UNIVERSITY OF CALIFORNIA

SPACE SCIENCES LABORATORY

BERKELEY, CALIFORNIA 94720

SPACE SCIENCES SYMPOSIUM

OCTOBER 28, 1966

HAAS CLUB HOUSE

A review of research on the Berkeley campus supported by the National Aeronautics and Space Administration

Space Sciences Laboratory
University of California
Berkeley, California 94720

ABSTRACTS

OF RESEARCH PROJECTS ON THE BERKELEY CAMPUS

SUPPORTED BY

THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Space Sciences Symposium
October 28, 1966
Haas Club House

INDEX

INDEX TO INVESTIGATORS AND PRINCIPAL EXPERIMENTERS

FOREWORD

The total research program in space science and space exploration at Berkeley embraces virtually every aspect of the physical, biological, and engineering sciences, as well as research in the social sciences. The purpose of this Space Sciences Symposium is to review some of the research efforts and to illustrate how research and education are tied together into an effective University program.

Since the construction of the Space Sciences Laboratory was made possible through a grant from the National Aeronautics and Space Administration, we have reviewed only NASA-supported research projects here. It should be pointed out, however, that considerable support for many space science projects is received from other agencies, such as the National Science Foundation, the National Institutes of Health, the Office of Naval Research, and the U. S. Air Force. A comprehensive summary of all research in the Laboratory may be found in the current Space Sciences Laboratory Semi-Annual Progress Report.

The Space Sciences Laboratory was established to develop a multi-disciplinary program of faculty and graduate student research in the space sciences and to provide special services and facilities for space experimentation in, for example, balloons, rockets, and satellites. Although many faculty members conduct their research individually, within the framework of their own departmental structure, others conduct their research in the Space Sciences Laboratory. The resulting complex administrative relationships are indicated in this booklet by the investigator's

departmental association and his relationship, if any, with the Laboratory. All research at Berkeley is reviewed and administered by the Campus Research Office, under the direction of Sanford S. Elberg, Dean of the Graduate Division.

It is a pleasure to note the enthusiastic cooperation of the faculty investigators in the preparation of the program.

Samuel Silver, Director
Space Sciences Laboratory

October 28, 1966

SPACE SCIENCES RESEARCH AT BERKELEY

University of California

Program Review

Haas Club House, Strawberry Canyon Road, Berkeley Campus

October 28, 1966, 9:00 a. m. - 4:00 p. m.

9:00 Welcome

9:10-9:40 Introduction and General Prospectus

"Education and Research in the Space Sciences at Berkeley"
Prof. Samuel Silver, Director of the Space Sciences Laboratory, Berkeley

9:40-10:20 Planetary Physics

"Infra-red Experiment for the 1969 Mariner Mission"
Prof. George C. Pimentel, Department of Chemistry and Space Sciences Laboratory

"Infra-red Instrumentation for Planetary Research"
Dr. Donald G. Rea, Space Sciences Laboratory

10:20-10:40 Coffee break

10:40-11:20 Exobiology and Related Research

"Chemical Evolution"
Prof. Melvin Calvin, Department of Chemistry and Molecular Biology; Director of the Chemical Biodynamics Laboratory

"Chemistry of Living Systems"
Prof. Thomas H. Jukes, Department of Medical Physics and Space Sciences Laboratory

11:20-12:00 Space Physics

"Balloon, Rocket, and Satellite Investigations of Solar-Terrestrial Interactions and Related Phenomena"
Prof. Kinsey A. Anderson, Department of Physics and Space Sciences Laboratory

"High Altitude Nuclear Physics Project"
Dr. William Humphrey, Lawrence Radiation Laboratory

12:00-1:30 Lunch

1:30-2:10 Physiological Problems

"Protein and Caloric Requirements in Men--The Penthouse Experiment"
Prof. Sheldon Margen, Department of Nutritional Sciences

"Primate Hemodynamics and Metabolism in Weightlessness"
Prof. Nello Pace, Department of Physiology

2:10-2:50 Social Sciences

"Management Science and Decision Making"
Prof. C. West Churchman, School of Business Administration and Associate Director of the Space Sciences Laboratory

"Technological Utilization-Application to Urban Problems"
Prof. Melvin M. Webber, Department of City and Regional Planning and Acting Chairman of the Center for Planning and Development Research

2:50-3:30 Engineering Science

"Space Science and Technology in the College of Engineering"
Prof. George J. Maslach, Dean of the College of Engineering

3:30-4:00 General Discussion

NASA Contract NAS 3-5743

INVESTIGATION OF KILOVOLT ION SPUTTERING

Principal Investigators: Harold P. Smith, Jr.,* Department of Nuclear Engineering and Space Sciences Laboratory

Franklin C. Hurlbut, Department of Mechanical Engineering (Aeronautical Sciences)

Thomas H. Pigford, Department of Nuclear Engineering

I. Introduction

Present studies are under way to investigate the interaction of various particles (heavy ions, protons, and photons) with material surfaces. The particles, when incident upon a material surface, transfer part or all of their energy to the lattice atoms and electrons, giving rise to many secondary particles (atoms, ions, electrons, and photons) being ejected from the crystal lattice. These secondary particles are being observed to determine the nature of the incident particle-crystal lattice interaction.

II. Heavy Ions

The heavy ion experiments have utilized cesium and mercury ions of 1 to 10 keV energy to bombard single crystal targets of copper, aluminum, molybdenum, and nickel. The energy loss of the incident ion results primarily in the ejection of neutral lattice atoms (a phenomenon called sputtering) and electrons. Extensive angular distribution measurements

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* 1966-67 White House Fellow, Washington, D.C.

made using radioactive tracer and neutron activation techniques have verified that the target crystalline state has an effect on the angular distribution, but this effect is smaller than was previously expected.

Work presently under way: (a) the implanted cesium ion distribution is being measured in targets of aluminum, copper, and silicon; (b) the energy spectrum of the sputtered atoms is being measured using a pulsed beam-time of flight method; and (c) the secondary electron yield dependence on ion beam-target orientation is being measured for single crystal targets.

III. Protons

The proton induced characteristic x-ray yields will be measured for 10 to 100 keV protons incident upon anodized aluminum films of known thickness. From the thin target and thick target results, the oxygen x-ray production cross section and the stopping power for protons in anodized aluminum as functions of proton energy can be determined.

IV. Photons

The interaction of laser pulses with material surfaces is being investigated by using low energy electron diffraction to determine the threshold for lattice damage and to see if contaminated surfaces can be cleaned with lasers. Also, using a time of flight technique similar to that in the heavy ion experiments, the energy spectrum of the various particles emitted during laser bombardment will be measured.

NASA Contract NAS 5-2222

SOLAR COSMIC RAY EXPERIMENT FOR THE FIRST ORBITING GEOPHYSICAL OBSERVATORIES

Principal Investigator: Kinsey A. Anderson, Department of Physics and Space Sciences Laboratory

The object of this experiment is to study the high energy solar protons that are emitted from solar flares. Experiments concern the place of origin in the solar atmosphere of the electrons and protons. These studies now appear to show that the protons are accelerated deep in the solar atmosphere in the chromosphere, while the electrons are accelerated high in the corona.

This experiment has been carried aboard the OGO-1 and OGO-3 spacecraft.

Work done on this contract is a continuation of that begun under Contract NAS 5-9094.

NASA Contract NAS 5-2989

ENERGETIC PARTICLE STUDIES ON INTERPLANETARY MONITOR SATELLITES

Principal Investigator: Kinsey A. Anderson, Department of Physics and Space Sciences Laboratory

The purpose of these experiments is to explore energetic particle phenomena at large distances from the earth. The two main areas of interest are particles in the Van Allen Radiation Zones and solar particles in interplanetary space. The satellites IMP-1, 2, and 3 have provided a large amount of data on both of these topics. A brief synopsis of the several experiments carried out is presented here.

1. Experimental evidence was found for three distinct spatial regions in the Van Allen Zones that could be characterized by the number of periodicities possessed by the particles. The innermost region is called the stable trapping zone, in which the particles are triply periodic, that is, they gyrate around the geomagnetic field lines, bounce between mirror points, and drift around the earth. In the skirt region, the particles gyrate and bounce but do not drift around the earth. Finally, there are regions from which particles escape the influence of the earth by gyrating along geomagnetic lines of force that connect to interplanetary field lines.

2. In the region of the magnetosphere behind the earth (geomagnetic tail) it has been found that the plasma is unstable, with energetic particles often having a higher energy density than the magnetic field.

3. It has been found that long wave length hydromagnetic waves in the magnetosphere are strongly coupled to the Van Allen particles. Particles

undergo large changes in energy due to the influence of such waves. Related to this are observations on particle acceleration in the bow shock due to the solar wind interaction with magnetosphere. This bow shock is a hydromagnetic wave disturbance, which also results in large changes in particle energy.

4. It has been found that electrons emitted from solar flares travel inside cones of propagation to the earth. Within these cones, the electron flux is usually anisotropic. These experiments have changed considerably. ideas about particle propagation in the interplanetary field.

5. Experiments on these satellites have shown that some field lines in the geomagnetic tail connect directly to the interplanetary magnetic field. An upper limit to the length of the geomagnetic tail also has been set by these experiments.

NASA Contract NAS 5-9077

ENERGETIC PARTICLE STUDIES ON THE LUNAR ANCHORED IMP SATELLITE

Principal Investigator: Kinsey A. Anderson, Department of Physics and Space Sciences Laboratory

The objectives of this experiment are much the same as those described under NASA Contract NAS 5-2989. The unusual orbit of the satellite allows the measurements to be carried out at a large, fixed distance from the earth. The first of these satellites failed to attain the lunar orbit but did achieve an earth orbit of very high apogee. This satellite is obtaining data simultaneously with the IMP-3 satellite. This has permitted comparison of particle arrival times at two widely separated points in space.

