RADIOSCIENCE LABORATORY

S T A N F O R D U N I V E R S I T Y

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INTRODUCTION

The Stanford Center for Radar Astronomy (SCRA) is a joint venture of groups at Stanford University (SU) and Stanford Research Institute (SRI) who share an interest in the application of radar and radio techniques to the study of our planet and the solar system. This interest has found expression in both observational and theoretical research carried out under the auspices of the Center. Studies involving the propagation of radio waves between ground terminals and a probe in space (bistatic radar astronomy) have received the greatest emphasis. This technique has been successfully applied to studies of the earth's ionosphere, the cislunar medium, the interplanetary medium, the solar corona, the atmosphere of Mars and Venus, and the surface of the moon.

The complex nature of radio and radar experiments requires expertise in a variety of subject areas in addition to the physics of the phenomena under study. For example, bistatic-radar experiments conducted with space probes require a familiarity with orbital mechanics, optimal signal detection theory, numerical analysis, and electromagnetic propagation and scattering theory. Equally diverse disciplines are required for the other experimental areas mentioned above. As a result the Center is made up of individuals of highly varied backgrounds and specialized abilities, and graduate student research assistants working toward dissertations on a broad range of subjects. However, the unifying principal underlying all the work of the Center has been, and remains, research into physical phenomena of the space and planetary environments, and other applications of the techniques of radio science.

Perhaps an example can best summarize this point about the importance of a unifying aspect in programs of the Center. In the area of planetary atmospheres, proposals initiated at Stanford a decade ago helped mark the start of the radio occultation method for the study of planetary atmospheres, and present or past Center personnel have participated and are involved in all of the past and planned occultation and related bistatic radar studies of all of the planets of the solar system. We were led into the study of planetary atmospheres from the radio technique of measurement, but have expanded our interest to the scientific study of the intrinsic properties of these atmospheres.

The recent publication (Astronomical Journal, March 1971) of the detailed analysis of the two Mariner V occultation experiments conducted by the Center and JPL mark, we believe, the coming of maturity of the occultation method for detailed and accurate measurements of atmospheric properties. Improved dual-frequency occultation measurements are planned for Mariner Venus-Mercury, Viking, and Grand Tour planetary missions after the S-band experiments for Mariner 71 and Pioneer F and G. All of these measurements need to be complemented with theoretical work and laboratory studies. In the past, we have conducted theoretical ionospheric studies as applied to Mars and Venus, and have made laboratory refractivity measurements of carbon-dioxide under simulated Martian conditions. (These are also applicable to the high atmosphere of Venus.) We are presently challenged by the Mariner V results to understand more fully the effects of condensibles which we believe are present in the Venus atmosphere, and which may be responsible for two separate and disinct cloud systems. We are now

investigating possible laboratory experiments to help in this study, and are proceeding with theoretical investigations. Also, refractivity and microwave absorption measurements for possible conditions in the Jovian atmospheres are under consideration.

Other programs at the Center are related to the occultation studies of other planetary atmospheres, and all of the programs benefit from the interaction. These include the radio-occultation dual-satellite method and the horizontal-sounding balloon method of studying the earth's atmosphere to aid in weather prediction, the program for radio-acoustic sounding of the terrestrial atmosphere to obtain pressure and temperature profiles at low altitudes, and the meteor echo program for obtaining upper atmosphere density and winds. Even the bistatic-radar study of the ocean wave state has an atmospheric interplay since it is the winds that drive the waves.

In addition to the above, we believe that technological and engineering interplay with the scientific investigations is of great importance to the success of the Center. With regard to the planetary atmospheres theme developed above, the Center has provided flight hardware for the Mariner V dual-frequency experiment and has been instrumental in helping in the decision to change the NASA Deep Space Net telecommunications to a dual-frequency system that will greatly improve radio science experiments and at the same time provide better communications and better tracking. We hope to be able to continue a strong program involving our radio and radar facilities, our ability to provide flight hardware, and continuing field

and laboratory studies involving systems and instruments built by the Center for both scientific experiments and communications and earth-applications programs.

The Center has been supported by both grant and contract sources. Projects, such as the Pioneer or Explorer 35 experiments, have been carried out on a contract basis, following the acceptance of the experiment by the sponsoring agency (usually NASA). Some grants for definite purposes have also been obtained, and both grants and contracts have been awarded for individuals in the Center to participate in the mission definition and implementation phases of the radio teams chosen for Venus-Mercury, Viking, and Grand Tour missions. However, the NASA sustaining grant has provided the fundamental nucleus from which other work has evolved.

At the Center, the sustaining grant (NGL 05-020-014) covers a broad spectrum of activity in space sciences. During the past year the grant has been used for support in three general areas. (1) Theoretical and experimental efforts of certain graduate student research assistants and staff members are supported by the grant, in a number of areas of space science or applications which may not have specific connections with any NASA flight project. (2) The efforts of some members of the Center are supported, at least in part from the grant, in areas which are either expected to develop into future separate projects, or which are peripheral to the main thrust of other present projects (such as a separately-funded

flight project), but which, nevertheless, show promise for possible future developments in that field. (3) Of vital importance to the activities of the Stanford Center for Radar Astronomy is the role of the grant in providing continuity and the ability to respond quickly to new opportunities, and in helping to provide for support equipment and support capabilities for the benefit of all of the space activities of the Center.

