Apollo 17 Lunar Surface Gravimeter (LSG)

Instrument Overview

The purpose of the Lunar Surface Gravimeter (LSG, figure 1) experiment (S-207) was to obtain highly accurate measurements of the lunar surface gravitational acceleration and its temporal variations at a selected point on the surface. Specific objectives were determination of the value of lunar gravity relative to Earth gravity, determination of the magnitude of lunar surface deformation due to tidal forces, measurement of vertical components of lunar natural seismicity, and monitoring of free oscillations of the Moon

Figure 1 - Lunar Surface Gravimeter in deployed configuration (NASA image S72-37253)

that may be induced by gravitational radiation from cosmic sources. The instrument was to act as a one-axis seismometer and also to be correlated with gravimeters on Earth to search for gravitational radiation. The crew deployed this experiment about 8 m from the Apollo Lunar Surface Experiments Package (ALSEP) central station. Problems with the suspended mass limited its usefulness.

Instrument Description

The basic equipment was a LaCoste-Romberg gravimeter, with associated electronics, sensors (spring mass suspension capacitor plates), a sunshield, and a ribbon cable to the central station electronics, with a total mass of 12.7 kg. The sunshield was equipped with a shadow device for alignment. The basic device (figure 2) comprised a beam extending horizontally connected at one end to a fixed pivot. At the center of the beam was a "zero-length" spring (a spring in which the restoring force is directly proportional to the spring length), attached above the beam to a fixed point on the instrument structure. Suspended from the midpoint of the beam by another spring (the “mass spring”, not shown in the diagram) was a mass, the downward force of the mass and the upward force of the spring were designed to keep the beam in a horizontal position

