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SCIENTIFIC INSTRUMENTS FOR A SOFT LANDING STATIONARY AND MOBILE LUNAR VEHICLE

by

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COMMENTS ON EXPERIMENTS AND INSTRUMENTS

INTRODUCTION

This report is intended to provide preliminary information on scientific instrumentation used for lunar exploration.

NASA has furnished ABMA tentative lists of instruments to be carried in the payload packages of a stationary vehicle and a roving vehicle. The instruments are shown in Tables 1 and 2, and are listed in the order of priority established by NASA. Data on weights, size, power requirements, and sampling time was compiled from studies made by the Research Projects Laboratory and from information furnished by NASA.

The data shown herein should be considered as preliminary, with possible additions to be made in the near future, probably by 11 August 1959. It is distributed at this time to enable DOD laboratories to make preliminary design studies without further delay.

Responsibility for vehicle design, communications, TV system and power supply rests primarily with Structures & Mechanics and Guidance & Control Labs. The information contained herein pertaining to these areas is set forth because of its availability in the Research Projects Lab.

Table 1. Instrumentation for a Stationary Soft Landing Vehicle

Instrument	Lbs Weight	Size	Operating Power (watts)	Desired Sampling Rate In Flight	Desired Sampling Rate On The Lunar Surface
TV System	80	Cyl 10" dia X 8"	2 per frame		
Seismograph	12	Cyl 8" dia X 5"	4		Continuous
Gravimeter	250*	30" X 18" X 15"	12*		Continuous
Thermal Experiment	4		2	1 per min	1 per hour
Mass & Ion Spectrometer	8	Cyl 2" dia X 15"	20	1 per min	1 per hour
Plasma Probe	5	Cyl 5" X 8"	10	1 per min	1 per hour
Magnetometer	5	Cyl 2" X 12"	2	1 per min	1 per hour
Particle Detector	20	Cyl 8" dia X 8"	20	1 per min	1 per hour

* Includes Thermal Protection and Orientation Mechanism.

Table 2. Instrumentation for a Mobile Soft Landing Vehicle

Instrument	Lbs Weight	Size	Operating Power (watts)	Desired Sampling Rate	
TV System	80	Cyl. 10" dia. 8"	2 per frame	400 frames per day	
Seismograph	10	6" X 6" X 12"	2.4	4 per lunar day	
X-Ray Fluorescence	40	4" X 12" X 15"	30	2 per day total 20 samples	
Thermal Experiment	4		2	5 measurements for each sample location	
Spectrometer	8	Cyl. 2" dia X 15"	20	1 per hour	1 per min in Flight
Particle Detector	20	Cyl. 8" dia 8"	20	1 per hour on surface	1 per min in Flight
Magnetometer	5	Cyl 2" X 12"	2	1 per hour on surface	1 per min in Flight

A. USES OF A MOON-BASED TELEVISION CAMERA

Introduction: Preliminary computations show that a television system based on the moon could be provided with a linear resolution of one part in 10^3 and a frame rate of one per second, and would require a telemetry transmitter capable of transmitting about one watt in a bandwidth of 1/2 megacycle per second. The uses of such a television system are considered briefly below.

Terminal Guidance: Some kind of television system will probably be required in any unmanned, soft-landing, lunar vehicle for selecting and achieving a suitable landing site. If feasible, it is logical to use this system, after landing, for scientific studies. The above-mentioned computation was performed with this in mind; the frame rate of one per second is probably much higher than needed for any anticipated scientific observation, but would be needed for terminal guidance purposes. It is possible that determination of horizontal velocity will require higher frame rates; this in turn will require proportionately higher telemetering bandwidth and power. Whether or not a television system could yield sufficient accuracy of range determination is open to question.

Velocity in three dimensions during the terminal guidance phase could be computed from television signals by autocorrelation in an earth-based digital computer.

Lunar Topography

Once the vehicle is settled on the surface the television camera can be used to scan the lunar landscape, using lenses of various focal lengths to obtain varying amounts of detail.

Microscopic Particle Examination

With a suitable optical system the television system could be used to transmit to earth images of the field of a microscope to be used for examination of lunar surface particles.

Spectroscopic Images

The television system could be used for transmitting optical spectrograms.

Cloud Cover of the Earth

The proposed television system, if provided with such a lens system that the earth filled the field of view, would yield a resolution limit on the earth of eight miles. Such an application would produce an instantaneous view of the cloud cover over approximately one-third of the earth's surface. A series of such views taken at intervals of minutes or hours would yield information on the dynamics of large-scale weather phenomena. This idea was discussed briefly with Professor Verner Suomi of the University of Wisconsin, whose initial reaction was favorable. In this application the proposed high frame-rate would be unnecessary. It seems reasonable, therefore, that the resolution of the system could be increased materially without increasing the bandwidth or transmitter output power.

