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Final Report *December 1984*

GEOPHYSICAL EFFECTS STUDY (U)

By: MARSHA ADAMS
TIME RESEARCH INSTITUTE

HAROLD E. PUTHOFF
SRI INTERNATIONAL

Prepared for:

DEPARTMENT OF THE ARMY
USAINSCOM
FORT GEORGE G. MEADE, MARYLAND 20755
Attention: LT. COL. BRIAN BUZBY

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SRI International

Final Report — *December 1984*
Covering the Period 15 November 1983 to 15 December 1984

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ESU 83-147

SRI Project 6600

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This document consists of 58 pages.

941/CL-0027

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Security Classification Guide
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I OBJECTIVE (U)

(S/CL-3/NF) The objective of this effort is to investigate the possible effects of ambient geophysical/extremely low-frequency electromagnetic factors on remote viewing (RV)* performance as a potential aid to increasing the performance levels of Army INSCOM remote viewers.

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*(U) RV (remote viewing) is the acquisition and description, by mental means, of information blocked from ordinary perception by distance or shielding.

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II EXECUTIVE SUMMARY (U)

(S/CL-3/NF) SRI International was tasked to conduct a study for Army INSCOM to investigate a potential correlation between remote viewing (RV) performance and ambient geophysical/extremely-low-frequency electromagnetic (ELF) activity. The possibility of such correlation is indicated, for example, by studies showing psychophysiological effects[1,2]* and behavioral changes[3,4] associated with ELF electromagnetic fields. The geophysical variables of interest include such factors as ELF intensity/fluctuations, ionospheric conditions, geomagnetic indices, sunspot number, and solar-flare characteristics. The questions addressed in this program are

- Do geophysical/performance correlations exist such that measurement of the ambient geophysical variables could be used as an indicator of expected performance?
- If so, can optimum performance windows be identified?

(U) The structure of the program to investigate the above issues consists of

- A literature search
- Real-time ELF measurements
  - -- SRI International (Menlo Park, California location)
  - -- Time Research Institute (Los Altos, California field station).
- Real-time geophysical data acquisition via the National Oceanic and Atmospheric Administration (NOAA) Westar IV satellite downlink.
- Computer correlation studies of RV performance versus variables of interest.

(U) In this report, we present findings from our over-six-year analysis of scored RV sessions--as they relate to geophysical environmental

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*(U) References are listed at the end of this report.

(U)

conditions during the times the sessions were in progress. These correlations have yielded positive results, indicating that geophysical processes may play a role in determining RV performance, and may, with further effort, lead to the forecasting of RV performance.

III INTRODUCTION (U)

A. (U) General

(U) In order to accomplish the goals listed in the Executive Summary, this program was designed to be a joint effort between SRI International and Time Research Institute (TRI) of Los Altos, California, with SRI as the prime contractor. Time Research Institute is a research organization that specializes in temporal analysis of geophysical variables and their potential correlation with phenomena of interest, such as weather patterns, earthquakes, and the like.

(U) Time Research Institute was responsible for establishing the appropriate hardware and software systems for collecting and analyzing data on environmental conditions and their correlation with RV performance. The purpose of the correlation study was to determine whether RV performance is enhanced or degraded by measurable changes occurring in the geophysical (including solar-terrestrial) environments. The specific geophysical data bases examined in this effort are given in Table 1.

(U) Should correlations between geophysical variables and RV performance be rigorously established over time, the application potential of the effort is twofold:

- Time periods in which enhanced RV performance might be expected could be identified, resulting in increased quality and accuracy of information obtained through such channels; similarly, time periods in which degraded RV performance might be expected could be avoided. Thus, optimum performance windows would be identified.
- An increased understanding of the types of environmental changes that correlate with RV performance could provide clues as to the mechanisms involved in RV functioning. Such knowledge would lead to a more focussed research on factors that could enhance RV performance, and would also provide information critical to the development of defensive countermeasures against RV.

Table 1

(U) GEOPHYSICAL DATA BASES

- Solar terrestrial
  - Geomagnetic--ground-measured indices A_p, sum of K_p, C_p, C9
  - Solar flux (MHz): 15,400, 8,800, 4,995, 2,800, 2,695, 1,415, 606, 410, 245
  - Sunspot number
  - Solar flares
- Ionospheric measurements
  - Sudden ionospheric disturbances (SID)
  - Sudden enhancements of signal strength (SES)
- ULF/ELF
  - 19 frequencies (from 1 to 30 Hz)

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B. (U) Report Organization

(U) The remainder of this report is organized to include: Method of Approach (Section IV), Results (V), Evaluation and Recommendations (VI), and Summary (VII). The Method of Approach section contains descriptions of the project tasks, which include Time Research Institute's data acquisition systems, other sources of geophysical data acquisition, lists of geophysical data that have been analyzed, and the analysis technique employed. The Results section contains the findings from the comparisons of both the ELF data sets among themselves, and the comparisons of RV performance data with the ELF and other geophysical data. The Evaluation and Recommendations section summarizes the findings and possible applications of our research, and identifies areas where further investigation is needed. The Summary section summarizes the overall effort and its implications with regard to RV performance enhancement and countermeasures development.

IV METHOD OF APPROACH (U)

A. (U) Literature Search

(U) A literature search into the areas of known effects of static and low-frequency magnetic and electric fields on biological processes was carried out. Much of the literature available in the ELF range dealt with the effects (or lack thereof) of 60-Hz fields. Papers were sought that described both the gross effects of these fields and the mechanisms by which they could affect biological organisms. Some reports describing higher electromagnetic frequencies (e.g., microwave) were also included for their inferential value. (A bibliography appears as an appendix to this report.)

B. (U) Data Acquisition

1. (U) ELF Measurements

a. (U) Introduction

(U) Although the ELF range (3 to 300 Hz) has been studied in some detail, many unknowns remain. Although it is known that extremely-low frequencies generated by geophysical means (e.g., electrical-storm activity) tend to distribute themselves globally, little information is available on the variation of the ELF environment from location to location. Therefore, local variations may exist that are caused by both man-made sources, and by the geological structure of the area. In the San Francisco Bay Area, man-made sources that generate ELF on a local scale include motors, telephone lines, power lines, and electrical subways [Bay Area Rapid Transit (BART)]; it needed to be determined whether the emission from such sources constitutes a significant contribution to the omnipresent global ELF field.

(U) In order to address the above issue, two ELF monitoring stations were set up--one at SRI Menlo Park (the RV laboratory), the other

(U)

at the TRI field station, 17 km distant. It was anticipated that the SRI environment might be an electrically "noisy" one due to the large amount of electrical and electronics activity in the area--a hypothesis that was verified. With the requirement that two ELF monitoring sites be implemented for the program, it was decided that the two systems would be made identical. In this way, differences between the systems would be minimized, thus reducing the opportunity for artifactual differences between the outputs.

b. (U) Los Altos Site (TRI)

(U) Since May 1982, TRI has been operating a prototype ELF monitoring site in Los Altos, where data have been collected twice daily for the purpose of correlating ELF disturbances against various phenomena of interest. In this period, analysis techniques were developed that were directly applicable to the present task.

(U) One of the first tasks was the upgrading of the Los Altos ELF monitoring site to provide coverage during power interrupts. Details of this effort can be found in an interim report prepared by SRI International.[5]

(U) The second task was the development of an upgraded high-data-rate ELF system (in duplicate) to be installed at the TRI and the SRI sites. Figure 1 is a block diagram of the basic upgraded ELF data-rate ELF system (in duplicate) to be installed at the TRI and the SRI sites. Figure 1 is a block diagram of the basic upgraded ELF data-acquisition system. The ELF signal is collected by an antenna, amplified, and then digitized by an analog-to-digital (A/D) converter so that the signal can be input into a computer for the purpose of analysis.

(U) The antenna is a "bioantenna" (a Live Oak tree). This procedure was based on one recommended by the Radioscience Laboratory at Stanford University. The detected signal is the voltage measured across a pair of electrodes implanted vertically approximately six feet apart along the lower tree trunk. A full description of the method is given in Reference 6, a reprint of which is included in the interim report mentioned above.

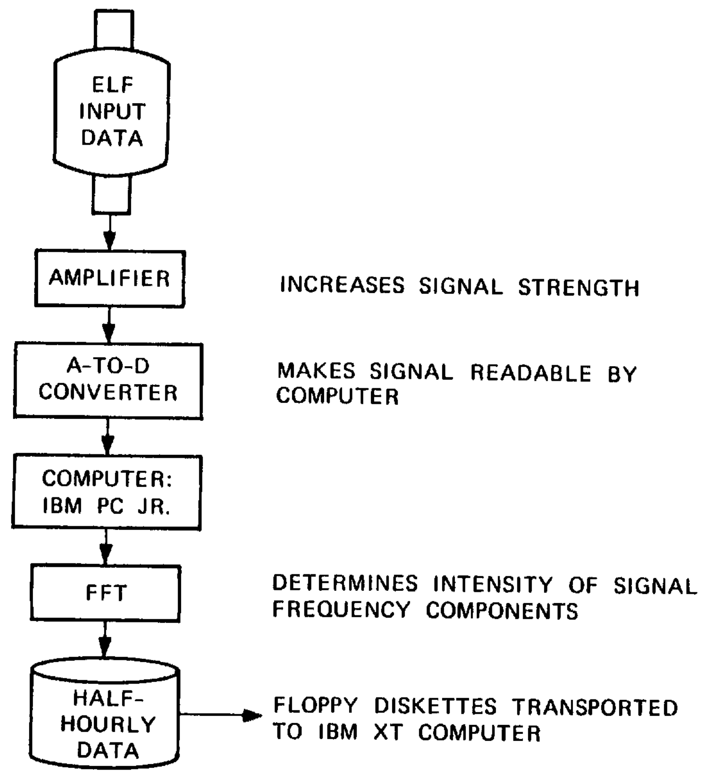

FIGURE 1 (U) ELF DATA-ACQUISITION SYSTEM

(U) The system is configured around an IBM PC jr. microprocessor, which is not only cost-effective, but is compatible with an IBM XT computer where much of the ELF analysis is done. Data transfer and reduction is simple; floppy diskettes are transferable from one computer to the other.