The remainder of this report is divided into the sections listed below which provide representative samples of the types of activities carried out by the Center. In each case, the actual percentage of grant support is indicated (Principal Support Elsewhere means that the grant contributes either indirectly or in minor amount to the project):

A. Faculty and student contributions describing current work

B. Recent publications

Section A consists of contributions, written primarily by students in the manner of a progress report, describing the thrust of individual research projects. It will be clear from a simple purusal of this section that the scope of individual research undertaken at the Center is large. We feel that past results have demonstrated that the quality of the efforts is also high.

Section B lists Center publications from the past two years. In every case the work cited has benefitted by the grant either indirectly, as we have indicated above, or directly by grant funds being used to supplement those from the project.

SECTION A
Faculty and Student Contributions

Eduardo W. Bergamini (100% Sustaining Grant)

We began our work two months ago on the development of real time structures that can perform functions like digital filtering or other special purpose digital processing. The approach chosen uses the digital differential analyzer (DDA) as a basic tool.

As a basic step for this development, we are considering configurations of highly parallel logic structures. Evaluation of performance and feasibility are under consideration. Simulation models are going to be tested in a general purpose computer. We then expect to achieve experimental basis for further practical realizations.

Essam Marouf (100% Sustaining Grant)

Neutral Atmosphere of Venus - Structure of the Clouds

Possible models for the lower region of clouds (between 35 and 50 km altitude) of the atmosphere of Venus have been investigated. Dust, mercury compounds and other radio wave absorbers and scatterers have been studied for the possibility of obtaining a loss profile that matches the microwave absorption profile measured by Mariner 5 (1967). The corresponding temperature profile is then used as a check for the validity of these assumptions. Models which match the absorption profile and give rise to a reasonable temperature profile would then be used to study the thermal balance problem of this layer of clouds. The models studied are hoped to give more insight to the possible interrelation of the occultation experiment to be carried out by the 1973 Mariner mission.

The radio occultation experiment carried out in 1967 by the American space probe Mariner 5 provided a fairly accurate refractivity profile of the neutral atmosphere of Venus (over a range of about 35 to 80 km above the surface of the planet). In deriving the number density profile, the temperature profile and pressure profile, it is generally assumed that the atmosphere is composed largely of CO_2 with a small percentage of N_2. Based on in situ measurements carried out by the Russian Venera 4 and spectroscopic studies from the earth, CO_2 is actually the major constituent of the Venus atmosphere. Therefore, the temperature profile derived must be reasonably accurate.

In the region extending from the visible clouds down to about 58 km from the surface, possible water vapor mixing ratios, temperature and temperature lapse rate make water and ice clouds very possible. On the other hand, another layer of clouds in the region below about 50 km (down to about 35 km) is strongly suggested by the Mariner 5 measured absorption profile. The structure of such clouds is still a puzzling question. CO_2 or a mixture of CO_2 and water vapor could not account for the amount of microwave loss observed. The problem is therefore that of looking for a constituent, or probably a mixture of constituents which would give rise to an absorption profile that matches the measured one. Dust clouds or clouds of particulate mercury halides are possibilities. The problem here is that the exact mechanism of loss is not known, particularly its dispersive properties. The derived temperature profile based on CO_2 atmosphere may be in doubt in this region if the absorbing constituent contributes in a significant amount to the refractivity profile.

Work is now directed towards studying in detail several possible structures for this region of absorbing clouds. Different absorbing and scattering constituents are assumed to match the microwave loss profile and then the corresponding temperature profile is computed to check the accuracy of the assumptions. Bounds on the density and mean molecular mass of the possible lossy constituent are obtained by assuming the validity of the temperature profile derived on a largely CO_2 atmosphere, i.e., by assuming that the absorbing constituents do not contribute much to the mean molecular number density. Models which fairly match the absorption profile with a reasonable corresponding temperature profile would then be used to check the heat balance of the clouds layer.

A closer look at the possible candidates for these absorbing clouds may be helpful in suggesting further additions to, and interpertations of, the occultation experiment to be carried out by the 1973 Mariner mission.

Bala Parasuraman (100% Sustaining Grant)

Software Interface Considerations for DDA's and Other Incremental Computers

The problem of interfacing differential analyzers with general purpose computers has grown to the point where it can be divided into two major areas of investigation -- machine organization and software requirements. Hardware considerations and other aspects pertaining to design are dictated by the particular organization, and they are described elsewhere in this report. User-oriented programs, and other problem-solving aids that are necessary to make the composite machine convenient to use, are described here.

In the last report, a translator program was introduced and its capabilities mentioned. The program has since been modified and extended to include a wider class of problems. It is an equation translating program which has as its input differential equations written in a prescribed format. It generates program interconnections for d.d.a. implementations of the equations. Most classes of ordinary differential equations can be handled provided that they do not exceed an order of 10.

