Introduction

The Apollo 15 mission to the Moon's surface is expected to be launched from Cape Kennedy on 26 July 1971 and to land a few days later near a very large and majestic mountain range, the Apennine Mountains. A sketch of the front side of the Moon is shown in figure 1 and the location of the landing site is shown in relation to other sites. This landing site is extremely attractive from the viewpoint of lunar science. It will give the astronauts their first chance to collect rocks from lunar mountains and to study at firsthand a feature, termed rille, which resembles in many ways the channels cut on Earth by meandering streams. The origin of rilles is probably not the same as that of the familiar terrestrial stream-cut channels because no water is present now on the Moon's surface and probably never existed there. The origin of rilles is a puzzle.

Near the landing site are Hadley Mountain, which rises about 14,000 feet above the surrounding lowlands and Mount Hadley Delta, which rises about 11,000 feet. The actual surface on which the Lunar Module or LM* will land is everywhere pock-marked by craters of various sizes. The smallest craters known are less than 1/1000 inch across; the largest exceed 50 miles. The craters were produced during the past few million years when objects from space struck the Moon. The craters are still being produced but there is no danger to the astronaut because collisions with the Moon are very infrequent. For example, an object larger than birdseed would strike the landing site only once every few years. But because erosion is so slow on the Moon, the craters produced millions of years ago are still preserved and appear as seen in photographs throughout this guidebook. The mechanisms of erosion, the process by which rocks and soil are removed from a particular spot, are very different on the Earth and the Moon. Most terrestrial erosion is accomplished by running water and is relatively rapid. Most lunar erosion is the result of impacting objects and the resulting craters destroy previously existing ones.

Since the first manned lunar landing, Apollo 11, in July 1969, significant improvements in both equipment and procedures have increased dramatically the capabilities of Apollo 15 over those of previous missions. Total duration of the mission has increased from 9 days to a planned time of about 12½ days and a maximum of 16 days. Actual time for the LM to remain on the lunar surface has doubled, from 33.5 hours previously to a planned 67.3 hours. The amount of time spent by the astronauts on the lunar surface outside the LM, which has become known as Extravehicular Activity or EVA, has more than doubled from a maximum of 9.3 hours previously to a planned 20 hours. The EVA time will be spent in three periods of 7, 7, and 6 hours' duration. The weight of the scientific equipment that will be used in lunar orbit has increased from 250 pounds to 1,050 pounds. The weight of the scientific equipment to be landed on the lunar surface has increased from 510 pounds to about 1200 pounds. And finally, the astronauts will have with them for the first time a small, four-wheeled vehicle for travel over the Moon's surface. It is termed Rover and can carry two astronauts, equipment, and rocks. Unlike the Russian vehicle Lunokhod that was recently landed and is still operating, it cannot be operated remotely from Earth.

A summary of major events for the entire Apollo 15 mission is shown in Table 1. Scientific activities while the spacecraft is in orbit around the Earth, consist mainly in photographing the Earth with film that is sensitive to ultraviolet (uv) radiation for the purpose of examining various terrestrial, cloud, and water features. By using uv, we hope to "see" these features more clearly than we could see

*Abbreviations and acronyms are very useful in situations where time is limited, such as a mission to the Moon's surface. Common ones are noted in this book where first used. An extensive list is given at the end of the text.

