LUNAR ORBIT

SCIENTIFIC EQUIPMENT

FOR

APOLLO 17

LUNAR EXPERIMENTS PROJECT OFFICE

MANNED SPACECRAFT CENTER
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TABLE OF CONTENTS

1.0 INTRODUCTION

2.0 ELECTRICAL POWER AND INSTRUMENTATION

2.1 DESCRIPTION

3.0 LUNAR ORBIT EXPERIMENTS

3.1 OPTICAL BAR PANORAMIC CAMERA

3.1.1 Experiment Objective
3.1.2 Experiment Description
3.1.3 Equipment Description

3.2 THREE-INCH LUNAR MAPPING CAMERA

3.2.1 Experiment Objective
3.2.2 Experiment Description
3.2.3 Equipment Description

3.3 LASER ALTIMETER

3.3.1 Experiment Objective
3.3.2 Experiment Description
3.3.3 Equipment Description

3.4 ULTRAVIOLET SPECTROMETER

3.4.1 Experiment Objective
3.4.2 Experiment Description
3.4.3 Equipment Description

3.5 INFRARED SCANNING RADIOMETER

3.5.1 Experiment Objective
3.5.2 Experiment Description
3.5.3 Equipment Description

3.6 LUNAR SOUNDER

3.6.1 Experiment Objective
3.6.2 Experiment Description
3.6.3 Equipment Description
1.0 INTRODUCTION

Apollo 17 is the third CSM J-Mission and will contain a scientific instrument module (SIM) with a unique complement of equipment. As can be seen from Figure 1, the third SIM Bay contains the standard complement of cameras and a laser altimeter. The high-resolution panoramic photographs are used to supplement the detailed geologic interpretation and classification of terrain characteristics provided by the earlier missions. The mapping camera photographs are used to extend the lunar geologic network already established and to support the reduction of data from the other lunar orbital experiments. The laser altimeter is used to provide the slant range information from which altitude can be determined. This altitude information will not only be used to determine the precise lunar topography, but will also aid in the study of the moon's gravitational field.

Three new experiments round out the Apollo 17 SIM Bay. The UV spectrometer is an electro-optical device used to determine the lunar atmosphere density and composition. The second experiment, an infrared scanning radiometer is used to map the thermal characteristics of the moon, particularly at the terminators. The third and most complex of the new experiments is the lunar sounder. Its function is to develop a geological model of the lunar surface and subsurface structure to a depth of one kilometer.
FIGURE 1, CSM 114, SCIENTIFIC INSTRUMENT MODULE
2.0 ELECTRICAL POWER AND INSTRUMENTATION

2.1 DESCRIPTION

The lunar orbit experiments receive electrical power from the CSM. The experiments are controlled from switch panels inside the CSM by the command module pilot during lunar orbit, Figure 2. Data from the experiments is processed through a special scientific data system installed in the CSM for all J-Mission configurations.
Figure 2, CSM Control Panel for Lunar Orbit Experiments
3.0 LUNAR ORBIT EXPERIMENTS

3.1 OPTICAL BAR PANORAMIC CAMERA

3.1.1 Experiment Objective

Obtain high resolution photography of selective areas during light side passes. This resolution will permit detailed selenological interpretation and classification of terrain characteristics. It will also support interpretation of the significance of other selenochemical and selenophysical experiments. Concurrent operation with mapping camera and laser altimeter is desirable.

3.1.2 Experiment Description

The immediate problem that must be solved in planning a successful lunar program of scientific explorations is the lack of high resolution photographic information in those areas of high scientific interest that lie outside of coverage of lunar orbiter missions. In this sense, the early objective of the panoramic camera experiment is to provide unified high resolution surface imagery which can be used to evaluate both the scientific merit of these landing sites as well as the vehicle landing constraints.

Similarly, this information also aids in the establishment of design parameters for various mobility systems, instrument systems, and support facilities that are presently proposed for extending the operating radius of manned and unmanned surface explorations. The requirement for high resolution photography to support the definition and design of these systems is likely to increase during the program as efforts are made to maximize the scientific return from landing missions.