Moon-Television Communication Computation

I. Characteristics of TV system:

Assume 1000 X 1000 dot definition and 1 frame per second. Video bandwidth = 0.5×10^6 cps.

II. Sources of Noise Interference For Earth Receiver,

A. Cosmic Noise

Assume the antenna is always pointed 10° or more in galactic latitude from the galactic center, and that, therefore, the brightness temperature of the sky at 1000 mc. is 200°K. This corresponds to a brightness of 5×10^{-20} Jansky/steradian. Assuming an antenna beamwidth of 1/2° and a receiver bandwidth of 1/2 mc, the power input to the receiver will be 1.7×10^{-15} watts. The powers from any of the discrete sources at 1000 mc are entirely negligible.

An antenna beam of 1/2° width, pointed at the center of the moon, would see very little cosmic noise from other sources.

B. Solar Noise Reflected From Moon:

Assume a slightly pessimistic value of flux from quiet sun at 1000 mc of 10^{-20} Jansky (1 Jansky = 1 watt/meter^2/cps). Total power spectral density reflected from "perfectly reflecting" moon (assuming isotropic scattering) = area of moon X 10^{-20} Jansky = 9×10^{-8} watt/cps.

Pawsey & Bracewell (p. 299) recommend 0.15 reflection coefficient. Reflected power spectral density is then 1.35×10^{-8} watt/cps. Using inverse square law, intensity at earth is 8.5 X 10^{-26} Jansky.

Using 0.5 mc. bandwidth the intensity incident on earth due to lunar reflection of solar noise is 4.2 X 10^{-20} watt/m^2. This result assumes isotropic scattering at 15% efficiency from the surface of the full moon. If the moon is not full, the figure is correspondingly reduced. If a solar noise storm should occur, more power density might result; however, the effects of noise storms at this frequency are usually very slight.

It seems reasonable to assume that the receiving antenna on earth will have a beamwidth equal to or smaller than the moon's diameter; thus, the solar noise reflected by the moon and the thermal noise of the moon's surface will be the only external sources of interfering noise.

The thermal noise from the moon has not been measured at 1000 mc., but is expected to be negligible.

The reflected solar noise in 0.5 mc bandwidth is equivalent to a transmitter radiating 6.7 milliwatts from an isotropic antenna (with the same bandwidth).

III. Assumptions About Earth-Based Receiver

A. Noise figure = 1 decibel

This is equivalent to 4 X 10^{-14} watts of internal noise referred to the receiver input port.

B. Antenna diameter 150 feet, efficiency 50%.

(Note: It is assumed that there is no depolarization)

Effective area = 1050 m^2

Beamwidth = 0.5°.

Moon-reflected solar noise power into receiver = 4.5×10^{-17} watt in 0.5 mc band. Thus, receiver noise is more important than reflected solar noise. If the antenna has strong side lobes which look directly at the sun the solar interference might be very important. Assume the strongest side-lobe of the 150 foot antenna is 25 db below the main lobe. The "effective area" of this lobe is then 1/700 of the effective area of the antenna. Assuming again a solar flux of 10^{-20} Jansky, the power received by this side lobe is 7.5×10^{-15} watt. This is about 10 db less than the receiver noise; thus, the importance of low side-lobe levels is illustrated.

IV. Power Output Required Of Moon-Based Transmitter

Assuming a minimum acceptable signal-to-noise ratio of 10 db and an isotropic transmitting antenna, the output power required would be 60 watts. This assumes, following the foregoing arguments, that receiver noise is the controlling factor in the threshold signal. It is reasonable to expect that the transmitting antenna could have substantial gain. The limiting parameter here would probably be the directivity that could be accomodated. The earth subtends less than 2° at the moon, and the moon keeps the same face toward the earth. A beamwidth of 10° would surely allow adequately for libration and for any errors in alignment of the antenna. The gain for a 10° antenna is about 24 db and the diameter is 7 feet. If such an antenna were employed, the transmitter power could be reduced to 250 milliwatts for 10 db signal-to-noise ratio.

