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Training Apollo *astronauts in lunar orbital observations and photography*

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ABSTRACT

Planning and implementation of astronaut observations and photography from lunar orbit during the *Apollo* program were based on two expectations: (1) orbiting astronauts would be able to add to our knowledge by describing lunar features from their unique vantage point, and, (2) as illustrated by the *Gemini* Earth-orbital missions, expertly obtained photographs would allow us to place detailed information from field exploration into a regional context. To achieve these goals, the astronauts had to be thoroughly familiar with concepts of lunar geology and intellectually prepared to note and document the unexpected. This required mission-specific training to add to their store of knowledge about the Moon. Because the activity was not part of the original program objectives, the training was conducted at the behest of the astronauts. The training time grew from occasional briefings on the early flights to extensive classroom sessions and flyover exercises for a formal "experiment" on the last three missions. This chapter summarizes the historical development and salient results of training the Moon-bound astronauts for these tasks. The astronaut-derived orbital observations and photographs increased our knowledge of the Moon beyond that possible from robotic sensors. Outstanding results include: realization of the limitations of photographic film to depict natural lunar surface colors; description and documentation of unknown features on the lunar farside; observation by *Apollo 15* of dark-haloed craters that helped in the selection of the *Apollo 17* landing site; and real-time confirmation that the "orange soil" discovered at the *Apollo 17* site occurs elsewhere on the Moon.

BACKGROUND

Most *Apollo* astronauts were astute pilots who were well versed in flying aircraft, but who did not fully appreciate the scientific objectives of lunar exploration. Their training in lunar orbital observations and photography entailed directing their competitiveness toward knowledge of the Moon and the value of scientific gains from each mission. This endeavor took root on *Apollo 13* and reached its zenith on the last three missions, *Apollo 15*, *16*, and *17*. To accomplish this, the astronauts had to be motivated by challenging them to do what no instrument could. They were taught to value the interaction between the

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eye and the brain, and the timely application of intellect based on a store of knowledge.

Prior to the lunar missions, the *Gemini* astronauts captured unique views of the features of Earth from orbit. Because of their military training, the phrase "targets of opportunity" was then coined to denote areas to be photographed. From *Gemini 8* onward—through *Apollo 7* and *Apollo 9* Earth-orbital missions—this activity was carried out through a program of 70 mm Hasselblad weather and terrain photography. Extensive planning and crew training were conducted by Richard (Dick) Underwood of the Photographic Laboratory at the Manned Spacecraft Center (MSC, later named the Lyndon B. Johnson Space Center [JSC]) in Houston, Texas. He was assisted in this task by others, particularly Paul D. Lowman of the Goddard Space Flight Center (GSFC), Greenbelt, Maryland. The resulting photographs have since been popularly used by the media, the general public, and in geography classrooms (see, e.g., Lowman, 1966, 1972).

Training of the Moon-bound astronauts in orbital photography followed the same scheme and took into account the mindset of fighter pilots and their military instincts of dealing with objects and places. Thus, lunar surface features to be photographed were also labeled "targets of opportunity." In addition, the astronauts were trained to make visual observations that were focused on the selection of "landing sites" or addition to our knowledge of the geologic features of the Moon. This enterprise required well-planned, regularly scheduled, and mission-specific training sessions that usually started over a year prior to each mission.

This chapter highlights the training activities of the *Apollo* astronauts, particularly the Command Module Pilots (CMPs), in lunar orbital observations and photography. The CMPs were the second in command after the commander of each mission. They piloted the Command Service Module (CSM) spacecraft during all separation and docking maneuvers, and they remained in lunar orbit as two of their crewmates explored the lunar surface. They belonged to an elite club; most people spoke of the "Club of 12" who walked on the Moon, but there existed a more exclusive club of six men who soloed around the Moon. Orbiting above the farside of the Moon left a unique impression on a CMP, who was alone and completely cut off from Earth, without communications with a single soul. Most of them felt exhilarated by flying solo in a spacecraft around the farside of the Moon, and often said: "You watch this panorama go by, and it's mind-boggling…One sight after another that is just absolutely extraordinary" (personal commun., 2010).

Very little has been written about the contributions of those *Apollo* CMPs. They have significantly added to our understanding of the Moon's surface features, particularly along the paths that led to the six *Apollo* landing sites (Fig. 1). This contribution will shed some light on the geologically significant additions made by these explorers from above, based on their specific training. The astronaut's own perceptions of their contributions to scientific knowledge of the Moon are extensively relayed in Chaikin (1994) and Chaikin and Kohl (2009).

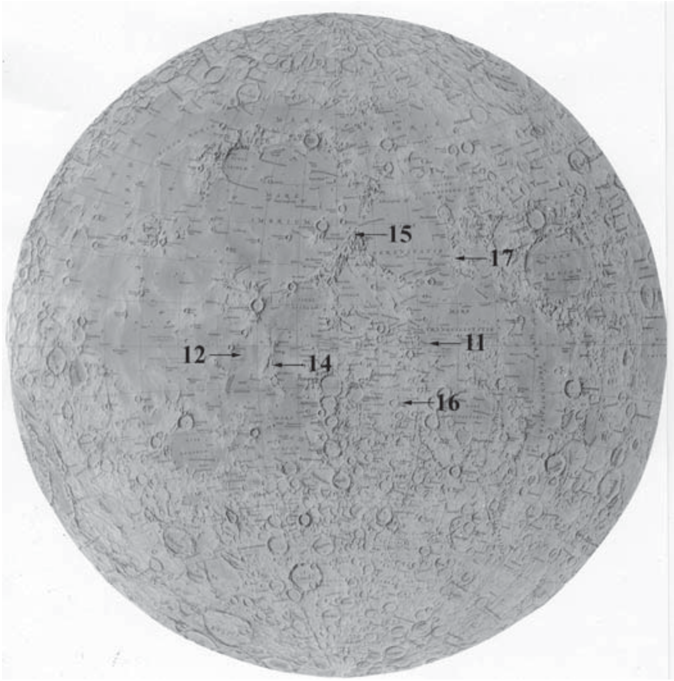

Figure 1. Locations of the six *Apollo* landing sites on the nearside of the Moon. The background is a shaded-relief map by the U.S. Geological Survey (USGS). Landing site locations are marked by the author, as modified from El-Baz (1975, p. 496).

My involvement in the *Apollo* program began in March 1967 as a geologist with Bellcomm, Inc. The latter, a division of the American Telephone and Telegraph Company (AT&T), was composed mostly of engineers from Bell Telephone Laboratories. Their mandate was to perform "systems analysis" for the National Aeronautics and Space Administration (NASA) headquarters in Washington, D.C. Bellcomm was the brainchild of James E. (Jim) Webb, the great first administrator of NASA from 1961 to 1968. In 1962, he wrote to AT&T requesting assistance for NASA, particularly in communications during the space missions. The company was pleased to oblige as a service to the nation's space effort. Top engineers from Bell Laboratories in New Jersey were relocated to Washington, D.C., in offices that were adjacent to those of the *Apollo* program director. They began to add people from outside of the Bell system, including geologists such as Noel W. Hinners, who hired me, and in turn, I hired James W. Head III. Throughout the *Apollo* years, the work of Bellcomm was compensated at cost plus $1 per year!

The establishment of such a behind-the-scenes organization at NASA headquarters was a stroke of genius. As Bellcomm employees, we reported to an unseen boss in New Jersey. NASA managers were not our bosses, and we could contradict them anytime verbally and in writing for the good of the program. In the meantime, when we traveled to any of the NASA centers, we had badges with a "headquarters" notation. This allowed us to work with people throughout the NASA structure in order to uncover problems and to solve them in a timely manner. Just to keep things straight, Bellcomm employees were advised not to directly communicate with the astronauts and not to speak to the press in all its forms. In due time, I became the first to break both rules, by request of NASA.

INTRODUCTION

Geological study of the Moon began through the interpretation of photographs from Earth-based telescopes (Wilhelms, 1987), and later those obtained by the unmanned *Ranger* (Trask, 1972), *Surveyor* (Wilhelms, 1993), and particularly, the five *Lunar Orbiter* missions (see Kosofsky and El-Baz, 1970; also, the recently enhanced farside images in Byrne, 2008). The interpretations were mostly performed by U.S. Geological Survey (USGS) geologists, who were seconded to, or supported by, NASA at the Astrogeology Branch in Flagstaff, Arizona, and Menlo Park, California. Donald A. (Don) Beattie, senior geologist at the Lunar Exploration Office of NASA headquarters, offered me his vast collection of lunar photographs for *Apollo* landing site selection (see Beattie and El-Baz, 1970). I expanded the collection of lunar photographs to the extent that the Bellcomm photo library became the main source of data for NASA headquarters. Beattie also introduced me to the USGS group during meetings of the joint NASA-USGS geology group for *Lunar Orbiter* photographic site selection at the Langley Research Center (LRC) in Hampton, Virginia. Somehow, I blended with these fellow geologists to be as one of them and became their spokesman at NASA headquarters and its centers.

Naturally, additional photographs from lunar orbit during the *Apollo* missions were of great interest to the geological community. Planning for this task was taken out of the USGS mandate for training the astronauts in favor of keeping it within JSC. As elaborated by Beattie (2001), JSC feared the loss of influence on scientific tasks to the USGS and tried to keep as much of it "in house" as possible. It became clear that the Mapping Sciences Laboratory (later named Mapping Sciences Branch) at JSC would greatly influence planning of *Apollo* mission photography, particularly from lunar orbit. Mapping Sciences became a frequent weekly stop to discuss the charts to be prepared for each mission to assist the *Apollo* astronauts in the photography tasks (Sasser and El-Baz, 1969).

