Chapter 2
Planning the Apollo Missions Sample Collection and Processing

On May 25, 1961, President John F. Kennedy addressed a joint session of Congress. Although Kennedy addressed a range of urgent national needs, one in particular electrified the nation and stunned the world. This one sentence is one often quoted from his short presidency: "I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon, and returning him safely to the Earth." Kennedy was not so much interested in scientific advancement but wanted to finally get ahead of its Cold War rival, the Soviet Union, in the race to the Moon. Volumes have been written on the geopolitical basis of Project Apollo, but in May of 1961, the scientific benefits of Apollo were not the goal. In Kennedy's mind, America was determined to prove that it was superior to Russia.

In his 2001 book, *Taking Science to the Moon – Lunar Experiments and the Apollo Program,* NASA engineer Donald A. Beattie wrote that the efforts to glean a scientific benefit from Apollo were initially an afterthought: "Because the president's mandate did not require that any specific tasks be accomplished once the astronauts arrived on the Moon, the initial spacecraft design did not include weight or storage allowances for scientific payloads…The earliest thinking was, 'We'll land, take a few photographs, pick up a few rocks, and take off as soon as possible.' The need to do much more was not considered in the planning. For many NASA engineers and managers, the lunar landing was a one-shot affair."

How this initial ambivalent attitude toward deriving any scientific findings from landing on the Moon and collecting a few samples grew to the development and use of the magnificent Lunar Roving Vehicle and Lunar Module capability to spend several days on the Moon exploring is a fascinating story, covered more thoroughly in other books. However, the story of getting those precious lunar samples and finding out what they might reveal about the Moon itself and perhaps Earth is the main goal in this work.

A. Young, *The Apollo Lunar Samples*, SpringerBriefs in Space Development,
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In the Beginning, There Was the Sonett Report

There had been a good deal of scientific inquiry about the Moon for many years. However, these had all been of a remote nature using telescopes and hoped-for space probes. Any manned lunar exploration up to 1961 was the stuff of science fiction. There had been annual meetings in the United States for a number of years, such as the Eighth Lunar and Planetary Exploration Colloquium, which took place in March 1960 in Downey, California.

In the spring of 1962, NASA's Office of Manned Spaceflight (OMS) contacted Dr. Charles P. Sonett in the Office of Space Science at the agency's Ames Research Center in California. The OMS wanted Sonett to gather a team of scientists to formulate a scientific rationale for the first several Apollo lunar landing missions and make recommendations. The OMS provided guidelines with which to begin considerations. Sonett, acting as chairman, drew on his professional affiliations with those he knew within NASA, the scientific community and other personnel. The committee was made up of members and consultants who offered input via short reports.

There were a broad range of scientific disciplines represented in an effort to satisfy the scientific requirements NASA was looking for. These included geology and geochemistry, geophysics, biology, the atmosphere, plasma physics, solar physics, astronomy and radio astronomy and similar disciplines. A number of participants on this committee would become very prominent during the Apollo program.

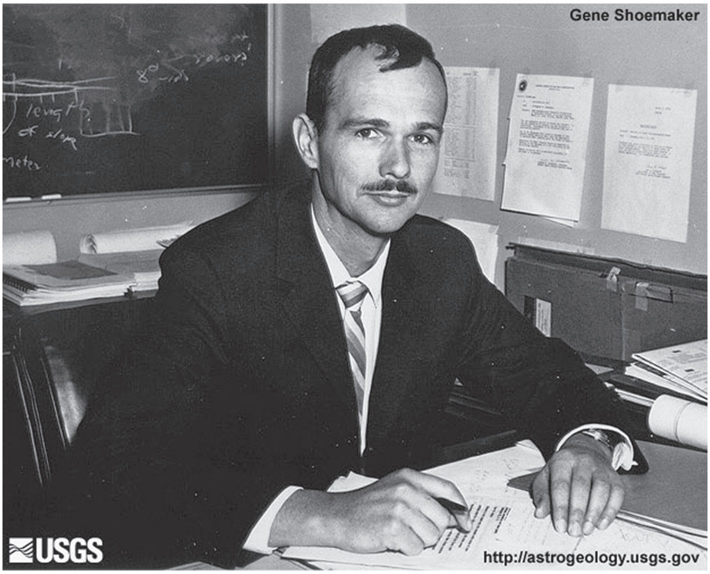

Fig. 2.1 Eugene Shoemaker at the U. S. Geologic Survey was instrumental in the creation of the field of astrobiology, exploration, sampling protocols and recommendations for lunar sampling tools. (USGS)

Among them were Dr. Eugene Shoemaker of the U. S. Geological Survey (USGS), Dr. Harold Urey, Dr. Thomas Gold and Dr. Gerald Kuiper.

During the late spring and early summer months of 1962, members of the ad hoc Apollo Group Committee and consultants worked to establish the parameters of activities by Apollo astronauts on the lunar surface on missions ranging from just a few hours to several days. Lunar surface feature observation and description, sample collection and placement of scientific experiments were covered in the developing report. The key activity of every Apollo lunar landing mission was sample collection for the purpose of extensive examination and testing by various means back on Earth.

In the report that was delivered in rough draft in July 1962, it was clearly stated that lunar samples needed to be collected and stored in sterile containers yet to be designed. Methods of sample retrieval, collection in containers, and storage of samples and the handling environment back on Earth would also have to be established. Significantly, the members of the group established the need to drill holes in the lunar surface to collect core samples, not simply collect loose, small samples from the surface alone. There was a separate section identified as "Drill Holes." Amusingly, in the first paragraph, it was suggested a shallow drill hole would be 100 feet deep. The report stated there was a "firm requirement for equipment that can reach a depth of 20 feet." Approximately half this depth was actually achieved during Apollo 15, 16 and 17.

