

COMINT Satellites - A Space Problem

BY

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A summary of a recent study on the application of earth satellite vehicles to communications intercept.

INTRODUCTION

Satellites of the earth are becoming rather commonplace objects now. There are 13¹ such devices or parts thereof circling in their respective orbits (out of the 24 or so which have achieved gravitational balance with our planet). The newspapers are punctuated with promises for many more, and probably some of these will have been realized by the time this issue of the *NSA Technical Journal* is in print. Many are pure research experiments which were suggested for IGY earth satellite vehicles² and now have been incorporated into the National Aeronautics and Space Administration program.³

Meanwhile, since the Sputnik splash, the several U.S. military organizations made elaborate plans and in fact started several projects for using space for defense. Project *Courier* is the Army's satellite communication system to utilize earth-satellite vehicles for relaying messages between two or more remote ground bases. The first attempt—*Atlas Score* — succeeded in carrying 1959 New Year's greetings from the President. The Navy is working on *Transit*, a navigation satellite to aid the fleet with accurate position information. The Air Force has made several attempts to launch, stabilize, and recover its *Discoverer* satellite, predecessor to *Sentry*, the reconnaissance vehicle being readied for launching in 1960. A major Air Force space project is to develop Weapon System 117L for wide-scale intelligence collection, a complete photographic reconnaissance and later surveillance of the target land-mass, and attempt to do the same from the standpoint of ELINT and COMINT. The feasibility of using a WS 117L-type satellite vehicle to collect COMINT is the subject of a recent RADE study.⁴ It was found that several communications signals of COMINT potential can, at least in theory, be intercepted at satellite altitudes. The remainder of this article summarizes the findings of that study.

¹ "Man's Reach Into Space — Satellites and Space Probes Today", *Sky Telescope*, Vol. XVIII, No. 7, p. 379; May 1959.

New York Times, p. E7, September 20, 1959; p. E9, December 27, 1959.

² Van Allen, J. A.; *Scientific Uses of Earth Satellites*, 2nd Revised Edition, University of Michigan Press, 1958.

³ "The Next Decade in Space — A Special Report on NASA Programs", *Aviation Week*, pp. 119–154, June 22 1959.

⁴ "Study Report on COMINT Collection from Satellite Vehicles," August 1959, R/D Technical Document 33.144.

The *Sentry* part of the WS 117L program (now called *Samos*) calls for several 300-mile altitude, polar-orbit launchings of stabilized vehicles by *Atlas* boosters from Vandenberg Air Force Base; these vehicles are to weigh nearly two tons each, and carry reconnaissance payloads of several hundred pounds (20 feet long by 5 feet in diameter). They would thus surpass *Sputnik III* (2925 pounds, 140 inches by 68 inches in diameter); what *Sputnik IV* will be is interesting to speculate. WS 117L is just an R/D program; when military satellite vehicles become a reality it may be that electronics will not be the only form of warfare taking place in extra-terrestrial regions.

COMINT COLLECTION PROBLEMS

While there are many target communications signals that might be considered for collection from a satellite at an altitude of a few hundred miles, there are very few COMINT possibilities for a high altitude "space-station" type of vehicle (at several thousand miles). The same is true of the popularized 24-hour satellite hovering at 22,240 miles. Distances of this order are just too great for present intercept techniques. This is mainly due to the inevitable free-space radio-propagation loss which varies as the squares both of radio frequency and path length. Thus, at 70 mc/s and over a 600-mile distance, there occurs a 130 db signal-power loss. Only 1 part out of 10 trillion (10,000,000,000,000) of the power transmitted is available for collection. The rest is gone forever. Of course the gain of the intercept antenna and receiver can compensate for such a propagation loss, but the fact remains that the transmitted power is radiating conically, and at large distances the power density is so low that sophisticated equipment is required for its detection. If the signal bandwidth is large or the radiated power is low, an additional factor—noise—becomes a problem. It is hard enough to install sensitive equipment that will work on the ground, but the space environment is many times worse.

