Dr. Rudolf Hermann
University of Alabama Research Center
P. O. Box 1247 West End Station
Huntsville, Alabama

Space TECHNICAL INFORMATION DIGEST

SPACE SYSTEMS INFORMATION BRANCH, GEORGE C. MARSHALL SPACE FLIGHT CENTER

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SPECIAL ISSUE

The following abstracts on meteorology and planetary sciences are from significant papers presented at the Second Western National Meeting of the American Geophysical Union in Stanford, California, December 27-29, 1962.

SATELLITE CLOUD PHOTOGRAPHS ASSOCIATED WITH A BLOCKING PATTERN IN THE PACIFIC OCEAN. Sidney M. Serebreny (Aerophysics Laboratory, Stanford Research Institute, Menlo Park, California) The uses of cloud photographs from satellites for operational purposes are demonstrated through a discussion and illustration of a series of Tiros 1 photographs on 14 orbits for the period May 18-24, 1960. During that time a blocking pattern developed in the east central Pacific accompanied by an invasion of tropical air aloft into northerly latitudes. The rationale for the positioning of the jet stream over the northern Pacific using cloud photographs is discussed and illustrated. As an aid to a better understanding and interpretation of satellite cloud photographs, such photographs are presented for Ocean Station Vessel Papa along with the corresponding surface observations. Time sections of vertical motion, temperature-dew point differences regimes, wind distribution, and lapse rates are illustrated and compared to a study made in the North Atlantic of a similar synoptic situation prior to the advent of Tiros 1. The inference is made at this time that since the parameters were virtually the same, the distribution of cloud in each case would have been highly comparable regardless of area.

THE LIFE HISTORY OF TROPICAL CYCLONES IN THE EASTERN NORTH PACIFIC IS REVEALED BY TIROS SATELLITES. James C. Sadler (International Indian Ocean Expedition, National Science Foundation, Washington, D. C.) The tropical eastern North Pacific is a meteorological paradox for tropical storms. It is a region of frequent storm development (many to hurricane intensity), as well as a region of storm dissipation or weakening to depression stage. Photographic data from Tiros are used to illustrate stages in the life cycle of such storms, and their histories are discussed in relation to the mean atmospheric circulation and sea surface temperatures. Comparisons are made with typhoons of the western Pacific.

SOME SURVEYS OF WESTERN UNITED STATES WITH THE AID OF SATELLITE PICTURES. Richard D. Tarble (Hydrologic Services Division, U. S. Weather Bureau, Washington, D. C.) The areal coverage of the snowpack is of major importance to hydrologists concerned with forecasting river flow and water supply from snowmelt in mountainous regions. Various methods of obtaining these data have been tested, including fixed photographs and areal reconnaissance. To date no method has been entirely satisfactory. Photographs from Tiros 1 weather satellite indicated that it would be possible to determine the areal snow cover by this means. Using photographs from Tiros 4 and 5 taken during the period from March-July 1962, the changes in snow-cover distribution over the mountain ranges of the western United States are shown. The potential for future observations from the Nimbus polar-orbiting satellite is discussed.

SUMMARY OF REFLECTED AND EMITTED RADIATION DATA MEASURED FROM TIROS 2, 3, AND 4. W. R. Bandeen and W. Nordberg (Goddard Space Flight Center, NASA, Greenbelt, Maryland) Tiros satellites 2, 3, and 4 carried medium-resolution scanning radiometers sensitive in three infrared and two solar regions of the spectrum, namely, 6.0-6.5μ, 8-12μ, and 7-30μ (except Tiros 4), and 0.2-6μ and 0.55-0.75μ. An attempt is made to interpret the intensities measured in these spectral ranges in terms of the planetary heat budget for the time period covered by these satellites. Several important features found initially by studying individual cases were analyzed for the additional satellite data which are now available. In particular, these features include the indication of the presence of water vapor in the stratosphere derived from relative radiation intensities in the 6.3 and 8-12μ region, the apparently excessive atmospheric absorption of emitted radiation in the 8-12μ 'window' region, and the spatial and spectral variations in the radiation reflected by the Earth.

RADIATION CHARACTERISTICS OF A MATURE HURRICANE DEPICTED BY TIROS SCANNING RADIOMETERS. Tetsuya Fujita (University of Chicago, Chicago, Illinois) Detailed analysis of radiation patterns over the area of hurricane Anna was made, using analog traces of medium resolution scanning radiometer of Tiros 3. Even though we do not know the noise superimposed upon the analog traces, all maximum and minimum values on the Earth-viewing swaths were plotted. It was found that most of the peaks and dips on radiation traces corresponded extremely well with the cloud patterns obtained by rectifying satellite photographs. Results of channel 1-V radiation patterns are presented in an attempt to explain the physical and dynamical processes taking place over the area of the hurricane.

TEMPORAL VARIATIONS IN THE PLANETARY-SCALE OUTGOING LONG-WAVE RADIATION AS DERIVED FROM TIROS MEASUREMENTS. Jay S. Winston and P. Krishna Rao (U. S. Weather Bureau, Washington, D. C.) Daily composite charts of outgoing long-wave radiation between latitudes 55°N and 55°S were derived from Tiros 2 measurements for 26 days between late November 1960 and early January 1961. In spite of the variability and incompleteness of the daily radiation data, latitudinal and over-all daily averages of outgoing long-wave radiation were obtained. Substantial temporal variations observed in the long-wave radiation over the northern hemisphere were found to be generally related to large-scale variations in kinetic and available potential energy. For example, during a remarkable cycle in available energy that occurred in this period, it was found, at lower latitudes, that the long-wave radiation decreased as the westerly flow intensified. Mean maps of outgoing long-wave radiation for four different periods during this energy cycle portray the geographical distribution of this radiation; over the northern hemisphere the radiation fields are well related to features of the mean 700-mb flow. An average latitudinal profile of Tiros 2 long-wave data for all days studied shows maxima of outgoing radiation of 20°N and 20°S (the latitudes of the subtropical highs), with lower values in two convergence zones north and south of the equator. Radiation is generally lower in higher latitudes in both hemispheres. Comparisons of these measurements from Tiros 2 with previous estimates of long-wave radiation made by investigators of the heat budget show relatively good agreement.