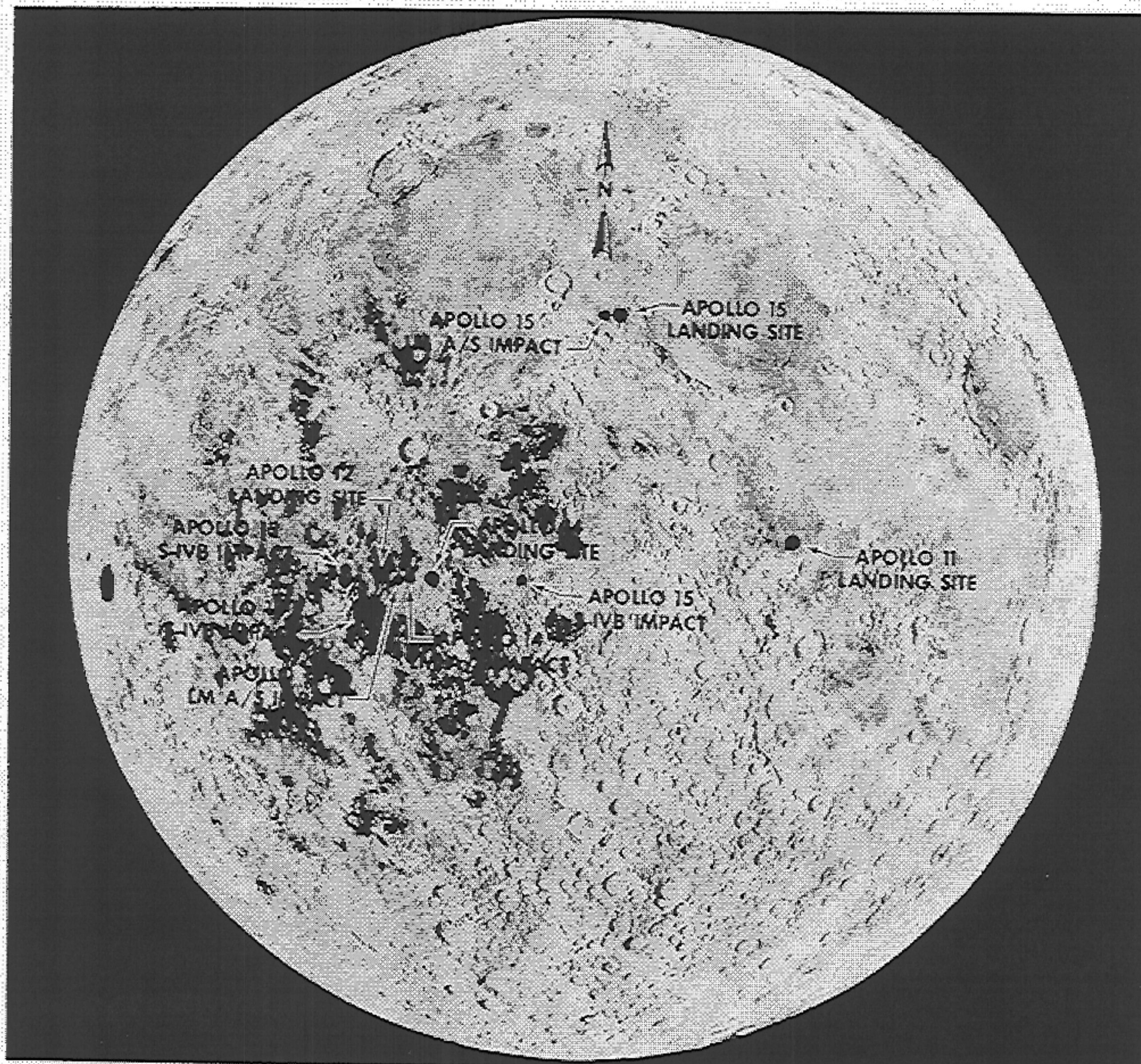

FIGURE 1.—Front side of the Moon. This side always faces the Earth. Shown here are locations of the previous Apollo landings and of the impacts on the Moon of spent S–IVB stages and LM ascent stages. The impacts create sound waves in the Moon that are used to study the interior of the Moon.

them with visible light. From space, the atmosphere gets in the way of seeing. The situation is somewhat akin to that of using sunglasses to reduce glare, so the wearer can see better. The uv photography will be continued during the journey to the Moon and pictures will be obtained at various distances from the Earth. During this journey and before the landing on the Moon, one of the spent stages of the rockets that were used to lift the spacecraft from the Earth, and designated S–IVB, will be crashed into the Moon. The sound waves generated by the S–IVB impact travel *through* the Moon and will be detected by sensitive receivers (seismometers) now operating at the Apollo 12 and 14 sites. (This experiment is discussed more fully later in this guidebook.)

Shortly after placing their spacecraft in orbit about the Moon, the astronauts separate it into two parts. One part, the combined Command and Service Modules (CSM), remains in lunar orbit while the other part, the Lunar Module (LM), descends to the surface.

One astronaut remains in the CSM and performs many scientific experiments. These orbital experiments will obtain data over a large part of both front and back sides of the Moon because the path of the point directly beneath the spacecraft, termed ground track, is different for each revolution of the spacecraft. See figure 2. Notice that the orbit of the CSM is not parallel to the equator. If the Moon did not rotate about its axis, the ground track would change very little on each successive revolution of the CSM. However, the Moon does rotate slowly about its axis. It completes one full revolution every 28 earth-days and therefore the ground track is different for each CSM revolution.

Several of these orbital experiments will measure the approximate chemical composition of the Moon's surface materials. Others are intended to measure the variations of gravity and of the magnetic field around the Moon. A laser altimeter will be used to obtain precise elevations of features that lie on the Moon's surface beneath the orbiting CSM. An extensive set of photographs will be obtained. The pilot will observe and photograph many features on the Moon never before available to astronauts.

The other two astronauts descend to the surface of the Moon in the LM. The rest of this guidebook is a discussion of their equipment and of their activities.