Lunar landing-site analysis and selection well in advance of the mission can significantly improve the efficiency of activities on the lunar surface. The same is even more true for manned or automated surface traverse missions. Only a thorough analysis of high resolution photography (the resolution must be three to five times better than the sizes of potential topographic hazards for the system under consideration) can provide high confidence in the operational suitability of landing sites or exploration areas. Identification and photogrammetric studies of features of high scientific interest in the vicinity of candidate landing sites can reduce the time needed for scientific activities during the lunar missions and also provide important inputs to the site selection process.

3.1.3 Equipment Description

The camera, Figure 3, operates in a nearly horizontal attitude with its line-of-sight folded to the vertical by two mirrors. Panoramic scanning is accomplished by rotating the lens, configured in an N-shaped cell,
about a horizontal axis. Forward motion of the vehicle is compensated for by tilting the stereo gimbal. The rate of tilt is regulated by an electronic signal which compares the spacecraft velocity with respect to the spacecraft height above the moon (V/h).

The camera operates such that the optical bar makes one revolution for every frame of photography. At the maximum design V/h rate of 0.050-radians per second, almost 5 seconds elapse between the end of one exposure and the beginning of the next, thus permitting a relatively long interval for effective foreaft tilt. This design consideration ensures that the tilt motion does not introduce forces acting to disturb the vehicle.

The camera is designed to operate in high-altitude vehicles with a minimum of control and program inputs. The data, in the form of film, is stored in a removable cassette which must be retrieved and returned to earth by the astronaut.
FIGURE 3, PANORAMIC CAMERA ENCLOSURE
3.2 THREE-INCH LUNAR MAPPING CAMERA

3.2.1 Experiment Objective

Obtain high quality metric photographs of surface from lunar orbit combined with time-correlated stellar photography for selenodetic/cartographic control. Desirable operation concurrent with 24-inch panoramic camera, laser altimeter.

3.2.2 Experiment Description

The mapping camera photographs provide a means for establishing a lunar geodetic network. The extent of coverage depends largely on the type mission on which the experiment is flown. The ideal situation is to obtain complete lunar coverage so that a single photogrammetric adjustment of the entire lunar surface sphere can be performed. This network fulfills all foreseeable requirements for positional reference on the moon. It also forms the basis for subsequent photogrammetric determination of the gravitational field through resection of camera position with respect to the control network.

The mapping camera photographs also form the basis of specialized cartographic maps ranging from small-scale flight charts, used for lunar orbit operations, to medium-scale topographic charts for planning lunar surface operations. These maps and photographs provide additional data on the form, distribution, and relative abundance of major lunar surface features, and provide terrain profile information required to plan subsequent lunar exploration missions.

The camera is oriented such that the terrain lens is pointed at nadir and the stellar lens points at the stellar field 96° from local vertical and 90° from the direction of flight. Photographs are taken with 78 percent forward overlap to provide stereoscopic imagery. Camera cycle interval is adjusted prior to flight between 78 percent and 55 percent overlap in concert with mission scientific requirements.

3.2.3 Equipment Description

The mapping camera system consists of a metric quality mapping camera utilizing 5-inch film coupled to stellar camera. The stellar camera provides an attitude reference for data reduction of the mapping camera film. The mapping camera has a 3-inch focal length and 74" x 74" field-of-view producing a 92 x 92-nautical-mile format at 60-nautical-mile altitude, Figure 4.

The data, in the form of film, is stored in a removable cassette which must be retrieved and returned to earth by the astronaut.
3.3 LASER ALTIMETER

3.3.1 Experiment Objectives

Provide precise time-correlated altitude information for use in conjunction with tracking data and pictures taken by the mapping panoramic camera and the infrared scanning radiometer.

3.3.2 Experiment Description

The determination of the moon's gravitational field from analysis of lunar orbiter perturbations, of which the main result is the mass concentrations, is of great importance to the study of the moon's structure and evolution. However, the lack of accurate topographic elevations makes it difficult to draw inferences as to internal structure because the contribution to the gravitational field of the visible topography cannot be subtracted out accurately. Also the spectrum of the long wave variations in topography is of significance to lunar structure itself. This experiment should yield data to facilitate resolving these problems.

The laser altitudes are used with DSIF tracking from the earth to determine improved orbits. The variations in topographic variations are then determined by subtracting the laser altitudes from the orbital radial coordinates. This procedure should give the topographic variations with an accuracy approaching that of the instrumentation, because the wavelengths of topographic variations are much shorter than the wavelengths of variations in the error of the radial coordinate of the orbit by DSIF.

