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POLAR LUNAR EXPLORATION AS A PRELUDE TO LARGE-SCALE OPERATIONS

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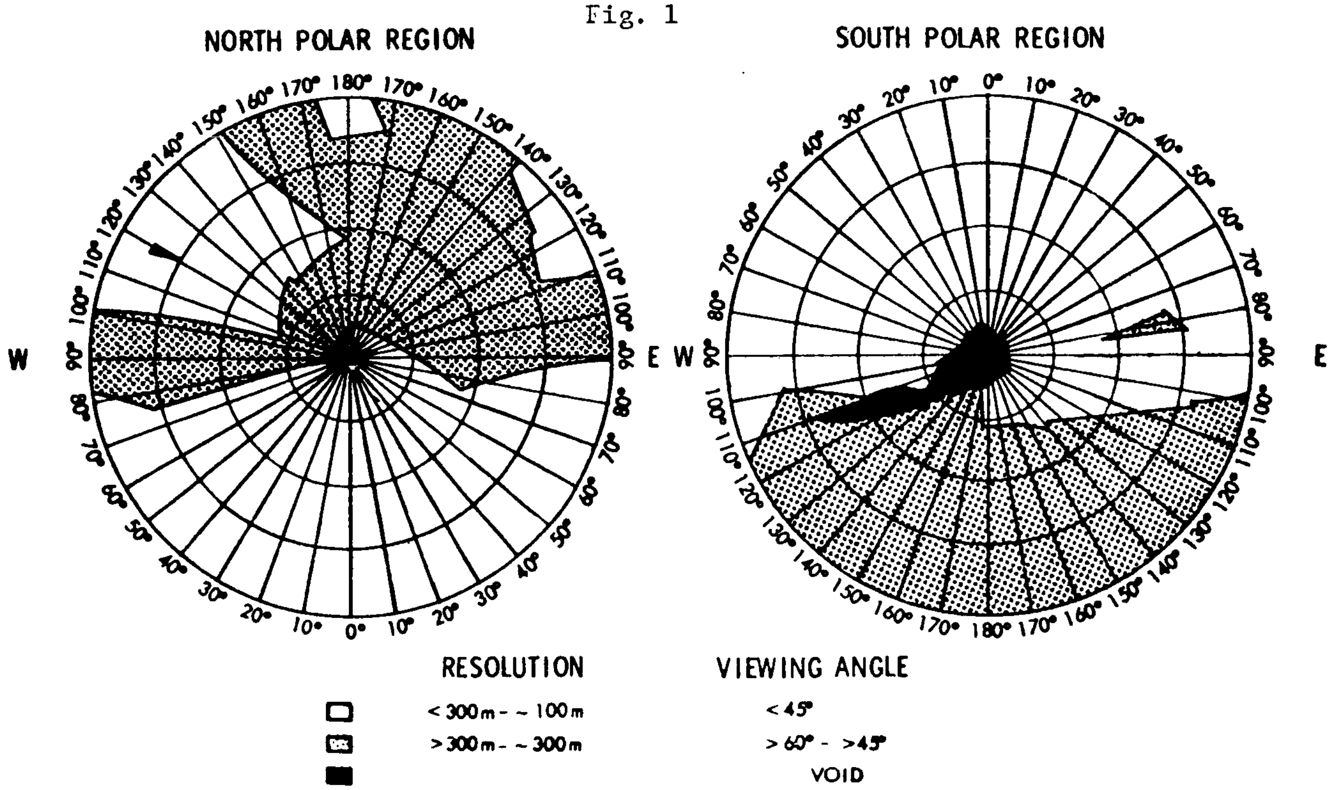
1. Introduction

Before planning large-scale ventures on the Moon it will be logical and prudent to learn more about lunar properties at high latitudes. Some of the needed knowledge can be supplied by an automated polar orbiting mission. Depending on the findings of the orbiter, it may also prove worthwhile to explore the polar regions by means of automated surface rovers. While much of the technology for such missions already exists, we have yet to go through a complete analysis of the objectives, methods, and problems of polar surface missions. Therefore this discussion is mainly about orbiters.

2. Lunar Polar Environments

Lunar Orbiters IV and V photographed the Moon's polar regions (Ref. 1). Figure 1 summarizes the extent and approximate resolution of polar photo coverage by the Lunar Orbiters.

Fig. 1



At the scale of this imagery the Moon's polar surface morphology is grossly similar to that at lower latitudes. There is, for example, no evidence of large-scale surface collapse due to sapping, or removal of subsurface ices, as has apparently happened on Mars in response to major climatic changes. This can mean either that no great amount of ice has accumulated beneath the lunar polar surface or that it has accumulated and not been removed. Of course, the orbiter photos do not show the permanently-shaded regions, which may be cold traps for lunar atmospheric volatiles (Ref. 2).

Lunar polar subsurface temperatures are quite low, as can be seen by extrapolating Earth-based microwave and infrared observations made at lower latitudes. Figure 2 shows the results of observations at 3 mm wavelength (Ref. 3).