These charts were basically shaded-relief maps with orbit tracks given in various colors and annotations of the photographic targets of opportunity. They were produced for NASA, based on the JSC plans, by the Aeronautical Chart and Information Center (ACIC) in St. Louis, Missouri. The first map was for use by *Apollo 8* and would be followed shortly by one for the *Apollo 10* mission (Table 1). *Apollo 8* was a daring, first lunar orbital mission that completed 10 revolutions around the Moon. Shortly thereafter, on *Apollo 10*, the Lunar Excursion Module (LEM) separated from the Command Service Module (CSM) to simulate the approach, orbit, and docking maneuvers to obtain close-up photographs for the first landing mission: *Apollo 11*.

TABLE 1. LAUNCH DATES AND DURATION OF DISCUSSED *APOLLO* MISSIONS

Mission	Launch date	Recovery date	Duration
Apollo 8	12 December 1968	27 December 1968	147 h, 42 s
Apollo 10	18 May 1969	26 May 1969	192 h, 3 min
Apollo 11	16 July 1969	24 July 1969	195 h, 18 min
Apollo 12	14 November 1969	24 November 1969	244 h, 36 min
Apollo 13	11 April 1970	17 April 1970	142 h, 54 min
Apollo 14	31 January 1971	9 February 1971	216 h, 2 min
Apollo 15	26 July 1971	7 August 1971	295 h, 12 min
Apollo 16	16 April 1972	27 April 1972	265 h, 51 min
Apollo 17	7 December 1972	19 December 1972	301 h, 52 min
Apollo-Soyuz	15 July 1975	24 July 1975	217 h, 28 min

Much was left to the initiative of the astronauts on these two *Apollo* lunar orbital missions. One of the most impressive views that transfixed the whole world was the "Earthrise" above the lunar horizon as seen by the *Apollo 8* crew (Table 2). It was Bill Anders, Lunar Module Pilot (LMP) of *Apollo 8*, who first captured the amazing view (Fig. 2). The Sun-lit half of our planet

Figure 2. The "Earthrise" as photographed in December 1968 by William A. (Bill) Anders, *Apollo 8* Lunar Module Pilot, as the half-lit Earth appeared above the lunar horizon. The photograph is considered by many as the "picture of the century" and is believed to have inspired worldwide concern for Earth and its environment.

TABLE 2. CREW MEMBERS OF THE DISCUSSED *APOLLO* MISSIONS

Mission	Commander	Command Module Pilot	Lunar Module Pilot
Apollo 8	Frank F. Borman	James A. (Jim) Lovell Jr.	William A. (Bill) Anders
Apollo 10	Thomas P. (Tom) Stafford	John W. Young	Eugene A. (Gene) Cernan
Apollo 11	Neil A. Armstrong	Michael (Mike) Collins	Edwin E. (Buzz) Aldrin Jr.
Apollo 12	Charles (Pete) Conrad Jr.	Richard F. (Dick) Gordon Jr.	Alan L. (Al) Bean
Apollo 13	James A. (Jim) Lovell Jr.	John L. (Jack) Swigert Jr.	Fred W. Haise Jr.
Apollo 14	Alan B. (Al) Shepard Jr.	Stuart A. (Stu) Roosa	Edgar D. (Ed) Mitchell
Apollo 15	David R. (Dave) Scott	Alfred M. (Al) Worden	James B. (Jim) Irwin
Apollo 16	John W. Young	Thomas K. (Ken) Mattingly II	Charles M. (Charlie) Duke Jr.
Apollo 17	Eugene A. (Gene) Cernan	Ronald E. (Ron) Evans	Harrison H. (Jack) Schmitt
Apollo-Soyuz	Thomas P. (Tom) Stafford	Donald K. (Deke) Slayton	Vance D. Brand

appeared in the black sky and framed the lunar horizon (Anders et al., 1969). None of us had thought of planning to capture that view. Our attention was so fixed on the lunar surface features that we neglected to think about what might appear in the Moon's sky. Anders later relayed: "Earthrise! Totally unanticipated. Because we were being trained to go to the Moon…It wasn't going to the Moon and looking back at the Earth" (personal commun., 2010). The breathtaking view that he captured was central to the initiation and popular appeal of the environmental movement worldwide, as people first saw the Earth as a fragile "blue planet" in the bleakness of space.

My Bellcomm colleague Alexander F. (Alex) Goetz flew red and green filters on *Apollo 8* to capture near-simultaneous, multispectral images using the handheld Hasselblad camera. However, Bill Anders took the photographs using color film rather than the prescribed black-and-white magazines. Somewhere in the *Apollo 8* photographic archives, there reside lots of red and green Moon shots that were of no use.

On Christmas Eve of 1968, *Apollo 8* Commander Frank Borman beamed a video while describing the lunar surface as "gunmetal grey…like Plaster of Paris." Jim Lovell echoed the same sentiment: "The back side is more mountainous than the front side…someone said that it was like papier-mache. Well, right, it's all shades of gray. There is no color" (Chaikin and Kohl, 2009, p. 41).

This characterization did not survive for long, and it was dramatically different from later descriptions by the *Apollo 10* Commander Tom Stafford of brown and chocolate-brown colors in the lunar maria (Stafford et al., 1971). It was realized that the astronauts were not fully prepared for what was being observed or well trained enough to describe the colors in an accurate and useful manner.

I asked John Young and Gene Cernan (companions of Tom Stafford) about his descriptions of glorious color differences, especially the brown shades in the lunar maria. They confirmed these color variations, but both said that the differences were not as stark as in the color video they reviewed after the mission. It became clear that good characterization of lunar surfaces color was of importance, particularly because photographic films did not record the colors as described by the astronauts. However, *Apollo 10* did an admirable job on orbital photography, as exemplified by the low-illumination views of the approach to the *Apollo 11* landing site that clearly depicted the gently undulating mare surface (Fig. 3).

The one knowledgeable astronaut in discussing color was Al Bean, who was preparing for assignment on *Apollo 12*. He told me about the Munsell Color System, and I began to seek information on color and its sensing. I proposed to prepare a color sheet with various shades of grays and browns for the astronauts to take on the lunar journeys to compare with the observed surface colors. However, it was vetoed based on "weight limitations." A color wheel was later designed for the *Apollo-Soyuz* Test Project (ASTP) of 1975, and the astronauts were able to use it to relay the colors of desert surfaces using one side and seawater and ocean currents using the other side (El-Baz, 1977). As stated later herein, such a device would be essential for visual observations on a mission to Mars for two reasons: (1) It has been established that surface features of Mars are analogous to those of Earth's hyperarid deserts, such as in southwestern Egypt (El-Baz and Maxwell, 1982), and (2) the surface of Mars, just like that of Earth deserts, displays great variations in color that are indicative of the chemical composition of the exposed particulate materials.

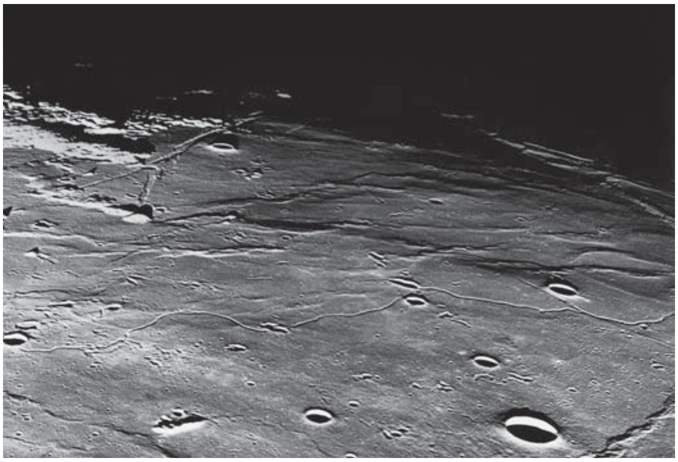

Figure 3. Details of the surface of Mare Tranquillitatis along the approach to the *Apollo 11* landing site, as photographed by *Apollo 10* under low-illumination conditions.

When preparations for *Apollo 11* began, I was promoted to Supervisor of Lunar Science Planning at Bellcomm and had more responsibility in mission planning, in addition to overseeing the work of six Ph.D. scientists and engineers. Rocco A. Petrone, the intrepid *Apollo* Program Director, called me in and gave me the lesson of a lifetime. When he became Launch Operations Director at Cape Canaveral, Florida (later named the John F. Kennedy Space Center [KSC]), Jim Webb grouped new managers to convey to them NASA's philosophy. He explained to them that a manager's responsibility was to motivate individuals under his supervision as follows: "If you get from each one who works for you all that he thinks he is capable of doing, we will surely fail. But, if you are able to get from all of your employees more than what they think they are capable of doing, then we will succeed and will make it to the Moon." Clearly, this philosophy, which characterized the early years of NASA, was behind the unusual "can-do" attitude that resulted in the incomparable success of the *Apollo* program.

Astronaut training in lunar geology began through an agreement between NASA and the USGS. Dale Jackson, a former marine and experienced USGS geologist, led the activity, which was based in Ellington Air Force Base near the site that was chosen for the JSC. At the outset, the "geology" training was not universally accepted by the astronauts. In time, it was deemed necessary for the astronauts to attend 100 h of classroom lectures and 10 field trips (Beattie, 2001). Most astronauts bemoaned the lectures but enjoyed the geologic excursions. These were planned in places where they might encounter analogs of lunar features, such as the Hawaii volcanoes or the Meteor Crater impact site in Arizona. This training, while adequate for the astronauts who would land on the Moon, did not take into account features and perspectives that would be encountered in the bird's-eye view from lunar orbit. Thus, there was a need to add such a component to astronaut training for the *Apollo* astronauts, particularly those who would circle the Moon for several days.

PROGRAM INITIATION

Astronaut training for visual observations and photography had to be done within the structure and procedures of Mapping Sciences at JSC. When it came time to train the *Apollo 11* crew, it was clear that the CMP of the mission, Mike Collins, would spend more time in his capsule orbiting the Moon and could do more than was possible on *Apollo 8* and *10* missions. As planning at Mapping Sciences continued, its chief, James H. (Jim) Sasser, wrote a letter requesting my participation in briefing the astronauts on photographic targets of opportunity. My bosses obtained NASA headquarters approval of this "formal" breaking of the Bellcomm rules.

