Moon Bounce Elint

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The monitoring of Soviet radars by way of the lunar surface.

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The capability of enemy anti-aircraft and anti-ballistic-missile systems, naturally a matter of intense interest to us, depends in part on the capability of a number of sub-systems, one of the most important of which is the radars used for target acquisition and tracking. We need to know the parameters of these radars as accurately as possible in order to plan penetration strategy and design the most effective equipment for electronic countermeasures. A considerable amount of such information on a radar's capability can be derived from observations of the signals it transmits. This is the classical Elint problem, to deduce the configuration and characteristics of an unknown system from the measured characteristics. of its signals.

Except for a very few specialized over-the-horizon devices, however, all radars operate on wave lengths which are too short to be reflected back to earth by the ionosphere but pass through and are generally lost in outer space. Under ordinary conditions, therefore, we are unable to observe them from ground collection sites when they are more than a few hundred miles inside the denied area of the Soviet Union.

So how to make such flint observations? Manned overflights of the Soviet Union are no longer permitted. Even if they were, the complicated equipment needed to measure the details of radar signals could not easily be carried in an airplane. If the characteristics of a particular emitter or class of emitters are known and we want only to find out whether such an emitter is in operation nearby, then the collection equipment can generally be fitted into a quite small, unattended package. But if the basic signal parameters are not known, or if precision measurements are needed, then it becomes very difficult to design small, automatic intercept equipment.

New Reflector

The possibility of solving this intercept problem with an entirely new technique emerged in 1948, when scientists detected for the first time a man-made signal reflected from the moon. The next few years saw many experiments (generally known as Moon Bounce tests) proving that radar signals so reflected could be reliably detected. The early experiments were monostatic; i.e., the transmitter and receiver were at the same location. Then bistatic experiments were performed, showing that transmitter and receiver could be separated by hundreds of miles on the earth's surface, the only requirement being that the moon be simultaneously in view of both. It now became clear that there was a good possibility of intercepting signals from radar transmitters located deep within the Soviet Union.

The dominant characteristic of signals reflected from the moon is extreme weakness. A typical signal received via Moon Bounce is more than a million billion times weaker than if it were received in an airplane ten miles from the transmitter. Very large receiving antennas are necessary to capture enough energy from this weak signal to bear it and distinguish it from other signals. Most of the very large steerable antennas in the Western world have been put to work on Moon Bounce intercepts. These include the ones at the Grand Bahama tracking station, the 150-foot dishes at the Naval Research Laboratory's Cbesapeake Bay Annex and at Stanford University, and the large dish at Sugar Grove, West Virginia. The 600foot dish that was planned for the Navy's Sugar Grove facility but never built would have been so used extensively. A 150-foot dish is about the minimum size usable on radars of normal power, so very few are available for our purpose.

The radar-reflective characteristics of the moon have been studied extensively over the past decade or so in the attempt to gather information on the lunar surface. (Radar was a principal source for such information until the recent spacecraft orbitings and landings.) When the moon was first proposed as a passive reflector, scientists predicted that it would "look" like a rough sphere at radio frequencies, that is, one that would scatter a good deal of energy in random directions instead of reflecting it at the angle it struck each point on the sphere. If so, a short burst of radio energy from the earth would be reflected back to earth first from the point on the sphere nearest the earth, then from a widening ring around this point, and finally from the rim. The elapsed time between the moment when the reflection from the near point returned to the earth and that when the reflection from the rim returned would be about .0116 second. Since radar pulses are on the order of .00001 second long, a rough moon would cause intolerable smearing of the pulses; every reflected pulse would be about .0116 second long, regardless of its initial length when transmitted, and very little information about the transmitter could be derived from the signal.

Fortunately for us, the moon appears only slightly rough to radio waves; most of the reflected energy comes back from an area at the near point just a few miles in diameter. The bulk of the energy striking farther around on the side is reflected out into space and never returns to earth. The moon reflection we get appears to come from a few large humps, not a uniformly rough surface. Depending upon their relative positions, these individual facets may give reflections that add or subtract from one another, creating a larger signal back on earth or making it even disappear. The effect is shown in Figure 1. Each oscillograph trace represents one pulse of a consecutive series received after a round trip to the moon. The variations in their amplitude (strength) and length (duration) are evident. Although thus distorted in the course of being reflected, the signal still contains much useful information.

