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PROJECT AGREEMENT

I have been briefed concerning Project __________ and I certify that I fully understand the import of this briefing. I further certify that I am now knowledgeable in a highly classified area of the utmost importance to the security of the United States.

I understand that access to information concerning any aspect of this program is limited to a strict "need to know" basis and that approval for access thereto can only be given by responsible officials of the Advanced Research Projects Agency, the Office of the Special Assistant to the Secretary of Defense (Special Operations), and the Office of Naval Intelligence.

In view of the above, I do hereby agree and declare on my honor that I will not discuss with or disclose to any person, regardless of his official capacity, position or status, any information relating directly or indirectly to Project __________, which comes to my attention, unless that person is authorized to receive, discuss, and/or handle same. I fully realize that the responsibility for determining that such authorization is valid and current rests solely with me.

~~I further understand and agree that this agreement~~ is of a continuing nature and is binding upon me even in the event of a change in my status, wherein I would no longer have a "need to know".

Fully realizing the import of all of the above, I hereby accept the responsibility to handle information concerning this project in accord with all security rules established.

Witness	Signature
Date	Organization

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INTRODUCTION

The Intelligence Problem

A long-standing requirement exists to collect electronic intelligence from the interior and infrequently covered maritime regions of Soviet Russia. The experiment being readied under the cover of Project GRAB, will be able to intercept and immediately retransmit data on S-band radar signals for a forty-minute period following interrogation. The radar data being transmitted by the satellite would be collected by the existing U. S. ELINT stations and processed in the usual ELINT channels. By interrogating the satellite only on a planned and programmed selection of passes, pertinent data may be obtained which will disclose the geographical disposition of the Soviet radars in this very important frequency band from 2.6 to 3.25 kMc.

OPERATION OF THE SATELLITE

The orbit for this satellite is to have approximately a 70° inclination and an altitude of 500 nautical miles plus or minus 80 miles. The orbit ephemeris will be established by tracking a small 60 milliwatt transmitter utilized for the cover experiment (Project GRAB) by existing Minitrack stations.

The satellite will carry two transmission systems, one is the tracking transmitter which will operate continuously on 108 Mc, the signal being modulated by sensors which monitor the internal package conditions as well as the GRAB data. The other transmitter system carried in the satellite will be that of the "ELINT Data Link", which will operate about 40 minutes, following interrogation, on a frequency near 150 Mc, with a peak power in the vicinity of 500 milliwatts. This transmitter will be modulated by the signals intercepted on a simple S-band omni-directional crystal-video receiving system carried by the satellite. The power for the satellite will be derived from a battery pack which is recharged by six solar cells mounted on the outer surface of the satellite shell. The approximate total satellite weight is forty pounds and the predicted life is in excess of one year.

GENERAL DESCRIPTION

Figure 1 shows graphically, the instantaneous situation of the three basic functions of the experiment; i.e. (1) Interrogation (2) Intercept of S-band and (3) Data Link Transmission. The path of the satellite is shown by the long ribbon-shaped arrow with the satellite ball over the Baltic Sea.

The pink, ladder-like arrow pointed toward the satellite represents the command signal being transmitted to the command receiver from the interrogation site in [redacted]

The white-colored ladder-like arrow pointing toward the satellite represents a signal from the S-band radar which is situated in the thin pink circular band. This band is the region where the main lobe of any horizon-looking radar would illuminate the satellite, as it comes above the horizon. The width of this band is determined by the vertical extent or height of the radar antenna pattern. This band represents the intercept region of only horizon-looking radars. There will be other radar types which will be scanning in elevation and which will illuminate the satellite in an irregular manner when they are within the circle formed by the pink bands of Figure 1.

The three ladder-like arrows which point away from the satellite are aimed toward the Ground-Based Intercept equipment located at the U. S. ELINT stations indicated geographically. For the predicted satellite altitudes, the ranges of both the S-band intercept and Data Link circuit are limited by the horizon.

The performance considerations for this satellite collection-system are grouped into three basic categories; (1) the S-band Intercept, (2) the interrogation, and (3) the Data Link transmission and reception. Each of these functions have a particular set of performance characteristics which will influence the performance of the operation as a whole.

