Studies in Intelligence
Summer 1984
Vol. 28 No. 2

SIGINT IN SPACE

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This paper attempts to trace the events that thrust the space age first upon the United States and then upon SIGINT. I believe that my closeness to the early space effort led to my pressing for SIGINT in space. During the gestational years three threads became interwoven to produce a nationally integrated space program. The first was rocket exploration of the upper atmosphere; the second, the International Geophysical Year; and the third, the rather bitter interservice rivalry that then prevailed in this field.

My involvement with rocketry began in 1948. I was chief of the Ionospheric Physics Laboratory, in the Geophysics Research Directorate of the Air Force Cambridge Research Center (AFCRC). We were engaged in an intensive study of the upper atmosphere and its effects upon radio wave propagation.

Serious US concern with rocketry after World War II had been sparked by the availability of captured German V2 rockets. In essence, after three decades of neglect, the US began to restudy the works of Konstantin F. Tsiolkovski (USSR), Hermann Oberth (Germany), and Robert H. Goddard (US). Further, during the 1946-1948 period, the US had the practical knowledge of Wernher von Braun. To obtain hands-on experience, the V2s were to be fired from the USA rocket range at White Sands, New Mexico. Also, rather than fire the rockets with ballast, the warheads were to contain instruments which could measure properties of the upper atmosphere.

In 1948 the principal Department of Defense groups engaged in rocket-borne exploration of the upper atmosphere were the Ballistic Missile Laboratory, the Rocket Sonde Research Section of the Naval Research Laboratory (NRL), and AFCRC. Each service prepared and defended its own program and budget. Although they acted independently, the groups interchanged information through a V2 Rocket Research Committee. Initially, the launch vehicles were the V2s. Later, rockets manufactured in the US were introduced (Wac Corporal, Honest John, Viking, Aerobee).

It was unfortunate, but true, that a considerable amount of tension existed between NRL and AFCRC. An unhealthy rivalry sapped the total US effort.

The first few years witnessed both successes and failures. Many of the latter could be attributed to problems in the propulsion system (leading to unpredictable rocket behavior), unreliable telemetry, or experimental deficiencies. Some of these problems persisted into the 1960s.

The International Geophysical Year (IGY) was an eighteen-month period (July 1957 – December 1958) during which most nations joined together for a detailed investigation of the planet as a whole. They recognized that national boundaries had no influence upon weather, ionospheric storminess, earthquake formation, and tidal changes, and that to better understand and predict these phenomena, a more thorough understanding of planetary physics was necessary.*

The International Council of Scientific Unions (an arm of the United Nations) endorsed Berkner's suggestion and invited all nations to participate. In response to this call, the US National Academy of Sciences established the US National Committee (USNC) for the IGY in 1953. I served as secretary of the USNC Executive Committee and as chairman of lesser committees.

The USNC first sought to develop an internal US program in geophysics, and then to coordinate the program internationally to insure that (a) global duplications were eliminated, and (b) gaps in coverage at national boundaries did not occur. All major nations joined the endeavor. The final program was truly global in nature. It incorporated studies on the continents and on the seas, in Arctica and Antarctica, and included rocket- and satellite-borne probings of the upper atmosphere.

The USNC Technical Panel on Rocketry contained many individuals on the old V2 coordinating committee, now named the Upper Atmosphere Rocket Research Panel (UARRP). It also included researchers not on UARRP, and thus was more broadly based. During early meetings the panel confined itself primarily to experiments which essentially continued or improved already ongoing efforts. S. Fred Singer and James A. Van Allen expanded their rockoon (balloon launched rockets) program for studying cosmic radiation to other areas on the earth. Singer in 1952 published his MOUSE (Minimum Orbiting Unmanned Satellite - Earth) proposal. He brought this proposal to the attention of the Rocketry Panel but it was not endorsed.

