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RESEARCH MEMORANDUM

PRE-D-DAY ELECTRONIC RECONNAISSANCE OF THE SOVIET UNION AND SATELLITE NATIONS (U)

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PREFACE

This research memorandum is essentially a status report of a RAND study of electronic reconnaissance. It is intended to outline the study, to give some conclusions which have been reached, and to state a number of problems which require further effort. The study reported here deals only with peacetime, cold-war, or pre-D-Day reconnaissance. A companion study on the active war phase has been under way for some time. It is planned eventually to relate these two studies and to devise plans for well equipped organizations which can be deployed in peacetime to meet cold war intelligence requirements and expanded in wartime to support an active war effort as completely as possible.

An examination of the list of problems remaining in this study shows that there are many aspects of electronic reconnaissance which are not well understood. This situation arises from the fact that electronic reconnaissance is a relatively new activity which is only beginning to demonstrate its intelligence potential, and from the fact that military electronics has progressed so rapidly in the last 20 years that electronic reconnaissance is continually confronted with new technical problems.

At the same time, a comparison of the conclusions reached at this point with the current equipments and organizational practices shows that considerable knowledge about electronic reconnaissance exists which has not yet been effectively applied, because of slow developments in equipments and organizations.

Subsequent reports covering individual aspects of this study and changes in the outline will be issued as they are completed.

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SUMMARY

When data obtained by electronic reconnaissance are properly analyzed along with information from other sources it is possible to develop useful intelligence of many types, in addition to the obvious ECM requirements. The best exploitation of this source of information depends on proper detailed direction of the electronic reconnaissance effort and on thorough coordination of this effort with other intelligence activities.

Electronic reconnaissance operations can be divided into three phases:

(1) detection, in which the radiations of interest are first located roughly through use of wide open equipment of low resolution;

(2) reception, in which detailed observations are made of the radiations of interest;

(3) analysis, in which the received data are examined for signal characteristics and compared with other types of data to produce useful intelligence information.

Propagation of radio signals and geographic locations of possible sources require that equipments for detection and reception be distributed widely in ground stations, ships, aircraft, missiles, and other places. Data from all the stations in each sector or theater must be collected rapidly for analysis in conjunction with other intelligence at analysis centers.

When flight over the Soviet Union and its satellite nations is forbidden, there is an area in Russia and Siberia large enough for the development, equipping, and training of a large force with a new weapon system, completely protected from our external observation. Agents within this area might be of some help, but we are not now receiving this type of information, and the total we may expect to receive is small. Nevertheless,

many improvements are possible and a great deal of information can be obtained without overflight.

The need for rapid analysis and the difficulties involved with a large volume of secure communication call for the development of theater analysis centers and theater control centers. These centers would direct the work of all facilities in each theater and analyze the data to produce results useful at theater level. This would reduce the amount of high speed communication needed from the theaters to the United States. All types of data, including communication intelligence, should be exploited in these centers.

All types of intercept stations are capable of unique contributions to the total effort. All stations within each theater should be brought under control of a theater control center for coordinated operations with each other and with other intelligence collection activities. Development of station types most useful for overflight should be carried out now, and stations capable of overflight should be tested in non-overflight operations so that they will be ready if overflight becomes possible. Development times for many of these station types will be much longer than the time in which the political situation can change to make them useful.

If overflight becomes possible, it may be undertaken with manned aircraft, missiles, or free balloons. Of these, manned aircraft could be put into operation earliest, but the other types would also be needed as there would be requirements both for sneak missions to observe the situation without exciting the defense and for observable missions in which the purpose would be to excite the defense and reveal its operations. Overflight operations could fill a substantial gap in our present coverage.

Improvement of the equipment and manpower of existing electronic reconnaissance organizations, and their unification under proper command in the theaters, together with good support from other intelligence agencies, would probably yield quicker and better results than the creation of another "special" force for the electronic reconnaissance mission. Present organizations can be strengthened, relocated somewhat, integrated into properly coordinated intelligence activity, and provided with the necessary flexibility to perform adequately at much less cost than the creation of a new force of equivalent capacity. Time would also be saved in this way.

Rapid changes in enemy techniques demand a high degree of adaptability in electronic reconnaissance equipment. This can be obtained by allocating laboratory and model shop facilities to the organization and by liberalizing military procurement regulations in regard to small quantities of specialized items. The present military research and development cycle is far too long to meet the needs.

The problems which need further detailed investigation for the completion of the continuing study are summarized in the last section of this report.

PRE-D-DAY ELECTRONIC RECONNAISSANCE OF THE SOVIET UNION AND SATELLITE NATIONS

I. EXAMPLES OF INTELLIGENCE WHICH CAN BE OBTAINED THROUGH ELECTRONIC RECONNAISSANCE

The term electronic reconnaissance will be used here to denote all activity devoted to detection, reception, and analysis of radio signals used by an enemy or potential enemy which cannot be reduced to literal text. Electronic reconnaissance complements communication intelligence activity by working with enemy radio signals which are not used for communication. Electronic reconnaissance originated during World War II with the need for information which could be used in devising and applying electronic countermeasures against the growing use of electronic devices in weapon systems. The intelligence potential of electronic reconnaissance has now grown to a point where it exceeds that of many other intelligence sources. Electronic reconnaissance is of prime importance in intelligence needed for airborne operations. Emphasis on this function could well be increased because of its great information gathering ability and the expanding use by the enemy of electronics in weapon systems. As more electronic controls are used by the enemy, intercept equipments and methods must be improved to detect the existence and determine the threats of the new radiating equipments. Some of the types of intelligence to which electronic reconnaissance has made substantial contributions are listed:

A. Order of Battle of Troops Equipped with Electronic Devices

When forces are equipped with weapon systems involving electronic devices such as radar, navigation systems, or remote control equipments, in many cases the signals radiated by these devices during necessary training and maintenance activities can be received and used to identify and locate the forces. For example, Soviet anti-aircraft units in East Germany were for some time equipped with a type of radar fire-control set which could be identified and located through its particular radiations. Soviet GCI radar sets used for air defense can be identified through their characteristic signals, and their locations can be determined through electronic reconnaissance. Order of battle has long been recognized as a very important intelligence item, and electronic reconnaissance can contribute materially in many cases.

B. Purpose of Electronic Devices in Soviet Operations

The signals radiated by an electronic device will reveal to a large extent the use to which the equipment is put. A thorough familiarity with the military requirements of many types of electronic devices will often enable an analyst to determine the purpose of the equipment under study from the characteristics of its radiations alone. In radar, for example, a set with a high pulse-repetition frequency and short pulse length is normally used for short-range work, such as fire control or air interception, whereas wide pulses at low pulse-repetition frequencies are normally used for early warning. In other cases the coincident observation of the electronic signals and other events provides the necessary information. For example, the radio beam signals which were used by the Luftwaffe in bombing England were observed before and during the bombings, and their characteristics were compared with the results of the bombings in determining the purpose of the system. A similar comparison of signals from new Soviet navigation devices with training operations of Soviet forces observed by other methods may yield a better idea of the purpose of these new devices in the next few months. A comparison of radar intercept data with fighter control communication might, for example, enable a complete analysis of the purpose of GCI radar in Soviet air defense.

C. Capability of Electronic Devices to Meet Requirements

When the purpose of an electronic device has been determined through the process outlined above, the efficiency and capability with which it meets its requirements can be determined by close observation and complete analysis of its signal. In the case of an aircraft interception radar, for example, the minimum range at which a target vehicle may be tracked can be ascertained to a large extent by the width of the transmitted pulse, and the rate at which information is presented to the observer can be obtained from the pulse rate and the scanning pattern of the set. If in addition, other intelligence is available concerning training exercises or flight patterns of Soviet aircraft, it may be possible to determine other performance features of the set such as maximum range, altitude limitations, effective angles, etc.

D. Vulnerability of Electronic Weapon Systems to Countermeasures

When the purpose and the capabilities of the electronic devices used in an enemy weapon system have been evaluated to some extent, it becomes possible to combine the electronic reconnaissance data with the other intelligence concerning the same system in order to select the devices in the system most vulnerable to countermeasures and to determine the countermeasure effort needed to reduce the effectiveness of the weapon system to a desired degree. In an air defense system, for example, it would be possible to evaluate the usefulness of countermeasures against the early warning radar, the GCI radar, the air interception radar, and radar or other devices which might be used for fire control or missile control. This sort of evaluation was the first objective of electronic reconnaissance, but it is no longer the only one of major importance. Also, this objective can be met much more effectively by a well-rounded intelligence program in which electronic reconnaissance data are combined with data from other sources. It is imperative that the vulnerabilities of enemy devices be determined in peacetime because of the time required for development and production of the countermeasures equipments and the training of necessary personnel.

E. Physical Characteristics and Limitations of Electronic Devices

A study of the characteristics of signals received in electronic reconnaissance can often lead to a visualization of some of the parts of the radiating device and to the determination of its minimum values of size and weight and minimum power requirements. These features can in turn be used to facilitate collection of more information about the device from photographic coverage or other sources. In World War II, for example, a measurement of the horizontal pattern of the German early-warning radar antenna was used by British analysts to predict that the antenna structure should consist of six dipole elements in a certain type of array. This information enabled the British to secure and identify photographs of the antenna structures involved.

F. Relations of Electronic Devices to Other Devices in Systems

When electronic reconnaissance shows the persistent co-location of two different devices or is able to show correlation among two or more different radiated signals, it is possible to analyze the relationship of the items in a single weapon system. If, for example, a certain type of scanning radar and a certain type of fire-control radar are often associated, it is reasonable to conclude that the scanning set is a target-acquisition device for the tracking set. If a pulsed transmission from a Soviet aircraft is always preceded by a pulse transmission from a Soviet ground station, it is probable that the two pulsed transmitters are associated in a system for navigation, fire control, or identification purposes. Here again, electronic reconnaissance information, when combined with supporting data, helps to complete an analysis.

G. Level of Soviet Operational Readiness

The achievement and maintenance of a state of readiness involves actual use of most types of electronic devices for training operations and maneuvers. When reasonable familiarity has been gained with the devices involved, and their place in Soviet organization is known, the state of readiness may be estimated from the extent of such use. Last year, for example, it was determined through electronic reconnaissance that the state of readiness of the Soviet air defense of Eastern Germany had increased considerably, because radar stations which had previously operated for only eight hours per day went on twenty-four-hour schedules.

H. Indications of Enemy Action and Intentions

The use of electronic reconnaissance data in indication schemes requires an integrated listening network wherein the enemy history and operating norms can be established and a continuous watch can be maintained. Any abrupt change in the over-all intelligence picture may signify an enemy action or an enemy intention to take action. The sudden introduction of a number of new devices, or the sudden withdrawal of devices previously identified would show a change in order of battle which might be important. A sudden increase or decrease in activity should likewise be considered as an indication of action or impending action. The poor coverage which now exists with our own air defense radar makes it probable that the enemy use of bomber navigational radar may be the first indication we shall receive of a surprise air attack. While it is not possible to place complete confidence in electronic reconnaissance as a sole source of intelligence for any of the categories listed above, it should be used wherever available as it is one very important aspect of a well-rounded intelligence program.

II. DESCRIPTION OF THE ELECTRONIC RECONNAISSANCE PROCESS

As in other reconnaissance or observation processes, it is possible to divide electronic reconnaissance into a number of steps which are usually carried out in chronological order. Chance events will sometime modify this order, but in general the process includes a preliminary step of detection of the signals of interest, an intermediate step of reception in which the signal characteristics are measured and recorded to the necessary precision, and a final step of analysis in which the signal characteristics are examined and compared with other intelligence information. It is sometimes necessary to repeat parts of the process many times in order to provide sufficient precise data.

A. Detection of New or Unusual Signals

Early detection of new or unusual signals is necessary in order to prevent technical surprise. The detection operation is roughly similar to pioneer reconnaissance in other fields. It requires the coverage of as much of the radio spectrum and as much territory as possible in order to pick out a small part of the search region for more concentrated attention. The major problems of detection differ to a considerable extent with various frequency bands. The propagation mechanisms which operate in these bands make the detection problems differ from band to band. In bands where there is little long-distance propagation and a low density of transmitters, the major problem of detection is that of providing a radio receiver with high sensitivity and a very wide coverage. In other bands, where long-range propagation is good, and where there may be a high density of transmitters, the major problem of detection is that of locating a new or unusual signal against a background of many similar signals. Early solution of the detection problem is very important because considerable time may be required between detection of a new signal type and satisfactory analysis of the device or system in which it occurs.

In some cases it may be possible to omit the detection phase and proceed immediately with the reception phase. These are usually cases in which other intelligence evidence has demonstrated the existence and approximate characteristics of a new type of enemy equipment before its radiations have been detected. For example, photographs of the Soviet V-beam radar were obtained in Moscow, and a set had been seen in Gdynia before the signals from the set were detected in electronic reconnaissance operations. In the case of the Gdynia equipment, the previous observation of the set made it possible to start electronic reconnaissance with a specific reception operation based on estimated characteristics. In other cases, electronic detection has occurred long before other intelligence provided any information.

B. Reception of Data for Analysis

Equipments which are suitable for gathering the precision data required for technical analysis are often useless in detection because they examine such a small part of the field at any time that they have a very low probability of receiving any new or unusual signal. On the other hand, the equipments which have large probabilities of detection of new or unusual signals are often inadequate to produce the precision data required for analysis. The reception phase of electronic reconnaissance is a process in which detailed search is directed to specific targets. The data to be obtained from the reception phase will be discussed under the heading of signal analysis.

C. Analysis of Received Data

The analysis phase of electronic reconnaissance consists of two parts. In the first part, the data from the reception phase is analyzed to yield the desired signal characteristics; in the second part the signal characteristics are used in connection with all other forms of intelligence information to produce finished intelligence of the types described in section I.

