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Studies for Space Experiment Development

Final Report

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J. H. Pope, Principal Investigator

National Oceanic and Atmospheric Administration
Environmental Research Laboratories
Boulder, Colorado 80302

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1.0 Introduction

The purpose of this contract was to provide support of scientific feasibility studies of various space experiment ideas proposed by the scientific community. Two types of activities were undertaken. One of these was to provide expert advice and studies regarding certain aspects of NASA programs. The second was to encourage the conceptual development by ERL staff of certain space experiments.

In the second type of activity, a number of potential experiments were considered by the ERL Satellite Advisory Panel. Four of these proposed experiments were selected for support. The selection criteria included the following: 1) that the proposed experiments be related to an ERL mission; 2) that a competent member of the ERL staff is available to carry through the experiment; 3) that the experiment require further conceptual development before feasibility judgments could be made; and 4) that a small amount of financial support could help to make a significant contribution.

No attempt was made to support observational or experimental studies. The funds made available to the individual proponents were matched by ERL funds so that about $4K were made available to each of the four proponents selected.

2.0 ERL Space Experiment Studies

The four experiments supported were: Satellite lasers for atmospheric remote sensing; optical occultation techniques for planetary atmospheric studies; the use of operational satellite systems for ionospheric operational requirements; and geomagnetism by satellite studies. The several experiments are summarized below.

2.1 Satellite-borne Laser System for Atmospheric Remote Sensing

This study was carried out by G. T. McNice of the Wave Propagation Laboratory, ERL. The study was primarily to determine the feasibility of using satellite-borne lasers to observe atmospheric constituents by means of certain optical processes. These processes included Mie, Rayleigh, and Raman scattering, and fluorescence. Two types of observational modes are possible: The observation of backscattered radiation from the atmospheric gases, and the measurement of the energy reflected from the earth's surface or from clouds. The different phenomena were considered using the mode appropriate for the phenomenon under consideration. Signal-to-noise ratios for each of the phenomena were estimated under reasonable variations of several different parameters.

It was found that backscatter systems, although marginal, may be feasible for studies in the upper atmosphere, but will probably be severely attenuated in the lower regions of the atmosphere below an altitude of 15 km. In particular it is suggested that a backscatter system operating at wavelengths below 2900 Å could make measurements in the ionospheric regions because the reflected sunlight background would be absorbed by the ozone layer. All of the processes described could in principle be used to obtain, for instance, density profiles in these regions.

A number of uncertainties regarding absorption, fluorescence, Raman and resonance Raman spectra of the neutral and ionized states of the atmospheric constituents in the ultraviolet range need to be resolved before specific systems can be proposed. Thus a program in optical spectroscopy is recommended before the feasibility of using these techniques for satellite experiment can be established. Some of these are in progress in the Wave Propagation Laboratory on other resources. Depending on their outcome, a space flight program may be proposed.

2.2 Optical Occultation Experiments

The possibility of using optical occultation in the UV and X-ray regions was examined by R. B. Norton, Aeronomy Laboratory, ERL. As a part of this work, a study of the absorption spectra of various atmospheric gases was made and the literature searched for information on absorption cross-sections in the UV and X-ray regions. Various concepts were developed for utilizing the occultation technique for aeronomical studies which would complement ground-based efforts. Existing occultation data in the X-ray and ultraviolet regions obtained by the SOLRAD satellites are under analysis to obtain O_2 profiles. A proposal will be submitted to add photometric detectors to meteorological satellites such as the ITOS series or NIMBUS. This work would provide profiles of several atmospheric constituents.

2.3 Telecommunications Prediction Services

A team comprised of Barghausen, Wieder, Watts and Crombie, Institute for Telecommunications Sciences, and Cohen, Aeronomy Laboratory, conducted a study to determine the utility of satellites with respect to telecommunications predictions services.

They considered the use of satellites for measuring a number of ionospheric parameters by various techniques, including inverse beacon, topside sounding, and in situ. The parameters included F-region critical frequencies, sporadic-E, the measurements of virtual and true height of the F2 layer, absorption, and measurements of total electron content. They also considered the use of radio signals from geostationary beacons to provide disturbance warnings.

For tropospheric parameters, measurements of refractive index, atmospheric water vapor, and field strengths were considered. In addition, angle of arrival and signal strength measurements of transmissions from an orbiting satellite obtained by stations on the surface would provide information regarding tropospheric propagation to determine such things as tropospheric ducting.

Economic benefits were estimated. These estimates suggest the possibility that the costs of satellite systems may be somewhat less than the savings in terms obtained by increase in telecommunications utility resulting from improved predictions. The team will resume consideration of moving ahead on this matter when management considers the time to be ripe considering national and organizational priorities.

2.4 Satellite Magnetometers for Space Disturbance Forecasting

Magnetic measurements in space were considered by W. Campbell from the point of view of utility in space disturbance monitoring and forecasting purposes. In his review of magnetometers in space missions, several types were discussed, including the spinning coil, rubidium, fluxgate, and proton magnetometers. The rubidium magnetometer has the advantage of being able to operate over a large dynamic range, but temperatures must be carefully controlled, and power requirements are relatively large. For measurements in weak fields the saturable core fluxgate magnetometer has a number of advantages because of low power and weight requirements and non-critical temperature.