V. Conclusions

Assuming a television system with a definition of 1000 lines in each coordinate (twice as good as U. S. Commercial TV), a frame rate of one per second, an earth-based receiving antenna of 150-foot diameter, a receiver noise figure of 1 db, a moon-based transmitting antenna 7 feet in diameter, a frequency of 1000 mc, and receiver performance limited by internal noise rather than cosmic noise, a transmitter power of 250 milliwatts would suffice to produce a signal to noise ratio of 10 db. For safety, this should be raised to 1 watt.

Such a television system would be useful not only for scanning the lunar landscape, but would also be useful, if fitted with the proper telescopic lens, for mapping cloud cover on the earth from the vantage point of the moon.

B. Primary Cosmic Ray And Electron Detectors

a. The object is to count positively-charged cosmic ray primaries and electrons separately both in flight and upon the lunar surface.

This may be accomplished simply with two Geiger-Mueller counters: one completely shielded except for a window along its axis, with provision for collimation of the incoming beam, and with a permanent magnet placed before the G-M tube window; the other also well shielded but placed to one side so that its axis makes an angle with the incoming beam along the axis of the first G-M counter. The first counter detects high energy protons and other energetic cosmic ray primaries which undergo practically no deflection in the magnetic field. The second counter detects electrons principally since these are deflected away from the window of the first counter onto the window of the second counter (the magnetic rigidity, flux density times cyclotron radius, is much smaller for electrons of a given energy than it is for protons and other heavy particles of the same energy).

Provision should be made to minimize bremsstrahlung x-rays produced by absorption of electrons and other charged particles within the shields of the G-M tubes.

At least two appropriate scaling circuits should be included for each of the above two counters.

This simple instrumentation would supply crude but extremely important information about (1) the two earth-located Van Allen belts, (2) any similar belts between the earth and moon, (3) any similar belts which may be moon-located (providing indirect evidence concerning any possible lunar magnetic fields at the same time), (4) primary cosmic radiation in space between the earth and the moon, (5) cosmic radiation incident upon the lunar surface,

(6) radiation doses, an essential consideration for manned missions.

Since the counters would be directional an attitude sensing device (a simple photocell as minimum instrumentation; 3 sets of photocells arranged orthogonally to obtain two of the three components of rotation as desirable instrumentation) is required as auxiliary equipment for the cosmic ray and electron detectors. On the lunar surface the counter window axis should be programmed to work through orientation directions over the entire 4-pi solid angle. Secondaries from the lunar surface may be detected when the counters are pointed toward the lunar surface.

b. An alternate instrumentation arrangement for the same experiments as above outlined would be to employ two scintillation detectors (crystals plus photomultiplier tubes) in place of the two G-M tubes and couple these detectors with electronic pulse-height sorting. This kind of instrumentation would achieve much better energy discrimination than the G-M tubes and probably would be more useful during the flight portions of the lunar landing. However, it is obvious that the G-M tubes would be more resistant to the shock of the lunar landing operation.

c. A recent development, semi-conductor p-n junction detectors being investigated by Hughes Aircraft Co. (T. D. Hanscomb, formerly of NRL), appears to be a promising technique for detection of energetic charged particles (cosmic ray primaries for example) and have practically no gamma-or-beta-ray sensitivity.

Detection of High Energy, Heavy Particles

The object is to detect, identify and measure the energy of particles such as high energy protons, high energy alpha particles and high energy particles, in general heavier than protons. This experiment is complementary to the experiment described above. It is noted that electrons and other possible lighter particles are not detected in the present experiment.

A Cerenkov detector is recommended. In this detector both velocity and magnitude of electric charge (counter pulse is proportional to square of electric charge magnitude) are measured. This device is rugged and no more complex electronically than a scintillation pulse-height detector.

(A brief description of the instrument and its uses appears in "Scientific Uses Of Earth Satellites", J. A. Van Allen: 2nd edition, University of Michigan Press 1958).

C. Magnetic Field Measurement

The object is to measure both the magnitude and direction of the magnetic field during the earth-moon flight and upon the lunar surface. Knowledge of the vector B will provide (1) information on the magnetism of the moon allowing a comparison of the earth and moon magnetism and indicating at least some factors in the cosmological origin of the moon, (2) information essential to an understanding of any charged particle containment detected by the instrumentation of item 1 above.

It is recommended that a combination of two instruments be used for the vector magnetic field measurements, one for the magnitude of the vector and the other for its direction.

Two instruments appear competitive for the magnitude measurement, the proton precession magnetometer and the metastable helium vapor magnetometer. The former is well known and will not be discussed here. The latter appears to be a promising instrument. It is a magnetic resonance device which measures the absorption of infrared radiation by helium vapor containing atoms excited in the metastable state ($^3S_1$). The population of this triplet is magnetic field dependent and the infrared absorption is state-population dependent, maximum absorption of the 10830A radiation corresponding to the resonant frequency-magnetic field value of 2.8 megacycles per oersted. Here the magnetic field is measured by measuring the resonnance frequency. In either instrument a sensitivity of some 0.05 gamma appears available and desirable.