1. Signal analysis

At any receiving antenna a radio signal can be described in terms of a time-varying electromagnetic field with certain polarization and direction of propagation. It is common practice, however, to generate and transmit signals of interest without reference to this exact physical description and to state the results of signal analysis in other terms, which can be defined as follows:

a) Frequency

In present day detection and reception operations the frequency of the signal is read from the dial of a receiver or a frequency meter or estimated from the face of a cathode-ray indicator. This technique is satisfactory in many cases, but it may leave something to be desired in complicated situations. The most common type of radio signal is produced by generating a sinusoidal voltage and modulating this voltage with a waveform determined by the purpose of the electronic device. With this type of modulation, and with most others, it is possible to locate a strong Fourier component of the signal at the originally generated frequency. This frequency is usually called the carrier frequency. There are, however, a number of modulation systems such as single sideband, frequency modulation, and pulse modulation in which the carrier is sometimes suppressed completely or reduced to a level comparable to that of the other Fourier components of the signal. Under these conditions it is important to know the entire spectrum of the signal, as it is possible to report erroneous frequencies when the receiver bandwidth is narrow compared with the modulation bandwidth, and the modulation is not recognized. Carrier frequencies of interest in electronic reconnaissance run from a few kc to 100 kmc or more.

b) Modulation type

The common methods of modulating a signal are to shift its amplitude or its frequency in accordance with the modulating waveform. In some cases, both amplitude and frequency are shifted simultaneously or independently. Either or both types of modulation may be discovered by displaying an oscillogram of the actual electromagnetic wave at the receiving antenna and examining it for amplitude and/or frequency modulation. It is more common, however, to operate on the received signal with amplitude or frequency-detector circuits and to examine the modulation waveforms which are produced.

c) Modulation waveform

The fastest time variation of the electromagnetic field at the receiving antenna is usually that associated with the carrier or radio frequency of the signal. Superimposed on this variation is a slower variation in either the frequency, phase, or amplitude of the radio signal which, when demodulated, can be presented as a definite waveform. This waveform may be classified for analysis purposes as cyclic, randomly repeated, or random. In the case of a cyclic waveform, such as that emitted by an air navigation beacon, a description of the waveform over one complete cycle is sufficient to describe it for all time. A randomly repetitive waveform, such as the response of an IFF transponder, may be described in terms of a complete waveform together with a statement of the times of occurrence of the repeated waveform. A random waveform, such as that from a noise jammer, can be described only in terms of a complete waveform record or of some statistical parameters. Communication signals are usually much more random in nature than non-communication signals. A simple radar system, for instance, has a waveform which is cyclic, whereas a simple radiotelephone involves the random waveform of speech. Modulation waveforms are recovered by demodulation of the signal and recording of the resultant wave on a medium appropriate to the speed required. When the waveform is so random that it is of little use in analysis, it may be converted into a power spectrum or an autocorrelation function for comparison with other waves, or it may be cross correlated with other known or unknown forms to discover relationships between them. Modulation frequencies from a few cycles per second to several hundred Mc are of interest in electronic reconnaissance.

d) Direction or location of transmitter

Direction data establish whether a signal originates from friendly or enemy territory and provide a means of sorting in regions where signals are numerous. Location data can be used in identifying particular pieces of electronic equipment and in many of the intelligence analyses outlined in section I, particularly in establishing order of battle. Although it is usually sufficient to measure azimuth or map location, in some cases elevation data may help in analysis. Accuracies required in direction and location finding vary widely with the use made of the data. For photographic work or attack, positions should be determined within one half mile or less. Other applications may be more or less critical.

e) Signal strength

In theory, a transmitter of given effective radiated power at a known location transmits a signal which can be received through an antenna of known cross section and known location. This signal can be amplified by a receiver of known gain to a measurable level so that the power level of the transmitter can be computed. In practice, the propagation between transmitter and receiver often varies by a large and unpredictable factor, and the cross section of the receiving antenna and gain of the receiver are unknown functions of frequency. Signal strength at the receiver output alone is therefore a rather unreliable measure of power at the transmitter output. Reasonably careful calibration will, however, distinguish between transmitters of markedly different power, when their positions are known, and between close and distant transmitters when their power levels are known. When other data, such as the purpose of the device and its range, are known, the necessary average power can be computed, and the necessary peak output power can be computed from a measurement of the antenna characteristics and the modulation duty cycle. An estimate of power output also helps to establish the physical size and weight of the enemy device.

f) Scanning pattern

The very rapid electrical vibrations at the antenna have been described in terms of frequency, and the somewhat slower ones in terms of modulation. A fluctuation which is usually slower than the modulation is that associated with a scanning antenna system. Many of the electronic devices considered in this report have high-gain antennas which are turned mechanically in order to direct the antenna radiation. When this is done on a reasonably regular basis, it is called scanning; the time pattern of antenna motion, as revealed by the time pattern of response of the receiver, is called the scanning pattern of the device. In the case of air-surveillance radar, for instance, the antenna beam is relatively narrow in azimuth and broad in elevation. The scanning pattern is usually one in which the antenna rotates continuously around a vertical axis so that the pattern of signal strength at the receiving antenna is a time display of the horizontal antenna pattern of the transmitter. In more complicated cases, such as the Palmer scan which is used in the search mode of air interception radar, the time pattern of response of the receiver is a complicated function of the location of the receiver in the radar search pattern and of the actual nature of the scan pattern.

g) Polarization

The use of an electronic device determines the polarization which is normally selected. A particular linear polarization is used to increase or suppress ground reflections, and circular polarization is used in some cases to discriminate against reflections from rain. It is important to know the polarization of a victim device in countermeasures. This may be measured by choosing the receiving antenna polarization which gives the best signal, or by rotating the polarization of a plane polarized receiving antenna.

h) Operating schedule

As has been discussed, the time interval occupied by the scan pattern is usually longer than that occupied by a modulation cycle, but shorter than the daily operating schedule of a device. The operating schedule which is to be measured here is a statement of the times of starting and stopping operation of the device and the times of significant change in modes of operation, such as starting and stopping scanning or changes in power level. It is important that this daily schedule be observed in the evaluation of such matters as readiness. The times of starting, stopping, and other changes in the operation should be measured as accurately as possible so that correlation with other intelligence observations will be possible. A precision which will permit comparison of measurements from different receivers to less than one second would be very desirable in many cases. For example, in comparing intercept data from two or more receivers concerning the flight of a short-range guided missile it would be very valuable to know the time correlation of the different radiations involved.

2. Intelligence analysis

This part of the analysis phase is the one in which signal characteristics developed from intercept data are used in conjunction with other intelligence to produce results such as those discussed in section I. It should be emphasized at this point that no one form of intelligence data can supply sufficient information about any of the items listed in section I. A complete analysis requires that data collected from all sources be brought together rapidly and combined freely to yield the desired intelligence. Since valuable military information is carefully safeguarded by an enemy or a potential enemy, even the existence of our intelligence operations must be kept within some security restrictions. On the other hand, security can become a barrier in the development of useful intelligence by interfering with proper combination of different forms of data and proper collection efforts. An optimal security policy would be one which is flexible enough that it could be readjusted continually; it should provide security appropriate for each situation and still allow the use of the information by the largest possible number of collectors and analysts. Some of our efforts might become known under such a policy and as a result some sources would be "dried up". However, technology and methodology of intelligence collection and evaluation would change with sufficient rapidity to make security breaks much less serious than they would be with a set of fixed methods. Also, some improvements in technique would undoubtedly result from being able to readily adapt our intelligence activities to the current situation. The cost to the enemy of continually improving security measures to protect his secrets would increase considerably, and his technical advancement would be hampered.

As an example, consider the policy on information derived from low-level voice radio traffic. This type of information can be very important in many research and development problems in the United States. Its widespread use would no doubt result in the discovery by the Russians that it was being used. Experience with this method of communication shows, however, that the application of strict security measures contributes to confusion, lost motion, and poor results. Development of suitable security devices for these low-level circuits would be a very expensive and prolonged program which would draw much effort from other useful projects.

Intelligence analysis controlled at a single security classification is probably not enough to produce the best results in this part of the process. An analysis should be made with the data available through open or less shielded sources, and at the same time a more complete analysis should be made with data obtained through the most closely guarded sources. The analysis at low classification should be distributed as widely as security will permit, and it should be modified by the highly classified analysis where possible. For example, when intelligence data are sent to operational commands for their immediate use, every effort should be made to keep information of different security levels separate so that maximum use can be made of the low-level material, unhampered by the classification of the higher-level analysis. When an analysis of high security information contradicts the low-level one, or when there is possibility of a dangerous error in the low-level analysis, an attempt should be made to justify the necessary changes within the proper security limits.

Some intelligence items, such as a clear indication of impending military attack, are so perishable that maximum speed must be used in all phases of collection, analysis, and transmission of the information to competent authority.

III. GEOGRAPHY AND PROPAGATION

The extent of effort needed in electronic reconnaissance is determined partly by the locations of the Soviet transmitters which send out signals of interest and partly by the propagation of the signals from the transmitters to possible intercept stations. In this section a sketch will be made of the probable distribution of Soviet and satellite electronic devices of interest, and the extent to which we may expect to receive signals from these devices without flying over any part of Soviet dominated territory will be shown.

A. Map Distribution of Electronic Devices

Figure 1 is a map of the Soviet Union and satellite states, showing the territory which Russia is now committed to defend and expand. The shading of Fig. 1 is based very roughly on the estimated distribution of electronic devices of potential reconnaissance interest. The cross-hatched area indicates the region we are now able to cover without flying over Soviet territory, and most of the frequency range of interest. This map shows that very little information can be obtained from many important areas. Although our coverage in Europe is fairly good, and we have a significant potential in the Black Sea area and the Far East, enough space remains in central Russia and Siberia to permit the development, production, training, and maneuvers necessary to the complete readiness of a special force of very large size, in an area which is completely protected from external electronic reconnaissance.

B. Propagation of Radio Signals

Although the map of Fig. 1 covers the majority of the frequencies of interest in electronic reconnaissance, the propagation situation should be examined in more detail. For this purpose the major modes of radio

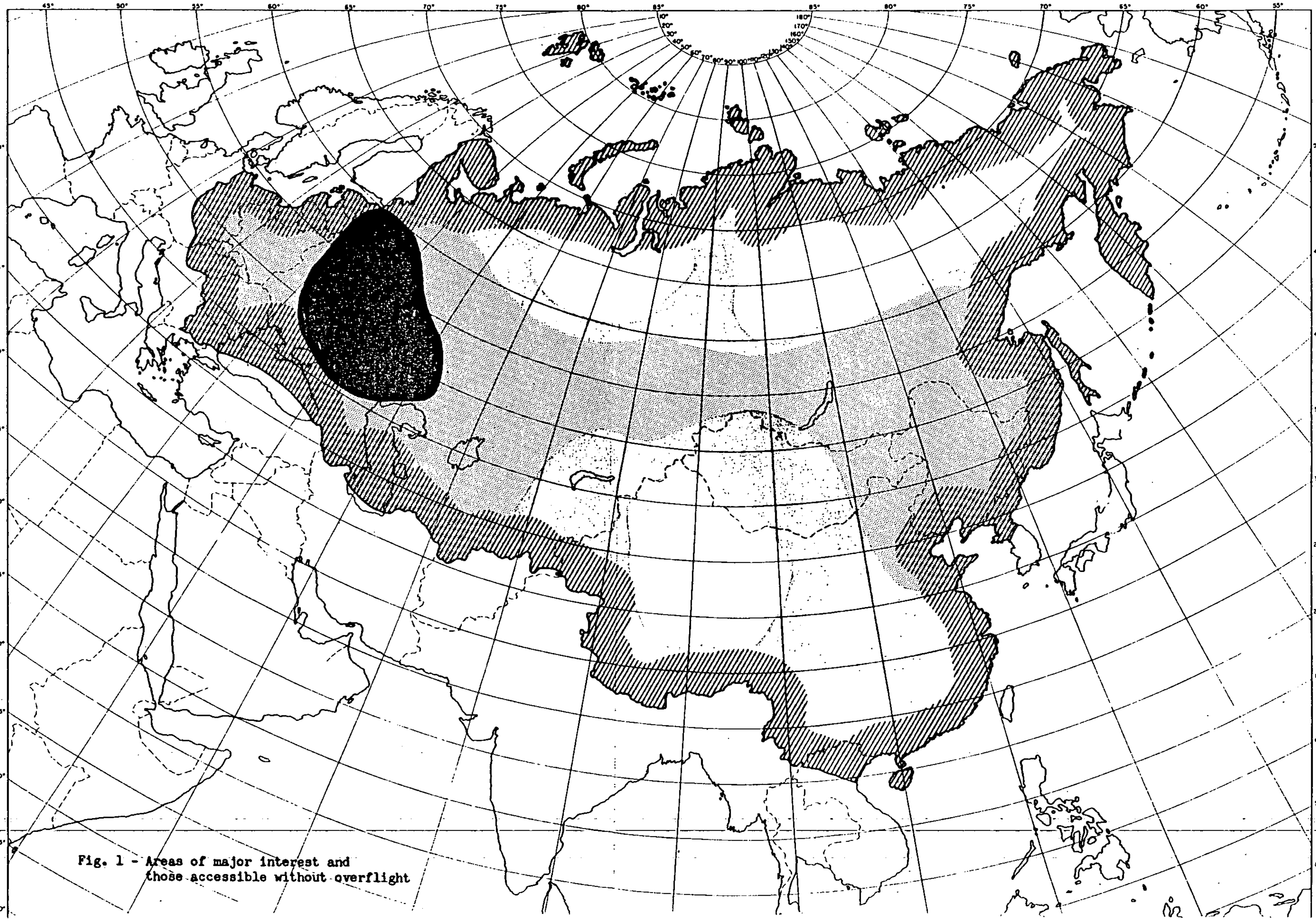

Fig. 1 - Areas of major interest and those accessible without overflight

propagation are outlined briefly, and some of the results to be expected in particular cases are shown. Figure 2 illustrates how the propagation mechanisms are related to radio frequency and the typical ranges of operation which may be achieved through use of the different effects.

Ground-wave or surface-wave propagation may be described in terms of diffracted or guided radio waves around the surface of the Earth. The surface wave which travels in the air around the surface is accompanied by a current wave which travels in the surface. Propagation depends on the conductivity of the Earth, its dielectric constant, and the radio frequency. At very low frequencies, propagation is excellent along sea-water paths. This frequency range is thus used for world-wide communication and navigation. The penetration of the wave into the water enables a submerged submarine to receive and send signals on these wavelengths.

As the radio frequency increases, the surface wave becomes much less important, and the sky wave, in which the radio signal is reflected from ionized layers in the outer atmosphere becomes dominant. Sky-wave propagation is complicated and highly variable. No effort will be made to treat it in detail here. It is principally important between about 3 Mc and 30 Mc, although these limits may change drastically with time and position. Under good conditions, world-wide propagation is possible. Under bad conditions, propagation by this means fades out completely. At any time and at any place there is a definite upper frequency beyond which the ionosphere will not reflect the signals back to the Earth's surface. In spite of its variability, sky-wave propagation is used for world-wide communication and navigation, and there have been suggestions

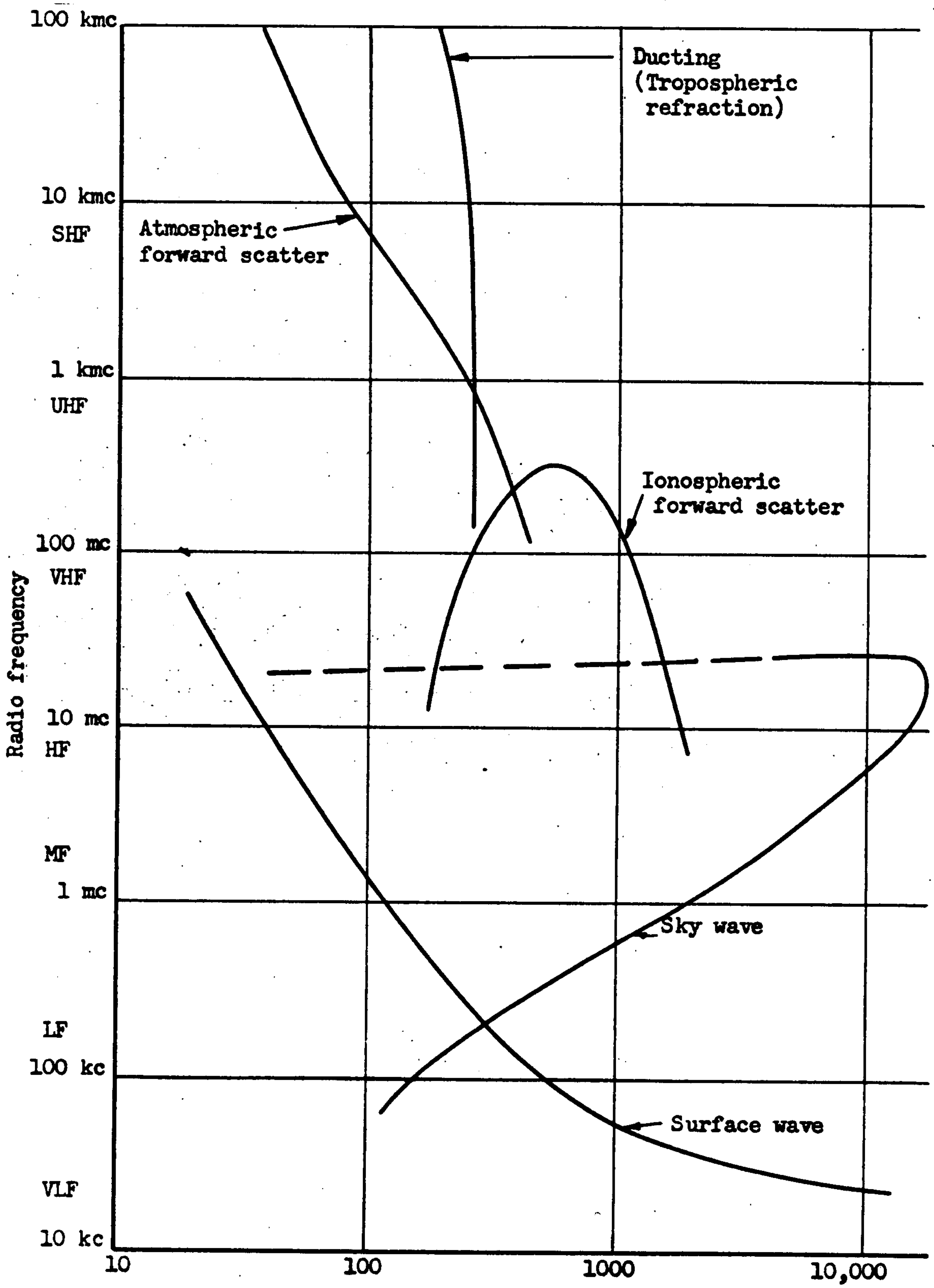

Fig. 2 -- TYPICAL PROPAGATION RANGES IN MILES. This figure shows which propagation mechanisms dominate particular frequency ranges, but it does not apply to any particular case, or show the tremendous variations which occur with time and specific path.

that it be used for long-range radar.