1. <u>S-band Intercept</u>

The basic philosophy of this collection experiment has been, from the very conception, to keep the design and performance simple and dependable. Consistent with this philosophy, there has been no effort toward providing any data storage in the satellite. The crystal-video receiving system intercepts an S-band signal of sufficient power density (in excess of 2 x 10 watts per square centimeter) to trigger the 150 megacycle transmitter in the satellite on a pulse for pulse basis. The repetition rate of the radar signal is preserved but the time duration of the pulses is increased so that the re-transmitted pulses are all in excess of 150 microseconds in length. This results in an information bandwidth requirement of less than 8 kc on the Data Link receiving system. There is no amplitude information in the signals which are re-transmitted over the Data Link; when the S-band signal triggers the modulator in the satellite, the Data Transmitter is keyed completely on so that each pulse will be at full peak power. This power is sufficient to assure reception on a system which experimentally has tracked the signal from Paddlewheel (whose power is 500 milliwatts) to a distance in excess of 24,000 miles, before being range limited.

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Components used in the S-band intercept system were built by the Farnsworth division of ITT of Fort Worth, Indiana. The Antenna System, Filter-Detector Unit, and the Amplifier and Bias Network are shown in Figure 2 and are described as follows:

A. Antenna System

The antenna system is a combination of six monopoles antennas equally spaced around the surface of a twenty-inch spherical outer surface of the satellite. One of the monopole antennas is shown in Figure 2. The r-f signal of each antenna is fed to a separate filter-detector unit. The combination of the six monopoles provides an omnidirectional reception pattern for any linear polarization. Experimental antenna patterns show the system has omnidirectional coverage within plus or minus one-half decibel.

B. Filter Detector Unit

The filter-detector unit is to provide the maximum system sensitivity in the 2.6 to 3.25 kMc frequency band and the minimum response to other frequencies. The insertion loss of the filter is at least 50 db at frequencies below 2.54 kMc, and at least 50 db above 3.57 kMc.

The filter provides the necessary r-f pre-selection for the system. To obtain a flat passband with the necessary steepness of cutoff, a seven-section filter is used. The network consists of slab-line resonators coupled by the odd and even TEM waves occupying the space between resonators. The filter is of simple mechanical construction in that it consists of seven posts properly located in a piece of rectangular waveguide. In addition to these posts there are three mode-suppression elements to reject spurious responses at X-band.

The crystal mount for the type MA-408 B crystal is an integral part of the filter, since the crystal element resonates as part of the seventh filter section. A forward d-c bias current of 20 microamperes is used to improve the crystal sensitivity and the uniformity of the crystal response across the passband.

The crystal mount was designed with low-mass spring-contacts to allow the crystal cartridge to move slightly to accomodate differences in thermal-expansion coefficients. The contact pressure is more than sufficient to prevent the crystal from vibrating with respect to the holder when subjected to severe environmental conditions.

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C. Amplifier and Bias Network

The amplifying system consists of two assemblies, a four cascaded-transistor feedback-pair amplifier and a crystal bias distribution network. The first transistor pair has a high input impedance and a high output impedance. It is therefore characterized by a voltage input and current output. The second and third pairs have low impedance inputs and high impedance outputs which makes them current gain pairs. The fourth pair has a low impedance input and a low impedance output which makes it an R_m pair to convert the signal to a voltage output.

The voltage gain of the four-pair amplifier is approximately 2000. A resistor in the second pair feedback provides for a gain adjustment from full gain with a 100-ohm resistor and 23 db below full gain with an open circuit. Any value between these limits is obtained with a suitable resistor of greater than 100 ohms.

The bias network provides a means of paralleling the signal outputs of six detector crystals while providing individual d-c bias of approximately 20 μa to each of the crystal detectors. The voltage across the coupling capacitor is limited to approximately 2 volts so that connecting and disconnecting the crystal, with the d-c power "ON" does not have any detrimental effect on either the crystal or the amplifier.

D. Modulator and Data Link Transmitter

The modulator is designed to convert the narrow pulses from the output of the video amplifier to pulses suitable for modulation of the Data Link Transmitter. The input pulses are .3 to 12 microseconds long and they are used to trigger a multivibrator which is adjusted to fire on signals about 3 db above tangent signal level. The output pulses are 150 microseconds long and are fed to the frequency doubler of the transmitter.