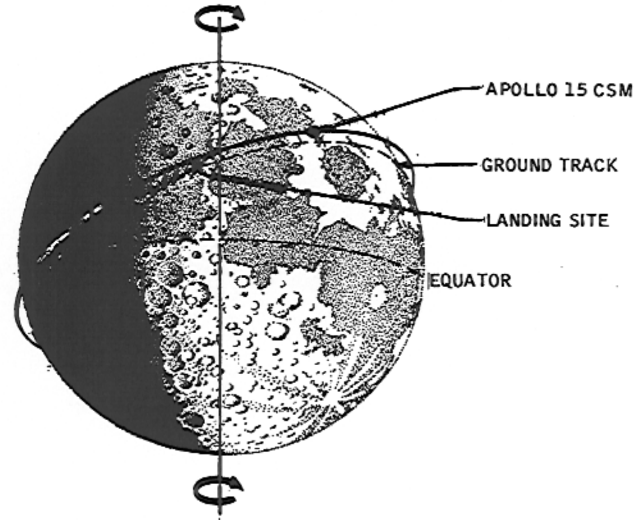

FIGURE 2.—Trajectory and ground track of Apollo 15. Because the Moon rotates, the ground track is different for each revolution of the CSM.

The LM, illustrated in figure 3, lands two astronauts on the Moon's surface. It has two parts, a descent stage and an ascent stage. The descent stage contains a rocket engine, fuel necessary to land both stages, a four-wheeled battery-powered vehicle to be used on the Moon, water and oxygen, and scientific equipment to be left on the Moon when the astronauts return to Earth. The other part, the ascent stage, contains the following items: (1) equipment for communications with the Earth and with the CSM, (2) navigational equipment, (3) a computer, (4) food, oxygen, and other life-support supplies, and (5) another rocket engine and fuel needed to leave the Moon and rendezvous with the CSM. All three astronauts return to Earth in the Command Module.

Soon after the LM lands on the Moon, about 1½ hours, the astronauts will spend a half hour describing and photographing the surrounding area. The commander will open the upper hatch and stand with his head and shoulders outside the LM. During this Standup Extravehicular Activity (SEVA), the LM cabin will be open to the lunar atmosphere and will therefore be under vacuum conditions. Both astronauts must wear their space suits. Because the commander's head will be above the LM, he will have excellent visibility of the landing site. If the LM lands within 100 yards, the length of a football field, of the planned spot, then the commander will see the panoramic view