For space disturbance purposes, magnetometers should be placed in regions where the physics of the magnetospheric interactions are well understood. A spacecraft with a magnetometer in heliocentric orbit on the evening side of the earth beyond the range of the magnetosphere shock would provide a one-to-two day warning of space disturbances. Geostationary satellites which would monitor the magnetospheric reaction to solar disturbances could give several hour-to-1/2 day warnings of disturbances. The fluxgate type magnetometer is recommended for these purposes because of long-term reliability and low power and weight requirements. It is considered that the techniques are sufficiently developed for operational applications, perhaps as piggy-back on space science satellites, as well as on operational satellites such as GOES, the present planning for which now includes a magnetometer.

3.0 Sunblazer Study

In connection with a NASA program to make studies of the solar corona using radio signals transmitted by sun-orbiting spacecraft, an ERL team was assembled. The members of this team were Dryer, Fritz and Klemperer, all of Space Disturbances Laboratory, and Gallet, Office of the Director. The study, which was requested by Calvin T. Swift, NASA Langley, was made primarily to review the present state of knowledge with respect to the solar corona. The parameters considered for the solar corona include the electron density and spatial fluctuations in electron density, and how these parameters change with time. The best information available from the literature was used to obtain an electron density model of the solar corona extending as far as 1 AU.

The available literature regarding the properties of the solar corona was assembled by Murray Dryer. These results were used to provide values of electron density and other solar corona parameters such as particle velocity with respect to distance from the sun. He also considered the effects of magnetohydrodynamic "blast waves" released by solar flare eruptions.

The methods of obtaining electron density information in space by radio techniques were reviewed by Fritz. He considered the techniques such as Faraday rotation and phase shift measurements. Some of the particular difficulties that may be encountered in the Sunblazer program were pointed out. These include the problems associated with observing signals through the earth's ionosphere and sorting out the effects of variations in the ionosphere from those in the solar corona. One problem in particular is the fact that because of refraction, radio waves on different frequencies propagating close to the sun follow different ray paths on their way to the earth. He also considered the relativistic effects on electromagnetic radiation propagating in the solar gravitational field. One other problem involves the propagation of the radio waves at different angles with respect to magnetic fields. In some parts of the path propagation is longitudinal, while in others transverse. Since for transverse propagation there is no Faraday rotation, some difficulties can be expected in interpreting the results in terms of electron density by the Faraday rotation method.

Irregularities in the interplanetary medium as observed by the scintillation technique were considered by Klemperer and applied to the Sunblazer program. He considered the observational size of the irregularities with respect to receiver bandwidth and distance of the scattering irregularity. He suggested some advantages in using the coherent signals from a satellite may be obtained in determining the distance of the irregularities over those techniques which make use of random noise as from radio stars.

Klemperer has also addressed the problem of designing the very large and costly antennas needed to receive the relatively weak signal from the Sunblazer. In this discussion he makes use of the experience obtained in developing the large antennas for incoherent scatter studies of the ionosphere.

Further studies with respect to the Sunblazer program were terminated because of NASA's cancellation of that program.

4.0 Scintillation Study

One phenomenon that affects radio signals propagating through the ionosphere is that known as scintillations. Scintillations are caused by field-aligned irregularities and are predominant in the polar and equatorial regions. This phenomenon needs to be considered in designing communications systems using satellites. Since this problem has a bearing on the aeronautical communications satellite system under consideration, Thomas Golden, of Goddard Space Flight Center, NASA, requested that we conduct a study to establish the scintillation effects on the S-band frequencies and to compare them with scintillations on VHF.

For this study, which was conducted by J. H. Pope, Office of Programs, and R. B. Fritz, Space Disturbances Laboratory, the AGC records obtained at the NOAA CDA station at Gillmore Creek, Alaska, were made available. These records contained simultaneously the received power levels at 137 and 1695 Mc/s. The records, covering a period of about 40 days during March and April, 1970, were examined and the scintillation amplitudes scaled.

Scintillations were detected at S-band frequencies, and these scintillations were found to have a general correlation with VHF scintillations. Elevation angle and bearing angle dependence, and diurnal variations were established for the two frequencies and were found to have nearly identical characteristics on the two frequencies. Instrumental limitations imposed a threshold on the S-band channel that was greater than the amplitude of S-band scintillations that would be obtained by $1/F^2$ extrapolation of the VHF amplitudes. When the S-band scintillations exceeded this threshold, it was found that the VHF scintillations were in general close to saturation. The weak scatter theory that is used for scintillations would predict a frequency dependence with an exponent of between 1 and 2. The S-band scintillations, however, were such that the exponent was somewhat less than 1, indicating a breakdown in the weak scatter theory, at least during conditions under which the S-band scintillations were observed.

The results are to be published in a NOAA Technical Report, "High Latitude Scintillation Effects on VHF and S-band Satellite Transmissions," by J. H. Pope and R. B. Fritz.

5.0 Interaction with NASA Personnel

More detailed though less formal reports on each of the studies were provided in a timely fashion to the appropriate NASA personnel, and in particular the scientific monitor, Dr. E. R. Schmerling. The full reports on the Sunblazer and Scintillation studies were shared and discussed with Mr. Swift and Mr. Golden, respectively. This final contract report is intended as a summary of all contract activities.