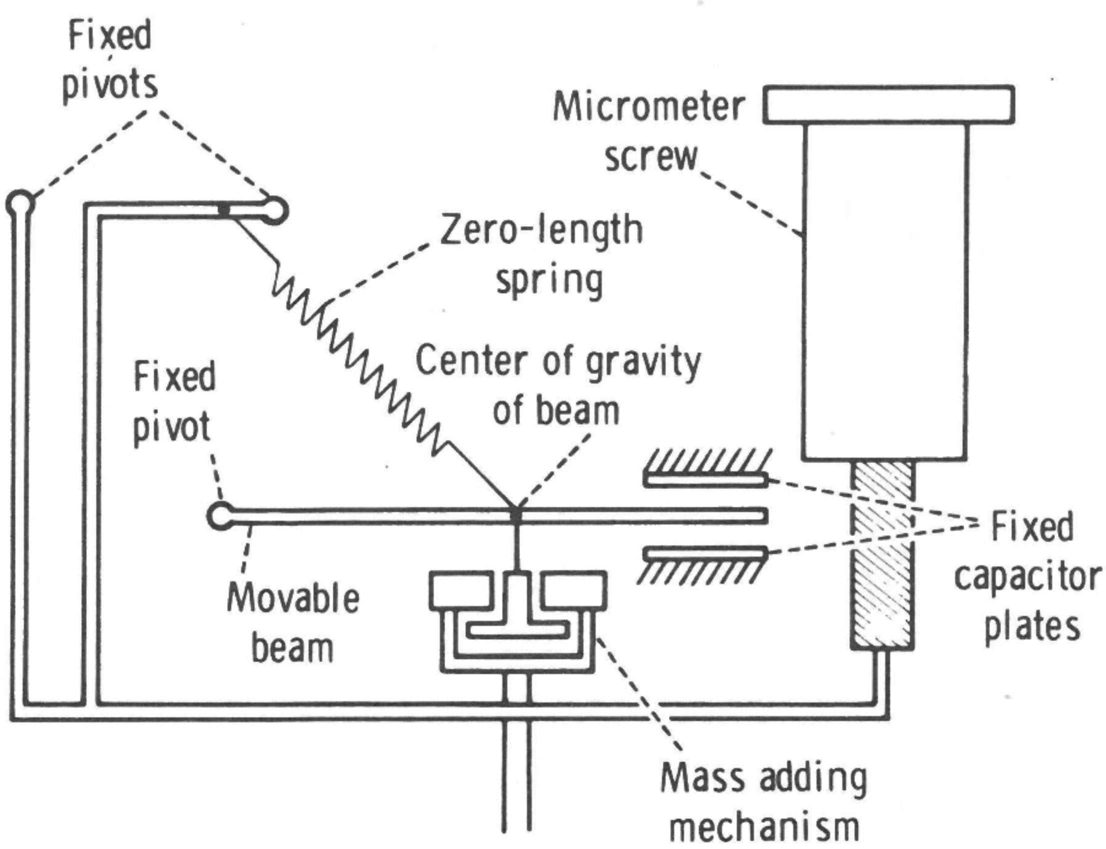

Figure 2 - Diagram of the Lunar Surface Gravimeter (Giganti et al., 1973)

at equilibrium. The mass was caged in a "mass-adding" mechanism, which could adjust the force by adding small amounts of mass to ensure the beam rest position was horizontal. Attached to the free end of the beam was a plate, suspended between two fixed capacitor plates above and below the beam. The plates are part of a radio-frequency bridge circuit, the beam plate is held equidistant between the two fixed plates when the beam is exactly horizontal. Any motion of the beam results in an A.C. error voltage, which can be amplified and used to restore the beam back to equilibrium using feedback to the capacitor plates, or it can be operated in a way that no restoring force is provided by the capacitor plates.

The optimal operational temperature for the spring was about 323 K, and the spring needed to be controlled to better than 1 millidegree near the optimal temperature over the day-night cycle. Insulation was used to limit heat exchange with the lunar surface and the sunshade kept direct sunlight from entering the instrument. A hole in the top of the instrument allowed heat to radiate to the dark sky, and a heater was used to maintain the temperature of the spring. The LSG was designed to cover the frequency range from 0 to 16 Hz in three bands. The band from 0 (D.C.) to 1 cycle per 20 minutes gave information on the lunar tides. The middle range covered 1 cycle per 20 minutes to 3 cycles per minute, and the final range, of interest for seismic and gravitational radiation studies, covered 3 cycles per minute to 16 Hz. The sampling rate was 48 samples/second. The LSG had a nominal sensitivity of 1 part in 10^11 of lunar gravity.

Instrument Operation

The gravimeter was deployed by the Apollo 17 astronauts on 12 December 1972 at 20.19 N, 30.77 E (figure 3). The procedure consisted of leveling and alignment within plus or minus 3 deg, using the sunshield shadow, and mating the ribbon cable to the ALSEP central station. After deployment, it was found that the balance mass was too light and was resting against the upper stop. The beam could not be balanced even after all the available extra mass was added by ground command. The beam could only be centered by applying an extra load of 140 milligrams (a force of 0.0017 N) on the beam through the mass support springs by partial caging of the mass-weight assembly, meaning the mass-weight assembly was in physical contact with the beam. In this configuration, the instrument was behaving like a gravimeter with a resonant frequency of 1.5 Hz and a post-amplifier gain of 17.

Attempts were made over the following year and a half to reconfigure settings by ground command to maximize the data return. (For details, see Lauderdale and Eichelman, 1974.) Although many of the objectives of the experiment could not be met, the Lunar Surface Gravimeter could still function in limited capacity as a one-axis vertical seismometer. On 15 March 1974 at 01:16 UT the heater regulation circuit failed in full on position, increasing the temperature off-scale high and making the science data unusable. On 20 April 1974 the LSG regained thermal stability and began returning