One of the key recommendations of the published report was the absolute need for scientist-astronauts to be members of each Apollo crew going to the lunar surface. All such candidates, the report stated, should hold Ph. Ds and have at least ten years working experience in their specialty. The committee's first choice was for a geologist with good knowledge of geophysics. NASA would eventually establish a distinct program for the selection of scientist-astronauts. The first such scientist-astronauts were selected in 1965, but only one would fly on an Apollo mission: Dr. Harrison "Jack" Schmitt. He was Lunar Module Pilot on Apollo 17, and his observations during the mission are recounted in a later chapter. This report also provided a list of required equipment to conduct geological work on Earth as a guide for similar equipment needed during lunar exploration. The list included two picks, a shovel, sample containers and supplies, some of which was not practical on the Moon.

The *Report of the Ad Hoc Working Group on Apollo Experiments and Training on the Scientific Aspects of the Apollo Program,* or the Sonett Report in short, was a foundational document on lunar surface exploration in the early years of the Apollo program. One member of the group, Verne C. Fryklund, worked as acting director of the Manned Space Sciences Division within the Office of Space Science. In October 1963, Fryklund received tacit approval of the recommendations from Homer Newell at the OSS and Joseph Shea at the OMSF. Fryklund then sent a memo to Dr. Robert R. Gilruth, director of the Manned Spacecraft Center (MSC) in Houston, Texas. According to Donald A. Beattie, this memo contained the first scientific guidelines for the early Apollo missions.

Fryklund's memo to Gilruth outlined three principal activities to be conducted on the lunar surface as a minimum: "a. Comprehensive observation of lunar phenomena; b. Collection of representative samples; and c. Emplacement of monitoring equipment." Shortly after the memo was reviewed by Gilruth and others at the MSC, it was announced 250 pounds would be allowed as the payload for scientific purposes. That was just the initial assessment. After the circulation of the Sonett Report, the Lunar Science Branch within the Manned Space Science Programs at NASA headquarters began to further develop the goals, methods and means of sample collection and evaluation for the Apollo missions.

During 1964, even as the country was trying to recover from the assassination of President Kennedy in November of 1963, NASA headquarters moved forward with a more formal outline of Apollo missions and the duties of its astronauts on the lunar surface. In December 1964, NASA issued *Apollo Lunar Science Program Report of Planning Teams* (TM-84139). During the spring of 1964, separate planning teams were established within the Lunar Science Branch for the separate disciplines that needed to be represented on each of the early Apollo missions. Chief among these disciplines were lunar sample collection, preservation and the methods of sample analysis back on Earth.

This document stated the "…single major scientific objective of the Apollo landings should be to return 60-80 pounds (limited by capability of the spacecraft) of representative lunar samples." Specifically, the geologic team recommended collection of a wide variety of small samples measuring 1 × 1 × 1 cm as sufficient for analysis. It was stated a number of larger, 0.5 to 1.0 kg samples, also be collected both from the surface and subsurface. The team stated that a chisel and hammer should be sufficient to acquire samples from much larger blocks. Also needed would be a sample scoop for fragmented pieces and particulate, or lunar soil. For sample containers and packaging, the document stated: "The field geology planning team indicated that most of the samples collected should be placed in individual, pre-numbered, gas-tight soft bags, and the bags placed in a tight, pressure-proof, rigid sample box which will be sealed outside the LEM before return to Earth. Besides the soft bags, several small, rigid containers should be available so that unconsolidated material such as dust samples can be taken and their structure preserved."

The ability of the astronauts to actually collect lunar samples certainly had a number of unanswered questions. The Apollo EVA suit had yet to be designed and tested. The flexibility of the suit and specifically of the gloves would determine, in large part, whether the astronauts could handle the chisel, hammer and scoop, as well as the sealing of the sample bags and closing of the sample containers. Members of the geochemistry, mineralogy and petrography, and geology planning teams wanted the sample containers to be capable of retaining their original vacuum condition once the container was closed and locked on the lunar surface. This would preserve the lunar samples in their original state. Another issue involved how far from the landing site the astronauts would be able to venture in order to obtain samples. The methods of sampling, depending on the type of sample desired, would also have to be developed so the astronauts could be trained in this method. Accommodation of the sample container or containers would have to be provided first aboard the lunar module that would descend to the landing site, inside the ascent stage that left the lunar surface and transfer of the containers to the Apollo capsule in a secure location for return to Earth.

TM-84139 was the first NASA document produced by the Lunar Science Branch to state the need for a laboratory in Houston, Texas, within the Manned Spacecraft Center to receive the collected lunar samples, catalog them, conduct requested testing by the various teams and disseminate the findings. It was initially identified as the "sample receiving laboratory." This ultimately became the Lunar Receiving Laboratory. A new ad hoc committee was established in the summer of 1964 to draw up the comprehensive requirements for the LRL in Houston. The LRL would also draw up the requirements for the sampling tools and the containers that would hold them. Most examination and testing of the samples would be performed at the LRL, but very specialized tests, such as gas analysis or isotopic studies, would be performed by an established outside laboratory approved by NASA.

This document also noted the need for the selection of investigators and experimenters and how the selection process would equitably satisfy the scientific community at large, be they individual scientists, universities or research institutions. There would be a great deal of prestige attached to the selection of a person or laboratory to examine the samples, apart from the findings that would emanate from that work. There would be the very human trait of ambition and professional honor in the competition for selection. TM-84139 also covered the scientific experiments the planning teams had recommended that would be deployed and left on the lunar surface.