Jim Sasser named the team that would participate in briefing the *Apollo 11* crew members. In addition to himself, it included Lewis (Lew) Wade (manager), Michael C. (Mike) McEwen (geologist), Richard (Dick) Underwood (photo-analyst), and me. As we followed the spacecraft tracks around the Moon, the rest of the team would describe the colors on the map sheets with the orbital tracks and their numbers, and I would explain the scientific objective of each target. My explanations would be met with silent approval, or just "Oh yeah!" Mike Collins, the CMP, both smart and sharp, kept these sessions on the lighter side by saying "Don't you guys have enough pictures?" or "I will do all you ask if you tell me what you're gonna do with those photos."

On *Apollo 11*, we were seriously constrained by the time allocated to scientific training in general. NASA engineers repeatedly reminded us that the objective was: "To land a man on the Moon and bring him safely to the Earth." They would underline the point by adding that the mandate did not include: "And bring back some photos or rocks!" However, we knew that after *Apollo 11*, the field would be wide open for science to become the central objective of lunar missions.

One of the great lessons of the *Apollo* program was the importance of formal "backups." Every crew member had an assigned backup, and for each procedure there was a backup plan. If something did not work as expected, the backup procedure was instantly implemented; in the most critical cases, there was a backup to the backup plan. This was dramatically illustrated during the *Apollo 11* landing. The selected site was the least cratered spot in the assigned area. An ellipse several kilometers in length was denoted as free of rough craters, particularly near its center. We were certain that the trajectory would lead the spacecraft to that flat, smooth spot. However, as the LEM descended, the view from its window was nothing of the sort. Neil Armstrong realized that the trajectory would lead to a dangerously rough crater with a boulder field. His backup procedure was to take the controls and manually fly the craft downtrack to land on a smooth site. As the whole world learned, by the time he landed, there were only few seconds remaining before the spacecraft would run out of fuel and crash!

Based on this experience, the *Apollo 12* objective was stressed as "pinpoint" landing. Its landing site was selected close to that of a previously landed *Surveyor* spacecraft, the location of which was visually confirmed by the seasoned astronomer Ewen Whitaker using a small hand lens while he examined a *Lunar Orbiter* image. (Based on a recommendation by NASA, Whitaker received a letter of thanks for a job well done from President Richard M. Nixon.) One of *Apollo 12*'s tasks became to return the camera lens of that *Surveyor* spacecraft to study the environmental effects of solar ray bombardment under lunar conditions over a 2 yr period. The successful "pinpoint" landing assured confidence in the ability to land on a prescribed spot within rougher terrain on later missions.

Emphasis on the precise landing objective did not inhibit inclusion of a whole new batch of photographic equipment on *Apollo 12*. I was able to brief the full crew on occasion and spend more time with Dick Gordon, the CMP. He was very receptive and complied with the added requirements (including a four-Hasselblad multispectral camera array) in high spirit. He clearly understood that visual observations could add to our knowledge, but he did not have enough of a background to do justice to the job. Instead, he enjoyed making fun of my "desert origins" and "camel-riding" expertise. However, he was briefed as much as his schedule allowed, which was many more sessions than for earlier CMPs. This was certainly progress, but it was too slow to make a real difference.

It was obvious that continuing to delineate the traces of orbital tracks on the lunar surface and select so-called targets of opportunity on either side of the spacecraft would limit any initiative by the astronauts. They would simply follow the procedures just as they punched numbers based on the flight plan. They would teach us nothing new. To counteract the passivity of established procedures, I decided to find a way to teach the astronauts what we knew and allow them to make their own additions. However, that would require many hours of training, above and beyond the time their schedules allowed or the time they were willing to devote to such tasks.

In discussing with Mike McEwen of Mapping Sciences options for the prospective *Apollo 13* crew, he relayed that most astronauts were fed-up with geologic training, which included definitions of many rock types and their chemical composition. It was commonly said that an astronaut at that time, "would not touch a geologist with a ten-foot pole" and some often said, "when you've seen a rock you've seen them all." When I convinced Mike that mine was a completely different approach, he promised to contact Ken Mattingly, the CMP of *Apollo 13*, on my behalf. He came back with an appointment for me to meet with Ken who had not minced words, and said that none of it would work out: "I have no desire to learn about the Moon…

I will grant you an hour, but I can assure you, it will be a waste of time for the both of us." He consented to a briefing for 1 h before dinner on a specific date at Cape Canaveral (the Crew Quarters at KSC). That appointment would either be a boom or bust!

I prepared a mosaic of *Lunar Orbiter IV* images (20 × 24 inch prints), which completely covered the ground track of the *Apollo 13* mission on the lunar nearside, and marked on it the first revolutions in distinct colors. The mosaic was taped along the wall of the astronauts' dining room—the only room that was large enough to accommodate it. Ken Mattingly showed up exactly on time and again declared that he did not think that much could come out of the futile exercise. I informed him that the objective was to allow him to identify the landmarks through the sextant (telescope with crosshairs, with which all pilots were familiar) to better delineate the spacecraft orbital position in real time. A larger number of accurate landmark sightings would provide better knowledge of the spacecraft position for ground controllers, which in turn would allow more precise engine firings, which in turn would result in a more accurate landing. The astronauts, particularly the CMPs, aspired, competed, and publicly bragged about achieving this accuracy.

During that hour, not a word was uttered about geological formations or rock types. The theme was how to do his job better by familiarity with the shapes of the features below, particularly ahead of a given landmark. Ken would look at a pair of craters ahead (east) of a landmark and say it looked like a doublet, and I would place the designation "doublet" right on the map. Fifty minutes later, he felt quite familiar with all the landmarks along the spacecraft's first ground tracks. So we stopped looking at the images, and he went through the landmarks one by one, describing the terrain along their approach. He delighted in using his own designations of lunar crater patterns. By achieving a new familiarity with the setting of landmarks, Ken Mattingly's first smile betrayed his feeling of a momentous accomplishment. At the end of the session, his only comment was: "Well, when can you come back?"

Another session was set up for the following week, and he invited me to dine with the whole crew: three prime crew members, three backup astronauts, and the Mission Scientist, Anthony W. (Tony) England. From that time forward, we had dinner first and the briefing session followed. That practice continued throughout the rest of the program. During each session, a new feature was added to the store of knowledge gained from the previous one. Because the whole crew began to participate, I added detailed views of the lunar surface. I was elected Secretary of the Lunar Landing Site Selection Committee of NASA's Group for Lunar Exploration Planning (GLEP) and brought to the crew the news that a landing site in the Fra Mauro Formation had been approved for their mission. It would be the first lunar landing in the relatively rugged lunar highlands (Fig. 4).

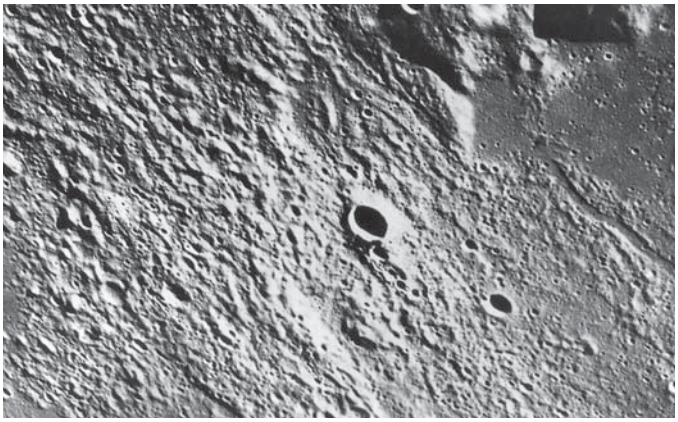

Figure 4. *Apollo 12* low-illumination photograph of the Fra Mauro Formation that emphasized the ruggedness of the *Apollo 14* landing site area. The prominent crater near the center (340 m across) was named "Cone" by James A. (Jim) Lovell Jr., commander of *Apollo 13* mission, during training for geological visual observations and photography.

Apollo 13 Commander Jim Lovell was fascinated by the detailed views and asked many thoughtful questions. He was the only *Apollo* astronaut who related to me his experience in Earth photography during the *Gemini* program. He pointed to the distinguished crater associated with the ejecta that was an objective of landing for *Apollo 13* (and later on, *Apollo 14*), and said, "It looks like a cone" (see Fig. 4). Following my practice with Ken, I marked it "Cone Crater," and thus began the naming of significant features within the lunar landing sites by the crews of each mission.

It is instructive to digress here to discuss the naming of small-scale features. During the later *Apollo* missions, this practice proliferated, and the informal lunar feature names began to appear in mission reports and then in the international professional literature. At the end of *Apollo 17*, NASA asked me to take the case to the International Astronomical Union (IAU), the scientific body that approved feature names on extraterrestrial bodies (El-Baz, 1979a). We had learned that the IAU approval was essential for adoption by the U.S. Board of Geographic Names prior to placing the names on official U.S. government maps. I pleaded the case during the IAU meeting of 1973 in Sydney, Australia. It took 11 d of campaigning to gain the approval of most of the "astronaut-given" names in the *Apollo* landing sites. Naming procedures in the future should take established IAU rules into account to limit potential problems.

Visual observation and photography briefing sessions for Ken Mattingly (*Apollo 13*) were continued in a conference room at Building 4 at JSC in Houston, during which Mike McEwen often joined me. The word spread, and when it reached the Director of Space and Life Sciences at JSC, it was ruled out as an "additional, time-consuming activity." By Ken's own request, Mike and I then began to conduct the briefings during evening hours, on the crew's personal time, at JSC's Building 17 (Mapping Sciences).