The Data Link Transmitter is a transistorized circuit consisting of a 75 Mc crystal controlled oscillator, a frequency doubler, and a power amplifier. The frequency stability of the 150 megacycle transmitter output better than ±2 parts in 10^6 for the conditions expected in orbit. The modulator output amplitude is used to key on the frequency doubler and hold the transmitter power output at the 0.4 watt level for the duration of the pulse. The transmitter will reproduce the input pulses up to a 50 percent duty cycle. Under these conditions, it will reproduce about 6,000 pulses per second.

The transmitter power is fed to a four element turnstile antenna through a broad-band hybrid network which is also coupled to the 108 megacycle transmitter and two command receivers.

E. System Performance

The system when mounted inside the spherical shell of the satellite has trigger threshold sensitivity of at least 2×10^{-9} watts/cm^2 at any frequency in the passband and for any linear polarization without respect to the orientation of the sphere.

2. Interrogation

Interrogation capability is provided in the satellite to limit the power drawn by the Data Link System to those times when it is actually needed. For 40 minute operation on seven orbits per day the duty cycle of 25% permits the use of one third the number of solar cells that would be required for full time operation. An additional interrogation facility is provided to permit short duration test of the package over Hawaii. The interrogation link is at a frequency of about 138 megacycles and the command receiver in the satellite is similar in design to the Vanguard unit. The receiver sensitivity of minus 90 dbm provides about 30 db of excess signal permitting reliable operation under adverse conditions of look angle and antenna pointing. The receiver is a double superhetrodyne with crystal control on both first and second local oscillators providing a stability of ± 2 kc which is twenty percent of the receiver bandwidth. Security from unauthorized turn-on is provided by the narrow band audio amplifier on the receiver output. The received signal must be amplitude modulated greater than 60% to energize the relay on the audio amplifier output. The receiver is provided with two tone amplifiers on the output so that Tone C initiates the 40 minute sequence and Tone D initiates the 40 second sequence.

The 40 minute sequencer consists of a 40 minute timer motor and a latching relay. The Tone C relay signal closes the latching relay which energizes the Data Link System and the 40 minute timer motor. The latching relay stays in the "ON" position until the switch on the timer motor cam furnishes a pulse to the "OFF" coil of the latching relay. For the forty second operation the time is determined by a transistorized clock and count down circuit which operates the "OFF" coil of the latching relay. The "ON" pulse is derived from the receiver Tone D relay.

 Interrogation

The Command or Interrogation transmitter is to be located in [redacted], with the equipment for this station being contained in a small shelter-hut. The location of the transmitter site has been carefully chosen to enable the interrogation of the maximum number of passes over the Soviet Union each day. All of the satellite passes which come within 1750 nautical miles of [redacted] may be successfully interrogated, since the interrogation system is limited in range only by line-of-sight. The passes which are beyond the range of interrogation, will be crossing the Soviet territory at approximately right angles to other passes and are not needed to give complete coverage of the Soviet Union.

[redacted] is a desirable location from the standpoint of compatibility with the transmitter involved with this interrogation effort, since several other transmitters are in operation at this site. [redacted] is, also incidently, in communication with Washington, D.C. continually.

A detailed description of the interrogation instrumentation is to be given in a later portion of this paper, devoted to the shelter huts.

3. Data Link Reception

The instrumentation for the reception of both the tracking and the Data Link signals is very similar involving the use of narrow band, crystal controlled converters preceding standard Navy R-390A/URR receivers (Figure 3). The output of either receiver can be selected for recording on the Data channel of the Magnecord PT-6 magnetic tape recorder. The other recorder channel, referred to as the log channel, is used for verbal annotations from the microphone or for the recording of time signals from the Digital Time Generator. Time, in hours, minutes and seconds, is recorded, in digital code, each second. The drift in this time signal is less than one second per week. To aid in the calibration and monitoring of this time generator, an antenna and switching procedure has been provided which enables the operator to connect the R-390A/URR receiver to a 25-foot whip antenna, for the reception of the local Standard Time Broadcast. With an oscilloscope it is possible to determine the difference between the Standard Time Broadcast and the digital time signal from the Generator. If the error is sufficiently great it may be necessary to recalibrate the digital time generator. The normal routine effort will be to measure the error of the digital time generator and report it, in this way interpolation of the time generator accuracy will be possible, through use of the drift rate.

