United States Department of the Interior
National Park Service

National Register of Historic Places Registration Form

This form is for use in nominating or requesting determinations for individual properties and districts. See instructions in National Register Bulletin, *How to Complete the National Register of Historic Places Registration Form.* If any item does not apply to the property being documented, enter "N/A" for "not applicable." For functions, architectural classification, materials, and areas of significance, enter only categories and subcategories from the instructions.

1. Name of Property

Historic name: Sunset Crater – Cinder Lake Apollo Mission Testing and Training Historic District
Other names/site number: N/A
Name of related multiple property listing: N/A

2. Location

Street & number: Roughly bounded by Sunset Crater Volcano National Monument (6400 U.S. 89) and Sunset Crater West Quadrangle, Section 12, Township 22 North, Range 8 East and Township 23 North, Range 8 East
City or town: Flagstaff State: Arizona County: Coconino
Not For Publication: [ ] Vicinity: [ ]

3. State/Federal Agency Certification

As the designated authority under the National Historic Preservation Act, as amended, I hereby certify that this _X_ nomination ___ request for determination of eligibility meets the documentation standards for registering properties in the National Register of Historic Places and meets the procedural and professional requirements set forth in 36 CFR Part 60.
In my opinion, the property _X_ meets ___ does not meet the National Register Criteria. I recommend that this property be considered significant at the following level(s) of significance: _X_ **national** ___ **statewide** ___ **local**
Applicable National Register Criteria: _X_ **A** ___ **B** ___ **C** ___ **D**

Jurkeira C Cowe, acting FPO 9/23/19
Signature of certifying official/Title: Date
National Park Service
State or Federal agency/bureau or Tribal Government

In my opinion, the property _X_ meets ___ does not meet the National Register criteria.
Kathryn Leonard 7 May 2019
Signature of commenting official: Date
State Historic Preservation Officer State Parks and Trails
Title : State or Federal agency/bureau or Tribal Government

4. National Park Service Certification

I hereby certify that this property is:

✓ entered in the National Register
__ determined eligible for the National Register
__ determined not eligible for the National Register
__ removed from the National Register
__ other (explain:) ______

For [signature] 11/8/17

Signature of the Keeper Date of Action

5. Classification

Ownership of Property
(Check as many boxes as apply.)

Private:	[ ]
Public – Local	[ ]
Public – State	[ ]
Public – Federal	[x]

Category of Property
(Check only **one** box.)

Building(s)	[ ]
District	[x]
Site	[ ]
Structure	[ ]
Object	[ ]

Number of Resources within Property
(Do not include previously listed resources in the count)

Contributing	Noncontributing	
		buildings
8	1	sites
		structures
		objects
8	1	Total

Number of contributing resources previously listed in the National Register 0

6. Function or Use

Historic Functions

LANDSCAPE/Park
LANDSCAPE/Forest
OTHER/Simulated Lunar Landscape

Current Functions

LANDSCAPE/Park
LANDSCAPE/Forest

7. Description

Architectual Classification

________N/A______

Materials: Principal exterior materials of the property: N/A

Narrative Description

Summary Paragraph

The Sunset Crater-Cinder Lake Apollo Mission Testing and Training Historic District (the district) is located approximately twelve miles north of Flagstaff, Coconino County, Arizona. The district is located in the eastern portion of the 1,800-square-mile San Francisco volcanic field. The topography, geology and setting of the district are dominated by volcanism.[1] In particular, the eruption of Sunset Crater in the late 1080s CE created many unique local geological features, including Bonito Lava Flow, which made the district attractive for Apollo astrogeology training. Common geologic features surrounding the district include volcanic cinder cones, basaltic a'a lava flows[2], red and black cinder fields and volcanic bombs. Vegetation generally consists of ponderosa pine and apache plume shrubs. The historic district includes nine Apollo testing and training sites: the Northern Bonito Flow Test Area, Cinder Lake Crater Field One, Cinder Lake Crater Field Two (non-contributing), and six Apollo 17 training sites used during simulated extravehicular activity (EVA) simulations from November 2-3, 1972. Five of the nine sites are located wholly or partially within the boundaries of Sunset Crater Volcano National Monument (SUCR). The remaining sites are within the Coconino National Forest. The district as a whole is being considered under Criterion A and retains a high degree of historical integrity.

The essential physical features of the district include natural geological formations, sampled rocks, fabricated craters and an access road. Important geological features include basalt a'a lava flows, volcanic bombs, lava domes and cones, as well as varying cinder cover and color. These geological elements, many of which are related to Sunset Crater Volcano, are an important reason for Apollo astronaut training within the district. These geological features tested the astronauts' field observation skills, sampling techniques, and problem-solving skills. Within the contributing sites, these geological elements are virtually unchanged since the period of significance lending the district a high degree of integrity in regard to location, setting, feeling and association. Sites associated with simulated Apollo 17 EVAs rely primarily on natural features for historical integrity but also include individual sampled boulders and rocks. Geological features, including a nearby a'a lava flow, are essential to the integrity of the Northern Bonito Flow Test Area, but the site also contains fabricated elements including a still-

[1] Lon Abbott and Terri Cook, *Geology Underfoot in Northern Arizona* (Missoula, MT: Mountain Press Publishing Company, 2015), 149.
[2] A'a (pronounced "ah-ah") lava flows are thick and characterized by a broken surface of jagged basalt blocks. See https://www.nps.gov/articles/lava-flows.htm.

visible access road along which various testing and training occurred. The essential physical features of the Cinder Lake crater fields are the size, shape and relative position of the fabricated craters as they relate to the original plan based on Surveyor photos of the lunar surface. Therefore, additional aspects of integrity, namely design, workmanship and materials, are important for these sites. Geology in the form of deep cinder cover remains an important natural element of these sites as it not only provided a blank canvas for the creation of the crater fields but helped to simulate the soil mechanics and vegetation-free lunar landscape. The essential physical features and aspects of integrity discussed above are present and visible throughout the district.

Narrative Description

<u>Northern Bonito Lava Flow Test Area (Contributing)</u>

This site straddles the northern border of Sunset Crater Volcano National Monument and encompasses areas used for Surveyor camera system testing, Apollo 17 astronaut training, lunar hand tool testing, and geological sampling techniques. Three volcanic features define the site geologically: the northern edge of the Bonito Lava Flow, a large lava dome (Darton Dome) and a 100-foot tall cinder cone sandwiched between the two. The southern portion of the site is dominated by a field of jagged black basalt a’a lava largely devoid of vegetation. Moving north, a cinder cone rises from the edge of the a’a flow. This cone is covered by a deep layer of black basalt cinder, the south side of which is mostly barren except for scattered clusters of apache plume shrubs and isolated ponderosa pines. Ponderosa pine cinder woodland covers that northern half of the hill and extends north and east onto Darton Dome. A 1,100-foot access road tracks a northeasterly arc pinched between the base of the cinder cone and the edge of the Bonito Lava Flow (Fig. 1).

The essential physical features of the site from its period of significance (1964-1972) include the road that facilitated access to an otherwise impassable area for vehicles and the geological features that USGS and NASA personnel believed were analogous to the lunar surface and therefore valuable for testing and training. These features include the a’a lava flow used for suited-tests of lunar hand tools and proof of concept geology sampling techniques. Additionally, the cinder cone and adjacent lava flow served as a training site during the November, 1972, Apollo 17 simulated EVA exercise. This site, designated “Station Three” during the EVA allowed astronauts to observe and sample points where the cinder cone contacted Darton Dome to the north and the Bonito Lava Flow to the south (Fig. 2-9).[3] All of these physical features and their associated viewsheds retain integrity of location, setting, feeling, association, and design (in the case of the access road). The site is located in a backcountry area inaccessible to motor vehicles. The portion of the site within the monument, including the entirety of the access road, is closed to the public. Apart from small changes in vegetation and natural erosion, the area appears much as it did fifty years ago. Using historical photographs as a basis of comparison, the site has not been disturbed by logging, OHV-use, wildfire, road-building or any other development. As a result, the historical integrity of the site remains intact.

[3] Schaber, 84-85.

The primary man-made feature of the area is a 1,100-foot access road tracking a northeasterly arc pinched between the base of the cinder hill and the edge of Bonito Lava Flow.[4] In 1964, the USGS Branch of Astrogeology excavated the road from the base of the cinder hill to facilitate access to the Surveyor camera test site.[5] Suited field-testing of geology equipment and sampling procedures took place on the road and nearby lava flow. The site's natural features are virtually unchanged since the period of historical significance. Re-photography shows that much of the vegetation along the road is little changed since the period of significance (Fig. 10-11). Due to erosion and the loose cinder cover, the roadbed is no longer as distinctive but clearly visible east of the SUCR boundary fence.

The surface of the Bonito Lava Flow also played a crucial role in the development and testing of Surveyor's television camera systems between January and October, 1964. Surveyor was a NASA program (June 1966 to January 1968) that sent seven robotic spacecraft to the surface of the Moon to demonstrate the feasibility of soft landings in preparation for the manned Apollo missions. The lava flow was an attractive test site because its barren surface and the reflective characteristics of the basalt rock matched what scientists in 1964 knew about the lunar surface.[6] The Surveyor test site encompasses a ridge of jagged basalt that rises several meters above the surrounding flow and runs northeast through the site. Photographs show that the USGS Branch of Astrogeology placed the Surveyor test camera atop this rocky prominence for some of the tests (Fig. 12-13). During the period of significance, the site was connected to the aforementioned access road by a north-south running wooden walkway elevated above the jagged lava by pylons (Figs. 14-15). The eastern terminus of the walkway was connected to a steel tram (not visible in historic photographs) that facilitated access to the test site. No remnants of the walkway or other manmade materials remain at the site.[7] Per an agreement with the National Park Service, USGS personnel removed the walkway and cleaned up the area after the conclusion of testing.[8] The site retains a high degree of historical integrity due to its remote and inaccessible location. The natural features that made the area attractive as a test site remain undisturbed since the period of significance.

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[4] The unnamed cinder hill may be one of O'Leary Peak's rhyodacite porphyry domes.

[5] Schaber, 84.

[6] Don E. Wilhelms, *To a Rocky Moon: A Geologist's History of Lunar Exploration* (Tucson: University of Arizona Press, 1993), 81-82; U.S. Department of the Interior, U.S. Geological Survey, *The U.S. Geological Survey, Branch of Astrogeology—A Chronology of Activities from Conception through the End of Project Apollo (1960-1973)*, by Gerald G. Schaber, open-file report, U.S. Geological Survey, 2005-1190 (Virginia, 2005), 83-85. Hereafter, this report is cited using the author's last name.

[7] Schaber, 84-85.

[8] Leslie P. Arnberger, Assistant Regional Director, Resource Planning to Director, "Special Use Permit SUCR-1-63, U.S.G.S., Branch of Astrogeology, Sunset Crater," January 14, 1964, SUCR Administration, Box L21, Folder SUCR 24.6, Colton Research Center, Museum of Northern Arizona, Flagstaff, Arizona. See also Russell L. Mahan, Superintendent, Wupatki-Sunset Crater to Regional Director, Southwest Region, "Use of Sunset Crater by Astrogeology Branch, U.S.G.S.," May 5, 1964, SUCR Administration, Box L21, Folder SUCR 24.6, Colton Research Center, Museum of Northern Arizona, Flagstaff, Arizona.

USGS Crater Field One (Contributing)

The three key objectives of the USGS during the Apollo program were to: 1) plan geological traverses 2) establish procedures for the geological traverses 3) develop facilities and methods for gathering information obtained from the traverses and communicating with astronauts during lunar exploration. In order to support these objectives, USGS built two simulated crater fields on the flats of Cinder Lake, a level area of loose cinder and ash located ten miles northeast of Flagstaff, Arizona in the Coconino National Forest and three miles south of Sunset Crater Volcano National Monument. Cinder Lake is a flat plain of loose cinder, the most recent deposit of which was produced by the eruption of Sunset Crater around 1080 CE. Cinder hills and cones rise above the plain to the north, east and south. The edge of the "lake" is ringed on all sides by ponderosa pine.[9]

USGS chose the area because of its anticipated similarity to the lunar surface. Early Apollo landing sites were located in lunar maria, generally flat terrain covered with impact craters of various sizes. The surface of these maria are characterized by soft debris atop consolidated rock. Cinder Lake's flat topography, soft cinder cover and sparse vegetation approximated the lunar maria. Cinder Lake's close proximity to Flagstaff and the temperate climate of Northern Arizona were also advantageous. USGS created two lunar crater fields in 1967 and 1968; both were replicas of areas within the NASA-designated landing site II-P-6-1, identified by Lunar Orbiter II and V photographs, in Mare Tranquillitatis. Using high-resolution imagery from Orbiter II, USGS staff determined the position and size of the lunar craters at II-P-6-1, allowing for a recreation of the surface at the two Cinder Lake crater fields.[10]

Located in the southeastern corner of Cinder Lake east of Flagstaff, Crater Field One was constructed by the USGS in July and October, 1967. Staff with the branch of Surface Planetary Exploration (SPE) based in Flagstaff and Geologist Norman G. "Red" Bailey directed construction of the field. In order to determine the appropriate size of charge and burial depth needed to recreate the entire crater field, Bailey and his team blasted test holes near the 1967 site. Once the formula had been worked out, Bailey's team created the original 500 by 500 foot site by blasting 47 craters, ranging from 5 to 40 feet in diameter from July 28-31, 1967. USGS blasted another ninety-six craters from October 3-12, 1967, bringing the final size of the field to 800 by 800 feet. During the first construction phase, all blast holes were dug by hand while the final ninety-six were excavated using a backhoe. Each crater was blasted individually using electric blasting caps and combination of Nitro-Carbo-Nitrate and dynamite.[11] In its final state, Crater Field One contained 143 craters ranging in size from five to fifty-eight feet in diameter. The largest of these required over 1600 pounds of explosives detonated at a depth of twelve feet to excavate (Fig. 16-19).[12] Bailey later burned off all vegetation on the crater field to create a

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[9] N.G. Bailey, G.W. Colton and Ivo Lucchitta, "Simulated Lunar Crater Fields Near Flagstaff, Arizona – Their Geology, Preparation, and Uses," *Geological Survey Research*, 1969, pp. 172-173. Hereafter cited as, "Bailey"

[10] Bailey, 173, 175.

[11] Nitro-Carbo-Nitrate is composed of ammonium nitrate fertilizer mixed with fuel oil. The smallest craters were blasted using only dynamite. See Bailey, 175.

[12] Bailey, 175; Acting Chief Branch of Astrogeology to Assistant Chief Geologist for Engineering Geology, Monthly Report for Director and Secretary, Geological Survey, Center of

more realistic facsimile of the lunar surface.[13] To further enhance the realism of the site, Bailey's team oriented the crater field so that sun angles and shadows were the same as those on the Moon.[14] The presence of conspicuous rocks on the field suggests that Crater Field One may have been "salted" with a variety of geological samples for astronaut training although documentary evidence for this is lacking (Fig. 20).[15] The end result of these efforts was a remarkable one-to-one scale facsimile of an area photographed by Orbiter II (Fig. 21-22). Crater Field One includes a number of features meant to simulate the lunar surface including "single-rimmed and double-rimmed craters" varying in diameter from ten to fifty feet. Additionally, the site includes "superimposed ejecta blankets and secondary-crater ray patterns" similar to lunar features.[16]

The essential physical features of the site include the relief and relative position of the craters as well as the lunar module (LM) ramp. Other important features include crater ejecta – used in astronaut training – and the flat barren cinder-covered terrain. Each of these physical features are still distinctly visible lending the site a high degree of historical integrity. The location of the crater field is unchanged and its overall design is still evident. The deep layer of flat black cinder that made the site desirable as a training site and facsimile of the lunar surface remains. Natural erosion is evident at the site but the spatial relationship between the craters as well as their varying size and depth are still readily apparent. The feeling of the site and its association with astronaut training remains palpable and tangible. Views of the surrounding cinder hills and ponderosa forest remain unchanged. Crater Field One also conveys the workmanship and precision required to produce such an accurate facsimile of the lunar surface. This attention to detail is evident in the symmetry of the large craters and presence of very small craters that USGS created to make the site as accurate as possible to the lunar surface (Fig. 23-24).

Since the period of significance ponderosa pine and shrubs have recolonized parts of the crater field, however, the visibility of the craters has not been significantly impacted (Fig 25-26). The site lies outside the Cinder Hills Off-Highway Vehicle Area and is separated from the more heavily used northern portion of Cinder Lake by ponderosa pine forest. There have been reports of OHV-users breaking through the fences and driving through the site, however, there is little evidence of such activity today.[17] The site is currently protected by a wire fence and signage to prevent vehicle travel on the site (Fig. 27). Historic photos appear to show that at least part of the

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Astrogeology, July 31, 1967, USGS Astrogeology Science Center, Flagstaff, Arizona; Schaber, 182.

[13] Schaber, 205.

[14] Acting Chief, Branch of Astrogeology to Assistant Chief Geologist for Engineering Geology, "Monthly Report for Director and Secretary," July 31, 1967, USGS Astrogeology Science Center, Flagstaff, Arizona.

[15] See Schaber, 205.

[16] Deputy Assistant Chief Geologist for Astrogeology to Assistant Chief Geologist for Engineering Geology, "Monthly Report for Director and Secretary," Geological Survey, Center of Astrogeology, October 30, 1967, USGS Astrogeology Science Center, Flagstaff, Arizona.

[17] Richard C. Kozak, Flagstaff Astrogeology Museum, Draft National Register of Historic Places Form, "Cinder Lake Apollo Astronaut Training Crater Field," December 1, 1999.

site was fenced-off during the period of significance (Fig. 19). It is possible that the area has always been fenced resulting in little OHV travel at the site.[18]

USGS Crater Field Two (Non-Contributing)

Crater Field Two is located in the northern half of Cinder Lake. Red Baily and personnel of the USGS SPE constructed Crater Field Two from July 8-27, 1968. Like Crater Field One, USGS designed the field to replicate a particular piece of the lunar surface, in this case, site II-P-6. USGS used ammonium nitrate fertilizer and dynamite in specific quantities and buried at different depths to blast craters of varying size out of the loose cinder. In order to simulate the different age of lunar craters and the overlapping ejecta produced by meteorite impacts, USGS set off the charges in three waves. The first wave of 354 charges simulated the earliest meteorite impacts. This was followed by sixty-one additional shots to create craters of intermediate age. Personnel blasted the eleven youngest craters last to complete the simulated lunar surface (Fig. 28-32). The construction of the field required 28,650 pounds of ammonium nitrate fertilizer, 1,153 pounds of dynamite, and 40,000 feet of Primacord. After the blasting, Baily burned all vegetation of the field to create a more realistic environment for astronaut training.[19] On January 17, 1969, USGS salted the field with hundreds of rock samples in preparation for simulated Apollo traverses. Bailey, Ivo Lucchitta, J.W. M'Gonigle, E.E. Caddell and B.C. Justus collected and place rock fragments as small as one inch on the crater field to "reflect geological events acting on a specific geologic terrane."[20]

The same loose cinder and sparse vegetation that made Cinder Lake an excellent astronaut training ground also made the area appealing to off-highway vehicle (OHV) users. Throughout its history, USGS personnel and other land managers struggled to keep OHV users out of Crater Field Two. Although USGS fenced-off Crater Field Two on June 19-20, 1968 – presumably to protect the integrity of the site for training—OHV users broke through the fences a few weeks later on July 1, 1968.[21] In August, 1972, Red Bailey talked with Russ Wahmann and George Ulrich about a proposal to preserve the crater fields for posterity.[22] Park Service officials at

[18] Coconino National Forest Plan, United States Forest Service, 1987, 182.
[19] Bailey, 176; Schaber, 205. The placement of charges was supervised by Franklin H. Persee from the U.S. Bureau of Mines. M.J. Grolier of USGS made a detailed study of the Lunar Orbiter II photos which allowed for an accurate recreation of the lunar surface at Cinder Lake. The USGS created a video documenting the construction of Crater Field Two. See USGS, "Mare Tranquillitatis in Flagstaff, Arizona," available from: https://astrogeology.usgs.gov/rpif/videos/making-craters.
[20] Deputy Assistant Chief Geologist for Astrogeology to Assistant Chief Geologist for Engineering Geology, "January Report for Director and Secretary," Geological Survey, Center of Astrogeology, January 31, 1969, USGS Astrogeology Science Center, Flagstaff, Arizona.
[21] Evidence of the fence that originally surrounded the site can be seen in photographs of the Apollo 12 crew training at the site. See *Arizona Daily Sun*, October 11, 1969.
[22] Schaber, 315.

Sunset Crater also supported preservation of the crater fields.[23] Apparently this proposal was never adopted. Given the difficulty that USGS encountered in keeping OHVs out of Crater Field Two, even while it was in use, the integrity of the site was probably compromised soon after the conclusion of Apollo astronaut training.

In 1987, Coconino National Forest included most of Cinder Lake, including Crater Field Two, in newly created Cinder Hills Off-Highway Vehicle Area. The 1987 management plan for the area mentions the need to, "close the astronaut training ground by adding a fence to exclude OHVs." This statement was likely a reference to nearby Crater Field One. Since the establishment of the Cinder Hills OHV Area, thousands of OHVs have used the craters in Crater Field Two as riding features resulting in severe erosion, degradation, and subsequent loss of historical integrity.[24]

Apollo 17, November 2, 1972, EVA2, Mock Lunar Module Site, Bonito Park (Contributing)

The Apollo 17 mock lunar module site is located in Bonito Park, a flat expanse of montane grassland within Coconino National Forest, a quarter mile west of the Sunset Crater Volcano National Monument visitor center. The site is near a small stand of isolated ponderosa pine at the eastern end of the park just south of Forest Road 545 (the Loop Road). A hummocky uplands of ponderosa pine and apache plume surrounds the grassland on three sides. Spectacular views of the San Francisco Peaks Inner Basin are visible to the west. Robinson Mountain and O'Leary Peak rise to the north. The location, setting, feeling, and association of the site are unchanged since the period of significance. Rephotography shows that the viewshed, topographical characteristics, vegetation, and open space of Bonito Park are unchanged since the period of significance (Figs. 33-36). The area is not subject to OHV use, logging, or other human impacts and retains its historical integrity.[25]

Apollo 17, November 2, 1972, EVA2, Station One (Contributing)

Station One extends northeast from the edge of Bonito Park and roughly parallels the eastern slope of Robinson Mountain. The site is characterized by hummock uplands covered with ponderosa pine cinder woodland. The site affords views of multiple volcanic massifs, principally Robinson Mountain and O'Leary Peak. Important geological features within the site for

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[23] Lee Dalton, Supervisory Park Ranger, Sunset Crater to General Superintendent, Navajo Lands Group, "Proposal to Preserve Crater Field as National Historic Landmark," December 21, 1972, SUCR Administration, Box L21, Folder SUCR 24.6, Colton Research Center, Museum of Northern Arizona, Flagstaff, Arizona.

[24] Coconino National Forest Plan, United States Forest Service, 1987, 182.