Emphasis remained on the ability of the Command Module Pilot to observe, describe, and photograph above and beyond what was already known. One approach I tried with Ken Mattingly became a real hit with all crews on later missions; it became known as "flyover exercises." The astronauts often flew T-38 jets solo between the various NASA centers, mostly between Houston and Cape Canaveral for launch operations, and

Houston to Los Angeles for spacecraft assembly. The day before such a flight, I would go to Houston armed with a Flyover Book, which would be made in exactly the same way as aircraft flight plans for pilots—pages that flip like a stenographer notebook with a hard (metallic) backing. In addition to aeronautical charts, pages contained pictures, maps, and questions about interesting features or geologic provinces along the flight path (Fig. 5).

For these flyovers, we tried as much as possible to modify the routes so as to pass over as many "Moon-like features" as possible, such as craters, ridges, faults, and the like. (In a way, that exercise was our first experience with "comparative planetology," using photographs of comparable surface features on different planetary bodies. This developed more significantly through comparisons of surface features on Mars to those in the eastern Sahara of North Africa, particularly in southwest Egypt; see, for example, El-Baz and Maxwell, 1982.)

Ken Mattingly swiftly acquired much knowledge of the lunar segment to be overflown during *Apollo 13*. The rest of the

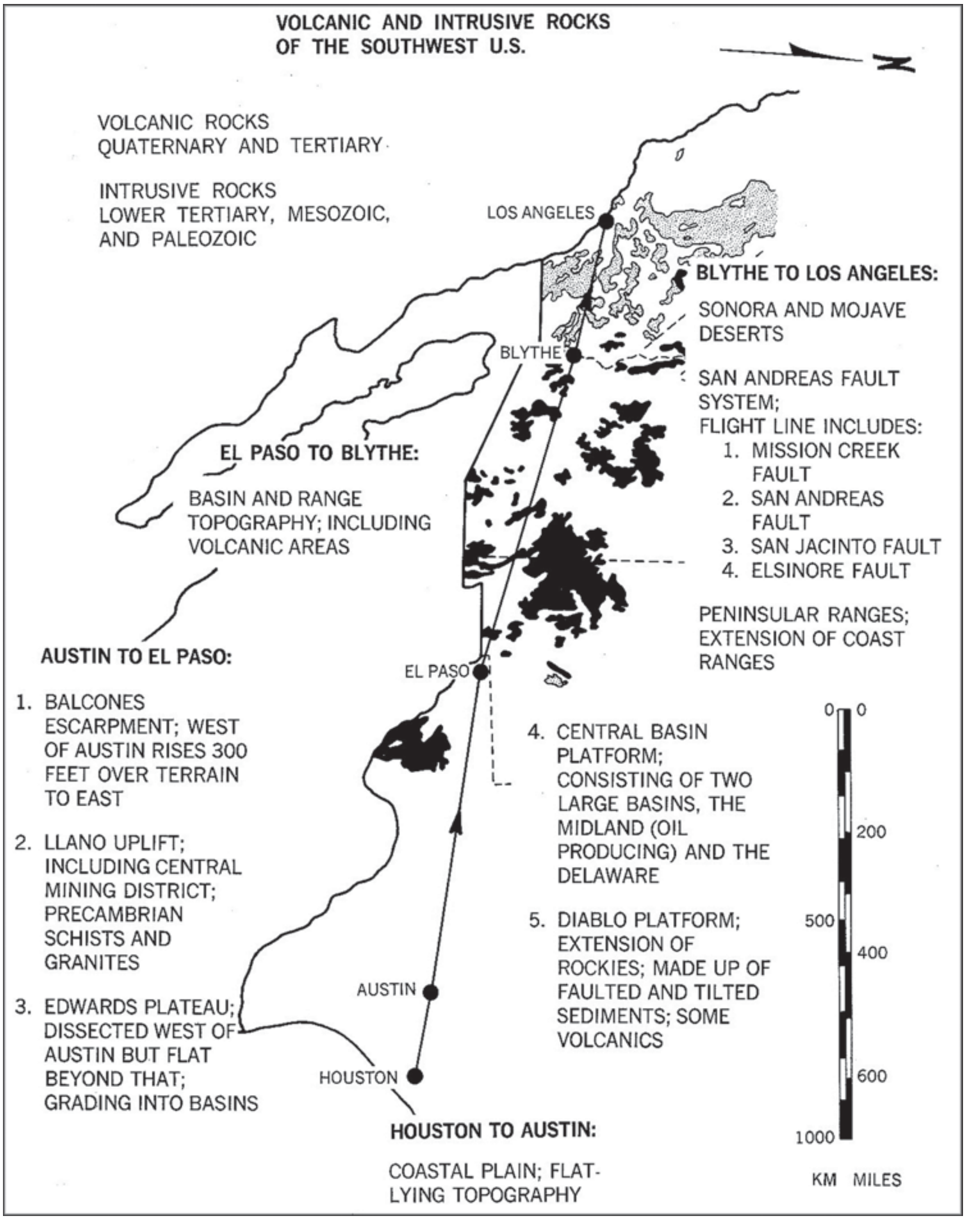

Figure 5. Example of a page from a "flyover exercise" book that was designed by the author for training flights conducted by the astronauts. Specific targets were listed along the path of an aircraft flight from Houston (bottom) to Los Angeles (top). In this example, regional volcanic and intrusive rocks are marked, leaving room for interpretations by the pilots. Pages that followed included a number of questions related to specified observation sites along the flight path (after El-Baz, 1977, p. 227).

crew were infected by his enthusiasm and began to speak with confidence about lunar features and their probable origin. The word spread throughout astronaut circles with a very positive effect. One day, as I entered Building 4 at JSC, where the astronaut offices occupied its second floor, an upright, redheaded man with a military demeanor was going out. He stopped me at the glass door and shouted with a distinct drawl: "Hey, are you Farak El Baez?" I was not about to correct his pronunciation and said: "Yes." He continued: "I am Stu Roosa…I will be the CMP on *Apollo 14*, and I want you to make me as smart as Ken." He hesitated for a few seconds and added: "Hell no, I want you to make me smarter than Ken!"

To me, this was the first sign that the competitive spirit of the *Apollo* astronauts had begun to shift from mastering the maneuvering and precise docking and undocking of the spacecraft to the scientific knowledge of the Moon. Eureka!

As it turned out, Ken Mattingly was exposed to measles, and John L. (Jack) Swigert, the backup CMP, had to replace him. Then, an oxygen tank exploded in the body of the *Apollo 13* Service Module, and the whole spacecraft stack was to swing around the Moon only once and swiftly return to the Earth using the only functioning engine, that of the LEM (Kranz, 2000). Not many observations could be accomplished under such dramatic emergency conditions.

Rocco Petrone signaled me at the Mission Operations Control Center. He suggested starting to plan taking photographs of the Service Module upon its separation from the Command Module just prior to re-entry into Earth's atmosphere. He had instantly foreseen the need for detailed pictures of the results of the explosion that crippled the Service Module. He also realized that the flight engineers would be exceptionally busy with procedures to bring the astronauts home, and that I was responsible for training the crew in photography.

Jack Swigert was the least trained of all the CMPs; a typical "seat-of-the-pants-pilot," he would require very clear, simple instructions to do the job right. That required my spending the next 30 h nonstop to produce a photography plan. Once in a while, I called upon Robert (Bob) Peppin, a young but experienced JSC flight planner, to make certain of my assumptions and check and recheck the math. The calculations entailed the spacecraft velocity, the rotation rate, the separation speed, the azimuth of the Sun, the window views, the lens coverage, and the film and camera speeds. Ready to issue instructions were relayed to Swigert near the end of the home trajectory. Although his hand was not perfectly steady, the pictures captured details of the affected top side of the Service Module that could not have otherwise been known. One whole side of the Service Module had been blown off by the explosion of the oxygen tank. Since then, flight planners began to place more value on photography and become a bit kinder to our requests for flight plan time.

Apollo 14's CMP Stu Roosa began to train regularly (Fig. 6) and used "flyovers" to master the scientific language. He established that at 25,000 ft above the Earth, the T-38 would mimic the speed of the *Apollo* spacecraft relative to the lunar surface. He sneaked me once into the backseat of a two-seater jet to simulate that speed. Thus, we figured that to capture an object in a stereo pair, an astronaut would click to take a picture and then utter (as Bob Peppin suggested): one potato, two potato, three potato, and click to take the next. The two photographs from the spacecraft altitude of the same lunar surface feature separated by 3 s produced a perfect stereo pair for three-dimensional viewing.

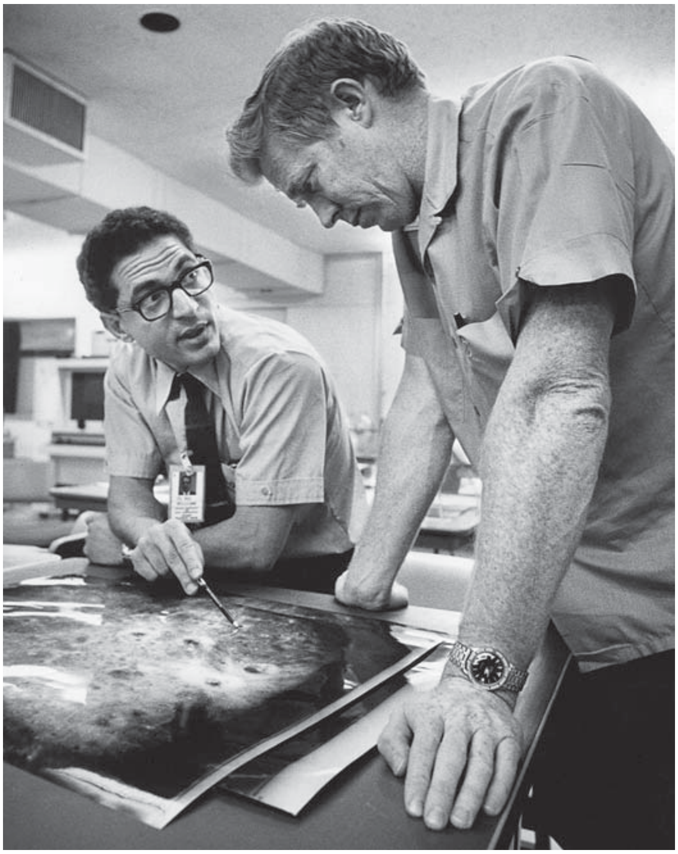

Figure 6. *Apollo 14* Command Module Pilot, Stuart A. (Stu) Roosa, right, as he examined enlargements of photographs obtained by *Apollo 12* during training for his mission's visual observations and photography tasks.