<u>ANALYSIS OF RADIATION MEASUREMENTS BY TIROS</u>. S. I. Rasool (Institute for Space Studies, NASA, N. Y.) Radiation data from Tiros 2 and 3 over particular regions of the globe are compared with surface meteorological observations for the same period. The comparisons involve Tiros radiation data and ground observations on temperature, humidity, and cloud cover. The radiation escaping from the top of the atmosphere is calculated for local regions in the 8-12μ and the 7-30μ intervals.

<u>ON WEATHER SATELLITE INSTRUMENTATION</u>. Konrad J. K. Buettner and Robert J. Charlson (Department of Meteorology, University of Washington, Seattle) Satellite reconnaissance of the lower atmosphere may use electromagnetic waves between 0.2 and about 10^5 μ wavelength. Of existing and proposed experiments, only a few seem to be helpful to the synoptician without overtaxing the satellite's capacity. Our proposals concern the measurement of the total ozone thickness and the detection of areas where rain is falling. Yellow solar light is reflected back to the satellite, thus passing through the atmosphere twice. A spectrophotometric study near the Chappuis band should yield data of total ozone and of total air above reflector height. The variable portion of this total ozone thickness will provide information on horizontal advection. Radio waves, emitted from all warm bodies, have been used to measure temperatures of, for example, the Moon, Mars, and Venus. The energy emitted from the Earth's surface is only moderately attenuated by clouds at the 1-cm wavelength; however, rain exceeding 4 mm/hr will measurably change the flux. If a 1-cm receiver with a 1-2m parabola is installed in an Earth-oriented satellite such as Nimbus, its passage over a raining cumulus cloud would result in sudden negative pulses of a width of approximately 0.1 sec.

METALLURGICAL INVESTIGATION OF SPUTNIK 4 FRAGMENT. Bill C. Giessen and Nicholas J. Grant (Department of Metallurgy, Massachusetts Institute of Technology, Cambridge) A 20-pound chunk of metal, still very hot, was found in Manitowoc, Wisconsin, on September 5, 1962, and is assumed to be part of the Russian Sputnik 4. It was shipped to the Smithsonian Astrophysical Observatory in Cambridge, Massachusetts, and a section was handed to MIT for investigation. The roughly cylindrical piece, about 3-1/2 inches tall and 8 to 10 inches in diameter, is composed of three main sections: (1) the cap, probably forged and machined from 0.32 per cent carbon steel; (2) the brim, a disc of larger diameter than (1), welded onto (1), hot-rolled and cut from 0.21 per cent carbon steel; (3) reacted frothy steel, slightly melted onto the other side of (2), 0.07 per cent carbon, 0.040 per cent nitrogen. The specimen was given a wet chemical and spectroscopic analysis, hardness tested, and investigated metallographically. The results show that melting has taken place from the top of part 1 (no decarburization at 0.001-inch depth) and the side of (2) (decarburization to 0.1 inch depth), while some decarburization (0.01-inch depth) occurred on the side of (1); the other regions of (1) and (2) are unaffected by heat or atmosphere. Part 3 consists of decarburized iron with spheroidized oxide inclusions and nitride needles, indicating slow solidification. The very high temperature gradient on the face of (1) is explained by brief exposure to high temperatures.

MINERALOGY OF THE MELTED PORTION OF SPUTNIK 4. Ursula B. Marvin (Smithsonian Astrophysical Observatory, Cambridge, Mass.) One of the present surfaces of the Sputnik 4 fragment is covered with a layer of melted and partially oxidized metal. X-ray diffraction films and polished sections of the resulting botryoidal mass reveal a complex assemblage of minerals that reflects nonequilibrium conditions of formation. The melted material consists mainly of α iron that is covered with a thin black crust of wüstite (FeO), and magnetite ($FeFe_2O_3$). Cohenite, or cementite (Fe_3C), the alloy (Al_3Fe), and several unidentified phases are also present. Periclase (MgO) occurs as a soft white coating upon the black oxides. Wüstite has heretofore been unknown as a natural mineral in either terrestrial rocks or in meteorites. However, the discovery of wüstite among the oxidation products of Sputnik 4 led to the examination by X-ray diffraction procedures of the crusts of numerous iron meteorites. Wüstite was found in association with magnetite in the crust of the Bogou iron that fell in Upper Volta in August 1962; in the crust of Braunau, Czechoslovakia, that fell in 1847; and in the crust of several others. It is evident, therefore, that wüstite can form and persist for long periods, although its phase relations indicate that it is unstable below 570°C. The periclase was deposited as a sublimate upon the surface of the iron oxides. As the steel is very low in magnesium, this element must have been derived from some magnesium alloy that was shielded during the main stage of melting and oxidation of the steel and that decomposed very late during flight in the atmosphere.

H^3 AND A^{37} IN A FRAGMENT OF SPUTNIK 4. D. Tilles, E. L. Fireman, and J. Defelice (Smithsonian Astrophysical Observatory, Cambridge, Mass.) Sputnik 4, launched in May of 1960, re-entered the atmosphere September 5, 1962. The orbit had an inclination of about 65°, and initial apogee of about 670 km. After April 1962 the apogee was below 400 km and in the southern hemisphere. A 9.5-kg fragment of steel believed to be part of Sputnik 4 was recovered in Manitowoc, Wisconsin, within a few hours after re-entry. Preliminary determinations of argon-37 and tritium activities are:

	disintegrations/min kg at fall	
	H^3	A^{37}
plate	<0.5	4.5 ± 1.0
cylinder	2 ± 1	5.8 ± 1.0

The argon-37 activity suggests a flux of about 1.5 nucleons/cm^2 sec during the last few months in orbit. Cosmic-ray fluxes near the Earth, together with some contribution from trapped protons over the South Atlantic near apogee, can account for this activity. The H^3 activity in the plate is less than 5 per cent of the amount expected to be produced by cosmic rays as estimated from the argon activity. Any additional contributions of H^3 from the solar flares of 1960-1961, from the stopping of trapped tritons and from the spallation by trapped protons in the early period in orbit, would decrease the 5 per cent limit. Very low H^3 activity has also been observed in some iron meteorites (e.g., Sikhote-Alin). Our results suggest diffusive loss of H^3 during and after re-entry heating. Thus the hypothesis that tritium in iron meteorites is lost from kamacite (α phase) is strengthened.