A fluxgate instrument is recommended for the magnetic field direction measurement. This is a simple and rugged instrument. The fact that relative values only are measured is not a disadvantage since an absolute magnitude measurement is available through the proton precession or helium vapor magnetometer.

The sensing period for this instrumentation can be considered as adjustable to meet telemetering problems. Continuous sensing is not necessary.

D. Mass-ion Spectrometer For Lunar Atmosphere Sampling.

A mass-ion spectrometer is proposed. Its features are (1) measurement of atomic and ionic content of extremely rarified gases such as may be expected near the lunar surface by a charge-accumulation pulse-counting technique rather than by current measurement; (2) measurement of the atomic and ionic content of denser gases such as would be encountered in the earth-moon flight; (3) measurement of both atoms and ions in the same instrument using a on-off voltage pulse to energize or de-energize an auxiliary electron gun (for "on", atoms plus ions are measured; for "off", ions only are measured); (4) measurement of both positive and negative ions in the same instrument using an alternating retarding potential on the collecting electrodes, alternate positive and negative pulses yielding pulses of negative and positive ions respectively; (5) use of a compact and light-weight permanent magnet to produce magnetic dispersion of the ions and so differentiate the various chemical elements or compounds in the gaseous environment; (6) use of an electric field to eliminate the incoming velocity of the atoms or ions. (7) use of a standard ion gauge to monitor the pulse-counting mass-ion spectrometer.

Figure 1 illustrates schematically the essential features of the proposed pulse counting mass-ion spectrometer.

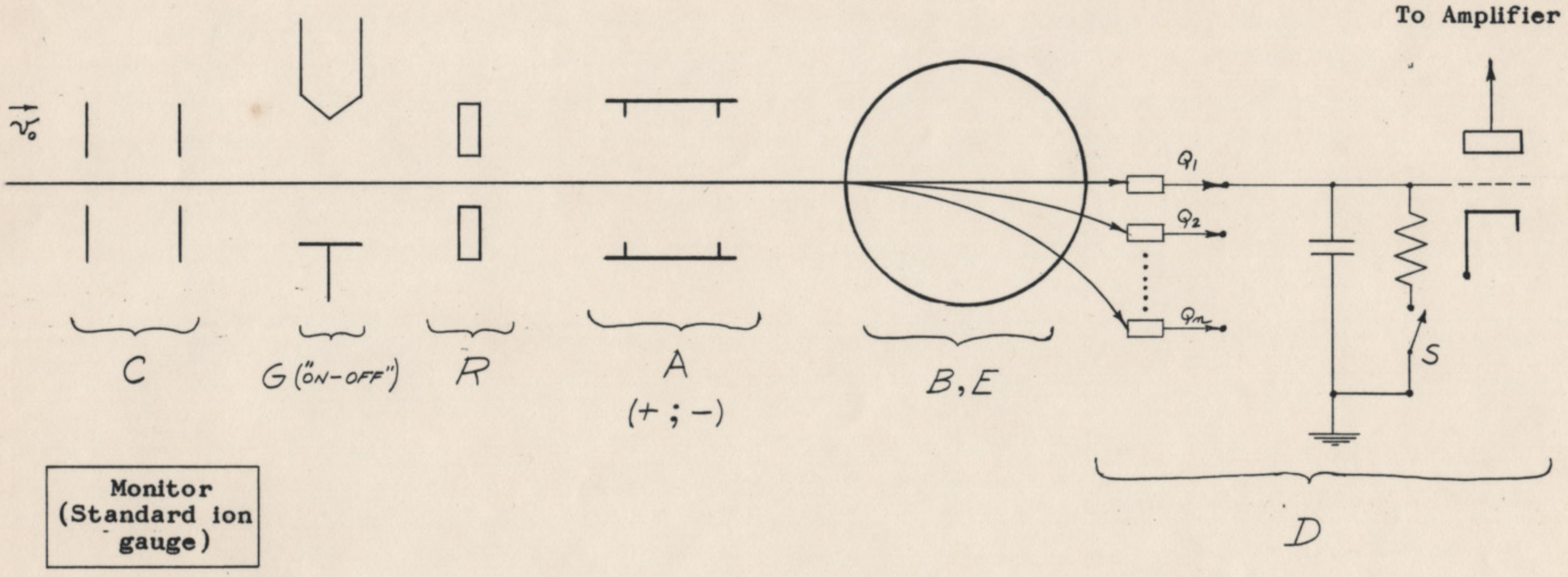

FIG. 1 - Proposed mass-ion spectrometer with charge integration for extremely low intensities.