When there is a line-of-sight path, either in a straight line or along a line of atmospheric refraction between the transmitting and receiving antennas, propagation is good. The extent of this path depends, of course, on the heights of the antennas above the surface of the Earth and on the atmospheric conditions along the path. Where the atmosphere is "normal", the effective rate of change of the index of refraction with altitude is such as to make the Earth look about 4/3 as big as it actually is. This leads to a formula for line-of-sight ranges, $d = \sqrt{2h_t} + \sqrt{2h_r}$, where h_t is the transmitter height, and h_r is the receiver height above the level at which the ray path comes closest to the Earth's surface; d is in miles and h is in feet.

The atmosphere under some weather conditions shows abnormal variations of the index of refraction with altitude. When the index falls more rapidly than normal, there is a chance that the refraction will be sufficient to make the Earth appear flat. This trapping or ducting usually takes place over ocean areas or over flat land areas and is effective for signals above some critical frequency. The critical frequency depends on the height of the abnormal index curve and on the severity of the disturbance. In some places, such as the Black Sea, anomalous propagation of this type is normal during the summer months. Ducting is shown on Fig. 2 as it becomes important at frequencies above 40 or 50 Mc. In many places ducting extends radar ranges greatly because it provides very good propagation when it occurs.

When ducting does not occur, it is often possible to observe signals at long ranges by atmospheric scattering. In experiments on propagation conducted over the North Sea, it was found that at the radio horizon the signal level began to fall rapidly as predicted by diffraction theory, but after the level had fallen about 60 decibels below the free-space level, the rate of fall diminished until it was nearly the free-space rate again. This observation was explained by the scattering of signals due to atmospheric turbulence and by the varying index of refraction of the atmosphere with height. Atmospheric scattering becomes useful when there is a high-power transmitter with a high-gain antenna, and when the receiver is sensitive and equipped with a high-gain antenna. This phenomenon was used in the Baltic area to intercept signals from a Soviet V-beam radar at a range of about 340 miles, with both receiver and transmitter near sea level. Although the phenomenon may persist at lower frequencies, it is much less important than other modes of propagation at frecuencies below 30 Mc.

The ionosphere is also a varied and turbulent medium. The National Bureau of Standards was able to demonstrate highly reliable propagation over distances of 600 to 1200 miles at 50 Mc, using high-gain antennas, high-power transmitters, and sensitive receivers. Communication circuits based on this effect have now been put into operation.[1] Frequencies between 30 and 100 Mc are of principal interest. Figure 3[2] shows the

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(1) D. K. Bailey, Regular VHF Ionospheric Propagation Observable over Long Distances, National Bureau of Standards, Report No. 8-A-111, 30 June 1952 (Confidential).

(2) R. C. Raymond and K. H. Underwood, Radio Wave Propagation, Haller, Raymond and Brown, Inc., Report No. 37-6, 15 October 1952 (Confidential).

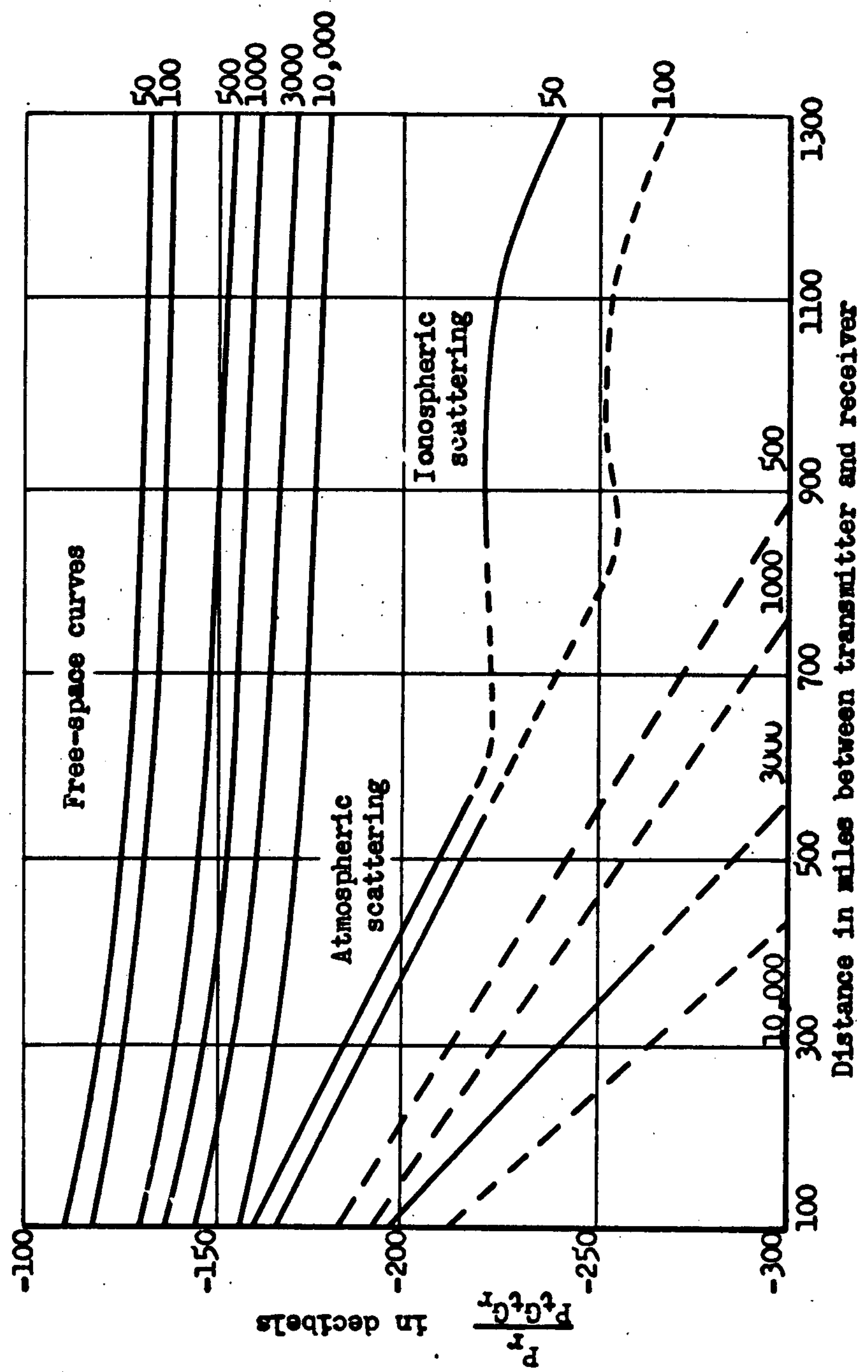

Fig. 3 — Propagation by atmospheric and ionospheric scattering between stations well below line of sight. P_r is power received by antenna of gain G_r from transmitter of power P_t and gain G_t. It is assumed that G_r is less than or equal to G_t.

expected propagation levels which will be exceeded 50 percent of the time as a function of frequency and distance for given transmitter power and given gain of transmitting and receiving antennas. It is assumed that the antennas are well below the radio horizon, that propagation close in is due to atmospheric scattering and that propagation far out is due to ionospheric scattering. Comparison of the lower curves with the upper free-space curves shows the loss to be expected in the scatter-type propagation. When ducting occurs, the propagation will fall above the scatter curves and possibly as high as or higher than the free-space curve. The scatter propagation is therefore not observed under ducting conditions.

The general result of propagation considerations is that intercept stations will need to be located within 200 or 300 miles of points of major interest in the Soviet Union and satellite countries to be sure of securing intercept data. This conclusion is used in plotting Fig. 1.

Some specific radar interception ranges have been computed in a separate report.(1) Examples of the ranges to be expected in particular cases are given in Figs. 4 through 10.

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(1) E. B. Soltwedel and A. L. Hiebert, Interception Ranges of Typical Radars, The RAND Corporation, Research Memorandum RM-1139, 1 November 1953 (Secret).

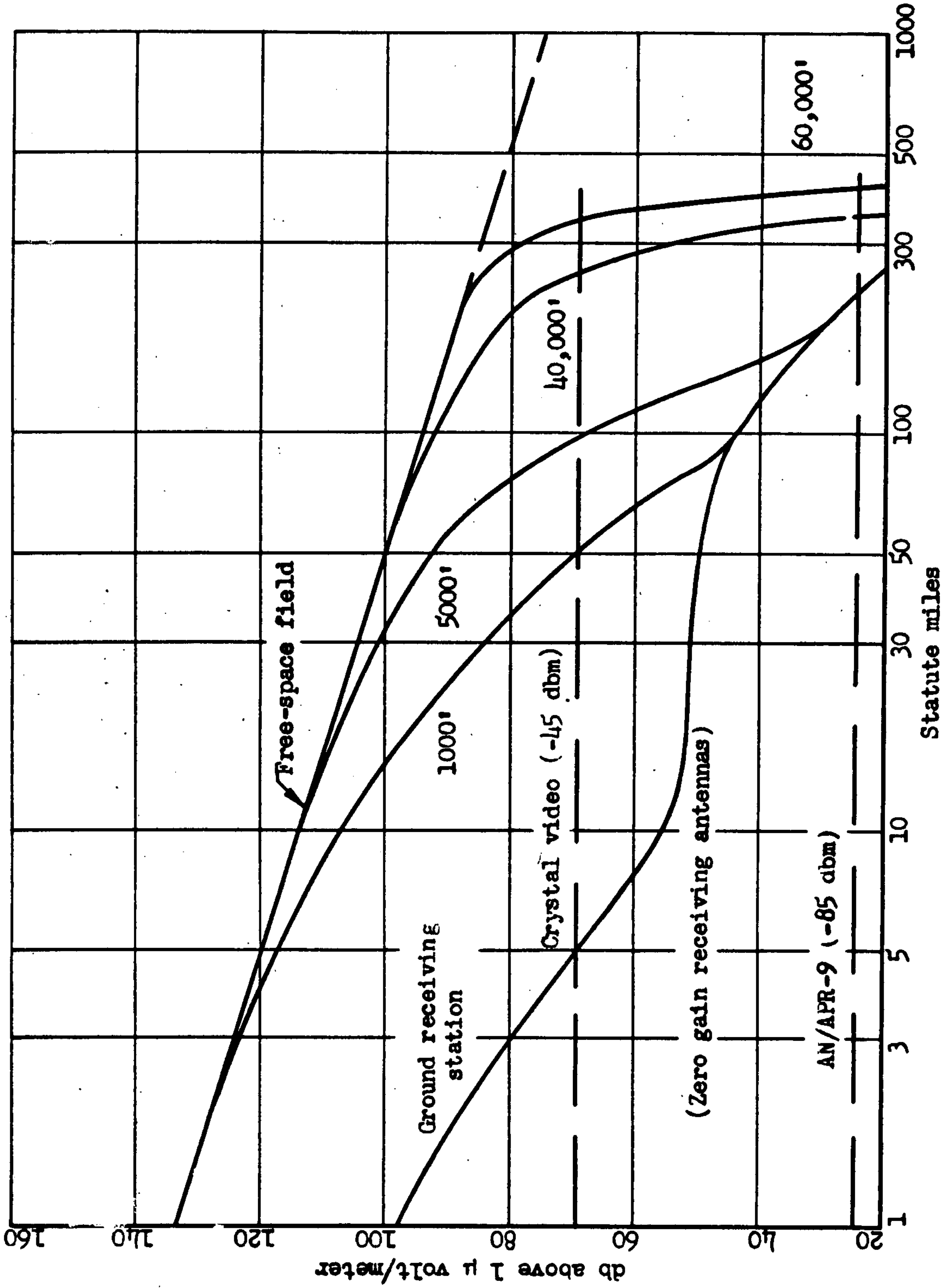

Fig. 4 -- Field strength of "Dumbo"

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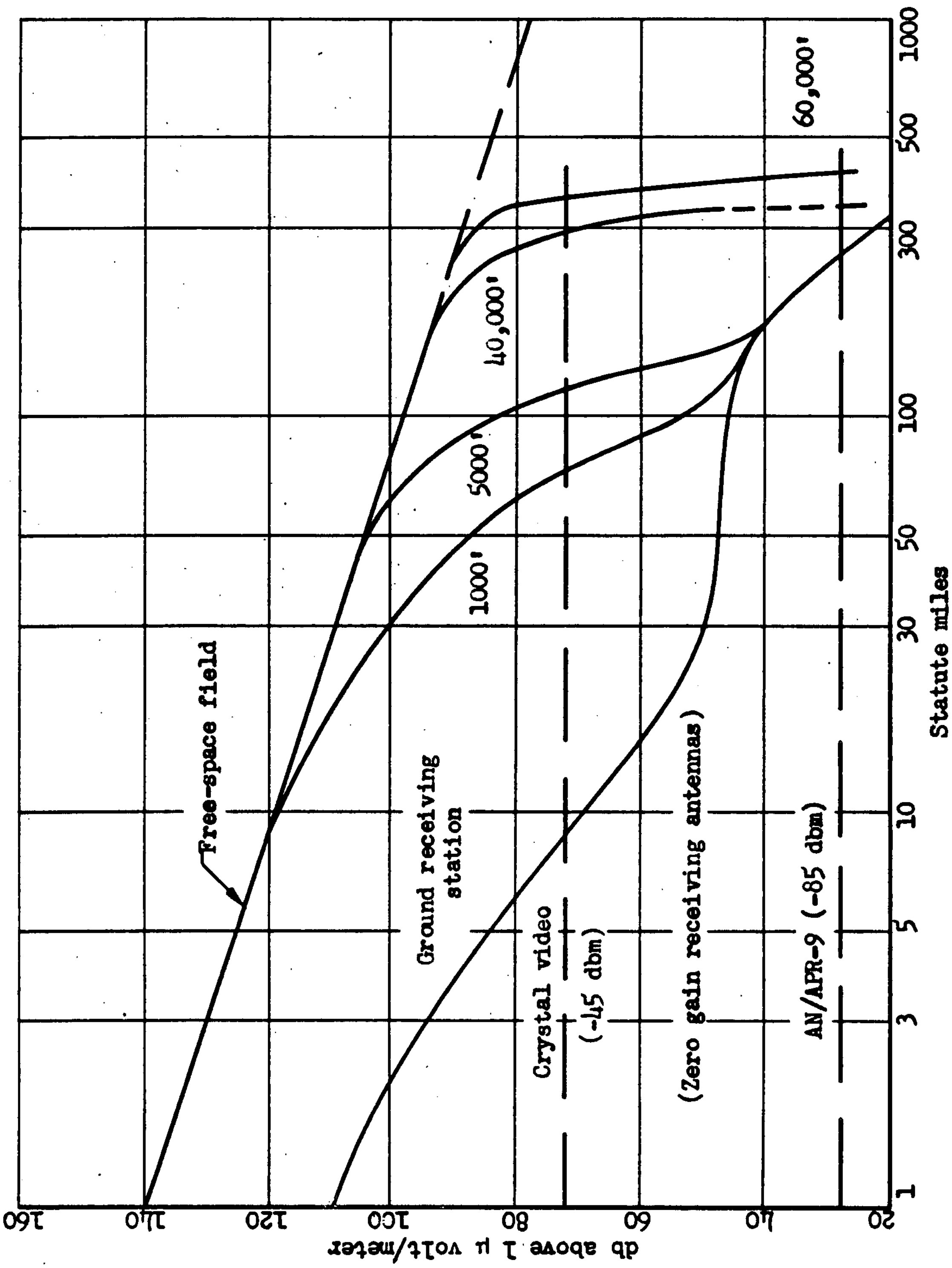