GAMMA-RAY SPECTROMETRY OF A SPUTNIK 4 FRAGMENT. Ernest C. Anderson and M. A. Van Dilla (Los Alamos Scientific Laboratory, University of California, Los Alamos, N. Mex.) Measurements of the γ-ray spectrum of a 6-kg fragment of Sputnik 4 were made using an 8 x 4 in. NaI (Tl) crystal spectrometer. A series of 1000-min measurements over a period of 3 weeks led to the identification and approximate quantitation of a number of cosmic-ray induced spallation products, including Mn^{54}, V^{48}, and Sc^{46}. The method is nondestructive and rapid and offers a simple means of identifying objects that have been in orbit.

RADIOACTIVITY IN SPUTNIK 4 FRAGMENT. John T. Wasson (AF Cambridge Research Laboratories, Bedford, Mass.) Positron and γ-ray activity has been measured in a 147-gram slice of the Wisconsin fall thought to be a fragment of Sputnik 4. Positrons have been measured by counting the annihilation quanta on a γ-γ coincidence spectrometer. The counting rate was determined to be 0.40 ± 0.05 cpm/kg on September 8, 1962. It fell to about 0.25 cpm/kg on September 16, and to about 0.16 cpm/kg on October 3. Thus, a sizable fraction of the initial positron activity decayed with a half life of about one week. The decay time is attributable to short-lived nuclides, such as 5.7-d Mn^{52}. Longer-lived positron activity is also present. A γ-ray spectrum taken on September 7-8 on a 3 x 3 in. NaI crystal and 100-channel analyzer showed a γ ray of 0.84-Mev energy attributed to Mn^{54}. The disintegration rate of this activity is 100 ± 20 dpm/kg.

CHEMICAL AND METALLOGRAPHIC STUDIES OF SPUTNIK 4 FRAGMENTS. O. F. Kammerer, R. Davis, H. L. Finston, and J. Sadofsky (Brookhaven National Laboratory, Upton, N. Y.) Metallurgical, radio chemical, and chemical analyses were performed on fragments of steel recovered after the disintegration of the U.S.S.R.'s Sputnik 4. These determinations indicated that the material was a hot-rolled carbon steel with hardness measurements similar to those found in a structural steel with a tensile strength of 55,000-60,000 #. Metallographic examination revealed that the major portion of the steel exhibited a banded structure characteristic of hot-rolled material. The upper surface of the material probably underwent heating to or near the melting point, causing the formation of a narrow band similar to an as-cast Widmannstaettan microstructure. Heat treatments are being conducted to simulate the temperature conditions and to reproduce the microstructural features between the base material and the structure found at the top of the specimen. A melted steel agglomerate that had formed at the bottom of the specimen was also examined. It consisted of a solidified steel containing several different varieties of inclusions and compounds. The argon-37 and tritium activities were determined: Ar^{37}, 2.3 ± 0.3 dis/min; Kg and tritium, 6.5 ± 0.7 dis/min; Kg, T/Ar^{37} atom ratio of 23 ± 3. The T/Ar^{37} atom ratio is approximately equal to the relative production cross sections for these isotopes; hence the large excess of tritium previously reported in satellites exposed to the November 1960 solar flare was not observed in this specimen.

PRELIMINARY REPORT ON THE CALCULATION OF UPPER ATMOSPHERE MODELS FROM FIRST PRINCIPLES. Gilbert Yanow (Douglas Aircraft Co., Santa Monica, Calif.) It is often forgotten when investigating general characteristics of the planets that the Earth, too, is a planet. The Earth has this advantage: a good deal of data has been compiled about it, permitting a check on values calculated from theory. In this work a list of the photochemical reactions, with respective rate coefficients, cross sections, and recombination coefficients which at present best describe the mechanisms of the Earth's upper atmosphere has been compiled from a careful search of the literature and from discussions with leading investigators in the field. From these reactions a set of simultaneous, nonlinear differential equations that determine the concentrations of the neutrals, ions, and electron density are integrated on an IBM 7090 in a nonequilibrium manner over the parameters of solar energy, time, and altitude. While the results are preliminary, the indications are most encouraging. When properly developed, the method may prove to be a powerful tool in the reduction of planetary probe data.

A MODEL OF THE LUNAR ATMOSPHERE. F. L. Hinton and D. R. Taeusch (Space Physics Research Laboratory, University of Michigan, Ann Arbor) A simple model of the lunar atmosphere is presented in this paper. This model was constructed on the basis of assumptions concerning the lunar surface temperature and probabilities for atomic processes. It is also implicitly assumed that the selenomagnetic field does not shield the lunar surface or atmosphere from the effects of the solar wind, that the entire sunlit side of the Moon is positively charged due to the solar ultraviolet radiation, and that the lunar atmosphere is essentially an exosphere. Mechanisms for the accretion and escape of various gases are combined to calculate the partial neutral number densities and positive ion densities at the surface. The results are given as functions of the solar wind flux J. Assuming $J = 10^9$ particles/cm^2 sec the following values are found: 5.4×10^3 atoms/cm^3 for H, 9.2×10^3 atoms/cm^3 for He, 1.7×10^3 molecules/cm^3 for H_2O, 5.4×10^4 atoms/cm^3 for Ar, 1.7×10^{-2} atoms/cm^3 for Kr, and 1.9×10^{-3} atoms/cm^3 for Xe. The total number density of the positive ions H^+, He^+, H_2^+O, and A^+_r is 1.5×10^3 ions/cm^3. Qualitative statements concerning the distribution of density over the lunar surface are made, based upon formulas for the range and time of flight of particles on ballistic trajectories on the lunar surface.

