A Pretty Outstanding Lunar Laser Operation

The Apollo 11 Lunar mission was the mission to beat the Soviet Union to the moon. This mission was the culmination of 9 years of hard work and dedication. If this mission was successful then President John F. Kennedy's promise to the United States of America would be fulfilled, and would cement them as the forefront in space activities. In addition to the major goal to land on the moon and return safely, many science experiments were done inflight to advance the scientific progress of America. One of these experiments was a Lunar Laser Ranging Experiment (LLRE) which would accurately measure the distance from Earth to the moon as well give us more knowledge about the moons orbit and the makeup of the moon (Apollo 11 Mission).

The Lunar Laser Ranging Experiment's main goal was to accurately measure the distance between the Earth and the moon. The experiment also helped "gain knowledge on the moon's orbit and the rate at which the Moon is receding from Earth...and of variations in the rotation of the Moon" (Apollo 11 Mission). The experiment was deployed on the Apollo 11, 14, and 15 missions. The experiment consisted of a cube-like reflector which was planned to be placed on the surface of the moon. After the placement of the reflectors on the moon, there would be lasers from multiple facilities on Earth shooting at the reflector. The facilities that are shooting the laser to the moon are in El Paso, Texas; San Jose, California; Kula, Hawaii and Greenbelt, Maryland. The laser that is being shot to the moon has a diameter of 7 km and when the laser reaches the moon, the laser's diameter is about 20 kilometers. The color of the laser is a bluish green color. The array reflector had a folding support structure aiming towards the Earth (Apollo 11 Mission). The laser experiment that was performed during the flight of the Apollo 11 mission only had a laser shot from the McDonald observatory that is affiliated with the University of Texas at Austin.

Mission Control during the launch and flight of the Apollo 11 mission is full of many different directors with specific jobs that make the launch and mission smoother. The Booster, Retrofire, Flight Dynamics, and Guidance officers are stationed in the front row, or "Trench". Their job is to handle the general movement and position of the spacecraft. Their close proximity to the front of the room lets them easily read the monitors at the front of the room that display the flight details of the spacecraft.

The second row consists of the surgeon, Spacecraft Communicator (CAPCOM), Electrical, Environmental and Consumables Manager (EECOM), Guidance, Navigation and Control Engineer (GNC), TELCOM, and Control. Their general job is to interact with the astronauts, giving them orders and ensuring their safety. The surgeon's job is to ensure the

overall wellbeing of the astronauts and keep them in good health through monitoring their body systems. If anything with the astronauts health goes south, the surgeon will be the first to know. CAPCOM's job is to manage the communications between the astronauts and mission control. They will ensure a message is received by the astronauts so the rest of mission control doesn't have to. They are also located right next to the surgeon, presumably to reduce the chance of miscommunication in the case of a medical emergency. EECOM's job is to monitor the several important systems aboard the spacecraft that are necessary for keeping the astronauts alive and safe. GNC's job is to keep track of the guidance, navigation, and control systems aboard the spacecraft. They make sure the several devices and instruments are operating normally so the astronauts know where they're going. TELECOM handles much of what EECOM does, except for the lunar module. Their job is slightly more difficult due to the very specific margins of the lunar module. CONTROL handles the operation of the lunar module's guidance system, attitude thrusters, and ascent and descent rockets. Their job is very similar to GNC, however, they focus on the lunar module, like TELECOM is to EECOM.

The third row consists of the Instrumentation and Communications Officer, Operations and Procedures officer, Assistant Flight Director, Flight Director, Flight Activities Officer, and the Network Controller. The Flight Director is responsible for is reporting to the Mission control with detailed information about the mission and works as the Mission Director in their absence. The Flight Director consists of a left and right seat, which means that two people are a part of the Flight Director's responsibilities. The Flight left and right Directors are located in the middle of the Mission Mission Control Center starting with the Apollo 11 mission. The Instrumentation and Communications Officer (INCO) was added to the watch the communications systems between the Command module and the Lunar module.

During the testing of the lunar laser experiment, the spacecraft is located over El Paso, Texas and the McDonald laboratory is shining the laser through an opening in the clouds. This experiment is rather unique because the experiment was done during flight. It is questionable whether or not the experimentation would have resulted in any useful data, as the distance from the current position of the spacecraft to the Earth is such an arbitrary distance. The astronauts in the spacecraft used a telescope and a sextant to see the laser. A sextant is an instrument that allows the user to measure the angular distance between two objects.