Fig. 5 -- Field strength of SCR-270-DA

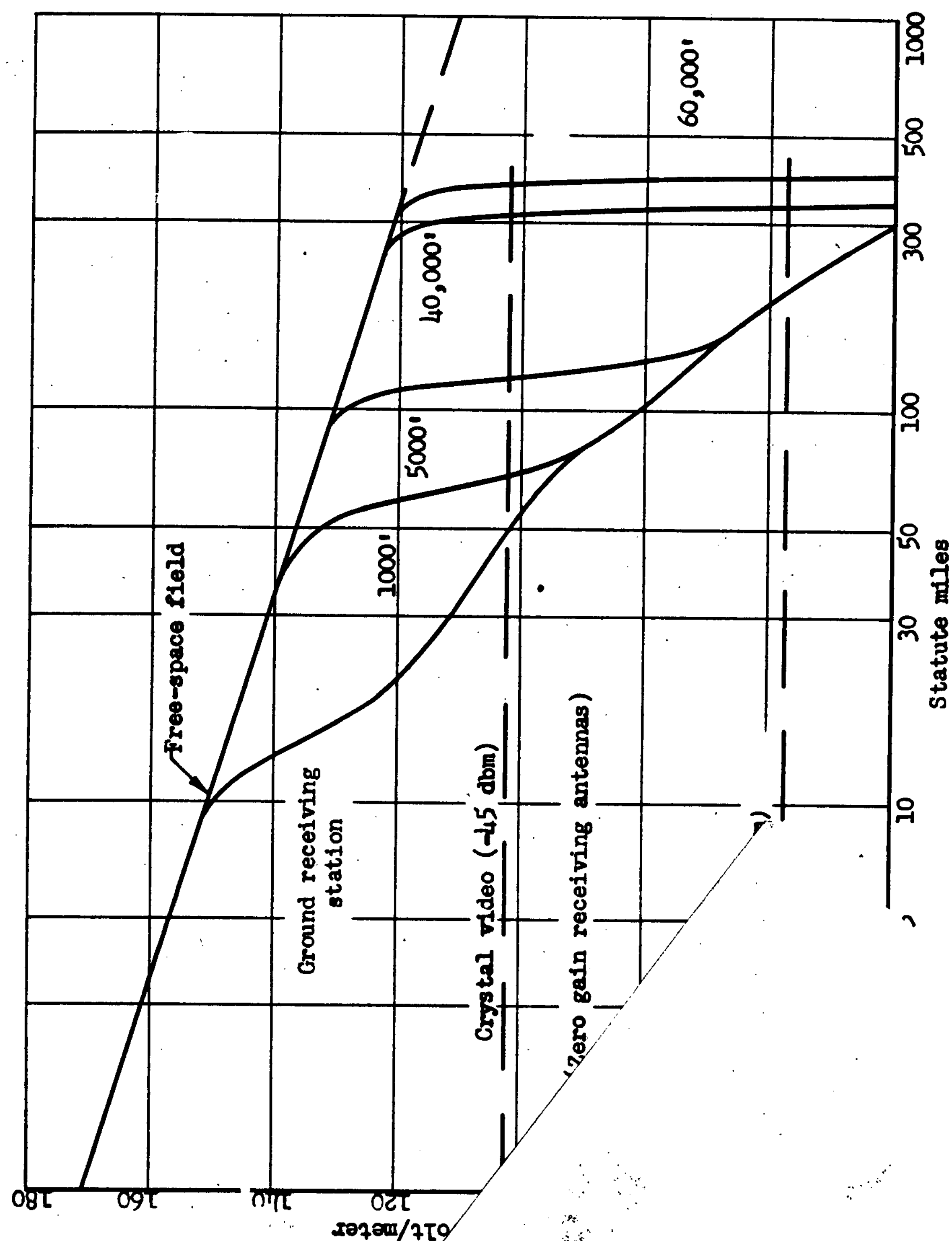

Fig. 6 -- Field strength of AN/CPS-6

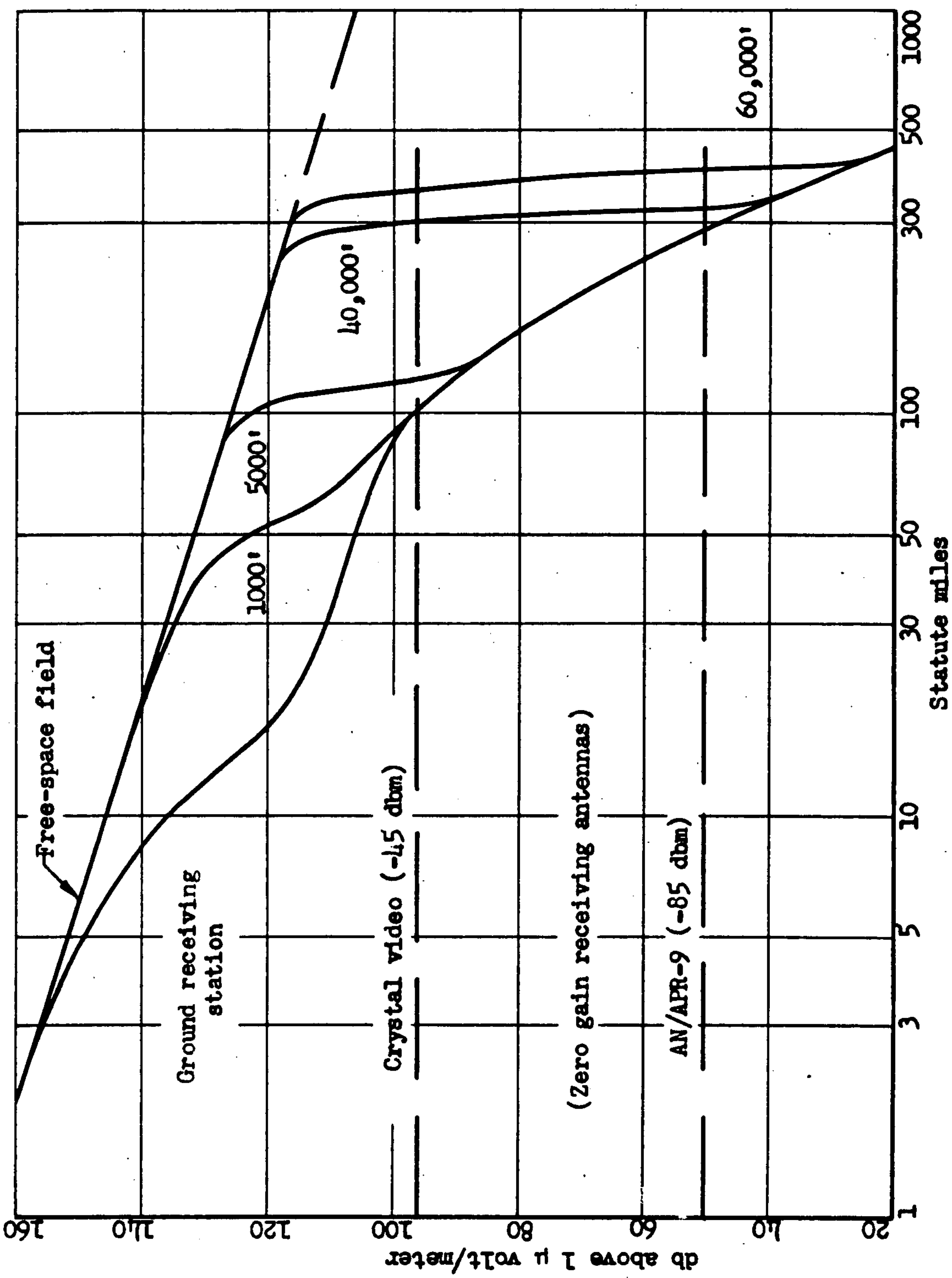

Fig. 7 — Field strength of AN/FPS-3

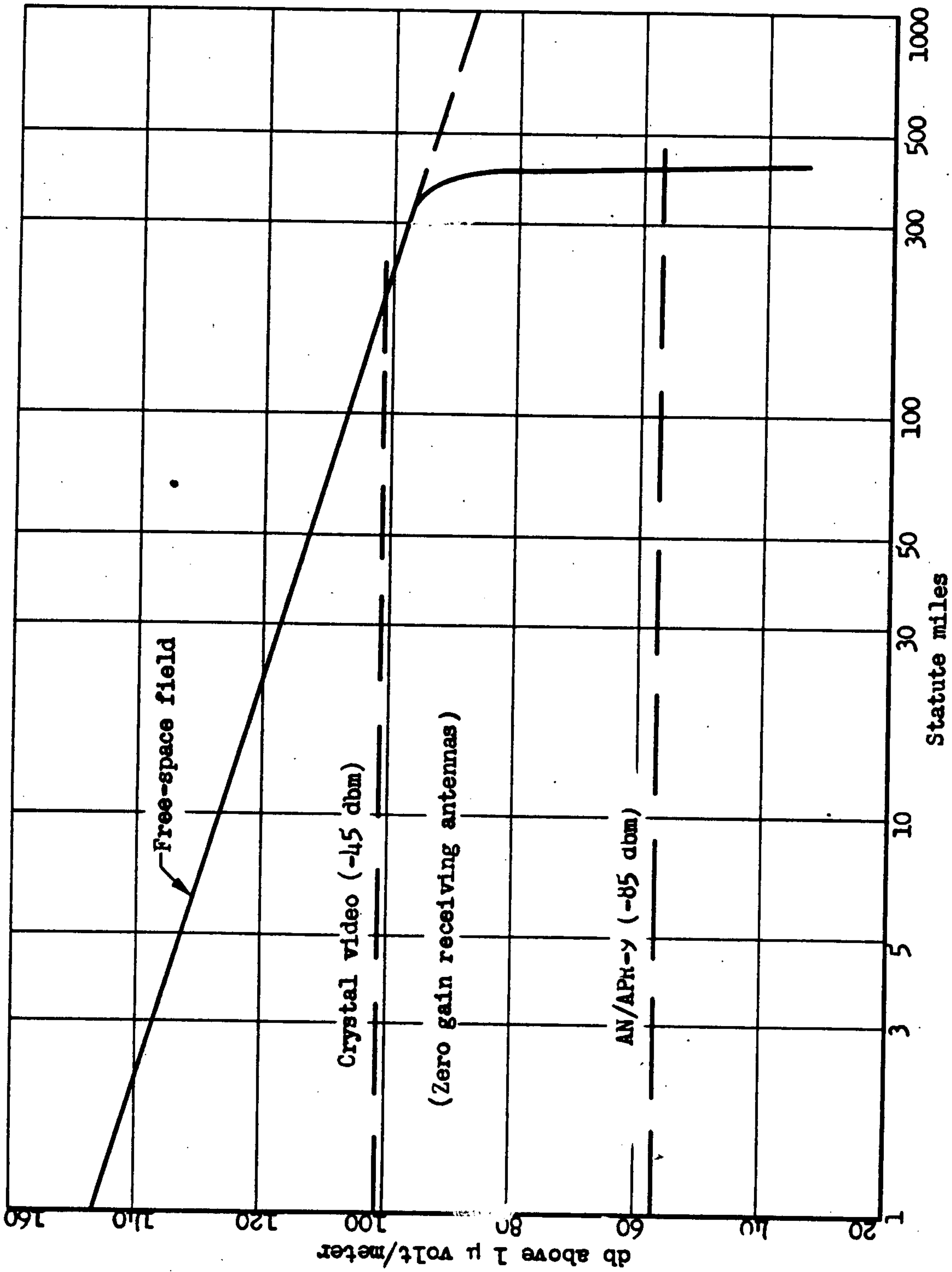

Fig. 8 — Field strength of SCR-720-A
(Receiver and radar at 20,000')