OZONE HEATING IN THE ATMOSPHERE OF MARS. A. Arking and S. I. Rasool (Institute for Space Studies, NASA, New York, N. Y.) The distribution of ozone and its effects on the structure of the lower Martian atmosphere are calculated for a composition of 2 per cent CO_2, 98 per cent N_2, and various trace amounts of O_2. The temperature profile is based upon exact numerical solutions of the nongrey radiative transfer equation with a heat source that includes the absorption of solar radiation by ozone and oxygen. It is shown that the ozone heating is effective only in the lower atmosphere and has a small influence on the temperature in that region.

THE GEOMAGNETIC FIELD BOUNDARY AND ASSOCIATED SOLAR WIND. V. L. Patel (Department of Physics, University of New Hampshire, Durham) and Laurence J. Cahill, Jr. (National Aeronautics and Space Administration, Washington, D. C.) The Explorer 12 satellite surveyed the magnetic field in the sunward region of space. During its active life, it measured the total vector magnetic field from 20,000 km to 83,000 km from the center of the Earth. It passed through the 'boundary of geomagnetic field' several times. The preliminary results have been reported elsewhere. Here further results are discussed, particularly on the position of the boundary and the change in the magnetic field at the boundary. The strength of the associated solar plasma, or the so-called 'solar wind,' is calculated from the measured value of the magnetic field at the boundary. It is found that the value of NV^2 increases by the factor of 6 in the high magnetic activity compared to the very quiet geomagnetic activity.

<u>THE SC AND THE MAIN PHASE OF A MAGNETIC STORM IN THE OUTER SPACE</u>. Laurence J. Cahill, Jr. (National Aeronautics and Space Administration, Washington, D. C.) and V. L. Patel (Department of Physics, University of New Hampshire, Durham) A severe geomagnetic storm was observed on the Earth on September 30, 1961. The SC time reported was 2109 UT. The Explorer 12 at this time was in the region outside of the 'magnetosphere' at 76,000 km from the center of the Earth. The complete results of the magnetic field measurement during this high-activity period are discussed. The detailed study of the field around SC time reveals that the field in the outer space decreased slowly by 20 γ six minutes before the SC was recorded on the Earth. It suddenly increased by 25 γ just before the SC time. On the next returning pass, a higher and varying magnetic field was observed outside the magnetosphere during the main phase. It is argued that some part of this higher field was possibly the consequence of the hydromagnetic turbulence outside the boundary. During the main phase the geomagnetic field boundary was penetrated by the satellite. The detailed study in the vicinity of the boundary shows the irregular magnetic field regions inside the magnetosphere.

<u>PARTICLE AND MAGNETIC OBSERVATIONS OF THE MAGNETOSPHERIC BOUNDARY AND SOLAR PLASMA WITH EXPLORER 12</u>. J. W. Freeman, J. A. Van Allen (State University of Iowa, Iowa City), and L. J. Cahill, Jr. (National Aeronautics and Space Administration, Washington, D. C.) The phenomena at and near the interface between the magnetosphere and the interplanetary medium on the sunward side of the Earth have been observed repeatedly with a system of low-energy particle detectors and a three-axis fluxgate magnetometer in Explorer 12 during the period August-December 1961. The radial position and nature of the interface vary markedly under varying solar and geophysical conditions. On occasion there is a sharp discontinuity in both trapped-particle intensity and magnetic-field intensity and direction at radial distances as small as 8 Earth radii. There is also evidence for the presence of a plasma containing electrons of energy 1-10 kev just beyond the interface. An associated effect is the strong enhancement of the intensity of electrons ($E \sim 50$ kev) in the outer portion of the trapping region. The radial distance to the interface under quiescent conditions is observed to lie between 10 and 14 Earth radii.

ON THE EFFECT OF A WEAK INTERPLANETARY MAGNETIC FIELD ON THE INTERACTION BETWEEN THE SOLAR WIND AND THE GEOMAGNETIC FIELD. John R. Spreiter and William Prichard Jones (Ames Research Center, NASA, Moffett Field, Calif.) Attention was directed recently by Axford and by Kellogg to the possibility that the presence of a weak interplanetary magnetic field may lead to the formation of a collision-free shock wave upstream from the boundary of the geomagnetic field and to a region of irregular magnetic fields in the intervening space. Previous calculations of the coordinates of the shock wave are improved upon by application of recent advances in the theory of gasdynamic shock waves developed for re-entry aerodynamic studies. It is found that the standoff distance of the shock wave is increased significantly over previous estimates and that the new results appear to be consistent with observations. Results are also shown to illustrate the differences to be anticipated in the region of irregular fields when the interplanetary field is aligned parallel or anti-parallel to the geomagnetic field in the equatorial plane and when the Alfvén-Mach number is greater or less than two.

THE EFFECT OF A UNIFORM EXTERNAL PRESSURE ON THE BOUNDARY OF THE GEOMAGNETIC FIELD IN A STEADY SOLAR WIND. John R. Spreiter and B. Jeanne Hyett (Ames Research Center, NASA, Moffett Field, Calif.) Approximate solutions are given for the shape of the boundary separating the geomagnetic field from the interplanetary plasma for a model that assumes the plasma pressure to be composed of two components. One is a dynamic pressure proportional to the normal component of the momentum of the particles of a steady and undisturbed uniform incident stream, as is customary in the usual formulation of the steady-state Chapman-Ferraro problem. The other is a static pressure considered to be constant over the boundary surface. Results are determined for the traces of the boundary in the equatorial plane and in the meridian plane containing the Sun-Earth line for a complete range of values for the ratio between the two pressure components. The principal qualitative feature which includes the effect of a uniform external pressure is that the geomagnetic field terminates at a finite distance from the Earth in the anti-solar direction that is only a moderate multiple greater than in the solar direction for all but extremely small ratios of static to dynamic pressure.