NASA Contract NAS 5-9091

ENERGETIC PARTICLE STUDIES ON THE INTERPLANETARY MONITORING PLATFORM SATELLITES F AND G

Principal Investigator: Kinsey A. Anderson, Department of Physics and Space Sciences Laboratory

The scientific objectives of these experiments are the same as those for the IMP-1, 2, and 3 satellites described under NASA Contract NAS 5-2989. The orbit of the IMP-F and G satellites will permit exploration of phenomena at the high altitude boundary of the Van Allen Radiation Zones.

NASA Contract NAS 5-9094

ENERGETIC RADIATION FROM SOLAR FLARES

Principal Investigator: Kinsey A. Anderson, Department of Physics and Space Sciences Laboratory

A modified and improved version of the OGO-1 and 3 experiment is being prepared for the OGO-E spacecraft under this contract. This new experiment will measure in a more complete fashion x-rays, electrons, protons, and alpha particles from the same solar flare. From this information, self-consistent models will be sought to explain the energetic particle features of solar flares.

NASA Contract [illegible]

[illegible] OF MOTIONS OF ARTIFICIAL SATELLITES

Principal Investigator: Leland E. Cunningham, Department of Astronomy

One of the principal problems undertaken in this project was the development of precise methods for the numerical integration of the orbital and rotational motions of artificial earth satellites. Effects of gravitational, drag, and magnetic torques were included in the integration of the rotational motion. One integration procedure took into account the discontinuous drag torques due to the shape of the satellite. These programs have been used to provide material for planning and for comparison with theory.

A second problem was the representation of the rotational motions of Pegasus A, B, and C as observed by the on-board sun and earth sensors. A formulation partly empirical and partly theoretical has led to a satisfactory representation of the orientation observations over an interval of one or two weeks. Work now in progress applies this formulation to the entire life of the three satellites as a prelude to a study of their rotational motions over many months.

NASA Contract NASr 112

DEVELOPMENT OF AN INFRARED SPECTROMETER SUITABLE FOR SPACE VEHICLE STUDY OF PLANETARY ATMOSPHERES

Principal Investigator: George C. Pimentel, Department of Chemistry

Under this contract, an infrared spectrometer is being developed for the study of the Martian atmosphere. This instrument has been selected as one of the six experiments to constitute the scientific payload of Mariner Mars 1969. It will record infrared spectra reflected and emitted from Mars through the Martian atmosphere in the spectral region 6500-650 cm^{-1} (1.5 to 15 microns) during the flyby period.

Such spectra will provide information relevant to the possibility, now or in the past, of life on Mars. The spectral region selected is the optimum for detection of organic molecules as well as all of the common polyatomic molecules that might be present in the atmosphere: methane, carbon dioxide, water, nitrous oxide, nitrogen dioxide, ozone, and so on. In addition, thermal mapping of the planet may provide clues to the nature of the light and dark areas on the planetary surface.

NASA Contract NASr 220

DEVELOPMENT OF A SCANNING SYSTEM FOR THE MARINER SPACECRAFT

Principal Investigators: Melvin Calvin,* Department of Chemistry and Space Sciences Laboratory

Samuel Silver,** Department of Electrical Engineering and Space Sciences Laboratory

Project Director: Donald G. Rea, Space Sciences Laboratory

In 1964 a contract was received to construct a device -- the "Mars Scanner" -- to be included in the 1966 Mariner flyby of Mars. Shortly thereafter the mission was canceled but funding of the project continued with a two-fold purpose: developing hardware for spacecraft observations of Mars, and carrying out pertinent supporting research in the laboratory. Since then, the hardware program has been primarily one of developing a visual display system for the data and of modifying the Scanner for convenient operation in the laboratory and in the field. The instrument itself is intended to produce maps of the surface temperature, the surface near infrared brightness, and the atmospheric water vapor composition. The first and last of these are particularly important in considerations of surface phenomena, including conditions for the existence of life. The supporting research has been integrated with the corresponding program in NsG 101-61 and is described in the paragraph on Mars.

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* Also, Director of the Chemical Biodynamics Laboratory.

** Also, Director of the Space Sciences Laboratory.

NASA Grant NGR 05-003-067

STUDY OF GROWTH IN RECENT AND FOSSIL INVERTEBRATE EXOSKELETONS AND ITS RELATIONSHIP TO TIDAL CYCLES IN THE EARTH-MOON SYSTEM

Principal Investigator: William B. N. Berry, Department of Paleontology and Space Sciences Laboratory

Shells of most intertidal-dwelling pelecypods and gastropods are formed of many minute growth increments. These minute growth increments are commonly grouped in some manner to larger bands or clusters of increments. Similar growth increments, both minute and large bands, may be observed in fossil shells. The increments in the fossil shells are interpreted to be related to the same basic environmental phenomena as are the increments in the modern animals.

Observations in Modern Animals

The growth increments of many intertidal-dwelling pelecypods and some gastropods are related to environmental rhythms such as day and night and the fortnightly tidal cycles. Some are clearly related to the diurnal tidal cycle. For example, the common mussel Mytilus edulis was observed for a period of one year from the time the larvae attached to posts placed in a local tidal flat. The shells were measured periodically through the year, and at the end of that time, the posts were taken to the laboratory for study. The shells of this pelecypod were observed to have twelve large growth bands, each of which was composed of small growth increments that reflected diurnal growth additions. Many modern pelecypod shells have been studied closely and a number found to have growth increments reflective of a similar close relationship with the diurnal tidal

cycle. Many of these pelecypods have been observed to have major growth bands reflective of either fortnightly or monthly clusters of the smaller growth increments.

A laboratory experiment has been constructed in which several species of pelecypods have been placed in aquaria under different environmental conditions. In these experiments, several individuals of the same species are placed together in a tank. In one tank, the environmental conditions are held as closely as possible to those at the place from which the animals were taken. For each of the other tanks housing the same species, the tidal cycles have been changed from the normal condition. In some, they have been lengthened; in others, they have been shortened. There are at least four different tidal cycles being used for each of the species under study. In addition, the duration of darkness and the corresponding duration of the period of light under which the pelecypods are living has been changed from the normal condition. Some of the pelecypods appear to be adding growth increments in response to the controlled environmental condition.

Observations in Fossil Shells

A great many fossil shells have been studied to determine those that are preserved well enough to reveal growth increments. Many of the fossil shells do not have the smallest growth increments preserved. Many others have only partial cycles of large and small growth increments preserved. Despite the problems imposed by preservation, some shells from many of the geologic Periods have proven useful to this study. The study has been confined to an investigation of the shells of those pelecypods and gastropods that apparently were living in the intertidal and that have related

species living there. The intertidal dwellers have been used because this is the interval in which tidal phenomena are in most direct contact with the animals. A great many animals that live beneath the intertidal, it has been found, do not add growth increments to their shells in any apparent direct relation to the tidal cycles.

The growth layers in both fossil and modern pelecypods have been found to have one of six different basic patterns. The basic patterns are most clearly seen by studying the shells in thin section and by photographic enlargements of the shells of such size that even the smallest increments may be seen and counted accurately.

Using the patterns of shell growth increments observed in both fossil shells and their modern counterparts, the periods of growth have been determined. Because the modern relatives of these fossils apparently add growth increments in relation to tidal phenomena, the growth increments counted, both the most minute and clusters of them into larger bands, have been considered similarly to reflect addition to the shell in response to tidal phenomena. The study of the shells has been centered on the best preserved specimens available; thus, to date, enough shells to give significant results have been studied from only a few parts of the geologic record.

Conclusions

The study of the fossil shells has indicated that the number of months per year has decreased slowly and continuously from 13 in the Carboniferous (approximately 300 million years ago), to 12.5 in the Cretaceous (approximately 100 million years ago), to 12 at the present time. Further, there appear to have been somewhat more days per synodic

month in the Cretaceous than at present. The data from the mid-Tertiary suggest that this decrease has been going on continuously, as is true of that for number of months per year. These data suggest that changes in distribution of angular momentum have taken place within the earth-moon system during prehistoric time.

NASA Grant NGR 05-003-068

CLINICAL NUTRITIONAL STUDY OF MINIMUM PROTEIN AND CALORIC REQUIREMENTS FOR MAN

Principal Investigators: Sheldon Margen, Departmental of Nutritional Sciences

Doris H. Calloway, Department of Nutritional Sciences

Because of engineering and logistic problems in space flights of either short or long duration, it is important that nutrition be adequate but minimal. "Adequate but minimal" nutrition means the nutritional status that will maintain biochemical, physiological, and psychological functions (i.e., maintain the total performance capacity of the individual without impairment). Since lack of space with concomitant lack of activity may offer serious physiological impairment and the relationships of activity and nutrition are important in maintaining capabilities of the subjects, these problems have been investigated.

The purpose of the studies already carried out under this grant has been to determine the minimum amount of protein necessary to maintain men fully fit with respect to a variety of biochemical, physiological, motor, and psychological criteria. This information is needed (1) to assure that protein needs are met by any stored or regenerative food system, and (2) to serve as a criterion of caloric adequacy in future studies of this dietary variable. The primary technique used in the studies is the determination of external metabolic balances, but the studies are unique in that all routes of nitrogen loss from the body have been measured: urinary,

integumentary losses, and solid waste and gaseous losses from the intestinal tract. In addition to investigations of nitrogen balance, extensive studies of body composition, mineral balances, blood chemistry, physiological responses, psychological alterations, and, in conjunction with the Space Sciences Laboratory, studies of socio-legal changes have been carried out. Experiments of 60 and 88 days' duration were designed to test the hypothesis that the amount of nitrogen excreted during the consumption of a protein-free but otherwise nutritionally adequate diet represents the absolute minimum value tenable as an expression of dietary protein need. Results of the studies generally support the hypothesis. However, when high-quality protein in an amount equal to endogenous loss was fed, nitrogen output did not vary appreciably from values recorded during nitrogen deprivation, but balance was not achieved.