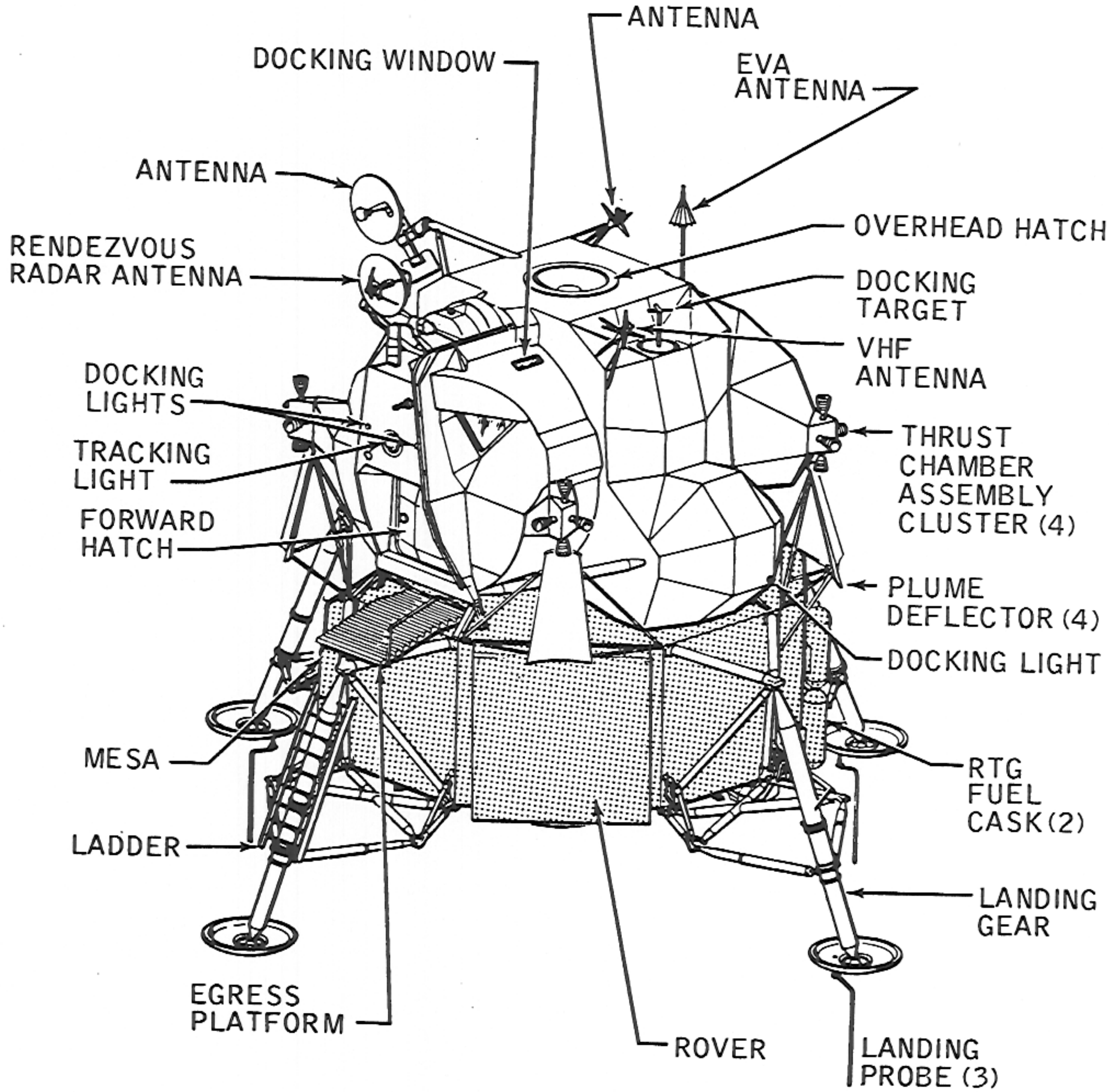

FIGURE 3.—The Lunar Module (LM). The shaded portion, the descent stage, remains on the Moon when the astronauts leave in the ascent stage to rendezvous with the CM and return to Earth.

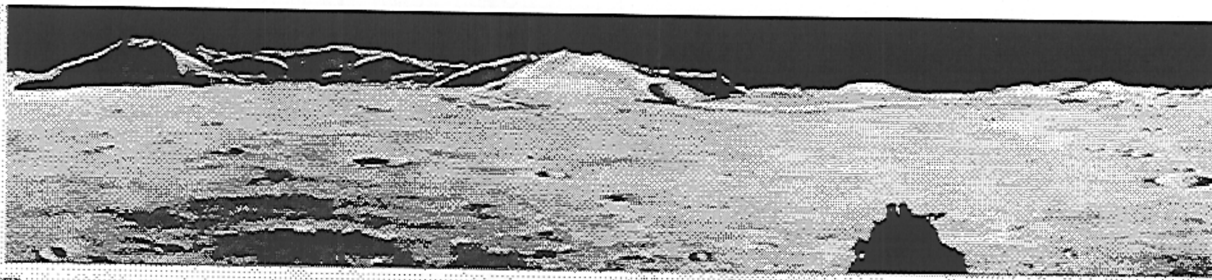

FIGURE 4.—SEVA Panorama. Artist Jerry Elmore has depicted here the panorama that the Commander will see from his vantage point above the LM during the SEVA. Mount Hadley Delta, due south, stands about 11,000 feet above the landing site. Hadley Mountain, the large dark mountain situated northeast of the site, is about 3,000 feet higher than Mount Hadley Delta.

sketched in figure 4. He will shoot photographs, which will include panoramas, with both 500 mm and 60 mm lens. His verbal descriptions during the SEVA will help Mission Control to accurately pinpoint the actual landing site. Of equal importance is the fact that the descriptions will assist in the continuing evaluation of the surface science plans. It is likely that the astronauts will draw attention during the SEVA to some surface features, previously overlooked, that we will wish to examine sometime during the three EVA's.

When the astronauts leave the LM, a process appropriately termed egress and shown in figure 5, they must wear a suit that protects them from the Moon's high vacuum. This suit is illustrated in figure 6. Although it was designed to allow freedom of movement, it still restricts considerably the motion of the astronauts. An example may be useful. Think how difficult it is to run, chop wood, or work outdoors on an extremely cold day in winter when you wear many layers of clothes. The astronauts' suits are even more restrictive. The Portable Life Support System (PLSS) contains the oxygen needed by the astronaut and radios for communication. It also maintains the temperature inside the suit at a comfortable level for the astronaut.

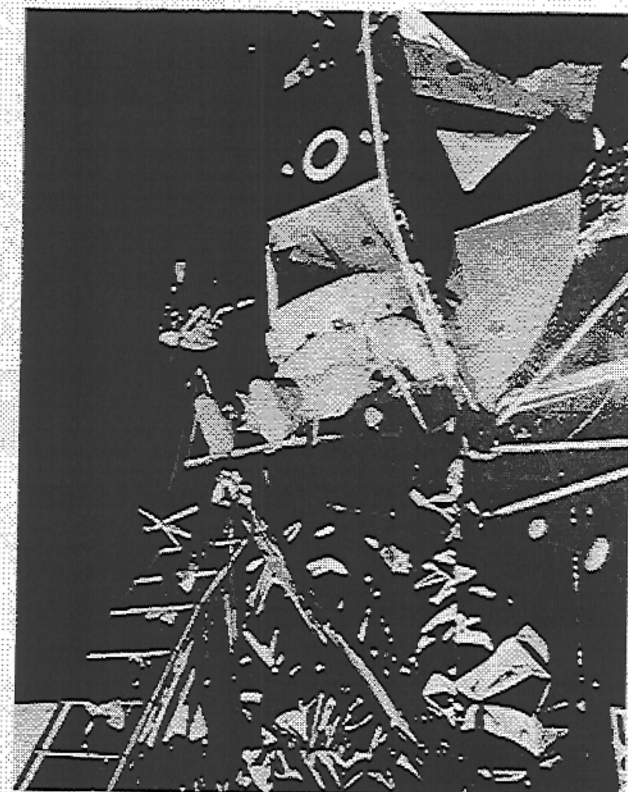

FIGURE 5.—Egress. Apollo 11 astronaut Aldrin is shown egressing from the LM. Note the ladder that leads down one leg from the platform.