Apollo 14 was to carry a metric camera to acquire high-resolution images of potential landing sites in the lunar highlands for later missions, particularly *Apollo 16*. As CMP, Stu Roosa was the one to handle that "Hycon" camera." The selection of its photographic sites was mine to handle, as assigned by the Apollo Photographic Team (APT), which was headed by Frederick J. (Fred) Doyle of the USGS. When the *Washington Post* asked NASA headquarters for details on the objective of the Hycon mapping camera, the question was relayed to me as the expert. However, as a Bellcomm employee, I was not allowed to speak to the press. Pressured by the newspaper, NASA made the request in writing to relieve me of that restriction. The printed piece was well written and showed NASA at the forefront of science and technology; the case opened the gates for Bellcomm employees to freely speak to the press with the approval of NASA.

It turned out that the Hycon camera was a dud and malfunctioned shortly after it was turned on during the flight (El-Baz and Head, 1971). Stu Roosa spent hours and much energy trying to fix the camera to no avail. However, he made up for the losses by handheld photography and very useful visual observations (El-Baz and Roosa, 1972a, 1972b). At the end of the mission, he and I wrote a paper that he presented at the Geological Society of America (GSA) Annual Meeting (Roosa and El-Baz, 1971). This started a tradition where, from that time forward, each crew made contributions to the GSA meetings based on professional knowledge that amazed the convening geologists.

SCIENCE TAKES THE LEAD

Apollo 11 landed safely and returned the first lunar rock and soil samples; *Apollo 12* achieved a "pinpoint" landing; *Apollo 13* was saved in spite of an onboard explosion; and *Apollo 14* managed to land in the relatively rugged highland terrain. All technical flying procedures were well accomplished. From that time onward, scientific objectives of the missions occupied the driver's seat. Even NASA engineers and flight planners began to speak the language of lunar science. For the first time, I was invited to address the NASA Management Council, which included the administrator and all directors of the various NASA centers; the title of the address was the "Geology of the Moon."

Preparations were under way for the upgraded "J missions" (El-Baz, 1975), which included a whole new set of equipment and experiments that were proposed by scientific principal investigators (PIs). The additions included: (1) a lunar roving vehicle, which would allow the surface crew to travel up to 7 km away from the landing point. This "rover" was equipped with a color movie camera, and to relieve the astronauts from the burden of its operation, the camera was controlled by "captain video" at the Mission Operations Control Center. (2) There was also an instrument package in the orbiting CSM for geochemical sensing of chemical compositions by X-ray (Isidore "Izi" Adler, PI) and a gamma-ray sensor (James "Jim" Arnold, PI), a laser altimeter (William M. "Bill" Kaula, PI), and a lunar sounder (Stanley "Stan" Ward and James "Jim" Phillips, PIs) for elevation mapping. (3) Two highly advanced cameras were included, metric (for topographic mapping) and panoramic (for high-resolution imaging), which were handled by the *Apollo* Photographic Team. Harold (Hal) Masursky of the USGS and I handled mission operations of these cameras on behalf of the team (Masursky et al., 1978).

To assure the proper acquisition of data, these PIs played a significant role in planning mission operations. Naturally, the orbital mission planning had to take into consideration the competing spacecraft-attitude requirements of all the sensors in the Scientific Instrument Module (SIM) Bay. For example, the geochemical sensors required a spacecraft attitude that was different from that necessitated by the cameras. Floyd (Rob) Roberson of NASA headquarters and Nathaniel (Nat) Hardee of JSC helped in implementing the requirements of the various sensors into the flight plan. Due to such additions, all the sensors required more CMP training. Furthermore, on these missions, the crews were scheduled to spend up to 6 d on and around the Moon. Thus, these J missions were to be long explorations that required many hours of science training.

The orbital observations and photography tasks were elevated from being ad hoc demands by the crews to an experiment with its own mission objectives, and they appeared on the crew-training schedules. I was named principal investigator of the Orbital Visual Observations and Photography Experiment on the last three *Apollo* missions, *Apollo 15–17*. Training sessions became regular events and were favored by the crews because they appreciated learning new things at which they could publicly compete.

The exposure of Ken Mattingly to measles right before *Apollo 13* added a quarantine period before each mission, as a precaution. On earlier missions, the returning astronauts were quarantined to make sure they did not carry "space bugs" to Earth. On later missions, the crews had to be quarantined for 2 wk prior to the missions. Thus, last-minute training during that time had to be done at the Crew Quarters at KSC from behind a glass wall (Fig. 7).

At the Mission Operations Control Center, science no longer had a back seat. Surface geology operations were supported by a large crowd in a back room. Traverses by the rover and rock sampling were followed by a geology team from the USGS headed by Leon T. (Lee) Silver on *Apollo 15*, William R. (Bill) Muehlberger on *Apollo 16*, and Gordon (Gordie) Swann on *Apollo 17*. I was also elevated from nomadic existence to a specific console position. The identifying call for incoming and outgoing communications with the flight plan engineers, the Flight Director (Flight), or the astronaut Capsule Communicator (Capcom) was dubbed "Visobs."

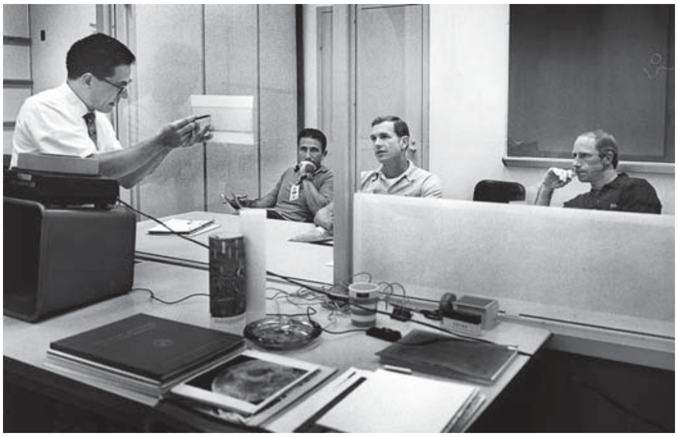

Figure 7. For 2 wk prior to their mission, the *Apollo 14–17* astronauts were quarantined in the Crew Quarters at the John F. Kennedy Space Center (KSC). As seen in this view, last-minute training was conducted from behind a glass wall to eliminate the possibility of transmitting infectious disease. Slide-projection facilities were rigged in the briefer side of the room to review lunar images under the mission's ground tracks. Seated are the *Apollo 15* prime crew members, from the left, James B. (Jim) Irwin, David R. (Dave) Scott, and Alfred M. (Al) Worden.

Al Worden was assigned to be the CMP on *Apollo 15*. His free spirit and unusual wit gave the training sessions a delightful flair. Soon his crewmates, Dave Scott and Jim Irwin, would join the sessions along with the backup crew and the astronaut Mission Scientist, physicist Joseph P. (Joe) Allen. Joe was particularly supportive of the training program and impressed on his fellow astronauts the significance of the scientific contribution of their explorations. His affable nature contributed to their trust and adherence to his suggestions. As usual, dinner preceded the briefings, which continued late into the night. Once, it was nearly midnight when Dave Scott looked at me in despair and said: "I tell you Farouk, the pay of this job is not so great, but at least the hours are long!"

Training sessions and flyover exercises for Al Worden and his backup crew member Vance D. Brand occurred on a weekly basis for nearly 18 mo. By the time the mission was ready, Worden could describe the spacecraft path on both the farside and nearside of the Moon without looking at the charts. On his second orbit around the Moon, he conveyed to Mission Control: "After the King's [my nickname] training, I feel I've been here before."

Mastering feature locations, however, was no longer a main issue; observations of scientific significance were. Worden made more than his fair share of significant descriptions from lunar orbit (El-Baz, 1971, 1972). At one of his assigned sites in the dark mantle of southeastern Mare Serenitatis, he described "a whole field of cinder cones, each with a summit pit and a dark halo" (Fig. 8). During training exercises for the mission near Flagstaff, Arizona, his crewmates walked through a field of intentionally blasted craters in a basalt flow that mimicked the lunar surface. At the same time, Worden flew overhead to scan the terrain from above. During that flyover, he became familiar with numerous cinder volcanoes in the vicinity. His descriptions of the lunar features were analogous to those explosive volcanic vents (El-Baz and Worden, 1972; El-Baz et al., 1972a, 1972b).

Everyone took notice, including the surface geology operations team in the back room, because Worden's descriptions implied young volcanic activity. We did not expect young extrusive volcanic deposits. Crisp-appearing cinder cones with a dark halo would signal volcanic activity younger than expected. Jack Schmitt, the only geologist in the astronaut corps, came out of the surface geology back room to discuss the implication of Worden's observation with me.

Jack was a backup crewmember and had played a major part in motivating the surface crew to become real geology enthusiasts, and he had recognized the value of the observation. Shortly thereafter, Rocco Petrone came to say, "Well Farouk, your student may have picked a landing site for you," which was exactly what was on my mind. The observed location of what might be relatively young volcanic cinder cones would warrant a visit on a later *Apollo* mission, *Apollo 17*.