(U) Software has been developed for the IBM PC jr. that reads input data from the A/D converter, performs a fast-Fourier transform (FFT), then outputs seven data files of 19 frequencies each to a floppy diskette. The system operates on universal time (UT), writing records of the means and standard deviations of 19 frequencies in the 1-to-30-Hz range--each half hour, half-UT day, UT day, and half Pacific-time day. This system is far superior in speed and accuracy to the prototype system. In the upgraded system, approximately 318 ELF samples are recorded each half hour. By comparison, the prototype ELF system sampled and processed

(U)

the ELF environment only 20 times in an equivalent period, for a total of about 420 samples in an entire day.

(U) The overall system calibration is as follows. A combined amplification of the signal is 1000X; the signal is amplified 10X in a preamplifier located at the antenna, and 100X in a main amplifier. This presents a maximum 5-V peak-to-peak signal at the A/D converter. The A/D converter operates on an input voltage in the range of 0 to 5.12 V. The output digital value is in the range of 0 to 256. Thus, each count on the digital output represents 20 mV at the input. The FFT algorithm converts the digital sample inputs into coefficients that are proportional to this input. A value of 100 counts at the frequency 1.6 Hz, for example, would be interpreted as indicating that the 1.6-Hz component of the measured signal has a voltage amplitude of 2 V at input to the A/D converter. The input signal having been amplified 1000X, this represents a 2-mV component at the antenna input.

(U) Further details concerning measurement and calibration, including special requirements in amplifier design, isolation circuit diagrams, and so forth, are available in the TRI subcontractor final report to SRI International.[7]

(U) The first new ELF data acquisition began five months after the start of the TRI subcontract with SRI International. TRI was able to initiate the first generation of the upgraded system in only five months in spite of delays in ordering specialized components for the new systems, and delays in the fabrication of the circuitry of the systems themselves. Further delays were experienced in ordering additional specialized components and in fabrication of a needed second-generation preamplifier. Final data acquisition was begun seven months after initiation of the subcontract.

c. (U) <u>SRI Site</u>

(U) The SRI ELF system was implemented after extensive testing of the upgraded system at Los Altos. A second-generation

(U)

preamplifier/amplifier was installed in August 1984. Some differences were immediately seen between the SRI and the TRI Los Altos stations. The dc output of the oak tree that was selected to be the ELF antenna at SRI was twice the level of the oak at Los Altos. It is a larger tree, and its dc potential with equivalent electrode spacing (300 mV) was twice that of the Los Altos site. This caused the amplified dc measurement component to exceed the limits of the A/D converter. Hence, no dc measurements are presently being made at the SRI site.

(U) As expected, the SRI location was found to be in an electrically-noisier area than the Los Altos station. The 60-Hz signal from power lines (and the like) at SRI was strong enough to approach the limits of the A/D converter when the amplification was adequate for ELF signal detection. The system software has been designed to omit data that exceed the A/D converter limits, then record the fact. To date, the system has operated successfully without losing data because limits were exceeded. There was a concern, however, that some large-amplitude ELF anomalies could cause the limits of the amplifier and the A/D converter to be exceeded, in which case data would be lost. A third-generation preamplifier has been designed, which contains the attributes of previous preamplifiers, but, a 60-Hz filter has been specially designed and added to the circuitry. This enables greater amplification of the ELF components of the signal without risk of exceeding the input limits to the A/D converter. The third-generation preamplifier is presently being fabricated and will be used in follow-on work.

2. (U) <u>Satellite Downlink Geophysical Data-Acquisition System</u>

(U) A near-real time satellite downlink system for solar-terrestrial data has recently become available from the National Oceanic and Atmospheric Administration (NOAA). With this unit, it is possible to provide immediate feedback and/or analysis in conjunction with RV sessions. (Normally, there are long delays in procuring solar-terrestrial data; without the downlink, delays of 10 days to 6 months are standard.)

(U)
By means of software developed at TRI,* the downlink system provides for accumulation of a detailed data base directly on computer diskettes.

(U) A satellite controller and a disk antenna for the downlink system were ordered and installed at the Los Altos site early in the project. The downlink system is configured around an IBM PC jr. microprocessor, as shown in Figure 2. Data transfer is accomplished by means

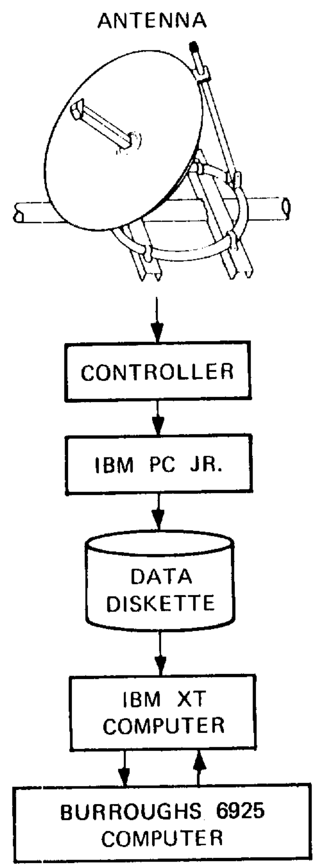

FIGURE 2 (U) REAL-TIME GEOPHYSICAL DATA ACQUISTION VIA WESTAR IV DOWNLINK

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*(U) The format of the NOAA downlink is oriented toward text transmission, and is not well suited to data-base acquisition. Software for recording the data is not provided by NOAA.

(U)

similar to that of the ELF system; that is, by transport of floppy diskettes from the downlink computer to the larger IBM XT analysis computer.

(U) The geophysical data downlink began data acquisition in the third month of the TRI subcontract. The initial data were in the form of a direct recording, which was received from the satellite, on to computer diskettes. The intent was to acquire as long a data base as possible by acquiring raw data at the same time we were developing the software to reduce it. The kernel around which the software was written was a BASIC program from NOAA. The original NOAA software supplied the text data (received from the downlink) in the form of tabular summaries on a monitor. This software did not have the capability to store or record data to any medium. TRI made extensive modifications so that the numerical data could be stored onto computer diskettes for inclusion into a data base. The software is capable of averaging and storing about 20 geophysical variables at multiples of five-min intervals (e.g., 10- or 25-min averages), which were defined at the time the program was run. It writes six separate data files to the diskette.

(U) Initially, the program was set to average and write the data at five-min intervals. After a few months of operation, it was found that the disk drive of the PC jr. tended to fail with such frequent operation. The time-averaging span was changed to half-hourly intervals to save wear on the disk drive. This is the same time increment used for the ELF data. The two systems now operate in synchronization.

3. (U) <u>Data-Acquisition System</u>

(U) The three systems described above (the Los Altos and the SRI ELF stations, and the Geophysical Data downlink), operate in concert, forming the Geophysical Data-Acquisition System. Figure 3 shows the system components and their relationship to one another. Three IBM PC jrs. operate 24 hours a day collecting ELF and downlink solar-terrestrial data. Data from these microcomputers are processed in the IBM XT to form continuous data bases. Copies of these data bases are sent to the

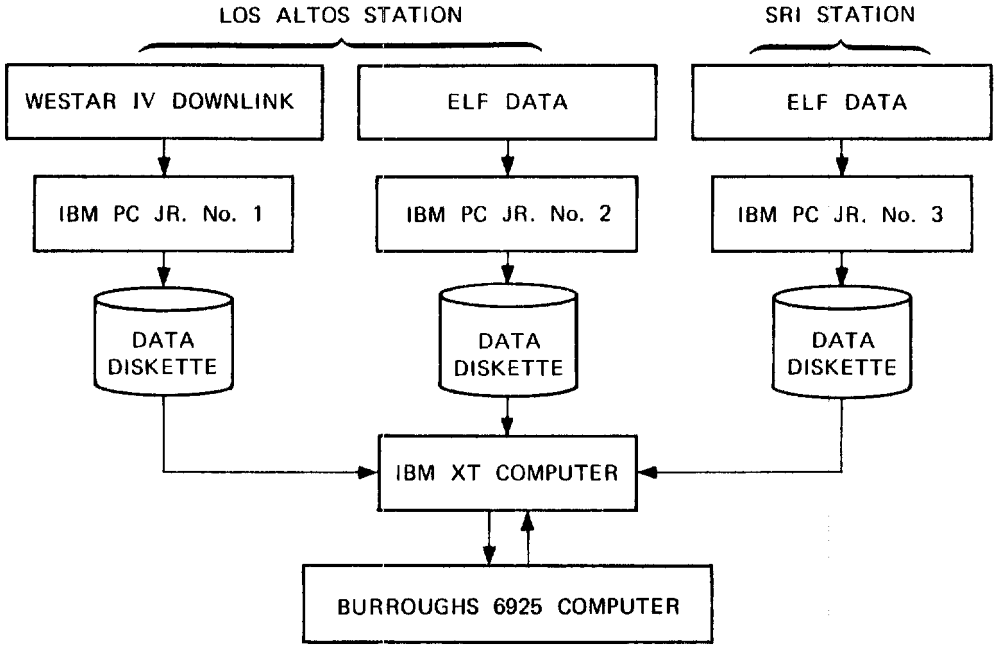

FIGURE 3 (U) REAL-TIME GEOPHYSICAL DATA-ACQUISITION SYSTEM

(U)

Burroughs 6925 computer for use in that analysis requiring high-speed or large memory capacity.

4. (U) Magnetic Data Tapes from NOAA

(U) In addition to the above data collection from ELF and down-link systems, archived solar-geophysical data of interest were selected. Two criteria in this selection were used: first, the theoretical likelihood the data might correlate with RV performance, and second, its availability--based on appearance in the regularly published NOAA bulletin "Solar-Geophysical Data Prompt Reports." The data were ordered from the National Environmental Satellite Data and Information Service at the National Geo-physical Data Center in Boulder, Colorado. Of 12 data sets requested, only 7 could be supplied; several of the data sets, although published in the "Solar-Geophysical Data Prompt Reports," were not available on magnetic tape.