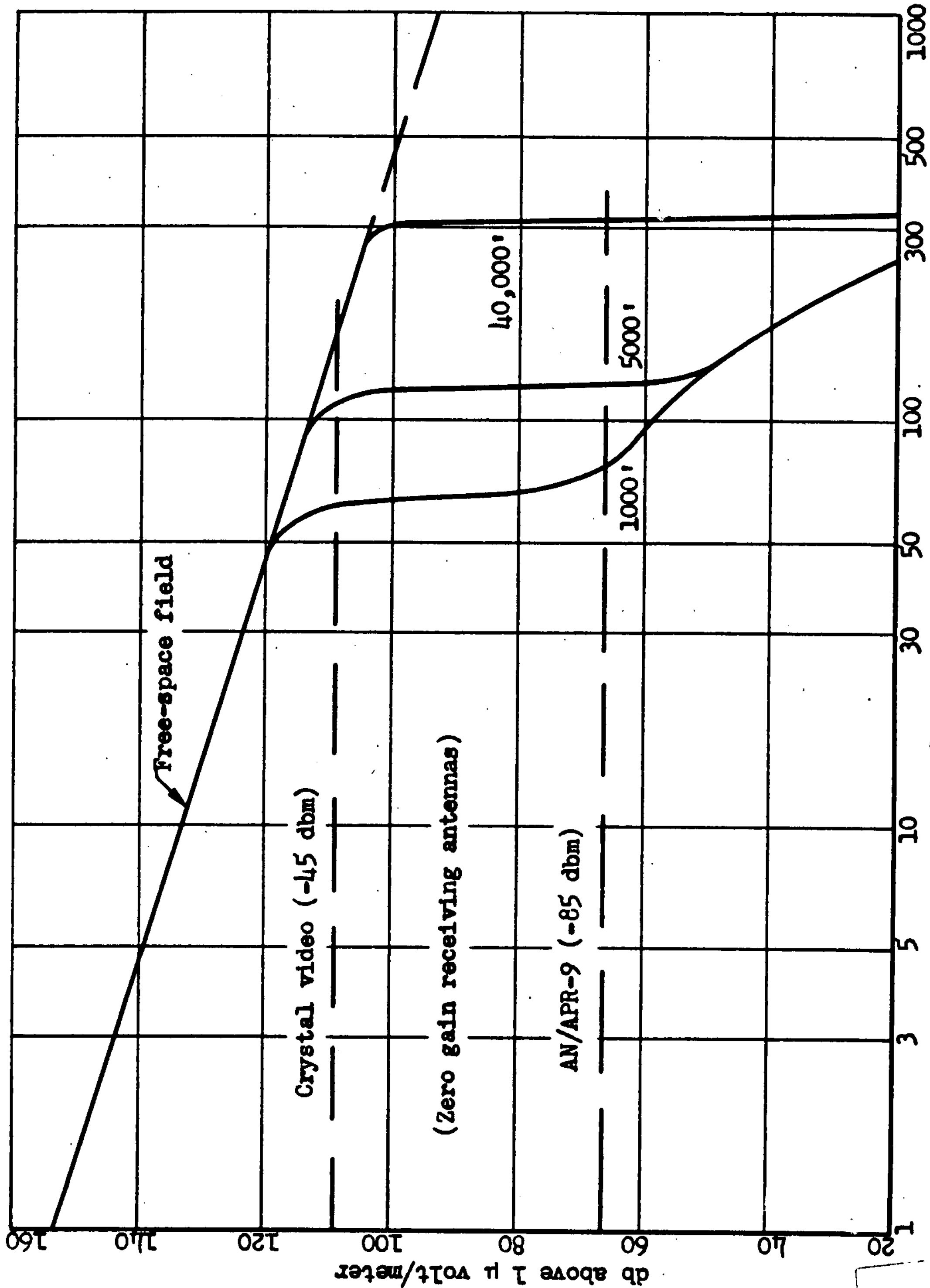

Fig. 9 — Field strength of AN/APS-23

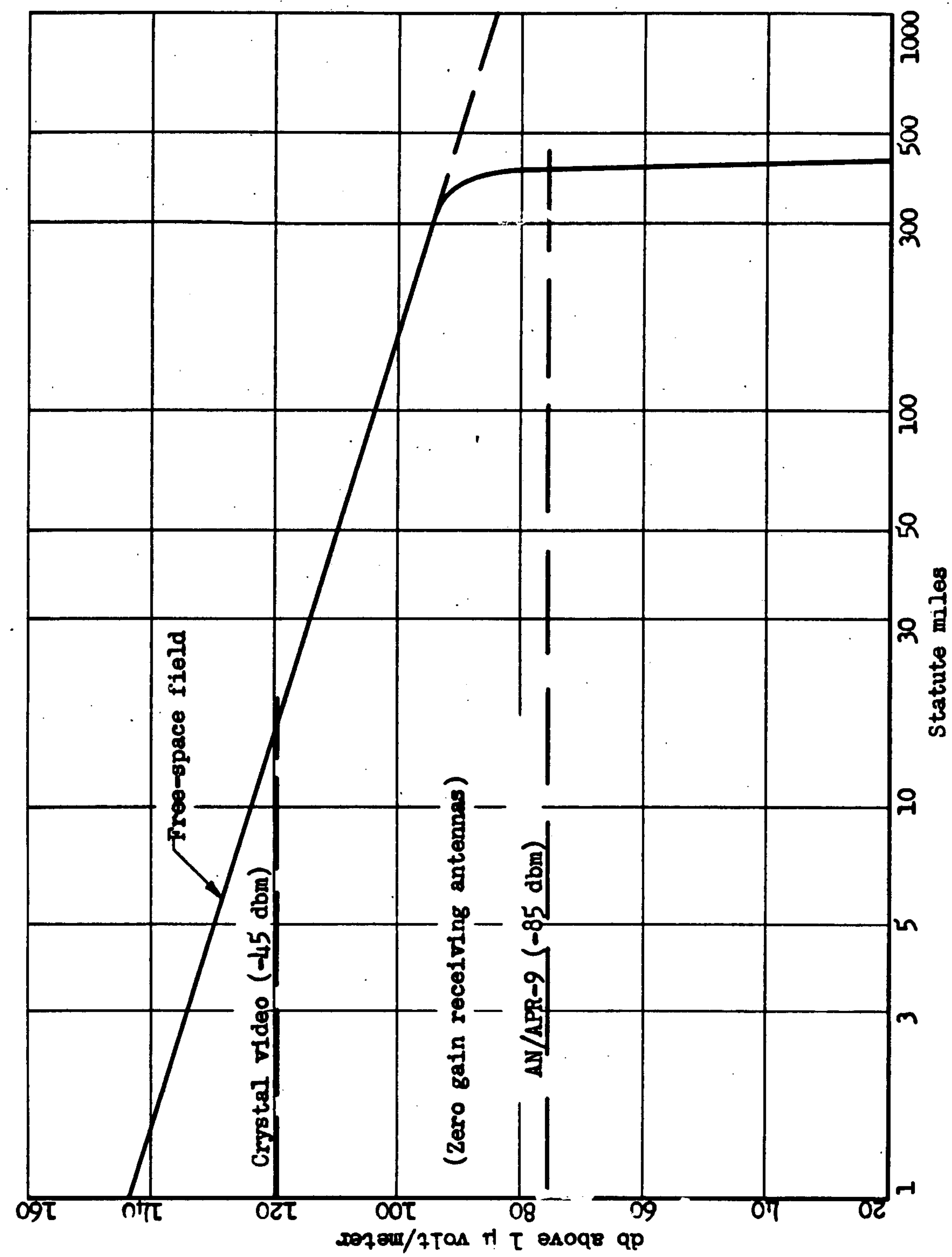

Fig. 10 -- Field strength of Sparrow II radar (terminal guidance)
(Receiver and radar at 20,000')

IV. ELECTRONIC RECONNAISSANCE SYSTEMS WITHOUT OVERFLIGHT

It has been established that an electronic reconnaissance system must perform the functions of detection, reception, and analysis of the electronic reconnaissance data. Considerations of geography and propagation have shown that the receivers used in the detection and reception phases of this process must be distributed rather widely in space in order to achieve significant coverage of possible Soviet sources. At the same time comprehensive, properly correlated intelligence is needed. The electronic reconnaissance system must therefore involve a considerable number of intercept stations at which the detection and reception operations may be carried out, and a smaller number of analysis centers properly organized to receive data rapidly from the intercept stations, produce results desired at the local level, pass out requests for additional data, and pass on for higher analysis both the raw data and the results of the primary analysis. The entire system must be mobilized under an adequate chain of command and provided with adequate communication facilities to permit rapid exploitation of new developments.

A. Intercept Stations

Experience has shown that it is generally desirable to house a number of individual equipments and operators in a single vehicle or a single location so that they may be provided with common security, communication, and logistic support. The optimum number of equipments and operators in each case will depend on the density of signals to be investigated, the time available, and the range of signal characteristics to be accommodated. This small collection of personnel and equipment will be called an intercept station. Several general types of intercept stations have been developed in the course of electronic reconnaissance work to date, and we may expect the development of new types as the necessary equipments become available.

1. Types and locations (vehicles)

Intercept stations may be sited at selected ground points or may be transported and used in suitable vehicles. Each type of installation has its own unique advantages and disadvantages. A complete electronic reconnaissance program requires several types of stations. In a later phase of this study the number of stations of each type necessary to provide good electronic reconnaissance will be determined, and suggestions will be made for locations and organization of these stations into effective networks.

a) Ground fixed

A permanently established ground station with adequate space is an ideal location for the operation of complicated and sensitive equipment and for the use of very-high-gain antennas. It also has the advantage of being able to remain in operation continuously for long periods of time. There is no effective limitation on the space, weight, and power available for the operation of special purpose intercept equipment, and there is no limitation on the number of operators who may be used if necessary. The position of a ground station is not subject to navigational error, and the station furnishes a much more stable platform for use of high-precision receiving and recording equipment than an aircraft or other vehicle.

On the debit side, a ground station must be installed close to enemy borders to be useful, because of the propagation problem outlined above. Its operations are subject to enemy observation, its personnel and equipment are subject to capture, and its fixed location makes it liable to a number of countermeasures. Such a station cannot maneuver to take advantage of favorable propagation conditions in other places, and it cannot secure a high-altitude look into enemy territory. It cannot make a number of direction finder readings on a transmitter of interest; only the direction can be determined. It is therefore evident that other types of intercept stations are needed.

b) Ground mobile

Ground station equipment which is housed in a truck or trailer has some advantages over that in fixed locations. The equipment may be moved more easily from one location to another, and it is possible to build engineered installations in places with adequate facilities and then move them quickly to the operating areas. On the other hand, space, weight, power requirements, and operator comfort must be sacrificed somewhat for portability. The permissible size of antenna structures is limited, and the equipment in the stations must be thoroughly rugged to survive the shocks of transportation. Communication facilities are less useful or less secure, or both. Mobile stations will probably be the most satisfactory ground stations in the event of ground warfare. In pre-D-day use, they will probably function mainly as satellites for the more permanent stations, or they will operate in the same place for so long that they will gradually acquire the large antenna structures, additional shelters, good communications, and other facilities of fixed stations.

c) Aircraft

Specially equipped aircraft have been used in electronic reconnaissance operations for some time. They have the advantage of extreme mobility. They can penetrate land and sea areas which are not suitable for the erection of other stations. They can reach high altitudes so as to take advantage of the best propagation conditions.

Specially equipped aircraft are very expensive. The conditions of audible and electrical noise and vibration to which their equipments and operators are subjected are very annoying. No use can be made of high gain antenna systems; and the weight, size, and power supply limitations on equipment are severe. The aircraft cannot guard particular locations for long periods of time, and the number of hours of actual operating time per month is not impressive.

Aircraft stations should therefore be directed carefully toward specific objectives in detecting and receiving signals, through the use of all available information. Wherever possible, fixed or mobile ground stations should be used. Aircraft should be used only where other stations cannot operate because of the terrain or where the existence of the aircraft may elicit a desired type of enemy activity which would not otherwise be obtainable. For example, reconnaissance of the Baltic coastline or the northern border of Russian territory is probably most practical by air. Aircraft might also be used to put the enemy air defense system on the alert in order to study its radiations.

In addition to the specially equipped aircraft, it may be found desirable to use aircraft which fly regularly scheduled routes that might yield useful information. Such routine flights will require a new approach to the equipment problem, which will be brought out later in the section on equipment. There are many cases where a suitable piece of equipment on one of these aircraft could obtain information which could not be obtained by the specially equipped aircraft.

d) Missile

A missile or a pilotless aircraft would be useful in non-overflight operations only if it offered some advantage in the way of high altitude or penetration of an area which could not be obtained with either the routine-flight or the specially equipped aircraft. The missile station would require generally the same type of equipment as the aircraft station, with the important difference that human operation would have to be eliminated and no advantage could be taken of human judgment. Ballistic missiles which might be fired to extremely high altitudes would command very long lines of sight into Soviet territory without overflight, but the time which a single receiver station would spend at the high altitude would be so short that the value of such an operation for electronic reconnaissance purposes is questionable. The firing would certainly have to be directed at some specific objective and timed on the basis of intelligence data to attain the desired result. Aerodynamic missiles would have little advantage over conventional aircraft in border operations except that the risk of loss or capture of personnel would be reduced, and the experience gained in the border operations would be very valuable in the event of overflight, using the same or similar missiles.

e) Free balloon

A completely new approach to equipment development will be required for best use of free balloons in electronic reconnaissance. The weight and power supply limitations are considerably more drastic than those encountered in aircraft or missile operations. On the other hand, the vibration and noise problems are much reduced, and the balloon platform is very stable. Balloon flights can reach altitudes up to 100,000 feet. The trajectory of a free balloon cannot be accurately predicted. In flights which are not intended to go over Soviet territory it would be necessary to monitor the balloon position continually and to bring down the essential parts if the balloon crossed an established limit. As in the case of missiles, free balloons have little to offer in non-overflight operations which cannot be achieved by aircraft. On the other hand, the experience gained in using balloons in non-overflight operations would be invaluable in case overflight operations become possible. Under some conditions a balloon could be launched in Western Europe, and would have a useful life of several hours or perhaps a day on or near the border of Soviet dominated territory. Such a flight could yield significant data. However, it should be repeated that an entirely new research and development program is required to implement a balloon for electronic reconnaissance.

f) Large ship

The exclusive availability of a large ship, either a naval or a merchant vessel, for electronic reconnaissance is unlikely. Large ships are even more expensive than special airplanes. An intercept station established in a large ship would be able to carry out electronic reconnaissance only on targets of opportunity within the normal range of its travel. A large ship can furnish sufficient space for equipment and for antennas of reasonable gain. Power supply is adequate. Working stations are fairly comfortable, and noise level is reasonable. Repair and maintenance facilities are usually good. Although a large ship is less mobile than an aircraft and the regions in which it can penetrate are much more limited, it can remain on station much longer than an aircraft, and it is suited to a slightly different class of duties. The presence of the ship may call into action enemy electronic devices, particularly those of naval interest, which would not be brought into use by the presence of an airplane. Communication facilities are usually good. The map of Fig. 1 shows that the Pacific area offers a considerable opportunity for the use of ship stations, as do some small regions in the West.

g) Small ship or boat

A small ship or boat will provide less space for equipment and personnel and will be limited to smaller antennas than a large ship. Such a boat, however, can penetrate waters in which a ship would not be risked for reconnaissance purposes, and it can remain on station for fairly long periods of time. The boat might also be disguised as a fishing vessel in order to minimize its threat, or it can be operated in such a way as to exaggerate its threat in order to bring about desired enemy responses. A tender or shore based logistic support would be required at frequent intervals. There are many uses for a boat in this type of service, and the expense of the smaller types is comparable with that of the special aircraft. As in the case of the aircraft, missile, and balloon stations, the boat should normally be sent out with enough intelligence information to permit the accomplishment of a detailed objective.

h) Agent

When a trained man can carry some equipment into Soviet controlled areas, make measurements, and report his results, he can make a very worthwhile contribution to the electronic reconnaissance effort.

The nature of the equipment he can carry is very limited in size, weight, power supply, and complexity of operation. He can rarely use a high gain antenna, and he can record very little information. On the other hand he can often occupy a position which is very near the equipment in which he is interested, and experience has shown that a skilled operator can produce very useful information even with very limited equipment. Unfortunately, intelligence available at present from personnel operating within Soviet borders is meager in quantity, and does not justify much dependence. We must develop our external facilities to the point of diminishing returns rather than wait for more from this source.

2. Equipments

Each of the station types mentioned puts its own limitations on the design of equipments. In addition to these limitations different equipment types are often needed for detection and for reception, and all of the conditions vary with the frequency range in which the equipment must operate. During later phases of this study these conditions will be examined in some detail and an attempt will be made to specify the requirements for detection, reception, and analysis equipments which will meet the conditions as well as possible. At present only generalizations can be made.

a) Receivers for detection and reception

In detection, no attempt is made to learn all of the characteristics of a new signal with the precision required for complete analysis. The characteristics are measured only well enough to tell whether a signal is radiated by a previously known enemy device or whether the signal is new or unusual in some respect. Receivers designed for detection operations may therefore be built with parameters such as bandwidth selected on the basis of the operation rather than on the basis of the expected signals.[1] For example, a pulsed radiation in the LF region may be detected through use of a narrow-band communication receiver which cannot respond to the pulse waveform of the modulation. At the same time, the narrow-band receiver may be a better detection receiver than a wide-band receiver would be in this case, because it may be necessary to select the desired signal from a number of overlapping signals. The narrow-band receiver would yield enough information about the transmission to permit its identification as new and interesting, although it would not transmit enough information to permit a study of the modulation waveform. Any parameter such as bandwidth in a receiver design is selected as a result of compromise among a number of factors such as manufacturing tolerances, operating ease, noise level, interference, bandwidth of desired signal, and technical ease of construction. In the design of detection receivers for frequencies below about 50 Mc, the most important items which must be compromised in selecting receiver bandwidth are the probability of reception of a short signal, and the rejection of interference. If an intermittent signal of short duration which is well above the receiver noise level is considered, and the detection receiver is tuned randomly through a band of frequencies wider than the modulation band of the signal, the probability of hearing the transmission increases as the

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(1) A. L. Hiebert, RAND Electronic Reconnaissance Conference Summary Report, The RAND Corporation, S-15, 1 August 1953 (Secret), Chapter XIV.

bandwidth of the receiver is increased. However, if the spectrum is cluttered with other signals which are of no reconnaissance interest, increasing receiver bandwidth also means an increased chance that the signal of interest will be lost among interfering signals which are received at the same time. Above about 50 Mc, the density of interfering signals is usually low enough to make the receiver noise the limiting interference factor rather than undesired radio signals.