Around the same time TM-84139 was published in December of 1964, Homer Newell queried the National Academy of Sciences' Space Science Board members to get opinions on the need for a laboratory to receive and handle the lunar samples. That board released its report to Newell at the Manned Spacecraft Center in February 1965. The report concurred there should be such a laboratory but questioned if it should be at the MSC. Stakeholders with regard to lunar sample evaluation wanted this laboratory removed from the control of personnel at the MSC. As with everything else regarding the Apollo, politics and pride came into play regarding the location of the Lunar Receiving Laboratory. It was finally decided that the laboratory would be built at MSC.

Lunar Sample Collection Tools and Equipment

In the mid-1960s, the Apollo program was moving quickly across all areas of spacecraft and launch vehicle design and testing, ground support equipment, mission planning and lunar site selection, astronaut training and related matters. The design of the lunar sampling tools and sampling procedures were developed by the U.S. Geologic Survey's Field Geology Team under the direction of Eugene Shoemaker. The USGS was headquartered in Flagstaff, Arizona. The facilities and geology of the surrounding area was ideal for astronaut training and design development of the sampling tools and collection equipment. Members of Shoemaker's team in Flagstaff coordinated efforts with the Manned Spacecraft Center Flight Crew Systems Division, which performed tests on the supplied prototypes. The finished lunar sampling tools and related equipment for the lunar landing missions were manufactured at the MSC, which was equipped to do so.

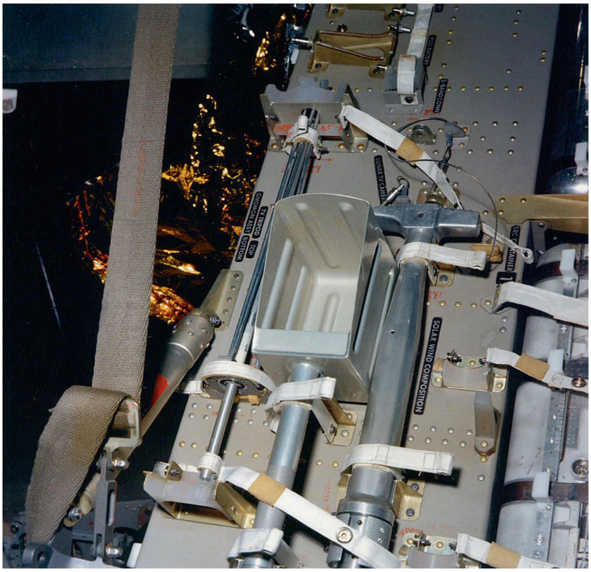

Fig. 2.2 Close-up of the large box scoop and hammer secured to the Modularized Equipment Stowage Assembly (MESA) (NASA). Detail of the extension handle, tongs and two stowed Apollo Lunar Sample Return Containers (ALSRC). Note the polished finish of the upper ALSRC. (NASA)

In February 1967, a Critical Design Review of the Apollo lunar hand tools was held at the MSC in Houston. At this meeting, the tools were selected that would be used on the early lunar landing missions, although some were not yet ready for review. A number of tools were not yet ready and were still undergoing design development to be used on the latter Apollo missions. The list of essential tools in this CDR included: (1) tool carrier, (2) tongs, (3) hammer, (4) drive tubes 1, 2 & 3, (5) scoop, (6) extension handle, (7) gnomon, (8) sample bags, (9) sample bag dispenser and sealer, (10) aseptic sampler, (11) spring scale, (12) color chart, and (13) a combination tool brush/scriber/hand lens. A surveying staff was originally proposed by the USGS but was eliminated due to the inordinate amount of time the astronauts would need to accomplish the tasks using it. Not included in this CDR, apparently, was the Contingency Soil Sampler; this was the first lunar sampling tool that would be employed on Apollo 11.

MSC and the USGS team agreed all the individual tools, extension handle, core tubes with caps, sample bags and essential items should be kept in a tool carrier so the astronauts could have them all in one place while on the lunar surface. The Small Tool Carrier had three legs with angled sides. Two sides stored the majority of the equipment. It was constructed of sheet aluminum, aluminum tube and machined aluminum parts. It also held a small tote bag. The Small Tool Carrier was manufactured at the Johnson Space Center. It was not used on Apollo 11, but was used on Apollo 12 and on the Apollo 14 Modular Equipment Transporter. (All lunar sampling equipment for Apollo 13 was destroyed along with its Lunar Module *Aquarius* after it separated from the Command Module and reentered Earth's atmosphere and burned up.)

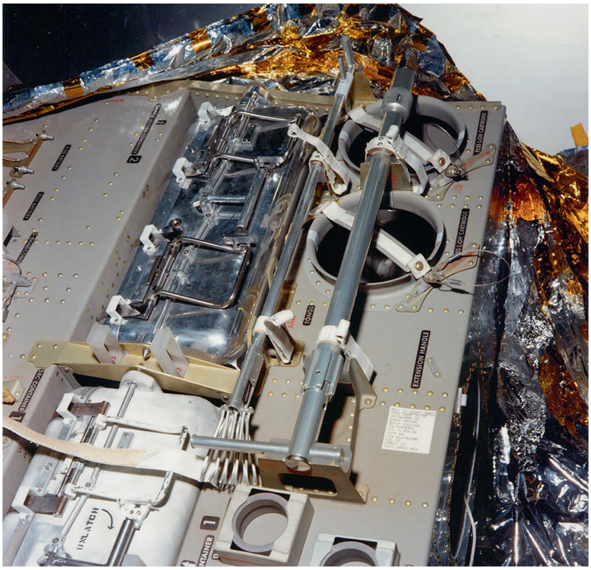

Fig. 2.3 Detail of the extension handle, tongs and two stowed Apollo Lunar Sample Return Containers (ALSRC). Note the polished finish of the upper ALSRC. (NASA)