A Digital Search and Control Unit is to be used by the analysis team, to rapidly locate on the tape recordings, a specific time which is selected by a group of controls on the instrument. If the analysis team is interested in a time when the signal from the satellite is recorded by two or more stations, it is possible, with this Digital Search and Control Unit, to very rapidly examine this specific time on the several tapes.

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4. ESV Shelter-Huts

Earth Satellite Vehicle (ESV) shelter-huts are being configured as two separate types. A third version which is a combination of the two types is also being prepared. These huts are manufactured by the Craig Systems, Inc., of Lawrence, Massachusetts and are sold under the trademark "Helicop-Hut". They are described as "a lightweight shelter designed for world-wide service conditions." It is transportable by helicopter, C-119 or larger aircraft, truck, rail or ship. It is an all-weather shelter constructed of lightweight rigid floor, roof, sidewall and end panels secured by two lifting-band assemblies. The panels are fabricated from panels formed by aluminum inner and outer skins bonded by a prepolymer isocyanate core. This type of construction provides an extremely lightweight shelter with high rigidity and strength. The fire-resistant material used in the panel construction is water proof and non-hygroscopic which prevents moisture condensation in the walls.

Eight of the Model 150 shelter huts and one, a modified Model 141, have been ordered from the manufacturer to be supplied with the following accessories:

1. Work bench across the back wall.
2. Work bench and spare parts cabinet on side wall to left of door.
3. Dual 600 CFM exhaust fans and filtered air inlet.
4. "Swivelier" incandescent lighting.
5. Power service entrance panel and distribution cabinet with circuit breakers.
6. Electric heater with thermostatic control.
7. Lifting and tie-down slings.

To these basic shelter-huts, equipped as noted above, the follwing items are being added at the U. S. Naval Research Laboratory:

1. Sheet-metal supporting-racks for containing the electronic equipment.
2. Electronics necessary for the several tasks of this program.
3. Antenna Mast as well as the antennas.
4. Antenna supporting cross-arms.
5. Roof bearing for the antenna mast.
6. Planetary-gear steering mechanism for the antenna mast.
7. Brake assembly for holding the antenna mast in one azimuth.
8. Remote antenna support and ground screen for the whip antenna.

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At the present time, five of the total order for nine shelter-huts are on hand and the remaining four will be at the Laboratory before 10 January 1960. The electronic equipment is in various stages of preparation, with over 90% on hand but not completely tested nor assembled into groups for each hut.

A. <u>Shelter-Hut for Receiving and Recording the Data Link and Tracking Signals</u>

Seven sites have been selected for receiving and recording the signals from this satellite, and they will each be provided with identical instrumenation, shown in the block diagram form in Figure 3. Two antenna arrays, shown in Figure 3, are attached to the rotating mast shown Figure 5. The antenna array is constructed from two ten-element Yagi antennas, and is located uppermost on the antenna mast. It is tuned to cover the frequency band from 104 to 112 megacycles and is used to intercept the GRAB data signal from the satellite and is used for tracking purposes as well. This antenna system provides a gain of about 14 db, with half-power beamwidths in azimuth and elevation of approximately 30 and 50 degrees, respectifully.

The four, ten-element Yagi antenna array, located on the horizontal supporting cross-arm directly above the shelter-hut, is tuned for the frequency band from 142 to 152 megacycles and is used to receive the signals radiated from the satellite on the Data Link. This antenna system provides a gain of about 16 db with the resultant half power beamwidths in azimuth and elevation of 22 and 50 degrees, respectively. The spacing of the four antennas in this array has been compromised to approach an azimuthal coverage similar to that provided by the array used for the tracking and GRAB intercept system, and at the same time to provide high gain without spurious side lobes in the antenna pattern.

Both of these antenna arrays on the shelter-huts are tilted upward at an angle of approximately 15 degrees in order to obtain better over-head coverage without sacrificing line-of-sight reception capability.

The antenna mast with its planetary-gear steering mechanism is shown in the center of Figure 4 . The mechanical advantage of this steering method is about six, and should greatly reduce the operator fatigue and improve the ability of the operator to track the signal. A brake assembly has been rigged to hold the antenna in any position against the forces of the wind.