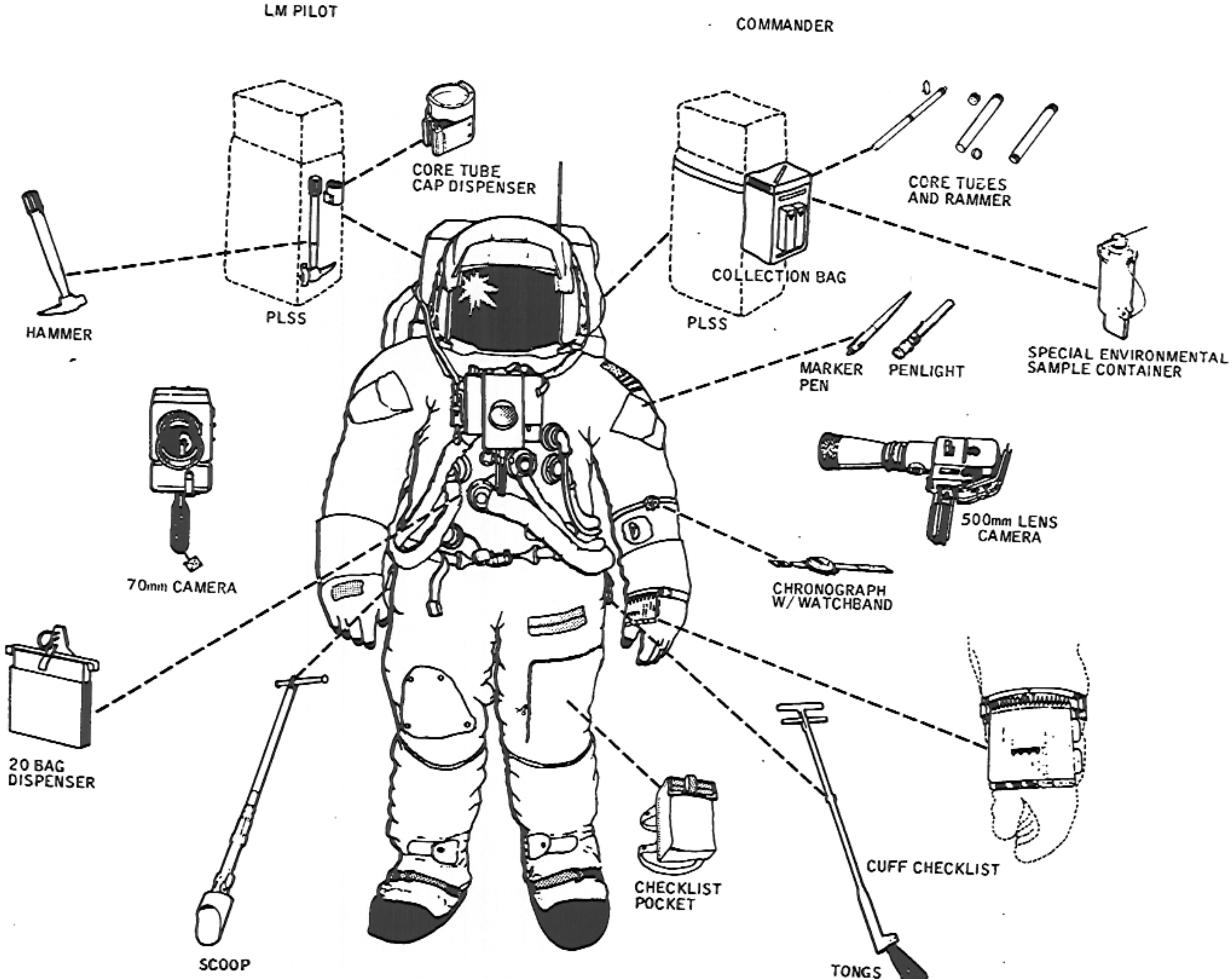

FIGURE 6.—Astronaut suit. The suit prevents exposure of the astronaut to the Moon's vacuum. It incorporates many improvements over the suits used on previous Apollo flights. Sketched also are several items of equipment.