Meanwhile the surface crew collected a treasure trove of information. Jim Irwin made his own exciting discovery of a crystalline anorthositic rock, which was later dubbed "genesis rock," perched on a pedestal-like exposure. Although the lunar rover allowed the surface crew to cover vast distances, it did not reach the rim of Hadley Rille (Fig. 9) to investigate this great incision in the mare surface. A premission proposal for a "lunar flying vehicle" to allow a crew member to sample the wall and the bottom of the rille was voted down. Thus, descriptions of the

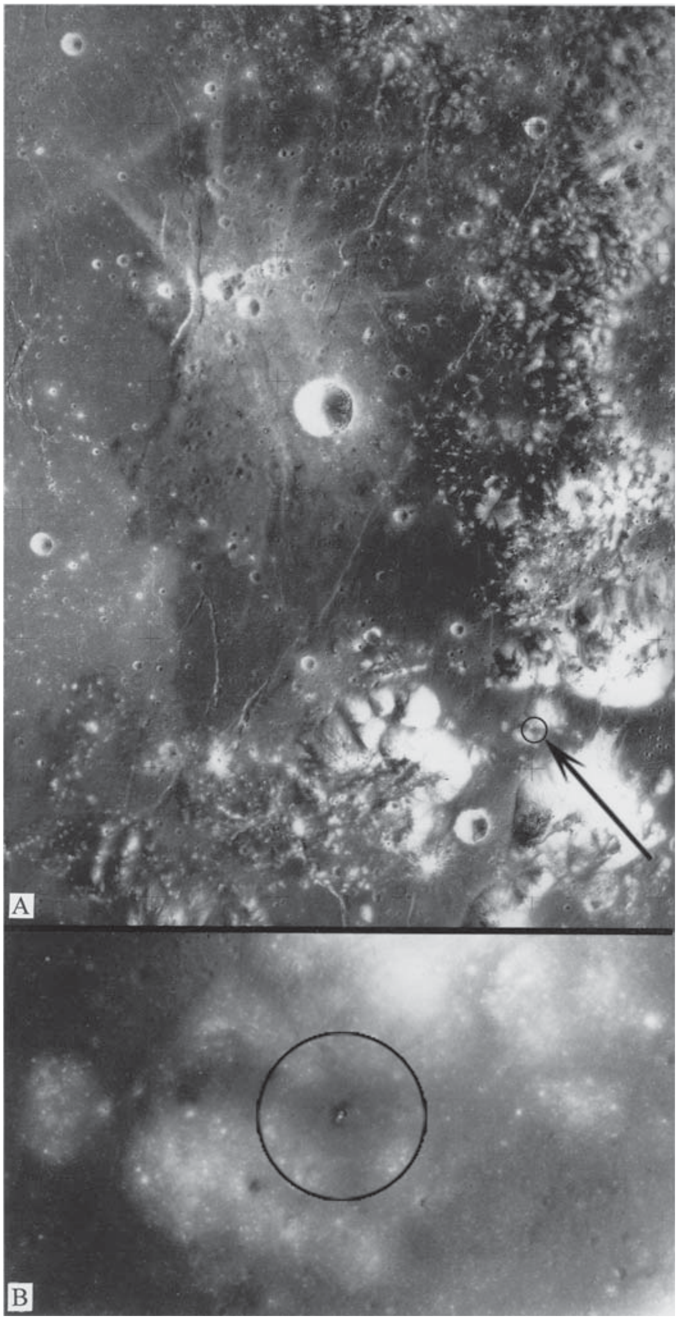

Figure 8. Enhanced photograph of the dark mantle deposits along southeastern Mare Serenitatis (darkest regions) that were described by *Apollo 15* Command Module Pilot Alfred M. (Al) Worden (A). The arrow points to the location of the cinder cone, at the center of the circle (diameter of both circles is 2.5 km), in a handheld photograph by Worden (B).

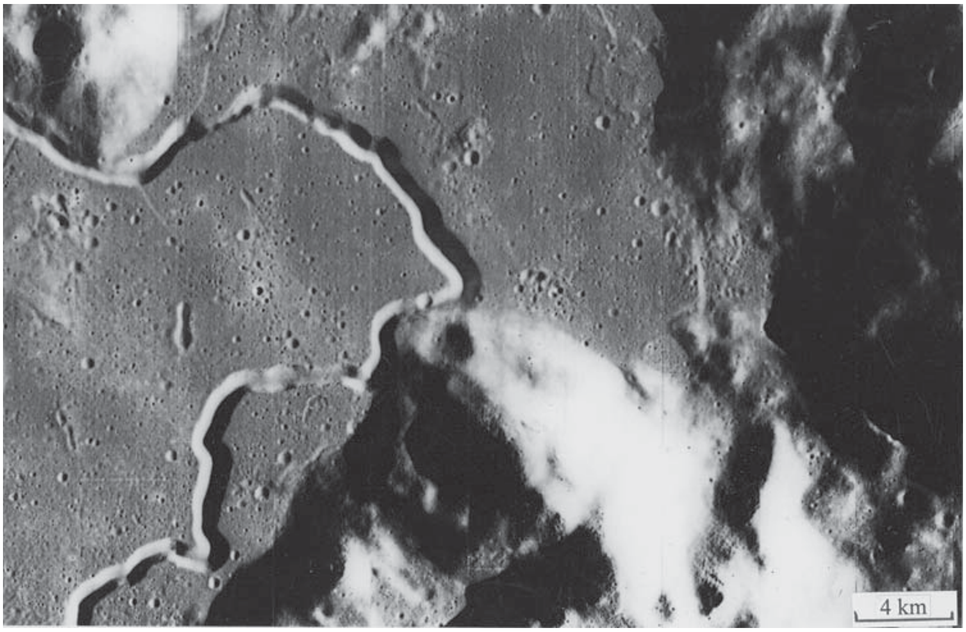

Figure 9. The Hadley Rille, just west of the *Apollo 15* landing site, near the bend of this sinuous depression that touches the base of the highlands of the Apennine Mountains.

interior of this "lava tube" had to be left to what Worden could discern from orbit (Worden and El-Baz, 1971).

Results of *Apollo 15* illustrated without a doubt that the program had reached a mature stage (El-Baz, 1972). This maturity was in large part due to the vision of Rocco Petrone and his unstinting efforts on behalf of science. Although he was an engineer, he often took evidence of "good science" to brief members of the U.S. Congress. He requested impressive photographs, studied them thoroughly, and took them along to campaign for the program budgets with "Italian" passion and great expertise. No wonder the science team of *Apollo 15* held a specific function to acknowledge and celebrate Rocco's contributions to the science returns, particularly from the J missions starting with *Apollo 15*. In many ways, that was an expression of thanks on behalf of all *Apollo* scientists.

The notion of a highly differentiated Moon that was Earth-like in the prevalence of both acidic and basic rocks within its crust was still alive then. Hal Masursky of the USGS had theorized that bulbous features such as the Marius Hills (Fig. 10) would be composed of granitic rocks. Furthermore, before the *Apollo 14* mission to the Fra Mauro site, the Cayley Formation had been interpreted as the result of terra volcanism (Wilhelms, 1971). Don Wilhelms and I picked up the basic notion and applied it to a segment of the southern lunar highlands near the crater Descartes. Most geologists were convinced of this, and the "proof" began to appear in writing (see, e.g., Head and Goetz, 1972).

Don Wilhelms used the term "grooved and furrowed" to describe the terrain in the Descartes region. To think of this terrain as a manifestation of acidic rocks was an attempt at comparative planetology. The interpretation established a clear analogy between Earth and the Moon in their geologic evolution. At the time, it was correctly theorized that Earth and the Moon were formed at the same time and from the same batch of chemical elements, albeit in different proportions (El-Baz, 1975). Because the Moon had not changed much during the past three billion years, its study would give us a window into the early history of Earth.

Figure 10. The dome-like features of Marius Hills, which were believed to represent more acidic rocks than those of the surrounding materials, were contenders for an *Apollo* surface exploration mission.

This strengthened the argument for additional lunar exploration missions, an objective that was championed by Rocco Petrone. He delighted in using "groovy highlands" in congressional and press briefings. (In the late 1960s, the descriptive term "groovy" had permeated American pop culture.)

The geological argument won in spite of the objections of most principal investigators of the orbital experiments. These objections were based on the fact that the Descartes highlands were at such a low latitude (Fig. 1) that it would limit the coverage of orbital sensors, including the metric and panoramic cameras. However, the site was certified for the mission, and the planning began. The assigned prime crew members were John Young, Ken Mattingly, and Charlie Duke.

My relationship with Ken during preparations for *Apollo 13* helped greatly in his training for *Apollo 16*. He proved his ability as a meticulous, by-the-book performer. In many ways, this was assisted by the many flights he made in a light plane that was flown by Richard A. (Dick) Laidley. The latter was a geologist-pilot at JSC who assisted me in the visual observations training on *Apollo 16* (Mattingly et al., 1973). Flying Ken in a small aircraft allowed him to describe what he saw from low altitude and voice real-time judgment as to what the observations meant.

Mattingly's observations during the mission were the first to hint that our idea of acidic rocks at the site were dead wrong. Observations by his crewmates on the surface supported his own. Exposures at the site were of the same nature as those of highland rocks encountered on *Apollo 14* and *15*. This suggested that the lunar highlands were composed of the same suite of rocks. At the Mission Operations Control Center, both Don Wilhelms and I realized right there and then that the *Apollo 16* site proved to be the only one that was selected for the wrong reason!

Meanwhile, Ken Mattingly was having a great time observing features beneath the spacecraft's ground tracks, particularly on the lunar farside. He enjoyed the loneliness that allowed him to concentrate on the meaning of what he saw without the chatter of ground controllers. After the flight, his assessment of that time was "the most exhilarating thing in the world…to be there by yourself, totally responsible for this thing. Dead quiet. And this spectacular, unreal world, nothing could be more exhilarating" (Chaikin and Kohl, 2009, p. 105).