INTERACTION OF PLASMA WITH DIPOLE MAGNETIC FIELD. J. B. Cladis and T. D. Miller (Lockheed Missiles and Space Co., Palo Alto, Calif.) The action of a directed hydrogen plasma in a dipole magnetic field is being studied. The plasma is generated by a pulsed coaxial plasma gun described by Gilleo (1961) and is directed radially in the equatorial plane toward the dipole. Double-probe measurements indicate a particle density of 2×10^{12} per cm^3 and a stream velocity of 5×10^6 cm/sec. Total light photographs show that the plasma penetrates to a radial distance roughly determined by equating the plasma and the magnetic pressures. Further motion of the plasma across field lines in the azimuthal direction appears to be quite small. However, the plasma moves along field lines into the polar regions of the dipole so that a cavity containing no plasma is formed. Magnetic probe measurements made radially in the equatorial plane from the dipole toward the plasma stream show (a) an increase of the field strength inside the cavity, (b) an interface a few centimeters wide in which the dipole field is reduced and finally canceled by the action of the plasma, and (c) a region of no magnetic field in the plasma beyond the interface.

FLUX AND ENERGY SPECTRA OF NATURAL PROTONS AND ELECTRONS OBSERVED IN A LOW ALTITUDE POLAR-ORBITING SATELLITE. J. D. Mihalov, D. D. Elliott, S. C. Freden, F. S. Mozer, G. A. Paulikas, and A. L. Vampola (Aerospace Corp., Los Angeles, Calif.) Two phoswitch-type proton spectrometers that time-shared a 12-channel pulse height analyzer with the electron spectrometer were included in the instrument package mentioned elsewhere. Electrons below about 1 Mev were deflected from the scintillators by sweeping magnets at their entrance apertures. These proton spectrometers covered energy ranges from about 60 kev to 4 Mev and from 2 Mev to more than 100 Mev, respectively. Together with the instrumentation described elsewhere, they measured the flux and energy spectra of protons and electrons in the natural radiation belts in the vicinity of the Brazilian and South African magnetic anomalies. Similar measurements were made on particles with $L \sim 4.5$ at many longitudes. Spectra and flux data will be presented.

THE FLUX AND ENERGY SPECTRUM OF PRIMARY COSMIC-RAY PROTONS AS A FUNCTION OF TIME. Peter Meyer (Enrico Fermi Institute for Nuclear Studies, Chicago, Ill) and Rochus Vogt (Normal Bridge Laboratory, California Institute of Technology, Pasadena) During July and August 1961 the energy spectrum of primary cosmic-ray protons was investigated in the energy range from 80 to 350 Mev. The observations were made in five high altitude balloon flights at geomagnetic latitudes $\lambda \geq 73°$N. Solar flare and quiet day spectra were obtained. A comparison of results obtained in 1960 and 1961 leads to the conclusions that (1) a significant flux of low energy protons is continuously present in the primary radiation in the years of high solar activity; (2) this flux, which decreases with the declining level of solar activity as the galactic cosmic-ray flux increases, is concluded, therefore, to be of solar origin; and (3) the time dependence of the observed proton flux rules out the possibility that these protons originate in the rare large solar-flare events. They must be produced within the solar system, either continuously or intermittently in association with frequently occurring small solar flares. We shall discuss the implications of these results.

THE MAGNETIC MOMENT OF MODEL RING CURRENT BELTS AND THE CUTOFF RIGIDITY OF SOLAR PROTONS. Syun-Ichi Akasofu (Geophysical Institute, University of Alaska, College, Alaska) and W. C. Lin (State University of Iowa,

Iowa City) The magnetic moment M_R of the ring current is calculated for model ring current belts, together with their magnetic fields along an equatorial radius. A graph is constructed to show the relation between the ratio M_R/M_E (M_E = the magnetic moment of the Earth) and the intensity H of the ring current field at the equator on the Earth's surface. It is shown that the ring current cannot produce drastic reductions of apparent cutoff rigidity of solar protons, which are observed by detectors that are carried by balloons and satellites.

PRELIMINARY OBSERVATIONS ON VARIATIONS OF EXTREME ULTRAVIOLET SOLAR FLUXES WITH VARIATIONS IN SOLAR ACTIVITY. W. E. Behring, J. C. Lindsay, and W. M. Neupert (Goddard Space Flight Center, NASA, Greenbelt, Md.) A scanning monochromator, mounted as a pointed experiment on OSO-1, has been used for observations of variations of solar extreme ultraviolet and soft X-ray fluxes in the spectral range from 50 A to 400 A. The period of observation encompassed more than two complete solar rotations, and more than 6000 spectra were obtained. Analysis of several of the brighter emission lines over a period of one solar rotation indicates variations which can be related to other indicators of solar activity. Data indicate an enhancement in the He II Lyman-α (304 A) emission, integrated over the entire solar disk, of 33 per cent during a period when the Zurich provisional relative sunspot number increased from zero (March 11, 1962) to a maximum of 94 (March 22, 1962). A corresponding decrease is observed as the sunspot number decreases from this maximum. Additional enhancement is observed during flares. In a typical case the increase is 14 per cent for a flare of importance 3 which occurred on March 22, 1962. The intensity of selected coronal lines is also observed to vary with solar activity, the amount depending upon the origin of the line in the solar corona. Preliminary correlations have been made between these variations and several visual indicators.

LASER REFLECTION FOR THE ANALYSIS OF LUNAR TOPOGRAPHY. Charles H. Wilcox and Alexander D. Jacobson (Hughes Research Laboratories, Malibu, Calif.) The recent detection of laser echoes from the Moon by Smullin and Fiocco has stimulated interest in the use of lasers for geophysical exploration. We have examined the use of high power, short-pulse (10 nanosecond) lasers, invented by R. W. Hellwarth, for the determination of lunar surface features. With such an instrument, height measurements could be made to an accuracy of 5 feet and resolution areas to a mile across, and external noise would be no problem, even with present short-pulse laser systems. Available powers are only marginally useful, but the advance of laser technology suggests that an adequate system will be developed in a year or less. Earthbound measurements will be limited, however, by libration and available beamwidths in the determination of accurate height profiles but not structural features such as 'boulders.' Information can also be obtained on the lunar albedo, slope distribution, and flatness ratio. In all these areas, laser radars have the potential of yielding more precise data than corresponding radar backscatter measurements.