C. (U) Data Analysis

1. (U) Integrated Data-Analysis System

(U) Statistical analyses are performed on the data bases described above, preferably on the IBM XT for cost effectiveness. Figure 4 shows the Geophysical Data/Performance Analysis System. Data from all direct geophysical sources are input into the IBM XT, where they are preprocessed into continuous data bases stored on floppy diskettes. Some data extractions are also performed at this time. The data bases and the extracted data are read into the Burroughs 6925 computer. The data tapes from NOAA are also read directly into the Burroughs computer. The NOAA data files are long (16,000 records per year is common), and require the high speed of the mainframe computer (and our existing software residing there) to correct, process, and extract the geophysical data in usable form. NOAA data were further processed to extract subsets of data of

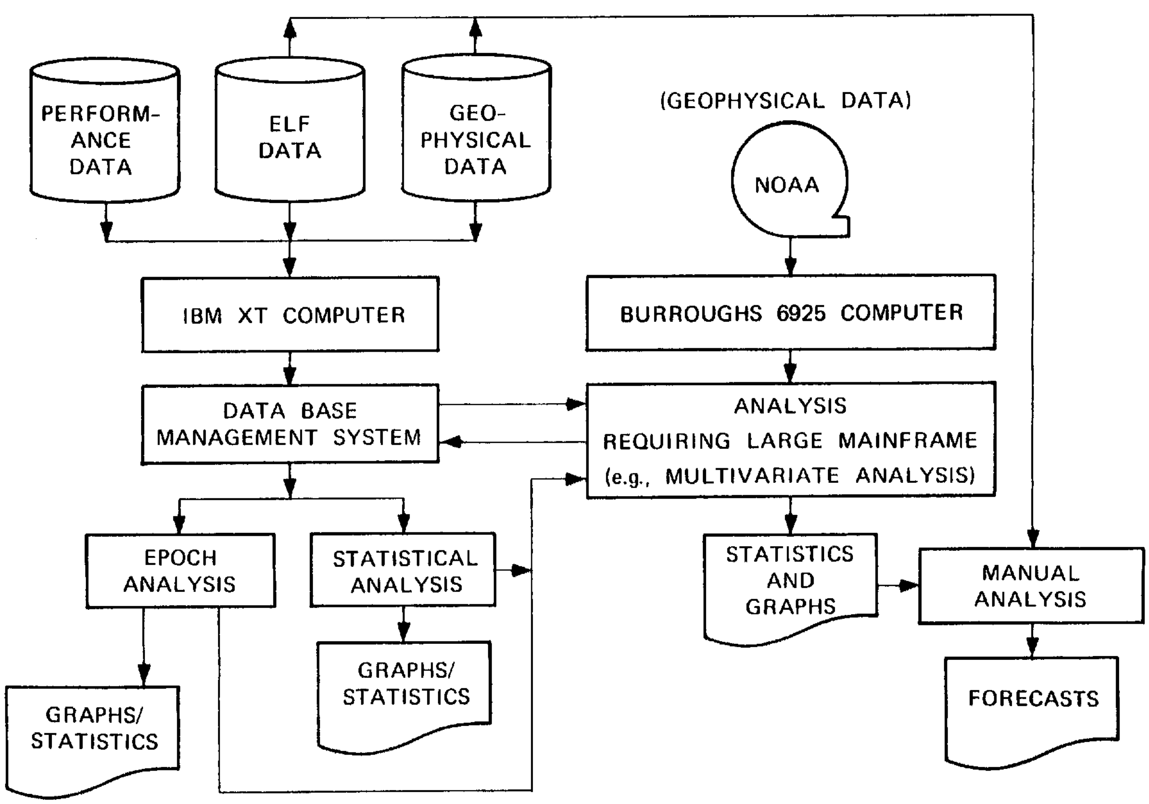

FIGURE 4 (U) GEOPHYSICAL/PERFORMANCE DATA-ANALYSIS SYSTEM

(U)
interest, and to summarize the daily number of occurrences of event-type data, e.g., solar flares (see analysis section below for details). These extracted and summarized data were down-loaded from the Burroughs by modem connection to the IBM XT, where statistical processing was performed.

2. (U) Summary of Data Analyzed

(U) Data were of two types: RV performance scores and geophysical. A detailed description of the analysis techniques appears in Section IV-D. In brief, the RV data were analyzed in five separate groups according to their generation in separate experimental series. These five groups were divided into highest- and lowest-score categories, and epoch analysis was performed on the eight subdivisions against each of the following geophysical variables:

- Geomagnetic indices:
  A_p
  Sum of K_p
  C_p
  C9
- Solar flux at the following frequencies:
  15,400 MHz
  8,800
  4,995
  2,800
  2,695
  1,415
  606
  410
  245
- International Relative Sunspot numbers (Ri) or Zurich Sunspot numbers prior to 1981 (Rz).
- Sudden Ionospheric Disturbances partitioned by:
  - Sudden enhancement or decrease of LF atmospherics at approximately 27 kHz; further partitioned by the intensity of the disturbance.

(U)

- Solar Flares partitioned as follows:
  - All reported flares
    - -- Area of flares
    - -- Brilliance of flares
    - -- 10-deg segments of longitude
  - Flares larger than Sub-Brilliant (SB)
    - -- Area of flares
    - -- Brilliance of flares
    - -- 10-deg segments of longitude
- ELF Data:
  - 19 frequencies from 1 to 30 Hz.

3. (U) Summary of Data Unanalyzed

(U) Certain geophysical data were not analyzed for the following reasons:

- Magnetic Intensities at Satellite Altitudes, Solar Protons--Although the Downlink system is operational, and the software functions well, there is a difficulty that is inherent to the Downlink system. The transmission error rate is exceedingly high; erroneous characters are transmitted frequently in the data, and would require hand editing--a time-consuming and labor-intensive task. Obtaining these data elsewhere was discussed with individuals at the SELDADS system, who were the data source. It was found that summaries of these data do not exist, and that the data are archived in a 3-s interval on magnetic tape. One month's data require an entire tape, at a cost of $120 per tape. We would require about 20 of these tapes for a complete analysis of the RV data. Obtaining data by this means was impractical from the data-processing and tape-expense standpoints.
- Solar Wind--Only fragmentary time spans of these data were available from NOAA. It was explained that the antennas used to receive data from Pioneer XII and its predecessor satellites were redirected to receive signals from the Martian satellites.
- Radio Propagation Quality Indices--These data were not available on magnetic tape from NOAA.
- Stanford Mean Magnetic Field--These data were not available on magnetic tape from NOAA, however, partial analysis was

(U)

performed on data entered by hand at TRI. About half of the data were analyzed before software difficulties prevented completion.

- Auroral Electrojet, Equatorial Dst Values--Auroral electrojet data were not available for the entire time period. Existing data for Dst values were sent with an explanation that the Japanese were now in charge of acquisition of this data set, but had not submitted data since 1981. Dst values ended in December of 1983. Three of the RV data sets could have been analyzed, but format problems prevented it. Most of the NOAA data received on the tapes were in formats suitable for direct publication, with titles, headings, monthly averages, and comments occurring after each month's daily data. In some cases, the day or month was given only in the test heading. This format was unsuitable for computer data analysis, and extensive software had to be written to reorganize the data into a usable format. Although such software was written to extract data from many of the NOAA data sets, this one was bypassed because the data were incomplete.
- Cosmic Ray Indices--These data were sent by NOAA in a format that would have required extensive software development to extract daily values. Although daily values are published in the "Solar-Geophysical Data Prompt Reports," they are evidently not available on magnetic tape.

D. (U) Analysis Techniques and Data Preparation

1. (U) Techniques Used

(U) The analysis was performed on two computers: an IBM XT and a Burroughs 6925. All analyses that did not require the large memory and high speed of a mainframe were performed on the IBM XT, at a substantial cost savings. In particular, an epoch analysis program was translated from ALGOL to C for use on the XT. The C version for the XT has enhanced capabilities not available on the ALGOL version.

(U) Two statistical techniques were used in screening the data (1) epoch analysis, and (2) time-lag linear regression and correlation coefficients. The epoch analysis was performed primarily on the IBM XT machine; the time-lag regressions were done on the Burroughs. While the time-lag regressions allowed definitive statistical statements to be made,

(U)

execution of this program was generally very costly (up to $150 per run), so such regressions were done sparingly.

2. (U) Description of Techniques

a. (U) Epoch Analysis

(U) The primary statistical program used to scan the data for possible relationships is called "epoch analysis." The purpose of epoch analysis is to detect time-lag relationships in noncontinuous, or nonscalar data sets of interest, such as "high-scoring viewing days." It will also show areas of nonexact time-lag relationships, where correlations will not (without further data manipulation such as running averages, and so forth). An overview of time periods that may relate to the data of interest is given in a quick and cost-effective way. Epoch analysis has been used here to indicate which time intervals will be appropriate to run time-lag regressions--a technique that is costly and frequently inaccurate if the timed relationships are approximate rather than exact.

(U) The epoch analysis technique compares events with other timed data sets (such as sunspot number) at intervals preceding and following the event. The program reads two files simultaneously. The first file is an event file, the second a data file. The program first reads an event, then scans the data temporally backward and forward in time around the event. This information is stored, a second event is read, and so forth. When all the events and surrounding data have been read, a printout is created that lists appropriate cross-correlation statistics between the event and data elements.

(U) As an example, the program calculates the average values of a variable, such as sunspot number, for discrete time intervals before or after a set of RV events of interest--say, high-scoring days. For all days, the technique determines the sunspot number one day prior to high-performance RV sessions (the events), the day of, the day after, and so forth. It will then calculate the average value for each day (e.g., -1, 0, +1), then tabulate and graph the results.

b. (U) Time-Lag Regression

(U) This is a standard regression analysis, which offsets the time base of the data in specified intervals. This program may be instructed to perform sets of regressions of many time lags at a time, even with data that are not continuous. Time lags are frequently encountered when analyzing solar-terrestrial data with respect to terrestrial events. For instance, approximately two to four days may elapse before magnetic storms resulting from solar flares are detected on earth. Assuming such mechanisms may also operate with respect to RV data, all geophysical correlations were carried out for a time-lag range of at least plus or minus five days.

3. (U) Description of Analysis Methods

a. (U) RV Data

(U) In order to determine whether RV performance correlates with geophysical activity, it is necessary to have access to RV data bases that have been quantified. Data bases that meet this criterion, both archival and those generated during the subcontract period, were made available to TRI for analysis.

