PRELIMINARY SOLUTIONS FOR THE LUNAR GRAVITY FIELD FROM ANALYSIS OF LUNAR ORBITER TRACKING DATA; *F. G. Lemoine*[1,2], *D.E. Smith*[1], *M.T.Zuber*[3,1], *D.D. Rowlands*[1], and *S. K. Fricke*[4], [1]Laboratory for Terrestrial Physics, NASA/Goddard Space Flight Center, Greenbelt, MD 20771, [2]Astronomy Department, University of Maryland, College Park, MD 20742, [3]Department of Earth and Planetary Sciences, Johns Hopkins University, Baltimore, MD 21218, [4]RMS Technologies Inc., Landover, MD 20706.

Knowledge of the gravitational field, in combination with surface topography, provides one of the principal means of inferring the internal structure of a planetary body. Previous analyses [1-11] of the lunar gravitational field have been based on data from the Lunar Orbiters, the Apollo subsatellites, and the low altitude passes of the Apollo spacecraft. Recently, Konopliv et al. [12] have reanalyzed all available Lunar Orbiter and Apollo subsatellite tracking data, producing a 60th degree and order solution.

In preparation for the Clementine mission to the Moon, we have also initiated a re-analysis of the Lunar Orbiter and Apollo substellite data. We have attempted solutions of 60th and 70th degree and order, which correspond to a spatial resoltutions of 160 to 180 km where the data permit. Our reanalysis takes advantage of advanced force and measurement modeling techniques as well as modern computational faciilities. We applied the least squares collocation technique which stabilizes the behaviour of the solution at high degree and order [13]. The extension of the size of the field reduces the aliasing coming from the omitted portion of the graviational field. This is especially important for the analysis of the tracking data from the Lunar Orbiters, as the periapse heights frequently ranged from 50 to 100 km.

While analysis of available data continues, our preliminary solutions are based on 80 orbital arcs from S-Band tracking of the Lunar Orbiters 2, 4 and 5 by the Deep Space Network (DSN) between November 1966, and January 1968. So far, 170,000 observations have been included in the solutions. The data were processed using the GEODYN/SOLVE orbit determination programs, which previously have been used in the derivation of the Goddard Earth Models (GEM) [14], as well as GVM-1, and GMM-1 gravity models for Venus and Mars [15,16].

The gravitational potential, V_M, at the spacecraft altitude is represented in spherical harmonic form as:

$$V_M(r) = (GM/r) \sum_{l=0}^{N} \sum_{m=0}^{l} \left[a_e/r \right]^l P_{lm}(\sin\phi) \left[C_{lm} \cos m\lambda + S_{lm} \sin m\lambda \right] \quad (1.1)$$

where r is the radial distance from the center of mass of the Moon to the spacecraft, θ and λ are the selenocentric latitude and longitude of the spacecraft, a_e is the mean radius of the reference ellipsoid of the Moon, taken to be 1738 km in our analyses, GM is the gravitational constant for the Moon, P_{lm}

are the normalized associated Legendre functions of degree l and order m, C_{lm} and S_{lm} are the normalized spherical harmonic coefficients which are estimated from the tracking data, and N is the maximum degree representing the size of the field.

To determine the solutions, the data were processed in arcs of 1 to 34 days. The Lunar Orbiter spacecraft possessed an uncoupled attitude control system which introduces accelerations during each sequence of attitude maneuvers. These maneuvers were modeled as finite accelerations, since the times and durations of these maneuvers are tabulated. One day arcs were used for the primary phase of each Lunar Orbiter mission, corresponding to the first few weeks in orbit when maneuvers were most numerous. Longer arcs are possible during the extended mission phases when the attitude changes were less frequent. For each arc, we estimate a state vector, a solar radiation pressure coefficient, Doppler tracking biases, and 3-axis accelerations for each batch of attitude maneuvers. The gravitational field was then found by adding together the information equations for each arc and solving the resulting linear system. We found that constraining the magnitudes of the maneuvers strengthened the gravity field solutions.

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