Commitment to Satellites

The first convocation of the Special Committee for the IGY, known as CSAGI from the initials of its French name, met in Rome in 1954. It presented an opportunity to begin integrating the various national programs. Berkner forced a decision on US plans for satellite explorations. He asked a number of us (including Joseph Kaplan, Hugh Odishaw, Harry Wexler, Wallace Joyce, Allan Shapley, Homer Newell, S. Fred Singer, John Adkins, Athelstan Spilhaus) to visit him one evening. He broached his concern; rumors were circulating that the Soviet Union was about to propose that CSAGI endorse the launching of earth satellites as an integral portion of the IGY program. Satellite-borne instrumentation would allow direct investigations of the upper atmosphere. Berkner wanted us to propose a US position.

* The IGY was conceived by Lloyd V. Berkner, president of Associated Universities Inc., Brookhaven, New York. The IGY was a continuation of a series of Polar Years. The First Polar Year of 1872 was conceived by Karl Weyprecht, a lieutenant in the Austro-Hungarian Navy. It was followed fifty years later by the Second Polar Year of 1922. The objectives of both were extensive examinations of weather, auroras, geomagnetism, and ice conditions in the Arctic and Antarctic. Berkner's proposed IGY shortened the period between Polar Years to 25 years and extended their scope to include middle and low latitudes.

The discussion lasted well into the evening. It was quickly apparent that practically everyone present felt that the US should either independently propose, or join in proposing, the launch of earth satellites during the IGY. We all understood that such a stand committed the US to implementing scientific satellite experiments before the end of 1958 or shortly thereafter. However, it was the considered judgment of most that such a schedule was not unrealistic. Several of us had a working knowledge of the difficulties and problems affecting launches: thrust availability, costs, and experimental possibilities. Berkner himself was familiar with the total US effort, including progress in propulsion systems, and from a much higher level in government than any of us.

Newell raised objections: there were no readily available boosters; solar cell outputs were too low; energy requirements could not be met; experiments could not be prepared in time; proven experiments were not at hand; batteries may boil. He stated that the US could not fabricate and launch an acceptable experiment in time, that the difficulties were too great, and that there were also doubts about Soviet capabilities. The rest of us felt comfortable about a positive stand for the US. Finally Berkner asked for a vote. It was unanimously in favor: the US would propose incorporation of a satellite program within the IGY framework. With this decision in hand, Berkner on behalf of the US, and Pushkov on behalf of the USSR, jointly proposed that an earth satellite program be included in the IGY. The plenary session of CSAGI adopted this recommendation.

After we had returned to the US, the machinery of government slowly began to clank. Berkner, who was on a first name basis with the President, briefed Eisenhower. On 29 July 1955 the President announced US participation. The government now had formally committed itself to support the decision of our rump meeting.

Deliberations within the Executive Committee of the USNC took an unexpected turn. Kaplan, the chairman, stated that the US effort would be wholly civilian in concept and fulfillment. Let the USSR use its military capabilities to launch a satellite for the civilian-scientific IGY; the US would not.*

The USNC found a surplus Vanguard rocket; it was refurbished to serve as a booster for the IGY satellite. About this time rumors reached several of us on the USNC to the effect that the Army planned to launch a rocket which would "accidentally" attain earth obit. I was later told that Kaplan had objected and that as a result, the Army was told to cease efforts toward this end.

* In "Beyond the Atmosphere," NASA (1980) contrasted actions of the two nations by considering the space effort of the US as primarily open and scientific, and that of the USSR as primarily military. It is not possible to characterize these activities so neatly. Both nations designed realistic programs to accommodate their respective national interests in both research and defense. Furthermore, the long term goals of one were not distinctly different from those of the other. Thus, their objectives *a priori* included a mixture of military applications, national prestige items (lunar and planetary probes), and space research. Both nations appreciated that research represents vital national insurance for the future.

As refurbishment of the Vanguard progressed, a meeting was held at the US National Academy of Sciences to discuss the satellite programs planned for the IGY. My invitation, in a telegram dated 30 September 1957, noted that the gathering constituted the international working party on rockets and satellites. Attendees comprised delegates from the US and USSR. The Soviet delegation, led by General Anatoly A. Blagonravov, invited us to a party at their Embassy on 4 October 1957. The meeting included prepared papers on scientific and technical topics, followed by a discussion period. Both nations outlined their respective projects. In typical national fashion, the US provided much more information than it received.