A great many of the receiver designs in use today were devised from a background of communication receiver design. In communications, the usual requirement is for the receiver to handle a single signal as well as possible. In detection, it is often necessary to handle a number of signals with unpredicted characteristics at unpredicted times and frequencies. We may expect therefore a considerably different approach.

A detection system is responsive in a number of dimensions. In addition to frequency, which has been mentioned, the system is responsive in time, space, direction, polarization, and sometimes in modulation characteristics. All of these aspects may be used to identify and describe the detected signal and they must all be considered in the design of suitable detection equipment. Propagation values are also important in receiver design. For the intercept function it is necessary to establish a number of stations to cover the area of interest. If signals are normally propagated, say, 500 miles, the spacing between stations can be of that order of distance, while with propagation distance of 100 miles or less, stations should be spaced much more closely. Yet it would be wasteful to spread facilities for intercept of the long-range signals in all of the closely spaced stations. Fortunately, signal density considerations and bandwidth requirements are also dependent on propagation so that it will probably be most economical to specify individual equipments for each general propagation region. This leads to a selection of four general spectral regions (section III). In the LF and VLF region, extending to about 200 kc, there is long range propagation and relatively high signal density. In the MF region the propagation ranges in daylight are quite short, but signal density may be high during the day, due to crowded conditions of the band, and it is sure to be high at night. In the HF region, there is usually good long range propagation, and signal density is normally fairly high, especially at night. In the VHF and higher ranges, propagation over long ranges is not common, and signal densities are not high except in a few special cases such as the concentration of Soviet radar in East Germany or the concentration of radar in the vicinity of a naval task force. These considerations suggest the development of detection receivers for the ranges:

10 kc to 200 kc

200 kc to 5 Mc

2 Mc to 50 Mc

30 Mc to 100 kmc

One unit should not necessarily contain all of any one of the bands, but the receivers which fill that band should have roughly similar characteristics, because the conditions under which they must detect signals are similar. It would be desirable in this program to develop all of these equipments so that they could be used in any of the station types outlined above. This is hardly practical, however, because some stations are manned and others are not; and the mechanical and electrical requirements on a receiver for use in a missile, for instance, would certainly prevent use of the same equipment in a free balloon. We must, therefore, in later parts of our continuing study examine each of the situations in detail to determine the minimum useful number of types and the order of priority in their development.

A preliminary estimate of this situation appears in Table I. Here the station types have been grouped so that limitations of size, weight, complexity, and power supply are approximately the same in each row of the table. Each square in the table may therefore represent a single equipment design or a single set of equipment designs to cover the indicated frequency range within certain weight, size, power supply, and mechanical limitations. The relative importance of each set of equipment designs has been estimated roughly. This may be modified somewhat in later reports on this study.

Table I

RECEIVERS REQUIRED FOR DETECTION AND RECEPTION OPERATIONS

	Detection				Reception			
Station Type	10-200 kc	200kc-5Mc	2-50 Mc	30Mc-100kmc	10-200 kc	200kc-5Mc	2-50 Mc	30Mc-100kmc
Ground fixed Large ship	High	High	High	Low	High	High	High	Low
Ground mobile Small ship Special aircraft	Low	Low	Med.	High	Low	Low	Low	High
Routine aircraft Guided missile	Low	Low	Low	High				High
Balloon		Med.	Low	High		Med.	Low	High
Agent	Low	Med.	Low	Med.	Low	Med.	Low	Med.

Theoretically, a good detection receiver would have a learning capacity. It would show response to a particular type of radio signal until the analyst or operator decided that the signal was of no further interest. The receiver would thereafter ignore or eliminate the particular type of signal or would alter its response to it in a beneficial way. This type of equipment is probably some distance in the future, but it represents an objective which should be considered. Many of the techniques now used in computer memory circuits may be applicable to this problem.

A receiver designed primarily for the reception process more nearly resembles a communication receiver than does one designed for detection. In reception, the receiver characteristics must be keyed to those of the signal to be received. Bandwidth, for instance, must be selected with a view to passing all essential components of the signal, instead of merely detecting the existence of the signal. At the same time, the existence of the detection operation makes it unnecessary to maximize the probability of intercepting the signal, because a detection receiver of high probability can usually be used to locate the signal in the spectrum. This is similar to the use of pioneer reconnaissance to select small areas for more intensive observation.

More consideration will be given in later reports to the selection of receiver characteristics, but a few rules of thumb may be stated at this time. In the ranges below 50 Mc atmospheric or cosmic noise rather than internal noise in the receiver usually limits the reception of small signals. Receiver bandwidth in this region should be matched as closely as possible to signal bandwidth. The majority of radio systems using single transmitters and antennas in this frequency range are limited to bandwidths of about 10 percent of the carrier or center frequency. This limitation comes from the necessity of matching low-impedance antennas to tubes of higher impedance. The reactive circuit elements in the matching networks limit the bandwidth over which this can be accomplished. There are a number of current development programs in the field of communication and navigation which will produce signals that are dispersed across considerably wider bands. However, these will generally be multiple systems, and it will be necessary to receive their signals in multiple channel receivers, each of which may be fairly narrow in bandwidth.

A general rule in both detection and reception is that the equipments should provide the maximum possible number of simultaneous open receiving channels, to increase the probability of detection and reception of signals transmitted by complicated multichannel systems.

b) Antennas and D/F

Antenna systems for use with detection or reception equipment must perform the following functions:

(1) Deliver the maximum signal strength to the receiving system from the area in which the transmitters of interest may be located.

(2) Help to eliminate interfering signals and noises.

(3) Work with the receiver and indicator in direction and/or position finding.

Each intercept station places its own requirements and its own limitations on the antenna system which may be used. In an aircraft station, for instance, the gain of an antenna is limited by the space which it can occupy and by the uncertainty in the direction from which a signal may be received. In a ground station much more space is available for the erection of high gain antennas and there is usually a better idea of the direction from which signals are desired. For the elimination of interference it is as useful to have a controllable null in the antenna pattern as to have a sharp maximum. As a detailed part of our continuing study the antenna requirements of each type of station will be examined and a layout of suitable antenna systems will be made. Gains will be chosen to meet operational requirements and to permit realization of the antennas within the confines of space usually available.

Direction finding antennas form a special case which has been handled separately in most past development programs. This study will evaluate the feasibility of including direction finding with the normal complement of station antennas. If this does not prove feasible, requirements will be determined for the direction finder antennas needed for the various station types.

c) Recorders

In both the detection and reception phases of electronic reconnaissance, important data can and should be preserved through the use of recorders. Studies have shown that the operator of a detection or reception system has a limited capacity for absorption and retention of information, that he may make gross errors in writing data on logs, and that it is possible to supplement his ability very considerably by use of recording devices. However, experience in a number of fields has shown that it is entirely possible to record so much information in such a complicated manner that analysis is very difficult. It is necessary to examine each type of operation in each of the station types to determine what information should be recorded, the time available for its transmission and analysis, and the necessary storage period of the recorded information. When these factors have been established, it will be possible to devise the best recording and read-out systems for use in the detection, reception, and analysis operations. In any system in which a large quantity of data is preserved for later analysis, it is vital that the recording system and the read-out system be designed to function cooperatively.

Generally speaking, recorders with responses varying from a few cycles per hour or less up to many Mc per second will be needed. Record lengths will vary from seconds to days or months, and the total recorded information will vary over wide limits. In many cases the cyclic or repetitive nature of waveforms used in electronic devices will permit considerable economies in the recording process. A repeated radar pulse, for example, may be compressed in bandwidth from megacycles to kilocycles and recorded on audio equipment. In the case of a random function of any bandwidth, it may often be sufficient to record the power spectrum or the correlation function on a narrow-band device. In a general purpose reception system it will be most helpful to record the waveform information according to the general categories of frequency, modulation, scan pattern, and operating schedule outlined in Section II.

Part of the continuing study will be devoted to determining requirements for recording and playback devices for all of the operations described above, for both attended and unattended equipments.

d) Indicators

An indicator is a device which presents information from a receiver to a human operator. Many of the devices now referred to as analyzers are indicators within the meaning of the term used here. An indicator should be designed to present to the operator that information on which he is required to take action in a readily assimilable form. The presentation of unnecessary data or the presentation of data which require excess mental effort on the part of the operator can do great damage to the operation. Human engineering studies in the Aero-Medical Laboratory at WADC[1] and elsewhere have shown the value of proper indicator design in many fields. Careful attention should be given to this aspect of indicators in electronic reconnaissance.

Generally speaking, all information which the operator needs for control of the equipment in accordance with his instructions should be presented to him, but any excess information which might be confusing should be recorded without presentation. The expected level of skill and training of intercept personnel is an important consideration here. An attempt should be made, of course, to secure the best personnel available for the electronic reconnaissance program, but there is a great deal of competition for good personnel, and many operations will be done by airmen with poor backgrounds in fundamentals and very little practical experience. With the development of a complete program, it will probably be desirable to retain the most capable people in the analysis centers and to rely on less experienced personnel to operate relatively intelligent equipment in the intercept stations. This means that a great deal of consideration must be given to proper indicator design and proper installation of equipment in the stations. Visual indicators must be brought to eye level and made large enough to permit easy reading without fatigue.

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(1) A. L. Hiebert, RAND Electronic Reconnaissance Conference Summary Report, The RAND Corporation, S-15, 1 August 1953 (Secret), Chapter VII.

Indicators which should be viewed simultaneously should be brought within the same visual field. Light intensities should be arranged so that no great changes are experienced in looking from one indicator to another (as, for instance, from a cathode ray tube to a tuning dial). Wherever it is necessary to read and write, the indication which is read should as nearly resemble what is to be written as possible. Controls should be located within easy reach and grouped in normal sequence. The individual control knobs and levers should be shaped so that they can be distinguished by touch, and they should convey some sort of impression of the operation which they carry out whenever possible.

The indicator requirements for each of the operations in each of the station types will be considered and an attempt will be made to devise a consistent approach to the indicator problem throughout the electronic reconnaissance field. The results will, of course, depend on the antenna and receiver designs and on the way in which the load is shared between indication and recording.

B. Analysis Facilities, Locations

The results of a good electronic reconnaissance program are useful at a variety of levels. It will be necessary to distribute analysis facilities organizationally and geographically to meet these needs. At the same time, the facilities cannot be spread too widely, as there is some benefit in centralized facilities which can be better staffed and better equipped than those which are widely separated. Each electronic reconnaissance station must have enough analysis ability to determine whether or not the received signals are of interest and whether or not particular missions assigned by command have been completed.

The next higher degree of analysis should be at a level which commands the electronic reconnaissance effort for a particular geographical area, such as a theater of operations. This level is chosen because it can be served with adequate, rapid communication, and because a mobilization of all of the intercept stations in such an area under a single analysis center and a single operational control will produce electronic reconnaissance data with the highest efficiency for a given total expenditure. This suggests an analysis center in England with possible forward elements in Germany and Africa, and an analysis center in Japan. Additional centers might eventually be needed in the Middle East, Alaska, and possibly the Philippine Islands.

Analysis at the station level should be confined to signal analysis sufficient for the purposes outlined above. At the theater analysis centers, all intelligence information pertinent to the theater should be available for combination with refined signal analysis to permit complete intelligence evaluation of the electronic reconnaissance data for information of the type outlined in Section I. This should include communication intelligence as well as attaché information, reports of agents, defector interrogations, and general background accumulated from open literature. In this connection it may be found more expedient to incorporate electronic reconnaissance information into the regular theater-level intelligence effort than to create all of the new supporting tasks for proper use of electronic reconnaissance data in a separate analysis center. A decision on this point must be based on the relative quantities and values of the different types of intelligence information and on the degree of security which is deemed essential in safeguarding any particular source of information. It would, of course, be preferable to assign these new functions to a properly augmented existing organization, provided this did not result in loss of valuable information through lack of attention or through excessive security. This organizational problem will be dealt with in more detail in further study of the electronic reconnaissance program.

A final level of analysis must, of course, be maintained in the United States. At this level, reports from all of the theaters are combined and correlated, and any additional information which may develop from other sources is fed into the system. Summary reports prepared here should serve in the guidance of technical planning and force programming at the highest levels. At the same time these reports would serve as a basis for planning additional electronic reconnaissance operations. The reports should also be sent down to the theater analysis centers and, where possible, to the field to serve as inspiration and information for personnel at the lower levels.

1. Signal analysis to yield measurable characteristics

At the analysis centers, the amount of information which will be accumulated in a relatively short time will make it necessary to use machine methods of data storage and recovery. A number of methods of storing electronic reconnaissance data have been suggested, and some of them have been worked out in detail.[1] Those which make use of punched business machine cards are probably the most promising at present. In

(1) Beacon Hill Report, Problems of Air Force Intelligence and Reconnaissance, Project Lincoln, Massachusetts Institute of Technology, 15 June 1952, (Secret), and A. L. Hiebert. RAND Electronic Reconnaissance Conference Summary Report, The RAND Corporation, S-15, 1 August 1953 (Secret), Chapter II.

most of the cases so far investigated the business machine card can carry enough information to identify a particular intercept experience or a particular enemy electronic device with complete satisfaction. Where more detailed or unusual information is needed, the punched card can serve as an index card to permit the quick location of the actual data on filed records of other types. The adoption of a uniform U.S. card punching scheme would be of some value as it would permit ready interchange of data and would focus the attention of all analysis centers on the same aspects of the problem. On the other hand, there is little reason for the wide circulation of the vast quantities of data in a punched card file, and standardization might cast the process in a mold which would be too rigid to permit future growth. In any case, it is safe to conclude that signal analysis equipments will be required in the electronic reconnaissance system to take data from the logs and records of the intercept stations and produce punched cards with a minimum of human effort. Particularly in the case of the unattended receivers, which must be carried in missiles and balloons and in routine aircraft flights, it will be desirable to develop analysis machinery which will receive the records from these equipments, encode the desired information, and punch it on the cards.

When the information from intercept operations has been applied to punched cards, it will be possible to perform a great many statistical and comparative operations with automatic machines. All of the individual interceptions of a particular transmitter may be sorted out and correlated, and a single card may be prepared for each transmitter. When this has been done, the distribution of transmitters in frequency and in geography may be worked out by machine, and summarized information will be available for comparison with other data in the intelligence analysis step.

One of the results to be sought in later work will be the general specification of analysis center equipment and personnel requirements to go with the station and station equipment requirements to be determined as outlined above.

2. Intelligence analysis, using all forms of collateral data

The interpretation of the characteristics of received signals in terms of desired intelligence objectives, such as order of battle, is a process which has never been successfully formalized and reduced to the rules of deductive logic. Electronic radiation is one observable aspect of enemy activity. It happens that it is one of the most readily observable aspects at reasonable distances. Electronic data can contribute significantly when combined with other aspects such as enemy communication, known enemy systems of transportation, logistic policy, and personnel and training philosophy.

It is important that the role of electronic devices in enemy operations be understood. To do this most efficiently a background of data must be accumulated, a number of possible enemy system frameworks must be projected, and our observations must be fitted in as they are made, in order to develop the intelligence picture. Characteristics to be expected of a Soviet air interception radar set, for example, can be derived from the requirements which are placed on that set for use in the observed Soviet aircraft and for operations with the observed Soviet GCI radar sets against our known aircraft. Coupled with these system facts is the observed Soviet propensity for producing and using equipments similar to those we find useful. This framework of facts and suppositions has led to a search for air-interception radar signals similar to those radiated by the SCR-720, and the rejection of some slight evidence of use of a much lower frequency set.