[25] "Sunset Crater Apollo 17 SIM 11/2-3/72, CDR; LMP (Backup Crew), EVA II," Folder: Sunset Crater Apollo 17 Sim, 11/2-3/72, CPR; LMP (Backup crew) EVAII, n.d. (11/72?), Box 7, Testing and Training Collection, NASA/USGS Astrogeology Regional Planetary Information Facility, USGS Astrogeology Science Center, Flagstaff, Arizona. Hereafter cited as, "Apollo 17, EVA2, Cuff Checklist, November 2-3, 1972, USGS Astrogeology Science Center, Flagstaff, Arizona"; U.S. Department of the Interior, National Park Service, Vegetation Map, Sunset Crater Volcano National Monument, Arizona (June, 2009), available from https://irma.nps.gov/DataStore/DownloadFile/593753. Hereafter cited as "SUCR Vegetation Map, 2009."

astronaut training include talus at the base of Robison Mountain and various xenoliths. An abandoned Forest Service road runs through the site and parallels the east face of Robinson Mountain. This road leads to Station Two on the edge of the Bonito Lava Flow and may have been used by the astronauts as they traversed the site in the Explorer LRV (Fig. 37- 38). The essential features of the site, included viewsheds of Robinson Mountain and O'Leary Peak and geological points of interest remain unchanged. The site retains the location, setting, feeling and, association from its period of significance.[26]

Apollo 17, November 2, 1972, EVA2, Station Two (Contributing)

This site is located on the northwestern edge of the Bonito Lava Flow just within the SUCR boundary and south of Forest Road 545A. Station Two is characterized by the dramatic transition between hummocky upland and a'a lava flow. The contact point between these two geological formations was the primary reason for its selection as a training site. Geological observation and sampling took place in a small cinder-covered gap in the a'a flow at the center of the site. A large and conspicuous dead ponderosa pine trunk lies horizontal atop the a'a lava at the point where the astronauts sampled the flow. This log is still visible today although parts of the decaying truck have collapsed. Rephotography shows that the natural features of the site are remarkably well-preserved (Fig. 39-45). The only significant alteration in the area is the addition of a wire monument boundary fence that blocks a western approach to the site. In 1972, astronauts approached the site from the west and parked the Explorer LRV at the base of the Bonito Lava Flow. However, the fence does not impact the geological features of the site or significantly detract from the viewshed. The essential physical features of the site, notably the a'a lava and associated natural features are unchanged since the period of significance. The historic appearance of the area, including the vegetation, open space, topographical characteristics and viewsheds are unchanged. The site retains integrity of location, setting, feeling, and association.[27]

Apollo 17, November 2, 1972, EVA2, Station Four (Contributing)

Station Four is located at the northwest base of Sunset Crater. This geographically complex area sits at the origin point of the Bonito Lava Flow. Sparse cinder hills extend to the north while Sunset Crater rises 1000 feet to the south. This site allowed astronauts to observe, sample and photograph several different lava flows as well as their contact points. The station sits close to the Loop Road as it winds its way along the base of Sunset Crater. The essential physical features of the site are natural/geological and include the base of Sunset Crater, the origin point of the Bonito Lava Flow, and the cinder cover to the north and east. These features remain visible and undisturbed lending the site a high degree of historical integrity (Fig. 46-47).[28]

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[26] Apollo 17, EVA2, Cuff Checklist, November 2-3, 1972, USGS Astrogeology Science Center, Flagstaff, Arizona; SUCR Vegetation Map, 2009; U.S. Department of the Interior, National Park Service, Geologic Map, Sunset Crater Volcano National Monument, Arizona (September, 2005), available from https://irma.nps.gov/DataStore/DownloadFile/598130. Hereafter cited as "SUCR Geologic Map, 2005."
[27] Ibid.
[28] Apollo 17, EVA2, Cuff Checklist, November 2-3, 1972, USGS Astrogeology Science Center, Flagstaff, Arizona; SUCR Vegetation Map, 2009; SUCR Geologic Map, 2005.

Apollo 17, November 2-3, 1972, EVA 2 and 3, Station Five (Contributing)

Station Five, part of the Apollo 17 EVA simulation on November 3, 1972, is located between Sunset Crater to the north and a line of unnamed cinder hills to the south. The area is topographically varied. Standing at the center of the site on Forest Road 776, which roughly bisects the location east to west, one can see the Sunset Crater cinder cone rising close to 1,000 feet to the north. To the south an unnamed cinder hill rises nearly 500 feet. The landscape is predominately ponderosa pine and apache plume woodland growing atop a blanket of fresh black basaltic cinder from the eruption of Sunset Crater in the 1080s. The area is geologically unique due to the presence of a parasitic lava flow that emerged from the southeast flank of the Sunset Crater cinder cone, a process that layered red cinder atop the predominately black basalt (Fig. 48).[29]

The geological characteristics of Station Five made it the highest priority site for the simulated Apollo 17 EVA with Eugene Cernan and Harrison Schmitt. Originally, USGS had planned to use Lennox Crater as a test site but this was abandoned because it lacked instructive geological characteristics for astronaut training. The presence of young cinder cone ejecta, fumarole sampling, and lineation features (stretched rocks) made the area geologically attractive. Additionally, the astronauts could make a real-world test of the gravimeter to determine lineaments near Sunset Crater. The site also provided an opportunity to document variations of texture and color in splatter as well as volcanic bombs of varying size and shape. These features made the site attractive for Apollo 17 astronauts whose scientific mission included sampling volcanic material in the Moon's Taurus-Littrow valley.[30]

The essential physical features of the site – parasitic lava flow, overlapping red and black cinder, and volcanic bombs -- remain virtually undisturbed on the northern half of the site. Rephotography confirms the remarkable preservation of natural features and viewsheds in this area (Fig. 49-50). This site extends from the base of Sunset Crater to the edge of the current alignment of Forest Road 776. This area is largely protected by a US Forest Service, Coconino National Forest-easement fence running east-west that parallels the SUCR boundary roughly 50 yards to the north. As a result, this area retains a high degree of historical integrity and has not been damaged by off-highway vehicles from the adjacent Cinder Hills OHV area. Within this protected area, the remnants of an abandoned road alignment can still be seen. This may represent the alignment of Forest Service road 776 at the time of the Apollo 17 astronaut training.

[29] "EVA Plan Apollo 17, Flagstaff Sim EVA 3, Nov.2, 1972," Testing and Training Collection, Box 7, Folder: EVA Plan, Apollo 17, Flagstaff Sim, EVA 3, 11/72, NASA/USGS Astrogeology Regional Planetary Information Facility, USGS Astrogeology Science Center, Flagstaff, Arizona. Hereafter cited as, "Apollo 17, EVA3, Cuff Checklist, November 2-3, 1972, USGS Astrogeology Science Center, Flagstaff, Arizona"; SUCR Vegetation Map, 2009; SUCR Geologic Map, 2005.

[30] Apollo 17, EVA3, Cuff Checklist, November 2-3, 1972, USGS Astrogeology Science Center, Flagstaff, Arizona.

The southern half of the test site has seen extensive use by OHV users. Significant ground disturbance and erosion is and the landscape no longer retains its original geological features and appearance from the period of significance (Fig. 51). Additionally, there are indications that Forest Service road 776 was realigned and resurfaced since 1972, further degrading the integrity of the area.

Apollo 17, November 2-3, 1972, EVA 2 and 3, Station Six (Contributing)

Located on the southern boundary of SUCR, the Apollo 17 Station Six straddles the SUCR boundary on the southern edge of the Bonito Lava Flow. The secluded site is topographically and geologically distinct. Looking north from Station Six, a largely barren basalt a'a flow makes a gentle arc northwest. This portion of the Bonito Lava Flow is bordered on two sides by a half cinder cone rising 100-300 feet above the surface of the flow (Fig. 52). This cinder cone partially obstructs the view of Sunset Crater to the east. A sparse, ponderosa pine/apache plume woodland, skirts the southern edge of the jagged lava flow. Here, powdery basaltic cinder, reminiscent of the lunar surface, is present along with volcanic bombs. A much older (Tappan age) basalt flow, distinct from the Sunset Crater eruption, borders the southwestern edge of the Bonito Flow. To the southeast, cinder slopes rise to meet Forest Service road 776. Enclosed on three sides by cinder hills, Station Six is secluded from the surrounding landscape (Fig. 53). Despite its close proximity to Forest Service road 776, the site is not visible from the road.

USGS selected Station Six as a testing site because it afforded excellent views and sampling of an isolated young basalt flow. From the site, astronauts Eugene A. Cernan and Harrison H. Schmitt could determine the source and structure of the a'a flow as well as observe mantle variation, volcanic bombs and the distinctive half cone. Astronauts also documented splatter varieties on the flow and compared them with samples from the northern portion of the Bonito Flow.[31]

The essential physical features of the site include the a'a lava flow, half cinder cone, and various volcanic bombs. These volcanic features and associated viewsheds are unchanged since the period of significance (Fig. 54-55). The site is currently protected by a USFS Coconino National Forest easement fence skirting Forest Road 776. As a result of this fence, the site is lightly trafficked and not subject to OHV use. The only significant manmade feature in the site is the SUCR boundary fence that terminates on the eastern edge of the lava flow. Two metal posts a few yards from the SUCR boundary fence may represent the remains of an old sign. Some modern debris has accumulated along the edge of the flow but these items were likely blow down to the site from Forest Road 776.

[31] Apollo 17, EVA3, Cuff Checklist, November 2-3, 1972, USGS Astrogeology Science Center, Flagstaff, Arizona; Apollo 17, EVA2, Cuff Checklist, November 2-3, 1972, USGS Astrogeology Science Center, Flagstaff, Arizona; SUCR Vegetation Map, 2009

8. Statement of Significance

Applicable National Register Criteria
(Mark "x" in one or more boxes for the criteria qualifying the property for National Register listing.)

- [X] A. Property is associated with events that have made a significant contribution to the broad patterns of our history.
- [ ] B. Property is associated with the lives of persons significant in our past.
- [ ] C. Property embodies the distinctive characteristics of a type, period, or method of construction or represents the work of a master, or possesses high artistic values, or represents a significant and distinguishable entity whose components lack individual distinction.
- [ ] D. Property has yielded, or is likely to yield, information important in prehistory or history.

Criteria Considerations
(Mark "x" in all the boxes that apply.)

- [ ] A. Owned by a religious institution or used for religious purposes
- [ ] B. Removed from its original location
- [ ] C. A birthplace or grave
- [ ] D. A cemetery
- [ ] E. A reconstructed building, object, or structure
- [ ] F. A commemorative property
- [X] G. Less than 50 years old or achieving significance within the past 50 years

Areas of Significance
(Enter categories from instructions.)

Science
Exploration
Invention

Period of Significance

1963 - 1972

Significant Dates

Significant Person
(Complete only if Criterion B is marked above.)

Cultural Affiliation

Architect/Builder

Statement of Significance Summary Paragraph

The Sunset Crater – Cinder Lake Apollo Mission Testing and Training Historic District is significant at the national level under Criterion A in the areas of science, exploration and invention for their importance in Apollo program astronaut training and equipment testing as well as the Surveyor project. Because of the property's exceptional importance for lunar science and exploration, district resources that achieved significance within the past fifty years meet Criterion Consideration G. Between 1963 and 1972, astronaut training, equipment tests, and simulated lunar exploration occurred in Sunset Crater Volcano National Monument (SUCR) and the surrounding Coconino National Forest. The testing and development of camera equipment, geological tools and lunar rover prototypes on the Bonito Lava Flow and nearby Cinder Lake makes the test sites significant in the area of invention. The first Apollo astronaut geology field training on January 16-17, 1963, took place at SUCR and served as the impetus for the creation of a formal geology-training program. In subsequent years, all twelve Apollo astronauts that walked on the moon trained in and around SUCR. Simulated geologic traverses, also known as extravehicular activities (EVAs), for Apollo 12, 15 and 17 crews also took place within the district. During these simulated missions, crews honed their geologic observation and sampling skills while sticking to a rigid timeline. They also practiced the deployment of scientific experiments and mastered photographic techniques all while in communication with the mission CAPCOM (Capsule Communicator) and support personnel. These exercises contributed directly to lunar exploration and scientific discovery. For these reasons the district is significant in the areas of invention, science, and exploration.

Narrative Statement of Significance

This section is divided into four subsections, each detailing a different aspect of the district's significance including astronaut geology field training, simulated geological traverses with Apollo crew, testing of lunar geology tools and lunar exploration studies, and equipment testing for NASA's Surveyor program. Because these activities do not fit neatly into one area of significance, the nomination addresses the relevant criteria (science, exploration, and invention) within each section.

Apollo Astronaut Geology Field Training

Because of its role in geology training for all Apollo astronauts, the district is nationally significant in the area of science. The Sunset Crater area was one of two sites, the other being Meteor Crater, selected by Eugene Shoemaker for the first Apollo astronaut geology field training exercise from January 16-17, 1963. During this training astronauts Neil A. Armstrong, Frank F. Borman, Charles "Pete" Conrad Jr., James A. Lovell Jr., James A. McDivitt, Elliot M. See Jr., Thomas P. Stafford, Edward H. White, and John W. Young visited SUCR and received instruction from Eugene Shoemaker—head of the USGS Branch of Astrogeology—on the formation of circular geological features. According to E.D. Jackson, a USGS geologist who helped develop the geology training program for Apollo astronauts, the purpose of these early fieldtrips was to "emphasize the diversity of origin of circular structures on Earth, and to emphasize criteria by which the origin of similar structures on the Moon could be deduced." At night the astronauts observed the Moon through telescopes at Lowell Observatory, the U.S. Naval Observatory and Arizona State College (Northern Arizona University) in Flagstaff. The training helped astronauts distinguish between volcanic and impact craters on the Moon. The astronauts reacted positively to Shoemaker's training and provided further impetus for the creation of a formal geology training program which was established in February, 1964.[32]

The USGS-led geology training program would expand in scope over the years but initially it focused on familiarizing astronauts with lunar terrain and geological observation so they could understand landing site selection, locate themselves when hovering in the lunar excursion module (LEM), and accomplish the Apollo missions' scientific objectives. To this end, the Apollo astronauts returned to the Flagstaff area in April and May, 1964 to observe the Moon from Kitt Peak, survey the San Francisco Volcano Field from the air, and conduct field training at Sunset Crater Volcano National Monument (SUCR). Trip leaders D.E. Wilhelms, E.D. Jackson and A.H. Chidester divided the astronauts into five teams. The first three teams including astronauts Edwin E. "Buzz" Aldrin, Eugene A. Cernan, and others completed their training April 29 to May 2, 1964. The final two teams, including astronauts Virgil I. "Gus" Grissom and Neil A. Armstrong, conducted the training between May 20 and May 22, 1964.[33] During the field exercises at SUCR, the astronauts studied the volcanic features of the area and attempted to map the complex stratigraphy of cinder cover and lava flows around Sunset Crater on large photographs. The astronauts practiced identifying the sequence of lava flows in the monument and locating themselves on a map using a mirror stereoscope. According to E.D. Jackson, the astronauts "showed considerable improvement in locating themselves precisely on the ground using stereoptic photography" (Fig. 56-58).[34]

Astronauts from the Apollo 14 crew including Al Shepard, Ed Mitchell and backup Lunar Module pilot Joe Engle undertook a geologic training exercise at the Cinder Lake crater fields on August 14, 1969.[35] The astronauts examined sixteen of the artificial craters to study how the age

[32] *Arizona Daily Sun*, January 17, 1963; E.D. Jackson, "Early Terrestrial Geology and Geophysics Training," Testing and Training Collection, Box 7, Folder: Geology Field Trips-Pre Mission, n.d. (1975), NASA/USGS Astrogeology Regional Planetary Information Facility, USGS Astrogeology Science Center, Flagstaff, Arizona. Hereafter this source is cited using the author's last name.

[33] The following is a list of all Apollo astronauts who participated in geology training in April and May, 1964 at SUCR. See Jackson, Table 4. Team 1: E.E. Aldrin, C.A. Bassett, R.B. Chaffee, Michael Collins, R.F. Gordon, D.R. Scott. Team 2: Frank Borman, E.A. Cernan, D.F. Eisele, T.C. Freeman, C.C. Williams. Team 3: W.A. Anders, A.L. Bean, R.W. Cunningham, J.A. McDivitt, R.L. Schweickart, E.M. See. Team 4: M.S. Carpenter, L.G. Cooper, W.M. Schirra, A.B. Shepard, T.P. Stafford, E.H. White. Team 5: N.A. Armstrong, C.C. Conrad, V.I. Grissom, J.A. Lovell, D.K. Slayton, J.W. Young.

[34] Jackson, 4-9, Table 4; Russell L. Mahan, "U.S.G.S, Astrogeology Branch Activities, Sunset Crater," July 1, 1964, SUCR Administration Collection, Box L21, Folder: Lunar testing at Sunset Crater 1964, SUCR 24.6, Colton Research Center, Museum of Northern Arizona, Flagstaff, Arizona; Jane Pritchell, "Scientists Here Play Key Apollo Role," *Arizona Daily Sun*, July 15, 1969. Pritchell's article mentions that the Apollo 11 astronauts participated in "simulated missions" at SUCR but the author was unable to find any additional sources to corroborate this assertion.

[35] Unfortunately, USGS, NASA and other involved personnel did not always make a distinction between Crater Field One and Crater Field Two. In many cases, primary and secondary sources

of ejecta on crater rims increased with the depth of the crater. The astronauts also studied the principle of inverted stratigraphy—the age of the rocks on the exterior crater rim get younger the further down one goes. The astronauts used these principles to identify the origin of ejected rocks and work out the relative age of craters.[36] This training related directly to later lunar exploration conducted by Al Shepard and Ed Mitchell in the Fra Mauro formation on the moon. One of the main scientific objectives of the Apollo 14 mission was to explore and date the moon's Cone Crater. Samples revealed that the crater was 25million years old. Impact-melt breccias retrieved from the site also show that parts of the Moon are rich in rare earth elements.[37]

Apollo 15 astronauts David Scott, Jim Irwin and Al Warden participated in field training at Cinder Lake Crater Field One and Meteor Crater on June 4-5, 1970. Also present were the backup crew for the mission that included Jack Schmitt, Dick Gordon and Vance Brand and two Apollo CAPCOMs, Joe Allen and Robert Parker. At both locations, the astronauts studied the geological features of impact craters including ejecta rays and blankets, meteorite fragments, "shocked rocks," and the folding of rim material.[38]

Astronauts David Scott, Jim Irwin, Dick Gordon, Jack Schmitt, J.P. Allen and R.A. Parker returned to Cinder Lake five months later to conduct lunar roving vehicle (LRV) training from November 2-3, 1970. L.T. Silver of Caltech and W.C. Phinney of the Manned Spacecraft Center, assisted by USGS staff from the Center of Astrogeology in Flagstaff ran the exercise. The objective of the exercises, which included LRV traverses at the Cinder Lake crater fields and Merriam Crater, was to familiarize the astronauts with the use of a wheeled vehicle during EVAs. The training also allowed the team to identify problems that could arise in regard to photography and sampling while using an LRV. The test allowed the whole Apollo team to see how craters and boulders would impact a traverse and assess the challenges associated with photographs from the LRV. These astronaut exercises were the first conducted using the USGS-built LRV simulator nicknamed, "Grover" (Fig. 59-60).[39]

This real-world testing provided the astronauts and support crew with valuable information that would be put to use during the Apollo 15 moonwalk. The tests showed that using the LRV in conjunction with lunar hand tools and cameras would require substantial practice. The photography and sampling exercises also revealed the usefulness of 1:25,000 and 1:10,000 scale

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simply make reference to training taking place at "Cinder Lake" or the "Cinder Lake crater field" without distinguishing between the two sites.

[36] Chief, Branch of Astrogeologic Studies to Assistant Chief Geologist for Environmental Geology, "August Report for Director and Secretary," Geological Survey, Center of Astrogeology, August 31, 1969, USGS Astrogeology Science Center, Flagstaff, Arizona; "Impact Cratering Mechanics and Crater Morphology," Lunar and Planetary Institute, available from https://www.lpi.usra.edu/exploration/education/hsResearch/crateringLab/lab/.

[37] David M. Harland, *Exploring the Moon: The Apollo Expeditions* (Chichester, U.K.: Praxis Publishing, 1999), 51-77.

[38] Schaber, 255-56.

[39] Chief, Surface Planetary Exploration Branch to Assistant Chief Geologist for Environmental Geology, "Monthly Report for November 1970," Geological Survey, Center of Astrogeology, December 7, 1970, USGS Astrogeology Science Center, Flagstaff, Arizona; Schaber, 266-67.

photo maps.[40] This training was significant because it contributed to Dave Scott and Jim Irwin's successful use of the LRV during a series of EVAs on the lunar surface between July 30 and August 2nd, 1971 (Fig. 62-63). These lunar surveys covered a total distance of over 25 km, far greater than any previous mission. The astronauts also recovered over 76 kg of samples, including the famous Genesis Rock, almost double the amount collected by Apollo 14. The Genesis Rock, part of the ancient lunar crust, allowed scientists to date the Moon to around 4.5 billion years old. This discovery revealed that the moon's surface is very ancient and had not changed much over the past 3 billion years. As a result, the Moon provided key insights into the early history of the solar system and the Earth.[41]

Apollo 16 astronauts John W. Young, Charles M. Duke, Fred W. Haise, G.P. Carr and W.R. Pogue participated in geologic training at Cinder Lake Crater Field One and Two from September 1-2, 1970, during a broader survey of the Eastern San Francisco Volcanic Field. The training was led by T.R. McGetchin of M.I.T. assisted by Frederick Horz and A.W. England of MSC and R.L. Sutton of the USGS SPE branch.[42]

Apollo Astronaut Simulated Geological Traverses

The district is also nationally significant in the areas of exploration and science for its role in simulated geological traverses, or EVAs (extra-vehicular activities), for the Apollo 12, 16 and 17 missions. At least one simulated geological traverse ran through each of the nine sites in the district. Unlike the field training described above, these EVA simulations were dry runs of the geological traverses that took place on the Moon. As such, they included planned routes, time constraints, and geological objectives. The astronauts wore mock Personal Life Support Systems (PLSS) and were in radio communication with the mission CAPCOM and support personnel at Mission Control in Houston. These simulations tested the astronauts' geological observation, description, and problem-solving skills.

The first simulated geological traverse within the district occurred October 9-10, 1969, for Apollo 12 astronauts at the Cinder Lake crater fields. This simulation occurred a little over a month before the Apollo 12 astronauts conducted their moonwalk on November 19-20, 1969. The simulation involved the entire Apollo 12 crew including Dick Gordon, Pete Conrad and Al Bean. Additionally, Ed Gibson, who served as the EVA CAPCOM for the moonwalk was involved in the test.[43] On October 9th, Gibson conducted a dry-run to prepare for the simulation.

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[40] Ibid.

[41] Harland, 79, 133, 176-77, 359; Donald A. Beattie, *Taking Science to the Moon: Lunar Experiments and the Apollo Program* (Baltimore: John Hopkins University Press, 2001), 269; "Apollo 15," Smithsonian National Air and Space Museum, available from https://airandspace.si.edu/explore-and-learn/topics/apollo/apollo-program/landing-missions/apollo15.cfm.

[42] Chief, Surface Planetary Exploration Branch to Assistant Chief Geologist for Environmental Geology, "Monthly Report for September 1970," Geological Survey, Center of Astrogeology, September 30, 1970, USGS Astrogeology Science Center, Flagstaff, Arizona; Schaber, 260-61. According to Schaber, this trip included a visit to the Cinder Lake crater fields.