Fig 1. Schematic diagram of essential features of Mass-ion spectrometer employing charge-accumulation pulse-counting technique. v_o, entering speed of atom or ion; C, collimating slits; G, electron gun (10 ma, 100 volts) for on-off operation to record both atoms and ions; R, retarding potential electrode to act as velocity selector for incoming atoms or ions (so evaluating v_o); A, accelerating electrode (alternating potential for both positive and negative ions); B, magnetic dispersion and E, electrostatic dispersion with both flux densities perpendicular to plane of page; D, detector consisting of array of small charge-accumulation plates Q_1 Q_n connected to R-C circuits which may be discharged after variable and adjustable time of charge accumulation by electronically closing switch S which causes discharge of capacitor and in turn creating a cathode-to-grid potential in turn causing a pulse in triode (or equivalent triode) finally yielding an amplified pulse which can be measured and counted. All switching of voltages is done electronically.

Weight: 5-10 pounds including mass-ion spectrometer withour power supply.

Volume: A few cubic inches for the mass-ion spectrometer without power supply.

Power: About 20 watts for continuous operation.

Sampling frequency: Adjustable within very wide limits depending on limitation imposed by telemetry.

E. Micrometrorite Detector

The operation of a light-pulse detector is based on the principle that a portion of a meteorite's energy will upon impact be converted to visible light, and that this portion of the meteorite's energy will be recorded by the photometer-telemeter system as a pulse-the pulse height being proportional to the meteorite's kinetic energy.

Physically, the detector is a conventional end type photomultiplier, ruggedized for rocket flight. The glass envelope will be aluminized with an opaque layer of aluminum to exclude visible sunlight, night sky radiation, airglow, etc.

In operation the meteorite impinges upon the exposed surface of the detector producting an instantaneous, incandescent area - the intensity and area of which is measured in the photometer system.

The emission of light from this area is caused by the incandescent heating of the meteorite material, of the aluminum layer, of the glass itself or of all three materials.

A recurrent, calibrated light pulser in the photometer system monitors any change in phototube sensitivity which may develop because of extensive perforation of the opaque layer or any other discrepancies in its operation. NASA is currently working on a system with the following characteristics:

Power Reg:	60 milliwatts (provided by batteries) (-750.)
Space:	7" X 7" X7" package
Operation:	Continuous preferred
Wt:	5 lb
TM Ref:	2 commutor channels - 60 bits/sec 1 cycle bandwidth

6¼V - 2 cm; 1 [illegible] each PM
- Pyrex glass - 1000 Å al film -

Cosmic ray Same effect -

F. Measurement of Pressure, Density and Gas Composition

The determination of gas composition in the vicinity of the moon and on the lunar surface should be included in any program of lunar study. Not only is such a study of definite scientific interest, but gauges for measuring pressure and density under extremely high vacuum conditions require a knowledge of the masses of the various particles present for accurate calibration.

Two types of instruments appear suitable for these measurements; the Bennett radio-frequency mass-ion spectrograph and the conventional magnetic-deflection mass-ion spectrometer. The integrated results from these instruments may be used to determine gas density and pressure. The R-F type has the advantage of not requiring a magnet but does not appear to have the precision or reliability of the magnetic type, which has been long tested in precise gas analysis. Research on, and development of both types of instruments, should be carried out to adapt them to use in lunar and planetary probes.

As neither instrument appears to have given acceptable measuring current at pressures below 10^{-10} or 10^{-11} mm of Hg, it is proposed that a charge collecting technique be used for measurement. A series of charged collector plates, placed so as to receive particles of the desired atomic masses, would be connected to an electronic pulse measuring system at suitable intervals, the size of the pulse obtained being determined by the number of particles collected on the plate. The method used is thus collection of charges on a capacitor during an electronically predetermined time.

An ionizing gun could be turned on or off to measure either ionized or neutral particles. By alternating the potential on the collectors either positive or negative ions could be collected. These can both be accomplished by using periodic voltage pulses on the electrodes.

The same direction programming to achieve gas sampling in various directions that has been proposed for the cosmic ray instrumentation could be used here.

With the simplicity of this device, using miniaturized circuits and a small permanent magnet, a weight of less than ten pounds and a volume of less than 100 cubic inches should easily be obtained. Power requirements will probably be 10-20 watts.