(U) Four sets of RV data were analyzed initially; they constitute the primary data base.* Each data set is referred to by the year in which most of the data were gathered. Table 2 shows the name, number of samples, and begin- and end-date for each data set. The RV data were processed for the epoch analysis by selecting the dates of the highest and lowest scores or ratings for each data set.+

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*(U) A fifth RV data base was examined near the end of the program, generally confirming the conclusions reached on the basis of the primary RV data base.

+(U) Selection was done by finding high and low scores in which the value range contained approximately one-third or less of the total data set. In most data sets, more than one session occurred on a given day--frequently with different individuals. In some cases, two individuals had extremely high or low scores on a given day (there are comments later about individual variability). These data were left intact, e.g., if two individuals both scored high or low on the same day, those data were

Table 2

(U) DESCRIPTION OF RV DATA

Name	Sample Number	Begin Date	End Date	Comments
79	36	05/14/79	08/03/79	6 × 6 orientation
80	97	01/18/80	12/14/81	RVer I.S., Class B
81	48	07/30/81	10/21/81	Targeting
84 (II)	231	01/12/84	08/17/84	RV Training (II)
84 (I)	103	03/19/84	07/10/84	RV Training (I)

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b. (U) Geophysical Data

- (U) ELF Data--ELF data sets were prepared by concatenating the data from several diskettes into a single, long-term file for both the upgraded Los Altos and the SRI data. This was done for daily, half-daily, and half-hourly data.
- (U) NOAA Data--These data required extensive preprocessing and specialized software to be written. For example, two of the data sets, Sudden Ionospheric Disturbances (SID) and Solar Flares, contained multiple reports of the same event observed from different stations. Indices of location and magnitude of the event frequently do not agree from station to station. Software was written to eliminate duplicate reports by extracting the single largest report for each event. Extractions of single events were done when appropriate. Data files were constructed that contained the number or value of the events of interest for each calendar day, from 1 January 1978 until the end of the available data--usually 31 August 1984. The dates were checked for order and continuity. In event-oriented data files such as SID and Flares, events did not occur every day.

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entered twice in the high or low data sets. If one individual scored extremely high, and another extremely low (on the same day), that day was entered in both the high and low data sets. The exception to this was the data set of RVer I.S., Class B sessions. Several sessions were carried out on a single day. To create the corresponding high and low data files, the mean score for each day was determined, and the high and low days were selected using the mean scores.

(U)

Records containing the appropriate null dates were inserted in these data files. Files were also prepared that were subsets of the event-type data files. Solar-flare data were cross-tabulated in 10-deg longitude segments by daily dates. Flares larger than Sub-Brilliant were cross-tabulated on a daily basis by area, brilliance, and longitude measurements. SIDs were extracted by LF Atmospherics and cross-tabulated on a daily basis by the intensity of the disturbance. The same was done for VLF Sudden Enhancements (SES).

V RESULTS (U)

A. (U) Results of Geophysical Analysis

1. (U) Introduction

(U) For many years man has speculated that relationships exist between various biological functions and solar activity or its resulting geophysical activity. Some empirical observations on the quality of RV sessions during periods of known solar activity led to the idea that a screening of solar-geophysical variables for correlations might be fruitful. If, indeed, measurable geophysical disturbances affect RV performance, and these relationships could be defined, the reliability of RV-derived information could be determined by considering the geophysical environment at the times of RV sessions, and possibly enhanced by scheduling.

(U) This screening of geophysical variables in this report appears in the order of gross measurements to refined measurements, which may be closer to the actual mechanisms involved in influencing RV performance. Because of the fact that changes in most measurable geophysical data are initiated by solar activity, geophysical data sets co-vary. Hence, relationships were found in several data sets simultaneously. These correlations are most likely not due to cause and effect relationship between the covarying variables, but rather are the result of one or more of the geophysical processes that are driven by solar activity. Although correlations to noncausative variables may be useful for forecasting purposes, forecasts will be greatly enhanced when the correlations used are closest to the actual geophysical-biological mechanisms involved.

2. (U) Solar Flux

(U) The solar flux is a measurement of the electromagnetic output of the sun at several different frequencies in the megahertz range.

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The measurement values are in units of $10^{-22} W\ m^{-2}\ Hz^{-3}$. These measurements are a gross indicator of the activity on the solar disk. Epoch analysis was performed for the high and the low scoring days of each of three RV data sets. (No solar-flux values were recorded for most of 1979 in the NOAA data, and the 84(I) data were not yet available when this analysis was performed.) The relationships found by epoch analysis in these data were generally unimpressive.

(U) Time lag correlations were run on two individuals from the 1981 experiment. Again, although certain correlations were found among the mass of data (some of them statistically significant), there was great variability between the individuals, and no definable pattern emerged.

3. (U) Sunspot Number

(U) Epoch analysis of RV versus sunspot number was performed. A low peak was found between 29 and 35 days prior to each of the four sets of high scoring sessions,* and a high peak preceded each of these sessions by 25 to 28 days. A low trough occurred 19 to 23 days before low-scoring sessions in each of the four data sets. On the day of the session, the sunspot number was at or above the epoch mean in each of the four low-data sets. Out of this analysis emerged three time intervals that may enable forecasting: 27 to 30 days, 16 to 19 days prior to the sessions, and (for theoretical reasons addressed later) two to four days after the sessions.

(U) To examine the time lags where possible correlations might exist, time lag correlations were performed for each individual in the groups from 1979, 1980, and 1984. Both positive and negative correlations to sunspot number were found. These results also indicated that clustering of correlations occurs near the time intervals both preceding and following session dates found in the epoch analysis. Overall, 779 correlations were performed. Up to 38 correlations at the $p = 0.05$ level would be expected

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*(U) 84(I) data were not processed.

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to occur by chance. Fifty-six correlations were observed, or about 50 percent over what would be expected by chance.

(U) Three time clusters were observed in the significant correlations. In a four-day interval, where 76 correlations are represented, the chance number of significant correlations at the $p = 0.05$ level is estimated to be 3.8. The interval from 27 to 30 days prior to the session (perhaps reflecting the solar-rotation rate) had eight individuals having significant correlations at $p < 0.05$; two other individuals were very close to significance. Another interval from 16 to 19 days prior to the sessions yielded eight significant correlations ranging from $p < 0.047$ to $p < 0.0003$. A third period appeared two to four days after the sessions. This three-day interval yielded five individuals having significant correlations, and four others having near-significant correlations.

(U) It can be surmised that because these correlations exist in patterns, there may be some phenomenon associated with sunspots that could be more closely linked to the actual mechanisms that influences RV performance. A likely candidate is the phenomenon of solar flaring, and its resulting effect on the terrestrial geomagnetic field. In particular, the finding that the strongest correlations to sunspot number consistently occurred two to three days after the sessions, points to flaring. At first one might dismiss observation of RV performance apparently forecasting sunspot number. However, if one considers that large flares from active regions on the sun (sunspots) can frequently be seen before the region rotates onto the solar disk, a hypothesis could be formed that incorporates flaring as a possible mechanism, because indeed, one can predict increases in sunspot numbers by observing flares on the east solar limb.

4. (U) Solar Flares

(U) Solar flares usually occur near sunspot groups called active regions. The sizes of these flares are classified in several ways by the intensity of various characteristics associated with them, i.e., according to their X-ray intensity, optical brilliance, area, and radio-wave

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signatures. There does not seem to be a readily-available comprehensive index that takes all of the their characteristics into account. For this reason, flares were subdivided into several data sets prior to analysis:

- The first set was the total daily number of all recorded flares; these flares were further subdivided into location of origin in 10-deg longitudinal segments from the central meridian of the solar disk.
- The second data set was an extraction of the larger flares from the data. These flares were selected for their classification of both size and brilliance. Those classified as sub-brilliant or larger were used. (The flares were divided by longitude because flaring at certain longitudes on the solar disk is known to produce greater terrestrial effects than at other longitudes. For instance, relativistic energy showers most frequently originate from the northwest quadrant of the sun.)

(U) In exploring the theory that limb flaring (flares on the edge of the solar disk) may play a role in RV performance, special attention was given to this area of the sun. Indeed, as anticipated, significantly higher rates of limb flaring were found on the day of (or just before) four of five of the high-scoring data sets,* and on the day of (or just after) low-scoring data sets in four of five cases.* What this implies is that some confidence can be placed on the validity of relationship between solar flaring and RV performance.

(U) Of key interest is the finding that the flares occurring on the solar limbs (80 to 89 deg) tend to group with respect to high- and low-performance data sets. Large flares occurred on the limbs the day of sessions in three of four of the low-scoring data sets. In the fourth set, a flaring peak occurred three days later. The number of flares was significantly greater on low-scoring session days (more than two standard deviations above the epoch period mean) in each case. The days following low-scoring sessions continued to have high flare rates across the solar disk. (On the other hand, in three of four cases, high-scoring

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*(U) 84(I) data were included.

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data sets were preceded by an increase in limb flaring by one day. These values were near-significant. We shall return to this point below.) In addition to the tendency of flares to cluster on poor performance days, the numbers of flares was more than double the daily expected value for three of the low-scoring RV data sets.

(U) A speculation from the data is that low-viewing scores might be associated with flares (occurring on the east limb) rotating onto the solar disk (because of the numerous flare peaks observed at all locations on the disk following poor RV sessions). By contrast, high scoring might be associated with regions rotating off the west limb of the solar disk because of the fewer flare peaks following good sessions. Indeed, when diagrams of solar-active regions were examined for the first set of 1984 data, nine of ten of the low-scoring days showed active regions near the east limb. On the other hand, eight of ten of the high-scoring days showed active regions near the west limb.

(U) Based on the observation that, statistically, limb flares coincide with and follow degraded RV sessions, but precede enhanced RV performance by one day, a speculation could be made that there may be a close time relationship for enhanced and degraded RV sessions. In hypothesizing which solar-terrestrial changes could cause changes in RV performance, the observed rapidity of change and the reversal of the character of the effect must be taken into consideration. The following scenario is suggested. As a new active flaring region rotates over the solar limb, associated with it is some kind of a fast-acting phenomenon that requires a day or less to produce terrestrial effects. The terrestrial effect must be relatively brief, and of a character that is capable of both degrading and enhancing RV performance. An example of one such phenomenon is the Sudden Ionospheric Disturbances (SID) caused by X-ray and other electromagnetic-radiation bursts associated with the flaring process. SIDs can both enhance and decrease the quality of global electromagnetic signal propagation--possibly at biologically-active frequencies. A specific type of SID, a direct solar-flare effect (SFE), causes geomagnetic effects observed simultaneously with solar flares.