[43] Harland, 39; Don E. Wilhelms, *To a Rocky Moon: A Geologist's History of Lunar Exploration* (Tucson: University of Arizona Press, 1993), 217.

The following day, Conrad, Bean, Gordon and their backup crew discussed various problems associated with the geology of craters with USGS geologists at the monument. They also discussed "sampling and photo techniques and verbal descriptions," that would be used during the moonwalk. In the afternoon, the astronauts performed a two-hour simulated lunar geological traverse while in voice contact with Mission Control in Houston. The Science Support Room personnel who aided the moonwalk were also involved in the simulation.[44] The simulation and training at Cinder Lake prepared the Apollo 12 crew for the first true geological traverse in the Ocean of Storms the following month.[45] The samples taken by Conrad and Bean during their moonwalk had tremendous implications for lunar science. First and foremost, the rocks showed that the Moon contained a hot mantle similar to Earth and that volcanic activity had shaped it for billions of years.[46]

The next simulated geological traverse at the Cinder Lake crater fields took place on March 30, 1971. This exercise involved Apollo 16 moonwalkers John W. Young and Charles M. Duke as well as other key mission personnel. The exercise was part of a two-day trip to the San Francisco volcanic field that included a simulated traverse at Merriam Crater. During the traverse at Cinder Lake, the astronauts focused on geological problems associated with crater, block field, and regolith stratigraphy. Young and Duke piloted the simulated roving vehicle (LRV) Grover while backup crew commander Fred W. Haise simultaneously drove the Explorer LRV with mission scientist Anthony "Tony" England who served as CAPCOM for the Apollo 16 lunar EVAs. Members of the USGS Surface Planetary Exploration Branch (SPE) in Flagstaff provided real-time mission support for the Cinder Lake exercise. During and after the traverse, SPE personnel including Ivo Lucchitta monitored and evaluated the astronauts' performance along with geologists from the Manned Spacecraft Center (MSC) in Houston, Texas. During the simulated EVA, Duke and Young practiced many of the activities—including the use of a remote controlled TV camera on the LRV—which they would later perform on the Moon in April, 1972.[47]

The district contributes directly to the scientific discoveries and lunar exploration conducted by Apollo 17 astronauts Eugene Cernan and Harrison Schmitt during their moonwalk through the Taurus-Littrow valley in December, 1972. On November 2-3, 1972, the Apollo 17 prime and backup crews performed simulated EVAs in and around Sunset Crater. This was the final field exercise conducted by Cernan and Schmitt before they walked on the moon a little over a month later. There were two EVAs, one on November 2nd with the backup crew consisting of Apollo 16 astronauts John Young and Charlie Duke, and a second exercise the following day with the prime crew.[48] According to a National Park Service press release, "the purposes of the exercises

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[44] National Aeronautics and Space Administration, *Science Training History of the Apollo Astronauts*, by William C. Phinney, Special Publication, Lyndon B. Johnson Space Center (Houston, 2015), 234. Hereafter this source is cited using the author's last name.
[45] "Apollo 12, The Pinpoint Mission," *National Aeronautics and Space Administration,* July 8, 2009, https://www.nasa.gov/mission_pages/apollo/missions/apollo12.html.
[46] Harland, 49.
[47] Chief, Surface Planetary Exploration Branch to Assistant Chief Geologist for Environmental Geology, "Monthly Report for March 1971," Geological Survey, Center of Astrogeology, March 31, 1971, USGS Astrogeology Science Center, Flagstaff, Arizona; Harland, 185.
[48] Phinney, 130, 255.

were to train and familiarize the astronauts in the use of lunar vehicles and to expose them to a hostile and barren landscape similar to the type they would encounter on the moon."[49] The scientific mission for Apollo 17 included the search for evidence of recent lunar volcanism, consider by some to be the "holy grail of lunar geology."[50] The young volcanic formations in and around SUCR made it an ideal location to train astronauts bound for Taurus-Littrow.

The first traverse, on November 2, 1972, started on the east end of Bonito Park, just outside the west entrance of SUCR with the backup crew, but probably included participation from Cernan and Schmitt in some capacity.[51] Astronauts John Young and Charlie Duke began the exercise in a simulated LM and the proceeded northeast towards the base of Robinson Mountain (Fig. 33, 35). At Station One, the crew deployed the Traverse Gravimeter Experiment (TGE), observed the Robinson and O'Leary Massif, sampled volcanic vents, and took panoramas of the area. From there, the crew traveled to the northern edge of the Bonito Lava Flow. Here, at Station Two, the crew observed variations in the Bonito Flow and hummocky uplands, compared the mantle to that found at Station One and collected samples at the edge of the flow (Fig. 39, 42, 44). At Station Three, just north of the Bonito Flow atop a cinder hill overlooking the 1964 Surveyor Test Site, the crew observed the O'Leary Massif and variations in the Bonito Flow. Young and Duke then sampled the a'a flow and boulders at the base of Darton Dome further east (Fig. 2,4,6, 8). From here the astronauts followed the edge of the lava south to the northern base of Sunset Crater. Here the crew observed and documented a series of overlapping lava flows in addition to taking TGE readings. Duke and Young then proceeded south around the eastern flank of Sunset Crater and documented a parasitic lava flow there and variations in the cinder cover. On the south edge of Sunset Crater, Station Five, the crew observed bombs, talus and attempted to determine the age of various lava flows. At Station Six, on the southern portion of the Bonito Lava Flow, the crew sampled, observed and cored geological features including the a'a lava found there. From this point, Duke and Young travelled to the southern base of Lenox Crater and then returned north to the mock LM at Bonito Park.[52]

This first traverse covered about 20km and took over five hours to complete. In the process, Duke and Young circumnavigated almost the entirety of SUCR. During the exercise, the crew

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[49] "Sunset Crater National Monument, Press Release," December 8, 1972, SUCR Administration Collection, Box L21, Folder: News and Press Releases, 1961-Present, SUCR 24.4, Colton Research Center, Museum of Northern Arizona, Flagstaff, Arizona.
[50] Harland, 242, 246.
[51] Phinney, 255. Although there were only two EVAs near SUCR, the archival records refers to the first EVA as "EVA2" and the second, involved Cernan and Schmitt as "EVA3". Phinney states that the backup crew only participated in the second traverse (EVA3), but this conflicts with evidence obtained from the USGS archive. The cuff checklists and maps, along with historic photographs from both exercises, indicate that the backup crew ran the first exercise (EVA2) on November 2nd followed by a revised EVA3 with the prime crew on November 3rd. See folder "Sunset Crater Apollo 17 Sim, 11/2-3/72, CPR; LMP (Backup crew) EVAII, n.d. (11/72?)" Box 7, Testing and Training Collection, USGS Astrogeology Center, Flagstaff, Arizona.
[52] Apollo 17, EVA2, Cuff Checklist, November 2-3, 1972, USGS Astrogeology Science Center, Flagstaff, Arizona

was in radio contact with the CAPCOM and other support teams in Houston that would be present during the actual moonwalk.[53]

The following day, Eugene Cernan and Harrison Schmitt started the second EVA at a mock lunar module (LM) on the northern edge of Cinder Lake and proceeded to six different stations including Cinder Lake Crater Field Two and Stations Five and Six (described above) that straddle the southern boundary of SUCR. As with the previous traverse, the astronauts were in radio contact with the CAPCOM and science back room in Houston for the exercise. The astronauts spent one hour at Station Five and another 25 minutes at Station Six.[54] In total, the EVA covered 12.75km and took six hours to complete. To cover this distance, Cernan and Schmitt drove the Lunar Roving Vehicle 1-G simulator ("Grover") to the various stations (Fig. 64). The astronauts deployed scientific instruments during the simulation that were later used on the Moon including the Lunar Traverse Gravimeter, Lunar Seismic Profiling and Surface Electric Properties experiments.[55] Cernan and Schmitt also practiced geologic sampling techniques including coring, trenching, raking, sampling and descriptions of rocks and landforms.[56] At Stations Five and Six, the astronauts deployed the Lunar Traverse Gravimeter, took core samples and described geological features including volcanic bombs, parasite flows and splatter variation (Fig. 49, 54). The training also included determining the source and sequence of various flows, including the isolated a'a flow on the southern edge of the Bonito Lava Flow. The astronauts also practiced taking panoramic shots of the landscape with their chest-mounted cameras.[57] Norman Bailey, a technician at the USGS Astrogeology Center in Flagstaff called the November 2nd EVA simulation at SUCR the most successful of the entire Apollo program.[58]

Six sites within the district derive their significance solely from their association with Apollo 17 simulated geological traverses on November 2-3, 1972, and achieved significance within the past fifty years. These sites include EVA Stations One through Six and the EVA Lunar Module site. These resources are eligible under Criterion G because of their exceptional importance to the Apollo mission. The training that occurred at these sites contributed directly to achievements in lunar <u>science</u> and <u>exploration</u> in the Taurus-Littrow valley. Cernan and Schmitt spend twenty-three hours exploring 30.5 kilometers of Taurus-Littrow valley and recovered 243 pounds of material. The length of the EVAs, distance traveled, and material recovered were all records for the Apollo program (Fig. 65-67).[59] As described above, simulated geological traverses within the district allowed Cernan and Schmitt to practice geological sampling, LRV navigation, and

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53 Phinney, 255.
54 Apollo 17, EVA3, Cuff Checklist, November 2-3, 1972, USGS Astrogeology Science Center, Flagstaff, Arizona.
55 Phinney, 255; Harland, 260, 264.
56 Phinney, 255.
57 Apollo 17, EVA3, Cuff Checklist, November 2-3, 1972, USGS Astrogeology Science Center, Flagstaff, Arizona.
58 "Sunset Crater National Monument, Press Release," December 8, 1972, SUCR Administration Collection, Box L21, Folder: News and Press Releases, 1961-Present, SUCR 24.4, Colton Research Center, Museum of Northern Arizona, Flagstaff, Arizona. Hereafter cited "SUCR Press Release, December 8, 1972."
59 Beattie, 248; Harland, 357-360.

the deployment of scientific instruments like the Lunar Traverse Gravimeter Experiment. Similar training of the backup crew occurred at Stations one through six and gave the entire science team invaluable practice in coordinating a real-time simulated moonwalk. Coordination between the astronauts, CAPCOM, and Science Backroom was essential for lunar science. For instance, Schmitt's exciting discovery of orange soil on the Moon required effective communication between the astronauts and personnel in Houston.[60]

Astrogeology Equipment Testing and Lunar Exploration Studies

The district is nationally significant in the areas of invention, exploration and science for its association with Apollo mission astrogeology equipment testing and lunar exploration studies conducted by the USGS Branch of Astrogeology at the Cinder Lake crater fields and Northern Bonito Lava Flow Test Area.

Some of the earliest Apollo field testing to determine the feasibility of practicing geology on the Moon took place at the Northern Bonito Lava Flow Test Area on June 15-20, 1964. This test was one of the earliest suited field tests for the Apollo program, taking place two months before similar exercises in Bend, Oregon. There were serious questions at this time about the ability of a fully suited astronaut to conduct meaningful geologic observations and sampling. The exercise was attended by personnel from USGS, the Manned Spacecraft Center in Houston, Texas, and the General Electrodynamics Corporation. During the exercise, test subject Gene Phillippi performed a simulated geological traverse over portions of the Bonito Lava Flow in a pressurized Gemini suit. The test included use of a prototype staff-mounted TV camera and sample collection procedures. During the traverse, the test subject was connected to a nearby support van that handled imagery transmitted from the camera and direct radio communications (Fig. 77-79). This early test helped pave the way for lunar science and exploration.[61]

In addition to the astronaut training described in the previous sections, the Cinder Lake crater fields were an important locus for the testing of hand tools, sampling techniques, and other aspects of lunar exploration and are significant under the criteria of science and exploration.

The first major test at the site in September, 1967, was to determine how quickly astronauts would be able to locate themselves on the lunar surface from the windows of the Lunar Excursion Vehicle (LEM). The location test held at Crater Field One was led by N.G. Bailey and involved twenty-eight test subjects. Each test subject entered a mock LEM positioned at the exact height above the field that the actual spacecraft would be on the Moon. Bailey then gave the test subjects either a 1:25000 or 1:5000 scale Lunar Orbiter photo of site P-6-1—the area the crater field was built to simulate—and tasked them with locating the LEM within the one square kilometer area show in the photo. If the test subject was unable to locate themselves in thirty minutes, they were given a smaller photo, to narrow the search area, and another quarter hour to

[60] Harland, 280-285.
[61] Russell L. Mahan, "U.S.G.S, Astrogeology Branch Activities, Sunset Crater," July 1, 1964, SUCR Administration Collection, Box L21, Folder: Lunar testing at Sunset Crater 1964, SUCR 24.6, Colton Research Center, Museum of Northern Arizona, Flagstaff, Arizona; Beattie, 159-162. See also E.M. Shoemaker to V.R. Wilmarth, "Monthly report for Director and Secretary," June 30, 1964, USGS Astrogeology Science Center, Flagstaff, Arizona.

complete the task. This process continued until the test subject was able to locate the LEM using Lunar Orbiter imagery. The test showed that "with the proper training and experience" astronauts could expect to locate themselves on the lunar surface within thirty minutes if the search area was no larger than one square kilometer. Baily further concluded that in ideal conditions, the astronauts would be able to find themselves within five minutes of landing.[62]

The following month, the USGS Surface Planetary Exploration (SPE) Branch conducted a full simulation of a geological traverse from October, 24-26, 1967 at Crater Field One. This test involved the use of two fully suited test subjects—geologists Tim Hait and David Schleicher. The simulation sought to establish the effectiveness of aerial photographs and maps during a traverse that would include observations from the LM, walking, sampling, photography, radio communication and verbal description of geologic points of interest to a team of geologists in a "data facility trailer," a mock "science backroom." During the test, Hait and Schleicher communicated with the geologists who recorded the descriptions and data provided by the test subjects. The simulation proved the effectiveness of both photographs and annotated geological maps for traverses on the Moon (Fig. 70-74).[63]

The USGS also used test subjects in pressurized suits at the crater fields to better understand the challenges of lunar geology in a simulated environment. These field experiments including determining how well test subjects could handle geological tools and whether prototype lunar hand tools could perform their intended functions. The USGS also tested the impact of helmet visors on the visibility of the landscape as well as maps and other printed material that astronauts might use. Other tests focused on the amount of time necessary to complete various geologic tasks and how well subjects could work as a team, both essential considerations given the limited time available for lunar geology on the Moon and the mobility constraints of the suits.[64]

The Cinder Lake crater fields also played an important role in various other simulations and tool tests for the Apollo missions. In October, 1968, R.M. Batson of the USGS Surface Planetary Exploration Branch used the crater fields to develop photogrammetric techniques (i.e. mapping terrain using photographs) for the Hasselblad cameras astronauts on the Moon. Using one of the crater fields as a test site, Batson demonstrated that the Hasselblad camera was an excellent tool for photograph mapping and was accurate up to seven centimeters.[65] USGS also used the crater

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[62] Deputy Assistant Chief Geologist for Astrogeology to Assistant Chief Geologist for Engineering Geology, "Monthly Report of Director and Secretary," September 29, 1967, USGS Astrogeology Science Center, Flagstaff, Arizona.
[63] Deputy Assistant Chief Geologist for Astrogeology to Assistant Chief Geologist for Engineering Geology, "Monthly Report of the Center of Astrogeology for Directory and Secretary," November 30, 1967, USGS Astrogeology Science Center, Flagstaff, Arizona. The monthly reports do no give a specific date for this exercise. Schaber gives the date as October 24-26, 1967. See also Schaber, 191-92.
[64] Bailey, 178.
[65] Deputy Assistant Chief Geologist for Astrogeology to Assistant Chief Geologist for Engineering Geology, "Monthly Report for Director and Secretary," October 31, 1968, USGS Astrogeology Science Center, Flagstaff, Arizona. As noted elsewhere, USGS did not always distinguish between Crater Field One and Two in monthly reports and other documentation. In regard to the October, 1968, photogrammetric tests, the monthly report simply states that the

fields to "evaluate utility of TV for locating and monitoring astronauts on a foot traverse from the Lunar Landing Module, and its effectiveness in depicting geologic features."[66]

The crater fields also gave USGS the ability to conduct real-world testing of procedures and methods for collecting lunar samples and other geologic data. Rock samples, descriptions and photographic documentation collected at the crater fields were sent to the Lunar Receiving Laboratory in Houston, Texas, to test the procedures that would be used to process lunar material returned by Apollo astronauts. The crater fields also gave USGS the ability to test and develop procedures and methods for the Astrogeologic Data Facility (ADF), a precursor to the Science Backroom that supported the Apollo missions.[67]

The district is also significant in the area of invention because the Cinder Lake crater fields served as a testing ground for several lunar roving vehicle (LRV) designs. Even before the successful Apollo 11 mission, planning had begun to increase the range of lunar exploration with a wheeled vehicle. In 1969, NASA's Office of Manned Space Flight approved the development of an LRV and in July of that year Bendix Aerospace Systems, Grumman Aircraft Engineering, and a joint Boeing-General Motors team submitted bids for the contract. USGS personnel in Flagstaff—who had been advocating for an LRV—were involved in the testing of several prototype LRVs.[68] On September 29-30, 1969, Grumman and Bendix tested competing LRV designs at the Cinder Lake crater fields (Fig. 76). During these field tests, USGS also demonstrated a tracking and range finding device called the Lunar Surveying System.[69]

The simulated LRVs Explorer and Grover were two of the most important tools developed by the USGS Surface Planetary Exploration (SPE) group in Flagstaff to aid astronaut training and the development of other systems and procedures for lunar exploration. R.A. "Putty" Mills, B.G. Tinnin, and I.L. Wiser constructed both vehicles in Flagstaff. The Explorer, built in May, 1967, could accommodate suited astronauts and featured electric steering. The vehicle's four wheel drive and oversized low-pressure tires allowed it to easily traverse cinder-covered slopes and craters.[70] USGS used the Explorer for various equipment tests at the Cinder Lake crater fields (Fig. 69). These included tests of a navigation unit and rubidium vapor magnetometer at the

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"entire Cinder Lake crater field was photographed" despite the fact that two different crater fields were then in existence.

[66] Bailey, 178.

[67] Ibid., 178; Schaber, 203, 208, 214.

[68] Beattie, 150-158.

[69] Chief, Branch of Surface Planetary Exploration to Assistant Chief Geologist for Environmental Geology, "October Report for Director and Secretary," Geological Survey, Center of Astrogeology, October 31, 1969, USGS Astrogeology Science Center, Flagstaff, Arizona; Schaber 233-34. While primary sources do not indicate which crater field was used for the LRV tests, historic photographs suggest the site was Crater Field One.

[70] Acting Chief, Branch of Astrogeology to Assistant Chief Geologist for Engineering Geology, "Monthly Report for Director and Secretary," May 31, 1967, USGS Astrogeology Science Center, Flagstaff, Arizona; Deputy Assistant Chief Geologist for Astrogeology to Assistant Chief Geologist for Engineering Geology, "Monthly Report for Director and Secretary," September 29, 1967, USGS Astrogeology Science Center, Flagstaff, Arizona.

crater fields on October 17, 1968, for NASA's Lunar Roving Vehicles Working Group.[71] USGS also used the Explorer to demonstrate a tracking and range finding device called the Lunar Surveying System in October, 1969.[72] Completed in August, 1971, the LRV simulator Grover was built to aid astronaut training and geology mission planning for lunar EVAs. The design replicated—as near as possible—the actual Boeing-designed LRV used during lunar EVAs for Apollo 15, 16, and 17. As detailed in the preceding sections, Apollo astronauts used Grover extensively for training and simulated EVAs, many of which occurred at the Cinder Lake crater fields.[73]

Surveyor Program Equipment Testing

The district is significant in the areas of invention, exploration and science at the national level for the extensive field-testing of Surveyor spacecraft television camera systems that took place at the Northern Bonito Lava Flow Test Area from January-October, 1964. The purpose of the Surveyor Program was to land a probe on the Moon to determine the topography, geology and soil mechanics of the surface in preparation for manned Apollo missions.[74] Field tests of the Surveyor's television camera systems on the Bonito Lava Flow ensured that the spacecraft could return valuable imagery of and data about the lunar surface to earth.[75] Available evidence at the time suggested the lunar surface would not only resemble the jagged a'a lava in Sunset Crater but also reflect light in a similar manner.[76] For these reasons, the Surveyor field tests took place on an acre plot within the a'a lava flow. Preparation for the tests began with aerial photography of the site using a photogrammetric camera attached to a low-flying helicopter (Fig. 1). USGS used these images to create detailed topographic maps, ostensibly to compare against imagery taken from the Surveyor camera. The USGS Branch of Astrogeology in Flagstaff collaborated with the Jet Propulsion Laboratory (responsible for programming and building the camera) and the Hughes Aircraft Company (fabrication of the Surveyor spacecraft) during field-testing.[77]

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[71] Deputy Assistant Chief Geologist for Astrogeology to Assistant Chief Geologist for Engineering Geology, "Monthly Report for Director and Secretary," October 31, 1968, USGS Astrogeology Science Center, Flagstaff, Arizona.

[72] Chief, Branch of Surface Planetary Exploration to Assistant Chief Geologist for Environmental Geology, "October Report for Director and Secretary," Geological Survey, Center of Astrogeology, October 31, 1969, USGS Astrogeology Science Center, Flagstaff, Arizona; Schaber 233-34.

[73] Chief, Surface Planetary Exploration Branch to Assistant Chief Geologist for Environmental Geology, "Monthly Report for July, 1970," Geological Survey, Center of Astrogeology, July 30, 1970, USGS Astrogeology Science Center, Flagstaff, Arizona; Chief, Surface Planetary Exploration Branch to Assistant Chief Geologist for Environmental Geology, "Monthly Report for August, 1970," Geological Survey, Center of Astrogeology, August 31, 1970, USGS Astrogeology Science Center, Flagstaff, Arizona; Schaber, 255-56; 259.

[74] *Arizona Daily Sun*, September, 1963; Harland, 12.

[75] Eugene M. Shoemaker to V.R. Wilmarth, "Monthly Report for Director and Secretary" Geological Survey, Branch of Astrogeology, January 31, 1964, USGS Astrogeology Science Center, Flagstaff, Arizona. Hereafter, Shoemaker to Wilmarth, January 31, 1964.

[76] Wilhelms, 81-82; Schaber, 83-85.

[77] Shoemaker to Wilmarth, January 31, 1964.

During testing, a USGS electronics van with a photo lab for processing images was connected directly to the camera with electronic cables. The field tests allowed USGS to practice rapid processing of incoming images, techniques for mosaicking pictures, and which projections to use. Additionally, the tests allowed officials to develop techniques and programming for survey panoramas, photographic sequences and astronavigation used by the spacecraft on the Moon. These included camera elevations that allowed for a view of the spacecraft's feet, an important consideration for determining soil mechanics at the landing site (Fig.68).[78] During Field Test No.2 at Bonito Lava Flow, from August to October 1964, the Surveyor camera produced 20 photogrammetric surveys, 360 photometric and stellar measurements for a total of 20,000 negatives.[79]

The Surveyor field tests at SUCR made the spectacular success of Surveyor 1 possible. After it landed on the Moon in June 2, 1966, the spacecraft transmitted over 10,000 images back to earth using a camera system nearly identical to the one tested at SUCR. A USGS team then mosaicked the images for analysis using the experience gained from field-testing.[80] Surveyor 1 greatly advanced human understanding of the lunar surface and helped pave the way for manned Apollo missions.