3.3.3 Equipment Description, Figure 4

The laser altimeter can be broken down into the following functional entities:

- Transmitter
- Receiver
- Range Counter
- Control Circuits
- Power Supplies
- Signal Conditioner

The heart of the transmitter is a Q-switched ruby laser. Telemetry signals are used to indicate sufficient output from the laser, proper Q-switch motor speed, and proper operation of the discharge circuit for the flash tubes. The temperature of the laser circuitry is monitored by an analog measurement.

The receiver contains a photomultiplier tube and its ancillary circuits.

The range counter provides the 18-bit altitude word. It basically is a gated counter which runs at approximately 150 mHz. Logic within the counter precludes the count from being stopped outside of the 40 to 80 nautical-mile-range window.
The low-voltage power supply supplies basic voltages to a majority of the electronics within the altimeter. The high-voltage power supply primarily supplies the voltage to the flash tube discharge circuit.
FIGURE 4, MAPPING CAMERA AND LASER ALTIMETER
3.4 ULTRA-VIOLET SPECTROMETER (UVS)

3.4.1 Experiment Objectives

The primary objectives are to determine the lunar atmosphere atomic composition, density and scale height for each constituent.

The secondary objectives are to (1) measure the temporary atmosphere created by the LM descent and ascent engines, (2) measure the UV albedo and its geographic variations, (3) study the dark side fluorescence, (4) measure the UV galactic emission, and (5) study the atomic hydrogen distribution between the earth and the moon.

3.4.2 Experiment Description

The ultraviolet spectrometer will determine the composition of the lunar atmosphere by detection of the resonance re-radiation of energy in the ultraviolet region. The UVS collects data on ultraviolet radiation in the range from 1180A to 1672.6A. This data is collected in a digital accumulator and transmitted to the Apollo Command and Service Module (CSM) as a serial bit stream. Each frame consists of 120 digital words. The frame can be readily identified by five special words containing synchronization and timing information, followed by 115 words in the range from 1180A to 1672A. Specific wave length assignments for these words have been derived directly from the instrument cam design. It might be noted that the cam is nonlinear, and is designed to dwell heavily upon those wavelengths of greatest interest.

3.4.3 Equipment Description

The instrument is a 1/2-meter focal-length Ebert spectrometer consisting of a baffle, entrance and exit slits, collecting optics, scan drive mechanism, and electronics, Figure 5.
FIGURE 5, UV SPECTROMETER
3.5 INFRARED SCANNING RADIOMETER (ISR)

3.5.1 Experiment Objective

Obtain a surface temperature map of unilluminated portions of lunar surface at higher resolution than heretofore possible. Locate, identify, and study anomalously hot or cold regions. Correlate results with other data from lunar orbiting spacecraft, and study possibility of obtaining emission spectra from lunar surface in follow-on experiments. Desirable lunar surface photographic data correlation with radiometer field-of-view.

3.5.2 Experiment Description

The infrared scanning radiometer will measure the thermal emission from the lunar surface beneath the spacecraft. The orbital velocity provides scanning along the flight path while the device itself scans transverse to the flight path.

A surface temperature map results which will lead to the calculation of cooling curves for various lunar regions and therefore to the characterization of such physical parameters as the thermal conductivity, the bulk density, and the specific heat. The identification of thermal anomalies at high resolution will permit the resolution of the problem concerning the origin of these features (rocks on the surface, structural differences, volcanic activity, etc.).

3.5.3 Equipment Description, Figure 6

The ISR can be functionally divided into two systems: (1) the optical scanning unit and (2) the bolometer with its supporting electronics. The optical scanning unit consists of a folded cassegrain telescope, field-of-view baffles, and the rotating mirror with its attendance drive motor and gear box.

The thermistor bolometer is optically coupled to a silicon hyper-hemispheric immersion lens. This type of field lens and its placement, ensures the full hemisphere seen by the detector is filled as nearly as possible with energy. The attendant electronics divide the 80° to 400° Kelvin range into three channels for telemetering. During operation, these electronics are clamped once per scan while the radiometer is viewing space. A temperature reference is provided while the scanning mirror is pointed inward and viewing the calibration patch. This temperature parameter is telemetered and serves as a reference for the bolometer readings.
FIGURE 6, IR SCANNING RADIOMETER
3.6 LUNAR SOUNDER

3.6.1 Experiment Objectives

The lunar sounder's fundamental scientific objective is the development of a circumlunar selenological model to a depth of approximately one kilometer. This model will be developed from the electromagnetic sounding of the moon. The soundings will yield a three-dimensional physical model of variations in the moon's electrical conductivity, dielectric constant, and magnetic permeability. Through analysis of these parts of the lunar model, major layers, inhomogeneities, mascons, and subsurface water can be detected.