A point of discord occurred during another meeting on the morning of 4 October 1957. It stemmed from US pressure for the Soviets to provide an official launch date for their IGY satellite. The Soviets were pushed rather relentlessly and intently—almost to the point of embarrassment. Finally Pushkov, answering forcefully, stated that, at the present state of the art, to predict the launch of a rocket is difficult. It becomes even more difficult to predict the launch of a satellite. There were too many uncertainties, too many things that could go wrong. Why state a date in advance when such doubt exists? He would prefer to provide a date after a successful launch.

Richard Porter was the chief US delegate at the meeting. At lunchtime the press got to him. He expressed himself freely and at some length. The Soviets, he claimed, were way behind the US. There was no other possible explanation for their reticence in providing a launch date for their satellite.

Sputnik 1

The sessions resumed that afternoon. Although I had an invitation for the party at the Soviet Embassy that evening, I had planned to miss it. Practically every other delegate attended. At the height of the festivities (I was later told) Berkner received a telephone call: the "beep beep" of the 40 MHz signal radiated by the earth's first satellite, Sputnik 1, had been found. Berkner returned to the room, stood on a chair, clapped his hands, and publicly commended the USSR on its accomplishment.

The USNC pursued its "open" space effort. The Vanguard was publicized and readied. The experiment was encapsulated and emplaced in the "bird." Complete television coverage took place during the day of launch to show the world that the US only utilized civilian-scientific talent in its space program. Vanguard did not cooperate. It fell over and burned—with complete television coverage. The US had learned a lesson. The Army was called in and asked to launch the next attempt. Van Allen prepared new instrumentation for observing cosmic radiation (essentially a particle counter to measure the intensity of particles bombarding the earth). The satellite, named the Explorer, discovered the radiation belts that now bear Van Allen's name. The US had not been first in space, but its scientific efforts to date had been best—we had discovered a hitherto unknown major feature of the planet.

The space effort soon was to acquire a national focus through establishment of the National Aeronautics and Space Administration (NASA).

To Obtain Telemetry

In 1956 I left AFCRC and joined the National Security Agency (NSA). My attention turned toward applied research in SIGINT[redacted] SIGINT task was obtaining telemetry signals radiated from rockets and missiles during their launch stage. Another was the reception of uhf or vhf sig-[redacted] Robert O. Alde, of the Research and Development Group (RADE), kept firing me up with his comment about the value to NSA of the telemetry: "One good intercept is worth $5M." The problem was not easy. It concerned reception of these nominal line-of-sight frequencies at distances far beyond their normal propagation distance on the earth.

To attack this problem I first examined natural causes that allowed propagation over extended ranges: sporadic E clouds at 110 km allowed extended ranges to 1,500-1,000 km; transequatorial allowed 7,000-11,000 km ranges north-south via the ionospheric layer; high solar activity raised the upper frequency limit of the ionosphere to 40-50 MHz for distances to 4,000 km. Other possibilities were auroral ionization, magnetic channelling (for vhf), meteorological ducting, antipodal, and meteor scatter. The occurrence of each phenomenon depended upon location, time of day, month of the year, and often time in the solar cycle. Because of their different physical origins, their properties, statistics, and climatology were different. However, when present they could be exploited for SIGINT. While each method provided some potential for intercept, few of them provided continuous or reliable coverage when needed. It was (and still is) essential to recognize their limitations.

For example, most of the above phenomena were not present constantly, and the radio frequencies they supported satisfied only a portion of NSA's needs. Because of these inherent deficiencies, I then considered possible man-made events that could be more reliable and might be located where and when needed: artificial electron clouds, orbiting dipoles (needles), orbiting satellite reflectors, and orbiting active satellites. (I also considered the influence of nuclear detonations on SIGINT, and prepared a plan for NSA participation during future detonations.) As the various stages of the study were completed, they were published in the NSA Technical Journal.

The investigations culminated (in 1959) in an in-depth approach for increasing intercept efficiencies, "Six Point Program for Improved Intercept." It appeared as a special report, and later the first portion was published in the NSA Technical Journal. (My subsequent involvement with moonbounce disrupted publication of the second half.) This report was widely used in planning and in answering queries from the Pentagon.