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Another mechanism could be proton storms resulting from high-energy flares. Very-high-energy flares can accelerate particles at near-relativistic speeds; these particles are capable of reaching earth in a matter of a few hours. Magnetic storms may accompany the arrival of this high-speed solar wind. Either of these two mechanisms could explain the immediacy of the observed effect.

(U) With regard to the tendency for RV performance to first be degraded then enhanced, one might speculate on possible mechanisms for bipolar behavior based on, for instance, known patterns of magnetic storms. If RV performance were correlated with the intensity of the earth's magnetic field, then the following known variations that occur as part of the magnetic storm process might be capable of introducing the observed patterns into RV performance. Typically, the storms that begin suddenly start with.

(1) A sudden increase in the horizontal (H) component of the earth's magnetic field; they then

(2) Have an initial phase lasting a few minutes to a few hours, during which H decays to prestorm values;

(3) This is followed by a main phase lasting about one to three days in which H is below the prestorm value, first decreasing, then increasing more slowly toward the prestorm value--many large random variations occur during this phase;

(4) There is a postperturbation period after the end of the main phase, in which the value of H continues to rise toward, or perhaps above the prestorm value;

(5) The last phase is an increase in the daily variation of H, which increases with increasing latitude. If RV performance correlated with magnetic intensity, patterns would certainly be found during the magnetic storm.

5. (U) <u>Magnetic Indices</u>

(U) Four magnetic indices, the sum of K_p, A_p, C_p, and C9 were screened with respect to RV performance. K_p is a quasi-logarithmic index of geomagnetic stations between latitudes 47 and 63 deg. K_p is specifically designed to measure solar particle radiation by its magnetic

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effects. A_p is a daily index of magnetic activity on a linear scale rather than on the quasi-logarithmic scale of the K indices. It is the average of the eight values of an intermediate three-hourly index A_p, defined as approximately one-half the average gamma range of the most disturbed of the three force components D, H, and Z, in the three-hour interval at standard stations. The C_p index is derived from the K_p indices by converting the daily sum of A_p into the range of 0 to 2.5. The C9 index is a geomagnetic character figure obtained from the C_p index by reducing the C_p values to integers between 0 and 9 according to certain keys. All these values are closely related, and, not surprisingly, gave similar results in the epoch analysis comparing them to RV performance.

(U) The four sets of RV scores yielded remarkably similar patterns with respect to K_p, and corroborated the solar flare findings extremely well. In each case, values were above the epoch mean the day preceding low RV scores, decreasing in all cases on the day of the sessions. In three sets, the decrease fell below the mean; in the fourth case, the value dropped considerably and was only slightly above the mean. The next day's values of this data set continued to decrease and were below the mean. Conversely, in the sets of high-scoring days, all four sets showed K_p indices that were below the epoch mean the day before the sessions and increased to values above the mean in three of the four data sets. The fact that these patterns were replicated in the majority of the test data sets, and that high- and low-scoring data sets yielded inverse patterns with respect to K_p is a strong indication of a valid phenomenon existing. Therefore, what we found were strong similar patterns in the geomagnetic data with respect to RV performance. The geomagnetic field was quiet just before all high-scoring sessions, then became more active the day of the session. Magnetic activity was higher than normal one to five days prior to low-scoring sessions. This would suggest that RV sessions be performed when the activity of the geomagnetic field is on the increase after a quiet period.

(U) Comparing these consistent results with the results of the solar flare analysis shows that there is evidence for the standard

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one-to-four day time lag between flare and subsequent magnetic activity. The magnetic indices are increasing on Day 0 (the day of the sessions), they continue to increase the day after the statistical flaring, then decrease in two to five days. Results using A_p, C_p, and C9 indices were similar; the best definition appeared to be seen with the K_p index followed by A_p, C_p, and C9. For forecasting purposes this is fortunate. The K_p (and A_p) are readily available by means of the satellite downlink, C_p and C9 are not.

6. (U) SIDs

(U) Sudden ionospheric disturbances result mostly from flaring of the sun, although not all flares cause SIDs, and SIDs can also result from unknown causes. SIDs are basically a disturbance of the upper ionized layer of the atmosphere called the ionosphere, specifically in the D region. During SIDs, radio waves at medium frequencies are strongly absorbed and long-distance communications fade out. Cosmic radio noise at 15 to 25 MHz is absorbed and also fades. At very low frequencies (15 to 40 kHz), however, the D region becomes a reflector, and atmospheric radio noise is enhanced. A SID is marked also by a sharp brief geomagnetic disturbance that behaves differently from a magnetic storm. SIDs are classified according to their intensity and types of terrestrial effects.

(U) Although many classifications exist, the two most common (known to enhance low-frequency transmission) were extracted from the data base; i.e., those classified as enhancing atmospherics, as measured at 27 kHz (SEA), and those which enhance signal strength in VLF transmissions (SES). (The effects of SIDs on ELF is not monitored and is unknown.)

(U) The results of the epoch analysis on SIDs correspond well to the results of the solar-flare and the magnetic analyses. While the SEAs showed some corroborative patterns, the results of the analysis on the SESs were remarkable. The results of the SIDs analysis are similar to the analysis of the occurrence of peaks of solar flares. That is, there

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are fewer peaks occurring around the times of high-scoring sessions than low-scoring sessions. There are more strong SIDs peaks on the day of, and after low-scoring sessions. A SIDs peak of importance (magnitude) "1" or greater occurs on the day of the low-scoring sessions in four of the data sets. Peaks of SIDs also occurred on the day of the session in four of five years of the high-scoring data sets, and on the day prior to the sessions in the other data set (1979). Therefore, nine of ten of the data sets had an SES-type SID occurring on the day of the session. The remaining data set had a peak in SIDs occurring in close proximity to the session--on the day before.

(U) It appears that SES-type SIDs are a good candidate for the previously hypothesized fast-acting result of solar activity that could influence RV performance. A peak of SES-type SIDs have occurred on or near every case of RV extreme-score sets. We speculate that there is some quality of the SID that is associated with the observed bipolar effect, resulting in both high- and low-quality RV performance. A quality of SIDs that might produce bipolar effects could be selective electromagnetic propagation. If SIDs selectively propagate certain VLF or ELF frequencies, it would not be surprising to find differing biological responses to frequency and intensity changes--assuming biological responses to ELF exist. Laboratory studies of ELF magnetic and electric fields (see references to work of Adey and others in Bibliography) suggest such ELF-biological relationships. An additional possibility to account for bipolar behavior might be the frequency characteristics of the atypical magnetic activity that accompanies SIDs. This can be accomplished by direct measurement of geomagnetic ELF, described in the section below.

B. (U) Results Pertaining to ELF

1. (U) Introduction

(U) The ELF environment, both naturally-occurring and man-made, is one good candidate for the mechanism by which many types of biological responses are produced. Laboratory studies have shown both sensitivity

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and selectivity in biological responses to specific frequency and intensity windows. The intensities found to be biologically active are very weak, and fall in the same ranges as naturally-occurring magnetic and electrical fields. For our initial effort, we selected the frequency window of 0 to 30 Hz for two reasons, one pedagogical and one practical:

- It is the frequency range of the known electrical activity of a human being--particularly brainwave frequencies.
- It is necessary to filter out 60-Hz power-line noise, and simple electronic 60-Hz filters begin cutoff at about 30 Hz.

With regard to the latter point, although sharper filters are available, they are elaborate and expensive. For this exploratory investigation, the most cost- and time-effective route was chosen.

2. (U) Intercomparison of ELF Systems

(U) A number of comparisons between the various components of the ELF monitoring system have been made. The systems compared include the prototype system at TRI involving the use of the oak-tree bioantenna, the upgraded system at TRI involving use of both the oak tree and a coil antenna on loan from the Radioscience Laboratory at Stanford University, and a duplicate upgraded system at SRI involving use of an oak tree.

(U) Correlations were performed between ELF data sets generated on each of the systems. Although variations existed, by and large the correlations indicated statistically-significant tracking between the various systems, including the comparison of key concern--tracking between the duplicate upgraded systems at TRI and SRI, 17 km distant. In fact, tracking between the separated TRI and SRI systems, both utilizing oak-tree antenna, was somewhat better than tracking between the oak-tree and coil antennas, both at the TRI site.

3. (U) ELF/RV Comparison

(U) Epoch analyses were carried out to determine correlations between ELF and RV data sets for those periods of overlap in operation.

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With regard to the prototype ELF system, whose data base began in May of 1982, the 1984 data base (before the fifth data base was added) was the only one available for comparison. Examination of the correlation graphs in the epoch analysis revealed some tendency (over time spans on the order of days) to inverse relationship between ELF and RV; that is, a tendency for ELF to be low in the vicinity of high-scoring days, and vice versa. There were not sufficient data of sufficient definition, however, to permit statistically-significant conclusions to be drawn.

(U) Beginning in June 1984, the upgraded ELF system became operational. RV data collected from then through August provided an opportunity to perform preliminary epoch analyses for a small sample of RV data (four cases each for high and low scores) on a half-hourly basis. (This is to be compared with the half-daily basis of the prototype ELF system.) An apparently consistent pattern that emerged in these analyses was a change from low-scoring sessions to high-scoring sessions during a rapid rise in ELF values; the separation between the two was on the order of an hour and a half (range one-half to two hours and a half). This appears as another example of bipolar effect mentioned earlier with respect to geomagnetic activity, where rapid crossing from below- to above-average activity on the days of extreme-scoring sessions was also observed. The time/funding scope of this level-of-effort project did not permit further exploration of this emerging relationship between ELF (and other geophysical activity) and potential rate-of-change effects on RV performance. This area appears to show exceptional promise, however, and will be pursued in a follow-on program.

(U) The emergence of a possible relationship between a period of time when the data are changing at a rapid rate (rather than peaking) is not surprising in light of known mechanism of biological processes. Several biological processes function by means of rates-of-change of stimuli in preference to any particular absolute values of those stimuli--if the intensity of the stimuli fall within certain ranges.

