# CREATING PLANETARY TERRAINS IN VIRTUAL REALITY FOR SCIENCE AND EXPLORATION: A RETURN TO THE APOLLO 17 LANDING SITE.

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**Introduction:** Apollo 17 landed in the Taurus-Littrow Valley 45 years ago and was the last crewed mission to the lunar surface **[1]**. The only way to visit the lunar landscape again, short of sending another mission, is to view data of the surface relayed to us by the Lunar Reconnaissance Orbiter (LRO) satellite and other recent missions. LRO's Narrow Angle Cameras (NAC) have mapped the surface of the Moon with high-resolution images (~0.5 m/pixel), which can be used to create digital elevation models (DEM) that show details of the terrain **[2]**. DEMs provide a means to interact with the lunar landscape spatially in 3D, but usually on a 2D screen. Our team wanted to take this a step further and explore the feasibility of recreating the lunar terrain in a Virtual Reality (VR) environment where it can be explored, from an astronaut's point of view. VR is rapidly becoming an accessible technology and has the potential to play an expanded role in science and mission operations for future exploration of the Moon and other planetary bodies.

**Objectives:** Our goal for this pilot project was to create an interactive lunar terrain based on LRO mission data and incorporate tools and technologies that could be used on future missions.

*Goal 1: Import LRO data into VR software Engine.*

Our first task was to create a terrain in VR based on actual lunar topographic data **(Fig. 1)**. The LRO NAC DEM provides 2D grayscale, raster images where black represents the lowest elevations and white represents the highest. A workflow was developed to convert and import this raw data into a 3D landscape within Unity, a game design software. The NAC image mosaic was imported to texture the landscape. Additional elements like a skybox with the stars and the Earth in the background were added for a more realistic experience.

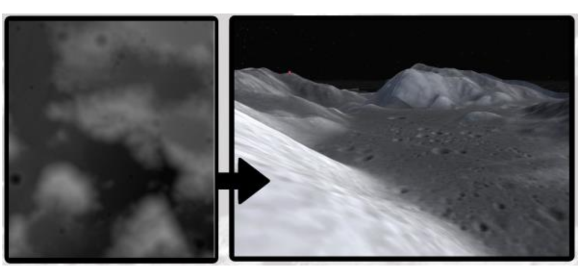

**Figure 1:** NAC DEM (left) of the Apollo 17 landing site rendered as a virtual reality (VR) environment (right) in the Unity software program.

*Goal 2: Create an interactive lunar environment.*

To maintain a sense of realism, it is imperative that the interactions on the lunar surface be as accurate as possible. We included some fundamental mission items to the terrain, including an Apollo Lunar Exploration Module, Lunar Rover Vehicle, an American flag, and virtual moon rocks **(Fig. 2)**. Navigation by walking and driving the rover proved cumbersome with our setup. However, with VR teleportation methods, the user can instantly hike to the top of South Massif for a grand view of the Lee-Lincoln scarp.

*Goal 3: Develop a scientific toolbox.*

Using VR, we were able to incorporate instruments not used on Apollo, but could be used on future missions. The scientific toolbox we developed contained an array of tools; including a moon rock identification tool, a way to mark regions of interest, and a heads-up display (HUD) to control and view the movements of the Lunar Rover Vehicle in real time **(Fig. 3)**. The purpose of the scientific toolbox is to test the utility of different instruments and practice science operations in the early stages of mission planning.

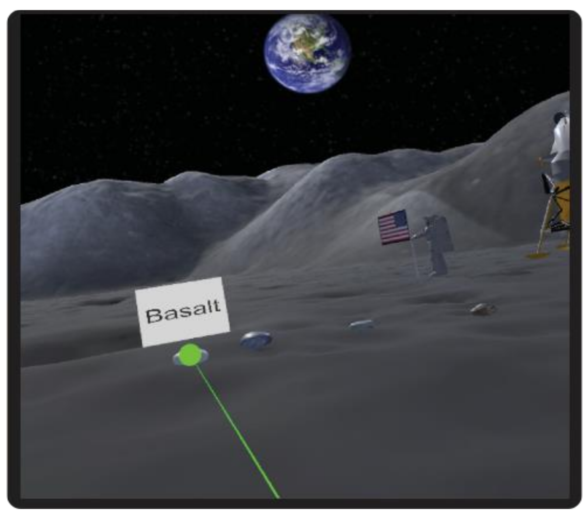


**Figure 2:** VR Moon Rock Identification tool in action. This initial concept represents a handheld tool that would be used to identify different rock types and display results in a heads-up display.

**Technologies and Methodology:** The simulator was built using Unity3D (a commercial game engine and development suite) **[3]** and Virtual Reality Toolkit (a plugin that integrates with Unity to handle VR specific interactions). An HTC Vive VR headset was used to develop and test the application since it currently has the best positional tracking, but the simulator can also be run on the Oculus Rift VR headset. Most of the Apollo 17 VR project was built over the summer in a 10-week period by two NASA interns (Mathew and Slocum), with only a few adjustments and improvements since.

**Figure 3:** HUD shows the view from the lunar rover camera as it navigates autonomously to waypoints

**Results:** Our team created a simulation that is capable of enabling the user to experience the Taurus-Littrow Valley in VR as if they were actually there in person. The simulation starts in the Lunar Command Module, where the user selects which Apollo Mission to simulate (currently only Apollo 17 is supported). The user is then teleported to the landing site, where they can interact with a mockup lunar module, virtual moon rocks, and mockup astronauts that are rigged to be animatable. There is also a driveable Lunar Rover Vehicle subject to realistic lunar gravity. The explorable area is 250 $km^2$ centered at the landing site. We are still working on appropriate scaling of the mockups to the terrain.

**Future Work:** We plan to continue to increase the fidelity of the landscape graphics and interactive features and tools of the Apollo 17 site. In 2018, we will add other Apollo missions to VR and incorporate ALSEP instruments. While the simulation application is still a prototype, its short development cycle is a testament that using VR to design, build, and test can outweigh the costs of building multiple physical models.

VR also has great potential for planning both robotic and human missions. VR allows scientists to view pre-mission data in new ways to scope out areas they might like to study, helping them to acquire a familiarity with the terrain before a mission ever starts. However, to realize VR's full potential, movement in the virtual environment needs to become more comfortable and efficient. But being a new technology, VR as a whole and especially movement within, is improving rapidly, and research into the area is yielding significant results **[4].**


Figure 4: Initial view from Lunar Command Module

**Summary:** We built an Apollo 17 VR simulator that models the Taurus-Littrow valley using LRO NAC images and DEM data. Our prototype showcases the applications of VR technology in the planetary sciences, particularly for analysis of data and operations training. VR allows scientists to interact with their data in natural ways, from the same point of view they would have in the field. It opens the door to efficient training and inexpensive field expedition planning, as well as interactive outreach and engagement. Most importantly, VR allows scientists to visit and revisit places they may never go - like the Moon and Mars - and study them from a new perspective.

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**References:** **[1]** Berg, O.E., F.F. Richardson, and H. Burton. (1973) Apollo 17 prelim. science report. NASA SP-330, 16. **[2]** Oberst, J. et al. (2010) 41st LPSC, Abstract 2051. **[3]** Unity website (2018), https://unity3d.com. **[4]** Heath, T. (2017) *Research into Comfortable Locomotion*.