Aside from the physical extremes of temperature, pressure, and cosmic radiation, and the resulting electronic reliability problems—these are being solved by the extensive efforts of industrial and government laboratories devoted to space research⁵—the possibilities are severely restricted by the realities of orbit mechanics.⁶ To maintain itself in orbit, a satellite of the earth must overcome the gravitational pull of the planet, and this requires a tangential velocity (and its accompanying centrifugal force) of some 5 miles per second for the lower altitudes. This means that the location of the vehicle relative to a ground target changes rapidly; a signal cannot be intercepted continuously, but only sampled. For COMINT this may be a great disadvantage. However, for some targets which are not being collected by other means, a large set of short samples may be valuable. A satellite passing 300 miles above a target is in view of it for

⁵ *Aviation Week*, Research for Space Edition, 16 June 1957, pp. 70-290.

⁶ Shternfeld, A.; *Artificial Satellites*, Moscow, 1958. (O.T.S. Translation PB141351T (TL796/Sh8E).

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about 10 minutes at a time. Depending on the radio frequency, power, and antenna of the transmitter, its signals may be intercepted for more or less than 10 minutes (from a few seconds to more than 20 minutes). An advantage of a polar-orbiting intercept vehicle is that it sweeps repetitively over the entire earth's surface so that no surface location escapes its view. The period of a 300-mile orbit is about an hour and one-half, and, although the exact figure depends on the ground coverage "look" of the intercept antenna, the time needed for complete overlap of its swaths is about a day or two. On the average, 80 minutes a day would be spent over the [redacted]. Such COMINT continuity as is developed from conventional intercept would not be possible. Total useful lifetime of a vehicle depends on air drag and primary electric power sources, but early WS 117L launches are planned to stay up about a month and eventually better electric power devices will extend this to six months or more. Such systems would be expensive collectors and thus would probably be economical only for unique COMINT problems.

Another mechanical problem is the stability of the satellite, which affects antenna orientation, and the associated difficulty in determining target location. The WS 117L vehicle is designed to look straight down at the earth, $\pm 10^\circ$ throughout its orbit, and a sensor will indicate deviations from the nadir look. The average ELINT antenna beamwidth to be carried is 30° , corresponding to an area on the ground about 150 miles in diameter. Knowing the time of intercept, then, the location of the satellite in its orbit can be computed and the approximate location of the target determined. The lower radio frequency of most COMINT signals requires correspondingly larger antennas to maintain narrow beams. Thus it is difficult to use such location-finding techniques. Also in the ultra-high frequency band the communications signals are so weak that even narrower antenna beams are required in order to achieve adequate gain, and this likewise leads to large antennas. Large, high-gain, narrow-beam intercept antennas are not only difficult to install and stabilize in space but they also limit the time of intercept on a single target. At a height of 300 miles, 150 miles on the ground would be passed in less than 30 seconds. In order to achieve longer samples of a target on which either good location information is desired or high signal strength is needed, a steerable antenna may be required, capable of tracking a signal as the vehicle passes over. Such an automatic, signal-controlled, moving antenna would be very complex, but would probably yield more valuable intelligence (though on fewer targets) than would a wide-open, less discriminating collector.

A major factor limiting intercept at satellite altitudes is the radio propagation medium. In addition to the free-space attenuation described above there are attenuation and other effects on the signal because part of the path is *not* in free space. The ionosphere, in particular, being