Fig. 2.4 Neil Armstrong training in the storage of lunar samples into the ALSRC. (NASA)

The Bendix Corporation had won a NASA contract to design and develop some of the sampling tools and support equipment for lunar surface operations. Joe O'Connor of the USGS recalled evaluating one Bendix concept for the Lunar Tool Carrier. It had multiple legs that O'Connor said was unduly complex. He decided to take the Bendix engineers out for a couple of drinks to try to convince him that design simplicity was essential for astronauts in bulky EVA suits trying to handle

Fig. 2.5 The Modular Equipment Transporter (MET) was designed to transport the Hand Tool Carrier and stow collected samples (NASA)

equipment. USGS geologist Gerald Schaber interviewed O'Connor as part of a history of the USGS in support of the Apollo program (see Bibliographical Sources). O'Connor said the following regarding the Lunar Tool Carrier:

> *I got a bar napkin – and I said you want a tripod. That's stable; that's as stable as you can get. I said you don't want a heck of a lot on it. And on the tripod you probably want a place to put hand sample containers that are easy to get at – not too high…but not too low that he has to do a lot of bending. So I sketched out these things on the napkin – and one of the guys from Bendix said, 'Oh, could I see that – would you mind if I keep it? That was the last thing I ever saw it until it came back in the RFP for the actual Apollo Tool Carrier. Well, that's how the Lunar Tool Carrier got designed.*

The Modularized Equipment Transporter (MET) was employed only on Apollo 14. It was a two-wheeled hand-drawn cart designed to carry the Small Tool Carrier with all its tools and accessories, close-up stereo camera, two Hasselblad 70-mm cameras, a 16-mm data acquisition camera (stored in the small tool carrier), film magazines, lunar sample bag dispenser, the trenching tool, and the Lunar Portable Magnetometer. The MET was designed almost entirely of aluminum alloy tubing, sheet metal and machined aluminum parts. The MET's two tires were engineered and made by Goodyear; they measured 4 inches wide and 16 inches in diameter, mounted to machined aluminum rims. The tires were inflated to 1.5 psi with nitrogen prior to flight and had an operational temperature range between –70 degrees F to +250 degrees F.

The MET measured 86 inches long by 39 inches wide when deployed. It had two vertical legs forward of the tires to keep it level when not being pulled by its handle by the astronaut. The MET was fully collapsible and was stored aboard the MESA in Quad 4 of the Lunar Module descent stage for Apollo 14. (Note: Because

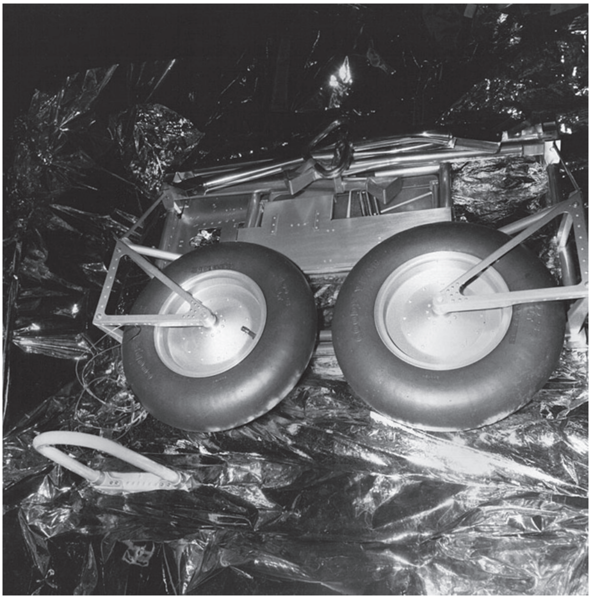

Fig. 2.6 The stowed Modular Equipment Transporter in one quandrant of the lunar module. (NASA)

Goodyear was the manufacturer of the MET tires, the company is often erroneously credited with the design and manufacture of the wheels of the Lunar Rover Vehicle used on Apollos 15, 16 and 17.)

The principal sampling tool used on Apollo 11, 12 and 14 was the large box-shaped scoop. It was fabricated of 6061 aluminum sheet metal and had a handle approximately 12 inches long. To this handle could be fixed the short extension handle to minimize the astronaut bending during sampling. There was also a small, non-adjustable scoop with a stainless steel front edge and handle designed to accept the extension. The small scoop was used on Apollo 12 and 14. A small adjustable-angle scoop was machined from 17 to 7 PH stainless steel with a hinge on the machined aluminum handle and was designed to accept the extension. This scoop was used just on Apollo 15. A large adjustable-angle scoop was used on Apollo 16 and 17. It was made of the same materials having a larger scoop and slightly longer handle.

Two different style hammers were used on the Apollo lunar missions. The one used on Apollo 11 and 12 is identified as the lighter weight hammer. The head was machined from AISI S5 tool steel with a vacuum-deposited aluminum finish. The handle was 6061-T6 aluminum, with the head pinned to the handle. It had an overall length of 41 cm and weighed 860 g. The hammer used on Apollo 14 through 17 had a more massive head also machined from tool steel and aluminum coated. This hammer had a stronger machined aluminum shank and was pinned to the head. It had an overall length of 39 cm and weighed 1,300 g. Both hammers were designed to accept extension handles.

