PRECISION ORBIT DETERMINATION OF LOW ALTITUDE LUNAR SPACECRAFT WITH LASER SYSTEMS

David E. Smith (1), Maria T. Zuber (2,1)
(1) Laboratory for Terrestrial Physics, NASA Goddard Space Flight Center.
(2) Dept of Earth, Atmospheric and Planetary Science, MIT.
dsmith@tharsis.gsfc.nasa.gov Fax: 301-614-6015

Abstract

The need for high accuracy positioning of spacecraft in orbit about the Moon is becoming more important as many nations consider going to the Moon for both exploration and science. Particularly challenging is the control and knowledge of spacecraft position on the farside of the moon where spacecraft are unobservable from the surface of the Earth. Although, spacecraft are routinely out of view of Earth when behind any planet or body it is unique that we are never able to see and study the farside of Earth's moon from the Earth's surface. This is particularly difficult for the positioning of low altitude spacecraft that are very sensitive to even small gravity anomalies of unknown location and magnitude on the lunar farside. Of course, a variety of 2-spacecraft gravity missions could reduce the problem of unknown gravity and if suitably placed could also act as a communications relay. In the long term the establishment of a farside communications spacecraft system will probably be the solution to this problem for most spacecraft. For scientific spacecraft in low altitude orbits requiring very precise spacecraft location this may not be adequate.

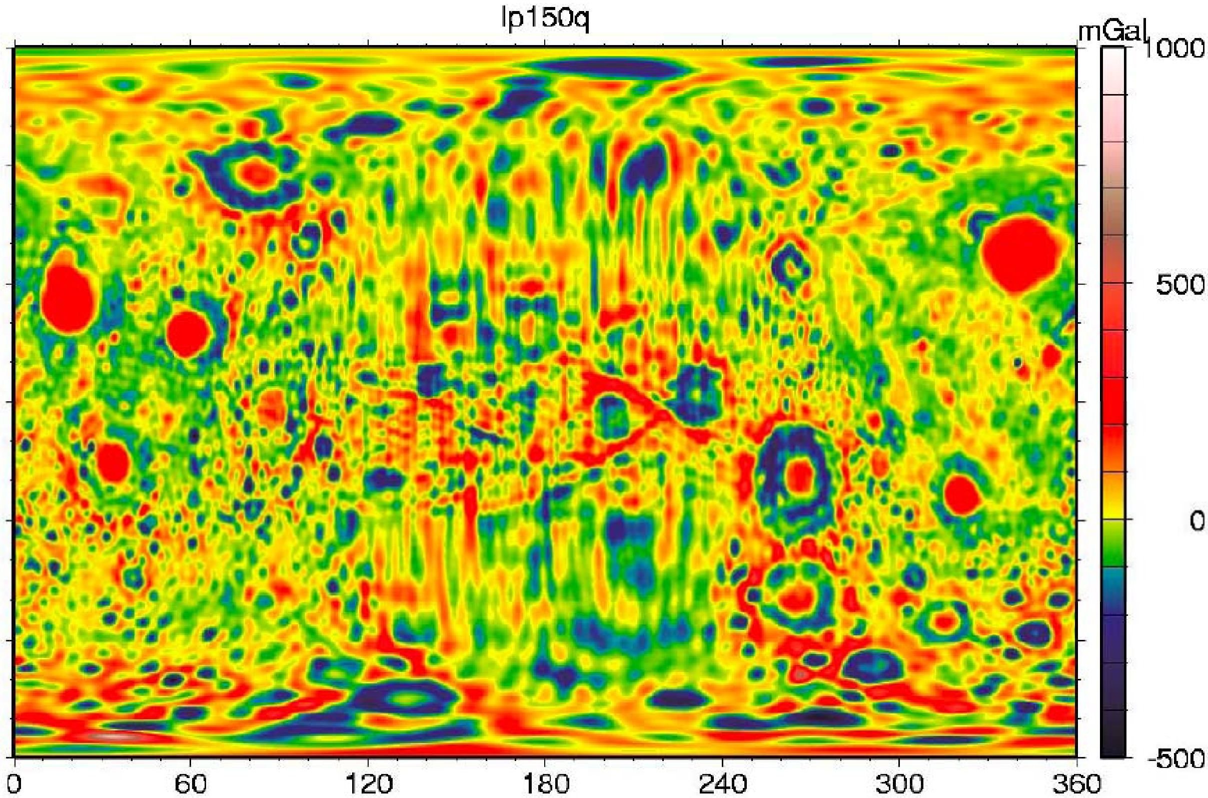

Figure 1. The gravity field of the Moon (Konopliv, 2001)

This issue reveals itself in fig 1, a map of the gravity anomaly field of the Moon derived from Clementine and prospector tracking data. The farside of the Moon is between longitudes 90 through 270 and the figure shows clear linear striping along the ground track of the spacecraft over these longitudes. In comparison the nearside shows no such linear patterns.

One solution to improving the gravity field of the Moon is Earth-based laser tracking of a lunar satellite in conjunction with a high quality laser altimeter. Laser tracking of a lunar satellite via an optical transponder system can provide sub-centimeter level range accuracy at several kilohertz rate, equivalent to a velocity of a few tens of microns/s every 10 seconds. In addition, laser altimetry can be used to assist in the orbit determination by the introduction of altimeter cross-over measurements into the orbit determination process. This technique has been used successfully with Earth altimeter satellites over the ocean areas but has also been used successfully at Mars with the Mars Orbiter Laser Altimeter (MOLA) in the determination of the orbit of Mars Global Surveyor. But the altimeter can also be used to help determine the gravity field. Altimeter data obtained at two distinct altitudes over a region is sensitive to the higher degree and order gravity coefficients that affect the lower spacecraft more than the higher altitude spacecraft. Thus, from the analysis of the altimetry for the surface topography it is possible to extract gravity information for the region; and with global coverage it is possible to obtain global solutions suitable for precision orbit determination. Thus, for the Moon, one method of improving our knowledge of the farside gravity is to analyze a combination of nearside tracking data and nearside and farside altimetry data acquired at different orbital altitudes. With this approach we believe it is possible to obtain 10 cm radial and 5 to 10 meter horizontal accuracy orbits over the entire Moon.