3.6.2 Experiment Description

Basically, the experiment requires the transmission of electromagnetic pulses from the spacecraft in lunar orbit, reflection of these pulses from the moon, and subsequent detection and recording of the reflected pulses at the spacecraft.

The experiment utilizes two antennas, one a center-fed dipole and the other a multielement yagi, with the dipole and yagi mounted at the rear of the Apollo Command and Service Module (CSM). Three transceivers will transmit through the two antennas a series of swept frequency (chirped) electromagnetic pulses at three different base frequencies (5, 15, and 150 mHz). The outgoing pulses are reflected from surface and subsurface interfaces of the moon and these reflected pulses are detected by the antenna/transceiver system in the receive mode. The detected pulses are then recorded on an optical recorder. At the conclusion of the experiment, the film from the optical recorder will be recovered by an astronaut for return to earth and subsequent analysis.

If the shape, amplitude and time of arrival of the detected pulses are known relative to the shape, amplitude, and time of the transmitted pulses, then the ratio of the detected to transmitted pulses may be interpreted in terms of the three dimensional distributions of scattering centers.

The scattering center distribution, together with calculated EM parameters, will be used to produce a structural model of the moon to a depth of one kilometer along the great circle paths over which the experiment is operated. The global coverage will cover a wide variety of lunar features and can be expected to deliver significant information about selenological parameters.

Thus, any known, inferred or postulated layering within the moon, such as the debris layer, permafrost layers, mare bottom contacts, and differentiated layers as well as gross lateral changes associated with known, inferred or postulated volcanism, igneous intrusions, mare-highland contacts, meteorite impacts, mascons and permafrost accumulations may be evident from the data obtained by the Apollo Lunar Sounder Experiment.
The lunar sounder can be divided into three functional parts: (1) the coherent synthetic aperture radar (CSAR), (2) the optical recorder, and (3) the antennas.

Functionally, the CSAR operates in two separate modes, the HF mode where the lunar surface is sounded with pulses of 5 and 15 mHz of energy and a VHF mode where 150 mHz is used in the sounding process. In both modes, the basic frequencies are generated in the programmer and frequency reference section. These basic frequencies are then sent into the modulator section. In the modulator, two basic operations are accomplished: first, the base frequency is gated, swept up through a predetermined frequency range and then sent on to the transmitter. In the transmitter, the pulsed RF signal is shaped, amplified and sent through the transmit/receive switch to the antenna assembly. The HF transmitter processes RF pulses of two frequency ranges so a matching network is employed on the output for impedance matching. The hybrid and matching networks which follow are used to phase and match the RF output to the antenna.

After the RF pulses have been generated, the receiver input is gated on, in preparation for reception for the return signals coming from the lunar surface and subsurface. After the return signal has been detected by the receiver the signal is gated through to the video output and on to the optical recorder.

The optical recorder's primary function is to process the CSAR output, record it on film and time-reference it for later data reduction and analysis. The video signal from the CSAR is used to intensity-modulate the cathode-ray tube (CRT). Gamma correction is necessary in this circuit to compensate for the nonlinear response of the CRT and the film throughout the intensity range.

The lunar sounder antennas are picture in Figure 7. The HF antenna is a dipole having a total span of 74-76 feet and can be deployed or retracted via switches within the CM. A jettison capability is also included in event of failure of the antenna to retract before a major delta V.

The VHF antenna is a yagi configuration having a single reflector, a driven element, and five directors. The antenna is displaced 20 degrees from the SIM centerline and is deployed when the SLA panels are opened during transposition and docking. Once deployed, the VHF antenna is locked into that position for the remainder of the mission.
FIGURE 7, LUNAR SOUNDER ANTENNA CONFIGURATION

OPTICAL RECORDER

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HF ANTENNA NO. 1

CSAR

OPTICAL RECORDER

HF ANTENNA NO. 2

80 FT TOTAL SPAN

103.8 IN.

20°

SIM &

NASA — MSC