WHAT CAN ASTRONAUTS LEARN FROM TERRESTRIAL IMPACT CRATERS FOR OPERATIONS ON THE MOON AND MARS? David A. Kring[1,2], [1]Center for Lunar Science and Exploration, USRA – Lunar and Planetary Institute, 3600 Bay Area Blvd., Houston TX 77058 (kring@lpi.usra.edu), [2]NASA Lunar Science Institute.

Introduction: Virtually any step an astronaut makes on the Moon will be in an impact crater. The excavated cavities, uplifted rims, and distributed ejecta of impact craters dominate the lunar landscape. Impact processes are even responsible for the lunar soil. Learning how to operate in that type of environment will be critical to the success of exploration. Impact craters are also our most treasured scientific sites for lunar exploration. These same observations apply to many regions of Mars.

Science Lessons to be Learned: A concentration of *c*. 3.9-4.0 Ga Apollo sample ages suggest there may have been a spike in the impact flux in an event called the lunar cataclysm. Not only did the bombardment affect the geologic evolution of terrestrial planets, it may have also influenced the origin and evolution of life on the Earth and potentially Mars. Because the impact flux to the inner solar system is both accessible and uniquely preserved on the Moon, additional samples to evaluate the impact flux are among the highest lunar science priorities. To complete that task, crew will need to study analogue sites to learn about crater morphology, associated structural elements, the distribution of impact lithologies, and how to locate samples suitable for determining the ages of craters.

Astronauts also need to be taught that complex craters and multi-ring basins are excellent probes of the lunar interior. Normal faults in the modification zones of these craters expose subsurface lithologies and their stratigraphic relationships. Uplifted central peaks and peak rings expose even deeper levels in the Moon's crust. Furthermore, clasts of subsurface lithologies are entrained in impact melt breccias deposited within the crater and beyond its rim. Thus, by combining observations of modification zones, central uplifts, and impact breccias, one can generate cross-sections of the lunar crust that may be kilometers to 10's of kilometers deep. The volume of material beneath an impact site that is melted extends to an even deeper level than the material that is excavated. Thus, while collecting melt samples to determine the impact flux, crew will also be collecting samples of the lunar interior.

Large craters may have formidable crater walls, so some missions may be limited to the crater interior, while others may be limited to the crater ejecta blanket. Learning how to conduct radial sampling of an ejecta blanket to probe the subsurface stratigraphy exposed in the crater interior will be another key training objective at terrestrial craters.

Exploration Lessons to be Learned: The expanded geographic scale of future lunar surface operations will be a new challenge. Excursion distances will be far greater than those of Apollo and even some of the topographical features have greater dimensions than those encountered during Apollo. The 1.25 km diameter Meteor Crater of Arizona is a perfectly good proxy for Apollo 16's North Ray Crater. It is even a good analogue for many of the morphological features of Shackleton Crater at the lunar south pole. However, the size of Shackleton Crater (20 km diameter and 3 times deeper than the Grand Canyon) may require training activities at Sierra Madera Crater (13 km) and the Ries Crater (24 km) to capture the operational (e.g., communication, rover mobility, and supply) issues that are affected by greater distances.

Crew Perspective: Apollo astronauts found field training and traverse exercises to be the most important component of their EVA preparation. Charlie Duke said "The geology field trips were outstanding. The monthly trips that we did from the time we started on the crew were just right." John Young added that a field exercise "helps you to get a team work pattern and I think that's real important. You are not very effective unless you're working as a team up there. Otherwise you're just going to be spinning your wheels on the Moon and that's not where they want you to spin them."

Fig. 1. Gene Shoemaker training Apollo astronauts at Barringer Meteorite Crater (aka Meteor Crater) in 1965. (NASA photograph S65-23562).