Ken's visual observations added a great deal to our knowledge of lunar surface features. His comments were in part responsible for our recognition of the largest and oldest basin (Al-Khwarizmi; El-Baz, 1973a), which was later named South Pole–Aitken (Wilhelms and El-Baz, 1977), on the farside of the Moon. Ken was particularly astute in describing details of features under low-light conditions (Fig. 11). He described the appearance of the lunar surface at or near the terminator. Under such illumination conditions, photographic films tended to oversaturate the image. He was also proficient in visual observations under Earth-shine, where the Moon's surface was lit only by reflected light from Earth.

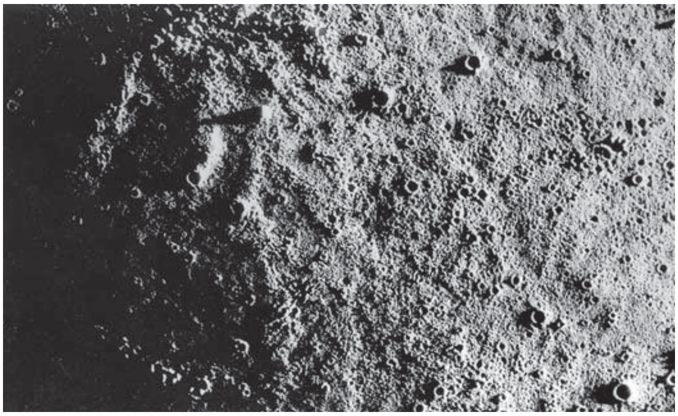

Figure 11. Low-illumination conditions emphasized variations in the lunar surface topography and depicted minute craters (smallest circular craters are 10 m across), as in this photograph close to the lunar terminator.

A case in point was when the *Apollo 16* spacecraft approached the west limb of the Moon—Ken Mattingly was most impressed by the first sight of surface features from the faint light that was reflected by Earth. He later stated: "I will never forget the view of the Orientale [Basin] in Earth-shine as we approached the Moon. I was sure that we had captured 'the picture of the year,' yet, in spite of the long exposure times, the exposed film was black. Maybe someone can pull out these images to investigate them with today's new techniques" (personal commun., 2010). This case illustrated that, in the *Apollo* era, the eye clearly saw more than what we captured on film.

Ken made significant observations of some of the peculiar features on the lunar surface; e.g., the 400 km spread of light-colored swirls near the east limb of the Moon (El-Baz, 1973b). These were reminiscent of Reiner Gamma, a feature that remains enigmatic, as explained by Hood and Williams (1988). However, these markings are more sinuous and somewhat irregular, particularly in Mare Marginis on the lunar east side (Fig. 12). Some possible causes have been proposed, including

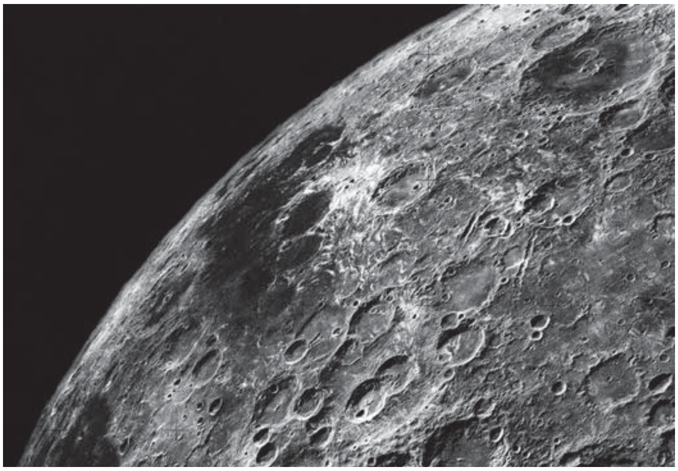

Figure 12. The light-colored swirls of unknown origin in the Mare Marginis region on the east limb of the Moon. The photograph was taken by Command Module Pilot Thomas K. (Ken) Mattingly upon the spacecraft's departure from lunar orbit during the *Apollo 16* mission.

the result of disturbances antipodal to large impacts, such as the one that caused the Orientale Basin on the west limb of the Moon. However, the probable origins of these features remain a matter of controversy.

His attention to detail during the training periods allowed Ken to understand and describe observations from orbit (Mattingly and El-Baz, 1973a, 1973b). For example, regarding the angle of repose of talus slopes, he recalled: "I remember when you showed me a picture of vertical outcroppings that appeared to have quite dissimilar heights above the mare surface, but with talus piles that seemed to be of uniform dimensions. You knew the answer, but it wasn't until I looked out and saw that condition in the context of a vast mare surface, that I recognized the 'bathtub ring' effect."

Similarly, because he was disappointed at the apparent monotony of features on the farside of the Moon compared to those on the nearside, he concentrated on unique features. At one point, he observed the only exposure of probable igneous intrusions (El-Baz, 1970) in the lunar highlands: "I was excited by seeing what appeared to be a unique dark splotch halfway down the inside of the crater. In this case, the low inclination of the orbit paid off, because I could ponder what I had seen and think about what I should look for on the next revolution to put the observation into better context."

During his mission, Ken relied a great deal on Hank Hartsfield, the Capcom, who was dedicated to communicate with the CMP in real time. While the CSM orbited the nearside of the Moon, Hank followed the flight plan to alert Ken to upcoming items that required his attention. This allowed Ken to spend more time observing, unlike when he orbited the farside of the Moon. In this way, relieving the lone observer from housekeeping tasks would pay off handsomely.

From the outset, we assumed that *Apollo* was planned up to mission 20. However, when NASA decided to pursue the *Apollo* Applications Program (AAP) in Earth orbit (i.e., *Skylab*), *Apollo 17* became the last mission to the Moon. Competition between proponents of potential landing sites reached its highest pitch. Hal Masursky continued to campaign for Marius Hills. Other members of the USGS campaigned for the rim of Tycho, the largest, deepest, and relatively young crater in the southern highlands; a *Surveyor* spacecraft had safely landed on its ejecta. Tycho would have given us a great swath of the southern highlands to observe and photograph. However, it was voted down by James McDivitt, *Gemini* astronaut who became director of the *Apollo* Spacecraft Program Office at JSC. He exploded, "You will go to Tycho over my dead body," because of the total lack of topographic elevation data, high-resolution photographs, or visual observations of the approach to the site.

Others invoked a landing on the lunar farside, specifically on the mare floor of the Tsiolkovsky Basin (Fig. 13). Al Worden had described it on *Apollo 15* in glowing terms. He emphasized the unique appearance of its mare floor and underlined the fact that its prominent central peak would represent a sample of the deep lunar crust (see Guest and Murray, 1969). This proposition was supported by Jack Schmitt. (Jack knew then that we were all campaigning for him to replace Joseph [Joe] Engle, of the already announced *Apollo 17* crew, on the basis that he was the only geologist astronaut.) Furthermore, Ken Mattingly had proposed a set of communications satellites to allow the Mission Operations Control Center to communicate with the surface crew when they were hidden from view on the farside of the Moon.

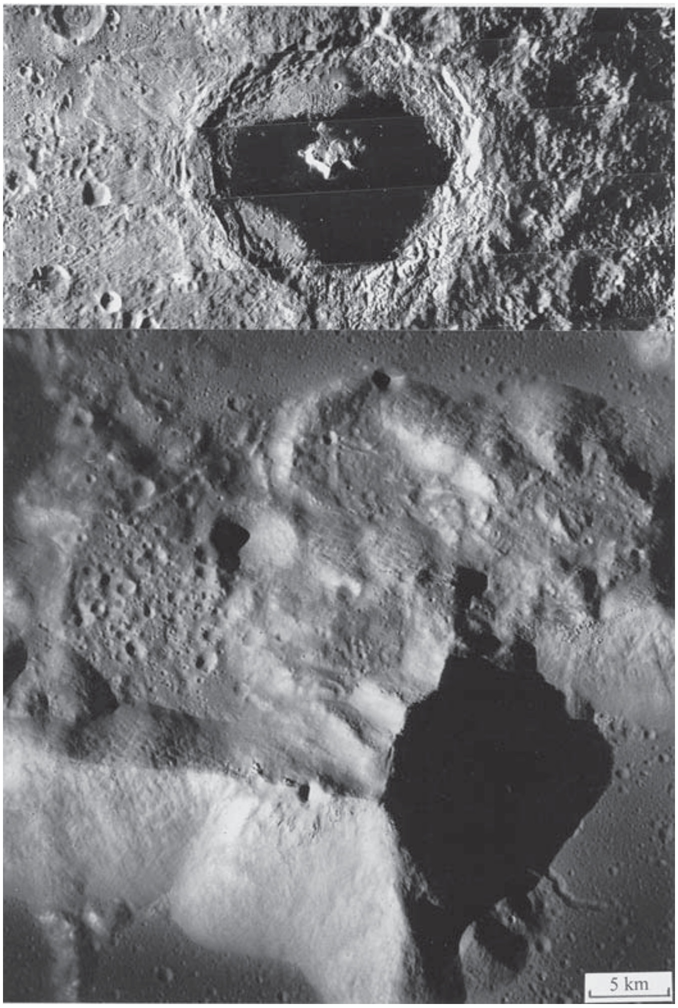

Figure 13. (Top) The Tsiolkovsky Basin (185 km in diameter) on the lunar farside as depicted in a *Lunar Orbiter III* photograph (see Kosofsky and El-Baz, 1970, p. 30). (Bottom) Handheld-camera photograph by Alfred M. (Al) Worden, which documents the sharpness of the basin's central peak. If plans develop for future landings on the Moon, this basin would undoubtedly be among those proposed for exploration to obtain samples of the farside mare deposits in its floor and of the deep lunar crust exposed in its central peak.

In the final analysis, the observations by Al Worden of cinder cones in the Taurus Littrow region helped to win the site's certification for the *Apollo 17* mission. Approach engineers at JSC objected to the "box-canyon"–like setting of the site. This characterization was previously invoked for the *Apollo 15* site (Fig. 9), but Rocco Petrone similarly insisted that the science objectives must be the first consideration and that engineering would have to find a way to achieve a safe landing, as was done on *Apollo 15*.