Another development has been the inclusion of a map drawing routine. The generated interconnections are printed out in the form of interconnected d.d.a. blocks with all the problem variables labelled accordingly. This provides an easy-to-read visual form for the interconnection information.

This program was developed as a general one which can be used to provide maps for d.d.a.'s as well as any other incremental computer using the standard integration algorithms. At present, work is being done on writing an implementation routine for these interconnections. The goal is to provide a complete software package in order to simplify the numerical solution of differential equations. Such a package would resemble typical simulation languages in end results, but would be two orders of magnitude faster and more convenient to use. It would also be more compact and suitable to use on mini-computers.

Work on related aspects of incremental computation is anticipated shortly. These include investigation of non-standard differential equations to find out any distinguishing features that would make them easy to solve; working out automatic magnitude scaling techniques; studying different types of numerical integration algorithms to yield faster and

more accurate solutions; seeking out new fields of application for incremental computers. There is considerable promise for this type of incremental computer in many engineering environments.

Richard A. Simpson (100% Sustaining Grant)

Work continues on lunar surface probing at multiple frequencies. The original suggestions of Burns[1] that reflective properties vary as the subradar point moves over the surface (a result of libration) is being pursued over the frequency range 25 MHz to 3 GHz.

Data taken last summer on 1290 MHz is being reduced at present. The data, obtained on four days at extremes on the libration ellipse (and hence maximum separations of the subradar points), are echoes from 13.3 μsec pulses beamed at the moon from the Stanford 150' dish fed by a 4 MW transmitter.

Interest will eventually be confined to echo behavior at the leading edge (first 20 μsec) since the return at later times represents averaging over a wide area and distinctions among the different subradar points would be more difficult. A preliminary estimate of rms surface slopes from the total echo is 5^{o}, slightly lower than values reported previously.[2]

The model employed for preliminary analysis is the "cracked egg" model which, albiet is undoubtedly a simplification, thus far has been most successful in explaining the relationship of surface slopes and radar scattering. It is a geometrical optics model in which reflection is assumed to be from tilted flat plates of dielectric material. The probability density function of the slopes of the plates is the primary influence in determining shape of the echo. Matching data to expected curves gives better agreement for gaussian than exponential slope distribution.

At the leading edge one range bin will be isolated and variations in echo strength there will be studied. Once Doppler and system modulations are removed only libration modulation remains. Preliminary evidence indicates

the libration modulation has a period on the order of 1 sec. With over 10 minutes of data on each day this gives more than 500 uncorrelated samples for analysis.

Assuming a gaussian distribution for the amplitude of the 500 uncorrelated samples leads to a probability of 0.8 that the mean of the sum of the squares of sample values is within $\pm 8\%$ of the actual mean. Another way of putting this is that if on one day we know the echo comes from a region with dielectric constant $\epsilon_r = 3.0$ and on another day the echo strength is down by 8%, the probability that this is merely chance is 0.1. If the surfaces were smooth and homogeneous this decrease could be accounted for by a dielectric of $\epsilon_r = 2.9$.

It seems unlikely that differences of this magnitude can be detected at L-band. Other data at 25, 50, 136 and 259 MHz representing greater surface penetration may show this, however. The L-band data will be used to estimate roughness and other factors at each subradar point.

Models based on geology as mapped by the U.S. Geological Survey[3] will be used to interpret the data. Two layer dielectric models have been used in the past, but these introduce unobserved resonances and excessively high reflection coefficients. Models in which the dielectric constant increases gradually with depth will be employed instead.

References

1. Burns, A. A., "Lunar Scattering at 6 and 12 Meter Wavelengths", Ph.D. Dissertation, Stanford University, May 1968.
2. Hagfors, T., "Remote Probing of the Moon", Radioscience, vol. 5, no. 2, pp 189-227, February 1970.
3. Howard, K. A. and H. Masursky, "Geologic Map of the Ptolemaeus Quadrangle of the Moon", U.S. Geological Survey, 1968; Wilhelms, D. E., "Geologic Map of the Mare Vaporum Quadrangle of the Moon", U.S. Geological Survey, 1968.

Robert Wang (100% Sustaining Grant)

Television Source Data Compression

Work is continuing in the development of a model for the monochrone video source. It has been shown that a promising model is that of a step process generated by a luminance process defined on a three-dimensional index set, viz, (x, y, t). A refinement is possible by considering this luminance process to be composed of two mutually independent processes, one being a step whilst the other a smooth process. Presently work is continuing to specify the model and show that it does indeed contain the salient properties of the source as discovered by earlier workers in this field.

In parallel with this modelling is the development of two compression schemes using the two dimensional spatial correlations of the source. The basic picture compression method is done on monochrone pictures. This is then extended to the problem of compressing the NTSC (1) signal for recording on an instrumentation type recorder rather than the higher priced video recorder. At the present there are no plans to implement either of the two techniques with hardware.