Landing Site Description

The Apollo 15 landing area, termed Hadley-Apennine, is situated in the north central part of the Moon (latitude 26° 04′ 54″ N. longitude 03° 39′ 30″ E) at the western foot of the majestic Apennine Mountains, and by the side of Hadley Rille. See figure 1. The Apennines rise 12,000 to 15,000 feet above the lunar surface and ring the southeastern edge of Mare Imbrium (Sea of Rains). For comparison with Earth features, the steep western edge of the Apennine Mountains is higher than either the eastern face of the Sierra Nevadas in the western U.S. or the edge of the Himalayan Mountains that rises several thousand feet above the plains of India. The actual landing point was selected so the astronauts could study the sinuous Hadley Rille, the Apennine Mountains and several other geological features. A beautiful perspective view of the local landing site, as seen from an angle of about 30 degrees, is shown in figure 7. In drawing this figure, we have combined the precision that is available from modern-day digital computers and the insights that can come only from an artist. Thus the features are very accurately drawn but they are displayed in a way that the human eye will see them.

In the rest of this section, I will discuss the several geologic features present at the landing site: The Apennine Mountains, Hadley Rille, the cluster of craters at the foot of Hadley Mountain, and the North Complex. All of them are clearly visible in figure 7.

THE APENNINE MOUNTAINS

These mountains form part of the southeastern boundary of Mare Imbrium and are believed to have been formed at the same time as the Imbrium basin.*

*To the scientist, the distinction between a mare, which is the surface material, and the associated basin, which includes the shape and distribution of materials at depth beneath the mare, is very important.

The general relations of the Apennine Mountains, Hadley Rille, and a branch of the Apennine Mountain chain, termed Apennine Ridge, are seen in figure 8. Most lunar scientists agree that the Imbrium basin was formed by impact of a large object but there is no general agreement on the details of the processes involved in the origin of the rille or the mountains. One possible process of basin formation is shown schematically in figure 9. The impact of the object causes material to be thrown out in much the same way that material is splashed when a large rock is dropped in soft mud. From a study of the samples of material that is ejected from the crater, we can measure the age of the material and obtain the date at which the impact occurred. We can also determine the nature of the material at depth in the Moon. I think it is very likely that most of the material available for sampling at the Apollo 15 landing site consists of rocks and soil ejected from Imbrium basin. Some material older than the Imbrium impact may be found at the base of Mount Hadley Delta. Thus one of the main geological goals of this mission is to sample those rocks.

Our understanding of the details of crater formation has been improved by the study of impact craters on Earth. One such crater that is generally well-known is Meteor Crater, near Flagstaff, Arizona. Other impact craters, less well-known but intensely studied by geologists, exist in Tennessee, Canada, Australia, Germany, and elsewhere. An oblique photograph of Meteor Crater is shown in figure 10.

HADLEY RILLE

Hadley Rille is a V-shaped sinuous rille that roughly parallels the Apennine Mountains along the eastern boundary of Mare Imbrium (figures 7 and 8). It originates in an elongated depression in an area of low domes that are probably volcanic in nature. It has an average width of about

