Next Generation Lunar Laser Ranging. S. M. Merkowitz and A. M. Preston, NASA Goddard Space Flight Center, Greenbelt MD 20771, Stephen.M.Merkowitz@nasa.gov

Lunar laser ranging (LLR) has been a workhorse for testing general relativity over the past four decades as well as dramatically increasing our understanding of Earth and Moon geophysics, geodesy, and dynamics [1]. The three retroreflector arrays put on the Moon by the Apollo astronauts and the French built arrays on the Soviet Lunokhod rovers continue to be useful targets, and have provided the most stringent tests of the Strong Equivalence Principle and the time variation of Newton's gravitational constant. The relatively new ranging system at the Apache Point 3.5 meter telescope now routinely makes millimeter level range measurements to these reflectors [2].

The precision of the range measurements has historically been limited by the ground station capabilities. With now routine millimeter level precision at Apache Point, future measurements are likely to be limited by errors associated with the Apollo retroreflectors. In addition, the clustering of the lunar arrays and similar latitudes of the available lunar ranging stations weakens our ability to precisely measure the lunar librations [3].

New retroreflectors placed at locations far from the Apollo sites (such as a pole or limb) would enable the study of additional effects, particularly those that rely on the measurement of the lunar librations. In addition, more advanced retroreflectors are now available that will reduce some of the systematic errors associated with using the current arrays, resulting in more precise range measurements. Retroreflectors are extremely robust, do not require power, and last for decades. This longevity is important for studying long-term effects such as a possible time variation in the gravitational constant. New retroreflectors with higher cross-sections would also enable more laser ranging stations to be used for lunar measurements.

We report here on the ongoing laser ranging development efforts at Goddard Space Flight Center as part of the NASA Lunar Science Institute's LUNAR team. At the heart of this effort is the development of next generation lunar retroreflectors. The recently completed LUNAR open cube assembly and testing facility is currently being used to design, assemble, and test large-scale open cube corners. Investigations into various bonding techniques, including the hydroxide bonding technique developed for Gravity Probe B, are underway and producing promising results. We are also investigating mirror coatings for the cubes that have dust mitigation properties.

[1] S. M. Merkowitz, "Tests of Gravity Using Lunar Laser Ranging," Living Rev. Relativity **13**, (2010).

[2] T. W. Murphy *et al.,* Publ. Astron. Soc. Pac. **120**, 20 (2008).

[3] S. M. Merkowitz *et al.,* Int. J. Mod. Phys. D **16**, 2151 (2007).