LRO Operations at the MLRS

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Abstract

The University of Texas at Austin's McDonald Laser Ranging Station (MLRS) is one of the first stations that is slated to participate in a one-way ranging experiment with the Lunar Reconnaissance Orbiter (LRO) in 2009. The experiment will entail the laser illumination of the LRO spacecraft by the MLRS and making precise and accurate time of fire measurements. This poses several interesting challenges that involve pointing, tracking, data format definitions, and unique operational procedures. Some heretofore unanswered questions concerning the MLRS telescope beam divergence and tracking stability must be answered. The newly defined ILRS Consolidated laser Ranging Data (CRD) format will be implemented and tested, and procedures will be established to insure proper handling of LRO schedules, predictions, processing and data distribution.

Introduction

The Lunar Reconnaissance Orbiter (LRO) will perform laser altimetry of the moon from lunar orbit and improve lunar gravity field modeling. To provide orbital accuracy at the required several-cm level, substantial amounts of one-way laser ranging data is needed [1]. MLRS has been selected as one of the primary laser stations to track LRO. To support the required operations, data accuracy, and data volume, a number of MLRS pointing, tracking, beam-divergence, software, and procedural issues must be resolved prior to the 2009 launch.

Hardware Issues

LRO will not be visible in the MLRS telescope, so accurate blind pointing is required. However, absolute pointing of the MLRS telescope is around 10 arcsec, which is not accurate enough for blind pointing to LRO. MLRS has decades of experience tracking lunar retro-reflectors and will apply the same technique to improve LRO pointing to 1-2 arc-seconds. These techniques involve offsetting to LRO from lunar features, possibly using the XY stage. Once LRO data has been acquired, the observer will re-center as needed using the same techniques for the 60 minute "passes." It has been shown that MLRS can track high satellites hands-off to a few arc-seconds over 15 minutes, implying that LRO tracking will be quite manageable.

Delivering only an appropriately low power laser pulse to LRO is critical to the safety of the LOLA detector pointing back towards earth. Power delivered to the spacecraft's detector depends on laser transmit power, seeing, and beam divergence. Beam divergence (controlled by defocus of the MLRS telescope) has been poorly known, and now needs to be better understood. Ranging high satellites (Glonass) using high laser power and high detector amplification while manually scanning through the laser beam along track and across track gives the MLRS beam divergence as modified by the atmospheric seeing. (Due to the extreme power and amplification, this data is not suitable for scientific use, and does not "leave the station.")

Tests with a collimated laser beam (focus = 0 on an arbitrary scale) show that the beam-width at the spacecraft matches the seeing estimate. Using a LAGEOS-level defocussed beam (-100 on the same scale) with Glonass shows a beam divergence of 7-16 arc-seconds greater than seeing. Using LAGEOS beam divergence and a laser energy of 60 mJ should deliver the proper power level at LRO. Additional tests of MLRS telescope optical path losses and laser power levels will be performed with Goddard employees to gain more knowledge of power output from the end of the telescope.

Other laser-related issues need to be addressed as well. First, the optimal laser fire rate for LRO is 28Hz, synchronized with the LOLA detector's earth window opening. However, MLRS will fire at 10 Hz as usual, as it is not possible to convert our existing laser to 28Hz (or probably even 14Hz) operations. The MLRS ranging detector will be used during LRO ranging to gather internal calibration data and the laser firing time. Assessing the one-way system calibration is being worked out. Finally, the compatibility of the MLRS laser transmit wavelength with the LOLA detection wavelength (532 nm) had to be assured, something that tests have confirmed.

Another issue to be worked out with Goddard personnel is the maintenance of the proper level of timing stability (1 part in 10^{-12}) over each hour of ranging. The existing crystal clock used for fire time control may or may not be stable at this level.

Software Tasks

The MLRS ranging acquisition software must be modified to handle some unique aspects of LRO ranging. First, ranging software must allow any target to be treated either as a lunar laser ranging (LLR) or satellite laser ranging (SLR) target through a set-up file. This will allow offset pointing from lunar features to LRO as is done for lunar retro-reflectors. The CPF prediction file "target type" (SLR, LLR, or transponder) must be passed in the raw data to trigger transponder processing in reduction software. Also, the LRO go/no-go flag, which specifies whether there are exceptions that preclude ranging, must be read and acted upon. These changes have all been accomplished.

For greater control over unintended high-power irradiation of LRO, go/no-go flags are being implemented for each of the lunar corner cube reflectors. The LRO mission will set the appropriate flag to "no-go" during the times LRO flies over the corner cube array. We are awaiting the ftp address of these files so that they can be added to our list of go/no-go flag files.

Similarly, the MLRS data reduction software requires several changes. First, the LRO predictions and schedule must be downloaded and processed. The go/no-go flags described above are downloaded by this system and passed to the ranging acquisition computer. Also, LRO must be recognized by "target type" in raw data, as noted above, to allow unique transponder processing to occur. During data reduction, the LRO data must be converted to CRD-formatted files. While most of these tasks have been accomplished, we are still working on defining and applying one-way calibrations, as noted above. Finally, LRO data will flow automatically to our Operations Center, HTSI, without any additional software changes.

Procedural Changes

The last area in which changes will occur are in the realm of procedures. To range LRO successfully and safely, the MLRS crew must check the integrated target schedule for LRO availability (1 hour out of every 2 while the moon is above horizon – and while we are allowed to range LRO). The laser power and the telescope focus must then be set manually to LRO levels prior to ranging (although software and hardware may be changed to make this task more dependable). Despite the fact that there are no photon returns from LRO, operator feedback is critical to obtaining data. Feedback will come from the LRO website's near-real-time (<30 seconds delay) graphical display which shows laser hits in the LRO earth window as a function of time.

Conclusion

Our build-up to LRO tracking has required addressing lingering questions about MLRS's pointing, tracking, and beam divergence. Additional impact on hardware, acquisition software, reduction software, and crew procedures have been or are being addressed.

Acknowledgments

We would like to thank NASA for support of LRO preparations through NASA contract NNG06DA07C.

References

Smith, D., Zuber, M., Torrence, M., McGarry, J., and Pearlman, M., *Laser Ranging to the Lunar Reconnaissance Orbiter (LRO)*, Proceedings of the 15th International Workshop on Laser Ranging, pp 468-471, Canberra, Australia, 2006.