Another important finding has been that the amount of calcium lost in the urine is directly proportional to the dietary intake; at low protein intake the urinary calcium loss is slight, and calcium loss increases as dietary protein increases. In addition studies have been carried out on the effects of the alteration of energy intake and work output on these variables. These results have demonstrated that complete chair and bed rest has little effect on protein requirements but does lead to increased calcium loss from the body. However, this calcium loss can be overcome, at least in part, by altering the dietary protein level.

Future experiments will continue to investigate the effects of these observed variables and will be concerned with the determination of maximal

protein tolerance of man, studies of carbohydrate requirements, and further work on protein-energy relationships and the effects on man of "unusual" foodstuffs.

NASA Grant NGR 05-003-080

MULTISPECTRAL PHOTOGRAPHIC EXPERIMENT BASED ON A STATISTICAL ANALYSIS OF SPECTROMETRIC DATA

Principal Investigator: Robert N. Colwell, School of Forestry

With only slight modification, a vehicle capable of carrying astronauts to the moon should also be able to orbit the earth for prolonged periods of time and in accurately prescribed orbits. The question therefore arises if such an earth-orbital version of the Apollo vehicle might be able to acquire information that would enrich man's life here on earth.

A major factor that will govern man's future comfort on earth is the intelligence with which he manages his rapidly dwindling supply of natural resources. An important first step toward the more intelligent management of these resources would be to obtain a more accurate inventory of them. For many years man has been using aerial photography and related imagery as aids in the inventory of these resources. Now he seeks to determine whether space photography and related imagery, flown from earth-orbital altitudes perhaps 100 times greater than previously possible, might be even more useful.

Consistent with this rationale, NASA is currently engaged in an active Natural Resources Program. Under this program, personnel of the School of Forestry on the Berkeley campus of the University of California are doing research primarily in wildland resources (e.g., timber, forage, minerals, fish, and wildlife). However, through their affiliation with the University's College of Agriculture, they continue to exhibit an interest of many years' standing in certain cropland resources (e.g.,

orchards, vineyards, cereal crops, and vegetable crops). They also continue to work with resources that are found on both wildlands and cultivated lands (e.g., soils, water, minerals, and livestock). Consequently, while undertaking NASA-financed research in the natural resources field, they also are vigorously continuing their closely related research programs with financial support from other agencies, and virtually all of the findings from this multifaceted research effort are proving to be highly relevant to the NASA Natural Resources Program.

The primary objectives for these research projects are:

1. To set forth clearly the specific kinds of information needed for more intelligent management of the resources (e.g., timber volume by species, size class, and topographic site; agricultural crop yield by type, vigor class, and location);

2. To determine the optimum specifications for photography and related imagery that will permit these kinds of inventory data to be obtained from aircraft and/or earth-orbital vehicles;

3. To determine the accuracy with which the desired identification can be made from a study of imagery flown to these specifications over representative areas for which ground truth is accurately known; and

4. To compile photo interpretation keys and other reference materials for operational use by those who soon will be called upon to make the desired natural resource inventories from such imagery.

Results achieved to date, both by the aforementioned personnel of the University of California and by their NASA-financed colleagues in many other institutions, show great promise for the eventual use of space vehicles in the global inventory of natural resources.

NASA Grant NGR 05-003-089

INVESTIGATION OF THE NUTRITIONAL PROPERTIES OF *HYDROGENOMONAS EUTROPHA*

Principal Investigators: Doris H. Calloway, Department of Nutritional Sciences

Sheldon Margen, Department of Nutritional Sciences

The object of the research under this project is to determine the nutritional quality of the hydrogen-fixing bacterium, *Hydrogenomonas eutropha*, as a basis of a bioregenerative system for atmospheric control during prolonged space flight.

Because of the relative scarcity of experimental material, initial studies were limited to analysis of bacterial samples and determination in mice of digestibility and physiologically available energy.

Quality of the protein of *H. eutropha* cells was determined by measuring nitrogen balance in rats fed the bacteria as the sole source of protein. Casein was used as a reference protein. Digestibility (net absorption) of *H. eutropha* nitrogen was 93% compared with 99% of casein nitrogen. Biological value (retention) was 77% of absorbed nitrogen in both cases, indicating a good balance of essential amino acids.

Washed dry cells were found to contain 74 mg% of chloride and 42 mg% of magnesium. Mixed solvent systems extracted 9.39% of lipids, of which at least 3.29% were protein-bound. Vitamin E content is substantial (5.76 mg of α-tocopherol per 100 g dry cells) but the organism contains no vitamin A.

Since the biological quality of bacterial protein is higher than would be expected on the basis of published amino acid composition data and since the published analysis does not account for all of the protein nitrogen present, it is planned to carry out laboratory tests of amino acid composition of all lots of H. eutropha received. In addition, total carbon and nitrogen balance studies of six diet groups of mice will be made.

NASA Grant NGR 05-003-090

STUDY OF ENVIRONMENTAL EFFECTS ON CELLULAR AUTOXIDATION

Principal Investigator: Daniel B. Menzel, Department of Nutritional Sciences

Working on the hypothesis that oxygen toxicity is a result of increased lipid peroxidation, three fields of effort have been developed: first, in vivo peroxidation effects on cell membranes have been measured using rats exposed to 100% oxygen at 260, 400, 600, and 760 mm Hg; second, an in vitro method of studying membrane oxidation has been developed using isolated rat kidney lysosomes; third, a new reaction involving the products of lipid oxidation, malonaldehyde, and other thiobarbituric acid reactive substances has been discovered and investigated. Rats exposed to 100% oxygen grew less than those exposed to air. Oxygen-exposed rats showed changes in their lysosomal enzymes in lung and brain tissue. The lung showed the most dramatic changes, while inhibition of brain lysosomal enzymes was noted. Liver lysosomes showed latent changes in the lysosomal membrane indicating that very subtle effects from oxygen exposure hitherto may have gone unnoticed. The effect of oxygen exposure on liver lysosomes was potentially harmful, however, since the lysosomes were more susceptible to physical damage. Brain lysosomes were found to be too fragile for use in preparative studies, while kidney lysosomes were isolated free of major mitochondrial contamination. An in vitro system for the study of the mechanism of lipid peroxidation and protective agents has been developed using kidney lysosomes. The effects of salts, pH, and osmolarity of the medium have been studied. The in vitro assay is being applied also to kidney lysosomes of oxygen-exposed rats. Aldehydes produced

during lipid oxidation have been demonstrated for the first time to react with proteins and amino acids. Polymerization of ribonuclease -- a lysosomal enzyme -- results from reaction with aldehydes, and the polymers are less enzymatically active than the native enzyme. The relationship of the aldehyde-protein reaction product to oxidized lipid-protein polymers is discussed, as well as the role of aldehyde-polymers as "age pigments." Preliminary studies indicate that a further outgrowth of this study will be evidence supporting the hypothesis that Vitamin A rather than Vitamin E is the limiting factor in the antioxidant deficiency syndrome. Electron microscopic studies of the lysosomal and mitochondrial membrane of oxygen-exposed animals is in progress.

In summary, the above results support the original hypothesis that exposure to increased oxygen pressure and to 100% oxygen results in an increased rate of lipid peroxidation in rats.

NASA Grant NGR 05-003-096

MULTIPLE BALLOON STUDIES OF ELECTRON PRECIPITATION

Principal Investigator: Robert R. Brown, Department of Physics

This project involves simultaneous study of features of electron precipitation by means of balloon-borne instruments, spaced by differences of the order of 100 km. The purpose is to examine features of the spatial extent of fast time variations in the electron flux as well as the spectra of bremsstrahlung x-rays within the atmosphere.

A series of balloon flights was carried out in the summer of 1966 from Ft. Wainwright, Alaska. These flights were made during some of the most intense solar activity of the present cycle and have yielded large numbers of high intensity events for study. It is anticipated that almost a year will be required to reduce the data, but from the data analysis will come the information sought after in this investigation.

NASA Grant NGR 05-003-118

NUTRITIONAL REQUIREMENTS AND BREEDING BEHAVIOR OF PEROGNATHUS

Principal Investigator: Rosemarie Ostwald, Department of Nutritional Sciences

Animals of the genus Perognathus (pocket mouse) have a number of characteristics that make them promising tools for the investigation of the effects of prolonged space flight on mammalian physiology. They are among the smallest known mammals, they do not require drinking water, and they are both hibernators and estivators. Their size and frugal life requirements permits use of a large number in small experimental packages. The ease with which they can be induced to hibernate and to estivate makes these animals suitable objects for the fuller investigation of the physiological aspects and consequences of prolonged periods of artificially induced retarded rates of metabolism. Thorough knowledge of these phenomena is of importance in any manned space flight of long duration.

Under this grant, attempts will be made to develop a colony of these desert rodents in order to have a reliable, steady supply of animals of known age and history for long-term studies. Neither the nutritional requirements nor the conditions suitable for their breeding are well known. Therefore, both of these areas are objects of this study.

The nutritional requirements will be investigated (a) by analysis of the usual diets of these mice, and (b) by the response of these animals to experimental diets. These diets will initially be chosen to resemble diets successful in the feeding of laboratory mice and/or of other desert rodents. These diets will then be developed to obtain an adequate

semi-synthetic diet, which can be modified to study the requirements of any nutrient of interest. The adequacy of a diet will be judged by the maintenance of weight and the usual signs of good health and normal behavior.

The breeding behavior will be studied by accepted animal husbandry methods. Special emphasis will be placed on the influence of the diet on breeding and reproductive capacity, as well as the influence of such environmental conditions as the light, temperature, and humidity of the animal room, number of animals per cage, and bedding and nesting material and places.