The instrumentation described shall be for use both during the earth-moon journey and on the lunar surface.

G. Seismic Investigations

Measurements with seismic apparatus will give information concerning the subsurface character of the moon; make possible the monitoring of micrometeorite impacts and may give some indication of the effects of sudden temperature changes on the moon's surface.

A series of seismic measurements constitutes one of the most versatile experiments that can be conducted with a single apparatus in a lunar vehicle.

Some of the problems that may be investigated directly or indirectly with seismic techniques are:

(1) The thermal state of the moon's interior.

(2) Physical structure of the moon.

  a. Near surface conditions

  b. Deep seated structure

(3) Meteorite impacts

(4) Effects of extreme temperature variation on the lunar surface materials.

In addition to the investigations outlined above concerning the moon's physical characteristics and environment, seismic apparatus may also be used as an important accessory in the sampling program to determine homogeneity of the vertical section.

The thermal state of the moon's interior may be investigated indirectly both with the recording seismograph and the gamma ray spectrometer. The moon has been regarded by most workers as being a cold body without the ability to undergo major structural change. Apparently during the previous history of the moon heating has occurred, enough, at least, to bring about large scale surface displacements.

The current opinion among scientists is that earthquakes are closely related to the outward flow of heat from the earth. Many of the crustal disturbances have their origin within twenty kilometers of the surface. Several hundred earthquakes per month, mostly small ones, can be recorded with a seismograph on the earth's surface.

A soft-landing lunar vehicle equipped with a recording seismometer should, in a period of several lunar days, determine whether or not seismic activity exists there. Since our present knowledge indicates that a perfectly cold earth would not experience major earthquakes, a lack of seismic activity on the moon would indicate that the radioactive heat being generated at depth is not of sufficient magnitude to cause a melting or plastic flow of sizable portions of the moon's interior.

With a major energy source available, such as the impact of a large meteor, or from a very explosive source, the deep seated crustal arrangement of the moon may be investigated. If the moon has a fluid core this condition may be detected through the analysis of seismic waves penetrating this zone that are recorded with seismic apparatus located at wide-spread positions on the moon's surface.

The existence of a fluid core in the moon is a question of great interest in connection with the study of the moon's magnetic field. Data obtained from the use of seismic techniques in conjunction with magnetometer surveys on the moon may give indirectly information about the connection between the earth's magnetic field with a fluid core.

A currently accepted theory on the formation of a crustal zone by the earth relates it to a phase change. The same phase conditions on the earth should not exist on the moon since it has a different gravitational attraction, density, and thermal history. If a crust is found on the moon through the use of seismic apparatus and an energy source sufficiently large to penetrate the crust, this discovery will help to evolve a new theory concerning the formation of the earth's crust.

Near subsurface structural conditions on the moon produce an immediately practical store of knowledge applicable to the goal of manned exploration of the moon. The existence of large underground crevices or discontinuities may be found with relatively simple apparatus already developed by a major company and modified for the lunar environment.

A great variety of seismometer designs based on different principles can be found in the literature. The sensing element of a seismometer presently being studied by Lamont Geological Observatory for NASA can be made as small as one cubic inch. The measuring and recording apparatus can be approximately placed in a container 8" diameter, 5" height. Power requirement is about 2 watts. For a study of subsurface conditions in the sampling area, a four amplifier system with power supply and geophones weighing around 7 or 8 lbs could be used that would require 2.4 watts maximum power. The amplifier and power supply volume would be around 6" X 6" X 12". Measuring depths of 200-400' could be made with 2 or 3 geophone stations in line covering 300 to 500'. Geophones would weigh 3 to 4 pounds.

Information received in the geophones would be in the 100 cps to 500 cps frequency range. Presumably the information could be stored on tape or telemetered directly.

The energy source would be a shaped charge. Fast explosive will remove the need for tamping the charge. Measurement time would be on the order of 0.1 to 0.2 seconds.

The same instrument set up could be used to record over long periods of time for the detection of moon tremors.

H. Chemical And Structure Analysis And Sampling

For chemical and structure analysis a combination of x-ray fluorescence and x-ray diffraction is recommended. Such a piece of equipment should have a power requirement of about 30 kilovolts at 1.5-3.0 ma. The duration of the run will be about 1/2 hr. The number of samples should be about 20. By manipulation of voltage and amperage, the duration of the running time can be changed to some extent.

The estimated weight, including power supply, is 50 pounds. The space requirements would be in the neighborhood of 1 cubic foot.