A vital sampling tool were the tongs employed on all the lunar landing missions to pick up individual rocks between 6 and 10 cm. The first design had a length of

67 cm with aluminum tines and the latter design had a length of 80 cm and had tines made of 17-4 PH stainless steel. The tines could be opened and closed using the spring-loaded handle at the end of tool. The astronaut's gloved hand was considered in the design of the tongs' handle design.

The trenching tool featured an adjustable 310 alloy stainless steel shovel with an aluminum handle. It had an overall length of 93 cm. This tool was used only on Apollo 14. The large adjustable-angle scoop replaced it on Apollo 15, 16 and 17.

For the later Apollo missions, a special rake was designed. It was an elegant and efficient design with curved 6061-T6 aluminum sheet metal sides, stainless steel tines, stainless steel reinforcing band and an adjustable aluminum shank that was secured to an extension handle. The tines along the bottom and curved tines at the back were spaced to gather and sift 1-cm pebbles from the regolith. This tool was dragged across the lunar surface in a specific technique developed during training. The rack basket measured 29.4 × 29.4 × 10.4 cm.

The Contingency Soil Sampler was developed to allow astronauts the opportunity to collect a sample of lunar soil and pebbles as one of the first tasks at the landing site in the event of an aborted mission. It featured a 10-cm stainless steel ring that held a sample bag and a multi-piece aluminum handle with internal lanyard that had to be assembled by the astronaut. It was placed in the leg pocket of the pants of one of the astronauts. Shortly after stepping onto the lunar surface the Contingency Soil Sampler was retrieved from the leg pocket, the handle assembled and the sample taken from the lunar surface. Once the sample was collected, the bag was closed and placed aboard a segment of the Lunar Module ascent stage. This tool was not manufactured at Johnson Space Center but by a contractor, Union Carbide.

Several core tubes were designed for the Apollo missions. The first tubes measured 2 cm in diameter and were made of 6061 T-6 aluminum. One end had a hardened bit, the other end an adapter fixed to it to accept an extension handle that was used to protect the tube and permit it to be hammered into the lunar regolith. When the core tube was extracted, the bit was removed and cap installed, and the extension handle removed and tube capped. These tubes had an internal length of nearly 32 cm and a capacity of 100 cm^3. The 2-cm core tubes were used on Apollo 11, 12 and 14.

For the Apollo missions of 15, 16 and 17, larger and more sophisticated drive tubes were designed. The tubes were made of 6061-T6 aluminum. There was a lower tube with 17-4 PH stainless steel bit and internally threaded on one end; this was affixed to the upper tube. Additional parts of these drive tubes included a plug, keeper, cap, cap dispenser and a ram. These assembled drive tubes were initially forced into the lunar regolith by hand, then hammered to the desired depth. When the entire tube was removed, the bottom was capped. The upper tube had a keeper inserted, a cap with small hole in the center secured to the end, then the ram was inserted through the hole in the top plug cap to push the keeper against the collected sample.

The most sophisticated lunar sampling tool employed during Apollo was the Apollo Lunar Surface Drill (ALSD). Martin Marietta in Denver, Colorado, was the prime contractor for this sampling tool. The drill was comprised of the battery, power head, drill stems and bit, and the treadle assembly. The power head was designed and built by Black and Decker. It was of a rotary-percussive design that delivered 2,270 blows per minute and 280 RPM to the drill stems. Due to the heat generated by its operation, a wire thermal shroud covered the entire power head.

The battery was made up of 16 silver-oxide-zinc cells inside a housing that accepted the power head. A handle was mounted separately to the battery housing and allowed the astronaut to turn the drill on and off. The battery and housing were manufactured by the Yardney Electric Corporation. Martin Marietta manufactured the drill stems from titanium alloy. The stems had an outer diameter of 2.5 cm and inner diameter of 2.0 cm. The exterior surface of the stems had flute-like screw threads to aid in drawing the stems into the regolith during drilling. A cutting bit was made of high-strength steel with five tungsten carbide teeth; this cutting bit was screwed into the lower drill stem.

On the lunar surface, the astronaut would remove the components of the ALSD from its carrier assembly in the MESA on the Lunar Module. The handle was mounted to the battery, which was attached to the power head and set aside. The drill bit was secured to the lower drill stem and an upper drill stem assembled to the lower stem. The astronaut attached the power head to the assembled drill stems, but the bit to the surface??, and turned on the drill. When the stems had drilled into the surface sufficiently, the drill was stopped, the power head removed and another drill stem attached. Then the power head returned to the drill stem to continue the drilling operation. As many as eight drill stems could be driven into the lunar surface. To remove the stems, a treadle was attached to the last stem, and the assembled drill stems were extracted using the method similar to an automobile jack.

All the components of the ALSD were carried on the Lunar Roving Vehicle during Apollo 15, 16 and 17. The assembled drill stems with core samples were sepa-