For use as a base line in setting nutritional requirements, weight records of a representative number of P. baileyi, P. penicillatus, and P. longimembris fed a mixed seed diet ad libitum were analyzed. Unexpected weight fluctuations were observed consisting of periods of 30 to 40 days of weight gain followed by weight loss amounting to 15-25% of body weight. This periodicity may be of importance in their "hibernation" behavior.

Two diets based on natural ingredients have been found that are well accepted by the animals and may be satisfactory basal diets. One is a commercial Purina mouse breeder chow, the other a pelleted diet made of sunflower meal and millet flour. A number of semi-synthetic diets look promising, but more time is needed because of the weight fluctuations on the natural mixed seed diet noted above.

Behavior records and pictures are being obtained of moulting of coat, "sand-balling," use of "nest boxes," storage of food, and activity cycles. Response to handling is good. Even P. longimembris can become quite "tame."

Work is underway to obtain data on such physiological characteristics as respiratory exchange, organ weights, body composition, and composition of blood (glucose, proteins, lipids). Preliminary experiments on tolerance to anesthesia and surgical trauma show that plans for the study of the rate of liver regeneration are feasible.

In the breeding program, success has been minimal to date. Large groups of P. penicillatus and P. longimembris, maintained at 78-80°F under natural light conditions and fed a mixture of seeds, have been observed for the occurrence of estrus. Only 3 or 4 animals were found between May and September to be in estrus and they failed to breed. A number of dietary variations were tried without any success.

Experiments in progress concern the manipulation of light-dark periods and of climatic variables of temperature and humidity in a controlled environmental chamber, and the administration of hormones, both estrogen and gonadotrophines, by injection and in the feed.

NASA Grant NGR 05-003-125

TECHNOLOGY AND URBAN MANAGEMENT

Principal Investigators: C. West Churchman,* School of Business Administration

Melvin M. Webber, Department of City and Regional Planning

The objective of the study of the Technology And Urban Management (TAUM) is to create a prototype for the systematic application of social and physical technology to the solution of urban problems.

The objective is similar in intent to the goal of NASA-supported centers for technological utilization by industry, but the methodology differs radically. A superficial examination of the problems of large cities shows that many technologies already available that the cities could use are: information systems, police two-way radios, lighter fire fighting equipment, and so on. Often the problem is not the technology per se, but either the budgetary constraints or the appropriateness of a public agency's use of the technical devices. Consequently, TAUM has been designed to provide as complete an understanding as possible of the nature of urban management as it relates to technological applications. This aspect of TAUM is a prelude to the creation of a feasible "shopping list" of techniques for urban use.

Oakland was chosen as the prototype city, after extensive discussions with the mayor, city manager, and other city officials. Work was begun

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* Also, Associate Director of the Space Sciences Laboratory.

in the spring of 1966. A study of the budgetary processes of the city has been initiated in order to attain a realistic picture of how change can occur. A detailed systems analysis of the fire department is nearing completion, this department having been chosen as the first for study because so many of its problems suggest engineering applications. The police department of the city will be studied next. A technique is being developed that will facilitate the translation of urban needs as expressed by the manager into the language of technology; this project should cast considerable light on the meaning of technological innovation. Finally, a conceptual model of urban management is being designed that will include the many variables in decision-making.

NASA Grant NGR 05-003-134

DEVELOPMENT OF ANALYTICAL INSTRUMENTATION AND COMPUTER TECHNIQUES FOR THE IDENTIFICATION OF LUNAR ORGANIC MATTER RETURNED BY APOLLO MANNED LUNAR LANDING MISSIONS

Principal Investigators: Alma L. Burlingame, Department of Chemistry and Space Sciences Laboratory

Melvin Calvin,* Department of Chemistry and Space Sciences Laboratory

This grant covers the initiation of a unified, automated approach to the complete characterization of organic matter on a minimum scale (submicrogram) for the express purpose of complete identification of lunar organic substances in returned lunar samples.

Recently, high resolution mass spectrometry has provided a very few laboratories with the capability for the routine determination of molecular structures by computer-aided interpretation of high resolution mass spectral fragmentation patterns. Such a mass spectral approach to the determination of the specific structural architecture of matter on a molecular level has several physico-chemical advantages: (1) the sample size may be minute--microgram and submicrogram amounts; (2) impurities from chemical isolation and separation procedures do not generally interfere; (3) the sample does not have to be crystalline; (4) the precise atomic constitution of the molecule and each fragment thereof is obtained on such minute amounts of sample (microgram); (5) the technique is not limited to specific classes or types of molecules or to any particular atomic composition.

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* Also, Director of the Chemical Biodynamics Laboratory.

In this laboratory, major effort is being devoted to the development of a closed-loop computer-controlled high resolution mass spectrometry facility. The dual role of a real-time on-line high speed digital computer system for the simultaneous functions--instrument regulation and high quality data acquisition--offers the potential analytical capability for an unprecendentedly large-scale systematic survey and characterization of organic matter of terrestrial and lunar origin.

The first stage in "computerized" high resolution mass spectral data acquisition, processing, and interpretation has been completed recently. This will lead to the closed-loop computer control of a high resolution mass spectrometry and capillary gas-liquid chromatography facility to be used for the complete (structural and isotopic) characterization of organic matter in lunar samples returned by NASA's Apollo mission.

The sophisticated facility made possible by development of such automated instrumentation will bring the most powerful analytical capability of this decade to bear on problems encountered in the study of the organic constitution of terrestrial, meteoritic, and lunar materials.

It is expected that the knowledge gained through these studies and automation of equipment will continue to provide the fundamental body of fact and experience that will prove indispensable, both in assessing the fate of ancient terrestrial life and in laying the foundation upon which the later evaluation of the analyses of lunar samples will rest.

A further consequence of this research and development will be to lay the groundwork of experience that is needed by the Berkeley group to develop a realistic conceptual and detailed design of an automated

lander to be used on either a Martian or Venusian mission in the 1970s or 1980s. The research experience gained in this earth-based computer-controlled laboratory will be invaluable for extension to remote characterization of the molecular composition on planetary surfaces, which should allow assessment of the existence of extraterrestrial life.

NASA Grant NGR 05-003-143

OPTIMIZATION OF DESIGN OF SPACE EXPERIMENTS FROM THE STANDPOINT OF DATA PROCESSING

Principal Investigators: Vidal R. Algazi, Department of Electrical Engineering (Davis) and Space Sciences Laboratory

David J. Sakrison, Department of Electrical Engineering and Space Sciences Laboratory

Samuel Silver,* Department of Electrical Engineering and Space Sciences Laboratory

The long range objective of this project is to consider the role of on-board data processing in the integrated design of a space experiment. Ideally in such a design, the information of interest to the experimenter should be sifted from the raw data on board and only this information should be transmitted via the telemetry link to the experimenter. This procedure allows a telemetry link of fixed capacity to serve a larger number of experimenters and can also simplify the job of processing and interpretation for the experimenter.

To date, attention has been directed to source coding or "data compression" of a high rate, particle-counting experiment. A coding algorithm suitable for use with a small on-board digital computer has been derived, which transmits the counting rate waveform with fidelity satisfactory to the experimenter and at a data rate 13 times less than the rate of the raw data. This basic coding algorithm should be suitable for many data

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* Also, Director of the Space Sciences Laboratory.

sources, with only small programming changes required to modify it to suit differing statistical properties of different sources.

Attention is now being directed toward other data processing tasks that actually extract from the raw data the information of direct interest to the experimenter. Different algorithms for these tasks will be written and programmed so that conclusions may be drawn about the machine organization that would be best suited for an on-board data processing computer.

NASA Grant NsG 101-61

REFLECTION SPECTRA AS A BASIS FOR STUDYING EXTRATERRESTRIAL LIFE

A. Chemical Evolution

Principal Investigators: Alma L. Burlingame, Department of Chemistry and Space Sciences Laboratory

Melvin Calvin,* Department of Chemistry and Space Sciences Laboratory

Harold F. Weaver,** Department of Astronomy and Space Sciences Laboratory

This project comprises two areas of research. One is a study of possible routes by which essential-to-life organic polymers (e.g., proteins) may have appeared on the prebiotic earth. The second is to examine the contents of very old terrestrial rocks for the presence of compounds that are life-involved or life-implicated.

The first study concerns the reactions of the simple organic "monomers" (e.g., amino acids and sugars) that are known to be formed by the action of high-energy rays or particles on gas mixtures similar to those of the presumed atmosphere of the prebiotic earth. We are seeking ways in which, under "primitive earth" conditions (e.g., dilute aqueous solution "room" temperature), these monomers might undergo the dehydration condensations that lead to polypeptides, sugar phosphates, etc. Recent work

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* Also, Director of the Chemical Biodynamics Laboratory.

** Also, Director of the Radio Astronomy Laboratory.

in the laboratory has indicated that two simple compounds that undoubtedly were present on the primitive earth, dicyandiamide and dicyanamide, do promote such dehydration condensations in dilute water solutions. We are now determining how general these reactions are and what specificities they show; for example, we are determining which amino acids most readily form peptides under these "primitive earth" conditions.

The second study approaches chemical evolution from the other end of the time scale. We are seeking to determine the interface in time (roughly 3 billion years ago) between the appearance of molecules that are recognizable biogenic residues and "older" molecules that are recognizable as abiogenic. We have sought, and found, in the oldest Precambrian rocks "chemical vestiges" of life in the form of polyisoprenoids. We are also studying the distribution of hydrocarbons from both biogenic and abiogenic sources in order to develop more convincing criteria for the presence or absence of life at the time of formation of any given Precambrian rock. A key feature of this work is the development of mass spectrometric techniques, in conjunction with sensitive gas chromatography, for the analysis of submicrogram quantities of organic compounds.

