

## ***Lunar Laser Ranging Experiment***

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Apollo 11, Neil Armstrong, Michael Collins, and Buzz Aldrin are best known for getting the Command Module “Columbia” to the Moon, landing the Lunar Module “Eagle” in the Sea of Tranquility, and returning Columbia to Earth<sup>1</sup>. All this happened more than 30 years ago, and has recently been celebrated in a variety of ways (see especially the NASA 30th Anniversary page<sup>2</sup>). We all know that the visitors left a plaque, a flag (subsequently knocked over by Eagle’s exhaust on departure), and some footprints. Many people, however, do not know that the astronauts left behind some experiments, and that at least one of them is still working.

The working experiment is the Lunar Laser Ranging Retroreflector<sup>3-7</sup>. This experiment was the work of Dr. Carroll Alley of the University of Maryland’s Physics Department. The key to the continuing success of this experiment is that the lunar component requires no power. The 77 kg device is a 46 cm square aluminum panel with 100 fused silica “corner cubes,” each 3.8 cm across. These corner cubes have the interesting property that they reflect light back in exactly the same direction as the received light. Thus, a laser beam from the Earth will return to the Earth if it strikes one or more of the corner cubes. The Apollo 14, Apollo 15, and Russian Lunakhod 2 missions left additional corner cubes on the Moon.

The experiment provides measurements of the distance from the Earth to the Moon with an accuracy of about 3 cm. Since the distance is about 385,000 km, the error is less than one part per 10 billion. Not only do the data provide accurate measurement of the distance to the Moon, they also provide information about the structure of the Moon as well as its rotational dynamics. The experiment has also provided accurate estimates of past and future eclipses, and has provided precise data on the plate drift, which changes the distance between the various observatories that are used with the corner cubes.

For more information on the LLRE, any of the references listed below will be useful.

### **References:**

1. “Apollo 11,” <http://nssdc.gsfc.nasa.gov/planetary/lunar/apollo11info.html>
2. “30th Anniversary of Apollo 11 : 1969 - 1999,” [http://nssdc.gsfc.nasa.gov/planetary/lunar/apollo\\_11\\_30th.html](http://nssdc.gsfc.nasa.gov/planetary/lunar/apollo_11_30th.html)
3. “Laser Ranging Retroreflector,” <http://nssdc.gsfc.nasa.gov/cgi-bin/database/www-nmc?69-059C-04>
4. “Apollo Laser Ranging Experiments Yield Results,” <http://seds.lpl.arizona.edu/nodes/NODEv4n2-4.2.html>
5. Untitled News Release, July 21, 1994. <http://www2.jpl.nasa.gov/files/releases/lunlaser.txt>
6. “Measuring the Moon's Distance: Apollo Laser Ranging Experiments Yield Results,” from *LPI Bulletin*, No. 72, August, 1994. <http://sunearth.gsfc.nasa.gov/eclipse/ApolloLaser.html>
7. “Experiment Left on Moon Still Works After 30 Years,” *Space News*, Vol. 10, No. 32, Aug. 23, 1999, p. 11



## Apollo 11 Lunar Laser Ranging Experiment

- 77 kg, 46 cm square aluminum panel with 100 fused silica 3.8 cm "corner cubes"
- reflects laser beams sent from Texas, Hawaii, France, California, Australia, Russia, and Germany
- provides lunar distance accuracy of 1 cm
- led to theory that moon has liquid core

