EPSC Abstracts
Vol. 8, EPSC2013-991, 2013
European Planetary Science Congress 2013

Next Generation Lunar Laser Retroreflector

D. Currie (1,2), S. Dell'Agnello (2), G. Delle Monache (2), B. Behr (1)
(1) University of Maryland, College Park, Maryland, USA, (2) INFN-Laboratori Nazionali di Frascati, Italy

Abstract

Lunar Laser Ranging to the Moon to the Apollo Retroreflector arrays has produced detailed information concerning the crust and interior of the moon (e.g., the discovery of the liquid core). It has also produced some of the best tests of General Relativity (i.e., the Strong Equivalence Principal, the Inertial Properties of Gravitational Energy and the Constancy of the Gravitational Constant G) [1, 2]. 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 the objectives, design and status of the "next generation" retroreflector package being developed.

1. Introduction

The Apollo Retroreflectors were developed by a national team centered at the University of Maryland. and were deployed on the surface of the moon during the Apollo 11, 14 and 15.[1], [2]. Observatory accuracy has improved by more than 200 so the interaction of the retroreflector design and the lunar librations means that the retroreflector arrays now limit the accuracy. The Univ. of Maryland now leads an effort to improve the range accuracy by one or two orders of magnitude, depending upon the method of deployment method. This will be accomplished with a single large solid Cube Corner Reflector.

2. Description of the LLRRA-21

We will describe the "Lunar Laser Ranging Retroreflector for the 21st Century" (LLRRA-21).

2.1 Objectives of the LLRRA-21

The LLRRA-21 will both improve the ranging accuracy and will allow participation by additional lunar observatories. The design will yield a signal level equal to that of Apollo 15. This should improve the science results by similar factors, to investigate the inner lunar solid core and some of the relativity theories addressing Dark Matter and Dark Energy.

2.1 Challenges of the LLRRA-21

There are challenges involved in deploying a 100 mm CCR in the harsh environment of the lunar surface. They involve the thermal environment – 70K to 400K -, the placement stability – at the hundreds of microns stability in the thermal environment and manufacturing precision of the CCR.

2.1.1 Manufacture of CCR

The first issue in the manufacturing of the CCR is the homogeneity of the material. This requires the highest level of SiO2 from Hereaus, a special grade of SupraSil 1. The requirement for the accuracy of the offset of the back angles is a factor of 2.5 beyond the current state of the art. .

2.1.2 Thermal Environment

To guarantee an acceptable signal, the CCR must provide a diffraction limited beam. A temperature gradient in the CCR will cause a gradient in the index of refraction which, will compromise the performance. An equatorial landing, the temperature range of the regolith will vary from ~70K to ~400K.

2.1.3 Deployment

There are three methods of deployment: on the lander, the lunar surface or anchored to the regolith at ~ one meter. The pros and cons of each will be reviewed.

3. LLRRA-21 Design

The current design addresses each of the above challenges. In Figure 1, we see the nominal design.

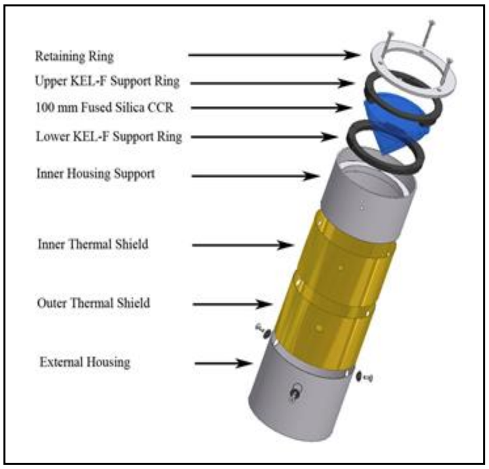

Figure 1 Current Design for LLRRA-21

4. Thermal Simulation

In order to address the overall design and the selection of the thermal coatings, a series of programs for the simulation of the solar input, the radiation exchange between the regolith and the external surfaces and the internal heat exchanges. This will be described.

5. Thermal/Vacuum/Optical Tests

At the INFN-LNF in Frascati, Italy, a new facility, the SCF has been created, with two thermal vacuum chambers especially configured for testing of retroreflector packages in a large clean room.

6. Current Status

Based upon the design effort, the simulations to date and the thermal vacuum testing, a prototype, with a flight certified CCR has been fabricated

7. Flights

While there are a variety of flight possibilities, detailed discussions are being conducted with the most immediate possibility, Moon Express, located at the Ames Research Center.

6. Summary and Conclusions

The LLRRA-21 is prepared for flight in the next several years and will greatly enhance the lunar science and tests of General Relativity.

Figure 2 A model the LLRRA-21 mounted on the instrument platform of the model of their MoonEx1. In the background are Joe Lazio, Deputy PI of LUNAR, Jack Burns, PI of LUNAR, Doug Currie, PI of LLRRA-21, Bob Richards, COO of Moon Express, Alan Stern, and Chief Scientist of Moon Express.

Acknowledgements

We wish to acknowledge the support of the University of Maryland, via the NASA "Lunar Science Sortie Opportunities" (LSSO program (Contract NNX07AV62G) and the LUNAR Consortium (http://lunar.colorado.edu) headquartered at the University of Colorado which is funded by the NASA Lunar Science Institute (via cooperative Agreement NNA09DB30A). We also wish to acknowledge the support of the INFN-LNF and the Italian Space Agency (ISA).

References

[1] Alley C., Chang R., Currie D., et. al.: Laser Ranging Retro-Reflector: Continuing Measurements and Expected Results, Science, Vol. 167, pp. 458-460, 1970

[2] Bender P., Currie; D., Dicke R., et. al.: The Lunar Laser Ranging Experiment, Science, Vol. 182, pp. 229–38, 1973

[3] Currie D., Dell'Agnello S. and Delle Monache G.: A Lunar Laser Ranging Retroreflector Array for the 21st Century, Acta Astronautica, Vol. 68, pp. 667-680, 2010