These techniques are being evolved with the express purpose of being applied to the returned lunar samples when they become available. They will also be applicable on both possible returned Martian or Venusian samples and for an Automated Biochemical Laboratory that might be sent to explore these, or other, planets.

B. Development of Mass Spectrometric and Analytical Techniques

Principal Investigator: Alma L. Burlingame, Department of Chemistry and Space Sciences Laboratory

This project, closely related to the work in organic geochemistry (described on page 37), is developing the analytical tools needed for the separation and structural characterization of complex organic molecules. The goal of this effort is to bring the most advanced mass spectrometric instrumentation, data processing, and interpretative expertise to bear upon the elucidation and identification of organic molecular structures, while expending the smallest amount of sample (microgram and submicrogram).

From mass spectrometric studies alone the following information, which is complementary in nature to that obtained from all other spectroscopic techniques of chemical analysis, can be ascertained: (1) exact molecular weight; (2) elemental composition of the molecule; (3) important features revealing the molecular structure; (4) complete determination of the molecular structure; (5) stable isotopic analysis, e.g., C^{13}/C^{12}, O^{18}/O^{16}, N^{15}/N^{14}, deuterium. Such unique aspects of mass spectra--both low and high resolution together--coupled with the inherent very high sensitivity of the mass spectrometric method, demand these techniques as an excellent, unified approach to the solution of the composition problems encountered in organic matter of natural origin, e.g., natural products, Precambrian sediments, carbonaceous chondrites. Thus, in this laboratory, mass spectrometry has played a key role in the past and continues to prove ever more indispensable in providing the organic geochemist with answers to his chemical studies concerning the nature and origin of organic "molecular fossils" contained in terrestrial and extraterrestrial materials.

Other techniques are being developed under these auspices. For example, a novel method of stable isotopic labeling of organic compounds has recently been discovered. This is accomplished by exchange of deuterium and oxygen-18 on a gas-liquid chromatography column. It has proved to be a convenient, rapid procedure for the preparation of isotopically pure samples on a small scale (milligram to microgram). Thus, compounds can be used for studying the electron-impact-induced fragmentation of molecules to elucidate correlations of their fragmentation patterns with the intimate features of molecular architecture.

C. Planetary Studies

Project Director: Donald G. Rea, Space Sciences Laboratory

The research in this group began as a program to record laboratory infrared spectra which would assist in interpreting spectra of Mars to be obtained from Mariner flybys. In the past five years it has developed into a broadly based examination of the planets, with the emphasis on Mars. The observational work is carried out from ground-based observatories and, hopefully, in the future from flyby and orbiter spacecraft. Laboratory measurements are included to provide data to assist in interpreting the observational data. Supporting this experimental program is a variety of theoretical studies, utilizing computers when necessary. A brief summary of highlights of the past work follows.

Observational data interpreted by other observers as indicating the existence of life on Mars have been re-examined in considerable detail. A major result is that minima in the infrared spectra near 3.4 μ are not due to organic molecules on Mars, but rather to HDO molecules in our own atmosphere. Other data, in particular the darkening wave, have proved to be better explained by inorganic rather than organic phenomena. Heat balance calculations suggest that temporary bright patches are formed preferentially in depressions where the partial pressure of CO_2 is higher than the surroundings. As a consequence, the "Mountains of Mitchel" should more appropriately be called the "Depressions of Mitchel."

Until recently, one of the vexing problems facing planetary scientists has been the explanation of the apparent atmosphere on the planet Mercury. This problem has been relieved somewhat by a careful study of the available

polarimetric evidence, which showed that previous interpretations were erroneous and that these data do not indicate an atmosphere on Mercury.

The fascinating problem of Venus--its atmosphere and surface--has been the subject of two or three studies. O'Leary has looked for a halo effect in the photometric and polarimetric phase curves and has detected it, although only marginally. This suggests that there are hexagonal ice crystals in the upper atmosphere. Calculations, carried out on the computer to estimate the effect of surface roughness on microwave emissivities and reflectivities, have been applied to Venus observations. The result is to bring the dielectric constants obtained by the two techniques closer together but not into coincidence. The remaining discrepancy may be due to inadequacies in the model of the surface or, conceivably, to emission from electrical discharges in the atmosphere.

Similar computer calculations on the microwave properties of planetary surfaces have been applied to the moon. For radar data at $\lambda = 68$ cm we have derived a dielectric constant of 2.6 and an average surface slope of ca. 12°. The application to passive measurements yields lower dielectric constants. Venus is a completely analogous situation. Clearly the interpretations of microwave data obtained on rough planetary surfaces require still further refinement.

NASA Grant NsG 104-61

DETECTION AND STUDY OF MICROORGANISMS IN THE UPPER ATMOSPHERE

Principal Investigator: William J. Oswald, Departments of Civil Engineering (Sanitary Engineering) and Public Health, and Space Sciences Laboratory

This research program encompasses experimental studies to develop a suitable sampling system for determining the distribution of microbial life at various altitudes and geographical locations within the earth's atmosphere. An ultimate aim is to prepare a recoverable microbial sampling system for use in high-altitude vehicles, artificial satellites, or deep space probes to determine the existence or nonexistence of viable organoids in the interplanetary region near other planets or satellites of the solar system.

Simulation experiments now are being conducted by explosively injecting a 15-year-old stable bacterial-laden dust into an aerosol chamber, and then passing the gas-dust mixture through an electrostatic precipitator. The dust bacteria are collected on the surface of the charged plates, cultured, enumerated, and identified.

Systematic experimental work in the laboratory with a "second generation" electrostatic precipitator configuration is now in progress. This apparatus has made possible a detailed study of the precipitation mechanism. Two major areas are now under study: evaluation of collection efficiency by varying independently aerosol flowrate, voltage, current, and polarity; and development of special aseptic techniques for retrieval and transfer of captured microbes from the precipitator to nutrient broths where they

can be incubated, enumerated, isolated, and identified.

Results have shown conclusively that the precipitator is a satisfactory low velocity collection device; and, therefore, with suitable apparatus, the collection and recovery of microorganisms from the upper atmosphere is a feasible process.

As the project progresses, systematic changes are made from time to time in the apparatus in order to move nearer to an ultimate configuration, optimizing both remote sampling and contamination-free recovery. At the same time, precision bacteriological techniques for subculture and identification are continuously being modified and perfected.

The first remote sampling system involving a novel spinning precipitator is now undergoing preliminary design studies.

NASA Grant NsG 243

INTERDISCIPLINARY RESEARCH IN THE PHYSICAL, BIOLOGICAL, ENGINEERING, AND SOCIAL SCIENCES

Principal Investigator: Samuel Silver,* Department of Electrical Engineering and Space Sciences Laboratory

A. Core Funding or Sustaining Grant

The purpose of the sustaining grant is to provide a core of funds to be used to stimulate faculty and graduate student programs in the space sciences and to maintain the continuity of the program of the Space Sciences Laboratory. One of the important uses of the core funding is "seed" money for the initiation of new research and the development of new areas of graduate study and training through research in the space sciences.

The projects supported by the core funds thus vary from year to year. Special attention has been paid to atmospheric and space physics. Studies conducted under this program range over such topics as hydromagnetic waves in the magnetosphere and the ionosphere and the origin of micropulsations of the geomagnetic field, auroral substorms, design of balloon- and rocket-borne experiments to observe the precipitation of charged particles into the auroral zones, millimeter wave radiation from planetary atmospheres, determination of water vapor and carbon dioxide in the atmosphere of Mars from high resolution near infrared spectra, and plasma physics, particularly the theory of instabilities in plasmas. Work in the biological sciences has dealt with biochemical behavior of microorganisms in simulated planetary environments, but that work has obtained an independent project grant. In the past year, the research in the engineering sciences

* Also, Director of the Space Sciences Laboratory

has also ranged over such a wide variety of subjects as the design of space experiments from the data processing standpoint, the human being as a component in a feedback system, ionization and sputtering of refractory materials, and plasma physics. The program of research in the social sciences is discussed separately as item B under this grant heading.

B. Social Sciences

Faculty Investigator: C. West Churchman,* School of Business Administration

The objective of the social science program of the Space Sciences Laboratory is the study of the management, organization, and social impact of research and development.

The specific methods used in the studies vary. Several studies aim at a detailed description of the organization of research projects or of whole centers. In these cases, there is extensive use of questionnaires and interviews. One study of the impact of system science on statewide problems has entailed observation of various types of political action. A study of information dissemination between individuals in different disciplines has employed a stochastic model of social interaction. Another study, directed toward the use of computers in organic chemistry and other disciplines, uses a fairly elaborate analytical model. Despite the variety of projects, there is an underlying methodology in the entire social science group, discussed in a multidisciplinary seminar that meets weekly. This seminar discusses not only individual projects but also the values and dangers of social science research, especially when it impinges on various aspects of the physical sciences.

The following studies have been completed or will shortly be completed: the economic health of the aerospace industry, the organization of a group in the University of California Lawrence Radiation Laboratory, the

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* Also, Associate Director of the Space Sciences Laboratory.

budgeting processes in R and D organizations, the decision-making processes in the development of exobiology, the role and significance of scientific advisory committees, the legal structures of confined microsocieties (such as those that may occupy spaceships on prolonged flights), the design of a scientific information dissemination system, the financial arrangements of research support in a large university, the manner in which research directors view their roles.

Projects in process include a study of the four aerospace contracts devoted to the social system problems of California (information, transportation, sanitation, and crime), the relation between teaching and research in a large university, the design of systems capable of conducting inquiry, the ethics of large-scale social systems, the conceptual basis of modern physics, the social-psychological problems of implementing technological innovation.

The social science project was also partially responsible for the initiation of the study of urban management described under NASA Grant NGR-05-003-125.