COMPOSITION AND TEMPERATURE MAPPING OF THE LUNAR SURFACE BY SPECTRAL ANALYSIS OF THE THERMAL EMISSION BY AN ORBITING VEHICLE. R. C. Speed, J. E. Conel (Jet Propulsion Laboratory, California Institute of Technology, Pasadena), and R. J. P. Lyon (Stanford Research Institute, Menlo Park, Calif.) Spectral analysis of thermal radiation from the lunar surface by instruments on an orbiting vehicle is a potential method of mapping lateral variations of composition of the lunar surface. Experimental data on the change in emissivity with wavelength in the 2.5 to 25 micron region indicate that different minerals and rocks can be identified by their spectral emittance. Spectra of granitic, basaltic, and ultrabasic assemblages can be distinguished with spectral resolution of 80 cm^{-1} (at 10 microns). With increased spectral resolution more precise data on mineral content and composition can be obtained, and glasses can be distinguished from holocrystalline rocks of the same bulk composition. Radiation temperatures of nonblack bodies in thermal equilibrium can be measured correctly only with spectral data. Emission from silicates at lunar temperatures departs considerably from a black-body distribution, though the degree of departure is a function of surface geometry. Both absolute and relative lunar temperatures calculated from total radiometric measurements or spectroscopic use of Wien's law will therefore be erroneous in many cases. For example, specimens of granite and dunite, both actually at 350°K, appear to differ by 11°K in radiation temperature as calculated from total flux measurements and the Stefan-Boltzmann law. The discrepancy results from differences in the average emissivities (from 2.5 to 25 microns) of the two rock types.

THE LUNAR SKIN: DUSTY OR POROUS? Konrad J. K. Buettner (Department of Meteorology, University of Washington, Seattle, and The Rand Corporation, Santa Monica, Calif.) The low values of $\sqrt{k\rho c}$ (k = heat conductivity, ρ = density, c = specific heat) are customarily explained by assuming dust with very low k. However, dust cannot explain the light reflection curve which indicates porous material. Arguments in favor of porosity will be described. Impacting meteors convert their kinetic energy first into that of rock vapor, which in turn disrupts the adjacent solid. The rock vapor then rides along with the cooling debris, thus providing a cementing agent at every random collision. Also, as noted by J. D. Halajian, we have vacuum cementing below 10^{-8} mm Hg. Further evidence of this porous structure can be seen in the odd-shaped meteorites recently collected in the stratosphere and on the Earth's surface. The ensuing porous matter could have a smaller ρ and therefore a larger k and, of course, a much larger $k/\rho c$. Heat and radio waves would penetrate deeper. Our previous statements about possible penetration of 10μ infrared and of sunlight would not be seriously altered by the above hypothesis.

THE CRATERS IN THE LUNAR WALLED PLAIN, PTOLEMAEUS. A. Palm and R. G. Strom (Space Sciences Laboratory, University of California, Berkeley) The diameters of craters in the lunar walled plain, Ptolemaeus, and in vicinal equal-area terrae were measured by means of some of the best lunar photographs available at this time. Statistical analyses of the data lead to the conclusion that the ghost and post-Ptolemaean craters came from distinctly different populations. The relative areal densities indicate that the rate at which the early ghosts were produced exceeded the subsequent rate of crater formation by one or two orders of magnitude. However, the mechanism that caused the craters may have been similar since the surface distribution, including the extent of alignments of both types of craters, suggests that internal and external processes were operative throughout the formative stages of Ptolemaeus. On the basis of the relative surface densities, age, and frequency distributions of the total Ptolemaean and adjacent terrae craters, it is tentatively inferred that these craters may have had a similar history.

<u>THEORETICAL TIDES ON A RIGID SPHERICAL MOON</u>. G. H. Sutton (Lamont Geological Observatory, Palisades, N. Y.), N. S. Neidell (Department of Geodesy and Geophysics, University of Cambridge, Cambridge, England), and R. L. Kovach (Jet Propulsion Laboratory, University of California, Pasadena) The recent development of seismographs for lunar use, with sufficient sensitivity at long periods to observe tidal tilts and changes in gravitational acceleration, makes the determination of gross physical properties from tidal observations possible. Theoretical equilibrium tides for a rigid Moon can be compared with observed tides to obtain the characteristic Love numbers, h and k, for the Moon. Numerical calculations of tides for 60-day intervals at several locations indicate: (1) the major perturbing body is the Earth--less than 1 per cent is contributed by the Sun; (2) three relative motions, distance variation, latitude, and longitude librations, are of equivalent importance; (3) the relative importance of these three motion components and relative amplitudes of the three orthogonal tidal acceleration components are strongly dependent upon location; (4) tidal changes in gravity and tilt are one to two orders of magnitude larger than those observed on Earth.

<u>THE SIGNIFICANCE OF TERRESTRIAL ANALOGS OF LUNAR FEATURES OF LUNAR BASING</u>. Jack Green (North American Aviation, Downey, Calif.) Similarities of pressure ridges in Galapagos lava flows with the Serpentine ridge on the Moon suggest a similar mechanism of origin. The use of the ridges, associated fissures, and lava tubes that may occur in the Hyginus rift area, as possible primitive lunar installation sites is exemplified by possible terrestrial analogs--the Grotajga rift of Iceland and lava tubes of Oregon. Features of the Valley of Ten Thousand Smokes are compared with 'smooth' intercrater areas of the southern lunar hemisphere. Caldera features involving rim craters (Ludent), multiple concentric terraces (Nyiragongo), and summit-pitted central volcanoes (Tengger, Toya, Newberry) are compared with similar lunar morphologies (Cichus, Bullialdus, Agrippa,

Langranus, Timocharis, Regiomontanus, Copernicus, and others). The mineralogy and petrography of calderas, involving sulfur and vesicular extrusives as at Aso, may be very important in lunar basing operations. The association of maar craters with caldera (Askja) and volcano-tectonic depression floors (Tarawara, Central Oregon) could be very important in the exploration of water in the lunar base area or even in the selection of the lunar base, because maars-type cratering appears to be related to a high water table.