completely below 300 miles, affects radio waves radiated from the earth's surface. Its effect on ground-based communications has been studied for many years and is understood in some detail.⁷ This experience helps to extrapolate the effects to the case of transmission *through* the ionosphere,⁸ but there is still too little experimental evidence to give answers to all of the questions. For example, it is known that the ionosphere reflects high-frequency radio waves from one point on the earth to distant locations, so that, presumably, such waves do not penetrate the reflecting layers. However, it is also known that the "reflection" mechanism is really a refraction process, and penetration to some extent must occur, depending on the frequency, the angle of incidence, and the local condition of the ionosphere. Thus under some circumstances propagation through the ionosphere to a satellite's intercept receiver is possible from transmissions intended to be received via "skip" on the ground. In general, this would occur on the higher frequencies (above 5 to 10 mc/s), but, since this has never been done, the extent and usefulness of such propagation for intercept purposes is not definitely known. Certainly there are many anomalous conditions, such as sunspot and auroral activity, magnetic and ionospheric storms, which confuse the situation, and other more regular variables, such as wave orientation relative to sunlit areas and the earth's magnetic field, which add to the complexity of high frequency (3 through 30 mc/s) radio propagation through the ionosphere. Beginning at slightly higher frequencies, it is common to think of point-to-point, line-of-sight radio propagation on the surface, with most of the energy going out into space. Yet within the last ten years, the *scatter mechanism* has been discovered,⁹ which propagates these frequencies, via the ionosphere, back to the earth in all directions. This would indicate that a satellite's radio horizon would also be extended, but again the real test has not been made. Above about 50 mc/s up through the very-high-frequency and ultra-high-frequency spectrum (30 through 300 and 300 through 3000 mc/s), calculations based on a theoretical ionosphere show that very little attenuation or refraction should be expected. This seems to be the best, or at any rate the least complicated, range to consider for satellite intercept. Above about 5000 mc/s the troposphere and lower atmosphere begin to affect radio propagation, owing to absorption by oxygen, water vapor, and raindrops. At 20,000 mc/s there may be a 200-db loss due to the atmosphere, in addition to the large free-space loss. Fortunately there are no known communications targets operating at these frequencies. Super-high-frequency (3000 through 30,000 mc/s) has been considered for satellite-to-satellite outer space communications, but this

⁷ Gerson, N.C., and [redacted] "Ionospheric Propagation," *NSA Technical Journal*, December 1958, III, 4, p. 33.

⁸ "Tentative Evaluation of Transmission Factors for Space Vehicle Communication," US Army Signal Radio Propagation Agency Project 664, Sept 58, Unclassified.

⁹ Proc. IRE, Vol. 43, No. 10, Oct 55.

opens up the whole new intercept field of space surveillance, and is not covered in the study.