C. High Altitude Particle Physics

Faculty Investigator: Luis W. Alvarez, Department of Physics, Lawrence Radiation Laboratory, and Space Sciences Laboratory

Until about ten years ago, the discovery of all unstable "fundamental particles" had come from cosmic ray experiments. The pion, the muon, the K mesons, and the three hyperons (Λ, Σ, and Ξ) were all first seen in cosmic ray experiments. In the past ten years, large accelerators have almost completely supplanted cosmic radiation as a source of particles for studying the fundamental interactions. Cosmic ray physicists have for the most part abandoned their studies of the interactions of the particles and have concentrated their attention on the cosmological aspects of radiation. This situation has arisen from the well-known fact that artificial beam intensities in the 1-25 BeV energy region far surpass those available in cosmic radiation.

The situation in the 100-10,000 BeV energy range is strikingly different. There is no artificial intensity now available and none as high as 300 BeV will be available for ten years. It has generally been thought that the cosmic ray intensity available in this region is so low as to make experiments with "natural beams" quite unattractive. Because of the almost simultaneous emergence of a number of seemingly unrelated techniques, we believe that cosmic ray experiments of a meaningful nature in the range 100-1,000 BeV can be carried out in the upper atmosphere at altitudes around 90,000 feet. These new developments offer a refinement in precision in comparison to traditional cosmic ray experiments that will make possible more detailed studies in and beyond the energy range now planned for exploitation with accelerators to be built in the next eight or ten

years. In this context, the new program can reveal the gross features of the high energy physics of the immediate future and, at the same time, perhaps provide helpful guidelines to the design of the accelerator facilities being planned.

Two of the recent technical advances that can be most profitably exploited in further studies with cosmic rays are the newly available ballooning capabilities and large superconducting magnets. Balloons bearing payloads of about three tons have been flown successfully to altitudes of about 80,000 feet as part of the "Stratoscope" astronomical program at Princeton University. This combination of high payload and high altitude is very attractive in studies with cosmic rays because it allows the experimenter to place rather sophisticated experimental packages above the bulk of the earth's atmosphere where most of the cosmic rays are consumed by nuclear interactions. In particular, the present high payload capacity of balloons allows the inclusion of a very large superconducting magnet in the experimental package. The magnet permits determination of the momentum and sign of charge of the cosmic rays by observation of the deflection of the orbit of the cosmic ray as it passes through the magnetic field. This is information that previously has not been available in the study of cosmic rays at the energies being considered.

The flight package cannot be fully described here; however, it can be functionally divided into two parts. The uppermost portion of the package achieves discrimination against low velocity particles through the use of a threshold Cerenkov detector, and the momentum of interesting cosmic rays is determined with an arrangement of spark chambers and special

nuclear emulsions that measure the deflection of the particle orbit produced by its magnetic field. The next section will generally contain the target in which the cosmic rays will undergo nuclear interactions with detectors arranged to collect data on the secondary particles created in the interactions. A typical balloon flight duration will be about 20 hours.

Exciting studies are anticipated concerning the nature of the cosmic ray flux entering the earth's atmosphere and the properties of these cosmic rays as they undergo nuclear interactions in experiments.

D. Planetary Telescope

Project Director: Donald G. Rea, Space Sciences Laboratory

While observations from flybys and orbiters are very fascinating, valuable, and exciting, a great deal can still be done from suitable ground-based telescopes. For planetary studies one wants to get above as much of the water vapor in the earth's atmosphere as possible and to have a low cloud cover, together with convenience to major research institutions. Evaluation of a site in the White Mountains of eastern California at an elevation of 4,000 meters (13,189 feet) is now being carried out since it is believed to be extraordinarily suitable for such a telescope. One of the principal parameters being measured is the total atmospheric precipitable water; this is being monitored on a nearly 24-hour basis by a telescope that continuously tracks the sun and the moon. If the results of our site evaluation are favorable, we will submit a proposal to NASA for the construction of a major planetary telescope at the site. We have no doubts that such a facility would prove to be a valuable component in NASA's planetary exploration program and that it would have a marked impact on the success and progress of that program. It would also be a major tool in the educational and research program of the University in planetary sciences.

Besides the evaluation of the site, we are also studying various possible telescope designs for their suitability for planetary studies. Currently our belief is that the conventional design for stellar observations is not the best for planetary work, and that configurations such as the heliostat and coelostat have major advantages over other mounts. These advantages are particularly marked for work at high elevations and for work in the thermal infrared.

NASA Grant NsG 274-62

STRESSES AND DEFORMATION IN THIN SHELLS OF REVOLUTION

Principal Investigators: Egor P. Popov, Department of Civil Engineering

Joseph Penzien, Department of Civil Engineering

This research program concerns itself with a fundamental investigation for the determination of stresses and deformations in thin shells of revolution of arbitrary meridional shape and thickness variation subjected to differential pressure and circumferential ring loadings and constraints. Studies include the effect of nonlinear properties of materials, and steady and transient states of dynamic response. In some of the studies of the elastic vibration of shells, the effect of the transverse shear deformation is being included. Procedures are being developed for obtaining solutions for large deformations of the shells.

NASA Grant NsG 354

ADVANCED THEORETICAL AND EXPERIMENTAL STUDIES IN AUTOMATIC CONTROL AND INFORMATION SYSTEMS

Principal Investigators: Charles A. Desoer, Department of Electrical Engineering and Electronics Research Laboratory

Elijah Polak, Department of Electrical Engineering and Electronics Research Laboratory

Lotfi A. Zadeh, Department of Electrical Engineering and Electronics Research Laboratory

Under this grant the principal investigators and their students are conducting research in the areas listed below, which relate to NASA objectives in guidance and control.

1. Problems in optimization, such as decomposition under vector-valued criteria, optimal-curve-following problems, stable sub-optimal control, continuous programming problems, etc.

2. Rendezvous and collision avoidance, such as the extent to which problems of this kind can be treated meaningfully as differential games, etc.

3. Nonlinear systems, such as the evaluation of sufficient conditions for stability, the construction of a unified theory of stability, etc.

4. Miscellaneous problems, such as system identification.

To illustrate the nature of the results obtained in above categories, we give abstracts of four projects recently completed.

CONSTRAINED OPTIMIZATION UNDER VECTOR-VALUED CRITERIA

Professor E. Polak

Nelson DaCunha

The purpose of this project was to examine in detail the nature of constrained optimization problems under vector-valued criteria. For this purpose, a standard problem was formulated to which all the problems of interest are reducible. Necessary conditions of optimality for this problem have been obtained, as well as conditions under which the vector criterion problem can be solved by solving a sequence of problems with scalar criteria. Among the specific results this study has yielded are a maximum principle for optimal control problems with a differential plant, a discrete maximum principle for optimal control problems with the plant described by difference equations, and extended F. John conditions and extended Kuhn-Tucker conditions for nonlinear programming problems.

GAMES, PURSUIT-EVASION, AND RENDEZVOUS PROBLEMS

Professor E. Polak

Jean-Paul Jacob

This project dealt with games of the form (X, Y, f), where X, Y, are sets and f is a mapping from X x Y into the reals. A pair $(\bar{x},\bar{y})$, $\bar{x} \in X$, $\bar{y} \in Y$ is defined to be a solution to this game if

$$f(\bar{x},\bar{y}) = \min_{y\in Y} \max_{x\in X} f(x,y) = \max_{x\in X} \min_{y\in Y} f(x,y).$$

Sufficient conditions for the existence of a solution to such a game were obtained when X and Y are compact, convex subsets either of a finite

dimensional space or of a Hausdorff, locally convex linear topological space and when the payoff function f is quasi-convex-quasi-concave. Such games include broad classes of pursuit-evasion games and differential games.

Rendezvous problems, in which two dynamical systems are jointly required to perform a maneuver subject to separate costs, were considered separately from pursuit-evasion games. This was necessitated by the fact that the standard assumptions of game theory become so restrictive for these problems as to render them trivial. A set of sufficient conditions for the existence of the solutions to rendezvous problems was established and the computation of solutions is explored to some extent.

STABILITY OF SINGLE-LOOP NONLINEAR FEEDBACK SYSTEMS

Professor C. A. Desoer

Chung Tak Lee

Sufficient conditions of stability of a single-loop feedback system were established when the input-output relation is characterized by

$$y = K(u - y)$$

where u and y are the input and the output of the system, respectively, and K is the operator describing the open-loop system.

The main contributions of this project were twofold. First, we established sufficient conditions in a Banach space and a Hilbert space under which the inputs of bounded norm produce the outputs of bounded norm. The results are generalizations of the results obtained by Sandberg and Zames; however, the proofs are far simpler. Second, we obtained

sufficient conditions of generalized absolute stability. Popov's results can be obtained as special cases of the results derived in this project. The derivation of these results was carried out in time-domain while Popov's results were derived in frequency-domain, which restricts its application. The extension to multiple-input multiple-output systems is included.

ESTIMATION OF PARAMETERS OF LINEAR SYSTEMS USING THE "INSTRUMENTAL VARIABLE" METHOD

Professor E. Polak

Kwan Yui Wong

This project dealt with the estimation of parameters of a linear time-invariant, single-input and single-output system. The output variable of the system under study was related to the input variable by a difference or a differential equation of known order. The output of the system was assumed to be corrupted with additive zero mean stationary noise (which is not necessarily "white") while the input was noise free.

In this project, identification of systems described by difference equations was accomplished by means of the "Instrumental Variable" (I.V.) method. The salient feature of this method is that it yields a consistent estimate of the unknown system parameters. To apply this method, one must generate a sequence of "instrumental variables", which are correlated with the actual output of the system and which are uncorrelated with the noise. Optimal instrumental variables, minimizing the asymptotic variance of the estimate of the unknown parameters over the class of estimates given by the I.V. method, were derived and a simple algorithm for computing them approximately was given. A modification of Plackett's matrix

inversion formula was used to express the estimate given by the I.V. method in a recursive form, resulting in a real time estimation scheme.