PRE-IMBRIAN HISTORY OF THE LUNAR SURFACE. R. E. Eggleton and C. H. Marshall (U.S. Geological Survey, Menlo Park, Calif.) The Imbrian system is the lowest widely exposed stratigraphic system in the area of the Moon mapped by the U. S. Geological Survey. This system consists of a basal sheet-like unit of regional extent (Apenninian series) and an overlying series of crater-rim and crater-floor materials (Archimedian series). The Imbrian is partly overlain by material of low albedo (Procellarian system) that forms the maria and the Oceanus Procellarum. The Procellarian is succeeded by crater-rim and crater-floor materials of the Eratosthenian system and, in turn, by crater-rim, crater-floor, and ray materials of the Copernican system. Recent studies have shown that around the edges of Mare Nubium and Mare Humorum and within some large craters, the Apenninian sheet rests on pre-Imbrian material with mare-like topography. This material forms a relatively smooth plain or plateau adjacent to the maria and partially fills the large craters. Some small craters were formed on this material prior to the deposition of the Apenninian. Before Procellarian time the pre-Imbrian mare-like material was displaced along faults and appears to have been gently warped. Pre-Imbrian history, therefore, includes (1) early formation of craters, (2) subsequent emplacement of mare-like material, and (3) formation of more craters. If the maria have been formed by volcanism, at least two major periods of volcanism of the mare type appear to have occurred in lunar history.

LUNAR MAGNETIC DIFFERENTIATION. Louis S. Walter (Theoretical Division, Goddard Space Flight Center, NASA, Greenbelt, Md.) The most obvious thermodynamic differences between the Moon and the Earth are atmospheric pressure and lithostatic pressure gradient with depth. This paper examines ways in which any lunar igneous processes would be modified by these differences. Experimental data on reactions in basaltic compositions indicate that the derivation of alkaline basalts on the one hand, and tholeitic basalts on the other, may depend on whether partial melting of peridotite material occurred at high pressure (where eclogite minerals are stable) or at low pressure (with basaltic mineras stable). Estimated pressure-temperature gradients within the Moon indicate that the temperatures at which peridotite partially melts to basaltic liquid are achieved at low pressure. Thus, lunar alkaline basalts, should be relatively rare.

Any widespread igneous activity on the Moon should cause lunar degassing. The lowered H_2O fugacity of lunar magmas which results would necessitate higher melting and crystallization temperatures. It would also result in any rocks of granitic composition on the Moon being richer in SiO_2 than similar terrestrial rocks. The lowered oxygen fugacity of lunar magmas may result in primary precipitation of fayalitic olivine and consequent silica-deficient differentiates. Fe might precipitate at still lower oxygen fugacity, thus yielding SiO_2-rich Fe-poor differentiates.

THE FLUX AND DISTRIBUTION OF FRAGMENTS EJECTED FROM THE LUNAR SURFACE BY METEOROID IMPACT. Donald E. Gault (Ames Research Center, NASA, Moffett Field, Calif.), Eugene M. Shoemaker, and Henry J. Moore (U. S. Geological Survey, Menlo Park, Calif.) Mass-size distributions of fragments, which were ejected from craters formed in rocks by hypervelocity impact, were experimentally determined. These distributions have been combined with estimates for the rate of impact and mass distributions of interplanetary debris that strikes the lunar surface, in order to find the rate and mass of fragments that were sprayed up from the surface. The flux of particles of a given mass, ejected from the lunar surface, is found to be at least three, and probably four, orders of magnitude greater than the flux of the impacting interplanetary debris of the same mass. Experimentally determined mass-velocity distributions indicate that almost all the ejected fragments, which leave the surface with velocities less than lunar escape velocity, contribute to secondary impact events. A mass of fragments greater than the projectile mass, however, should leave the surface at velocities greater than escape speed and thus escape the gravitational field of the Moon. Some of this debris, ejected with velocities up to perhaps three times the impact of velocity, would escape the Earth-Moon system. These results imply the presence of a lunar 'atmosphere' of flying projectiles. The major fraction of the projectiles is estimated to be concentrated in a layer a few kilometers deep, with a spatial density at the lunar surface of the order of 10^5 to 10^7 times the spatial density of the interplanetary debris. The secondary particles, together with the debris, should be a powerful eroding agent that will continually abrade the lunar surface and reduce rubble to finer sizes. This suggests that there must be a layer of fine particles on the lunar surface. The accumulation of an appreciable depth of dust-sized fragments, however, would be inhibited by the reducing effect which the impacts of the interplanetary debris would have. This reduction of the lunar surface (negative accretion) should provide a source for some of the solid debris in interplanetary space, such as the gegenschein, the zodiacal dust, the Kordelowski clouds, and a geocentric concentration of dust.