Time and Geometry

Two conditions must be satisfied before we can receive an enemy's radar signals via Moon Bounce. First, the signals must strike the moon, at least momentarily. Second, the moon must be simultaneously visible at our receiving site. Since these conditions are so dependent on the position of the moon, they create very serious limitations.

Long-range search radars (early warning or anti-ballistic-missile) generally sweep over a sector of azimuth keeping very close to the horizon. Consequently, to give us a successful intercept, the moon must be passing through the radar's search sector, be within a few degrees of the radar's horizon, and be visible to us. How often all these conditions are simultaneously met is a complicated function of many variables. Take for example the research radar we call "Hen House" at the Sary Shagan missile test range in the south-central part of the Soviet Union. If this radar were operating continuously and covering a 360-degree azimuth, we could observe its signal via Moon Bounce for about 38 hours a month in Palo Alto, California, or for somewhat longer than that at the Navy's Chesapeake Bay facility. That is the total of periods in which we would see flashes of signal when the rotating beam struck the moon each time around. If the radar were looking only westward from Sary Shagan, the intercept time at Palo Alto would be reduced to about 20 hours. Actually, it sweeps an azimuth sector of only 31.9 degrees, limiting our possible intercept time there to 18 hours.

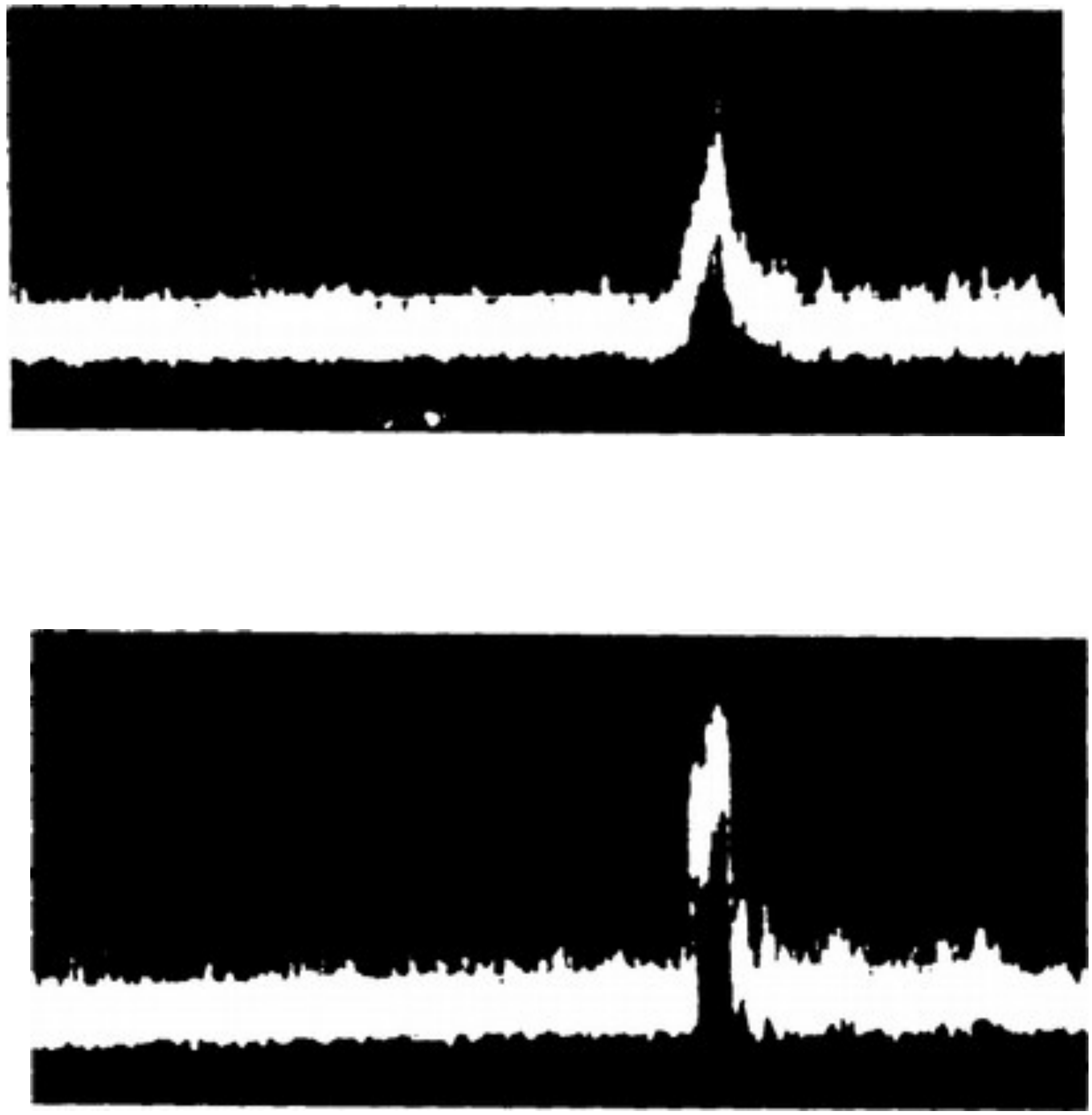

Figure 1. Oscillograph traces of three consecutive pulses spaced 20 seconds apart. Each transmitted pulse was 800 microseconds long. The top trace shows considerable lengthening of the trailing edge. The middle one shows degradation of the rise time. The bottom trace most closely resembles the shape of the original transmitted pulse.

In practice, we unfortunately have somewhat less time than that to look at this radar; it may not be operating during those brief periods when we look for it. Being a research device, it can be expected to be "down" a large portion of the time. The Soviets might even avoid letting its beam hit the moon, in order to prevent our intercept of the signals. Research radars are the most important to intercept, since they give hints about what may be operational in the future.