Reference

1. Color Television Standards, NTSC, McGraw-Hill Book Co., Inc., 1955.

John F. Vesecky (50% Sustaining Grant)

Type III Solar Radio Noise Bursts Observed at 30 to 100 kHz

The OGO III satellite (experiment B-17, R. A. Helliwell, PI) measures magnetic flux with a sweeping receiver in the 0.2 to 100 kHz range. Some of this data was formatted as magnetic flux spectra

on movie frames. 120 hours of filmed data in September, October, and November 1966 have been searched and 3 type III bursts identified. The type III bursts are often accompanied by bursts of "hi-pass" noise of magnetospheric origin. The type III bursts can be identified because they have a much smoother and lower intensity spectrum than the "hi-pass" noise. "Hi-pass" noise bursts and solar flares confirm that these LF and VLF type III events are correctly identified. Where comparison is possible the lowest frequency attained by the type III burst ($\approx$25-30 kHz) corresponds with the plasma frequency of near-Earth solar-wind plasma measurements by the VELA-3 satellite. Perhaps the most striking correlation is with prompt 40 keV electrons observed on IMP satellites (Lin, 1970). There were two prompt keV electron events observed during the 120 hours of radio data and both of these coincided with the low frequency type III events mentioned above. These observations tend to confirm the hypothesis that 40 keV electrons do indeed escite type III events (50 keV protons have also been suggested). The frequent onset of the magnetospheric "hi-pass" noise just after a low frequency type event suggests that the 40 keV electrons which probably excite the type III event may well trigger the phenomena which result in the "hi-pass" noise.

Reference

Lin, R. P., "The Emission and Propagation of 40 keV Solar Flare Electrons", Solar Physics, vol. 12, 266-303, 1970.

Michael L. Olson (25% Sustaining Grant)

Cost-Performance Analysis of Horizontal-Sounding Balloons in Global-Meteorological-Data-Collection Systems

Satellites with remote sensors satisfy the bulk of the requirements for global meteorological-data collection, but horizontal-sounding balloons (HSB's) are required to supplement remote-sensor data. The objective has been to describe the technical and subjective costs of providing various types of supplemental coverage with horizontal-sounding balloons.

Previous comparisons of the performance of existing HSB data-collection systems (OPLE, EOLE, IRLS, SWAMI, SPINMAP, RADEM and Mother GHOST) were made with respect to the gross aspect of prototype cost. These comparisons are misleading, however, since the designers of the prototype systems were concerned with feasibility rather than operational economy. The cost analysis of the proposed HSB systems has been performed on the basis of both economy and feasibility. Comparisons are made on the basis of the transmission of: 1) four weather parameters, and 2) adequate information for position determination.

In order to provide a clear picture of the costs for data collection with each possible horizontal-sounding balloon system, the basic tradeoffs between cost and coverage are presented. Particular attention is given those HSB systems that provide coverage supplementing the data-collection capabilities of satellite-borne remote sensors, buoys, ships-of-opportunity, and conventional weather stations. The 1975 cost estimates for HSB systems of special interest are summarized below:

1) Five-level, 600 balloon RADEM system--$28 to 34 million per hemisphere year.

2) Mother GHOST system, two dropside launches per balloon day--$34 to 37 million per hemisphere-year.

3) Single-level RADEM system at 150 mb, providing a pressure reference--$3.9 to 6.8 million per hemisphere-year, depending upon effective balloon stay in the tropics.

4) Single-level RADEM system at 300 mb, providing a pressure reference--$9.4 million per hemisphere-year.

5) Southern hemisphere reference level at 150 mb, with a tropical dropsonde system--$30 to 34 million per hemisphere-year.

6) Tropical coverage with dropsondes--$28 to 31 million per hemisphere-year (more economical than equivalent coverage with a five-level RADEM HSB system, costing approximately $37 million per year).

In the next year, I will be involved in three projects which will receive PSE:

1) The definition of power system alternatives, performance and cost for a geophysical observatory to be placed in Antarctica and the completion of the data communications link interfacing Stanford and the COMSAT earth terminal at Jamesburg, California.

2) The teleconferencing study on a domestic TV which will be aimed at clarifying the technical costs for potential professional education systems systems. Emphasis will be placed in defining the alternative methods of implementing a system with domestic satellite, ground wave links, and local cable TV network as probable components.

3) The examination of the practical potential of medical data transmission via synchronous satellite. Several experiments are envisioned that will clarify the capabilities of 136 MHz ground stations costing less than four thousand dollars for equipment.

Thomas A. Croft (10% Sustaining Grant)

The Radio Propagation Study -- A Measurement of Interplanetary Electron Density

J. A. Landt (Ph.D. candidate) conducted a thorough study of the correlation between fluctuations in our Pioneer and Mariner V electron content measurements and the occurrence of geomagnetic disturbances reported

by others. Using statistically unbiased methodology, he found 11 examples where the content changes were clearly related to geomagnetic disturbances. In addition, a number of other possible correlations were noted. This work serves primarily as an objective demonstration that the solar wind disturbances that cause variations in the geomagnetic field can be detected by a sensitive content measurement like ours. It also provides a data base with which we can judge the potential value of studies of selected events. This work was reported in our Scientific Report No. 4 and was verbally presented at the Solar Wind Conference recently held at Asilomar, in the proceedings of which it will be published.