For systems described by differential equations, Shinbrot's method of "projecting" a function and its derivatives, without computing them, onto certain "projection functions" was extended to apply to system outputs corrupted with noise. This yields a continuous time version of the I.V. method. Sufficient conditions were given for a set of instrumental variables to minimize the asymptotic variance of the parameter estimate, as given by the I.V. method, for a fixed set of projection functions. Criteria and methods for picking projection functions are derived and, finally, a real time estimation scheme was obtained.

NASA Grant NsG 387

STUDIES ON HIGH ENERGY RADIATION FROM SOLAR FLARES AND AURORAL ZONE PHENOMENA

Principal Investigator: Kinsey A. Anderson, Department of Physics

This grant is concerned with the development of a variety of energetic particle detectors to study astrophysical phenomena. The detectors that result from this development are flown on balloons and rockets, mostly in the auroral zone, both to obtain scientific data and to verify the operation of the detector in naturally occurring fluxes of particles. Finally, some of the detectors are then incorporated into satellite experiments. The balloon and rocket flights supported by this grant involve several graduate students, and several Ph.D. theses have been written concerning this work. For the past two summers, a rocket program has been carried out at Fort Churchill, Canada, in the auroral zone. In connection with the rocket flights, an extensive balloon-flight program is being carried out.

In 1966, a total of 17 balloon flights were made at Flin Flon, including 11 large volume balloons. In addition, 13 balloon flights and 4 rocket flights were made at Fort Churchill. During a 10-day period when geomagnetic storms were in progress, a total of 23 balloons and 3 rockets were launched. On one occasion, 3 balloons and one sounding rocket were simultaneously collecting data on the same event. Since many of the balloon payloads were quite complex and the balloons large, this represented a very considerable effort. In all, approximately 900 pounds of scientific payloads were launched on rockets and 1200 pounds on balloons. The total volume of the balloons flown was over 35 million feet.

An important scientific objective of this year's operation was to correlate the dumped particle fluxes with micropulsations of the geomagnetic field. A group under Professor S. H. Ward from the Department of Mineral Technology at Berkeley set up micropulsation gear at both Flin Flon and Fort Churchill. Several very interesting correlations have been found that promise to shed light on mechanisms for some of the electron precipitation into the auroral zone.

NASA Grant NsG 452

NEUTRON ACTIVATION ANALYSIS OF REMOTE SURFACES

Principal Investigator: Hans M. Mark, Department of Nuclear Engineering and Space Sciences Laboratory

Since 1960, a number of experiments to determine the feasibility of using activation analysis and other radioactive methods to determine the elemental composition of remote surfaces have been conducted. The work has been performed at the Lawrence Radiation Laboratory (Livermore) and on the University of California campus. The work at LRL has been devoted primarily to studies of the method in which inelastic gamma rays following the scattering of 14.0 MeV neutrons are detected. The gamma ray spectrum observed in this manner is characteristic of the materials on the surface. A small mock-up package containing a 14.0 MeV neutron source, an NaI scintillation gamma ray detector, and some of the associated electronic components was constructed at LRL. In addition, many feasibility experiments using different rock samples and the Cockroft-Walten accelerator were performed. The results of this work showed that it was possible to get a crude estimate of the composition of the material but that the method was limited by rather severe signal-to-noise ratio problems.

The work on the Berkeley campus has complemented some of the LRL work and has also been concerned with several independent matters. Several theoretical studies have been made of the transport of 14.0 MeV neutrons and energetic gamma rays through rock-like materials in an effort to determine the "size" of the sample analyzed. In another area, an experiment was performed to determine the effect of the surface structure on the α-particle backscattering analysis method. More recently, some work

has been done to investigate the possibility of using the newly developed lithium drifted germanium detectors as gamma ray counters. Since these devices have much higher intrinsic resolution than the NaI scintillation counters, it was felt that the signal-to-noise ratio situation could be improved. A recent study has shown that the germanium detectors are somewhat more sensitive to 14.0 MeV neutrons than are the NaI crystals. This work is being extended at the present time to thermal neutrons as well. It is too early at this point to draw any definitive conclusions regarding the potential usefulness of the new detectors.

NASA Grant NsG 479

CHEMISTRY OF LIVING SYSTEMS

Principal Investigator: Thomas H. Jukes, Division of Medical Physics and Space Sciences Laboratory

The project is directed toward certain aspects of the fundamental biochemical mechanisms of heredity and gene expression, their adaptation to environmental extremes, and their possible relationships to the origin and development of life. Biology is undergoing a remarkable period of expansion and discovery. We hope to contribute to the advance of the field and simultaneously to obtain information on specific properties of terrestrial life that enable living organisms to cope with adverse conditions. In the latter category, the following studies are in progress:

1. Mechanism of Protection of DNA Molecules

(a) Enzymatic repair of damage to DNA, as shown by following the replication of DNA in vivo and in cell-free systems.

(b) The properties of the "anhydrous" form of DNA in spores and its resistance to ultraviolet light.

(c) The protein component of the bacterial chromosome.

2. Thermostable Proteins

(a) The mode of action of the proteolytic enzyme thermolysin.

(b) Composition and structure of thermostable ribosomes.

(c) Properties of heat-stable RNA polymerase and amino-acid-activating enzymes from B. stearothermophilus.

Concurrent with these studies are investigations of corresponding mesophilic systems from organisms such as E. coli and B. subtilis.

General studies of the chemistry of living systems include:

Properties of RNA polymerase. This enzyme uses one of the two strands of DNA as a template and produces strands of complementary RNA of antiparallel sequence and of varying strand lengths. The RNA chain can be initiated with ATP, and the triphosphate group is retained at the starting point of the RNA molecule. This indicates that RNA polymerase preferentially binds to pyrimidine groups on DNA. Binding to the template is inhibited by Congo red.

The sequence of bases in RNA. Base sequences in the nucleic acids are being studied in tobacco mosaic virus RNA by combinations of enzymatic degradation and the chemical tagging of end groups. The base composition of purified oligonucleotides is being analyzed by the use of the Cary 15 spectrophotometer coupled with a Datex analog-to-digital converter.

Replication of the chromosome in B. subtilis. A DNA-protein complex has been isolated from B. subtilis. The protein in the complex differs from histones. DNA replication is a necessary condition for the isolation of the complex. Its transforming activity is greater than that of DNA. The DNA molecule in spores has been studied with respect to ultraviolet damage and has been found by this criterion to differ from DNA in vegetative cells.

Relationships between RNA and ribosomes. Ribosomes move along the mRNA strand during protein synthesis. This was demonstrated by showing that the composition of the segment of the messenger that initially attaches

the ribosome differs from the segment that is attached to the ribosome after incubation with an amino-acid-incorporating system. By similar procedures, evidence has been found that the direction of travel of the ribosome during protein synthesis is from the 5' -OH end of mRNA toward the 3' -OH end. The formation and release of polypeptides in cell-free amino-acid-incorporating systems has been studied with synthetic polyribonucleotides. Release did not take place unless U and A were both present in the polynucleotides. Ribosomal RNA, 23s, from E. coli has been shown to start with the sequence pGpPupPy ... . Studies with Bacillus stearothermophilus are in progress on the effect of temperature on ribosomal stability, ribosomal composition, and the nature of thermostable RNA polymerase and amino-acid-activating enzymes.

Metabolic regulation in E. coli. E. coli B_3 is a mutant that requires thymine for growth. Revertants of this strain show changes in thymine metabolism as compared with the original wild strain of E. coli B; the results indicate the existence of two pathways for the formation of thymine compounds. A protein is rapidly produced after infection of E. coli with T-even bacteriophages. It may function to initiate the synthesis of viral DNA.

Studies of the primary structure of proteins and the relation between enzyme function and primary structure. Thermolysin, a heat-stable protease from the thermophilic organism B. thermoproteolyticus Rokko, attacks preferentially the peptide bonds at the amino sites of leucine and isoleucine in cytochrome c, insulin, and tobacco mosaic virus protein. To a somewhat lesser degree, valine and phenylalanine bonds are also attacked. Spinach ferredoxin has a composition differing markedly from those of the

bacterial ferredoxins. (In collaboration with the Department of Cell Physiology.)

Optical rotatory dispersion, X-ray scattering and birefringence of DNA and RNA. The optical rotatory dispersion curves of bacteriophages fall into three general types; the differences are thought to mirror differing conformational characteristics of the DNA inside the phage and are suited for studies of this aspect of phage structure.

Molecular evolution. Computer methods were used to explore the amino acid sequences in proteins by means of the genetic code. Evidence was found that repeating sequences of 15 residues are present in the cytochromes and of 21 residues in the hemoglobins, partially observed by evolutionary changes. Evidence has been found for the evolution of transfer RNAs from a common archetype.

NASA Grant NsG 513

PRIMATE HEMODYNAMICS AND METABOLISM IN AN ORBITING SATELLITE

Principal Investigator: Nello Pace,* Department of Physiology-Anatomy

The object of the work being performed under this grant is to understand the physiological effects of prolonged exposure to weightlessness. Such understanding will in turn provide substantial insight into the basic physiological mechanisms of mammalian organisms as they have evolved in the gravity field of the earth. Space flight provides the only means available for cancellation of normal gravitational attraction for long periods of time. Therefore, an intensive program is under way to prepare for physiological observations in suitable animal subjects during earth-orbital flights lasting 30 days or more.

In order to make meaningful observations of the physiological effects of weightlessness, it is essential that sound and extensive base line values be available in the normal earth environment. It is also important to establish the physiological effects of abnormal environmental conditions that might develop during an orbital mission and that might confuse the effects of weightlessness per se. In particular, these include the effects of exposure to high and low ambient temperatures, high and low ambient oxygen pressures, high ambient carbon dioxide pressure, high acceleration, and confinement.