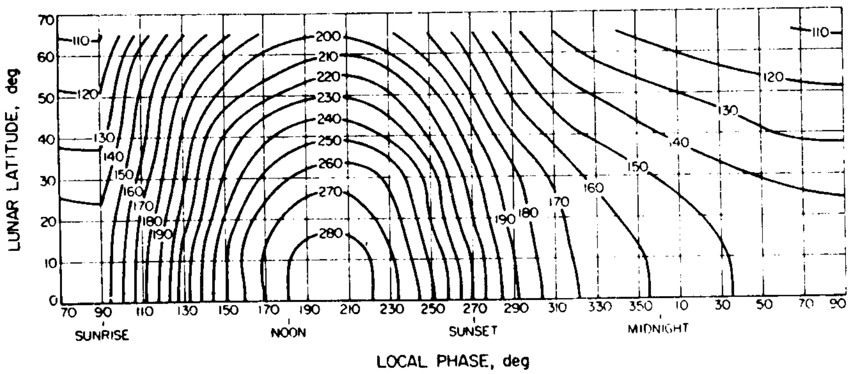


FIG. 2 —An empirical model showing the dependence of brightness temperature (° K) on lunar latitude and local phase. No corrections have been made for effects related to emissivity or depth of emission. This plot may be used in comparing the observed brightness temperature of a particular region with the average observed brightness temperature of all other regions at the same lunar latitude and condition of solar illumination.

Clearly there is the potential for trapping volatiles at the poles, if any volatiles have been available in the Moon.

Other environmental effects that may differ at the poles are (a) solar particle implantation in soils and (b) electrostatic levitation transport of particles near the terminator. Both of these effects could result in altered lunar soil chemistry at the poles; the effect, if any, on large-scale operations is unknown.

3. Significance of Polar Environments to Large-Scale Operations.

Any man-made subsurface structures in the polar regions will be surrounded by very cold material. This can be either a benefit or a problem depending on the application. Continuous access to the sun, which may be possible from some near-polar locations, offers the prospect of simpler and more efficient energy management for a habitat. Also, a polar location permits ready access to orbital services (communications, resupply, rescue) because of the frequent passages of a polar orbiter over the poles. Disadvantages are that less of the sky is visible for astronomy, and the Earth is always close to the horizon. Though previous lunar base studies have treated these tradeoffs, many of the assumptions are now obsolete and it will be wise to re-examine the question once more is known about (a) lunar polar characteristics and (b) the nature and purposes of planned lunar habitats. Should available volatiles, especially water, be found only at the poles, this would dominate the choice of sites.

4. Contributions of a Lunar Polar Orbiter

At JPL a study is now in progress to define a Lunar Polar Orbiter project for continuing the scientific exploration of the Moon. Characteristics of the mission are listed in Table 1.

Lunar Polar Orbiter

Mission Summary

1. Measurements for geochemistry, gravity, topography, magnetism and heat flow.
2. Data system correlates multidimensional data from all experiments.
3. 290 Kg orbiter in 100 km polar orbit.
4. 65 kg of instruments continuously pointed to nadir.
5. 32 kg relay in high orbit, and/or gravity gradiometer.
6. One year operation.
7. 4000 bps data continuous when orbiter in view.
8. 250 ksps tape dumps when orbiter near poles.
9. DSN 26m stations + possibly STDN 26m.
10. Opns. mostly routine; command updates approx. weekly; data received in blocks, most off-line opns. one shift.
11. Extended mission depends on fuel (orbiter) and orbit evolution (relay).

The main mission objectives are to measure from orbit all lunar properties that can be so measured and that are relevant to understanding the present state and past history of the Moon.

Examples of these properties and the planned means for measuring them are:

Gravity	Doppler tracking, including far-side Doppler via a radio relay
Surface composition	IR reflectance spectrometry X-ray spectrometry Gamma-ray spectrometry UV spectrometry
Figure, topography	Radar altimetry
Electromagnetic properties	Magnetometry Electron reflection
Heat flow	Passive microwave radiometry, IR photometry

In the process of meeting its scientific objectives the Lunar Polar Orbiter will produce information of value to planning large-scale operations. For example the orbiting gamma-ray spectrometer can detect subsurface hydrogen, and hence can tell whether or not the single most important polar resource (water ice) is likely to be recoverable (Ref. 3). The orbiting microwave-infrared heat flow experiment effectively measures brightness temperature at various depths, and hence yields information useful for designing subsurface lunar base elements. The gravity and topography measurements are essential for planning orbital tranfers and polar landings. The compositional and magnetic experiments will map available mineral resources.

In the aggregate, by providing information to constrain models of the Moon's history and interior composition, the Lunar Polar Orbiter mission has the potential of helping to guide farther-future large-scale operations such as the creation of artificial lunar atmospheres. Thus in carrying out this relatively modest mission we may once more be actively enroute to the vistas of the future for human activities on the Moon.

Ref. 1. Kosofsky, L. J. and El-Baz, F. The Moon as Viewed by Lunar Orbiter. NASA SP-200, 1970.

Ref. 2. Arnold, J. R. Water on the Moon. Paper presented at this conference.

Ref. 3. Arnold, J. R., Metzger, A. E., Parker, R. H., Reedy, R. C., and Trombka, J. I. Preliminary Design and Performance of an Advanced Gamma Ray Spectrometer for Future Orbiter Missions. Proc. Lunar Sci. Conf. 6th 1975, p. 2769 - 2784.