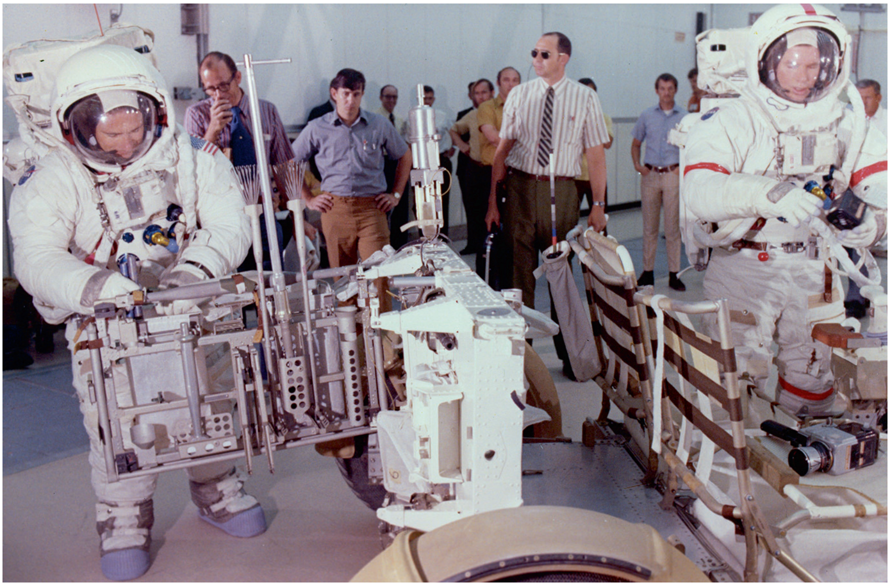

Fig. 2.7 Apollo 15 astronauts James Irwin and David Scott train using their pedestal-mounted Lunar Roving Vehicle (LRV). Irwin stands next to the large tool carrier in the open position. (NASA)

rated, each end capped and secured on the LRV for placement inside the Apollo lunar sample return container with the collected samples. Only the core stems with caps were returned to Earth.

There were several different sample collection bags of various sizes used during the Apollo lunar surface missions. The first of these used on Apollo 11 and 12 were described as weigh bags that measured 42 cm high, 22 cm wide and 15 cm deep. They were made of white Teflon; a wire frame gave them shape. These bags could be attached to the astronaut's suit or to the base of the Lunar Module. The weigh bags used on Apollo 14 were of white woven cloth and also had a wire frame to retain its shape.

The weigh bags were eventually replaced with sample collection bags (SCBs) having more features, including pockets and different construction, but having the same essential dimensions. The extra sample collection bag was of the same size but without the pockets. There were also the smaller documented sample bags, which were seen being handled by the astronauts on the lunar surface. The protective sample bag was designed with padding inside to cushion the larger collected rock samples. They measured roughly 15 cm × 14 cm × 5 cm. These were used on Apollo 16 and may have been used on Apollo 17.

The special environmental sample container (SESC) was a rigid circular container with the can and its sealable lid made from 304 L stainless steel. The container measured 6 cm in diameter, had an overall length of 21 cm and had an interior volume of 360 cc. A removable protective seal was left on the can lip while lunar soil and pebbles were poured inside. When filled, the protective seal with its tab were removed by the astronaut, and the lid secured using its torque handle. According to documentation, the SESC was used on all the Apollo missions, but is clearly seen in the photo of Apollo 12 astronaut Alan Bean taken by mission commander Pete Conrad, who is reflected in Bean's helmet visor.

The core sample vacuum container (CSVC) was designed to hold a single 4-cm drive tube while retaining the lunar vacuum environment once the lid was secured. It was also manufactured from 304 L stainless steel, and the lid functioned the same way. The CSVC was used on Apollo 16 and 17, but documentation indicated these were never opened in the Lunar Receiving Laboratory.

The gas analysis sample container (GASC) was a shorter version of the SESC and was of the same construction and functional design. It had a capacity of 69 cc. It was designed to sample the molecular makeup of the lunar environment when a small amount of soil was also collected.

The magnetic shield sample container (MSSC) had special alloy housing and a non-metallic exterior protective coating. It was first included on Apollo 14, but there were no subsequent records or documentation indicating that lunar samples were collected and returned to Earth using the MSSC.

Two Apollo lunar sample return containers (ALSRCs) were taken on each mission. These were manufactured by the Y12 National Security Complex, in Oakridge, Tennessee. This facility had the manufacturing capability of producing containers that could hold nuclear material. The bottom container and its lid were machined from the same block of 7075 aluminum alloy. The exterior dimensions of the ALSRC were 48 cm wide by 27 cm deep × 20 cm high with generous curved edges

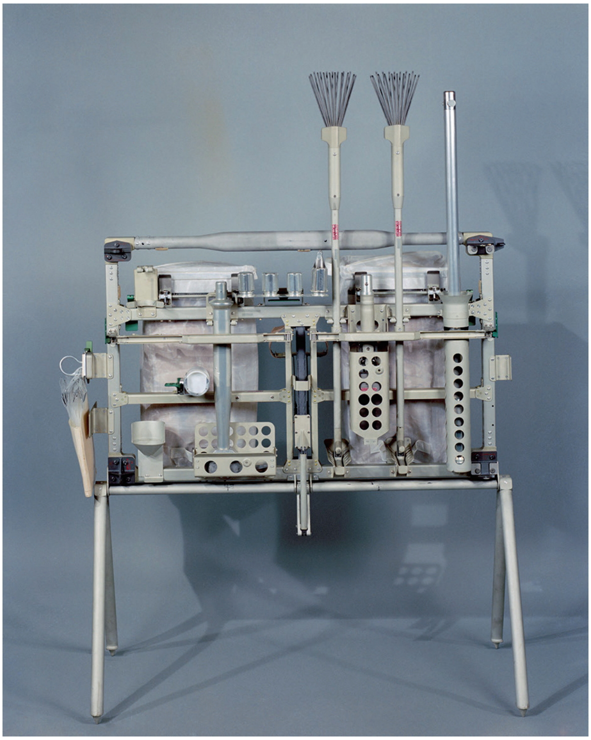

Fig. 2.8 View of the large tool carrier on a stand with a few of the lunar sampling tools, including two tongs, extension hand and hammer. (NASA)

and corners. A lip ran around the entire edge of the bottom and the lid to provide a triple seal made up of a knife edge against a soft indium band with two fluorosilicone O-rings along the entire perimeter. The lid was not hinged to the bottom. The interior was lined with wire mesh woven from 2024 aluminum wire. After the sample bags, rocks and core or drive tubes were place in the container, Teflon seals were removed from the edge of the lid and bottom and the lid closed over the bottom. Two cam latches at the front of the ALSRC used four steel straps running over the lid to provide uniform sealing pressure. Two latch pins were pushed into position to keep the container closed. Both ALSRC containers were preloaded with sample collection bags and tools prior to flight and secured in the MESA of the Lunar Module.

