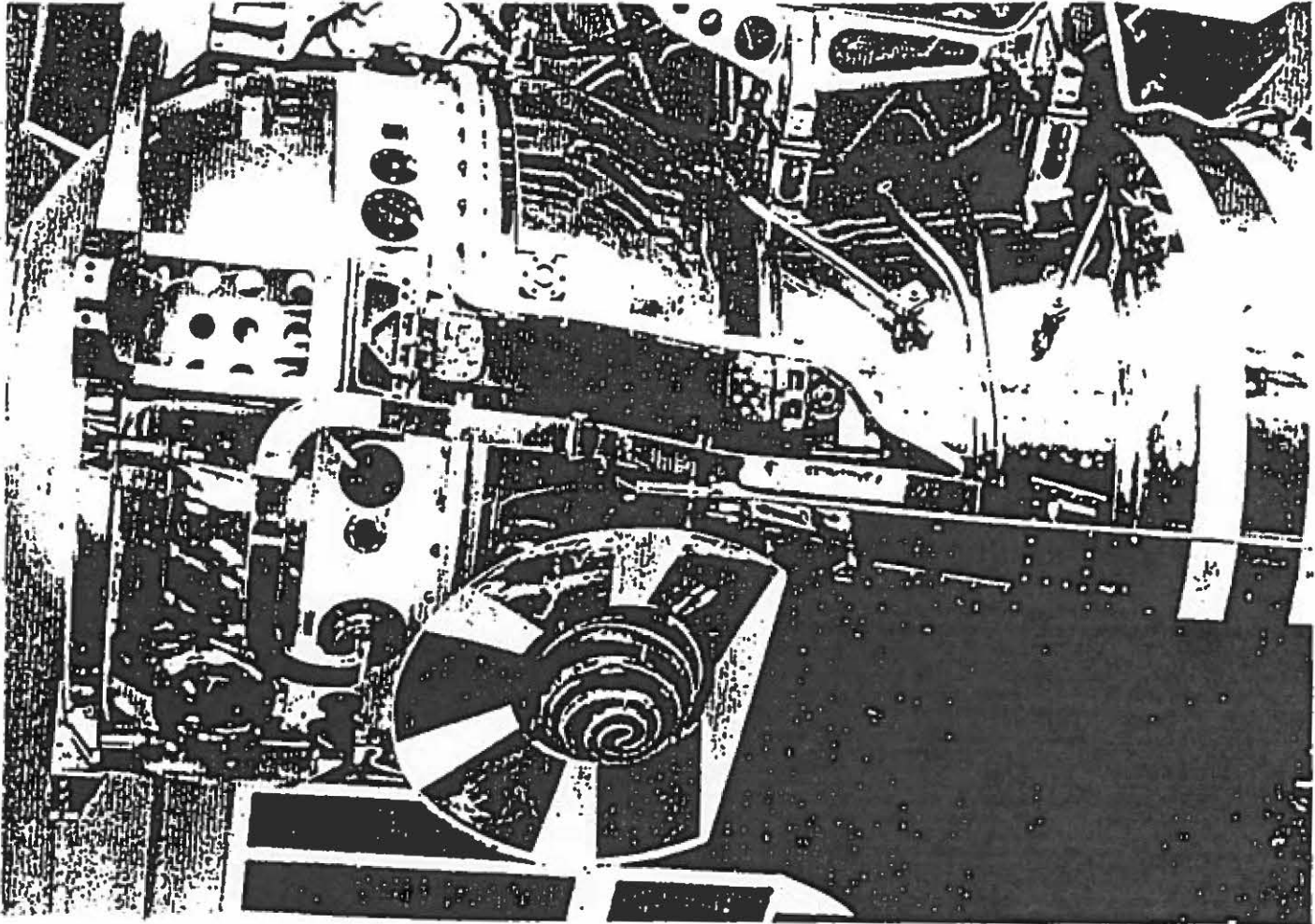


Fig. 3: ZOND 3 type spacecraft, EXPO-67, Montreal. Centimeter-band waveguide is the curving rectangular tube emerging from camera compartment (left) and going to main spacecraft body (right). Part of the rear of high-gain paraboloid antenna can be seen along top edge of picture.