The units below the bench on the left side of Figure 4 are the two converters shown in the block diagram of Figure 3 plus two spare units which may be connected into the circuit by the single switch in the upper right hand corner of each of the top two panels. A cooling fan has been installed in each of these areas to assure proper ventilation. The lower unit is the power supply for the Digital Time Generator.

The equipment on the top of the work bench on the left side is the R-390A/URR receiver for the Tracking or GRAB reception. This receiver will normally be used by the operator controlling the antennas. The Time Generator is located above this receiver.

The equipment on the right side of the work bench is, starting at the top, a tape transport mechanism of the Magnecord recorder, an amplifier for the tape recorder and the lower unit is the R-390A/URR receiver which is connected to the converter tuned to the Data Link circuit. The rack containing this equipment is rotatable so that under certain circumstances when a single operator may not be sufficient, the equipment may be rotated around to face a second operator who will be responsible for monitoring both the Data Link receiver and the signal levels on the tape recorder.

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B. Shelter Hut for Interrogation

The electronic instrumentation in the interrogation shelter-hut includes that shown in Figure 3 except that no tape recorder or Digital Time Generator will be used. In addition to the receivers and low-noise preamplifier Converters, two transmitters, complete with the modulators and control circuits have been installed. These transmitters have a power output of about 250 watts. With this power, and the satellite command receiver sensitivity, the transmitting antenna must provide only about six to eight db of gain to assure line-of-sight interrogation ranges. At the present time the same antenna array is being used for transmitting and reception of the Data Link signals.

The control circuits for the transmitter are outside the transmitter enclosure proper so that the transmitter may be kept locked except for routine periodic maintenance and tuning operations. Four modes of modulation are being provided which will enable the satellite to be interrogated in four different ways. The command system utilizes audio tones on an r-f carrier which must remain on for at least a certain minimum length of time before the command receiver responds. One of the special modulations is for activation of the S-band intercept system for a period of about 30 seconds.

This thirty second activation of the S-band intercept system will be used early in the life of the satellite to determine that it is functioning. With considerably more effort and time it will also be possible to determine just how well it is performing against specific radar installations and types of radar. To carry out this phase of the program the large shelter hut shown in Figure 4, has been equipped with the complete instrumentation for both receiving and interrogating the satellite. This shelter-hut is referred to as the "Calibration Hut" and the site for its use is in Hawaii.

5. Performance of the Satellite Collection System

Figure 6 provides a comprehensive picture of the intercept range which this satellite will provide against S-band radar as a function of the radar power and radar antenna gain. It must be understood that Free Space conditions are assumed in this illustration but for the realistic situation when the satellite is 500 nautical miles in altitude, the line-of-sight horizon is approximately 1900 miles, so all ranges in excess of this value are purely hypothetical.

Figure 7 shows in pictorial form how two typical Soviet radar, Gage and Token, illuminate the first 1300 miles of space with a power density sufficient to trigger this satellite system. These patterns

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HANDLE VIA BYEMAN ~~TALENT-KEYHOLE~~ CONTROL SYSTEMS JOINTLY are contours of signal density just sufficient to trigger the satellite system. The tick marks on the 500 mile altitude curve represent one minute of travel of the satellite. It may be seen that it takes the satellite about one minute to travel through each of the two most powerful beams of the Token radar and about two and one-half minutes to traverse through the pattern of the GAGE. It is this time which establishes the width of the pink band discussed in reference to Figure 1.

LAUNCH SITE PREPARATION

The present schedule of the work at the launch site is based on having the flight units of the satellite at the launch site thirty days before launch. NRL will have six men in the field for the pre-launch tests. The broad requirements of NRL have been outlined to APL and a preliminary trip to Cape Canaveral by M. Votaw and [redacted] developed tentative solutions to the problems that were encountered. NRL is expecting to utilize a portion of the airconditioned laboratory space in the Air Force Payload Facility Building (AA) for an electronic tests on the unclassified portions of the satellite. Tentative arrangements were made to share the screen room facility in Hangar F with Cape personnel. Security can be maintained under these circumstances if the NRL test equipment is mounted in a closed cabinet and if the Cape personnel are excluded from the screen room when NRL is conducting tests. Space for a receiver and recorder within the APL area of the building will be provided to facilitate recording of signals during the launch phase.