Following up on this work, Landt has carried out a detailed study of a single event when large changes were seen in the content measurement and additional electron density measurements were obtained in the vicinity of earth. From comparison of the two forms of data, coupled with careful use of magnetograms inferences, Landt has been able to construct a likely cross-sectional picture of the plasma cloud which passed between earth and the Pioneer spacecraft. This work follows the method used by Landt and Croft (JGR, 1970, 4623) wherein similar data were analyzed but then it was necessary to conclude that any one of three possible plasma models were possible; this undesired conclusion was a consequence of very weak signal strength at the time of the Pioneer measurement which produced ambiguous data. In his recent work, Landt has been able to isolate a single best-fit model and he was subsequently pleased to discover a close quantitive similarity between his model and a magnetosphere-bow shock model which has been published by Spreiter (Physics of the Magnetosphere, D. Reidel, 1968). Landt appears to be able to show that the driver gas within the

solar wind assumes a form whose leading edge bears a resemblance to the earth's magnetopause and which is preceded by a shock front quite similar to the bow shock of earth.

Following his studies of the macroscopic flow patterns of the solar wind, (Radio Science, 1971, 55) T. A. Croft has discovered a pattern of events in mid-1970 which appears to provide the most convincing evidence yet found that thin streams of plasma are ejected from preferred spots in the vicinity of the sun and that these emissions are intermittent on a time scale of roughly one day. The 1970 event was particularly illuminating because it occurred on each of four successive solar rotations just after a quiet period (that is, a period when the density was relatively low and unchanging). On each rotation, after about a week of such quiet behavior, there occurred a large increase in the content which lasted only approximately one day. Since the corotation interval was three days, it was clear that the reappearing stream was not a steady flow. It was concluded that the most likely explanation was an intermittent, thin stream. This work was described in Scientific Report No. 3 which was presented at the Solar Wind Conference held at Asilomar and will be published in the proceedings thereof.

During a technical discussion with other members of the staff, Croft undertook to predict the qualitative form of a solar type III burst which would be emitted by the sun just after the cessation of an intermittent stream ejection, according to the hypothesis described in the preceding paragraph. The predicted type III burst decreased in frequency and then turned around and increased in frequency as a consequence of the entry

of the high energy particles into the trailing edge of the receding plasma enhancement. Subsequently, J. F. Vesecky produced a report from his files which showed just such a record, called a "U-burst". A subsequent survey of this specialized subject revealed that U-bursts have been commonly observed and that they have a number of characteristics which have been very difficult to explain. The conventional explanation has involved the ejection of high energy particles from the sun into a closed magnetic field line which then guides the particles around and back toward the sun. In such an event, U-bursts are expected but they should show greater symmetry than is observed. Some highly asymmetric forms are called J-bursts and L-bursts and they are even more difficult to reconcile with the magnetic loop theory. However, the intermittent stream hypothesis provides a ready explanation for many of these phenomena and therefore a paper is being prepared to describe this alternative explanation. At the present time, it appears that the guilding loop and the intermittent stream mechanisms both produce U-bursts and similar asymmetric variations on the type III burst. There is no reason to expect that only one of these mechanisms should explain all the data forms observed.

We have made an extensive study using different kinds of logic to determine the best way for computing autocorrelation of content versus time over a period of many years. Our data span more than five years now, and we should be able to determine detailed characteristics of solar corotational mechanisms from a careful autocorrelation. We must be unusually meticulous because our content is a spatial average and

thus the definition of the central meridian of the sun (which depends on the location of the observer) loses its conventional meaning and we must compensate for the distortion in the time axis which inevitably results. Also, we are making a correction for the non-circular orbit of the earth, a factor which has been neglected by previous investigators of these same kinds of data. It happens that if the sun rotated as a rigid body and we measured the time between appearances of a solar surface feature on the central meridian, we would find that the period varies by almost four hours during the progress of the year. A simple autocorrelation study of the time rate of appearance of surface features would then be degraded by the variability of the period; a greatly improved result should follow from the correction of this mechanism which is attributable to the non-circular orbit of the earth, causing our heliocentric angular rate to undergo an annual variation. At the present time we have our computer programs written and working, but we are going to correct our time base to eliminate these masking effects before we undertake large autocorrelation computations. Previous workers have found subtle trends in autocorrelation which were used as a basis for drawing some rather sweeping deductions concerning the rotation of the sun. The total size of the measured effects is comparable to the size of the errors discussed above. Therefore we wish to understand the effect of these errors on the autocorrelation before we proceed.

Daniel S. Allan (PSE)

I am presently splitting my time equally between the following two projects. The asterisked issues are the ones I am focussing upon.

1) Teleconferencing Systems

*What terminal and transmission hardware is available today for building a regional/nationwide network for professional education?

*How much does this hardware cost?