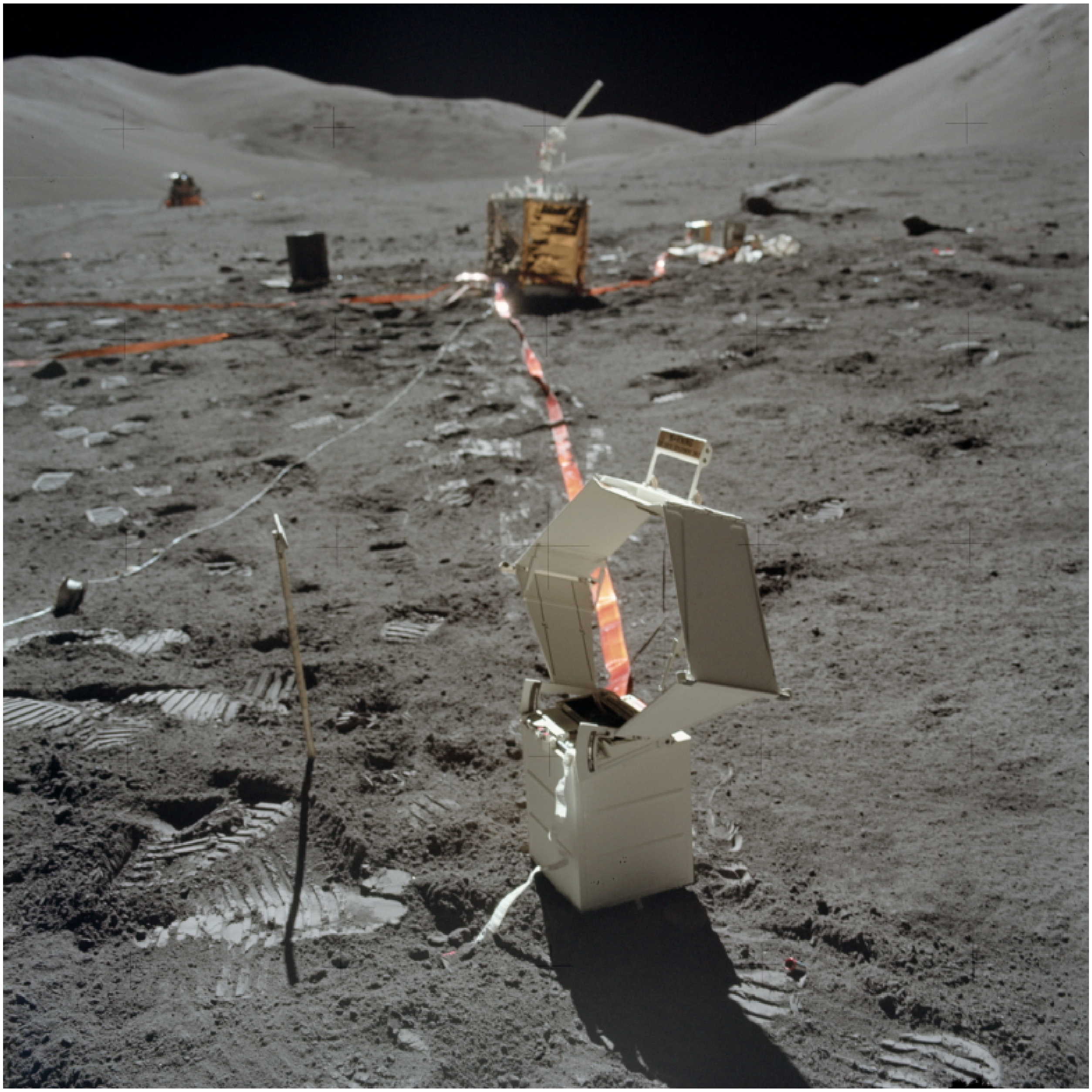

Figure 3 - The LSG deployed at the Apollo 17 ALSEP site. The sunshield is tipped appropriately for the latitude of the site. The central station, radiothermal generator, and Lunar Module are visible in the background (AS-17-134-20501, Sullivan, 1994)

useful data. The heater regulation circuit again failed in full-on position on 7 July 1975, raising the temperatures to off-scale high. On 30 July 1975 the high temperatures caused intermittent operation of the analog-to-digital converter, this was alleviated by commanding the heater on/off manually to maintain the operational temperature range of the converter. It regained normal operation when the heater circuit became operational and temperature stabilization was regained on 2 September 1975. Bates et al. (1979) and ALSEP performance summary reports state that the anomalous automatic regulation of temperature control reoccurred on 19 September 1975, and that attempts to regain control since that time were unsuccessful. However, it appears that the LSG was still returning useful data after this time, and continued to do so until shutdown of the ALSEP stations on 30 September 1977.

References

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Source

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