The district is also significant in the area of invention due to the testing of proposed Surveyor Lunar Roving Vehicle designs in the Northern Bonito Lava Flow Test Area. From May 5 to 7, 1964, Bendix and General Motors tested two competing Surveyor LRV designs on the Bonito Lava Flow and adjacent cinder surfaces under the direction of personnel from the Jet Propulsion Laboratory (Fig. 75). While the proposed Surveyor LRV never flew, the tests gave General Motors – which later developed the LRV design used by astronauts on the Moon—useful information on mobility and guidance problems. Additionally, Ben Milwitzky, who managed the Surveyor program and later oversaw the effort to procure an LRV for the Apollo missions, used the lessons from these Surveyor field tests to guide development of a larger lunar vehicle.[81]

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[78] Schaber, 83-85, 100. The van was supported on the cinder by surplus military landing mat, probably perforated steel planking (PSP).
[79] E.M. Shoemaker to V.R. Wilmarth, "Monthly Report for Director and Secretary," Geological Survey, Branch of Astrogeology, November 30, 1964, USGS Astrogeology Science Center, Flagstaff, Arizona.
[80] Schaber, 160-61.
[81]E.M. Shoemaker to V.R. Wilmarth, "Monthly Report for Director and Secretary," Geological Survey, Branch of Astrogeology, May 31, 1964, USGS Astrogeology Science Center, Flagstaff, Arizona; Russell L. Mahan, "U.S.G.S, Astrogeology Branch Activities, Sunset Crater," July 1, 1964, SUCR Administration Collection, Box L21, Folder: Lunar testing at Sunset Crater 1964, SUCR 24.6, Colton Research Center, Museum of Northern Arizona, Flagstaff, Arizona; Beattie, 152.

Developmental history/additional historic context information

Cold War Context

In 1957, the Soviet Union launched the first satellite, Sputnik, stunning the world and the American public.[82] In 1959, the Soviet Union, using its superior R-7 rockets, put the first probe into orbit around the moon. Two years later the Soviet Union put the first man into space. The list of firsts continued through the middle of the decade and on February 3, 1966, the Luna 9 probe made the first lunar landing and transmitted images of the surface back to earth.[83] These achievements and their obvious military implications propelled U.S. entry into the Space Race.

In response to the Soviet Union's successes, President Dwight Eisenhower and Congress moved to address the perceived technological gap between the two superpowers by creating the National Aeronautics and Space Administration (NASA) in 1958. Congress also passed the National Defense Education Act of 1958 to increase funding for math and science at all levels. The first U.S. satellite, Explorer I, launched in 1958. Despite these efforts, the White House adopted a conservative space policy and did not approve the aggressive and costly proposals emanating from the newly formed NASA for manned space missions to the moon. Evaluating such plans on the basis of military and scientific necessity, Eisenhower saw no need to commit to a costly space program. Technical planning for space missions, however, continued despite Eisenhower's policy.[84] The election of John F. Kennedy to the presidency and Yuri Gagarin's historic flight, the first manned mission into space, in 1961 pushed the nation towards a more aggressive space policy. Gagarin's accomplishment convinced Kennedy to enter the Space Race and compete with the Soviet space program. Kennedy and his advisors seized upon a manned lunar landing mission as perhaps the best way to establish American preeminence in space. On May 25, 1961, Kennedy delivered his famous "We choose to go to the Moon" speech to rally support for the Apollo program and its new mission.[85]

Initially, the Apollo Project had nothing to do with science as its main objective was to land a man on the Moon and return him to Earth but questions quickly arose about what astronauts might do once they were on the surface. Max Faget, the director of engineering for the Manned Spacecraft Center (MSC)—whose primary mission was to land an American on the Moon—felt there should be some objective beyond a display of technological superiority. According to Faget, "it wouldn't look very good if we went to the Moon and didn't have something to do when we got there." Given the ongoing debate about the origins and formation of the Moon (discussed below), lunar exploration and geological sampling emerged as the secondary mission. As the American space program matured, science took on ever greater importance.[86]

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[82] The U.S.S.R. also developed the first Intercontinental Ballistic Missile (ICBM) in 1957. The first American ICBM, the Atlas, appeared in 1959.

[83] Harland, 1-2.

[84] John M. Logsdon, *The Decision to go to the Moon: Project Apollo and the National Interest* (Chicago: The University of Chicago Press, 1970), x.

[85] Logsdon, x.

[86] Phinney, 1.

Popularization of Science in the Mid-Twentieth Century

The growing popularization of science in the United States—as demonstrated by the appearance of new curriculum including earth science—focused attention on the origins of life, the Earth and the Solar System. Growing interest in space exploration for scientific purposes was expressed in Lloyd V. Berkner and Hugh Odishaw's 1961 book *Science in Space*. The former was Chairman of the Space Science Board of the National Academy of Sciences.[87] "During the early 1960s, as Project Apollo was being built, a group of researchers and theoreticians who began to think of themselves as space scientists was mobilized under the aegis of the National Aeronautics and Space Administration (NASA). Their spokesmen were highly optimistic about the prospect that an avalanche of new knowledge would cascade out of the heavens with the advent of probes and the manned space vehicles."[88]

Lunar Science on the Eve of Apollo

Before the Apollo missions, two major questions animated lunar science: What was the origin of the Moon and what processes formed the basins, craters and mountains visible on its surface?[89] The importance of these questions was magnified by the fact that lunar scientists expected the answers to shed light not only on the history of Earth but of the entire Solar System.[90] Scientists believed the lunar surface had escaped significant weathering and therefore preserved the conditions that shaped a young Earth.[91] "Thus, the investigation of the Moon was essential to the understanding of planetary evolution, which had become the most challenging question in natural history of the twentieth century."[92]

Planetary scientists believed that the origins of Moon's craters, mares and mountains contained clues to lunar evolution. If the Moon's craters were of volcanic origin, then it had a molten core and its evolution might have been similar to Earth. If meteorites and impacts caused the craters, the Moon's evolution may have followed a very different trajectory.[93] "With great ingenuity and imagination, the dispute over the forces that had the main role in shaping the Moon's surface was continued into the twentieth century by the rival schools of volcanism and impact."[94]

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87 Lewis, 14.
88 Richard S. Lewis, *The Voyages of Apollo: The Exploration of the Moon* (New York, New York: The New York Times Book Co., 1974), 13-14.
89 Lewis, 19.
90 Lewis, 15.
91 Lewis, 14.
92 Lewis, 19.
93 Lewis, 19; Beattie, 15.
94 Lewis, 22. "The paucity of large meteorites in modern time, or in man's historic time, is cited in attacks on the impact theory. But the impact theorists argue that most the big rocks orbiting near the Earth-Moon system were scooped up long ago by the planets…the great bombardments, however, ended billions of years ago, before men or vertebrate animals appeared on Earth. Time has nearly erased the scars on Earth but not on the Moon" (Lewis, 24).

Debates over the formation of the lunar surface fed into three principal theories about the genesis of the Moon. Some scientists believed that the Earth and Moon had formed from the same debris cloud orbiting the Sun. Others theorized that the Moon was once a part of the Earth and had broken off due to a catastrophic impact or because of tidal forces. A third camp offered that the Moon originated elsewhere in the Solar System and was captured by the Earth's gravity field during a close flyby.[95] Analysis of the chemical and mineral properties of the Moon could reveal the answer. If Moon rock was composed of cold chondrites (meteorites) or showed alien patterns of iron and siderophile, than its origins were likely far from Earth, favoring the capture theory. But if the rocks were analogous to terrestrial ones and deficient in siderophile, the Moon probably formed from or near the Earth.[96]

The Apollo missions promised to answer many of these questions by gathering rocks and dirt directly from the Moon. As the project progressed, lunar scientists were increasingly hopeful that manned landings would put to rest the old debates and questions. "Manned exploration, they hoped, would uncover the creation. Exploring the Moon was a return to Genesis."[97] For these reasons, geology quickly became Apollo's most important scientific mission.[98]

The importance of geology to lunar science compelled leading figures including Professor Harold C. Urey to recommend that trained geologists be send to the moon. This would eventually come to pass when Harrison Schmitt, a trained geologist, took part in the final Apollo mission. But for most of the program, astronauts would require geological training to complete their mission. Geological considerations also greatly influenced the Apollo landing sites. Urey, for instance, suggested that the Mare Tranquillitatis should be the site of landings because of its potential to yield information on possible lava flows.[99]

The Development of Apollo Science Mission

In the early days of the U.S. space program, science was a low priority except when it was needed to plan and develop the technical and engineering problems associated with space flight. The first science training began in May, 1959, and included such practical subjects as space physics and celestial navigation. Training for subjects other than those associated with spaceflight began to emerge in December, 1961, when Mercury astronauts including John Glenn received suggestions for astronomical observations from NASA's Space Sciences Steering Group. During Glenn's historic orbit of earth in the Friendship 7 capsule on February 20, 1962, he was able to complete many of the suggested observations. Subsequent Mercury missions followed Glenn's lead and demonstrated the potential of space science.[100]

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[95] Beattie, 14.
[96] Lewis, 16, 36.
[97] Lewis, 37.
[98] "Second priority was the setting up of scientific instruments that would measure the intensity of moonquakes, meteorite impacts, heat flow, magnetic fields, atmospheric gases, and the flux of solar wind particles." (Lewis, 39).
[99] Lewis, 17-18.
[100] Phinney, 1-2.

The number and type of scientific experiments expanded rapidly with the Gemini Program. In January, 1964, the newly formed Manned Space Flight Experiments Board (MSFEB) began proposing experiments in micrometeoroids, radiation and atmospheric sciences among other things. Over the course of ten Gemini spaceflights, astronauts conducted fifty such experiments.[101]

As the Apollo program began in earnest, the question of where manned spacecraft might land became a pressing question. NASA initiated the Lunar Orbiter project in August, 1963, to survey the lunar surface and photograph areas suitable for Apollo landing sites. Lunar Orbiter I launched on August 10, 1966 and photographed nine potential landing sites. Its successor, Orbiter II, mapped eleven more potential landing areas. Imagery from the Orbiters was later used in the construction of the USGS Cinder Lake crater fields for astronaut training.[102]

Unlike the Orbiter, the objective of the Surveyor program was to land a spacecraft on the Moon and investigate the surface of several potential Apollo sites. On May 30, 1966, Surveyor I landed on the Moon and began transmitting panoramic shots of the moonscape back to Earth. The Surveyor program proved that the lunar surface was suitable for Apollo and yielded important information on the geology of the Moon.[103]

Astrogeology and the USGS Branch in Flagstaff

Between October 1962 and January 1963, a new science training program began the study of a variety of subjects including lunar geology. In January, 1963, Apollo astronauts conducted lunar observations at Lowell Observatory and took fieldtrips to SUCR and Meteor Crater during a two-day visit to Flagstaff. During this trip they received instruction from Eugene Shoemaker of USGS who was then on loan to NASA.[104] During their fieldtrip to SUCR they studied the formation of volcanic cones in the monument.[105] Additional training took place on Bonito Lava Flow in April and May of that year.[106] The success of the Flagstaff fieldtrip led Shoemaker to develop an unofficial arrangement between USGS and NASA whereby the former would conduct geological training for astronauts.[107]

In early 1963, Shoemaker moved the USGS Astrogeology Center to Flagstaff. Shoemaker chose Flagstaff as the base for his USGS Astrogeology Center and Field Geology Team because of its central location close to landscapes formed by both volcanism and impact cratering. These areas including Sunset Crater, Meteor Crater, Cinder Lakes, Hopi Buttes, Merriam Crater and others. The proximity of Lowell Observatory –which played an early role in lunar mapping and

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[101] Phinney, 2.
[102] Harland, 7-12.
[103] Harland, 12-18.
[104] Phinney, 2.
[105] *Arizona Daily Sun*, January 17, 1963.
[106] E.D. Jackson, “Early Terrestrial Geology and Geophysics Training,” Testing and Training Collection, Box 7, Folder: Geology Field Trips-Pre Mission, n.d. (1975), NASA/USGS Astrogeology Regional Planetary Information Facility, USGS Astrogeology Science Center, Flagstaff, Arizona
[107] Phinney, 3.

observation—was another consideration.[108] In 1964, NASA funded the construction of a new observatory and telescope on Anderson Mesa for USGS geologic mapping of the Moon.[109] Thus, excellent night sky visibility played a role in concentrating USGS personnel in Flagstaff.

The significance of Flagstaff as a hub for astronaut training seems to have increased after an unsuccessful space suit test in Bend, Oregon in August 1964. For this test, astronaut Walt Cunningham traversed volcanic terrain in the Bend region using a prototype Apollo space suit. The prototype suit afforded little mobility and weighed over one hundred pounds. During the simulation, Cunningham fell over and damaged the suit while the press snapped photos of the mishap. The bad press resulting from the Bend simulation led to recommendations from Will Foster and E.Z. Gray that Flagstaff be the site of future simulations.[110] Additionally, the close proximity of a variety of relatively remote public lands also made Flagstaff attractive as NASA personnel were eager to avoid undue attention during equipment tests and astronaut training.[111]

From the beginning of the Apollo program it was recognized that lunar geological fieldwork would present special problems and USGS moved forward in the early 1960s to address them.[112] Basic questions including what should be sampled, how much material could be collected, and how it would be stored needed to be answered.[113] Moreover, not only would tools and techniques need to be adapted for a new environment, but the astronauts themselves would require geology training if they were to select areas and samples of scientific value. Moreover, unlike terrestrial fieldwork, the Apollo astronauts would only get one chance to get things right.[114] Under Shoemaker's guidance, the USGS Astrogeology Branch in Flagstaff emerged as the organization capable of addressing these concerns.[115]

By 1965, the USGS Astrogeology Branch in Flagstaff had become an important part of the larger Apollo mission. NASA designated Shoemaker as the principal investigator for the early Apollo missions and the coinvestigator for the Ranger and Surveyor programs. NASA also tasked Shoemaker and the Astrogeology Branch with lunar geologic mapping and astronaut training. As the list of assignments grew, funding and support from various NASA offices poured into Flagstaff. By 1968, Shoemaker's USGS team of over 190 staff in Flagstaff received $2.5 million annually from NASA. In order to help organize their many responsibilities, Shoemaker divided his staff into three offices: Unmanned Lunar Exploration – responsible for supporting the

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[108] Gerald G. Schaber, "Flagstaff and the History of the Apollo Missions," n.d., History of Flagstaff Series, Flagstaff Visitor Center, Astronomy Vertical File, Cline Library Special Collections and Archives, Northern Arizona University, Flagstaff, Arizona.
[109] Beattie, 60-61.
[110] Beattie, 162. Following the problems at Bend, the Office of Space Medicine also recommended that simulations shift to Flagstaff and recommended that test subjects rather than astronauts be used for simulations.
[111] Beattie, 162.
[112] "By 1964 the growing fraternity of space and lunar scientists began to see the Apollo missions as an opportunity to address many age-old questions." (Beattie, 125).
[113] Beattie, 110.
[114]Beattie, 107.
[115] Beattie, 108. Early tool develop revolved around all-in-one designs that combined several functions but these ideas were eventually abandoned.

Ranger, Surveyor and Lunar Orbiter programs, Astrogeologic Studies, and Manned Lunar Exploration.[116] The latter group worked on lunar geological methods, lunar field geophysical methods, lunar field surveying, electronics investigations for field systems and documentation of lunar field systems. By the following year, these projects produced recommendations for sampling tools including scoops, core tubes, hammers and sampling bags. USGS also developed radio and TV communication systems and conducted geological tests with subjects in pressurized suits to determine what types of geological activities could be practiced on the Moon.[117]

However, the development of lunar science including astrogeology did not proceed in a straightforward manner but was split between different—sometimes competing— NASA Centers, offices and advisory committees. Rivalries and miscommunication was amplified by rapid organizational growth. In 1963, for instance, NASA Headquarters doubled in size and the Manned Spacecraft Center (MSC) in Houston grew from a staff of 750 to 14,000 over the course of four years. In 1963, as Shoemaker ramped up the astrogeology program in Flagstaff, he was unaware that MSC was building their own geology training program. When USGS staff learned of this parallel program, it was unclear who was responsible for doing what. Eventually, USGS and MSC agreed to divide the training with the latter taking responsibility for basic geology training while MSC geologists handled mineralogy and petrology. Fieldwork was handled jointly. However, animosity between USGS and MSC staff in Houston eventually resulted in the former's retreat back to Flagstaff where they worked to fulfil their end of the bargain.[118]

Responsibility for astrogeology training continued to evolve over the course of the Apollo program. For Apollo 11 and 12, most field training was planned by MSC geologists. But this responsibility gradually shifted to USGS and by Apollo 15, USGS had taken the lead in planning and executing EVA simulations including those undertaken at SUCR for Apollo 17.[119] The creation of the Cinder Lakes Crater fields by USGS beginning in 1967 was emblematic of the agency's growing leadership in geology fieldwork and EVAs. The Cinder Lakes Crater Fields "became the last tests for the astronauts, requiring them to use all the observational skills they had gained." All astronauts from Apollo 13 onward trained at the Cinder Lakes sites.[120]

Astronaut Geology Field Training

Geology training had the simple goal of instructing astronauts which rocks to sample and how to verbally describe and document them.[121] The guiding philosophy of the geologic field training was "you learn by doing, and doing some more." Because practicing geology requires extensive

[116] Beattie, 61-62; Schaber 48.
[117] Phinney, 3; Alfred H. Chidester and Ted Foss to Capt. Charles A. Bassett II, "Geological training program for astronauts," April 10, 1965, Folder: Memorandum with attachments, R. Regan to G. Ulrich, History of Geologic training of astronauts, 5/74, Testing and Training Collection, Box 7, NASA/USGS Astrogeology Regional Planetary Information Facility, USGS Astrogeology Science Center, Flagstaff, Arizona.
[118] Phinney, 3, 5.
[119] Phinney, 8.
[120] Beattie, 182-3. The Cinder Lakes Crater Fields were based on images taken by Orbiter.
[121] Beattie, 115.

experience in the field with a wide variety of sites, the astronauts travelled to locations around the North American West. In addition, fieldwork focused on replicating the sorts of geological traverses that the crews would be undertaking on the moon.[122] These geological traverses involved not only the astronauts, but the CAPCOM and other individuals who would play a role during live moonwalks. The principal investigator, operating through the Field Geology Experiment, led the training of astronauts. Eugene Shoemaker led training for Apollo 11 and 12 followed by Gordon Swann for Apollo 13-15. William Muehlberger was the last PI for Apollo 16-17.[123]

Geology training for the Apollo astronauts presented a number of difficulties. To begin with, the astronauts were working on a constricted and busy schedule. The astronauts needed to learn observational skills and have the knowledge to recognize significant geological features. Additionally, unlike a normal geology field trip, the astronauts would be working in a hostile, life-threatening environment. The dangerous lunar environment required that geology be practiced with a highly constrained timeline. The bulky space suits limited mobility, restricted the astronauts' field of view and necessitated special procedures for documenting and collecting samples. Sampling tools were also unique and unusual. Thus Apollo astronauts needed to not only learn geology but master specialized procedures and equipment as well to accomplish the mission's scientific objectives.[124]

As the scope of EVAs increased, especially with Apollo 15-17 (the J missions), field training became more extensive. Surface operations increased from 2-4 hours in the early missions to twenty hours over the course of three days with Apollo 15-17. Crucially, the crews of these later missions were committed to the scientific objectives of the J missions. Another factor was the increasing complexity of lunar geology given the discoveries made on earlier missions.[125]

Beginning with Apollo 15, field training increased substantially with 2-3days of fieldwork per month in addition to 2-4 hours of classroom instruction. Thus, the scientists had much greater access to the astronauts. In the 18 months leading up to launch, astronaut crews participated in between 16-19 field trips and spent an additional 250-300 hours in the classroom. All told, later Apollo crews spent around 1000 hours in science training.[126]

The J mission geological traverses took place over the course of a single day and began with a prebriefing that included geologic context of the area based on photographs (since this is all the astronauts would have before the real thing) and the scientific objectives for the traverse. During the prebriefing, the crew received a map of the traverse with station locations and a timeline indicating how much time was to be spent at each station and in travel between the stations. Typically, the astronauts spent between 30-50 minutes at each station. The astronauts were in communication with the CAPCOM via two-way radios. The CAPCOM was in communication

[122] Gary E. Lofgren, Friedrich Horz, and Dean Eppler, "Geologic Field Training of the Apollo Astronauts and Implications for Future Manned Exploration," The Geological Society of America, Special Paper 483 (2011), 34.
[123] Ibid., 34.
[124] Ibid., 34.
[125] Ibid., 34.
[126] Ibid., 34.

with the “science backroom” whose job it was to help direct scientific investigations on the moon. In order to simulate an actual moonwalk, neither the astronauts nor the science backroom had any detailed information about the traverse area beyond the maps the timeline provided during the prebriefing. [127] All communications with the astronauts was funneled through the CAPCOM during traverses and actual moonwalks.

Each traverse was composed of a series of stations – or points of geological interest – chosen by the “geological planning team” that were illustrative of the geology of the traverse area. The placement of the stations also mimicked those that astronauts would visit on the Moon. Most traverses lasted four to six hours—the approximate time for an actual moonwalk. During the traverses, the astronauts were alone and out of the site of the support crew including the CAPCOM with the exception of the “field observer” who designed the traverse and a local geology expert. Between eight and twelve geologists took part in the exercises usually split into two simulated “back rooms”, one for the backup crew and one for the prime crew. A further six to ten people provide technical support for communications systems, cameras, and vehicles include lunar rover simulators like Grover. Additionally, the Fight Director, Science Liaison and Program Managers also participated in many traverse exercises. A field party of twenty-five people was typical.[128]

During geological traverses there were four main goals: 1) describe and photograph geological context and features along the traverse and at the stations 2) sample representative rock and soil from each station as well as observe and collect unusual rocks 3) take all of this data and try to reconstruct the geological history of the area 4) conduct all of the above while sticking to the timeline and traverse route.[129]

During traverse exercises, the astronauts wore mock Portable Life Support Systems (PLSS) in order to simulate the constraints of bulky pressurized suits. The aluminum frame of the mock PLSS included a chest-mount for the Hasselblad camera as well as a place to stow a two-way radio, sample collection bag, and bag dispenser. Because of the limited mobility of the suits, the astronauts were not able to stow their own samples and instead had to place collected material in their partner’s bag. Field exercises allowed astronauts to practice the teamwork necessary for efficient collection of samples.

A Typical Geological Traverse

A geological traverse began with a pre-briefing the night before during which time the astronauts received an aerial photograph of the traverse as well as cuff checklists. For the J missions, crews used cuff checklists to navigate the traverse, keep track of station objectives and tasks, and stay on the mission timeline. During an actual moonwalk, life support constraints limited the amount of time that could be spent outside the lunar module (LM). Field tests helped crews practice navigating to points and completing tasks within a timeframe. During the final field exercises for crews, this timeline was rigid and crews had to leave a station if they did not complete all their objectives in the allotted time.