*What are the possible alternative configurations of such a network, and which is of lowest cost? Does the lowest-cost system include a satellite?

If such a system is built will there be enough demand for it to support itself?

2) Medical Care in the San Francisco Mission District: Joint Mission Coalition Community Development Study

What is the present level of health and of health care in the Mission District?

How can a community-based action group (specifically the Mission Coalition) best use its power and resources to improve health and health care in the Mission District?

*What are the pressure points in the decision structure of the City of San Francisco which can be used to bring about needed changes in health care delivery? What aspects of the decision structure are barriers to such change?

*What are the hardware, service and managerial elements of a medical triage (patient screening) system? What are the system alternatives and which alternative can deliver the best triage service at reasonable cost?

John Albernaz (PSE)

With the increasing use of the geostationary orbit by commercial and in the future by special purpose satellites a need has arisen for inexpensive antennas with low side lobes.

As the frequency spectrum presently in use is becoming saturated, better isolation between signals coming from adjacent satellites must be obtained in order to allow the reuse of the same frequency band.

A computer program which calculates the antenna beam pattern for reflector antennas has been written and is being used as an analytic tool for investigating various schemes for enhancing side lobe reduction.

The accuracy of the models used are being verified experimentally for an inexpensive 7-foot sectioned quasi-parabolic reflector designed here at Stanford. Predictions made for this type of reflector show that for certain planes considerable side lobe suppression is obtained.

I have also been engaged in a project to make use of low cost terminals for special communications applications via satellite such as transmission of relevant medical information from one point to another. In this task we were interested in developing equipment requirements and testing available equipment.

In the past few months adjustments were made on our transmitting equipment and now we are within 0.5 db from complete saturation of the ATS transponder. Low loss cable will be installed to improve this figure. An interference test was set up recently with the support of the Mojave and Rossman stations. The objective of this test was to gather information about the interference through the satellite transponders when both

are turned on and two low cost stations, as the one used at Stanford, are transmitting to different (ATS-I and ATS-III) simultaneously. Results of this test will be available soon.

With the acquisition of another transmitter and receiver equipment for use in another project, tests of full duplex communication between two low cost terminals will be performed.

Michael S. Frankel (PSE)

Stanford Meteor Trail Radar Systems

The Stanford Meteor Trail Radar system which was constructed and is still in use at Stanford, produces good results at low cost. Atmospheric density measurements at heights from 85-105 km were found promising, as were the wind measurements in the same region. This station's rugged construction has allowed the system to operate nearly unattended except for periodic changes of the magnetic tape, onto which data are recorded.

The success of the first station prompted the construction of a Mark II system which is being used at Eglin Air Force Base in Florida. The choice of this location was to allow comparison between the data acquired by the Meteor Trail Radar and that obtained from Rocket experiments. In particular, on May 13, 1971 data were obtained simultaneously by the MTR and a rocket launched by AFCRL. The reduction of the raw data for both systems is in progress, and the results are soon to be compared. This dual investigation of the atmospheric parameters mentioned in paragraph one will allow an evaluation of the effectiveness of the MTR as it is now being employed.

This station, being the Mark II version, is somewhat more sophisticated than that at Stanford. The newer station is capable of determining both the azimuth and elevation of the meteor trail being investigated. For these angle measurements four antennas were used, two for each parameter. A calibration of the antennas was conducted in March 1970 and we have found that the elevation angle of the meteor trail can be determined to within $\pm 1.5^{\circ}$ over a range from 30°-65°.

Future plans include the building of a two frequency station so that simultaneous measurements of the parameters we are investigating can be conducted. Theory indicates how the measurements of these parameters, e.g., density and wind profile, depend upon frequency and such a composite station would allow the verification of whether the theory is correct as used or if some modifications are necessary.

It would also be interesting to set up a multiple station arrangement to allow the direct measurement of turbulence in the upper atmosphere and perhaps thus finding the relationship between upper and lower atmospheric disturbances.

James M. Janky (PSE)

Low-Cost Microwave Adaptors for Direct Reception from Satellites

The aim of this NASA sponsored project is to:

1) Continue development of a 2.6 gHz single-channel receiver;

2) Begin development of a 12 gHz receiver system, in which the system parameters are part of the design;

3) Evaluate the interference effects which wideband FM television signals have on terrestrial AM television signals in the ITFS educational television band.

For the 2.6 gHz work, a number of improvements in the circuit design of the receiver have been incorporated. Also, a circular polarization capability is being developed. The next step is to fabricate a new mixer-feed housing which incorporates a new diode-mounting structure and new circuit-board compartments.

Considerable work has been done on the 10 segment antenna and is described by John Albernaz.

For the 12 gHz design, a number of alternative realizations have been identified as being feasible. Our first goal is to specify the best configuration as a function of noise figure. We then plan to specify the parameters which relate the subsystem, and to make a gross evaluation of the relative costs for each subsystem.

For the interference study, the main effort to date has consisted of planning the experiment. A list of prospective courses and professors has been assembled, and the necessary test equipment has been procured.