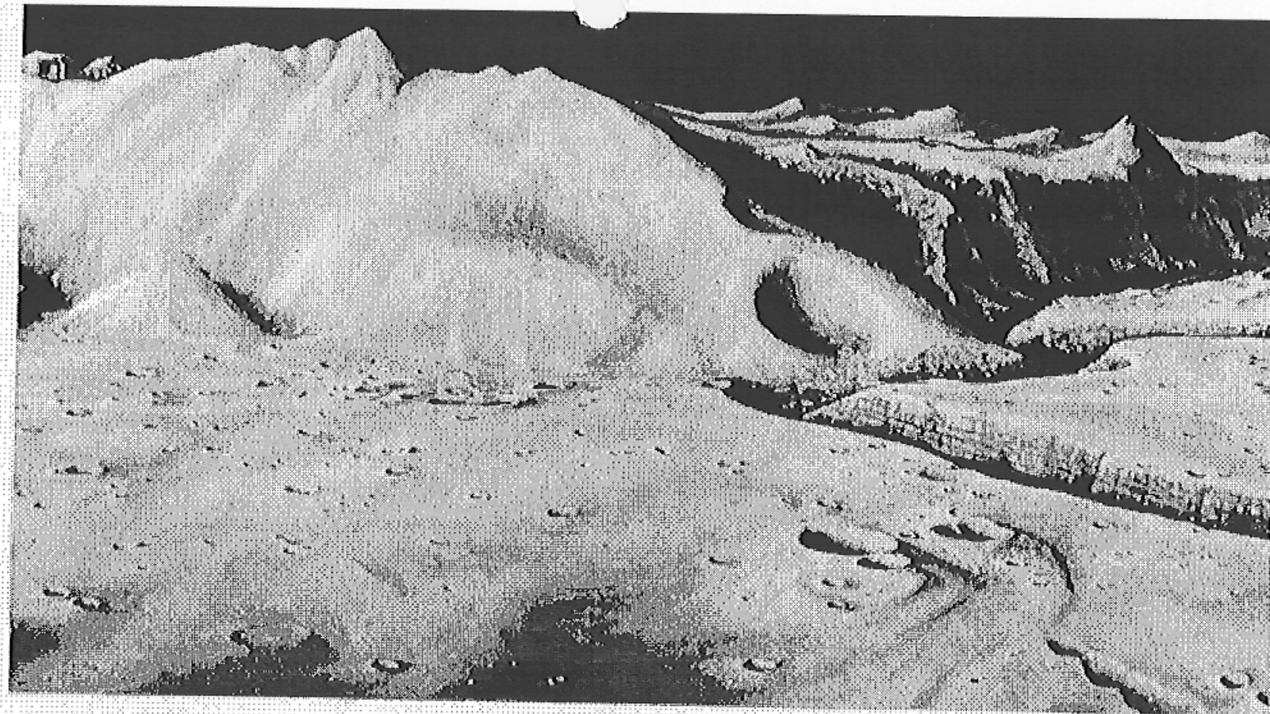

FIGURE 7.—Landing site for Apollo 15 as seen from the north. The large mountain, Hadley Delta, rises about 11,000 feet above the nearby plain. The valley, Hadley Rille, is about one mile wide and 1,200 feet deep. Origin of the rille is a puzzle and its study is one of the objectives of this mission. (Artwork by Jerry Elmore.)

1 mile, a depth that varies generally from 600 to 909 feet but at the landing site is 1,200 feet, and is about 80 miles long. Such sinuous rilles are very common on the surface of the Moon. Their origin in general, and of Hadley Rille in particular, is very puzzling to lunar scientists and has been debated for many years. It has been attributed by various scientists to flowing water (although as a result of studying rocks returned on previous missions, we no longer believe this hypothesis), the flow of hot gases associated with volcanism, the flow of lava (in much the same way that lava flows down the sides of the Hawaiian volcanoes), and to collapsed lava tubes. Today, most scientists agree that the origin of such rilles is associated with fluid flow or with faulting. Yet we now know that water is generally absent from the Moon and probably never existed there in large quantities. The visit by the Apollo 15 crew to Hadley Rille will undoubtedly shed some light on the origin of rilles.

The approximate slope of the sides of Hadley Rille, near the landing site, is about 25 degrees. The depth is about 1,200 feet. Many fresh outcrops of rock that are apparently layered are seen along and just below the rille rim. The layers probably represent lava flows. Many large blocks have rolled downslope to settle on the floor of the rille. An analogous terrestrial feature that clearly has its origin in the flow of water is seen in figure 11, the Rio Grande Gorge near Taos, New Mexico. An important part of the Apollo 15 astronauts' training was a study for two days of this feature.

Examination of the rille floor and sampling of the rocks located there would be extremely valuable. Evidence on the origin of the rille would almost certainly be found. But perhaps more importantly, rocks from a depth of about 1,200 feet would be collected. The study of the vertical changes in rocks, termed stratigraphy, provides the basic data necessary to construct the history of the Moon. (For example, many facts about the geological history of the Earth have been read from the rocks exposed in the walls and bottom of the Grand Canyon.) The scientific need to examine rocks from the bottom of the rille is so great that many people have tried to solve the problem of how to get them. One prominent scientist suggested that the astronauts use a crossbow with string attached to the arrow for retrieval. Of course the arrow would have been modified so that it adhered to rocks in some way rather than pierce them. This idea, as well as others, was abandoned because it was not practical. Even though access to the rille floor is not possible, sampling of the rocks that occur along the rim and photographing the walls are planned and may aid lunar scientists in determining the origin of rilles.

SECONDARY CRATER CLUSTER

A group of craters, labeled "South Cluster" on figure 16, will be observed and photographed during the second EVA. This group or cluster of craters is thought to have formed from impact of a group of objects that struck the Moon at the same time. Those objects were, in turn, thrown out from some other spot on the Moon by the impact of a single object from space. Hence the term secondary impact crater is applied to such craters.

Because the objects that created secondary impact craters came from some other spot on the Moon, the rock samples collected from such features may include samples from other parts of the Moon, and perhaps from considerable distance. Most of the material present in the vicinity of the craters is undoubtedly the material that was present before the craters were formed. The exotic material, that which came from elsewhere, is probably quite rare and the amount present at any crater may be less than 1 part per 1,000. Only after extensive investigation of the samples back in the laboratory on Earth can we be reasonably sure about the origin of a particular sample. Some lunar scientists believe that the objects that produced the South Cluster craters came from the very large crater Autolycus, situated about 100 miles to the northwest.