Earlier, in 1958, I had outlined the potential of satellite intercept to John Crone, of the Research Mathematics and Physics Group. I was convinced that a goodly number of urgent and specific intercept problems facing NSA could be surmounted only by utilizing satellite-borne receivers. Natural phenomena could be exploited when present, but accurate predictions were not at hand and the phenomena could be lacking when needed. Only receivers aboard satellites could provide the in-depth reception required by NSA. Also, satellite launchings were becoming more routine, costs were decreasing, and sophistication was increasing.

Crone could hardly wait for me to finish. He picked up the telephone and arranged a meeting with General Ralph Canine, the Director. DIR/NSA was impressed and placed this topic (satellite-borne intercept) on the agenda for his next staff meeting. Unfortunately, the idea went over like a lead balloon. I had not expected this reaction. After thinking about the matter I felt that the only logical step for me was to educate senior staffers through their subordinates. Thus I concentrated on writing the series of articles and reports mentioned above.

The concept took hold. One of the very first trials used a rocket-borne receiver in the vhf range. For reasons beyond our control, the launch was delayed considerably, and firing occurred just as the TV station (which served as the target transmitter) was going off the air. Only a few seconds of "The Star Spangled Banner" were received before the station closed. Even so, those few seconds of intercept confirmed the potential of the technique.

It was during this period that someone decided to attempt triggering responses from Soviet satellites. Equipment was dispatched to the field. Before it was activated, Aide called in Donald H. Menzel, director of Harvard Observatory (an NSA consultant) and myself for comments. We were both bothered about the precedent. It could prove self-defeating and result in constant electronic tampering with the other's satellites. By the end of summer 1960, the equipment for this purpose (in the field) was disabled to prevent even an accidental occurrence of tampering.

There were experiments with electron clouds. After I had outlined this possibility to him, Aide induced me to seek funding from the Air Force, which supplied $1M one year and smaller sums in other years. The experimental plan involved three sites: (a) a TV station in Shreveport, Louisiana, (b) a receiving site in the Bahamas and (c) the rocket launch facility at Eglin Air Force Base, Flordia. The chemicals, aluminum oxide and cesium nitrate, would be detonated and dispersed near 100 km and near the mid point of the path. The experiments were successful and ultimately allowed reception of TV signals far beyond the line-of-sight. The TV signals had been reflected from the electron cloud produced by ionization of the chemical mixture. Reception persisted for about 60 minutes, and despite fading, allowed acceptable ratios of signal/noise at vhf.*

[redacted]

The needles concept originated with Lincoln Laboratory, Massachusetts Institute of Technology. It was based upon the principle that orbiting dipoles would scatter a signal of the proper frequency back to earth. Small wires cut to the wavelengths of interest would be used. The scattered signal would be

* Today the Soviets have implemented several dozen "ionospheric heaters" which could accomplish a similar function. The refractivity discontinuity created also could allow insertion of a high frequency ray into a low loss ionospheric duct. A similar heater near the reception facility would allow ejection of the ray.

modulated with a doppler frequency caused by motion of the wires. When the experiment was first proposed (for communications purposes and without NSA involvement or participation), the radio astronomers were alarmed. They were outraged when the needles were actually placed in orbit. Many scientific bodies condemned the action as environmental pollution. Other techniques then overpassed both the electron cloud and needle techniques.

Orbiting Reflectors

Late one summer night in 1957, Eugene Fergusson of RADE and I examined the possibility of receiving signals returned to earth from orbiting reflectors. We then extended the calculations to include reflections from the moon, and as an afterthought, from Mars and Venus. We were both somewhat surprised with the results: the concept was feasible if a sufficiently high gain antenna were available. Later I realized that the location of the target on the earth also could be determined by noting the time when the received signal abruptly "died." If the transmitter was still emitting, this loss of signal meant that the transmitter must lie on a certain line of position determined only by moon-earth geometry. Observations made on the same transmitter over a period of weeks then would provide additional lines of position (because of changing earth-moon geometry).