At first it might be thought that California would be the worst possible location from which to intercept the nearly antipodal Sary Shagan. But using a receiving site closer to Sary Shagan like the Navy's on Chesapeake Bay, which has the effect of making the moon visible to both places when higher in the sky, doesn't yield much more intercept time because the radar beam sweeps so close to the horizon, with very little energy transmitted above 20 degrees or so. And what advantage the eastern location has in intercept time is offset by the advantage of the Palo Alto location in being able to see eastwardlooking Soviet radars which are nearly hidden from the eastern United States.

Hen House Observation

During its last Soviet operations in 1960, the U-2 photographic collection system had noted a very large antenna structure near the Sary Shagan missile test range. We believed that it was the antenna of a new radar system, but since the location was deep within a denied area we were not able to detect signals from it. Its signals were first heard by Western observers in 1962, not via Moon Bounce but by reflection from the ionized cloud of a Soviet atomic test explosion. Since analysis of this brief, crude intercept showed that the Soviets had a new radar system of advanced capability, the intelligence community immediately attempted to intercept the signal by other means.

The first searching via Moon Bounce was done by the Navy using its 150-foot dish on the Chesapeake. The faint signal could not be found, however, until some specific information on its frequency reached us from other sources. Navy made the first successful intercept in January 1964 and in subsequent monitoring defined roughly the parameters for the Hen House frequency and scan.

Stanford's 150-foot dish at Palo Alto, because of its potential with respect to eastward-looking Soviet radars, was chosen for CIA's Moon Bounce collection project. Quite sophisticated collection equipment, including two unique receivers, was built especially for this purpose and installed there. In August 1965 the Palo Alto project made its first intercept of the Hen House radar, which remains its most important target.

CIA has undertaken a continuing analysis effort to define carefully the exact parameters of the Hen House system, using data from the Department of Defense intercepts and more recently from Palo Alto. Three major discoveries have been made about the signal. First, using special receiving equipment, it was determined that the signal has a "spread-spectrum" mode. This means that the spectrum (frequency spread) of the signal can be intentionally broadened to increase either the radar's range or its range-rate resolution, that is its accuracy in reading its target's speed.