It is evident, therefore, that the final intelligence analysis phase of electronic reconnaissance is not one which belongs to electronic reconnaissance alone. Observations from all sources, including communications, photo, attachés, agents, literature, and others, must be brought together on a basis of common availability and subjected to a complete comprehension. There has been no computer built to date that is better than the human brain for this process. It is unimportant from the national interest standpoint whether this over-all function is performed as an adjunct to the electronic reconnaissance program or the photo reconnaissance program or the communication intelligence program, so long as it is done thoroughly, and so long as the security safeguards which must be established around the results are made as reasonable as possible.

C. <u>Command of Electronic Reconnaissance Effort</u>

The United States Department of Defense now has the largest stake in an effective electronic reconnaissance program, although there are other Federal agencies which are also interested in its results. Within the Department of Defense the program must support the individual intelligence needs of the armed services as well as the general over-all intelligence requirement in the determination of national policy. Considerations of uniform availability of information and prevention of duplication in electronic reconnaissance would seem to call for a single command of the electronic reconnaissance program under an agency of the Government or the Department of Defense, but the individual intelligence requirements of the individual armed services and the benefits to be derived from a certain amount of free competition tend to argue for separate command of the programs by the authorities of the three services. This question cannot be settled at this time, but it will be kept in mind in further study of the requirements of the electronic reconnaissance program. Theater command of electronic reconnaissance is a somewhat simpler question.

1. Unified command at the theater level

Where electronic reconnaissance teams may be brought into contact with Soviet forces, there is little doubt that all of the facilities available in a particular geographic area should be brought under a unified command. As has been mentioned, each type of station has unique capabilities depending on its location and its equipment. Coordinated operation of stations of all types will often be required for the most effective deployment of electronic reconnaissance forces for a particular problem. It is therefore apparent in this activity, as in other military operations in the face of an enemy, that it is desirable to bring the operations under control of a single commander who may be free to use the forces as he sees fit, and who is personally responsible for the execution of instructions given him by higher echelons. The electronic reconnaissance commander should work closely with the theater analysis center. He should support the theater commander by furnishing appropriate electronic reconnaissance information, and he should be responsible for meeting requirements placed by headquarters in the United States for electronic reconnaissance within his capabilities. It was shown several times in World War II that cooperative operations among air, sea, and ground stations could bring out information which could not be gathered otherwise. This effort may often be organized on a basis of general agreement at theater level, but it should be insured by the proper establishment of a theater command organization with operational control over the stations.

2. Use of all intelligence in programming effort

Within a theater or a smaller operational sector, it will be possible to gather electronic intelligence much more rapidly if the electronic reconnaissance effort is programmed on the basis of current intelligence information. All sources, including communication intelligence, should be used by the theater electronic reconnaissance commander to formulate operating schedules for all of the electronic reconnaissance stations in his theater. This programming should include watch and operating schedules for the ground stations, position and operating schedules for the mobile stations, flight schedules and operating schedules for the aircraft stations, routing and operating schedules for ships and boats which may be available, instructions for use of receivers in routine aircraft flights, and instructions for any missile or balloon operations which may be undertaken. In addition, instructions should be formulated for the activities of agents when they are available.

When electronic reconnaissance operations are conducted on a basis of uninstructed search, the probability of detecting and receiving significant signals is considerably reduced. The use of all forms of intelligence information in directing search in certain geographic regions at certain times and in certain frequency bands for certain types of signals can very greatly increase the chance of gaining a complete picture. In addition, this type of scheduling permits cooperative scheduling of other intelligence operations which can result in much improved finished intelligence. When there is danger of compromising a high security source of information, cover plans must be worked out to permit the operation to continue under disguise.

3. Dissemination of electronic intelligence

After gathering a complete intelligence picture of enemy activities and intentions, it is highly important to make this information available to people who need it. Sometimes this need conflicts with the need to conceal our sources of information and the need to keep the enemy guessing as to how much is known about his situation. In some cases inadequate security destroys the revealed sources of information and permits the enemy to plan more logically. On the other hand, an overzealous security policy may play into enemy hands by preventing our full use of intelligence information. Lack of knowledge and failure to act on it are operationally equivalent.

a) Classification as low as permitted by security

The need for wide dissemination of electronic intelligence coupled with the need for security suggests a number of different levels of analysis and dissemination of the results of electronic reconnaissance. Preliminary analysis and results applicable to field problems should be available as rapidly as possible at the individual sectors. More sophisticated analysis should go on simultaneously in the theaters, and final analysis at several security levels should be carried out for appropriate distribution in the United States. Care should be taken at every step to produce material at the lowest practical level of classification, and highly secure information should not be mixed with lower classification data except for the preparation of high level reports. Material of great value to commercial research and development companies, for instance, can often be prepared at a Confidential or Secret level and used to good advantage, whereas a Top Secret document could not be so widely distributed.

4. Coordination of electronic reconnaissance with other collection efforts

Electronic reconnaissance continually draws target information from other types of intelligence activity and at the same time can furnish target material to such activities as photographic reconnaissance. As an example, when new radar frequencies were detected by electronic reconnaissance operations in 1944, the station location on the basis of direction finder plots was turned over to the photo reconnaissance wing with a request for low-level oblique coverage. The resulting photographs returned to electronic analysts enabled a much better description of the new radar type and a better analysis of its performance. To make the most of this type of cooperative operation it is necessary for the personnel of other reconnaissance efforts to be aware of the benefits of successful electronic reconnaissance. This can best be demonstrated by furnishing them useful data. The missions of other collectors, such as attachés and agents, may be augmented in the same way.

D. Communications in Electronic Reconnaissance

Widespread, successful electronic reconnaissance operations cannot be carried out without rapid, explicit communications in both directions along the chain of command, and in other directions as well. These communications are, of course, subject to enemy communication intelligence efforts, and provisions must therefore be made for security as well as speed. Further, it is often a matter of considerable interest to transmit waveform information or other data which cannot easily be spelled out in spoken or written text.

1. Communication needs

Communication requirements in the electronic reconnaissance process can be expressed in terms of the lines of communication needed, the estimated flow of traffic over these lines, and the acceptable delay in transmission of messages and data over the lines. In common with all other intelligence collection devices, an electronic reconnaissance station is a point at which an early indication of enemy attack may be received and recognized. A message announcing this information is very important and should not be delayed, even for reasons of security. It is therefore important that each electronic reconnaissance station have a communication facility which is immediately accessible for a small quantity of high precedence traffic. Security on this system is desirable, but is considerably less important than the quick transmission of the message. The line of communication over which this message travels can well be the direct line from the station to the sector or theater analysis center, provided that there is a qualified 24-hour-duty officer at the center to receive this message and notify the proper authorities.

A second rapid line of communication is needed between two or more stations which are cooperating in a single operation. Here, rapid communication is essential for such activities as the coordination of direction-finder activity or concentration of facilities on a newly revealed target, but in this case the need for security is probably as great as the need for rapid communication. The volume of traffic is fairly small, but any appreciable delay is intolerable. This problem will be examined more fully in later reports in which an attempt will be made to compare the cost of operation without adequate communication facilities against the cost of establishing sufficiently complicated facilities for this purpose.

The lines of communication by which operation schedules are transmitted from control points to stations and by which received data are transmitted back to analysis centers can tolerate some delay in the interest of security, but they also pose peculiar problems in some respects because of the requirement for transmitting data in pictorial form. Maps, waveform pictures, circuit diagrams, and other pictorial data should not normally be delayed long enough to go by regular courier service, although a special courier service might be adequate and might be less expensive than the necessary secure electrical communication.

Lines of communication from overseas theaters to the United States are required to pass brief, summary information rapidly and to follow through with detailed information on a slightly delayed basis. Transmission times for secure communications of the order of one hour or two will not be objectionable, provided that high precedence messages concerning an imminent outbreak of war or a similar emergency can be passed more rapidly. Some types of detailed information should be sent by electrical means, and others can be sent by courier without any large penalty provided that local action which might be based on them has already been ordered in the theater or sector control center.

2. Possible solutions

For the communication link between stations involved in a coordinated operation, there is no substitute for a wire or radio circuit with on-line cryptographic facilities. This type of equipment can be provided for use in some stations, but it is expensive to operate, and the situation will require further study before a suitable recommendation can be made. For communication with aircraft and ship stations involved in combined operations, short-term security could be obtained through the use of pro forma procedures, brevity codes, broadcast techniques, and other special signals; but none of these is adequate to produce long term security, and most such procedures attract enemy attention and increase enemy interest in recovering the significance of the traffic. Further study will be necessary to specify the term of the security which is required in these operations and to suggest specific solutions.

Communication links between intercept stations and control stations in which a small delay is tolerable can be served by current cryptographic techniques, and in many cases the necessary messages can be sent over existing communication services. Existing facsimile circuits, because of their lack of security equipment, are not satisfactory for the transmission of pictures, drawings, and diagrams. At present, magnetic tapes, photographic films, and other record material must be delivered to the analysis center by courier service.

Present electrical communication facilities between the United States and overseas theaters are probably adequate for the additional traffic from electronic reconnaissance, and present message handling times of the order of two to six hours are not objectionable for most of the information to be processed in this system. Present courier times of the order of one week seem excessive for much of the information of interest. Means of speeding up this type of communication should be studied.

V. OVERFLIGHT SYSTEMS

Most of the considerations in connection with an electronic reconnaissance system without overflight can be applied to overflight systems. Overflight would not effectively modify much of the activity which has been discussed. It would merely extend the reach of the airborne stations, and it would carry electronic reconnaissance into areas which cannot be observed at all without overflight. The overflight facilities could be fitted into the rest of the system as it is envisioned here. Operations orders and schedules would be based on intelligence data, and cooperation between overflying and non-overflying stations would be arranged. Intelligence missions would be arranged with other collection agencies to observe the total reaction to overflight missions. Overflight by means of manned aircraft, guided missiles, and free balloons will be discussed. Each method has its own peculiar advantages for specific purposes.

A. Manned Aircraft

Under present and foreseeable conditions, a U.S. aircraft over Soviet territory would be subject to attack by the Soviet air defense forces. Protection against such an attack would normally be sought by making the flights under cover of darkness or bad weather and by flying either at an altitude high enough to avoid anti-aircraft fire and make fighter performance poor or low enough to avoid continuous radar surveillance and tracking.

1. High-altitude mission

A high-altitude mission would proceed on the assumption that the aircraft was being continually tracked and plotted by the Soviet air defense forces and that Soviet reaction might vary from amused curiosity to attack by fighters or guided missiles. With available aircraft types, this mission could penetrate from U.S. bases overseas to any point in Russia and return. Coverage could be obtained on all of the interior region which is now effectively concealed. Success in finding unusual types of signals would depend on the use of properly designed detection and reception equipments, on the Soviet reaction, and on the means for data recovery in case the aircraft is shot down or forced down through mechanical failure. Arrangements made in advance for transmission of important data by radio from the aircraft would be subject to the security and communication problems that have been mentioned. The most satisfactory method of data recovery would be to have the aircraft return to base and land with the information. The extent of information which would be obtained might be limited by the choice of darkness and bad weather as a time for operations. Signals connected with research and development activities and those connected with training would be less likely during that time. The depth and effectiveness of the air defense network would probably be revealed by the efficiency in tracking the intruding aircraft. The advantage of this information should be balanced against the risks of loss of the aircraft and crew and the risk of provoking international friction. Resolving power required in the detection and reception equipment for the individual analysis of interfering signals would be quite high in the high-altitude mission. In East Germany, for instance, an aircraft at 60,000 feet would be visible to several hundred radar sets on both sides of the frontier at the same time. With deeper penetration, this density would probably diminish.

The big advantage of overflight with manned aircraft over other techniques is that aircraft for some phases of this operation are available now. Others could be equipped quickly with available types of receivers. These would not be the best stations which could be devised for this type of activity, but they would give us far more information than we are now getting out of the central parts of Asia. More study will be required to determine the exact scale of high-altitude effort which would pay, but an initial assignment of five to ten aircraft to this service would yield much useful reconnaissance data.

2. Low-altitude mission

The low-altitude mission would be much harder for the Soviet air defense forces to track and plot, so that it might gain access to some regions which could not be pentrated at high altitude, and it might reach some areas before adequate warning of its arrival could be broadcast. On the other hand, the reception range of the low-altitude aircraft is quite limited, and navigation is also difficult. Receiving equipment for the low-altitude mission would not need the high resolving power of that used at high altitudes because the signal density would never be so great. Aircraft and equipment suitable for this type of mission are now available. Data recovery by communication poses the same problem as in the case of the high-altitude aircraft, but there is probably a better chance of recovering the aircraft. If the enemy is unable to plot the aircraft accurately, there is some chance that unusual defense force behavior will be observed which will be useful from an intelligence standpoint. Low-altitude flights in which the navigation is good can pinpoint the locations of intercepted devices fairly well, because they do not hear them over long ranges. The low-altitude aircraft suffers in the same way as the high-altitude one in flying at night and in bad weather. Many of the activities of interest are probably off the air. At the same time, much useful information could be collected in this way. The risk would be about the same as that for the high-altitude operation.

B. Guided Missiles

Pilotless aircraft or aerodynamic missiles such as the Snark, Matador, or Navaho, offer a somewhat better chance of overflight without the risk of personnel, but with perhaps an increased risk of a serious incident. Vehicles of this type now available do not in general have sufficient range to fly into Russia to the required distances and return to U.S. bases. On two-way missions they could cover a part of the territory of interest, and on one-way missions they could cover it all. On the two-way missions, it would be possible to recover the missiles or parts thereof for recovery of the data. On one-way missions, the use of high-frequency radio telemetering of the intercept data to ground stations would not be objectionable from a security standpoint, since the launching of the missile on a one-way mission would require a previous decision of the same security question. A suitable data transmission system could be developed from available components. The missile is somewhat behind manned aircraft in time of availability because of the lack of suitable unattended receiving systems. Complete requirements for these systems are awaiting the results of this and other similar studies.

The risk involved in a missile flight of either the one-way or the two-way type is considerable, but conditions under which this risk would be justified may be imagined, and it is quite likely that when they occur, there will not be time left for the development of suitable equipment. It appears, therefore, that, subject to further study, development of unattended equipment for these activities and actual experimental flights in missiles can be justified.

A guided missile offers a facility which cannot be duplicated with manned aircraft for intentional excitation of defense systems so that their reactions may be observed and analyzed.(1) If a reconnaissance missile is actually fired on by electronically controlled devices, the use of suitable receiving and transmission equipment will permit analysis of the devices which would be hard to obtain in any other way.

Since the guided missile would most probably operate at high altitude, the resolving power required in its receiving equipment to separate signals for recording and transmission to base will be comparable to that required of the equipments in the manned aircraft. This is an exceedingly difficult and complex problem, and further studies are needed before definite recommendations can be given. When a missile excites the defense system, there is little chance that it will accumulate research and development information from interior laboratories or other types of radiation which are carefully safeguarded. It is possible that later developments such as the Navaho, and the satellite missile will escape detection or will not excite the defense forces. These missiles may be used to collect information which would not be available to a missile which would excite the defenses.

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(1) A. L. Hiebert, RAND Electronic Reconnaissance Conference Summary Report, The RAND Corporation, S-15, 1 August 1953 (Secret), Chapter XIII.