These spontaneously generated results later proved useful because of two unexpected developments. During the early 1950s the Advanced Research Projects Agency (ARPA) began funding construction of the Arecibo Ionospheric Observatory (AIO) in Puerto Rico. ARPA also was developing a high frequency over-the-horizon radar, and asked NSA to allow me to serve as a consultant. NSA agreed and I worked on both projects for ARPA. I wanted to use AIO for NSA purposes because it provided the high gain that would allow intercept via moonbounce.

William Scheerer of the Army Security Agency and I examined the potential in detail, and published "~~Moonbounce Potential from Scooped~~ Antennas" in three volumes. It showed that high power earthbound transmitters could be received at AIO. (We considered only vhf and uhf.) Joseph Norvell of RADE later set out to test the conclusions in the report. The two of us briefed the Director of ARPA, Charles Herzfeld, on the proposed experiment. Herzfeld told us in no uncertain terms that AIO had been funded as a wholly scientific and open facility, would not be allowed to undertake classified studies, and that it was presumptuous of us to ask. He later relented and plans for the test proceeded. The open designation of our work was a study of lunar temperatures.

Mitford Mathews, Deputy Director for Research, provided us with $30K to undertake the experiment. (We returned funds to him.) Norvell, Earnest Marsh, and John Peaslee designed the equipment. The electronic and mechanical construction was beautifully done despite several severe challenges that faced us. The distance between the feed and its reflector was a function of frequency. Both were located about 500 meters from our controls and 180 meters above the bottom of the antenna. Once in place outside the "carriage house" (180 meters above the ground) both were inaccessible but had to work with no malfunction.

A curious and interesting development occurred during the planning stages. After its strong initial resistance ARPA went out of its way to assist us. During the early discussions I had noted to them that the location of AIO was not optimal for our use, and that a site in the Seychelles would be much better. Codell of ARPA later approached me and offered to construct a scooped antenna for NSA, in the Seychelles or elsewhere. A nuclear detonation would be employed, and ARPA guaranteed a minimum residual radioactivity and the proper shape of the crater in which the antenna subsequently would be placed. We never pursued this possibility. The nuclear moratorium between the US and the USSR was signed somewhat later and this possibility disappeared.

We were fortunate. After just about one week of operation we intercepted Soviet radar operating on the Arctic coast. (As a by-product of my involvement, I could never look at the moon again without thinking of our experiment.)*

What about an intercept site on the moon? It is conceivable. In time the logistic problems would be overcome, and a lunar base for that one otherwise unattainable signal might become reality. One question is whether an atmosphere could be produced on the moon, and if so, what its properties would be like.

The greatest problem is the small lunar gravity (one-sixth that of the earth) which would not allow retention of an earth-like atmosphere for any length of time. There are other problems: distilling the needed gases from lunar rocks, the thermodynamic properties of the atmosphere, and the warming of the dark side of the moon once an atmosphere is established.

In thinking about the problem, I proposed an atmosphere of 20 percent oxygen and 80 percent argon with a surface pressure about equal to that of Denver. (On the earth the composition is 21 percent oxygen, 78 percent nitrogen and 1 percent argon.) Argon rather than nitrogen was chosen as a potential "filler" gas because of its greater molecular weight. The thermodynamic properties of this atmosphere were extremely interesting and completely different than I had expected. The unsurmountable obstacle was the loss of gas: the low gravity allowed the oxygen to "boil off" at an almost irreplaceable rate. Obviously, the answer is to utilize domed cities. The needed gases could still be extracted from the rocks by using solar energy.

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This paper has recounted the events that led NSA to one course of action. It illustrates the progression of thought on problems of the time, and the chain of events that led inexorably to our present concepts. What we need now are ideas for tomorrow.

This article is classified ~~SECRET~~

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* The dish at AIO has been updated considerably since the time of the NSA experiments. Its surface now is spherical over its 300 meter radius to within two centimeters. It remains one of the best radio telescopes the US ever constructed and by any reasonable measure, probably the cheapest in relation to the research potential that it provides.