Jeremy A. Landt (PSE)

The Radio Propgation Experiment - Measurement of Average Interplanetary Electron Density

A large body of data has been acquired from five sun-orbiting spacecraft and from four earth satellites in geostationary orbits. By radio propagation means we have obtained measurements of the electron

content from earth to each of these craft, at various times in various sequences spread continuously over the last 5.5 years. Through processing and analysis it is possible to infer the electron content of the solar wind along the radio path above the orbit of the geostationary craft, effectively removing the influence of the earth's ionosphere and magnetosphere from the derived result. Dividing the interplanetary content by the spacecraft distance yields the average free electron number density of the solar wind along the radio path. During the past year, studies of these data and comparisons with other data have given new insight into the nature of the solar wind. My work has been concentrated on three main topics and results of this work is summarized here:

1) Geomagnetic field sudden increases or storm sudden commencements were compared with measurements of electron content of the solar wind. Measurements were examined during time periods which included 40 of the geomagnetic disturbances (gmd's) reported between January 1, 1966 and June 30, 1969.

These studies indicate that some widely reported solar wind discontinuities have been detected by the radio propagation experiment. Eleven of the 40 gmd's were classified as storm sudden commencements, which usually result when a shock in the solar wind strikes the magnetosphere. The relative timings of these 11 events are consistent with conclusions drawn from comparisons of experiment geometry to prevailing shock models, however, this evidence is not so conclusive that other models can be ruled out. Compared to the nature of these 11 events, the characteristics of the solar-

wind disturbances corresponding to the remaining 29 gmd's were generally found to have been less favorable for detection by the radio propagation experiment, but sharp changes in the content were clearly evident at the time of several minor gmd's.

These findings were presented at the Asilomar Conference on the Solar Wind in March 1971 and will be published in the proceedings of that conference. This study is also the topic of Scientific Report No. 4 (1971).

2) For measurements from January to March 1967, monthly averages of electron content (obtained with Pioneer 7) and proton number density (obtained by the Vela 3 spacecraft) were compared. These averages were found to be in agreement if the solar wind contained a helium abundance of 4% and if the wind spreads as the inverse square of the distance from the sun (both expected), provided a slight additive calibration error in content measurements exists for Pioneer 7. This study forms a base for comparisons of data for specific events.

3) The remaining topic was a study of an event in May 1968. During this event very high densities were measured in the solar wind near the earth by the Vela 4 spacecraft but only a moderate increase in content was measured. Several models of disturbance shape were considered, and of these, the least square error model covered less than 6^{o} in solar longitude in the ecliptic plane. Several arguments tend to rule out a broad model for this event.

It appears that the features of this disturbance can be explained by a model characterized by a dense region moving supersonically in the wind, preceeded by a shock, similar to the earth's magnetosphere-solar wind interaction and attendant bow shock. Several other features of this disturbance are very similar to the model of the earth-solar wind interaction of Spreiter et al. (in Physics of the Magnetosphere, D. Reidel, Dordrecht, 1968).

A similar event may have occurred in July 1966. For this event a threefold ambiguity resulted due to low signal strengths. However, one of the possible models was also very limited in extent. (J. A. Landt and T. A. Croft, J. Geophys. Res., 75, 4623, 1970).

In the near future, these studies will be expanded and the completion of a Ph.D. thesis is anticipated.

E. M. North (PSE)

Radio-Acoustic Sounding System

Equations have been derived indicating that coherent scattering of electromagnetic energy from an acoustic wave traveling through the atmosphere can be detected to a distance of several kilometers. A Radio-Acoustic Sounding System is being developed to remotely measure air temperature by monitoring the speed of an acoustic wave propagating vertically.

A preliminary experiment was performed with an acoustic frequency of approximately 85 Hz to determine the limitations of such a system. Results largely confirmed the derived equations and proved the practicality

of the method. Usable signal-to-noise ratios were obtained reliably to scattering heights of 1.5 km. No attempt was made in this experiment to measure temperature profiles.

Two RASS terminals are presently under development. One system will operate at a higher frequency (200 Hz acoustic signal) to reduce the size of components (antennas and acoustic array) necessary and check the frequency dependence of the scattering relations theoretically derived. The second terminal is a version of the original low frequency experiment, upgraded with much higher acoustic power and equipment to measure doppler frequency and thus temperature.

James G. Potter (PSE)

In response to funding from NASA for a study of domestic teleconferencing requirements, the emphasis of my work concerning satellite communication systems has shifted from small-user systems suitable for developing countries to more sophisticated systems tailored for U.S. requirements. I have focused on the feasibility of a dedicated satellite network to provide interactive continuing education to regional areas. It appears at this juncture that Stanford's ITFS program could be extended to the Western states at a cost (excluding teacher salaries and University overhead) of approximately $50 per student per course.

The cost-effectiveness of the system under consideration is limited by the need for audio feedback. Other investigations on the project are considering more limited feedback alternatives which would not severely limit class size--significantly enhancing the economics of a satellite distribution network.