As for the sampling device, a mechanical drill is probably the most reliable and straightforward method of obtaining and dispensing the material. The space requirement is about 18" X 8" X 4". The weight, about 20 lbs. The power requirement 125-200 watts. Duration of sample procurement will vary between 2 min. and 25 min; depending upon the location and characteristics of the material to be sampled. Power for drill could also be obtained from compressed gases.

Transmission of information time will be the same as the run time unless information is stored. The X-ray information could be obtained by a specially designed Geiger-Mueller counter or scintillation detector.

It is planned to incorporate a monitoring scheme for checking the instrument performance.

I. Measurement Of The Electric Field On And Near The Moon

One of the physical quantities that may be of importance on and near the moon is the electric field. In exploring the physical constituents of the moon, electric field measurements should not be forgotten.

If the surrounding medium of the moon is not electrically conductive a conventional electric field meter could be used. The field meter consists of two electrodes which are electrically connected through a parallel RC network and are mechanically maneuverable so that one electrode is alternately exposed to and shielded from an external electric field by the second electrode. The latter is generally grounded. The external field terminates on the fixed electrode and charges it by induction. As the shielding electrode interrupts the field, the induced charges flow to ground via the RC network. Depending on the time constant of the RC network and frequency of interruption of the field, either the maximum charge on the ungrounded electrode or its rate of charge is directly proportional to the unknown field. The voltage produced in this manner is measured electronically.

The typical input impedance of conventional field meters operating in the voltage mode exceed 10^{10} ohms and in the current mode is of the order of one megohm. The resistivity of tropospheric air, in which such meter are often employed, is very large by comparison. The resistivity in the ionized layer of the upper atmosphere and perhaps of the moon are orders of magnitude smaller than the typical minimum input impedance of the field meter. Thus the external conductivity would short-circuit the meter.

If there are ionized layers around the moon, a conventional instrument cannot be used. If two mutually insulated conductors separated by a distance d, are placed in a conducting medium each will achieve the potential of its immediate surroundings. If a field E exists in the medium, the potential difference V between the two probes will be

$$V=Ed$$

The effective area of the probes would have to be worked out before any weight values could be given. In the case of an electrical shield around the moon a high input impedance would be necessary. For this reason an electrometer tube should be used as the input stage of the amplifier. If transistors are used for outer stages, the package can be kept relatively small, about 12 cubic inches, with a weight of about 8 ounces, and one watt of power.

J. Analysis By Electron, Neutron And Gamma Backscatter

The problem of studying the composition of the material of the lunar surface may be attacked crudely by means of neutron, electron, and gamma backscatter. The techniques of backscatter have been developed to a high degree by the oil well loggers and by those studying albedo effects in the Aircraft Nuclear Propulsion Program.

Neutron backscatter has been used extensively for logging oil wells. The presence of hydrogenous materials is readily indicated, and the detectors of backscattered neutrons can be made to be light, compact, rugged, and low in power requirements. The most probable detector is a BF_3 proportional counter.

Neutrons absorbed in the material of the moon can result in capture gamma which are characteristic of the materials and in radioactive nuclei whose decay products are characteristic and identifiable. On the whole, however, the reactions following the absorption of a weak beam of neutrons are likely to be difficult to detect above background and perhaps impossible to analyse.

The neutron could be supplied by a α-n reaction, such as is effective in the Polonium-Beryllium neutron source, or by small accelerators developed by the oil industry for well logging.

Gamma backscattering is a sensitive function of atomic number and a less sensitive function of material density. The photon source could be a gamma emitting radioisotope such as Cobalt 60 or an X-ray machine. The detector could be a simple Geiger tube. Gamma backscattering studies, although simple to execute, would provide only a crude measure of average atomic number.

Electron streams impinging on a sample of material will perhaps provide the most powerful means of identifying lunar materials. In principle, electromagnetic radiation from the infrared through the X-ray region should result from the bombardment of materials by electron streams. In addition to bremsstrahlung, characteristic radiation, corresponding to transitions between electronic energy states, should be observed.

The hot spot created by a well-defined electron beam should act as a point source for the various optics involved. The visible, infrared, and ultraviolet radiation should be examined by a prism grating with a thermistor or semiconductor detector. The soft x-radiation should be examined with a thin scintillator complete with a photo-cell or with a thin walled Geiger tube. X-ray spectroscopy should be possible with a crystal spectrometer using a small Geiger detector.

These possibilities are based on sound physics, but will need specific developments.