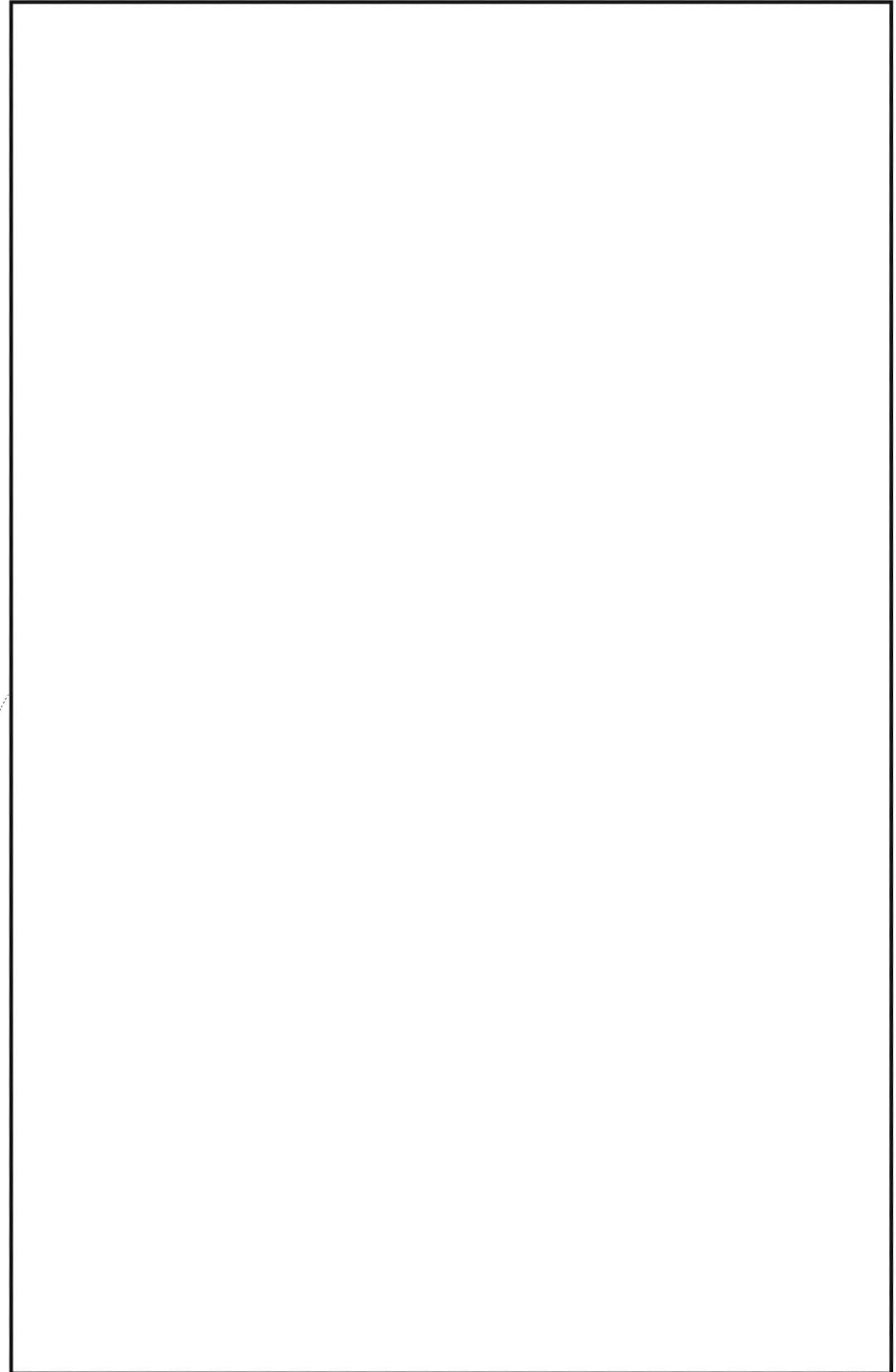
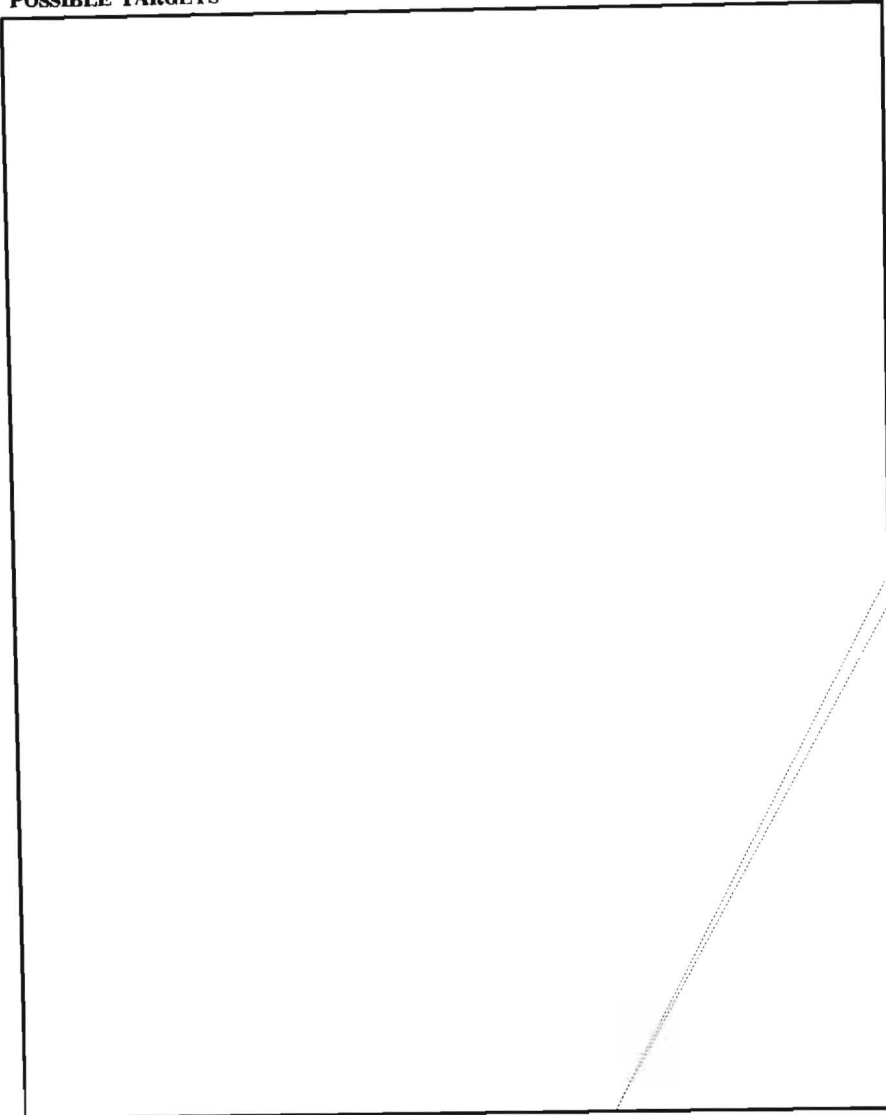
A general concept of operation of COMINT collection using satellite vehicles follows that of the WS117L. That is, the intercept equipment in the vehicle is programmed to search in frequency and possible direction while over the target areas. When a signal is received, scanning is stopped and locked while a magnetic tape recording is made, and search is then resumed. Upon the vehicle's passing over friendly territory, it would be tracked from the ground and commanded to play the tape back by radio to the ground receiver and recorder. Commands might also be injected at this time reprogramming the succeeding intercept operation. This all seems to be straightforward enough, but the technical details bring up many more problems than can be discussed here. A few will be pointed out. More simplified schemes have been proposed, such as relaying the intercepted signal directly by radio, but active retransmission might be considered jamming. A simple mapping operation has also been suggested where only locations and frequencies of some *types* of signals are indicated, but the COMINT value of this technique is unknown.