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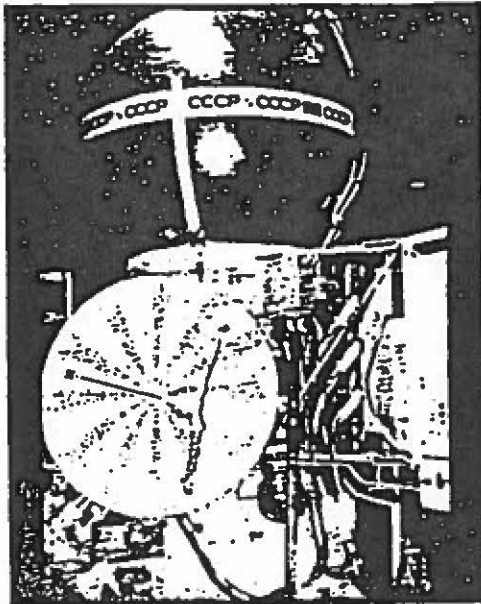
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Fig. 4: Venera 9/10 type spacecraft. Parasol-like object is directional antenna.



Fig. 5: Venera 9/10 directional antenna feed showing centimeter-band waveguide and coaxial cables for two other signals

waveguide; the coaxial cables probably carry the narrow-band 32-cm and 8-cm signals.

Just as spacecraft components give some information on intended radio frequencies, so do ground installations. Figure 6 is a Soviet-released photo of one of the Crimean deep-space sites, showing in the foreground the eight-dish array that probably handles the 32-cm narrow-band signals, and in the background two 25-meter antennas of unknown function. Figure 7 is another view of these, showing a feed structure with four square horns and a central circular aperture. The horns could be for tracking the 32-cm signal and the on-axis circular feed could be for some higher frequency—perhaps the broad-band, 5-cm transmission.

Apart from hardware evidence, we have, over the years, gathered in a few other clues to the unknown signal frequency. In 1973 the Soviets launched four spacecraft toward Mars while we were preparing to launch Mariner 10 to Venus and Mercury. It was suggested that NASA Deep Space Net stations should acquire signals from the Soviet craft as a test of our new X-band (3-cm) radio system. Dr. John Naugle of NASA wrote to Academician B. N. Petrov suggesting this test, offering to share any acquired data, and mentioning the U.S. X-band frequency, 8400 MHz. Academician Petrov politely declined, adding that the Soviet frequency was "more than two GHz below" the U.S. frequency; i.e., lower than 6400 MHz, in the 5-cm wavelength region.

We then looked for nearby regions of the radio spectrum allocated, by international agreement, for deep-space use. (Such allocations, though unenforceable, are often observed because they give mutual protection against radio interference.) The nearest allocated band was the region from 5670 to 5725 MHz, so we decided to look first in this band.

Narrowing the Search

STONEHOUSE searched diligently in the selected region against the 1973 Mars missions and found nothing. In our post-mission reviews we concluded that we had not

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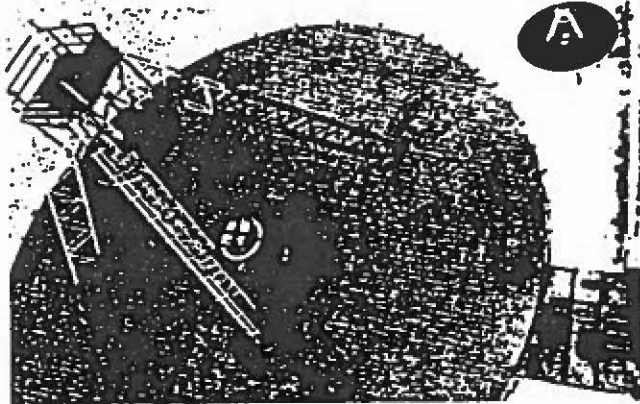
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Fig. 7: Crimean 25-meter antennas



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Photography of antennas structure