C. Free Balloons

The type of vehicle which probably offers the smallest risk in overflight operations is the free balloon.(1) Such vehicles have been built to carry substantial weights. Launching and recovery techniques have been worked out. No suitable electronic reconnaissance equipment has yet been designed, and it would probably require a minimum of three years to produce operationally useful models. Weather data show that during some months of the year, launchings from a single area in the North Sea would result in coverage of all of the important regions of the Soviet Union and most of the satellite nations, with a maximum probability in the central part.(2) By making the gondolas as small and light as possible, it would be practical to expect flight at very high altitudes. Detection and plotting of the balloons would be unlikely, and attacks on them would probably be impractical. No particular balloon could be programmed to cover any given area at any time, but a number of balloons launched at intervals of a few hours would probably guarantee coverage of the point in question at least once. The line-of-sight propagation range of nearly 400 miles attainable from 70,000 feet would mean a very high density of signals at the balloon during a large part of the flight. High resolving power would be required for work with individual signals. Good statistical data on distributions of signals in frequency

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(1) W. W. Kellogg, S. M. Greenfield, D. T. Griggs, Preliminary Study, Pioneer Reconnaissance by Balloons, The RAND Corporation, Research Memorandum RM-494, 28 November 1950 (Top Secret).

(2) W. W. Kellogg, S. M. Greenfield, Revised Study of Pioneer Reconnaissance by Balloons, The RAND Corporation, Research Memorandum RM-979, 30 November 1952 (Top Secret).

might be obtained with equipment of lower resolving power. The balloon is probably the only vehicle which will be available in the next few years which might fly over sensitive interior areas during working hours without exciting the defense system. For this reason it might be the only vehicle which would obtain much information on Soviet research and development and on the training of new forces deep inside Soviet territory.

Data recovery from the balloon could be by recovery of the essential parts of the gondola in the Pacific area. Some techniques for this have been established. The organization and the equipment required are not out of proportion with the results expected. An alternate system, in which the balloon would transmit results over long range by radio would require the use of high-frequency radio signals.(1) This system is less secure and is also subject to jamming. The Soviet Union has the best developed jamming organization in the HF region that has ever been exhibited. It might be possible to communicate small amounts of information without interference, but for the relatively large amount desired, recovery of the gondola is a more promising approach.

As in the case of missiles, the risk of overflight operations with balloons should be re-evaluated continually.(2) The fact that such operations may not seem advisable should not be cause for deferring the equipment development, because the political situation can change much more rapidly than the development program.

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(1) L. E. Larmore, Electronic Considerations for Missile Reconnaissance, The RAND Corporation, Research Memorandum RM-1065, 2 April 1953 (Secret).

(2) This is the subject of a current RAND study which has not yet been reported.

VI. ORGANIZATION FOR ELECTRONIC RECONNAISSANCE

It has been determined that the personnel who gather, transmit, and analyze electronic reconnaissance data must be distributed in a number of areas throughout the World, and their work must be integrated closely with the work of personnel who gather, transmit, and analyze all other forms of intelligence data in order to provide the most complete and well-rounded intelligence picture possible. An organization for electronic reconnaissance must provide for:

(1) Operational control of small, widely scattered groups of personnel who operate electronic reconnaissance stations throughout the World.

(2) Rapid transmission and analysis of received data at several different geographic, operational, and security classification levels.

(3) Close cooperation, or integration with other intelligence collection and analysis systems at all applicable levels, both for operational control and for analysis.

(4) Supplying and administration of properly trained personnel for collection and analysis activities.

(5) Logistic support of collection and analysis facilities. This includes both conventional housekeeping support and a highly specialized technical support. The technical support must provide a great degree of flexibility in the numbers and types of equipments supplied to the stations, and it must demonstrate a quick reaction to any new enemy development which calls for new types of intercept devices or new operating techniques.

Such a wealth of intercept data can be observed at any electronic reconnaissance station that it is necessary to plan operations directed at the specific items of major interest. Particularly where two or more stations in the same sector or same theater can be brought to bear on the same intercept problem, it is important to bring those stations under common operational control so that their attention can be directed specifically at the desired objectives. This need suggests that although it may be desirable to keep the electronic reconnaissance organizations of the three armed services separate at the United States headquarters level, it is certainly desirable to bring the facilities of all of the services under common operational control at the theater or sector level. The retention of separate organizations in the United States provides elements of competition and flexibility which are desirable, but competition should be replaced by a high degree of cooperation during actual operations against an enemy. The need for common operational control suggests that such control be exercised by electronic reconnaissance specialists on the staffs of theater intelligence officers. All services maintaining forces in the theater could be represented there. This type of organization would provide for integration of the electronic reconnaissance effort with other intelligence efforts and for satisfaction of the requirements of the theater commanders as well as the requirements of their headquarters in the United States. It would also provide effective theater support for the electronic reconnaissance forces, which is always desirable.

Electronic reconnaissance information and the intelligence developed from it are needed at a number of command levels and at different levels of security classification. In general, the most detailed information is needed at the lowest command levels. As this information flows upward from the intercept stations through the analysis centers, it can be summarized and combined with other intelligence data to produce intelligence of progressively greater general interest, and (usually) progressively higher security classification. The organization by which electronic reconnaissance data are transmitted upward through analysis facilities should be laid out accordingly. Since electronic reconnaissance information is a perishable commodity, the organization must be designed for very rapid data transmission and analysis to provide the necessary information at each level on a current basis with the required speed and within the limits of a reasonable expenditure for communications.

As an example, let us consider intercept data with respect to a new type of Soviet radar system. It will be assumed that the data are collected during the course of a day as a result of directed search in a ground station near the border. The original intercept information at the station may be quite detailed. It will contain the time of each interception of the signal, photographs or sketches of the waveform, scanning pattern, and signal strength variations observed, frequency readings, estimates of pulse repetition rate, d/f bearings, and any other data which can be observed. As the program continues, the same sort of data may be produced each day over a period of several weeks.

The original interception of the new type of signal might be the occasion for a high-precedence message to the theater control center, giving the time of intercept, frequency, and other distinguishing characteristics of the signal so that appropriate action might be taken in alerting other stations for the same signal or same type of signal. Later, accumulation of more data might call for a more detailed message summarizing the results of the first few hours of operation. This message could be sent at an operational precedence, as it would be of value in directing further operations at the control center. At the end of the first day the log and all other recordings, films, and other data would be sent by courier to the control center. Thereafter, information concerning the operation of the particular system could be transmitted to the control center in periodic summary messages at a precedence determined by the control center and the daily logs and records could be forwarded by courier. This is current practice in some installations.

Information concerning this development would be of immediate value to the local ground, air, and sea commanders. They would need the general characteristics of the radiation of the set, its estimated purpose and place in enemy order of battle, its specific location, probable physical appearance, and vulnerability to countermeasures so that they could be prepared for operations which might involve this particular piece of equipment. Part of this information could be supplied on the basis of electronic reconnaissance data alone. This could be released to field units at a relatively low security classification. Part of it would require the corroboration and expanded detail which could come only from combination with other intelligence data and would have to be classified and released accordingly.

In the United States, the information given above would be of immediate value to the headquarters of the operational commands. They should receive the material at low security classification as rapidly as possible. Where the highly classified information would serve to modify the results appreciably, they should receive it also. The information useful in research, development, and planning would not involve the complete detail required by the operational commands. The need for speed in transmission of the bare essentials to research and development planners would be just as great, because research and development decisions with a vast influence on the future are being made every day, and any new piece of intelligence like the one mentioned may modify such decisions considerably. Research, development, and planning personnel would need to know the frequency band occupied by this type of set, the average and extreme values of characteristics such as waveform, output power, scanning pattern, physical size and weight, the approximate number of sets of this type in use by the enemy, and the function of the set in enemy systems. Exact order-of-battle information and exact locations of the sets would not be needed for most purposes. Within the research and development structure, the summarized information should be prepared at a number of classification levels, for use by contractors, project officers, and personnel responsible for plans and budgets.

Thus a flexible organization is required, to operate at several levels with facilities for a relatively small volume of rapid communication and an outlook for possible uses of intelligence information as well as for collection and analysis.

It has been a recurrent theme in this memorandum that electronic reconnaissance supplies one type of intelligence data which must be combined suitably with other types for the best results. This means that electronic reconnaissance operations must be directed on the basis of or in support of other intelligence collection operations and that analysis of electronic reconnaissance data must be carried out by personnel who have complete access to other forms of intelligence on a current basis.

These requirements suggest that electronic reconnaissance collection and analysis be incorporated as specific functions in existing intelligence organizations. Integration at the theater level is essential, because the time lags involved in coordination at the higher levels are so great that much of the benefit is lost. For example, there is little value in learning that an opportunity existed to collect an item of intelligence interest after the opportunity has passed.

This means, of course, that in some cases electronic reconnaissance missions will be directed in support of requirements established by other intelligence interests. This loss of sovereignity, however, should be tolerated in view of the improved results obtained by the whole program.

Where originality in equipments, methods, and lines of attack on particular problems are involved, there is some advantage in competitive work among a number of organizations. This advantage can best be realized, of course, with free interchange of information. This consideration weighs quite heavily against the creation of a single, United States authority to control electronic reconnaissance at the highest level. It is apparently incumbent on those who wish to maintain the present, separate control to show by their performance that they can indeed obtain the advantages which are inherent in the system, without allowing any of the possible disadvantages, such as overzealous competition, to damage the over-all effort.

There are a number of personnel problems in connection with electronic reconnaissance. Some of them are listed below:

(1) Most of the operating locations and theater analysis centers are outside of the United States, so that service in the electronic reconnaissance organization is almost a guarantee of overseas assignment.

(2) Enlisted military personnel, who must do most of the operating, are in service for such a short length of time that they have only a limited opportunity to become experienced.

(3) Current military policy of continual reassignment of officer personnel interferes with the development of real competence, except in a few rare cases.

(4) As in other branches of intelligence, the rewards for good performance in this field are largely confined to classified feelings of personal satisfaction with a job well done. This is insufficient motivation for a great many people.

Policies which may correct some of these difficulties have been advocated in a number of places, but there are many obstacles to be overcome in the proposed solutions.(1) Some gains may be realized by equipment development programs, and improved training plans and mission assignments. For instance, enlisted personnel, after a much abbreviated training in electronics, could be sent directly to actual intercept stations for on-the-job training. They do not need to know the principles of electron optics in order to operate an intercept receiver. They need only to know what knob to turn to carry out an assigned mission and what results to report. Improved equipment design can aid in this respect.

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(1) <u>Beacon Hill Report, Problems of Air Force Intelligence and Reconnaissance</u>, Project Lincoln, Massachusetts Institute of Technology, 15 June 1952, (Secret).

The internal complexity permissible in a piece of equipment is determined by the ability of maintenance personnel; in somewhat the same way the permissible external complexity is determined by the ability of the operators. If a small number of maintenance personnel can be very well trained, they can service internally complex, conservatively designed equipment for a relatively large number of poorly trained operators. Furthermore, in air operations, the operators are expended at a considerably higher rate than the maintenance personnel, so the equipment should be made as simple externally as possible, and maintenance capability should be extended to cover the resulting internal complexity. A balance in this sort of thinking is suggested in a recent article on military electronic equipment.(1)

One of the major features of electronic reconnaissance is that the equipment development field is growing rapidly. Unpredictable, and sometimes radical, changes in direction may be expected. Many of these find us improperly equipped or organized to respond promptly. For example, the recent Soviet development of Loran-type signals on 150 kc found the United States without an adequate search receiver in this band. We would be similarly embarrassed by the appearance of multichannel guidance and control signals, radar in bands above 11,000 Mc, and a number of other highly probable enemy developments.

Organizationally, such a situation requires a flexibility which is seldom contemplated in the planning of military units. The force required for electronic reconnaissance is small by military standards, and the

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(1) R. J. Nordlund, Is Complexity of Military Electronics Necessary?, Proc. I.R.E., Vol. 41, pp 965-967, August 1953.

equipments which are used are usually purchased in small quantities, compared with other types of military equipment. Yet electronic reconnaissance is often burdened with the same type of overhead structure on supply and procurement which is arranged for the large scale operations of such fields as military communication. Time for establishing requirements is very long. Procurement is slow. Reaction to a new enemy development is restricted to illegal modifications of station equipment, improper assembly of new equipment by personnel with inadequate facilities, and very limited procurement of commercial equipment types which may or may not be suitable. Perhaps more than other intelligence operations, electronic reconnaissance needs a built-in reaction capability, supplemented by a streamlined purchasing procedure for the procurement of small quantities of badly needed hardware at a speed commensurate with the need. This requirement can probably best be met by the creation of a field laboratory and model shop organization at theater level, operating under the theater control center and supported by a purchasing technique which is realistically designed to carry out a small amount of business on a rapid basis. Many of the equipments used in electronic reconnaissance are required in such small numbers that they need not be accepted and approved as military standard, provided that the organization is designed to maintain them and able to purchase the necessary spare parts with minimum delay.

VII. PROBLEMS FOR FURTHER INVESTIGATION

The following problems are contemplated as part of the continuing study of electronic reconnaissance:

A. Determine the number of stations of each type required for adequate electronic reconnaissance of the Soviet Union and the satellite nations under pre-war conditions. Show how these stations should be integrated into nets and coordinated with analysis centers. Show how overflight facilities may be incorporated and used (1) in non-overflight operations, (2) in overflight operations. Determine the number of receiving channels required in each station in each frequency band to assure a reasonably complete coverage of the available information.

B. Study the operating conditions of detection and reception equipments in all frequency ranges to specify the requirements which these equipments must meet.

1. Investigate frequency range, channel widths, number of channels, scan rates, recording characteristics, and other features of detection receivers for use in all types of stations. Among the problems which will be considered here will be the detection of signals which occur for very short times, and those which are shifted rapidly in frequency or other operating parameters, such as pulse-to-pulse frequency dispersal radar equipment. Long-range detection of electromagnetic radiations from fission and fusion blasts will also be considered. Results of the signal density study now under way in support of the active-war electronic reconnaissance study will be used here to help in defining the detection requirements.

2. Determine frequency ranges, channel widths, number of channels, tuning characteristics, correlation facilities, and other features which may be required of receivers for reception use in all types of stations.

C. Determine the requirements of each type of intercept station for antennas and lay out a minimum number of antenna types which might meet these requirements. Examine the feasibility of including d/f capability in the design of regular antenna and receiving equipment used in detection and reception. If this is not feasible, work out requirements for direction finders needed for detection and reception operations in all types of stations.

D. Determine the requirements in detection and reception processes for recording equipment and lay out general specifications which this equipment must meet. Determine which equipments are most important from a standpoint of the over-all program.

E. Determine the requirements for indicators to be used in electronic reconnaissance work in manned types of stations. Show how the indicator requirements are related to receiver design choices, recorder choices, and requirements of human engineering.

F. Determine the organization required for proper exploitation of the opportunities offered by electronic reconnaissance. Show whether the organizational needs can be met by modification and enlargement of existing intelligence groups, or whether a new special force is justified. Show in detail how existing organization or the special force could be integrated with existing cold war organizations. By tie-in of this study with an active war study, show how the preferred organization would serve in the prosecution of an active war. Determine whether complete unification is desirable or not.

G. Study the function of the analysis centers proposed in the first problem to determine what equipment and internal organizations they require and to propose methods for their operation.

H. Determine the communication requirements of the proposed electronic reconnaissance networks and estimate the costs of operation of the necessary circuits as compared with the additional costs of reconnaissance carried on without electrical communication for part or all of the activities. Show what facilities would be required for transmission of the items of special interest in electronic reconnaissance such as waveforms. Determine the period of security required in ground-to-air communication for electronic reconnaissance purposes, and suggest security measures which can yield this degree of security while permitting the operations to continue.

I. Determine the force of aircraft, missiles, and balloons required for overflight operations in connection with properly organized non-overflight activity. Show what initial planning of routes and initial listening schedules should be, and how the overflight organization would tie in with the existing non-overflight organization. Determine the best types of vehicles for each overflight application and the requirements for detection, reception, and recording equipment and for data recovery equipment.

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