We are rapidly acquiring detailed knowledge of the performance and cost of the main sub-components of a satellite ground station. Hopefully, this data will be of assistance in defining the potential of satellite communications systems for meeting a range of telecommunications requirements.

Calvin C. Teague (PSE)

Bragg Scatter Probing of Sea State

Analysis of the data from the March and August 1970 experiments has been extended to include an estimate of the background noise level. This estimate makes use of data in areas of the delay-doppler map outside the first-order Bragg region. Using this technique, the increase in noise level due to a nearby thunderstorm observed during one day of recording is clearly seen. A theoretical analysis is also being conducted to determine the required antenna directivity and optimum baseline lengths and orientations to provide a maximum unambiguous coverage of ocean-wave space. It is hoped that one or two loop antennas, properly phased, will provide sufficient directivity.

Construction of a new LORAN receiver is nearing completion. Two rate generators have been built and tested, one to lock to the desired signal, and one to provide a blanking function by locking to an interfering signal. Both generators make use of a tracking range gate to compensate for slight frequency offsets between the various LORAN stations and the receiver frequency standard. An A/D converter has been ordered. The digital data from the converter will be recorded in a serial PCM format on an analog tape recorder at either 5 to 10 kbits/sec. The PCM encoder and 1200-bit

buffer memory (necessary because the peak input data rate is many times the average data rate) is being completed and will be tested shortly. A loop antenna and slightly modified receiver RF section are currently being built. A bit and frame synchronizer, which will allow entry of the serial PCM information into the Sigma 5 computer, has also been completed and will be tested shortly.

An experiment using the new LORAN receiver is currently being planned for the latter part of August 1971, in an area of open ocean near Hawaii. The area and time were chosen by oceanographers at Scripps Institution of Oceanography to provide a sea which is homogeneous over several hundred kilometers. Thus, in contrast to the experiments along the California coast, the directional spectrum measured by the bistatic technique should be representative of the conditions over the entire observation area. Two orthogonal baselines are planned, using a master and slave LORAN pair in the Hawaii area, and a receiver on board a ship about 350 km from each of the transmitters. Antenna directivity will be used to resolve the ambiguities of the delay-doppler processing technique.

Steven G. Ungar (PSE)

Work on the present phase of the earth occultation study has been brought close to completion in the last six months. As described in the Semi-annual Status Report No. 16, the occultation project consists of two studies being pursued simultaneously. One is the analysis of radio propagation data obtained in Hawaii during the month of June 1970. The second is an error analysis for a proposed system to determine the altitude of a pressure level in the atmosphere.

In the Hawaii experiment, we have completed spherically symmetric raytracing through the index of refraction profiles (see Report No. 16). This analysis has shown a strong correlation between profiles obtained during periods of intense fading, and the occurance of multipath when these profiles are used in raytracing. In other words, it would appear that the fading observed in the radio signal was associated with multipath.

Since multipath is known to be a low altitude phenomenon, there is good reason to believe that the occultation system, which operates at a closest approach altitude of about 8 km, will not be affected.

Within the next month, horizontal gradients will be introduced into the Hawaii data, and these new profiles will be used in the raytracing program. In addition, the effect of the Hawaii data on a satellite-to-satellite path will be analyzed.

The second part of this phase of the occultation project, the error analysis of the pressure reference level system, has been completed. The proposed system will supplement pressure-temperature data supplied by passive IR sensors by fixing these profiles as a function of altitude. In the final error analysis, we used simulated data from an IR sensor, supplied by NOAA, to determine the accuracy obtainable from the occultation system. We have found that the system is capable of fixing the altitude of the 300 mb pressure level to within about 26 meters rms, if the temperature error of the IR profile is less than $2^{o}K$ rms, and if a climatological correction (however crude) is used to eliminate the effects of water vapor.

We have submitted a proposal to NASA to study the systems problems associated with flying the occultation experiment aboard the next available platform.

SECTION B
Recent Publications

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Symposia Attended and Papers Presented

V. R. Eshleman was on sabbatical leave from about 15 September 1970 to 15 June 1971. He spent from one to two months each at the NOAA Environmental Research Laboratories and the University of Colorado in Boulder, Colorado, at the Commonwealth Scientific and Industrial Research Organization's Division of Radiophysics in Sydney, Australia, at the European Space Research Organization's Space Technology Center in Noordwijk, Holland, and at the Comissão Nacional de Atividades Espaciais at São José dos Campos, São Paulo, Brasil. He discussed matters of mutual interest and presented a number of lectures on U.S. space research projects and results at these organizations and at other nearby institutions, including the National Center for Atmospheric Research, the University of Sydney, the University of Adelaide, University of Leiden, ESRO Headquarters in Paris, the ESRO Tracking Center in Darmstadt, the University of Madrid, the University of São Paulo, and the Geophysical Institute in Lima, Peru. In addition, he visited the NASA deep space tracking stations and offices in California, Canberra, and Madrid to continue his study of the potential scientific use of the tracking facilities for both radio astronomy and for experiments using earth-spacecraft links. A report is being prepared on this subject.

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