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[127] Lofgren, 35.
[128] Lofgren, 35.
[129] Lofgren, 35.

Crews usually arrived in the field from 0600-0700 for a 0800 start time. Once the traverse began, only the geologist field observer who had designed the traverse accompanied the crew. All other support personnel, including the back room team and CAPCOM, remained out of sight and had limited knowledge of the traverse area. As in the live missions, all communication from geologists and other support crew flowed through the CAPCOM to the astronauts and vice versa. This allowed all participants to practice the communication and coordination essential for a successful mission.

Field exercises typically ended early in the afternoon after which the geologist field observer would walk the crew and back room through the traverse providing constructive criticism along the way. During the walk-through, the back room would explain their understanding of local geology based on the information provided by the crew during the traverse. These walk-throughs allowed the crew to hone their observational skills and procedures while giving the back room a sense of how to communicate most effectively with the astronauts. In short, the field tests were vital to creating an efficient and effective team.

Two to three weeks after the traverse exercise another debrief would be held in Houston. In the intervening time, geologists analyzed all the photographs taken by crew, usually around 1000. These would include panoramas and the sets of five shots taken for each individual rock. Some of this analysis involved geologists attempting to determine which rocks were collected on the basis of the astronauts' photographs. During the Houston debriefing, these geologists would then critique the crew's photograph-documentary performance. The rocks collected during the traverse were also sent to Houston. Geologists would go through the samples with the astronauts and help to refine their ability to spot scientifically significant rocks. The collected samples were also weighed to determine if they exceeded the payload for the actual mission.[130]

All told, each field exercise or geological traverse required two to four months of planning and involved twenty to twenty-five support personnel. Another one to two months of evaluation followed each traverse.[131]

Geologic Tools

Apollo astronauts used specialized tools to document and collect geologic samples on the lunar surface. Due to the various constraints of lunar geology including limited mobility and dexterity in pressurized suits, the tools themselves as well as their users would needed extensive testing and training. The Apollo 11 tool kit included a scoop, hammer, tongs, core tubes and extension handles. A gnomon with attached color chart, spring scale, 15 sample bags and bag dispenser rounded out the set. This tool set would evolve over the course of the program.[132]

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130 Lofgren, 41.
131 Lofgren, 41.
132 J.E. Ulrich and J.A. Scorann [sp?], "Development of Geological Tools and Mechanical Procedures," Testing and Training Collection, Box 7, Folder: Geology Field Trips-Pre Mission, n.d. (1975), NASA/USGS Astrogeology Regional Planetary Information Facility, USGS Astrogeology Science Center, Flagstaff, Arizona.

Apollo geology hand tool development began in March, 1965, when Eugene Shoemaker and other USGS geologists sent a letter to NASA proposing the development of equipment for geologic sampling, collection, and documentation during lunar EVAs. A.B. Carraway from MSC's Experiments Program Office designed and fabricated the first tools, the Apollo Lunar Hand Tools (ALHT) kit, in June, 1966. Initial development continued through May, 1967, and included representatives from the Lunar Sample Receiving Laboratory, the Space Sciences Division, USGS, and the Crew Systems Division who did most of the tool testing.

Early in the program, the design of geological tools was constrained by, in order of importance: 1) the weight of the tools 2) biological contamination which involved elaborate efforts to keep the instruments sterile 3) durability and survivability as the nature of the lunar environment was poorly understood 4) efficiency and ease of use by suited astronauts 5) monetary cost. As the Apollo program matured, the importance of the above factors reversed itself with cost and efficiency becoming paramount in tool design. Early in the development of geologic tools, Eugene Shoemaker pushed for the development and use of more sophisticated tools noting that the ALHT kit was little changed from that used during scientific exploration of the United States a hundred years earlier. Under Shoemaker's guidance, the USGS branch in Flagstaff developed and tested a variety of new geologic hand tools beginning in 1966 on test sites in Northern Arizona. These included a tool carrier, later used for the Apollo 14 mission, as well as a lunar surveying staff that was never used.[133]

By the time of the J-missions (starting with Apollo 15), the ALHT included tongs and a small shovel for picking up rocks, necessary given the limited mobility of the astronauts when using working in a pressurized suit. Other tools included a hammer, used primarily for driving core tubes into the lunar regolith. Each tube was 40 cm long and included adapters that allowed the two to be combined for a longer core sample. Also used was a rake, designed to capture a representative sample of rock greater than 1cm. The rake and core tubes were easily damaged during fieldwork so they were rarely used outside of laboratory simulations. Astronauts used a special gnomon with a color chart and measuring rod to record the location, orientation, size and color of photographed samples. Depending on the type of sample, astronauts placed lunar material in pre-numbered Teflon or padded bags and vacuum-sealed containers.[134]

One of the most important, and difficult to master, tools was the chest-mounted Hasselblad camera. The cameras were essential to lunar science because they were the primary tool for documenting the location and context of samples as well as scientific experiments.[135] The scientific objectives of the J-missions required that astronauts document each rock sample with five different photographs: 1) an overview shot of the sample area to provide geological context 2) a down-sun shot 3) two cross-sun stereo photo shots taken three steps apart, these provided the best illumination of the sample 4) a cross-sun shot after the sample was collected so that scientists could later determine which rock was collected. This photographic sequence had to be

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[133] J.E. Ulrich and J.A. Scorann [sp?], "Development of Geological Tools and Mechanical Procedures," Testing and Training Collection, Box 7, Folder: Geology Field Trips-Pre Mission, n.d. (1975), NASA/USGS Astrogeology Regional Planetary Information Facility, USGS Astrogeology Science Center, Flagstaff, Arizona.
[134] Lofgren, 35-37.
[135] Beattie, 119.

accomplished without the benefit of a camera viewfinder and each shot had to include the gnomon so that the scale, orientation and color of the sample could be determined. The astronauts also took panoramic shots that required the user to rotate their body 360 degrees while taking a minimum of 15 shots. Because the Hasselblad cameras had limited film, the astronauts needed to be accurate as well. All this meant that crews spent a considerable amount of time mastering photography procedures with the Hasselblads.[136]

Selection of Training Sites

Analogous terrestrial geology, mission objectives, and logistics all influenced the selection of astronaut training sites. One important consideration when MSC and USGS geologists selected sites for field training was finding terrestrial features analogous to the lunar environment. As basaltic volcanism and impact cratering shaped the lunar surface, terrestrial areas with these geological features were natural training sites. Sites with plutonic rocks, including anorthosites, were also important as igneous rock of this type constitutes large portions of the lunar surface. Beyond this, field sites also needed to present geological problems for the astronauts to solve. The scientific objectives and unique geographic and geologic features of each moonwalk also influenced training site selection. For instance, Apollo 15 astronauts visited the Rio Grande River gorge in New Mexico because its dimensions are similar a feature near their landing site. Astronauts visited the nuclear test craters in Nevada because their size was similar to impact craters near the Apollo 16 site. In addition to all this, training sites had to be close to hotels and an airport capable of handling commercial and military aircraft, such as the T-38 jets that astronauts used for travel around the country. Accessibility by road was also important to reduce travel time. The attractiveness of the Flagstaff area for astronaut training, particularly sites in and around Sunset Crater Volcano National Monument, becomes more apparent when all these factors are taken into consideration.[137]

The Scientific Contributions of Apollo

The Apollo missions, much as lunar scientists had hoped, greatly increased humankind's understanding of the Moon, early Earth history and the larger Solar System. Prior to Apollo, there was a great deal of debate about the composition of the Moon. Manned exploration showed that the Moon's structure is similar to the Earth with a thick crust, uniform lithosphere and hot liquid asthenosphere. Lunar exploration also allowed scientists to conclude that the craters on the Moon are of impact origin, a hotly contested issue before the program. The study of lunar craters also advanced comparative planetology and gave scientists insights into the geological evolution of Earth, Mercury, Venus and Mars through their crater records. Analysis of rocks and dust confirmed that the Moon is ancient and preserves the early history of the Solar System (first billion years). The analysis of oxygen isotopic composition in the rocks also showed that the Earth and Moon formed from a common pool of material but that the latter lacked important elements needed for the formation of an atmosphere and water. Close analysis of samples also revealed that the Moon is/was lifeless. Apollo exploration further showed that while lunar craters originated with impacts, volcanism and heat played an important role in the Moon's evolution. All moon rocks—basalts, anorthosites and breccias—formed in the presence

[136] Lofgren, 36-37.
[137] Lofgren, 41.

of heat without the influence of water. The dark mares visible from Earth are in fact composed of lava basalts. Moreover, early in the Moon's history its surface was covered with a vast and deep magma ocean. As lighter rocks floated to the surface of this "ocean," lunar highlands were formed. Afterward, huge meteorites pummeled the surface, leaving behind craters that were later filled with lava floods. Finally, because the Moon's surface is ancient and undisturbed by erosion, its rocks contain a record—etched in chemical elements and isotopes—of the last 4 billion years of the Sun's history.[138]

[138] Harland, 332-333.

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Previous documentation on file (NPS):

____ preliminary determination of individual listing (36 CFR 67) has been requested
____ previously listed in the National Register
____previously determined eligible by the National Register
____designated a National Historic Landmark
____ recorded by Historic American Buildings Survey #____________
____recorded by Historic American Engineering Record # __________
____ recorded by Historic American Landscape Survey # ___________

Primary location of additional data:

____ State Historic Preservation Office
____ Other State agency
____ Federal agency
____ Local government
____ University
____ Other
Name of repository: _____________________________________

Historic Resources Survey Number (if assigned): ________________

10. Geographical Data

Acreage of Property ________13.72 sq. km (contributing and non-contributing)_______

UTM References
Datum (indicated on USGS map):

☐ NAD 1927 or ☒ NAD 1983

Apollo 17, EVA, Lunar Module Site

450092.00 m E, 3914363.00 m N
450286.00 m E, 3914340.00 m N
450268.00 m E, 3914184.00 m N
450075.00 m E, 3914206.00 m N

Apollo 17, EVA, Station One

450189.00 m E, 3914602.00 m N
450444.00 m E, 3915056.00 m N
450594.00 m E, 3915044.00 m N
450677.00 m E, 3915220.00 m N
450884.32 m E, 3915266.31 m N
450974.58 m E, 3915174.34 m N
450257.08 m E, 3914539.90 m N

Apollo 17, EVA, Station Two

451529.00 m E, 3915290.00 m N
451580.00 m E, 3915282.00 m N
451574.00 m E, 3915233.00 m N
451528.00 m E, 3915239.00 m N

Northern Bonito Flow Test Area

452185.50 m E, 3915919.00 m N
452603.00 m E, 3915926.30 m N
453021.00 m E, 3916047.00 m N
453050.45 m E, 3915946.57 m N
452743.21 m E, 3915839.28 m N
452710.63 m E, 3915482.86 m N
452578.89 m E, 3915408.60 m N
452173.35 m E, 3915494.40 m N

Apollo 17, EVA, Station Four

453604.86 m E, 3914060.86 m N
453825.84 m E, 3914254.55 m N
453901.77 m E, 3914122.20 m N
453723.09 m E, 3913965.73 m N

Apollo 17, EVA, Station Five

454323.88 m E, 3912788.40 m N
454473.70 m E, 3912808.87 m N
454647.76 m E, 3912872.06 m N
454810.91 m E, 3912976.79 m N
454940.23 m E, 3912804.98 m N
454967.73 m E, 3912673.58 m N
454841.00 m E, 3912397.00 m N
454275.00 m E, 3912464.00 m N

Apollo 17, EVA, Station Six

452868.81 m E, 3912849.42 m N
453304.10 m E, 3913030.30 m N
453492.06 m E, 3912784.27 m N
453456.77 m E, 3912602.11 m N
452895.46 m E, 3912516.97 m N

Cinder Lake Crater Field One

454025.00 m E, 3907466.00 m N
454332.00 m E, 3907388.00 m N
454188.00 m E, 3906844.00 m N
453896.00 m E, 3906920.00 m N

Cinder Lake Crater Field Two (non-contributing)

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453243.00 m E, 3908990.00 m N
453140.00 m E, 3908567.00 m N
452634.00 m E, 3908713.00 m N

Verbal Boundary Description

The Sunset Crater-Cinder Lake Apollo Mission Testing and Training Historic District, Coconino County, Arizona, is located eleven miles northeast of Flagstaff, Arizona. The district is a 357.1 -acre discontinuous district with nine different sites, all of which sit on and are surrounded by rural public land administered by Sunset Crater Volcano National

Monument (SUCR) or Coconino National Forest. The boundaries of the district are shown as bold red lines in the accompanying maps.

Boundary Justification

The boundaries of the district encompass historically significant areas associated with Apollo mission testing and training. The author referenced geological traverse and cuff checklist maps used by Apollo 17 astronauts during EVAs in November, 1972, to identify and define the boundaries of sites around SUCR. These areas include the EVA Landing Module Site and Northern Bonito Lava Flow Test Area as well as EVA Stations One, Two, Four, Five and Six. The boundaries of Crater Field One and Two were previously established by archeological surveys conducted by the Coconino National Forest. The boundary around Crater Field One follows a barbed wire fence that currently surrounds and protects the site. The crater field boundaries encompass all historically significant features. The area between the various sites is not included because historically significant astronaut training and equipment testing as well as instructive geological features are primarily confined to defined stations and the Cinder Lake crater fields.

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11. Form Prepared By

name/title: _____Dr. Benjamin T. Carver______________________
organization: ____
street & number: _________4005 Lake Mary Road______________________
city or town: ____________Flagstaff___ state: ____Arizona__ zip code:____86005_______
e-mail____________flagstaffcarver@gmail.com_____________________
telephone:______218-213-8355___________________
date:_________________7/30/18____________

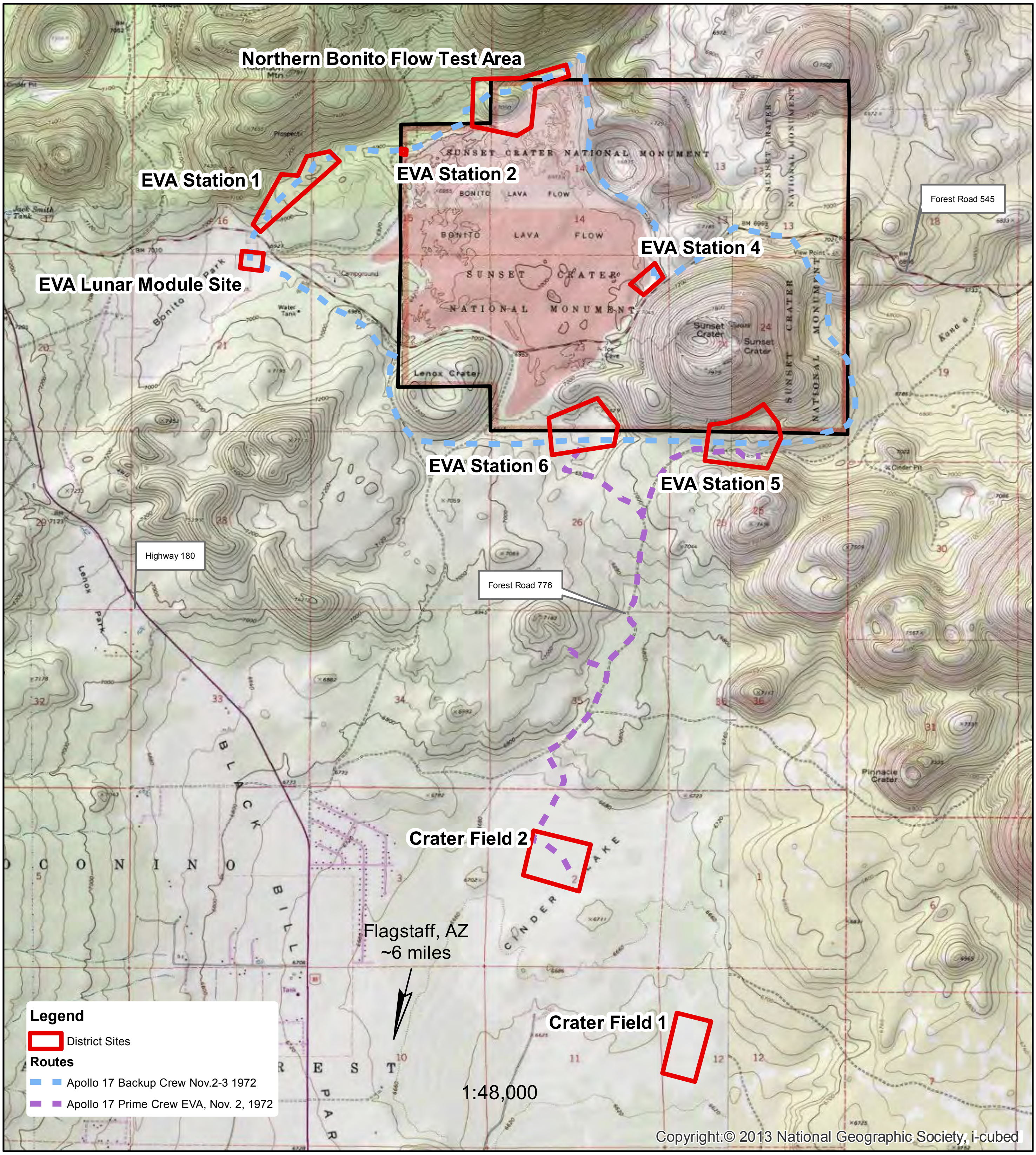
Additional Documentation

Submit the following items with the completed form:

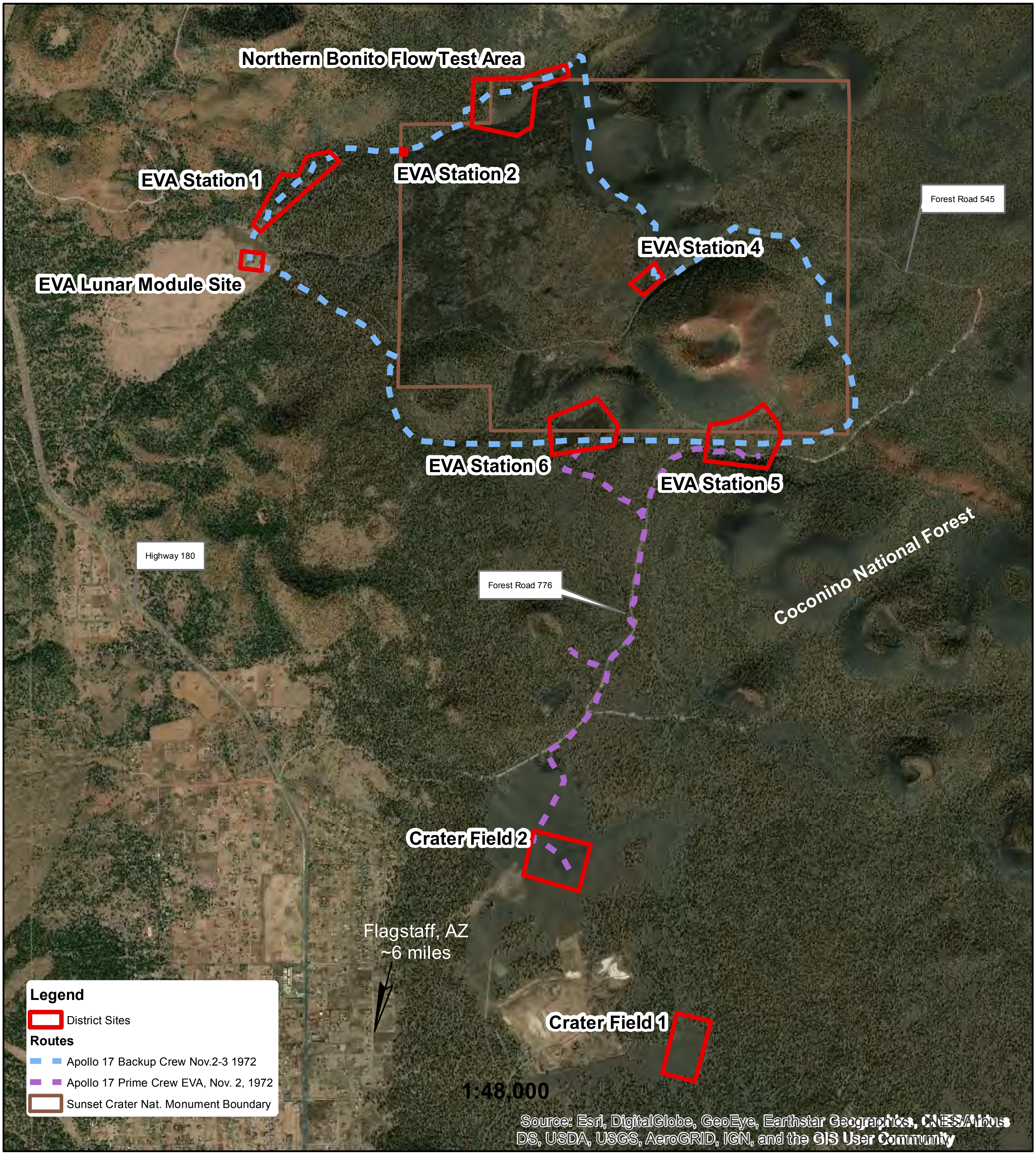
- ☐ **Maps:** A **USGS map** or equivalent (7.5 or 15 minute series) indicating the property's location.

- ☐ **Sketch map** for historic districts and properties having large acreage or numerous resources. Key all photographs to this map.