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VI EVALUATION AND RECOMMENDATIONS (U)

(U) This study has a threefold purpose:

- To determine whether geophysical factors correlate with RV performance.
- If correlations are found, to identify which geophysical factors correlate with RV performance with enough lead time that RV performance could be forecast in advance.
- To optimize the potential for forecasting by seeking those geophysical factors that constitute the best candidates for the mechanism by which observed effects on RV performance are produced.

(U) Some degree of success has been achieved in all three categories. Significant correlations of some significance have been found to exist between RV performance and solar flux values, sunspot number, and magnetic indices M_p, A_p, C_p, and C9. Epoch analysis has shown that flares and resulting SIDs have a strong tendency to cluster in certain time intervals with respect to extreme-scoring RV sessions. Flares, especially those on the solar limbs, tend to occur on the day of low-performance RV sessions, and on the day preceding high-scoring sessions.

(U) SIDs resulting from flares may produce a bipolar effect, such that an intimate time relationship exists between high-scoring and low-scoring sessions. Epoch analysis on SIDs show enhanced sudden enhancement of signal strength in VLF (SES) on the day of, or before, both high- and low-scoring sessions.

(U) Evaluation of the ELF environment with data from the prototype ELF monitoring system revealed patterns in ELF measurements a number of days preceding the sessions which were oppositely configured over time with respect to high-and low-scoring sessions.

(U) A very encouraging aspect of this study is the corroboration of the findings by all of the various data sets examined. The relationship of geophysical phenomena to RV performance may be traced from solar

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activity, to terrestrial activity--including SIDs and geomagnetic activity. All of these data sets appear at specific time intervals, which are known to occur with respect to each other, and at definable intervals with respect to the RV performance data.

(U) The following conclusions have been reached as a result of this data analysis:

- Correlations between several geophysical phenomena and RV performance are significant, and have a high probability of constituting a valid cause-effect phenomenon.
- Time periods of low-scoring sessions cluster (within 24 hours or less) with high-scoring sessions. This suggests that the mechanism that influences RV performance has a bipolar effect.
- ELF appears to be a reasonable candidate for a linking mechanism; it is capable of changing rapidly, is most likely affected by SIDs and other solar effects, and specific changes have been noted at the times of the sessions.
- Should further in-depth statistical studies confirm the results to date, a successful long-range forecasting system could possibly be developed using a combination of solar-terrestrial and monitored ELF data. Solar-terrestrial correlations were significant, but the time intervals are not yet defined accurately enough for reliable forecasting. Successful forecasting might be accomplished by using solar-terrestrial data to identify approximate time periods when enhanced and degraded performance is expected. Then, by monitoring the ELF environment during these periods, the exact effects can be known or anticipated.

(U) The objectives of a follow-on effort should be to (1) confirm the findings (especially with respect to the ELF data), (2) seek finer time resolution, and (3) clarify the mechanisms involved in the RV solar-terrestrial relationship. The final product of such an effort would be trial forecasts in a blind study in order to determine whether forecasting (and its companion, scheduling) can lead to increased reliability of the RV process.

VII SUMMARY (U)

(U) Past experiments in RV have shown considerable variability in RVer performance over time; that is, RVers are seen to perform better at some times than at others. This variability has not yet been fully explained nor examined in detail. The possibility exists a priori that performance might be affected by certain external factors. If this is the case, identifying these factors and understanding the way they influence a trainee's performance could lead to significant improvement in the RV product.

(U) As a starting point, human beings have been shown to be sensitive to certain forms of electromagnetic radiation that are known to exist in the geophysical environment; there is also some evidence that certain aspects of human behavior and performance are related to changes in yet other aspects of the geophysical environment. An important question relative to RV performance is the extent to which a trainee's performance is subject to such electromagnetic or geophysical factors. Investigation of this question is necessary in the course of developing a reliable RV capability. The results of such an investigation would show whether RV performance is influenced by these factors, and, if so, the degree to which such influences can be controlled, and whether they point to directions for further research into the fundamental nature of psi function in its broadest sense.

(U) The project described in this report is a first step in the process of determining the relationship between RV performance and various environmental factors. This project had a two-part aim. First, it was necessary to set up an environmental monitoring facility for real-time measurement of certain variables, and to identify available, reliable sources of other environmental data. Second, the degree of correlation between the available environmental data and the RV results needed to be developed. In this report, we describe the monitoring facility and the

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specific environmental variables, and a preliminary analysis of the correlations between RV performance and these factors is given. Some interpretation is also provided as an aid to planning future work along these lines.

(U) Basically, in the monitoring facility we detect and record the local geomagnetic field, using a Fourier analysis technique to separate the various frequency components in the electromagnetic spectrum (in the range 0 to 30 Hz). A prototype facility had been in operation for more than two years, and some relatively coarse data were already available when the project began. These data, and the experience gained while gathering them, were used to design and calibrate more precise instrumentation for this program. Data from these systems were then used in the investigation to correlate against RV performance data for the corresponding time period of operation of this facility. An equally important part of the project consisted of correlating RV performance data against other geophysical observations available from the National Oceanographic and Atmospheric Administration--some of it by real-time acquisition from a Westar IV satellite downlink installed specifically for this purpose.

(U) As shown in this report, several significant correlations have been found between various geophysical factors and RV performance. These correlations have a strong tendency to cluster in certain time intervals with respect to high- and low-performance RV sessions. In some cases, the clustering precedes the correlated RV activity, thereby yielding the possibility of performance prediction, should such correlations continue to be viable in further work.

(U) Among the most interesting correlations to RV performance found are flares occurring on the sun, especially those on the edge (limbs) of the solar disk. These flares play an important role in producing upper atmospheric disturbances known as SIDs (sudden ionospheric disturbances), which influence terrestrial radio-signal propagation. SIDs are known to block higher-frequency communications, but at the same time, to enhance lower-frequency propagation at LF and VLF frequencies. Although the effect of SIDs on the yet lower-frequency ELF portion of the electromagnetic

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spectrum is unknown, it could provide a promising link between the solar-terrestrial environment and known electromagnetic effects on biological processes. With regard to ELF itself, preliminary evaluation of the ELF environment in half-hourly time intervals has shown a possible relationship to frequencies between 10 and 30 Hz, particularly as ELF intensities change from below average to above average values.

(S/CL-3/NF) Considering the modest level-of-effort for the survey of geophysical/ELF factors, and their possible relationship to RV performance, a considerable amount of progress has been made in delineating potential correlations of value. What can be said at this point is that this pilot study provides evidence that the quality of RV functioning may be intimately related to the geophysical environment. What remains to be done is (1) an in-depth statistical evaluation of those findings of this study that were strongly intercorroborated by the various data sets used, and (2) a structured attempt at blind RV performance forecasting. As a result, continued collection and analysis of such data will be pursued to determine whether the correlations found are stable over time, and will thus provide a solid continuing basis for RV performance prediction. From both scientific and practical viewpoints, knowledge of this kind makes it possible in an operational environment to consider methods for both enhancing the overall RV product, and for developing countermeasures.

REFERENCES (U)

1. Persinger, M. A., H. W. Ludwig, and H. P. Ossenkopp, "Psychophysiological Effects of ELF Electromagnetic Fields: A Review," Perceptual and Motor Skills, Vol. 36, pp. 1131-1159 (1973).

2. Weber, R., "Human Circadian Rhythms under the Influence of Weak Electric Fields and the Different Aspects of These Studies," Int. J. Biometeorology, Vol. 17, No. 3, pp. 227-232 (1974).

3. Friedman, H., R. Becker, and C. Bachman, "Effect of Magnetic Fields on Reaction-Time Performance," Nature, pp. 949-950 (4 March 1967).

4. Konig, H. L., "Behavioral Changes in Human Subjects Associated with ELF Electrical Fields," ELF and VLF Electromagnetic Field Effects, M. A. Persinger (ed.), Plenum Press, New York, pp. 81-99 (1974).

5. Puthoff, H. E. and M. Adams, "Geophysical Effects Study (U)," Interim Report, SRI 941/CL-0022, SRI International, Menlo Park, CA (July 1984), SECRET/NOFORN.

6. Fraser-Smith, A. C., "ULF Tree Potentials and Geomagnetic Pulsations," Nature, Vol. 271, No. 5646, pp. 641-642 (16 February 1978).

7. Adams, M. H., "The Effect of the Geophysical and ELF Environments on RV Performance (U)," Final Report, Time Research Institute, Los Altos, CA (28 November 1984), UNCLASSIFIED.

BIBLIOGRAPHY (U)

Adair, E. R. and B. W. Adams, "Microwaves Induce Peripheral Vasodilation in Squirrel Monkey," Science, Vol. 207, pp. 1381-1383, (1980).

Adey, W. R., Chapter 15 in Functional Linkage in Biomolecular Systems, (Raven Press, New York), pp. 325-342, (1975).

__________, "Frequency and Power Windowing in Tissue Interactions with Weak Electromagnetic Fields," Proc. IEEE, Vol. 68, No. 1, pp. 119-125, (1980).

__________, "Tissue Interactions with Nonionizing Electromagnetic Fields," Physiological Rev., Vol. 61, No. 2, pp. 435-514, (1981).

Adey, W. R. et al., "Effects of Weak Amplitude-Modulated Microwave Fields on Calcium Efflux from Awake Cat Cerebral Cortex," Bioelectromagnetics, Vol. 3, pp. 295-307, (1982).

Arehart-Treichel, J., "Electromagnetic Pollution: Is It Hurting Our Health?," Science News, Vol. 105, pp. 418-419, (1974).

Bassett, C.A.L. et al., "Augmentation of Bone Repair by Inductively-Coupled Electromagnetic Fields," Science, Vol. 184, pp. 575-577, (1974).

Bawin, S. M. and W. R. Adey, "Electric Fields and Nerve Activity," Proc. Natl Acad. Sci., (1976).

Beal, J. B., "Spontaneous Electromagnetic Radiation from Natural Dielectrics," Planetary Assoc. for Clean Energy Newsletter, Vol. 3, No. 1, p. 30, (1981).

Becker, R. O. et al., "The Direct Current Control System," N. Y. State J. Med., pp. 1169-1176, (1962).

Becker, R. O., "Electromagnetic Forces and Life Processes," Technology Rev., pp. 32-38, (1972).