The basic problem is bandwidth. A range from 10 to 5,000 mc/s is nearly nine octaves to cover, and even on the ground this would require several search positions and a multitude of intercept positions to collect all the COMINT targets available. It is not believed that a satellite intercept vehicle or system of vehicles could or should replace, or even resemble, a ground-based operation. Space equipment is so very expensive that the intelligence value of the expected COMINT output must be carefully considered before requirements are established for a satellite intercept vehicle. Similarly, R/D's first efforts should be largely guided by practical use in order that the most valuable output may be produced as early as possible. A signal sorting or target-selection technique is indicated. Another kind of bandwidth problem, assuming that the wide spectrum and high signal density can be overcome, is the individual signal bandwidth. Many of the communications signals encountered in the very-high and ultra-high frequency bands are very complex; they transmit at high information rates, and thus are wide-band. This presents problems in receiving and recording, even if conventional intercept techniques are used. Signals using short pulses or multichannel frequency modulation can have bandwidths of several megacycles. Receiver bandwidths must be comparable, yet maintain sensitive and low-noise operation and—more serious—the recorders must be compatibly wide-band so as not to degrade the receiver output. Magnetic-tape recorders for megacycle bandwidths have been developed only recently, and for ground-based use. These must be modified and refined for installation in satellites, but even if this can be done, recording and particularly playback bandwidths are limiting factors. One difficulty with retransmitting re-

corded intercept information is the shortness of the time during which a friendly tracking station can maintain contact with the satellite (compared with the time available for the intercept itself). Either a speeded-up playback is required (which multiplies the bandwidth further) or multiple-channel retransmission or several track stations must be used.

With all of the above and other problems considered, there are nevertheless some COMINT targets which it is technically possible to intercept from an earth satellite. These are indicated below.