Competition in geologic knowledge continued throughout the training period of *Apollo 17*. Commander Gene Cernan was not about to allow any "rock doctor" like Jack Schmitt, the mission's LMP, to outperform him. Cernan was so taken by the surface exploration that he attempted, to no avail, to cut short planned sleep cycles during the mission (Cernan and Davis, 1999). He would later say: "You're on the surface of the Moon, and it is time to rest or go to sleep, which is the biggest waste of time in the world—who wants to go to the Moon to sleep?" (Chaikin and Kohl, 2009, cover). Ron Evans, the CMP, was just as competitive in his own quiet, but determined way. He developed a keen interest in the implications of many tiny features, and that became a very useful capability during his mission (Evans and El-Baz, 1973).

The training of Ron Evans in visual observations and photography benefited greatly from the imagery by the mapping and panoramic cameras on earlier J missions. This was particularly the case of photographs by *Apollo 15*; the similarity of its latitude to that of *Apollo 17* (Fig. 1) meant that it covered much of the same terrain, albeit under differing Sun angles. For his training, we were able to utilize a comparatively advanced light table that projected a strip of film transparencies on a screen that looked much like a television monitor (Fig. 14). This also allowed the images to be enlarged or the film to be rolled back and forth. In 1971, this was the pinnacle of high technology; no one had heard of digital imaging yet.

Figure 14. *Apollo 17*'s Command Module Pilot Ronald E. (Ron) Evans (right) greatly benefited from photographic strips by the mapping and panoramic cameras that were obtained on *Apollo 15*; the two missions covered much of the same regions of the lunar surface (see Fig. 1). For the purpose of visual observations training, the film transparencies of *Apollo 15* were projected onto a screen in one of the dark rooms in the Photographic Laboratory at the Lyndon B. Johnson Space Center (JSC), Houston, Texas.

At the landing site of the *Apollo 17* mission, Jack Schmitt had electrified the Mission Operations Control Center by locating and describing an exposure of orange-colored soil along the rim of crater "Shorty" (Schmitt, 1974; Lucchitta and Schmitt, 1974). He even went on to hint that the color might be the result of hydrothermal activity, i.e., relatively recent volcanic venting. This might have been tinted by Al Worden's description of cinder cones in the general locality (Fig. 8). Thus, the place was abuzz by the possibility of lunar fumaroles that signaled young volcanic activity. Without reservations, many of us made declarations to the press of encountering young volcanism on the Moon. Why not? The tell-tale observation was made by an experienced geologist!

I immediately communicated the discovery to Ron Evans and asked him to first focus on the rim of crater Shorty to ensure that he could discern the spot of "orange soil," and second, to see if he could identify similar occurrences along the spacecraft tracks. Sure enough, he was able to locate the color in the landing site, and then in numerous dark halo craters across Mare Serenitatis, some 700 km away (El-Baz and Evans, 1973). Either the perceived young lunar volcanism was widespread along the edges of the lunar basins, or the orange color was just a common hue in the ejecta of small craters near the periphery of large basins. The latter turned out to be the case, and the color was due to zircon-rich glassy beads in the ejecta blanket of the small impact crater (El-Baz, 1973c). This observation clearly exemplified the utility of orbital views in placing detailed surface features within a regional lunar context.

In the aftermath of the *Apollo* program, the methodologies applied to training CMPs for lunar visual observations and photography were applied to the crews of the *Skylab* missions. Al Bean of mission *Apollo 12* was responsible for the *Skylab* astronaut-training program. He was able to apply some of the *Apollo*-tested methods and called upon many of us to brief the *Skylab* crews on lessons learned and expected contributions. *Skylab* had the luxury of the length of the missions to acquire many useful observations and repeat photographs of the same area. This allowed documentation of such events as environmental hazards or flash floods and oil spills as well as the detection of changes to urban areas or agricultural regions over time.

Furthermore, the *Apollo-Soyuz* Test Project (ASTP), an Earth-orbital mission in July 1975, elevated observations and photography as an experiment, for which I served as principal investigator. In addition to Tom Stafford, Commander of *Apollo 10*, and Vance Brand, backup CMP of *Apollo 15*, the ASTP crew included Donald K. (Deke) Slayton (El-Baz, 1977). During the *Apollo* program, Deke had served as head of the Astronaut Office and selected mission crews. In the early *Apollo* days, he was central to limiting our access to the crews and questioned the value of the time that they spent on "science." As he completed the first flyover exercise during preparations for the ASTP, he confessed: "I flew over the damned things a thousand times and never saw them; I guess you're right about Visobs training." After being fully trained for his mission, he

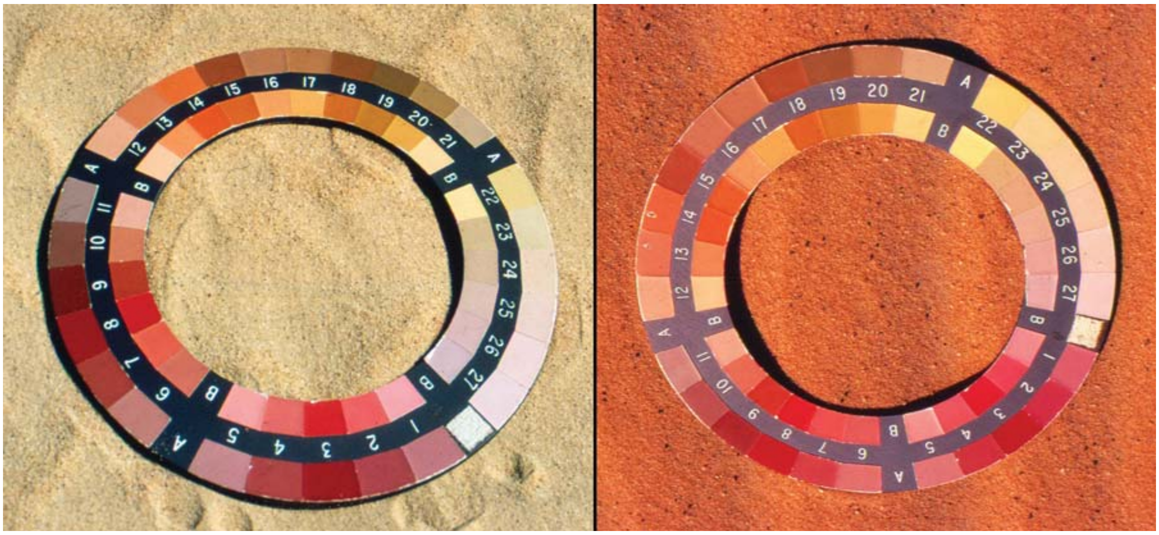

Figure 15. One side of the color wheel (12 cm across) that was designed by the author for astronaut use to describe and compare desert colors during the *Apollo-Soyuz* Test Project (ASTP) of July 1975. Desert sands portray many hues, as documented in these photographs by the author. (Left) Sand in southwestern Egypt, part of the Great Sahara of North Africa. (Right) Redder sand in the eastern part of the Arabian Peninsula. Such a device would be most useful in establishing the natural color of the surfaces on Mars, perhaps one side for the plains and the other for the highlands.

did a superb job in relaying visual observations of surface features from Earth orbit.

The ASTP mission put my design of a color wheel (Fig. 15) to very good use. The wheel had 54 shades of desert colors on one side and a similar number of seawater colors on the other. The color chips were arranged in two rows, one around the outer rim and the other along the inner circle. This made possible the inclusion of a large enough number of color shades to allow comparisons with the numerous Earth tones, for example, the sand colors in Figure 15. It was also possible to attach the wheel to a spacecraft window by Velcro for hands-free viewing, color comparisons, or simultaneous photography.

Vance Brand was particularly adept at relaying the observed colors of desert surfaces. NASA had contracted Kodak, Inc., to produce an especially sensitive color film, based on a variety the company had produced for the U.S. Navy. Still, the film did not record the colors as observed by the astronauts. In critical cases, through the expertise of Noel Lamar of the Photographic Laboratory of JSC, we were able to print photographs that better represented the tones reported by Brand, utilizing the color wheel.

Such a color comparison device would be essential for a manned mission to Mars, because of the similarities between the deserts of Earth and the dust-covered plains of Mars (El-Baz and Maxwell, 1982). Analogs of the Martian features to those of Earth's desert are not limited to color similarities, but also to the reasons behind the color difference. Desert colors were shown to be indicative of both the origin of the particulate materials (El-Baz, 1979b) and their transportation during alternating humid and dry periods (El-Baz and Prestel, 1982) by both water (in the past) and wind (at present). Such conditions could have been just as active on Mars.

CONCLUSION

The *Apollo* program repeatedly proved that visual observations from lunar orbit were critical to establishing the context of samples collected in situ on the lunar surface. These observations also assisted in modifying plans of surface activities before and during the missions, as well as the selection of landing sites for later missions. However, it was clearly evident that any astronaut can look, but one had to be well trained in order to see. Only a well-trained astronaut is able to communicate the observations to others in a precise and clearly useful language. Having been specifically and regularly trained for the task, the *Apollo* astronauts accomplished the task extremely well.

This, however, required long-term dedication to the effort of preparing individual astronauts for the task, each at the proper pace. Emphasis was placed on what the eyes could discern among complex features and on how the brain reacted to the constantly changing scenery. Ken Mattingly summed up the process by stating: "The lessons you taught us about how to see, rather than look, have stayed with me and proven to be useful whenever I was overwhelmed by a mass of apparently disorganized data. You provided the background that allowed us to appreciate the complexity of the extraterrestrial geology problem."

There is no question that NASA will some day prepare to send astronauts either back to the Moon or onward to Mars and beyond. Therefore, it is essential to recognize the value of extensive training of the astronauts in visual observations and photography. When the human mind is well trained, it is able to acquire and then process and communicate useful (often critical) information. This unique human characteristic significantly adds to the quality and meaning of the data gathered by the most advanced robotic sensors.

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