__________, "The Significance of Bioelectric Potentials," J. Bioelectrochem. & Bioenergetics, (1974).

"Biomedicine--How Electrical Healing Works," Science News, Vol. 122, p. 57, (1982).

Bodznick, D. and R. G. Northcutt, "Electroreception in Lampreys: Evidence that the Earliest Vertebrates Were Electroreceptive," Science, Vol. 212, pp. 465-467, (1981).

Borgens, R. B. and E. Roederer, "Enhanced Spinal Cord Regeneration in Lamprey by Applied Electric Fields," Science, Vol. 213, pp. 611-617, (1981).

Bracken, T. Dan (Editor), "Proceedings of the Workshop on Electrical and Biological Effects Related to HVDC Transmission," Pacific Northwest Laboratory Report PNL-3121, Department of Energy, (1979).

Buettner, K. J., "Present Knowledge on Correlations Between Weather Changes, Sferics, Air Electric Space Charges, and Human Health and Behavior," Bioclimatology-Federation Proceedings, pp. 631-637, (1957).

Burr, H. S. and S. C. Northrup, "The Electro-Dynamic Theory of Life," Quart. Rev. of Biology, Vol. 10, (1935).

Calhoun, J. B. (Editor), "Environment and Population: Problems of Adaptation," (Praeger Scientific), pp. 28-30, (1984).

Chou, C. K. and A. W. Guy, "Holographic Assessment of Microwave Hearing," Science, Vol. 209, pp. 1143-1144, (1980).

Deno, D. W. et al., "Measurements of Electric and Magnetic Fields in and Around Homes Near a 500-kV Transmission Line," presented at IEEE/PES Meeting, (1982).

Dodge, C. H., "Clinical and Hygienic Aspects of Exposure to Electromagnetic Fields, from Biological Effects and Health Implications of Microwave Radiation," Symposium Proceedings, Richmond, VA, 17-19 September 1969, pp. 140-148, (1969).

Eichmeier, J. and P. Buger, "Uber den Einfluss Elektromagnetischer Strahlung auf die Wismutchlorid-Fallungsreaktion nach Paccardi," Int. J. Biometeor., Vol. 13, Nos. 3 and 4, pp. 239-256, (1969).

Fischer, W. H. et al., "Laboratory Studies on Fluctuating Phenomena," Nat. J. Biometeor., Vol. 12, No. 1, pp. 15-19, (1968)

Fraser-Smith, A. C., "ULF Tree Potentials and Geomagnetic Pulsations," Nature, Vol. 271, No. 5646, pp. 641-642, (1978).

__________, "Some Statistics on Pc 1 Geomagnetic Micropulsation Occurrence at Middle Latitudes: Inverse Relation with Sunspot Cycle and Semi-Annual Period," J. Geophys. Res., Space Phys., Vol. 75, No. 25, pp. 4735-4745, (1 September 1970).

Fraser-Smith, A. C., "Long-Term Predictions of Pc 1 Geomagnetic Pulsations: Comparison with Observations," Planet. Space Sci., Vol. 29, No. 7, pp. 1902-1907, (1964).

Frey, A. H., "Biological Function as Influenced by Low-Power Modulated RF Energy," IEEE Trans. Microwave Theory and Tech., Vol. 19, No. 2, pp. 153-163, (1971).

__________, "Neural and Behavioral Response to Changes in Weak Electromagnetic Fields," Workshop on Behavioral Sensitivities on Animals Possibly Relevant to Earthquake Prediction, Galveston, TX, 1979, pp. 1-10, (1979).

Friedman, H. et al., "Geomagnetic Parameters and Psychiatric Hospital Admissions," Nature, Vol. 200, pp. 626-628, (1963)

__________, "Psychiatric Ward Behaviour and Geophysical Parameters," Nature, Vol. 205, pp. 1050-1052, (1965).

Friend, A. W., Jr. et al., "Low-Frequency Electric-Field-Induced Changes in the Shape and Motility of Amoebas," Science, Vol. 187, pp. 357-359, (1975).

Garmon, L., "Something in the Air," Science News, Vol. 120, pp. 364-365, (1981).

Gauquelin, M. and F. Gauquelin, "Review of Studies in the USSR on the Possible Biological Effects of Solar Activity," J. Interdiscipl. Cycle Res., Vol. 6, No. 3, pp. 249-252, (1975).

Gavalas, R. J. et al., "Effect of Low-Level, Low-Frequency Electric Fields on EEG and Behavior in Macaca Nemistrina," Brain Res., Vol. 18, pp. 491-501, (1970).

Gnevyshev, M. N. and K. F. Novikova, "Solar Activity and Manifestations in the Biosphere," National Research Council Report TT-1679, (1973).

Goodman, R. et al., "Pulsing Electromagnetic Fields Induce Cellular Transcription," Science, Vol. 220, pp. 1283-1285, (1983).

Guha, S. K. et al., "Electrical Field Distribution in the Human Body," Phys. Med. Biol., Vol. 18, No. 5, pp. 712-720, (1973).

Hamer, J. R., "Effects of Low-Level, Low-Frequency Electric Fields on Human Time Judgment," Int. J. Biometeor., (1969).

__________, "Biological Entrainment of the Human Brain by Low-Frequency Radiation," Technical Memorandum, Northrop Space Laboratories, (1965).

Heiligenberg, W. and R. A. Altes, "Phase Sensitivity in Electroreception," Science, Vol. 199, pp. 1001-1004, (1978).

Herin, R. A., "Electroanesthesia: A Review of the Literature (1819-1965)," Activitas Nervosa Superior, Vol. 10, No. 4, pp. 439-454, (1968).

Heynick, L. N. and P. Polson, "Bioeffects of Radiofrequency Radiation: A Review Pertinent to Air Force Operations," USAF Report No. USAFSAM-TR-83-1, SRI International, Menlo Park, CA, (1983).

Hicks, W. W., "A Series of Experiments on Trees and Plants in Electrostatic Fields," J. Franklin Inst., Vol. 64, No. 1, pp. 1-5, (1957).

Hill, H. L. et al., Transmission Line Reference Book HVDC to 600 kV, (EPRI, Palo Alto, CA).

__________, "Radio Interference," Transmission Line Reference Book HVDC to 600 kV, (EPRI, Palo Alto, CA), pp. 46-58.

__________, "Direct Current Field Effects," Transmission Line Reference Book HVDC to 600 kV, (EPRI, Palo Alto, CA), pp. 73-96.

Hillman, J. S. and J.D.C. Turner, "Association Between Acute Glaucoma and the Weather and Sunspot Activity," Brit. J. Ophthalmology, Vol. 61, pp. 512-516, (1977).

Hirsch, F. G. et al., "The Psychologic Consequences of Exposure to High-Density Pulsed Electromagnetic Energy," Int. J. Biometeor., Vol. 12, No. 3, pp. 263-270, (1968).

Houghton, A. et al., "Increased Incidence of Malignant Melanoma After Peaks of Sunspot Activity," The Lancet, pp. 759-760, (1978).

Jitariu, P. et al., "L'Influence des Champs Electro-Magnetiques Pulsant sans Interruption sur les Fractions Proteiques Plasmatiques et sur Le Processus de la Coagulation chez les Lapins," Rev. Roum. Biol.--Zoologie, Vol. 12, No. 2, pp. 91-95, (1967).

Kholodov, Y. A., "Effect of Electromagnetic and Magnetic Fields on the CNS," Foreign Sci. Bull., pp. 17-23, (1967).

Kloss, D. A. and E. L. Carstensen, "Effects of ELF Electric Fields on the Isolated Frog Heart," IEEE Trans. Biomed. Eng., Vol. 30, No. 6, pp. 347-348, (1983).

Konig, H., "Biological Effects of Extremely-Low-Frequency Electrical Phenomena in the Atmosphere," J. Interdiscipl. Cycle Res., Vol. 2, No. 3, pp. 317-323, (1971).

Larkin, R. P. and P. J. Sutherland, "Migrating Birds Respond to Project Seafarer's Electromagnetic Field," Science, Vol. 195, pp. 777-778, (1977).

Lawrence, A. F. and W. R. Adey, "Nonlinear Wave Mechanisms in Interactions Between Excitable Tissue and Electromagnetic Fields," Neurological Res., Vol. 4, Nos. 1 and 2, (Butterworth Publishers), pp. 115-152, (1982).

Leach, J. F. et al., "Effect of Ozone Variation on Disease in Great Britain: I. Skin Cancer," Aviation, Space, and Environ. Med., Vol. 49, No. 3, pp. 512-516, (1978).

Lerner, E. J. (Editor), "Biological Effects of Electromagnetic Fields," IEEE Spectrum, pp. 57-69, (1984).

Lin-Liu, S. and W. R. Adey, "Low-Frequency Amplitude-Modulated Microwave Fields Change Calcium Efflux Rates from Synaptosomes," Bioelectromagnetics, Vol. 3, pp. 309-322, (1982).

Lokken, J. E. et al., "A Note on the Classification of Geomagnetic Signals Below 30 Cycles per Second," Canadian J. of Phys., Vol. 40, pp. 1000-1009, (1962).

Lokken, J. E. and J. A. Shand, "Man-Made Electromagnetic Interference at Extremely Low Frequencies," Canadian J. of Phys., Vol. 42, pp. 1902-1907, (1964).

Lotmar, R. et al., "Dampfung der Gewebeatmung (Q02) von Mauseleber durch Kunstliche Impulsstrahlung," Int. J. Biometeor., Vol. 13, Nos. 3 and 4, pp. 231-238, (1969).

Luben, R. W. et al., "Effects of Electromagnetic Stimuli in Bone and Bone Cells in vitro: Inhibition of Responses to Parathyroid Hormone by LF Fields," Proc. Natl. Acad. Sci., Vol. 79, p. 4188, (1982).

Ludwig, H. W., "A Hypothesis Concerning the Absorption Mechanism of Atmospherics in the Nervous System," Int. J. Biometeor., Vol. 12, No. 2, pp. 93-97, (1968).

Magnus, K., "Incidence of Malignant Melanoma of the Skin in the Five Nordic Countries: Significance of Solar Radiation," Int. J. Cancer, Vol. 20, pp. 477-485, (1977).