POSSIBLE TARGETS



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[REDACTED]

COMMUNICATIONS SECURITY PROBLEMS

The question of communications security arises in considering an active intercept-retransmission device. The data collected and stored in a satellite must be delivered to the user, and if there is an urgent time requirement for getting the data to him, a radio transmission is necessary. Some bulky, very-wide-band data may best be physically recovered (this is planned as an alternate method for the photo Subsystem E of the WS 117L), but the feasibility or even security of recovery techniques is not yet proven. For at least the first COMINT satellites, retransmission of the raw data seems to be the best method. There are two security problems involved in data transmission by radio. Unintended reception of the satellite transmitter must be assumed possible from within the read-out area; and further, unintended triggering of the satellite playback may be possible elsewhere, if the proper command is used by an interceptor. If a priority were to be placed on the two requirements, authentication and encipherment, the former would come first, since if the intercept and read-out commands are not secure, control of the system may be lost. Also, such authentication is an easier problem; the necessary techniques are available.

[REDACTED]

[REDACTED]. Both radio signals (to and from the vehicle) are in the 2000 mc/s frequency region and require a 60-foot antenna at the track station, which is to be located within the continental United States. Intercept-signal quality certainly could be obtained from the WS 117L by an unintended receiver using lesser equipment (e.g., that which could be mounted in a submarine or fishing boat). The ELINT data in the early systems is narrow-band (10 kc/s) and will be in pre-processed, digital form. This, in itself, provides some security against the unintended listener, and correlation with vehicle time, location, and frequency of intercept would present equal difficulties. To read the WS 117L output signal completely, a highly specialized enemy operation would be required.

The National Security Agency considers all unprocessed raw intercept data (for example, magnetic tapes, video, voice, FSK, CW, ELINT, from field stations) as classified at least *Confidential*. This policy might be extended to the read-out transmissions from the satellite. Unfortunately, *Confidential* traffic requires nearly as much equipment to secure it as *Top Secret* does. If it is considered necessary to secure all of the COMINT read-out, a wideband crypto-device (to work on analog signals, perhaps 3 or 4 channels of 1 to 2 mc/s each), capable of remotely commanded operation, would have to be developed. The problem of synchronization of the ground and satellite ends of the link is a major one, which

has yet to be solved. A very-long-life satellite (such as a semi-permanent, 24-hour, stationary-orbit vehicle) would encounter severe authentication and retransmission security problems. For lower-altitude, periodically transmitting vehicles, it is possible that synchronization could be re-established prior to each read-out period, and this would allow the cryptographic device to be turned off, immediately after transmission, for the remainder of the orbit period. There are known techniques capable of enciphering a TV bandwidth signal on the ground, after it has been converted to a 6-megabit PCM signal. Other less complicated equipments are now available for securing 150,000-bit digital signals (e.g., from computers), and transistorized packaging makes them very compact—50 cubic inches—and efficient. The cryptographic process usually requires pulse conversion of the analog COMINT signals. This would further increase their bandwidth (3 to 15 times, depending on the definition required), but the additional equipment could be carried, at the sacrifice of space, weight, and power for the intercept tasks. The magnitude of the conversion and enciphering equipment depends on the bandwidth of the input signal.

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PROCESSING

The article and the RADE study referred to deal primarily with the collection mechanism of a COMINT satellite vehicle. Large data-processing jobs, however, are implied. The signals must be separated, correlated with intercept time and location, identified, demultiplexed,

¹⁰ Mathews, Mitford M. Jr.; "Narrow Band Speech Security Equipment"; *NSA Technical Journal*, Vol. III, No. 4; 4 December 1958; p. 25.

translated, and evaluated. Some of the preliminary steps could be taken on planned WS 117L-type automatic equipment, but the real signal and COMINT analysis would best be done on existing or expanded facilities at NSA. Due to the short samples but large number of signals expected, it may be necessary to revise some of the techniques of COMINT processing known today.

CONCLUSION

A satellite-borne intercept system is only one of several methods of automatic COMINT collection which may influence NSA planning for the future. It is technically feasible to intercept some target communications signals from low-altitude earth-satellite orbits and retransmit them on a secure link to friendly control-track stations. Though future advances in space technology may make earth satellites, moon bases, and outer-space stations common objects, it is believed that owing to their cost, COMINT intercept from such platforms should be very specialized and not duplicate any other means of collection or source of intelligence. Thus the choice of what signals to intercept by such an advanced device must be based on careful consideration of the value of the expected end-product.

Non - Responsive