K. Possible Radio Propagation Experiments and Problems Pertinent To A Lunar Probe Project

1. Choice of Telemetry Frequencies   Choice of frequency will be dictated by considerations of required information bandwidth, of noise in the receivers and in the cosmic background, of required tracking accuracy, and of the state of the transmitter-design art. In general, a wide numerical bandwidth is more easily accommodated at a higher frequency than at a lower frequency. Frequency assignments of substantial bandwidth are more easily obtained in the UHF

band than in the VHF band. It is likely that many channels of telemetered information will be needed, and that the bandwidth may therefore be substantial. Cosmic noise varies as the 0.7 power of the wavelength, approximately; therefore, a high frequency insures less cosmic interference than in a low one. However, the quiet sun's output increases as frequency increases, throughout the band of usable telemetry frequencies, and so a compromise is needed. For a given antenna aperture, the attainable angular tracking accuracy varies directly as the frequency, but large parabolic antennas have mechanical tolerances that limit their use to frequencies below certain values. At the present time, transistor oscillators and amplifiers are of limited utility at ultra-high frequencies, though nonlinear-capacitor frequency-multipliers promise to permit for the generation of substantial amounts of power in the UHF band. Finally, the use of ultra-high frequencies results in narrow antenna beams, requiring precise orientation of the transmitting vehicle in order to illuminate the earth adequately.

A choice of frequency representing a reasonable compromise among all these considerations appears to be about 960 megacycles. Experience with Pioneer IV, which used this frequency, was eminently satisfactory in all respects. Further development of parametric and/or maser amplifiers should soon permit substantial improvement of signal-to-noise ratios over those obtained with Pioneer IV. This frequency is essentially unaffected by the earth's ionosphere; tropospheric effects have not been investigated.

2. The Moon's Ionosphere The atmosphere of the moon is known to be so rare that no measurements can be expected to succeed which depend on moon-ionosphere influence on a transmitted radio signal.

3. The Earth's Ionosphere Substantial effort has been devoted in the past to the study of the earth's ionosphere through the use of extra-terrestrial radio sources. Radio stars, reflected signals from the moon, and both direct and reflected signals from rockets and satellites have been utilized in these studies. A transmitter (or group of transmitters) on the surface of the moon would supplement these existing sources in valuable ways. As compared with those of radio stars, the moon-transmitted signals would have very narrow spectra and definite polarizations, permitting the use of the Faraday-rotation method of determining integrated electron density. As compared with that of an artificial satellite, the moon's motion is stable, well known, and highly predictable. It would therefore provide an ideal vehicle for an ionospheric experiment requiring years of observation. A directly transmitted signal from the moon makes a one-way trip through the ionsophere; thus, the effects imposed by the ionosphere are less-ambiguously determined than they are in the case of a moon-reflected signal from the earth.

A number of methods of studying the ionosphere using artificial satellites has been proposed or used. Most have not been very successful to date because the satellites available have the wrong characteristics for the most part. However, the proposed NASA ionosphere-beacon satellite has been designed to provide the necessary features to determine integrated electron densities by several methods: differential Faraday rotation, differential Doppler shift, differential refraction, and differential absorption. In addition, it should be well suited to studies of the fine structure of the ionosphere by observation of signal scintillation.

Briefly, the specification of the NASA Ionosphere Beacon Satellite are as follows:

Frequencies:	20, 40, 41, 135, 360 and 940 mc.
Power:	100 milliwatts minimum on each frequency All frequencies derived from same oscillator.
Polarization:	linear

Similar characteristics would be suitable for moon-based beacons. It is anticipated that a great many observers throughout the world would utilize such a facility for ionospheric studies. It is also conceivable that it would provide a useful facility for navigation and/or geodetic applications.

L. Lunar Biology

Although Biology is probably of secondary importance in the study of the moon, several possibilities should not be ignored in any lunar venture.

1 - Physical measurements of the lunar environment should be made with biological implications in mind.

a. UV measurements should be made at 200 mu - peptide bonds
260 mu - nucleic acids
280 mu - amino acids

b. Presence or absence of CH, CO, H_2S, NH_3

c. Temperature

d. Moisture

e. Atmospheric components

The identification or organic molecules on the moon would be of great interest.

2 - Although the probability of positive findings is remote, it should be remembered that the moon can serve as an excellent instrumentation testing ground for future studies (Mars and Venus) where the chances are greatly improved for finding living systems.

3 - At such time as the moon is being considered as suitable for a base (manned or otherwise) it should be considered as a Biological Experimental Laboratory from the point of view of basic research and from the practical point of view - that biological research must be done before we could sucessfully man such a base.