On Apollo 15, 16 and 17 the astronauts used the lunar roving vehicle (LRV) to greatly expand the range of exploratory operations. The LRV used the large tool carrier at the rear of the vehicle to expand the tool and sample carrying capability for these missions. It was capable of storing the rake, tongs, scoop, hammer, extension handle, and sample collection bags and had provisions for related tool components. Two large sample collection bags could be secured to the back of the large tool carrier, which was hinged on the left to open for access to the tools. It was constructed of aluminum tubing, sheet metal and machined parts. It was designed and built at the Manned Spacecraft Center and shipped to the LRV prime contractor, Boeing, for installation.

Fig. 2.9 The opposite side of the large tool carrier could accept two large lunar sample bags. (NASA)

Another tool designed exclusively for use by the lunar module pilot while seated in the LRV was the LRV soil sampler. It had an 8-cm diameter metal ring with wire frame mounted to a universal handling tool. The wire frame held up to 12 sample bags in the shape of a long cup, and these were nested as each cup bag was filled; it could then be removed from the tool, sealed and set aside. This tool allowed the astronaut to scoop up samples without having to leave the LRV. It was used on Apollo 17.

The Lunar Receiving Laboratory

It naturally followed that the gathering and return of lunar samples to Earth would require a laboratory to catalog the samples and have facilities to examine and test them to determine their composition. What was originally conceived was a modest laboratory. Apollo was a government program of immense size and management, so it is little wonder what became known as the Lunar Receiving Laboratory would end up far larger and more complex than NASA program managers themselves even thought it would be, as mentioned earlier. In addition, the LRL was started late in the Apollo program and had to be rushed to completion in order to receive the first samples from Apollo 11. Progress on the laboratory was hampered by debates among the various groups, committees and individuals involved with lunar samples and even agencies outside of NASA as to where the laboratory should be built, which delayed the start of its construction.

An additional issue that emerged during discussions of the design of the LRL was that of back contamination. In addition to the need to protect the lunar samples from any contaminants from Earth's environment, there were concerns that Earth and humans needed to be protected from potential and unknown lunar sample contaminants; this was labeled as back contamination, and it added a whole level of complexity to the LRL with its attendant cost.

Another contributor to the size and sophistication of the laboratory was the decision to bring the Apollo capsule there for quarantine as well as the astronauts. Naturally, all of this required procedures never before established. What originally begun as a recommendation of the Sonnet Group for a small laboratory to examine the lunar samples grew to involve the Public Health Service and the Centers for Disease Control along with the creation of the Interagency Committee on Back Contamination. Ultimately, the name of the Lunar Sample Receiving Laboratory was changed to the Lunar Receiving Laboratory to reflect its vastly expanded scope.

Serious discussions for the LRL did not begin until 1964. It became clear that the LRL would need its own program management, much like Apollo itself, if it was to be completed on time. The LRL's location was to be at the Manned Spacecraft Center in Houston. Dr. Robert Gilruth was the center director, and initially, he did not believe a dedicated laboratory was necessary; another NASA facility could conduct examination of the samples with an existing laboratory. Even the U. S. Geologic Survey had its champions who argued that placing the LRL in Flagstaff made perfect sense for the examination of the lunar samples. Like many such proposals generated at NASA, Gilruth requested more research on the matter. Gilruth came to support the LRL, but even he would be surprised as to the size the facility would become.

One memo, written by Aleck Bond, manager of Systems, Tests and Evaluation at NASA in April 1964, detailed the scope of the laboratory duties believed essential up to that time. In part it stated: "MSC should build a facility that…initially receives the samples collected by the astronauts on the Apollo missions; opens the containers under precisely controlled, uncontaminated, sterile conditions; checks the samples for the presence of viable organisms; performs some control testing of the samples; carefully divides the samples into appropriate amounts for distribution to the various investigators; prepares and repackages the portion of each sample in accordance with the analytical technique to be used by each investigator; and delivers the portion of the sample to the individual investigator."

Three months later, the planning teams for mineralogy and petrology, geochemistry and biology detailed the specific functions the LRL would be dedicated to, stating in a memo, "…the primary purpose of such a facility at MSC is to provide a central laboratory for preliminary biological, geological and chemical examinations and analyses of lunar samples." While there were advocates for the LRL to be located outside of the MSC and even outside a NASA facility to maintain its scientific independence, those in favor of the laboratory's location at the MSC and won the day.

Soon, the issue of back contamination began to have an impact on the size and scope of the LRL, as relevant departments of the U. S. government learned of its creation. Even the Department of Agriculture and the Department of the Interior entered the fray. What would the astronauts bring back with them while on the lunar surface? Clearly, the astronauts would have to be quarantined, and their capsule as well, and there would need to be facilities for this. Interestingly, management at NASA headquarters in Washington had a far less ambitious view on the scope and operations at the LRL in 1964.