FLUID IMPACT CRATERS AND HYPERVELOCITY--HIGH VELOCITY IMPACT EXPERIMENTS IN METALS AND ROCKS. H. J. Moore (U. S. Geological Survey, Menlo Park, Calif.), D. E. Gault, and R. W. MacCormack (Ames Research Center, NASA, Moffett Field, Calif.) The effective deformation strength for a hemispherical water crater is equal to the sum of strength due to hydrostatic pressure head, the strength due to surface tension, and the estimated viscous head loss, as shown in the following equation:

$$S_w = \frac{3}{8}\rho g p + \frac{3\gamma}{p} + \mu \frac{1}{t}\int_0^t \frac{d(z)/dt}{vol_p/\pi p^2}\, dt$$

where ρ is the density of water, g is the acceleration of gravity, p is the maximum crater depth, γ is the surface tension of water, μ is the viscosity of water, t is the duration of the cratering event, d(z)/dt is the radial velocity of the fluid shell, and vol_p is the volume of the projectile. Deformation strengths of water that are computed in this manner are in substantial agreement with calculations of deformation strengths using a formula derived on a theoretical basis by Charters and Summers for impact craters formed in metal targets in the fluid-impact regime. Fluid-impact or near fluid-impact craters in metals and rocks may be correlated with fluid-impact craters produced by water drops impacting with water when the deformation strength of rocks and metals is related to the shear or compressive strengths of the target materials. Although the correlation using strengths at low confining pressures is not in perfect accord with theory, the use of the product of the heat of fusion and density of the target material as a maximum possible deformation strength suggests that the effective deformation strength for rocks and metals during impact lies between the unconfined compressive strength and the product of the heat of fusion and density of the target material. The use of shear strengths and densities of the target at 49-kb confining pressure improves the correlation between craters produced in metals near the fluid-impact regime, the theory of Charters and Summers, and craters produced by water drops impacting water. Craters in rock do not correlate exactly with water craters and metal craters when the target shear strengths and densities at 49 kb are used, but such a difference should be expected. It is concluded that shear or compressive strengths of the target material are more realistic parameters to use in correlating impact-crater data than acoustic velocities.

PHOTOGRAPHIC INVESTIGATION OF THE EARTH-MOON LIBRATION REGIONS L_4 AND L_5 FROM MOUNT CHACALTAYA, BOLIVIA. Elliot C. Morris and Hal G. Stephens (U. S. Geological Survey, Menlo Park, Calif.) In the spring of 1961, K. Kordylewski of the Krakow Observatory reported photographing faint luminous cloud-like objects in the L_5 libration region of the Earth-Moon system, and later in the same year he reported similar objects in the L_4 region. As these objects were reported to be extremely faint by Kordylewski, it was evident that further investigation should be conducted from a site with unusually dark night skies. Systematic photographic investigation of the L_4 and L_5 libration regions was begun by us during the summer of 1962 at Mount Chacaltaya (elevation 17,600 ft) in Bolivia. This location has the advantage not only of high altitude but of a low latitude (16°21'S) where the orbit of the Moon and path of the libration regions pass close to the zenith. Previous studies of the zodiacal light at this site have indicated that the brightness of the night sky is unusually low. Our work was performed in collaboration with the University of Wisconsin and the University of Manchester Zodiacal Light Expedition. The libration regions were photographed using two equatorially mounted large-aperture aerial cameras, each covering a sky area 45° by 37°. A smaller camera was mounted parallel to one of the larger cameras. Photographic plate sizes were 4 x 5 in. and 8 x 10 in. The emulsion types used were Eastman Kodak 103a F with maximum sensitivity in the visual range, and red-sensitive 103a U. Examination of photographic plates of the L_5 libration region with a microphotometer reveals that, if a cloud of particulate matter was present in this libration region during July and August 1962, its maximum luminosity as recorded on the photographic plates was insufficient to be discriminated from other causes of small variation in background density of the plates. Definitive information on the L_4 region was not obtained because of operational difficulties. Investigation of the libration regions will be resumed during the summer of 1963.

<u>TEKTITES--ORIGINAL SURFACES PRESERVED BENEATH FLANGES, RAYED BUBBLES, AND REORIENTED STRAIN</u>. Virgil E. Barnes (University of Texas, Austin) The study of special features in tektites, such as rayed bubbles, the welded juncture of flanges, and bodies of australites, is facilitated by using the universal stage. Beneath the flanges, the surfaces of australites are preserved, as they appeared before atmospheric flight. These surfaces range from very slightly irregular to fairly rough in four examples. In each case hemispheric bubble pits on the body of the tektite are filled by flange glass of a lower refractive index. This difference in index is the result of the removal of the more volatile constituents during the formation of the flange. Rays of unidentified glassy material extend outward from bubbles in two indochinites and one moldavite. In the same moldavite two spatulate forms of similar glassy material were observed on opposite sides of another bubble, and these forms, as well as the rays, are of higher refractive index than the enclosing tektite glass. In the indochinites, all rays except one are of lower refractive index. The rays are not uniformly distributed; most fall roughly in or near planes passing through centers of bubbles. Some are distributed in patches, a few have random distribution, and all are probably the result of explosive volitilization of unstable minerals. Reoriented strain about etch features provokes the thought that much of the peculiar sculpturing on tektites may be in response to the shifting of strain as etching progresses.

LUNAR MELTING AND MELTING OF GABBRO AT HIGH PRESSURES. E. Azmon (Northrop Space Laboratories, Hawthorne, Calif.) The melting curve of gabbro at pressures of 1,000 to 50,000 atmospheres was determined through the use of a transistronics kiloton press with an internally heated graphite furnace. These pressures cover the estimated range of pressures in the rocks from the surface of the Moon to near its center. By plotting the melting curve of gabbro against the various published curves of lunar thermal gradient, the depth within the Moon at which gabbroic rocks would melt can be determined.

APPLICATIONS OF LUNAR BASING PRACTICES TO TERRESTRIAL SHELTERS. Charles E. Kaempen (Ground Systems Group, Hughes Aircraft Co., Fullerton, Calif.) Current space programs related to the manned exploration and utilization of the Moon and planets have highlighted the need for developing systems and practices that promote an optimum management of limited resources while subjected to a hostile external environment. This paper discusses how and to what extent such systems and practices are directly applicable to the construction and implementation of certain advanced terrestrial facilities. Special attention is given to facilities or shelters that will be necessary to enable personnel to operate effectively in hostile terrestrial environments that exist or may arise due to natural or man-induced circumstances. Comparisons are made with regard to the number of shelter personnel and their probable stay times in hostile environments associated with representative lunar, planetary, and terrestrial operations. Performance characteristics and descriptions are provided of applicable life support, power supply, display computer, temperature control, communications, waste management, and remote handling systems. Particular emphasis is given to the character of the training programs needed to enhance the effectiveness and/or survival of shelter personnel.