For many reasons, including direct extrapolation of the findings to human astronauts, we have chosen a primate as the experimental subject,

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* Also, Director of the White Mountain Research Station.

namely, the pig-tailed monkey, Macaca nemestrina. This animal is a native of Southeast Asia and is readily amenable to handling and training. Young adult males weigh 8 to 12 kilograms and are thus of sufficient size to permit extensive instrumentation without impairing physiological integrity. The research has been concentrated largely on the study of the cardiovascular system, the respiratory system, and the endocrine system; it has involved extensive biochemical work as well. New instrumentation techniques have been devised for study of various physiological parameters in the unattended, comfortably restrained, unanesthetized monkey for periods of up to 90 days. One important development made under this project has been the technique of surgical implantation of plastic catheters in the major blood vessels of monkeys, permitting continual access to the animal's cardiovascular system over many months. An analogous development currently in progress is a surgical technique for chronic catheterization of the ureters of the monkey, which will permit continual collection of all urine produced by the kidneys as it is formed.

In another facet of the work, new microchemical procedures are being developed that will permit the analysis of small samples of blood and urine for a wide variety of biochemical constituents. From these metabolic profiles of monkeys obtained during weightlessness, much can be deduced concerning the adaptive changes that may go on. In an extension of this work, a collaborative project is being undertaken with the Jet Propulsion Laboratory for the development of an automated urine analyzer that will make possible on-line analyses every 6 hours during the projected 30-day primate flight to be carried out as part of the Biosatellite Program. These analyses will be for urinary calcium, creatine, and creatinine excretion rates to provide data concerning the bone demineralization and

muscle atrophy effects currently suspected as a result of long exposure to weightlessness in man.

Finally, methods are being evolved for the in vivo estimation of body composition of the monkey so that the animals can be studied before and after orbital flight. These include methods for measurement of total body water, extracellular fluid space, total plasma volume, total red cell volume, total body potassium, and total body fat. From these measurements, it will be possible to define quantitatively changes in gross body composition resulting from the weightlessness experience.

It must be emphasized that although the primary goal is a study of the specific physiological effects of weightlessness, the broader contribution will be the enhancement of our basic knowledge concerning normal physiological function.

NASA Grant NsG 600

SPACE PHYSIOLOGY

Principal Investigators: Thomas H. Jukes, Division of Medical Physics and Space Sciences Laboratory

Hardin B. Jones, Division of Medical Physics and Donner Laboratory

Research Biophysicist: R. Stuart Mackay, Division of Medical Physics and Space Sciences Laboratory

This project is concerned with designing and constructing improved radio transmitters for physiological measurements and exploring the use of these for measuring body temperature, intestinal motility, and blood pressure.

The main areas of study are:

- Temperature transmitters
- Measuring intestinal motility
  - Low frequency pressure transmittal
  - High frequency pressure transmittal
- Voltage sensing transmittal
- Ingestible sound transmitting capsule
- Measurement of blood pressure
- Telemetering of pH

Studies on the patterns of peristaltic activity in human subjects were conducted at the U. S. Naval Hospital in Oakland, using ingestible radio transmitters. Four ulcer patients were observed, and the

pattern over an extended period displayed by two normal subjects also was followed.

Two different aspects of transmitter design were studied, namely, the attainment of greater range through the use of higher power, and the necessary frequency stabilization required by FCC regulations on more powerful transmitters. Several circuits that give ranges of 100 megacycles were tested. It was necessary to stabilize the frequency of the crystal accurately in some of these. Adjustment of such circuits is rather critical, but when properly made, they prove quite stable.

Plastic absorption data at the end of two years of soaking were compiled from weight measurements similar to those previously reported for shorter intervals. The effectiveness of paraffin as a coating was indicated by the lack of absorption by underlying epoxy.

A pH transmitter was designed and a unit was constructed. The completed unit is still in the experimental stage.

An electrocardiogram transmitter implanted in a rabbit failed at about the time its batteries were exhausted because of the breaking of one of the lead wires at the entrance to the transmitter package. The sterilized transmitter had caused no problems until the lead broke, and then a massive infection developed in the rabbit about this region. A new electrocardiogram transmitter type was designed and constructed along similar lines to the previously mentioned one, but giving a larger frequency deviation for a given voltage input. This new transmitter uses two stages of amplification to vary the capacity of a varactor diode; this frequency modulates the output oscillator. The signal is in part

radiated from the oscillator coil, but a loop in the electrode lead wires couples some of the radio frequency energy back into the leads themselves, thus circulating relatively large radio frequency currents over a much larger area path.

Several ingestible pressure sensing units were constructed for use in gastrointestinal experiments, and several temperature units were built for use by other experimenters in NASA. The very small temperature unit was redesigned so that a lower average current drain was required.

NASA Contract NsG 702

GASDYNAMICS OF EXPLOSIONS

Principal Investigators: Antoni K. Oppenheim, Department of Mechanical Engineering

Harold P. Smith, Jr.,* Department of Nuclear Engineering and Space Sciences Laboratory

The purpose of this research program is the study of the interrelationship between molecular or atomic processes that result in a significant amount of power deposited in a compressible medium and the continuum mechanics of its concomitant nonsteady motion. Experimental insight into such phenomena is obtained by the observation of the generation of pressure waves due to deposition of energy released by chemical reaction or atomic fission in a gaseous substance, as well as by the investigation of the development and structure of gaseous detonation waves. Recently, experiments in this field of study have been performed by the use of a laser schlieren-rotating mirror camera system capable of frame photography with nanosecond exposures at a megacycle frequency, as well as by means of pressure transducers with a sub-microsecond rise-time, combined with a variety of photographic techniques for recording the multiwave interactions that characterize these processes.

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* 1966-67 White House Fellow, Washington, D.C.

NASA Grant NsG 704/05

ENZYME ACTIVITY IN TERRESTRIAL SOIL IN RELATION TO EXPLORATION OF THE MARTIAN SURFACE

Principal Investigator: A. Douglas McLaren, Department of Soils and Plant Nutrition

Our objective is to develop qualitative and quantitative tests for various enzyme activities in soil and to adapt the most sensitive and suitable of these to procedures compatible with telemetry from Mars probes.

The Martian environment has a limited moisture content and biological reactions possibly take place at interfaces and on surfaces in an environment of restricted water availability. A study of surface effects in the hydrolysis of insoluble chitin by adsorbed chitinase and lysozyme is being conducted in order to investigate some of the factors influencing reactions at interfaces. Similarly, a study of urea hydrolysis by urease at a limited moisture availability is in progress.

Phosphatase activity in soils has been studied to investigate further various factors influencing the determination and behavior of enzymes in soils.

There exists a possibility that extraterrestrial microorganisms can metabolize hydrocarbons; present knowledge, however, of the microbial metabolism of alkane hydrocarbons is scanty. We have initiated a study to examine the initial metabolic steps of hydrocarbon degradation by terrestrial microorganisms.

Instrumentation for an all solid state, semiconductor type, C-14 carbon dioxide detector is being developed for a possible use with urea as a substrate to detect its catalytic breakdown in a Martian environment. The detection of a urease-like activity has been selected because of the possible primordial origin of urea as an organic substance and because of its relative chemical stability as an enzyme substrate.

It is also of interest to examine terrestrial soils that may be found in adverse climatic environments. Geologically preserved permafrost soils, desert soils, and soils stored for more than half a century have been examined for their biological activities.

NASA Grant NsG 707

ADVANCED INFRARED DETECTORS FOR USE IN PLANETARY SPECTROSCOPY

Principal Investigator: Harold F. Weaver,* Department of Astronomy and Space Sciences Laboratory

The immediate goals of this program are: (1) to investigate detector performance with respect to material, fabrication, and usage parameters so that optimum detectors may be tailored to the demands of particular astronomical observations; and (2) to develop preamplifiers and networks with lower noise levels than those inherent in the detectors. Long term goals are: (1) to provide detectors and associated electronic, optical, cryogenic, and mechanical equipment in complete systems for use in observations, and (2) to use the systems in ground observatories, high altitude aircraft, and balloons to obtain astronomical data otherwise inaccessible to observation.

Principal constraints restricting astronomical observations are detector sensitivity and the wavelength region within which sensitivity is maximum. The infrared region of the electromagnetic spectrum consists of wavelengths from approximately one micron (the red end of the visible region) to approximately one millimeter (the short end of the radio region). This region furnishes information on molecular composition, thermal structure, energy processes, and particle size of distant objects. In the past, most of this region, particularly from about 10 microns to 1 millimeter wavelengths, has been inaccessible to observation because of the lack of

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* Also, Director of the Radio Astronomy Laboratory.

sufficiently sensitive detectors. In addition, most of the infrared region is blanketed by absorption from constituents of the earth's atmosphere, principally water vapor, so that detection systems must be simple and rugged enough to operate from high altitudes in jet aircraft, balloons, or satellites.

Currently under investigation is a heat detector, i.e., radiation of any wavelength incident on the detector warms it and changes its resistance. The device's sensitivity comes from holding the detector temperature to only a few degrees above absolute temperature and from an extremely steep coefficient of resistance change with respect to temperature. The demonstrated sensitivity of this detector approaches the best performance of any other infrared detector; the potential limit is equal to or better than any other infrared detector and approaches the sensitivity of the photomultiplier at short wavelengths and of radio receivers at long wavelengths, with equal sensitivity at all wavelengths. Its simplicity and ruggedness have been demonstrated in a balloon flight, including survival from a hard parachute landing.

New testing equipment has been fabricated to evaluate performance. Initial studies and tests have shown that the inherent noise levels of the detectors are lower than those of available advanced amplifiers; therefore, the development of extremely low noise amplifiers and signal processing networks has become an integral part of the detector development.