Over the next two years, the creation of the design and standards for the LRL were written and rewritten, and funding for the ever-increasing complexity of the facility even resulted to budget hearings in Washington, D. C. By 1965, there was concern for scheduling of construction and completion of the facility because all the procedures the LRL would conduct had to be put into practice and validated before a single sample or astronaut entered the building. All personnel who would work there would have to be trained. The LRL program office was established to accomplish this and keep the project on schedule.

Establishing operational procedures and protocols for each area of the LRL began in 1966. These were crucial because they affected the design of the facility. One of the institutions the MSC contracted with to investigate and draw up recommended protocols was the Baylor University College of Medicine, also in Houston. Baylor's biological protocol was conceived to examine the effect of the lunar samples upon plant and animal life and had three main areas of interest: "(1) crew microbiology, (2) in vitro attempts to culture microorganisms from the lunar sample; and (3) the direct challenge of the lunar sample in biological systems." The procedures to achieve this were detailed in an extensive report, but came with a caveat. There were obviously many unknowns with regard to the effects of lunar samples upon plant, animal and human life. The MSC did not know if there might be catastrophic effects upon biological life. This was the cautionary approach. However, after the first several missions returned from the Moon with their samples and the LRL developed definitive results from this testing, it would prove that the lunar samples were not a danger.

Construction of the LRL at the Manned Spacecraft Center began in 1967. It was to be a multi-story building that would include the Crew Reception Area, Operations Area, Administration and Support Area, the Radiation Counting Laboratory (which was partially underground), and the Sample Area, which ironically was the smallest portion of the LRL in terms of square footage.

Due to the highly specialized tasks that the LRL would perform and the disciplines that would be required to do all the tasks, MSC Director Gilruth recommended the employment of contract personnel to fill these very specific jobs. Thus, the LRL contracted for individuals from laboratories, universities and research institutions for many of these open positions. It brought in civil servants for many of the support roles from within NASA and other government agencies.

Even during the LRL's construction, those who would become Principal Investigators from across America and overseas wanted their concerns heard and addressed. NASA's Office of Space Science and Applications (OSSA) was charged with selection of more than 100 PIs to conduct testing, research and report findings; curiously, much of this work would not be conducted at the LRL but at the PI's own institution.

In January 1967, a meeting was held at the Communicable Disease Center in Atlanta, Georgia, with personnel from the LRL, George Low from NASA and officials from the Public Health Service. The outcome of the meeting was to state the most important function of the LRL would be quarantine of the crew, spacecraft and samples. It seemed at this point that the scientific findings that would derive from examination, analysis, experimentation and testing were secondary.

In August of 1967, NASA appointed Dr. Persa R. Bell as Chief of the MSC's Lunar and Earth Sciences Division and as manager of the LRL. He came from Oakridge National Laboratories in Tennessee where he had been director of the Thermonuclear Division. Bell would manage the LRL until January 1970, when he resigned his position to return to ORL. For all the emphasis on back contamination and quarantine, Bell would prove to have more interest in seeing the lunar samples remained uncontaminated and that the maximum possible level of science was conducted there in lunar sample analysis. Bell did not believe back contamination to be a very great concern, and this later proved to be true.

To ensure the LRL certification was completed in time to receive the Apollo 11 samples in July 1969, Gilruth putd Richard S. Johnston in charge of this task. However, Johnston became the defacto operational manager of the LRL. As assistant to Gilruth of the MSC, Johnston had management experience that Pell lacked. Johnston's new role in fact proved vital in getting all certification completed on schedule.

NASA Administrator James Webb did not want the science findings to come out of the lunar sample research to be overwhelmed by all the issues over quarantine and related concerns. To supplement the efforts of the LRL, the Lunar Science Institute was created. This was so significant a development that President Lyndon Johnson announced LSI's formation during a visit to the MSC. The LSI was created to operate independently of the LRL but would work with the laboratory to permit scientists the means to gather the scientific findings they sought from the lunar samples and disseminate the information.

Once the LRL was built, the certification began. The standards laid down by the Interagency Committee on Back Contamination (ICBC) were very stringent because they employed a double barrier system. Gilruth implemented the Operational Readiness Inspection Team in October 1968. Practice sessions on the receiving of the astronauts, spacecraft and simulated samples would be conducted almost up to the flight of Apollo 11. There were a number of failures that had to be resolved before certification was completed. These practice sessions often went on for 10 to 12 hours or more. The Lunar Sample Analysis Planning Team (LSAPT) was instrumental in many aspects of not only proper testing procedures for the samples but also during the certification process.

Full-scale simulations of LRL operation began in early 1969. The lunar sample simulants were handled in a vacuum environment comprised of glove boxes with transparent Lexan windows and flexible arm-length gloves that permitted technicians to handle the samples. The vacuum was between 10^{-6} and 10^{-8} tort. As the simulations were conducted in this environment, examination and distribution of simulated lunar samples proved difficult. During June and July of 1969, the LRL was still continuing its certification procedures and operations. The LRL was in readiness mode by July 14.

This vacuum environment would remain in place through Apollo 11 and 12. To prepare the samples for distribution, they were processed in a small sterile glove box in a dry nitrogen atmosphere. This proved to be a faster and less cumbersome method of processing. This was adopted for the actual lunar samples from Apollo 11 and 12 and proved so efficient without degrading the lunar materials that the cumbersome vacuum system was replaced by the nitrogen atmosphere throughout the lunar sample facility for all remaining Apollo missions. With the increased quantity of lunar samples after Apollo 12, an additional processing line was constructed at the LRL.

The rigorous quarantine requirements were lifted after the Apollo 14 mission. The established procedures with respect to handling and scientific methods at the LRL remained in place. It was determined after the first several missions that no potential biological threats were detected in any of the lunar samples.

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