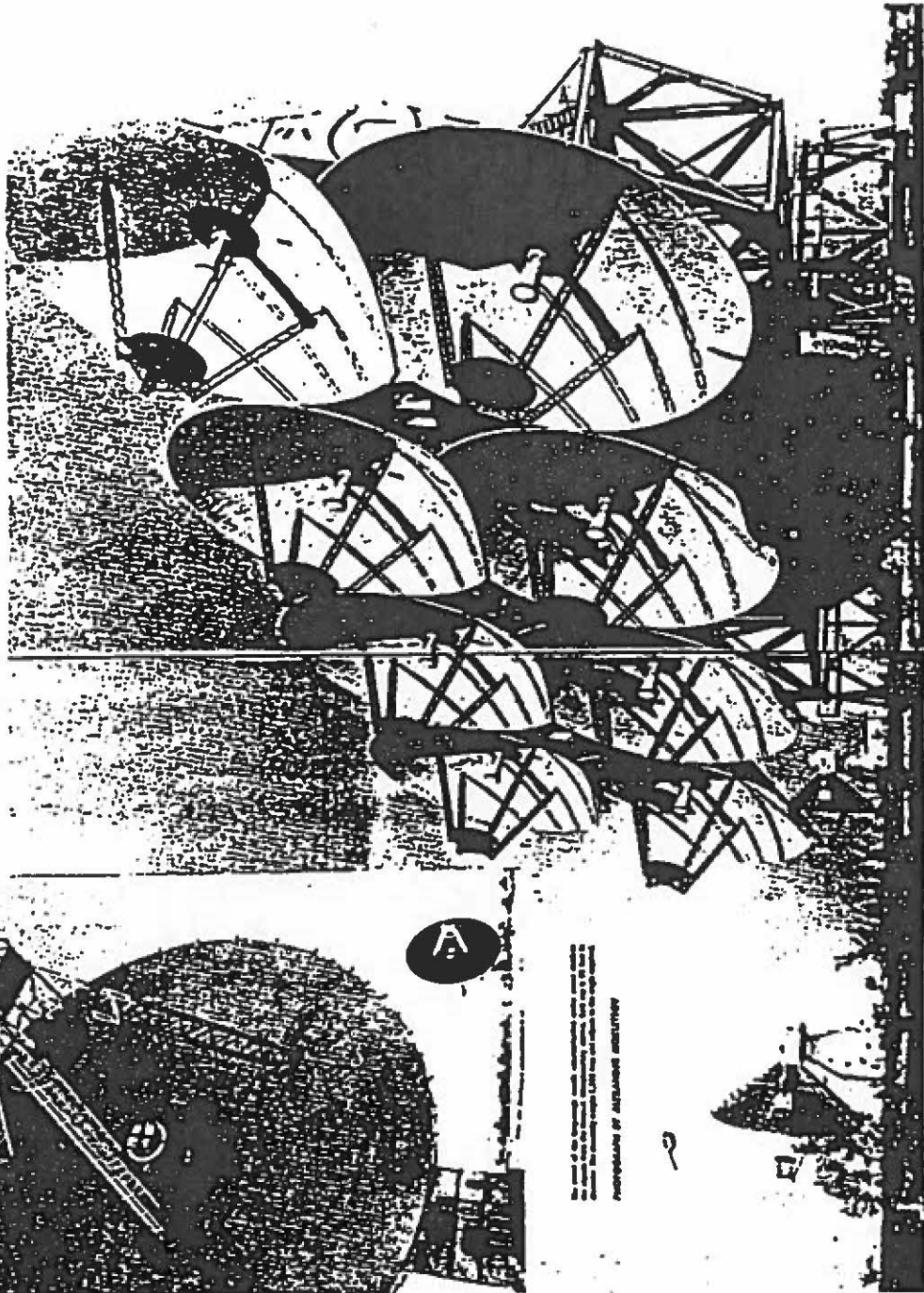


Fig. 6: Crimean deep-space antennas; 8-dish array in foreground, 25-meter antennas in background

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negated the signal: not all of the band had been swept out when the signal was known to be present and with all equipment at peak sensitivity. We therefore resolved to go after the 5670-5725 MHz band again at the next opportunity. This came in 1975, with the successful launch of Venera 9 and 10. Unfortunately we no longer had STONEHOUSE, and while the spacecraft were en route to the planet we also lost the use of the stations in [REDACTED].