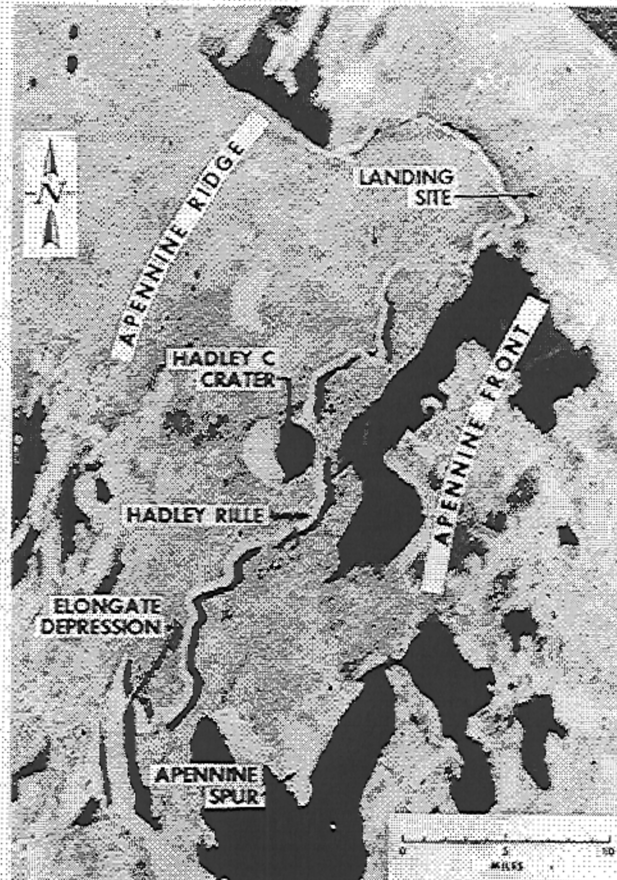

FIGURE 8.—General geography of the Apennine-Hadley landing site. Note that Hadley Rille is about 80 miles long.

An additional reason for collecting rocks in, or near, craters is that the impact, in forming the crater, always exhumes rocks from the bottom of the crater. Therefore the material that surrounds a crater includes material that originally was located at the bottom of the crater, at the top, and at all intermediate depths. If the material changes within the depth of the crater, then a study of the rock samples will very likely indicate that change.

Thus, for these two reasons, that we may sample distant localities and that we may see changes in the rocks with depth, the collection of samples at South Cluster is an important objective of the Apollo 15 mission.

NORTH COMPLEX

Not all features on the Moon's surface were formed by impacting objects. Some were formed

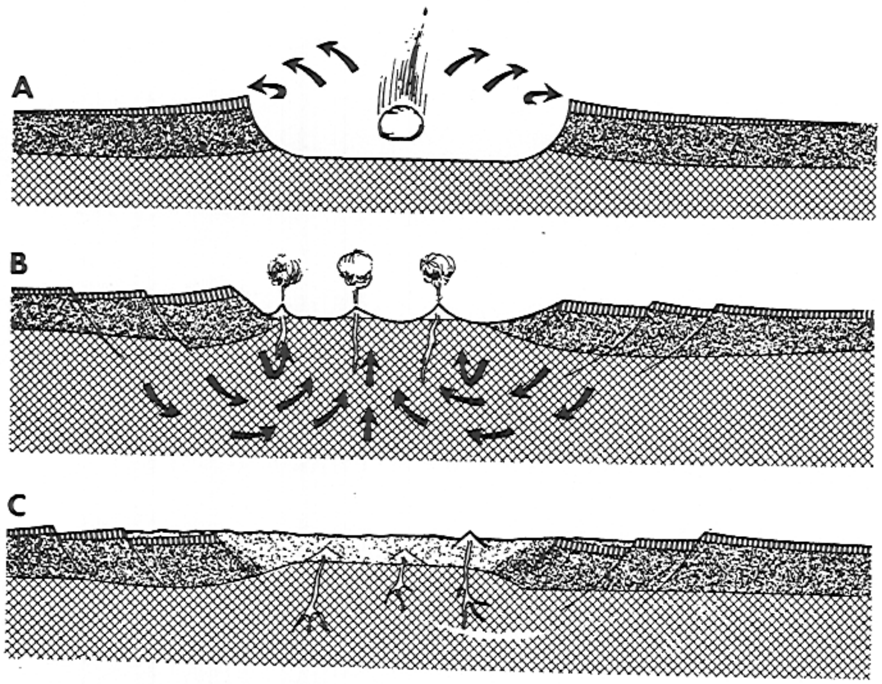

FIGURE 9.—Possible explanation of the origin of large basins on the Moon. In A, impact of an object from space, a large meteorite, created a hole and splashed material great distances. Some rocks were thrown hundreds of miles. The presence of the hole and the high temperatures generated by the heat from the impact create volcanoes. Material is transported to the surface of the basin. In the final stage, Part C, the basin has been largely filled again but with less dense rock at the surface. This explanation was suggested originally by Professor Donald Wise.

by internal processes. It is never easy on the basis of photographs or telescopic observations to distinguish between an internal and an external origin for a particular feature. In fact Galileo, the first man to look at the Moon through a telescope, about 300 years ago, suggested that all the craters on the Moon were due to volcanoes. His hypothesis stood unchallenged for two centuries until someone suggested the impact hypothesis. As so often happens in science, long, and sometimes bitter, arguments over which hypothesis was correct raged for about 100 years. Today, we believe that most lunar features have resulted from impacts but some have been caused by internal processes.

The features in the North Complex appear to have resulted from internal processes. Apollo 15 will give us the first opportunity to study at first hand the form of such features and the nature of their rocks and soils.