35 hours into the Apollo 11 mission, FLIGHT received a notification from CAPCOM that the astronauts had the Earth in their telescope.(FLIGHT 34:24:00) With the Earth in view from the spacecraft, they had the opportunity to begin a small experiment requested from McDonald Observatory, where a laser would be beamed from Earth, up to the spacecraft, and hopefully the astronauts would be able to see it. FLIGHT questioned CAPCOM as to how they knew that the earth was in their telescope, to which CAPCOM responded that they talked to INCO about the topic. It is assumed that INCO received this information through observation of the camera that is attached to the spacecraft, and subsequently had a conversation with CAPCOM reporting on this matter, but recording of this could not be found. However, FLIGHT was skeptical about the validity of INCO's information, calling it "shaky data," and asks

CAPCOM to contact the astronauts directly to determine whether they could really see Earth, since they had free time waiting for a message from McDonald saying the laser was ready. (FLIGHT, 35:24:27) However, McDonald contacts FLIGHT right after that they are ready to perform the laser experiment. FLIGHT then tells CAPCOM to instead go ahead with messaging the astronauts that the experiment with the bluish laser is ready for them. (FLIGHT 35:25:20)

The astronauts were instructed by CAPCOM to prepare to visually identify the laser being shone up to them through the clouds above the El Paso area.(CAPCOM, 35:25:49) At 35:33:43, FLIGHT receives a message from McDonald Observatory that they have begun modulating the laser. CAPCOM, overhearing this, proceeds to inform the astronauts that the laser is active and they should look out the window, telescope, or sextant to see it.(FLIGHT 35:34:20) McDonald then tells FLIGHT the optimal settings that they should set their telescope (AOT) to best see the laser. FLIGHT was also repeatedly asked by McDonald whether or not the astronauts could look out the window to identify the laser, to which FLIGHT sternly responded, "They can't see it through the window," with a slight annoyance in his voice.(FLIGHT 35:34:56) Several minutes later, FLIGHT messaged McDonald to confirm once again whether or not the laser was actually on, as the astronauts could not see it and they had to do a scheduled return to PTC (Passive Thermal Control) shortly. (FLIGHT, 35:38:08) This interaction between FLIGHT and McDonald shows that neither truly trusted the information given by the other as they had to continuously check in with each other. From there, Mike Collins confirmed that neither Armstrong nor himself could see the laser, so the experiment was discontinued. (INFLIGHT, CAPCOM, 35:40:06)

Since the Apollo 11 mission, this initial experimentation with long range lasers has continued to be beneficial to scientists across the globe. After the first retroreflector was placed on the moon during the Apollo 11 mission, NASA had difficulty finding it without precise coordinates. In the later Apollo 14 and Apollo 15 missions and the Soviet Union's Lunokhod rover missions, more retroreflectors were brought to the moon by the astronauts and cosmonauts, respectively, bringing the total number of retroreflectors to 5. With more retroreflectors on the moon to hit, it became much more likely that one of the lasers would be able to receive data and measurements from the moon (Tune).

For the time of Apollo 11, the measurements from Earth to the moon were scientifically astounding. Nothing like it had ever been done before and that data was an added bonus to beating the Soviet Union to the moon. However, now the most accurate measurement from the Earth to the moon has been taken from the Apache Point Observatory in Sunspot, New Mexico. The Apache Point Observatory Lunar Laser-ranging Operation (APOLLO) is able to measure the distance to an accuracy of 1 millimeter (Murphy). This is the highest level of precision any laser has ever gotten in order to retrieve data about the moon, significantly better than the original data from Apollo 11. Through this innovation, it may become clear that the data which is currently accepted may be inaccurate to the point of discredit.

Works Cited

"Apollo 11 in Real-Time." *Apollo 11 in Real Time*, https://apolloinrealtime.org/11/.

"Apollo 11 Mission." *Apollo 11 Laser Ranging Retroreflector Experiment*, www.lpi.usra.edu/lunar/missions/apollo/apollo_11/experiments/lrr/.

"Apollo 11 Mission." *Apollo 11 Laser Ranging Retroreflector Experiment*, Lunar and Planetary Institute, www.lpi.usra.edu/lunar/missions/apollo/apollo_11/experiments/lrr/.

"Lunar Laser Ranging (LLR)." *NASA*, NASA, ilrs.cddis.eosdis.nasa.gov/science/scienceContributions/lunar.html.

Bootle, Adam. "Alignment Optical Telescope (AOT)." *NASA*, Apollo Lunar Module News Reference, 18 Apr. 2013, www.hq.nasa.gov/alsj/aot.htm.

Hutchinson, Lee. "Apollo Flight Controller 101: Every Console Explained." *Ars Technica*, 1 Nov. 2012, arstechnica.com/science/2012/10/apollo-flight-controller-101-every-console-explained/3/.

Murphy, T.W., et al. "APOLLO: Multiplexed Lunar Laser Ranging." *NASA*, cddis.nasa.gov/lw13/docs/papers/llr_murphy_1m.pdf.

Tune, Lee. "UMD Physicist for Apollo Experiment Gets Chance to Send Next Gen Version to Moon." *UMD Right Now :: University of Maryland*, 11 July 2019, umdrightnow.umd.edu/news/umd-physicist-apollo-experiment-gets-chance-send-next-gen-version-moon.