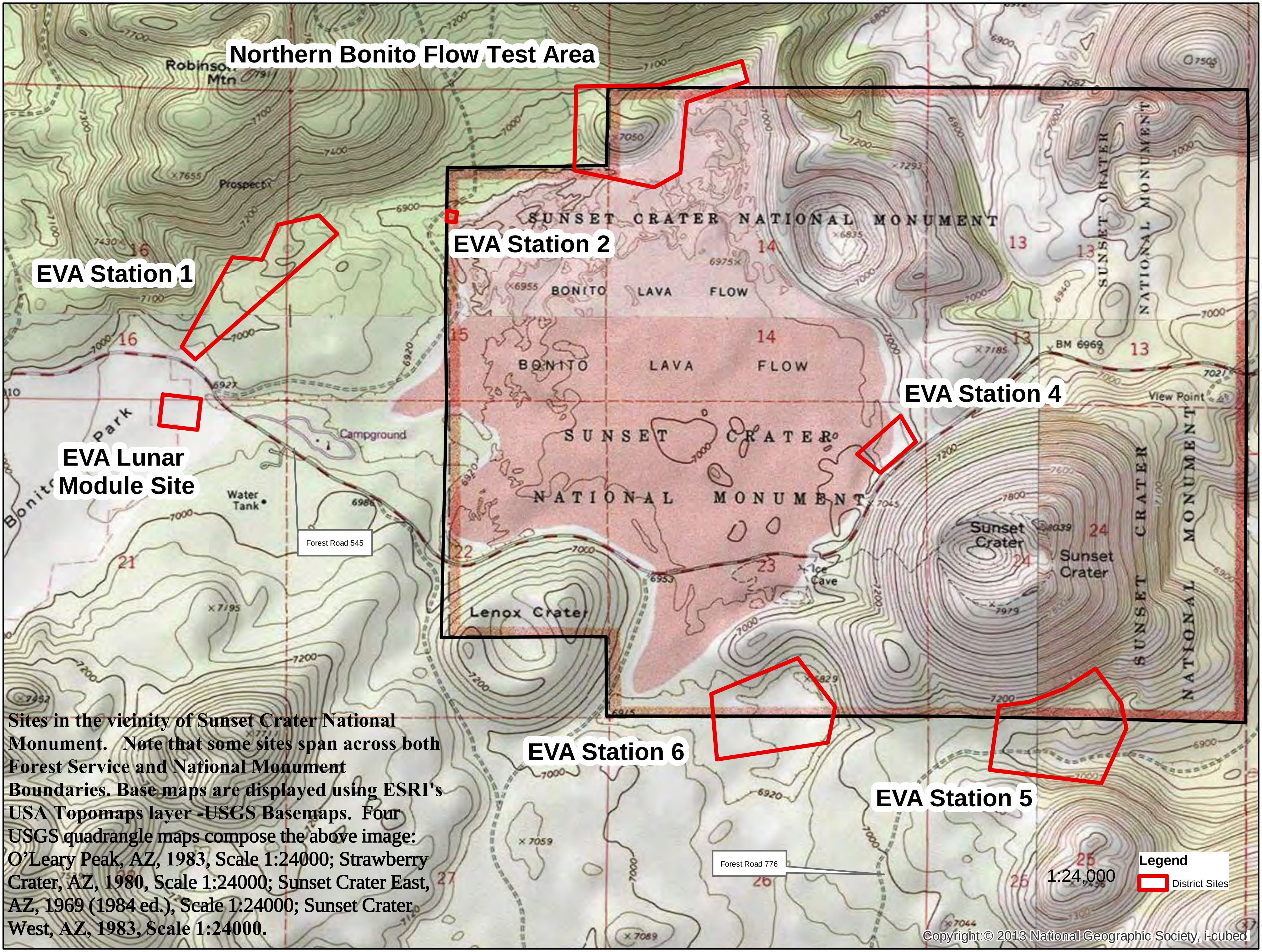
- ☐ **Additional items:** (Check with the SHPO, TPO, or FPO for any additional items.)



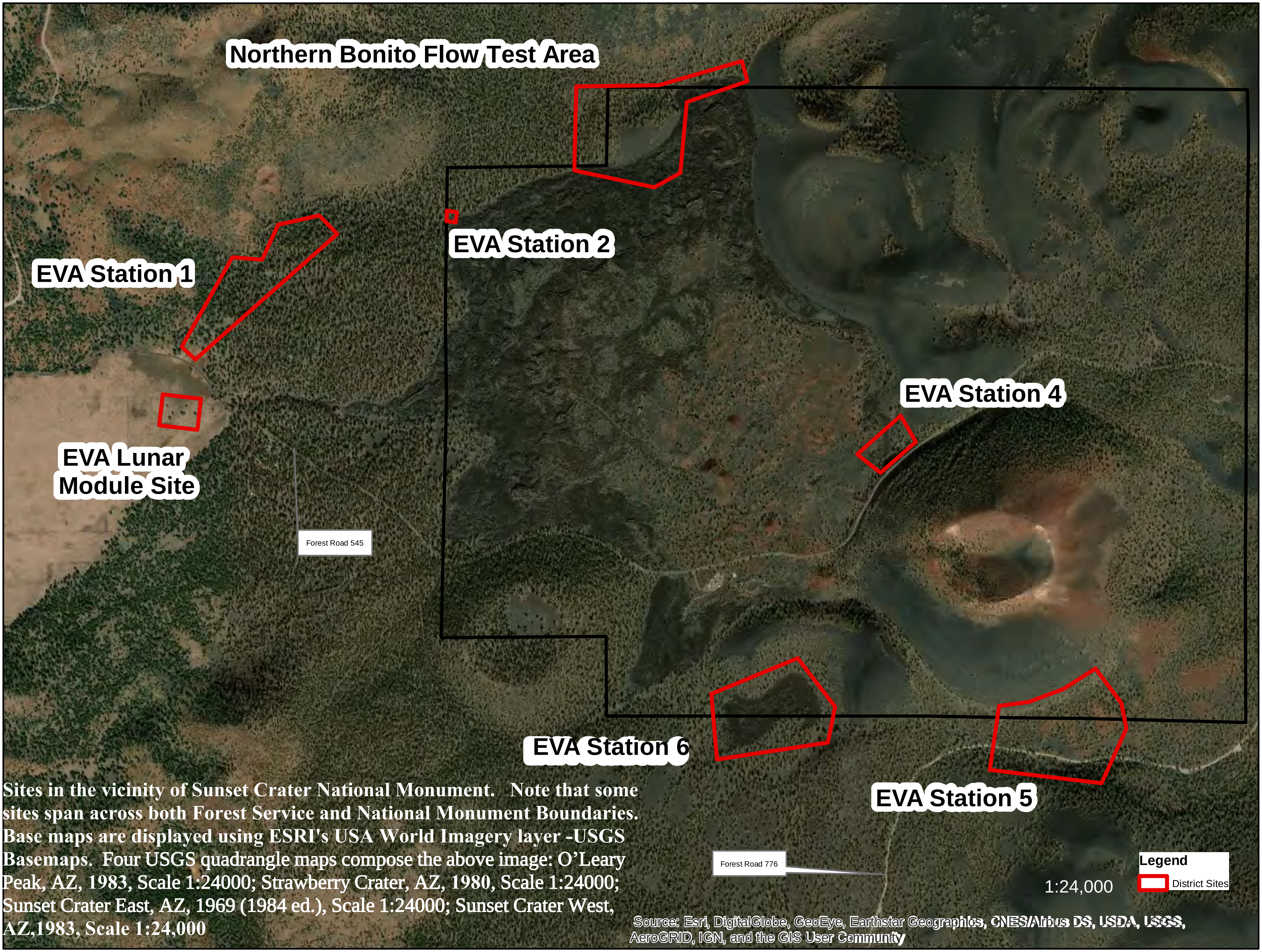
Overview map of the SUCR-Cinder Lake Apollo Testing and Training Historic District. SUCR sits at the intersection of four USGS quadrangle maps. Base maps are displayed using ESRI's USA Topomaps layer -USGS Basemaps. Four USGS quadrangle maps compose the above image: O'Leary Peak, AZ, 1983, Scale 1:24000; Strawberry Crater, AZ, 1980, Scale 1:24000; Sunset Crater East, AZ, 1969 (1984 ed.), Scale 1:24000; Sunset Crater West, AZ, 1983, Scale 1:24000.



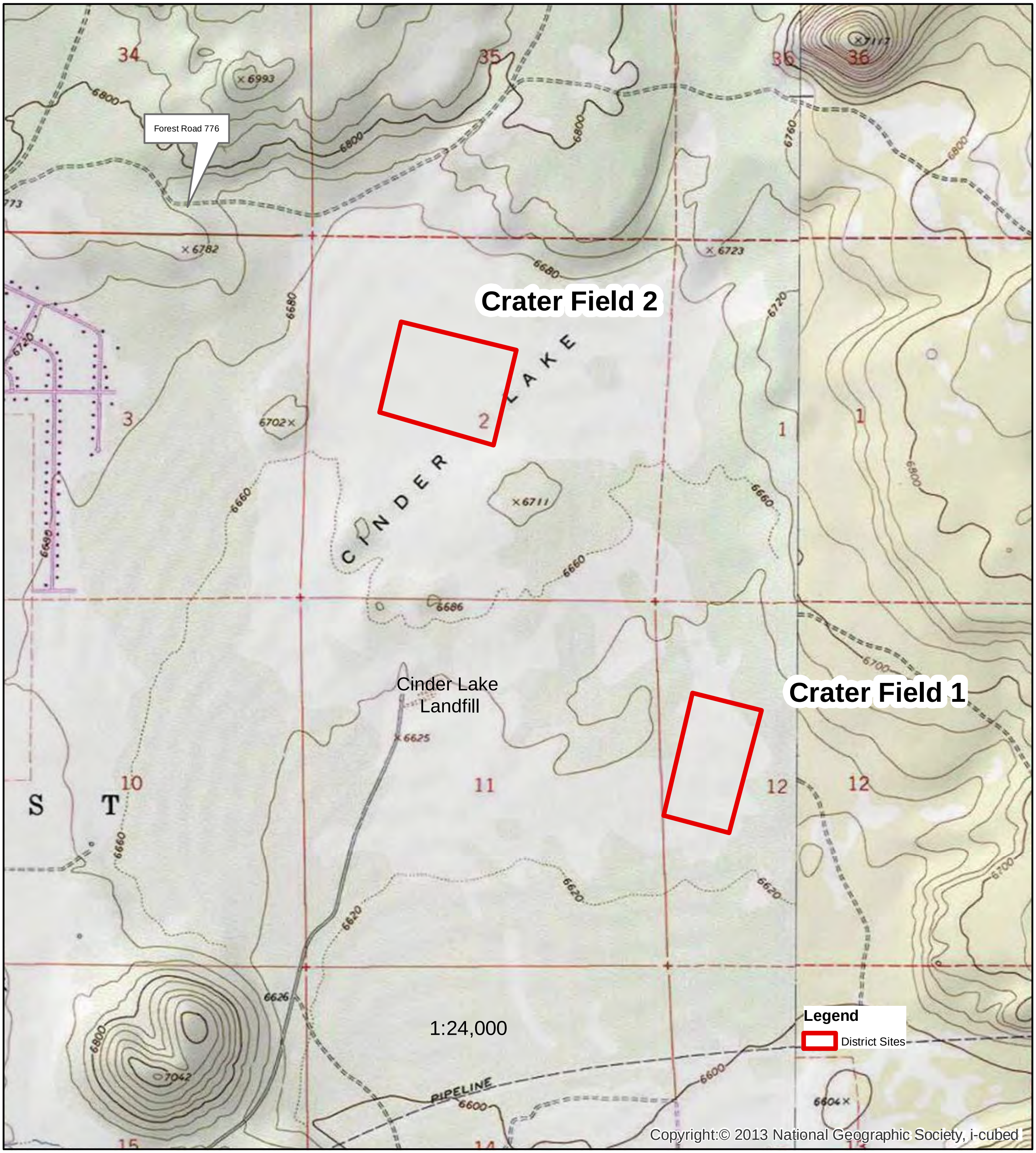
Overview map of the SUCR-Cinder Lake Apollo Testing and Training Historic District. SUCR sits at the intersection of four USGS quadrangle maps. Base maps are displayed using ESRI's World Imagery layer -USGS Basemaps. Four USGS quadrangle maps compose the above image: O'Leary Peak, AZ, 1983, Scale 1:24000; Strawberry Crater, AZ, 1980, Scale 1:24000; Sunset Crater East, AZ, 1969 (1984 ed.), Scale 1:24000; Sunset Crater West, AZ, 1983, Scale 1:24000.



Sites in the vicinity of Sunset Crater National Monument. Note that some sites span across both Forest Service and National Monument Boundaries. Base maps are displayed using ESRI's USA Topomaps layer -USGS Basemaps. Four USGS quadrangle maps compose the above image: O'Leary Peak, AZ, 1983, Scale 1:24000; Strawberry Crater, AZ, 1980, Scale 1:24000; Sunset Crater East, AZ, 1969 (1984 ed.), Scale 1:24000; Sunset Crater West, AZ, 1983, Scale 1:24000.



Sites in the vicinity of Sunset Crater National Monument. Note that some sites span across both Forest Service and National Monument Boundaries. Base maps are displayed using ESRI's USA World Imagery layer -USGS Basemaps. Four USGS quadrangle maps compose the above image: O'Leary Peak, AZ, 1983, Scale 1:24000; Strawberry Crater, AZ, 1980, Scale 1:24000; Sunset Crater East, AZ, 1969 (1984 ed.), Scale 1:24000; Sunset Crater West, AZ,1983, Scale 1:24,000



Location of Cinder Lake Crater Field One and Cinder Lake Crater Field Two. Note that Crater Field Two is non-contributing to this nomination. Base maps are displayed using ESRI's USA Topomaps layer -USGS Basemaps. USGS Quadrangle, Sunset Crater West, AZ, 1983, Scale 1:24000 and USGS Quadrangle, Sunset Crater East, AZ, 1969, Scale 1:24000

Location of Cinder Lake Crater Field One and Cinder Lake Crater Field Two. Note that Crater Field Two is non-contributing to this nomination. Base maps are displayed using ESRI's World Imagery layer. USGS Quadrangle, Sunset Crater West, AZ, 1983, Scale 1:24000 and USGS Quadrangle, Sunset Crater East, AZ, 1969, Scale 1:24000

Photographs

Photo Log

Name of Property: Sunset Crater-Cinder Lake Apollo Mission Testing and Training Historic District

City or Vicinity: Sunset Crater Volcano National Monument

County: Coconino State: Arizona

Figure Number:	Description and Source
1 of 79	Aerial overview of Northern Bonito Lava Flow Test Area from the period of significance. The Bonito Flow is clearly visible to the left (south) and the cinder hill rises to the right (north). The wooden walkway that facilitated access to the Surveyor camera test site is visible at the center of the image. The access road running along the base of the cinder hill is also visible. This image was taken from a low-flying helicopter to facilitate mapping of the Surveyor camera test site, 1964. (Uncatalogued USGS photo, Astrogeology Regional Planetary Information Facility, USGS Astrogeology Science Center, Flagstaff, Arizona).
2 of 79	Astronauts Charlie Duke and John Young sample a boulder near the northern edge of the Bonito Lava Flow at Station Three. The Explorer LRV is in the foreground along with the Traverse Gravimeter Experiment (blue box). (SUCR Photo Archive, SUCR 2396, Colton Research Center, Museum of Northern Arizona, Flagstaff, Arizona).
3 of 79	Repeat photograph of Fig 2 in the Northern Bonito Lava Flow Test Area looking east. The area retains its historic appearance. Given the isolated nature of the site, it is possible that the tracks in the foreground are from the Explorer LRV. (Photo by author. October 27, 2018).
4 of 79	Astronauts Charlie Duke and John Young photograph and sample a boulder near the northern edge of the Bonito Lava Flow at Station Three.

	Several lunar hand tools are visible including a rake. The Explorer LRV is in the foreground. (SUCR Photo Archive, SUCR 549, Colton Research Center, Museum of Northern Arizona, Flagstaff, Arizona).
5 of 79	Repeat photograph of Fig. 4 in the Northern Bonito Lava Flow Test Area looking east. (Photo by author. October 27, 2018).
6 of 79	Astronaut Charlie Duke samples a boulder using a core tube at Station Three. Note the rock chips at the base of the rock from sampling. UTM: 452806.00 m E, 3915948.00 m N. (SUCR Photo Archive, SUCR 550, Colton Research Center, Museum of Northern Arizona, Flagstaff, Arizona).
7 of 79	Repeat photograph of Fig. 6 in the North Bonito Test Area looking northeast. Note the historic appearance of the site and rock chips from geological sampling. (Photo by author. October 27, 2018).
8 of 79	Astronauts Charlie Duke (front) and John Young (back) sample and document the edge of the Bonito Lava Flow at Station Three during the Apollo 17 EVA2 at Sunset Crater Volcano National Monument, November 2-3, 1972. (SUCR Photo Archive, SUCR 1895, Colton Research Center, Museum of Northern Arizona, Flagstaff, Arizona.)
9 of 79	Repeat photograph of Fig. 8 in the North Bonito Test Area looking northeast. The natural features of the area including vegetation have changed little since the period of significance. (Photo by author. October 27, 2018).
10 of 79	Suited test subject collecting a sample on the northern edge of the Bonita Lava Flow. Note the mock Personal Life Support System. (Image from Schaber, open-file report, 2005).
11 of 79	Repeat photograph of Fig. 10, facing southwest. (Photo by author. March 13, 2018.)

12 of 79	GM personnel with the Surveyor test camera on the Bonito Lava Flow, 1964. (Image from Schaber, open-file report, 2005. USGS photo, P879B, F651112).
13 of 79	A present-day view of the Surveyor camera test site looking east from the access road. (Photo by Steward Deats. November 7, 2017.)
14 of 79	View from the Surveyor test site looking north. This image shows the wooden walkway used to cross the jagged Bonito Lava Flow and access the site. (SUCR Photo Archive, SUCR 532, Colton Research Center, Museum of Northern Arizona, Flagstaff, Arizona).
15 of 79	View of Surveyor walkway area looking north/northwest. (Photo by Stewart Deats, November 6, 2017).
16 of 79	Construction of Crater Field One, July 27-28, 1967. (Image from Schaber, open-file report, 2005. USGS Photo P447, F106754.)
17 of 79	Scale map (1:50) of USGS Crater Field Number One, 1967. The inner square shows the 500' x 500' foot area constructed first. (Uncatalogued USGS Map, USGS Astrogeology Regional Planetary Information Facility, USGS Astrogeology Science Center, Flagstaff, Arizona.)
18 of 79	Aerial photo of USGS Crater Field One. Compare with scale map (Fig. 17). The large crater in the bottom left corner of the image was created using leftover explosives. (Uncatalogued USGS Map, USGS Astrogeology Regional Planetary Information Facility, USGS Astrogeology Science Center, Flagstaff, Arizona.)
19 of 79	The final appearance of Crater Field One after the addition of 96 craters in October, 1967. In total, the field contains 143 craters of varying size. Note the ramp at the center of the field that was used to simulate the height of the lunar module on the

	moon. A fence surrounding the field is also visible. (Image from Schaber, open-file report, 2005.)
20 of 79	These conspicuous rocks at Crater Field One were probably placed here for training purposes. (Photo by author. April 15, 2018.)
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23 of 79	Crater Field One looking north from atop the LM ramp. Note the barren landscape and well-preserved craters. (Photo by author. April 15, 2018.)
24 of 79	Crater Field One looking south from atop the LM ramp. (Photo by author. April 15, 2018.)
25 of 79	Largest crater in the northwest corner of the Crater Field One looking west. Note the relief and high degree of integrity. (Photo by author. April 15, 2018).
26 of 79	Another example of a well-preserved crater at Crater Field One. View is to the south. (Photo by author. April 15, 2018.)
27 of 79	Contemporary signage and fence surrounding Crater Field One, looking east. (Photo by author. April 15, 2018.)
28 of 79	This aerial image shows the first sequence of 354 blasts that created part of Crater Field Two, July 27, 1968. (Image from Schaber, open-file report, 2005. USGS photo 768227-3.)

29 of 79	Second sequence of sixty-one blasts during construction of Crater Field Two. (Image from Schaber, open-file report, 2005. USGS photo P642 F768215.)
30 of 79	Final sequence of eleven blasts during construction of Crater Field Two. (Image from Schaber, open-file report, 2005. USGS photo P645, F768228-8.)
31 of 79	This aerial view shows the final appearance of Crater Field Two. The light-colored ejecta is clay excavated by the blasting. (Image from Schaber, open-file report, 2005. USGS photo, P645, F768228.)
32 of 79	USGS 1:1000 scale map of Crater Field Two. Compare with Fig. 31 and note the precision of workmanship and design. (Uncatalogued USGS Image, USGS Astrogeology Regional Planetary Information Facility, USGS Astrogeology Science Center, Flagstaff, Arizona.)
33 of 79	Lunar Module site for Apollo 17, EVA2, November 2-3, 1972. Note the "Explorer" LRV simulator (left) and mock LM (center). (SUCR Photo Archive, SUCR 534, Colton Research Center, Museum of Northern Arizona, Flagstaff, Arizona.)
34 of 79	Repeat photograph of Fig. 33 highlighting the historical integrity of the LM site. The ponderosa pines in the background have grown significantly since 1972. (Photo by author. October 27, 2018.)
35 of 79	Astronauts Charlie Duke and John Young at the LM site in Bonito Park, 1972. (SUCR Photo Archive, SUCR 535, Colton Research Center, Museum of Northern Arizona, Flagstaff, Arizona.)
36 of 79	Repeat photograph of Fig. 35. (Photo by author. October 27, 2018.)
37 of 79	Old Forest Service road running through Station One. This route may have been used by astronauts Charlie Duke and John Young during their 1972

simulated EVA for Apollo 17. (Photo by author. November 4, 2018).

38 of 79	Talus slope at the base of Robinson Mountain in Station One looking north. This talus may have been sampled by astronauts Duke and Young during their 1972 simulated EVA for Apollo 17. (Photo by author. November 4, 2018.
39 of 79	Astronauts Charlie Duke and John Young take photos and sample the edge of the Bonito Lava Flow at Station Two, 1972. (SUCR Photo Archive, SUCR 545, Colton Research Center, Museum of Northern Arizona, Flagstaff, Arizona.)
40 of 79	Repeat photograph of Fig. 39. Note that the large ponderosa log has collapsed. (Photo by author. October 27, 2018)
41 of 79	Repeat photograph of Fig. 39. The natural features of this area exhibit a high degree of historical integrity. (Photo by author. October 27, 2018)
42 of 79	Astronauts Charlie Duke (back turned) and John Young take photos and sample the edge of the Bonito Lava Flow at Station Two, 1972. This image was taken from on top of the flow. (SUCR Photo Archive, SUCR 546, Colton Research Center, Museum of Northern Arizona, Flagstaff, Arizona.)
43 of 79	Repeat photo of Fig. 42. Station Two appears much as it did in 1972. (Photo by author. October 27, 2018).
44 of 79	The Explorer LRV and astronauts Charlie Duke and John Young at the base of the Bonito Lava Flow in Station Two. (SUCR Photo Archive, SUCR 548, Colton Research Center, Museum of Northern Arizona, Flagstaff, Arizona.)
45 of 79	Repeat photograph of Fig. 44. Note the presence of a wire boundary fence in the background. (Photo by author. October 27, 2018).
46 of 79	Overview of Station Four looking north from the Loop Road. The cinder in the foreground is the

	base of Sunset Crater Volcano. This is the origin point of the Bonito Lava Flow. (Photo by author. November 4, 2018).
47 of 79	Contact point between Sunset Crater Volcano and Bonito Lava Flow at Station Four, looking west below the Loop Road. (Photo by author. November 4, 2018).
48 of 79	Overview of the northern portion of Station Five looking north from Forest Service road 776. The parasitic lava flow (red cinder) is visible in the background. (Photo by author. April 15, 2018.)
49 of 79	Apollo 17 astronauts Harrison "Jack" Schmitt (left) and Gene Cernan (left) document and photograph a volcanic bomb at Station Five during the Apollo 17 EVA3, November 2-3, 1972. Note the gnomon next to the sample, mock Portable Life Support Systems (PLSS) and chest-mounted Hasselblad cameras. (SUCR Photo Archive, SUCR 1878, Colton Research Center, Museum of Northern Arizona, Flagstaff, Arizona.)
50 of 79	Repeat photograph of Fig. 49 showing the sampled rock. A careful look at the background reveals that the natural features of this site are virtually unchanged since 1972. (Photo by author. November 4, 2018).
51 of 79	View looking south across the non-contributing half of Station Five. Forest Service road 776 (gray gravel) is just beyond the USFS easement fence. Note the cinder disruption and tracks due to OHV use. (Photo by author. November 4, 2018).
52 of 79	Overview of Station Six looking west. The slope in the foreground is the half cinder cone. The a'a lava flow is visible if the background. This image conveys the isolation of the area. (Photo by author. September 1, 2018).
53 of 79	View of Station Six, looking north. The half cone (background) and southernmost portion of the Bonito Lava Flow (foreground) are both visible. (Photo by author. April 15, 2018.)

