THERMAL ANALYSIS OF LUNAR CORNER CUBE RETRO-REFLECTORS

. Douglas Currie[1], Giovanni Delle Monache[2], Bradford Behr[1] and Simone Dell'Agnello[2]
[1] Department of Physics, University of Maryland, College Park, Maryland, 20742, USA, currie@umd.edu,
[2] Laboratori Nazionali di Frascati (LNF) Laboratorio dell'Istituto Nazionale di Fisica Nucleare (INFN),
Via E. Fermi, 40, 00044 Frascati (Roma) Italy INFN-LNF, Italy

Introduction: Lunar Laser Ranging to the Moon to the Apollo Retroreflector arrays has produced detailed information concerning the crust and interior of the moon (i.e. the discovery of the liquid core, the "Q" of the moon and Love Numbers of the crust, etc.). It has also produced some of the best tests of General Relativity (i.e., the Strong Equivalence Principal, the Inertial Properties of Gravitational Energy, the Constancy of the Gravitational Constant G, etc.)[1, 2]. This analysis has been based on ranging measurements, continuing to the present, to the retroreflector arrays placed on the moon during the Apollo missions. However, the combination of the design of the Apollo arrays and the lunar librations are now the limit the accuracy of the range measurements. We will now address both the "next generation" retroreflector package being developed and measurements of the Apollo array.

Motivation: There are several critical challenges associated with developing a "next generation" large Cube Corner Reflector (CCR) for lunar laser ranging. Significant among those is the thermal performance and the associated return signal. In the case of the next generation lunar retroreflector, this type of analysis is essential in the design of the thermal control surfaces for the housing, since thermal gradients in the CCR will reduce or eliminate the return signal. In addition, in the case of the Apollo arrays, a very detailed analysis is important in understanding the role of dust in the degradation of the signal strength that has been observed over the past four decades.

Thermal Analysis Program and LLRRA-21: To address the next generation CCR, a unique set of thermal analysis programs that have been developed for this "Lunar Laser Ranging Retroreflector for the 21st Century" or LLRRA-21 [3], which will be described in detail. This set of linked programs employs Thermal Desktop, Code V and a set of unique programs developed in IDL. This is designed to handle the absorption of the solar influx, both within the CCR and on the external surfaces, the radiation from the CCR and the housing to space, the radiation interaction with the regolith and the internal heat exchanges within the CCR. The latter includes the conduction from the housing into the CCR at the support tabs, the thermal radiation exchange between the CCR and the pocket, the thermal radiation to space and the internal conduction. As a particular example, we will describe the behavior of a "bare" CCR, that is, the case of a CCR, which is subjected to only the solar input and the radiation to space. The requirements and procedures for developing an optimal enclosure will be addressed.

Degradation of Signal from Apollo Arrays: Laser Ranging to the Apollo arrays has continued to provide accurate range data for the continuing analysis program. Ground stations have improved in accuracy by a factor of ~200 over the past four decades. The signal return from the arrays has decreased by a factor of 10 to 100. To investigate these phenomena a set of data has been collected during a lunar eclipse. However, to analysis this in detail will require the application of the Thermal Analysis Program to the small Apollo CCRs. The eclipse observations and the preliminary analysis will be discussed. This will particularly ad dress the role of dust in this problem.

References:

[1]) Alley C. O.; Chang R. F.; Currie D. G.; et. al. (1970) Laser Ranging Retro-Reflector: Continuing Measurements and Expected Results, *Science*, Volume 167, Issue 3918, pp. 458-460. [2] Bender P. L.; Currie; D. G., Dicke R. H.; et. al. (1973) "The Lunar Laser Ranging Experiment", *Science* **182** pp. 229–38. ; [3] Currie D. G. Dell'Agnello S.; Delle Monache G. s A Lunar Laser Ranging Retroreflector Array for the 21st Century *Acta Astronautica*, v. 68, iss. 7-8, p. 667-680