Malin, S.R.C. and B. J. Srivastava, "Correlations Between Heart Attacks and Magnetic Activity," Nature, Vol. 277, pp. 646-648, (1979).

Marha, K. et al., "Electromagnetic Field and the Living Environment," State Health Publishing House, (1968).

Markson, R. J., "Geophysical Influences in Biological Systems," (thesis), Pennsylvania State University, (1967).

Markson, R., "Tree Potentials and External Factors," (Masters thesis), Pennsylvania State University, (1967).

Marshall, E., "ELF Resurrected After Drowning by Navy," Science, Vol. 212, pp. 644-645, (1981).

Mayyasi, A. M. and R. A. Terry, "Effects of Direct Electric Fields, Noise, Sex and Age on Maze Learning in Rats," Int. J. Biometeor., Vol. 13, No. 2, pp. 101-111, (1969).

Michaelson, S. M., "Human Exposure to Nonionizing Radiant Energy-Potential Hazards and Safety Standards," Proc. IEEE, Vol. 60, No. 4, pp. 389-421, (1972).

__________, "Physiologic Regulation in Electromagnetic Fields," Bioelectromagnetics, Vol. 3, pp. 91-103, (1982).

Michrowski, A., "USSR ELF Emissions Were Predicted for Remote Viewing and Mind-Control Capabilities," Planetary Assoc. for Clean Energy Newsletter, Vol. 3, No. 1, pp. 26-27, (1981).

Moos, W. S. and R. Reiter, "Biological Effects of Electric, Magnetic and Electromagnetic Fields," (study group). Int. J. Bioelectricity, pp. 204-205, (1969).

NRC Report, "Biologic Effects of Electric and Magnetic Fields Associated with Proposed Project Seafarer," National Research Council, pp. 27-54, (1977).

Nordstrom, S. et al., "Reproductive Hazards Among Workers at High-Voltage Substations," Bioelectromagnetics, Vol. 4, No. 1, pp. 91-101 (1983).

Park, C. G. and R. A. Helliwell, "Magnetospheric Effects of Power Line Radiation," Science, Vol. 200, pp. 727-730, (1978).

Paschal, E. W., "Design of Broad-Band VLF Receivers with Air-Core Loop Antennas," Stanford Electronic Laboratories (SEL) Report, (1980).

Persinger, M. A. et al., "Psychophysiological Effects of Extremely-Low-Frequency Electromagnetic Fields: A Review," Perceptual and Motor Skills, Vol. 36, pp. 1131-1159, (1973).

Persinger, M. A., "Geophysical Models for Parapsychological Experiences," Psychoenergetic Systems, Vol. 1, pp. 63-74, (1975).

__________, "Geophysical Variables and Human Behavior: VIII," Perceptual and Motor Skills, Vol. 56, pp. 243-249, (1983).

Phillips, R. D. et al., "Effects of Electric Fields on Large Animals," Third Interim Report, EPRI Report No. EA-331, Research Proj. No. 799-1, Battelle, (1977).

__________, "Effects of Electric Fields on Large Animals," Second Interim Report, EPRI Report No. EA-458, Research Proj. No. 799-1, Battelle, (1977).

Phillips, R. D. and W. T. Kaune, "Biological Effects of Static and Low-Frequency Electromagnetic Fields: An Everview of United States Literature," EPRI Report No. EA-490-SR, Battelle, (1977).

Phillips, R. D. et al., "Effects of Electric Fields on Large Animals (Section 4, Biological Studies)," EPRI Report No. EA-331, EPRI Research Proj. No. 799, Battelle, (1979).

Pinneo, L. R., "Electrical Control of Behaviour by Programmed Stimulation of the Brain," Nature, Vol. 211, No. 5050, pp. 705-708, (1966).

__________, "On Noise In The Nervous System," Psychological Rev., Vol. 73, No. 3, pp. 242-247, (1966).

Pinneo, L. R. et al., Neuroelectric Research, Chapter 43, pp. 405-428, (1971).

Poumailloux, M., "Repercussions Humaines De L'Activite Solaire Interne," Europe Medica, Vol. 10, No. 15, pp. 1201-1214, (1969).

"The Radiofrequency Environment," Science News, Vol. 124, p. 92, (1983).

Ravitz, L. J., "History, Measurement, and Applicability of Periodic Changes in the Electromagnetic Field in Health and Disease," Annals New York Acad. Sci., pp. 1144-1201.

__________, "Electrodynamic Field Theory in Psychiatry," Southern Med. J., Vol. 46, No. 7, pp. 650-660, (1953).

__________, "Electromagnetic Field Monitoring of Changing-State Function, Including Hypnotic States," J. Amer. Soc. Dent. & Med., Vol. 17, No. 4, pp. 119-129, (1978).

Ray, J., "Citizens Protest High Power Lines," Bull. At. Scientists, Vol. 36, No. 4, pp. 28-30, (1980).

Roller, W. L. and R. F. Goldman, "Estimation of Solar Radiation Environment," Int. J. Biometeor., Vol. 11, No. 3, pp. 329-336, (1967).

Sazonova, T. E., "A Physiological Assessment of the Work Conditions in 400-500-kV Open Switching Yards," Abstract, (translation from Russian), IEEE Power Eng. Soc., (1965).

Schiefelbein, S., "The Invisible Threat," Saturday Review, pp. 16-20, (1979).

Scott-Walton, B. et al., "Potential Environmental Effects of 76 5-kV Transmission Lines: Views Before the N.Y. State Public Service Commission," (Section II), Department of Energy Report No. DOE/EV-0056, SRI International, Menlo Park, CA, pp. II-1-28, (1979).

Senseman, D. M. and B. M. Salzberg, "Electrical Activity in an Exocrine Gland: Optical Recording with a Potentiometric Dye," Science, Vol. 208, pp. 1269-1271, (1980).

Shoenholz, S., "Commentary--High Power Lines," Bull. At. Scientists, pp. 59-60, (1981).

Shul'ts, N. A., "Effect of Solar Activity on the Frequency of Functional Leu-kopenias and Relative Lymphocytoses," NASA Report TT F-592, (1967).

Sidaway, G. H. and G. F. Asprey, "Influence of Electrostatic Fields on Plant Respiration," Int. J. Biometeor., Vol. 12, No. 4, pp. 321-329, (1968).

Solon, L. R., "A Public Health Approach to Microwave and Radiofrequency Radiation," Bull. At. Scientists, Vol. 39, No. 8, pp. 51-55, (1979).

Southern, W. E., "Orientation of Gull Chicks Exposed to Project Sanguine's Electromagnetic Field," Science, Vol. 189, pp. 143-144, (1975).

Steneck, N. H. et al., "The Origins of U.S. Safety Standards for Microwave Radiation," Science, Vol. 208, pp. 1230-1236, (1980).

Stoupel, E., "Solar Terrestrial Prediction--Aspects for Preventive Medicine," International Solar Terrestrial Physics (ISTP) Workshop Paper, (1979).

Takashima, S. and T. Asakura, "Desickling of Sickled Erythrocytes by Pulsed Radio-Frequency Field," Science, Vol. 220, pp. 411-413, (1983).

Tell, R. A., "Broadcast Radiation: How Safe Is Safe?," IEEE Spectrum, pp. 43-51, (1972).

Teorell, T., "Application of 'Square Wave Analysis' to Bioelectric Studies," Research Paper, University Uppsala, Sweden, pp. 235-254, (1946).

Thomas, J. R. et al., "Microwave Radiation and Chlordiazepoxide: Synergistic Effects on Fixed-Interval Behavior," Science, Vol. 203, pp. 1357-1358, (1979).

Venkataraman, K., "Epilepsy and Solar Activity--An Hypothesis," Neurology India, Vol. 24, No. 3, pp. 148-150, (1976).

Verfaillie, G.R.M., "Correlation Between the Rate of Growth of Rice Seedlings and the P-Indices of the Chemical Test of Piccardi," Int. J. Biometeor., Vol. 13, No. 2, pp. 113-121, (1969).

Vogelsang, R., "A Search for Electromagnetic Cortical Stimulation," Int. J. Bioelect., p. 131, (1969).

Weisburd, S., "DNA Helix Found to Oscillate in Resonance with Microwaves," Science News, Vol. 125, p. 248, (1984).

Wentworth, R. C., "Enhancement of Hydromagnetic Emissions after Geomagnetic Storms," J. Geophys. Res., Vol. 69, No. 11, pp. 2291-2298, (1 June 1964).

__________, "Evidence for Maximum Production of Hydromagnetic Emissions above the Afternoon Hemisphere of the Earth, 2. Analysis of Statistical Studies," J. Geophys. Res., Vol. 69, No. 13, pp. 2699-2705, (1 July 1964).

Wertheimer, N. and E. Leeper, "Electrical Wiring Configurations and Childhood Cancer," Amer. J. of Epidemiology, Vol. 109, No. 3, pp. 272-284, (1979).

Wever, R., "Human Circadian Rhythms under the Influence of Weak Electric Fields and the Different Aspects of These Studies," Int. J. Biometeor., Vol. 17, No. 3, pp. 227-232, (1973).

Wigle, D. T., "Malignant Melanoma of Skin and Sunspot Activity," The Lancet, p. 38, (1978).

Zaffanella, L. E. and D. W. Deno, "Electrostatic and Electromagnetic Effects of Ultrahigh-Voltage Transmission Lines," (Section 3), EPRI Report No. EL-802, General Electric Company, pp. 3-1 to 3-29, (1978).

__________, "Electrostatic and Electromagnetic Effects of Ultrahigh-Voltage Transmission Lines," (Section 5), EPRI Report No. EL-802, General Electric Company, pp. 5-1 to 5-46, (1978).

__________, "Electrostatic and Electromagnetic Effects of Ultrahigh-Voltage Transmission Lines," (Section 6), EPRI Report No. EL-802, General Electric Company, pp. 6-1 to 6-3, (1978).

__________, "Electrostatic and Electromagnetic Effects of Ultrahigh-Voltage Transmission Lines," (Section 7), EPRI Report No. EL-802, General Electric Company, pp. 7-1 to 7-105, (1978).

__________, "Electrostatic and Electromagnetic Effects of Ultrahigh-Voltage Transmission Lines," (Section 8), EPRI Report No. EL-802, General Electric Company, pp. 8-1 to 804, (1978).