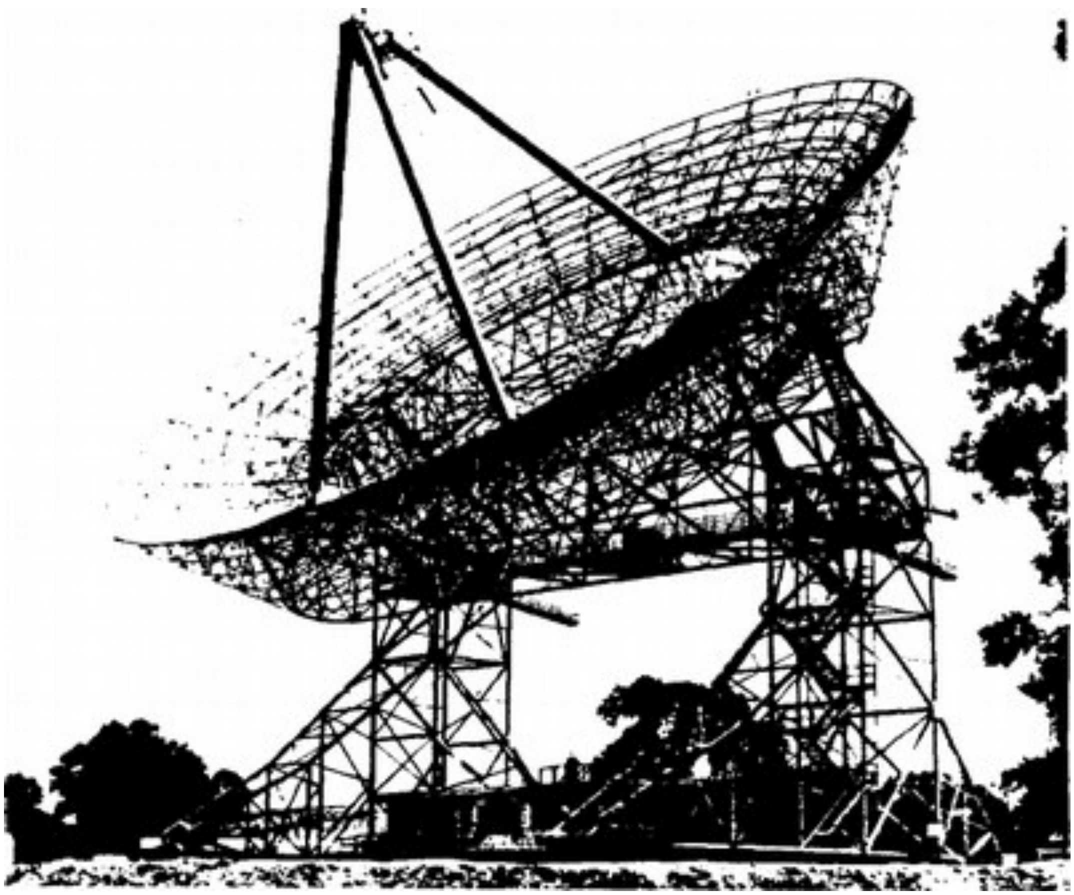

Figure 2. The 150-foot receiving antenna at Palo Alto, California.

The second discovery was that the Hen House uses a rather advanced scanning system. We expected to see a regular scanning, or "search" mode, and a tracking mode, where the beam follows a target. Both of these have been observed. In the latter, the Soviets, apparently just for practice, have set the radar to track the moon for as much as half an hour. This makes the intercept job much easier, as we then see the signal continuously rather than in short bursts as the beam swings by the moon. But in addition to the standard scanning and tracking modes we have observed the system in a combination mode wherein it is basically scanning but will dwell for a short time on any target it sees. Apparently it is set to look at a target just long enough to identify it and measure its parameters before moving on. We imagine the radar can keep track of several targets at once. Since the scan and dwell times are quite short, it must operate under computer control.

The most recent significant observation is that the transmitter's peak power is about 25 megawatts. This, if correct, makes it one of the highest-powered radars in the world.

All of these observations lead us to believe that the Hen House is a new, sophisticated ABM radar. Knowledge of Soviet ABM capability has become of increasingly critical importance to the United States. By accurately defining the parameters of the new radar, we can now start the design of countermeasures and tactics to reduce its effectiveness.

The Moon Bounce effort is one of those intelligence collection techniques which seemed at first "far out" but has in the event more than paid for itself.

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