54 of 79	Astronaut Harrison "Jack" Schmitt on the southern portion of the Bonito Lava Flow at Station Six during Apollo 17 EVA3, November 2-3, 1972. (SUCR Photo Archive, Photo 1877, Colton Research Center, Museum of Northern Arizona, Flagstaff, Arizona.)
55 of 79	Repeat photograph of Fig. 54. (Photo by author. September 1, 2018).
56 of 79	Astronauts D.K. Slayton (left), N.A. Armstrong (center) and J.W. Young (right), use a wide-angle mirror stereoscope at the Bonito Lava Flow. (Fig. 5 in E.D. Jackson, "Early Terrestrial Geology and Geophysics Training," Testing and Training Collection, Box 7, Folder: Geology Field Trips-Pre Mission, n.d. (1975), NASA/USGS Astrogeology Regional Planetary Information Facility, USGS Astrogeology Science Center, Flagstaff, Arizona. NASA photograph S-64-23817.)
57 of 79	Neil Armstrong and J.W. Young on the Bonito Lava Flow during geology field training, 1964. (Image from SUCR Administration Collection, Box L21, Folder: Lunar testing at Sunset Crater 1964, SUCR 24.6, Colton Research Center, Museum of Northern Arizona, Flagstaff, Arizona.)
58 of 79	Astronauts (l-to-r) C.C. Williams, Frank Borman, and Gene Cernan on the Bonito Lava Flow with USGS geologist Dale Jackson, April 30, 1964. (Image from Schaber, open-file report, 2005. NASA photo S-64-23729.)
59 of 79	Apollo 15 astronauts Jim Irwin and David Scott practice documenting and sampling rocks at Crater Field One. Pictured are (l-to-r) Jim Irwin, Bill Phinney (MSC/Houston), Lee Silver (Caltech and USGS) and Dave Scott. Sunset Crater Volcano is visible in the background to the north above Irwin. (Image from Schaber, open-file report, 2005. NASA photo S-70-53304.)
60 of 79	Apollo 15 astronauts Jim Irwin (left) and Dave Scott (left) training at Crater Field One. The USGS

	simulated LRV "Grover" is in the background near the elevated LM ramp. This image was taken facing northeast. (Image from Schaber, open-file report, 2005. USGS photo F117045.)
61 of 79	Apollo 15 astronauts Jim Irwin (left) and Dave Scott (right) train in the USGS LRV simulator Grover on one of the Cinder Lake crater fields. (Image from Schaber, open-file report, 2005. NASA photo AP15-S70-53283.)
62 of 79	Astronaut James B. Irwin trenching lunar soil during an Apollo 15 moonwalk. (July 31-August 2, 1971, NASA photo AS15-92-12424.)
63 of 79	Apollo 15 astronaut James Irwin with the Lunar Roving Vehicle. (July 31, 1971, NASA photo AS15-86-11603.)
64 of 79	Astronauts Eugene Cernan and Harrison "Jack" Schmitt train in the USGS LRV Grover at Station Six during the Apollo 17 EVA3, November 2-3, 1972. (SUCR Photo Archive, Photo 1884, Colton Research Center, Museum of Northern Arizona, Flagstaff, Arizona.)
65 of 79	Eugene Cernan pilots the Lunar Roving Vehicle during an Apollo 17 EVA, December 11, 1972. Before driving on the moon, Apollo 15, 16 and 17 astronauts trained using simulated LRVs in the district. (NASA photo AS17-147-22526).
66 of 79	Astronaut Harrison H. Schmitt holds a lunar rake used for sampling small rocks during an EVA for Apollo 17. Schmitt and other astronauts practiced sampling with these tools in the district. (December 11, 1972. NASA photo AS17-134-20426)
67 of 79	Eugene Cernan took this picture of Harrison Schmitt using a lunar rake to sample the surface during EVA on December 12, 1972. Note the gnomon in the foreground. The photography and sampling practices shown here were practiced first in and around Sunset Crater Volcano. (NASA photo AS17-145-22157)

68 of 79	Map of the Surveyor camera test site on the Bonito Lava Flow. (Uncatalogued USGS Image, USGS Astrogeology Regional Planetary Information Facility, USGS Astrogeology Science Center, Flagstaff, Arizona.)
69 of 79	Suited test subject John Hendricks next to the "Explorer" LRV at Cinder Lake Crater Field One along with SPE personnel (l-to-r), Dick Wiser, Bill Tinnin and Putty Mills. (Image from Schaber, open-file report, 2005. USGS photo P726c, F126845c.)
70 of 79	Suited subjects Tim Hait and David Schleicher test tools at Cinder Lake Crater Field One with a mock Lunar Module in the background. The ramp was necessary to simulate the actual high of the Lunar Module. (Image from Schaber, open-file report, 2005. USGS photo P463, F11067199.)
71 of 79	Repeat photo of Fig. 69. Some erosion of the LM ramp is evident. (Photo by author. July 21, 2018).
72 of 79	Suited test subject Tim Hait drives a core sample tube into the rim of a crater at Cinder Lake Crater Field One. Note the prototype tool carrier in the foreground. Astronauts used similar tool carriers during Apollo 12-14 moonwalks. (Image from Schaber, open-file report, 2005. USGS photo P564, F36819c.)
73 of 79	Suited test subject with lunar hand tool carrier. (Uncatalogued USGS Image, USGS Astrogeology Regional Planetary Information Facility, USGS Astrogeology Science Center, Flagstaff, Arizona.)
74 of 79	Apollo 12 astronaut using lunar hand tools and a carrier similar to the one tested at Crater Field One. (November 19-20, 1969, NASA photo AS12-49-7318.)
75 of 79	Bendix prototype Surveyor Lunar Roving Vehicle on the Bonito Lava Flow, May, 1964. (Image from Schaber, open-file report, 2005.)
76 of 79	Apollo 17 astronaut Harrison "Jack" Schmitt (left seat) and an unidentified passenger drive a

prototype Bendix Lunar Roving Vehicle at on the Cinder Lake Crater Field One, 29-30, 1969. (Image from Schaber, open-file report, 2005. USGS photo P916c, F116929.)

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USGS Branch of Astrogeology conducts their first spacesuit test on the access road within the North Bonito Lava Flow Test Area in June 15-20, 1964. The suited test subject (either Gene Shoemaker, G. Phillippi, or J. Harbour) is visible in front of the support van holding a prototype lunar staff for taking pictures. The general characteristics of the site are evident here including the sharp distinction between the cinder hill and a’a lava flow. (Photo by Paul Long. Image from Schaber, open-file report, 2005).

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Suited test subject climbing a portion of the Bonito Lava Flow while engineers carry communications cables, June 15-20, 1964. (Photo by Paul Long. Image from Schaber, open-file report, 2005).

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A suited test subject with prototype lunar staff on the northern edge of the Bonito Lava Flow, June 15-20, 1964. (Photo by Paul Long. Image from Schaber, open-file report, 2005).

Fig. 1. Aerial overview of Northern Bonito Lava Flow Test Area. The Bonito Flow is clearly visible to the left (south) and the cinder hill rises to the right (north). The wooden walkway that facilitated access to the Surveyor camera test site is visible at the center of the image. The access road running along the base of the cinder hill is also visible. This image was taken from a low-flying helicopter to facilitate mapping of the Surveyor camera test site, 1964. (Uncatalogued USGS photo, Astrogeology Regional Planetary Information Facility, USGS Astrogeology Science Center, Flagstaff, Arizona).

Fig. 2. Astronauts Charlie Duke and John Young sample a boulder near the northern edge of the Bonito Lava Flow at Station Three. The Explorer LRV is in the foreground along with the Traverse Gravimeter Experiment (blue box). (SUCR Photo Archive, SUCR 2396, Colton Research Center, Museum of Northern Arizona, Flagstaff, Arizona).

Fig. 3. Repeat photograph of SUC 2396 in the Northern Bonito Lava Flow Test Area looking east. The area retains its historic appearance. Given the isolated nature of the site, it is possible that the tracks in the foreground are from the Explorer LRV. (Photo by author. October 27, 2018).

Fig. 4. Astronauts Charlie Duke and John Young photograph and sample a boulder near the northern edge of the Bonito Lava Flow at Station Three. Several lunar hand tools are visible including a rake. The Explorer LRV is in the foreground. (SUCR Photo Archive, SUCR 549, Colton Research Center, Museum of Northern Arizona, Flagstaff, Arizona).

Fig. 5. Repeat photograph of Fig. 4 in the Northern Bonito Lava Flow Test Area looking east. The natural features of the area are virtually unchanged since the period of significance. (Photo by author. October 27, 2018).

Fig. 6. Astronaut Charlie Duke samples a boulder using a core tube at Station Three. Note the rock chips at the base of the rock from sampling. UTM: 452806.00 m E, 3915948.00 m N. (SUCR Photo Archive, SUCR 550, Colton Research Center, Museum of Northern Arizona, Flagstaff, Arizona).

Fig. 7. Repeat photograph of Fig. 6 in the North Bonito Test Area looking northeast. Note the historic appearance of the site and rock chips from geological sampling in 1972. (Photo by author. October 27, 2018).

Fig. 8. Astronauts Charlie Duke (front) and John Young (back) sample and document the edge of the Bonito Lava Flow at Station Three during the Apollo 17 EVA2 at Sunset Crater Volcano National Monument, November 2-3, 1972. (SUCR Photo Archive, SUCR 1895, Colton Research Center, Museum of Northern Arizona, Flagstaff, Arizona).

Fig. 9. Repeat photograph of Fig. 8 in the North Bonito Test Area looking northeast. The natural features of the area including vegetation are changed little since the period of significance. (Photo by author. October 27, 2018).

Fig. 10. Suited test subject collecting a sample on the northern edge of the Bonita Lava Flow. Note the mock Personal Life Support System. (Image from Schaber, open-file report, 2005).

Fig. 11. Repeat photograph of Fig. 10, facing southwest. (Photo by author. March 13, 2018.)

Fig. 12. GM personnel with the Surveyor test camera on the Bonito Lava Flow, 1964. (Image from Schaber, open-file report, 2005. USGS photo, P879B, F651112).

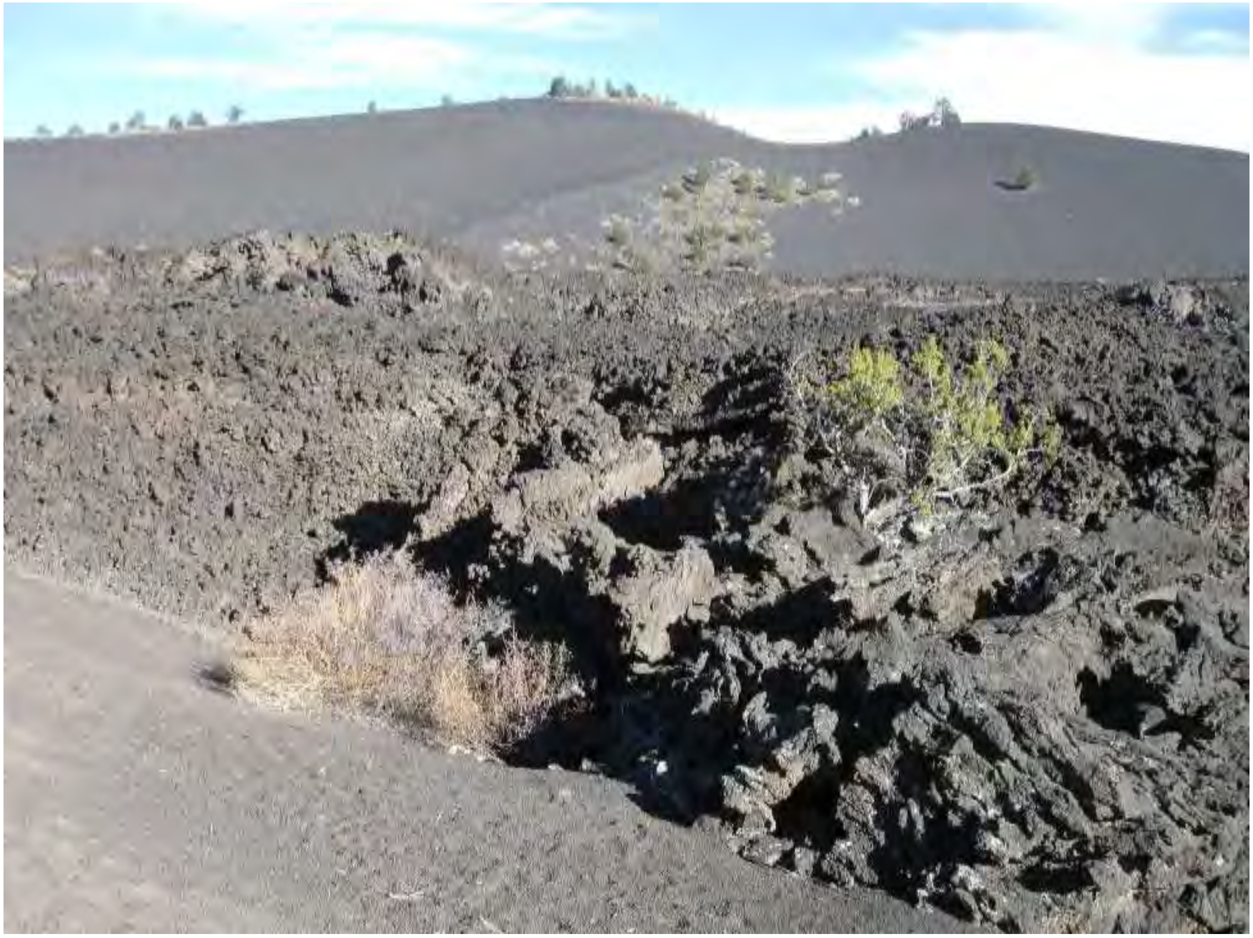

Fig. 13. A present-day view of the Surveyor camera test site looking east from the access road. (Photo by Steward Deats. November 7, 2017.)

Fig. 14. View from the Surveyor test site looking north. This image shows the wooden walkway used to cross the jagged Bonito Lava Flow and access the site. (SUCR Photo Archive, SUCR 532, Colton Research Center, Museum of Northern Arizona, Flagstaff, Arizona).

Fig. 15. View of Surveyor walkway area looking north/northwest. (Photo by Stewart Deats, November 6, 2017).

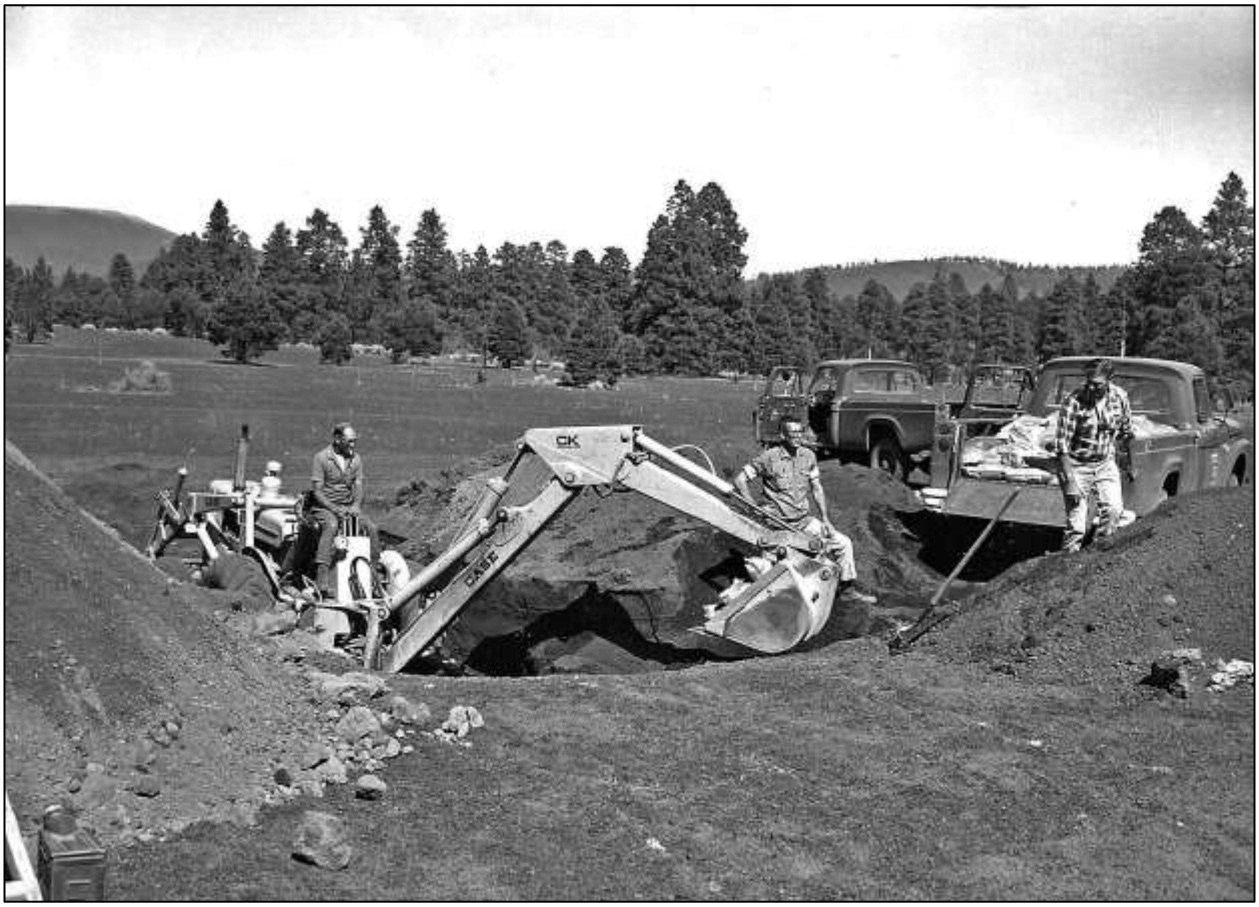

Fig. 16. Construction of Crater Field One, July 27-28, 1967. (Image from Schaber, open-file report, 2005. USGS Photo P447, F106754.)

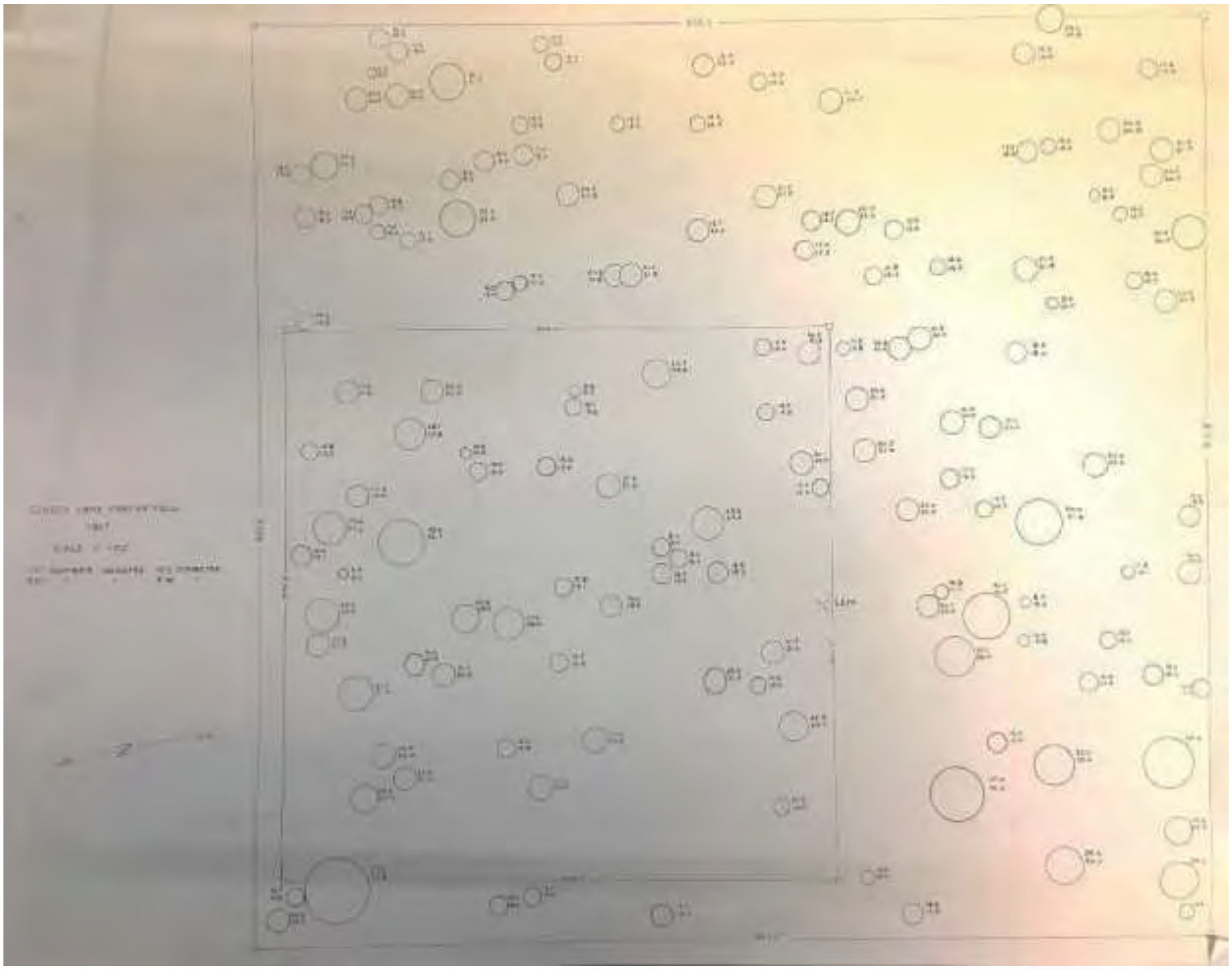

Fig. 17. Scale map (1:50) of USGS Crater Field Number One, 1967. The inner square shows the 500’ x 500’ foot area constructed first. (Uncatalogued USGS Map, USGS Astrogeology Regional Planetary Information Facility, USGS Astrogeology Science Center, Flagstaff, Arizona.)