We improvised a substitute search plan. While collaborating European sites prepared to record the known 32-cm and 8-cm signals with mission support through DEFSMAC, the CIA made an arrangement with [REDACTED] authorities permitting us to use the former NASA deep space station near [REDACTED] to search for the broad-band signal. Equipment was quickly designed, built, and flown to the site, and high-sensitivity searches began before the Venera spacecraft arrived at Venus. By the time this intercept effort ended without success, we believed that we had truly swept out and negated a good part of the 5670-5725 MHz band, and there was a certain amount of gloom. (All was not lost: a collaborating site produced excellent recordings of the 32-cm data, including panoramas of the surface of Venus which were relayed over the narrow-band link.)

In the aftermath of this first definitive but unsuccessful search, a review of all our knowledge was organized. Its main conclusion was that the signal was still most likely to be found somewhere in the 5-cm band, perhaps outside the allocated region but still in a region relatively free from other interfering signals. This led us to scan lists of known Soviet radar signals and other radio services; we concluded that there are several reasonably quiet regions around 6 GHz, any of which could contain our target. The haystack is a big one.

While we pondered what to do next, an exasperatingly specific clue came to light. A source of unknown veracity¹ said that one of the Venera 9/10 data links had operated in the band 5532-5538 MHz. We went back and looked at our records and found that valid searches had been made in this band, though not at peak sensitivity since it was outside the prime target region, with no signal recorded. And there the matter rests today.

The Future

Perhaps we will never know what we are missing. The whole problem is more an annoyance than a crisis. Soviet planetary results have seldom been of primary importance to the United States and, when unique data are obtained, they are eventually published in the scientific literature. Because of the relatively low priority of orbital planetary imaging in the Soviet program, our own planetary mapping has been much better than theirs. And yet there may be valid reasons for pursuing the search. In both our program and theirs, the tendency has been for communication links to move upward in frequency with time: as technology has advanced, more efficient links can be designed for shorter and shorter wavelengths. If the centimeter-band signal ever replaces the decimeter-band ones in the Soviet scheme and we have not yet found it, even our present limited source of prompt and objective deep-space information will disappear. Also, any such search is an exercise of techniques that have other uses. Should it turn out that the Soviets have been deliberately hiding the signal by any of several possible spread-spectrum or suppressed-carrier techniques, we will have learned something important. There is some evidence that a similar signal may be in use as a privacy link from certain Soviet Earth satellites.

¹(SECRET) FTD Message 091845Z Jan. 78, Quoted in NSA W14/Vista Conf. 001-78, 11 Jan. 1978.

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Finally, in pursuing this deep-space search whenever opportunities appear, we will be gathering rudimentary experience toward the much greater problem of searching the whole sky for signals from other civilizations in the cosmos. That effort, which both the United States and the USSR are now beginning to pursue seriously, will involve development of vastly more powerful search techniques.⁴ Systems will exist a few years from now, able to scan in space and frequency at rates thousands or millions of times as great as those of our present intercept sites—as if one could toss the entire haystack at once in search of the needle. When these techniques are in hand we may look back on our present efforts as feeble ones. Meanwhile, however, our target remains in view. We expect Soviet Venera missions in 1978, encountering the planet during December. As political conditions change, so does our access to collaborating deep-space sites; we just have to make the best of whatever resources come to hand. Nevertheless it is possible that this year there may again be an opportunity to seek, and perhaps this time to find, the missing link.

⁴ "The Search for Extraterrestrial Intelligence" NASA SP-419, 1977. U.S. Gov't. Printing Office Stock No. 033-000-00696-0.

Acknowledgement

To pursue a search of the kind described in "The Missing Link" takes advanced equipment, fast international action, discipline, devotion and skill. An acknowledgement is due the many dedicated people here and abroad who have, usually in the presence of other priority tasks, given their energies to this search.

J.D.B.

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