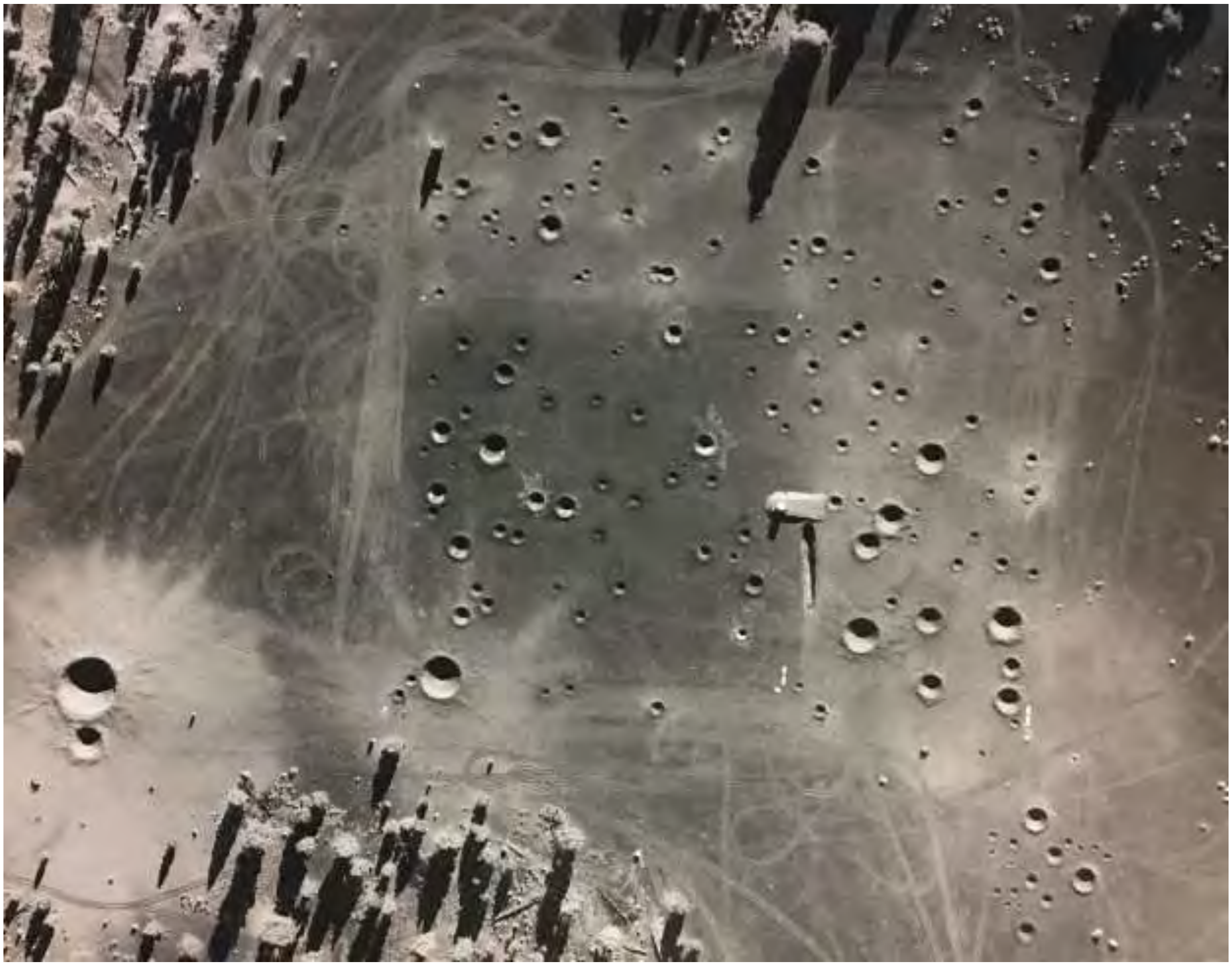

Fig. 18. Aerial photo of USGS Crater Field One. Compare with scale map (Fig. 17). The large crater in the bottom left corner of the image was created using leftover explosives. (Uncatalogued USGS Map, USGS Astrogeology Regional Planetary Information Facility, USGS Astrogeology Science Center, Flagstaff, Arizona.)

Fig. 19. The final appearance of Crater Field One after the addition of 96 craters in October, 1967. In total, the field contains 143 craters of varying size. Note the ramp at the center of the field that was used to simulate the height of the lunar module on the moon. A fence surrounding the field is also visible. (Image from Schaber, open-file report, 2005.)

Fig. 20. These conspicuous rocks at Crater Field One were probably placed here for training purposes. (Photo by author. April 15, 2018.)

Fig. 21. Aerial photo of Crater Field One superimposed over Lunar Orbiter photos of the lunar surface. (Uncatalogued USGS Image, USGS Astrogeology Regional Planetary Information Facility, USGS Astrogeology Science Center, Flagstaff, Arizona.)

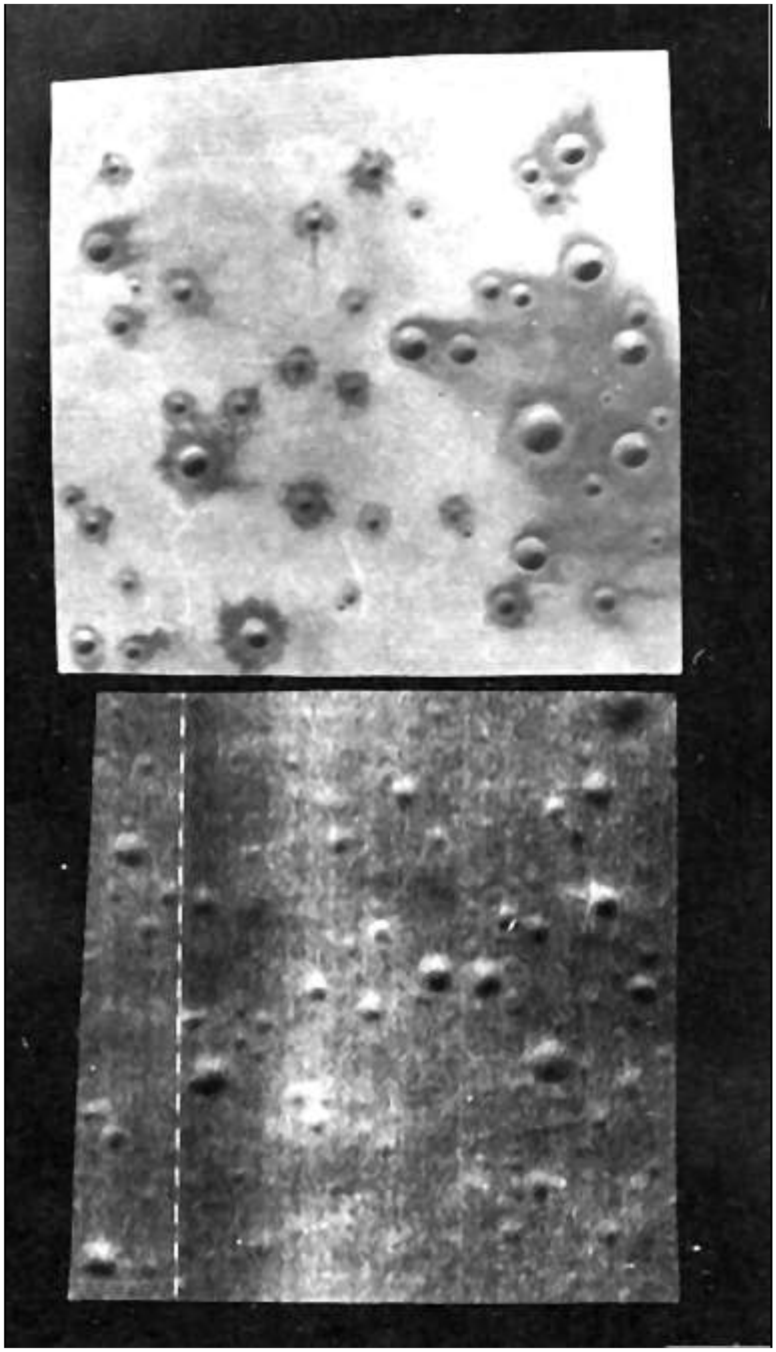

Fig. 22. Comparison of Cinder Lake Crater Field One (top) and a portion of the Apollo 11 landing site photographed by Lunar Orbiter II (bottom). (Image from Schaber, open-file report, 2005. USGS photo, USGS photo P421, F867187.)

Fig. 23. Crater Field One looking north from atop the LM ramp. Note the barren landscape and well-preserved craters. (Photo by author. April 15, 2018.)

Fig. 24. Crater Field One looking south from atop the LM ramp. (Photo by author. April 15, 2018.)

Fig. 25. Largest crater in the northwest corner of the Crater Field One looking west. Note the relief and high degree of integrity. (Photo by author. April 15, 2018).

Fig. 26. Another example of a well-preserved crater at Crater Field One. View is to the south. (Photo by author. April 15, 2018.)

Fig. 27. Contemporary signage and wire fence surrounding Crater Field One, looking northeast. (Photo by author. April 15, 2018.)

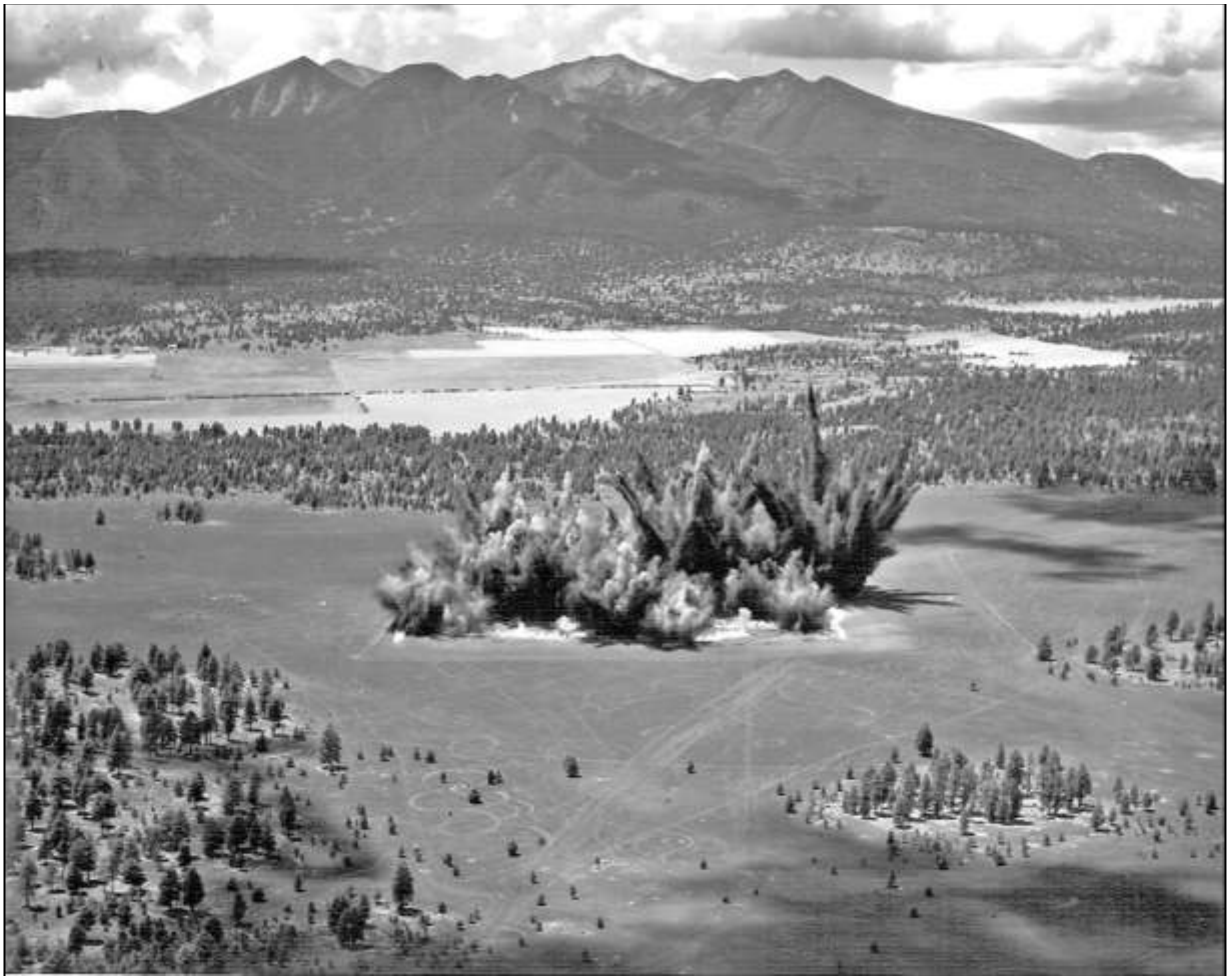

Fig. 28. This aerial image shows the first sequence of 354 blasts that created part of Crater Field Two, July 27, 1968. (Image from Schaber, open-file report, 2005. USGS photo 768227-3.)

Fig. 29. Second sequence of sixty-one blasts during construction of Crater Field Two. (Image from Schaber, open-file report, 2005. USGS photo P642 F768215.)

Fig. 30. Final sequence of eleven blasts during construction of Crater Field Two. (Image from Schaber, open-file report, 2005. USGS photo P645, F768228-8.)

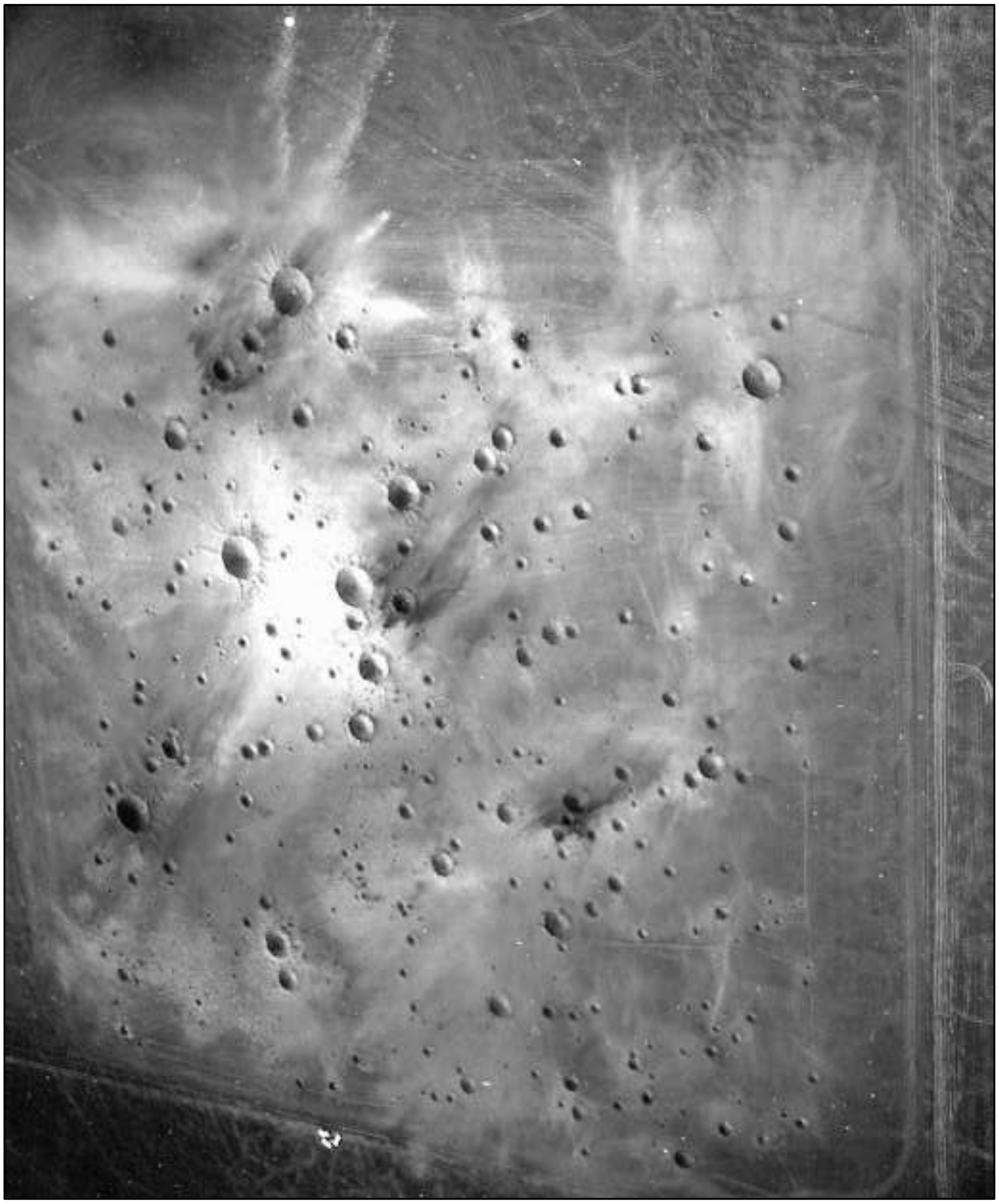

Fig. 31. This aerial view shows the final appearance of Crater Field Two. The light-colored ejecta is clay excavated by the blasting. (Image from Schaber, open-file report, 2005. USGS photo, P645, F768228.)

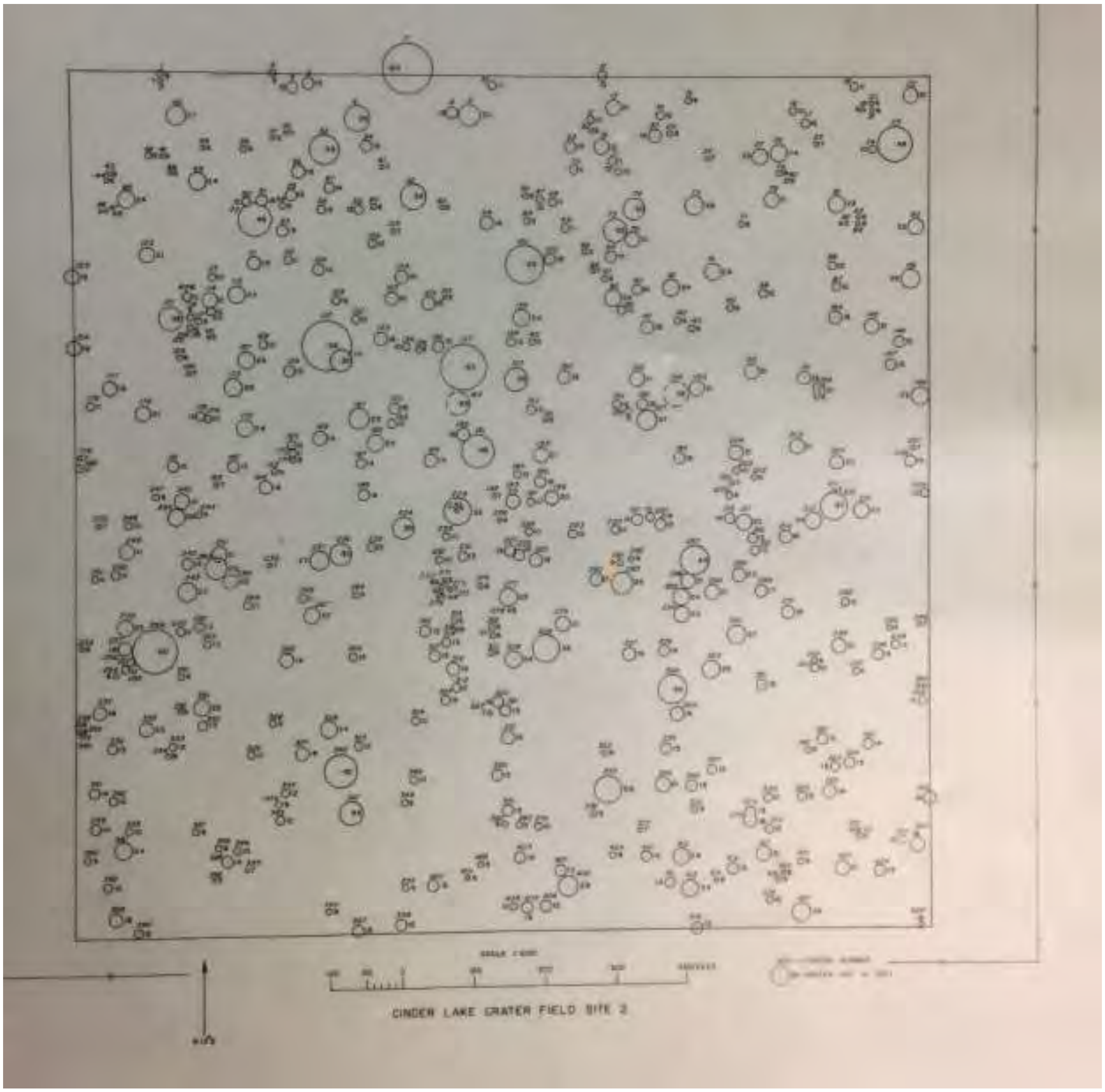

Fig. 32. USGS 1:1000 scale map of Crater Field Two. Compare with Fig. 31 and note the precision of workmanship and design. (Uncatalogued USGS Image, USGS Astrogeology Regional Planetary Information Facility, USGS Astrogeology Science Center, Flagstaff, Arizona.)

Fig. 33. Lunar Module site for Apollo 17, EVA2, November 2-3, 1972. Note the “Explorer” LRV simulator (left) and mock LM (center). (SUCR Photo Archive, SUCR 534, Colton Research Center, Museum of Northern Arizona, Flagstaff, Arizona.)

Fig. 34. Repeat photograph of Fig. 33 highlighting the historical integrity of the LM site. The ponderosa pines in the background have grown significantly since 1972. (Photo by author. October 27, 2018.)

Fig. 35. Astronauts Charlie Duke and John Young at the LM site in Bonito Park, 1972. (SUCR Photo Archive, SUCR 535, Colton Research Center, Museum of Northern Arizona, Flagstaff, Arizona.)

Fig. 36. Repeat photograph of Fig. 35. (Photo by author. October 27, 2018.)

Fig. 37. Old Forest Service road running through Station One. This route may have been used by astronauts Charlie Duke and John Young during their 1972 simulated EVA for Apollo 17. (Photo by author. November 4, 2018).

Fig. 38. Talus slope at the base of Robinson Mountain in Station One looking north. This talus may have been sampled by astronauts Duke and Young during their 1972 simulated EVA for Apollo 17. (Photo by author. November 4, 2018.

Fig. 39. Astronauts Charlie Duke and John Young take photos and sample the edge of the Bonito Lava Flow at Station Two, 1972. (SUCR Photo Archive, SUCR 545, Colton Research Center, Museum of Northern Arizona, Flagstaff, Arizona.)

Fig. 40. Repeat photograph of Fig. 39. Note that the large ponderosa log has collapsed. (Photo by author. October 27, 2018)

Fig. 41. Repeat photograph of Fig. 39. The natural features of this area exhibit a high degree of historical integrity. UTM: 451558.00 m E, 3915252.00 m N. (Photo by author. October 27, 2018)

Fig. 42. Astronauts Charlie Duke (back turned) and John Young take photos and sample the edge of the Bonito Lava Flow at Station Two, 1972. This image was taken from on top of the flow. (SUCR Photo Archive, SUCR 546, Colton Research Center, Museum of Northern Arizona, Flagstaff, Arizona.)

Fig. 43. Repeat photo of Fig. 42. Station Two appears much as it did in 1972. (Photo by author. October 27, 2018).

Fig. 44. The Explorer LRV and astronauts Charlie Duke and John Young at the base of the Bonito Lava Flow in Station Two. (SUCR Photo Archive, SUCR 548, Colton Research Center, Museum of Northern Arizona, Flagstaff, Arizona.)

Fig. 45. Repeat photograph of Fig. 44. Note the presence of a wire boundary fence in the background. (Photo by author. October 27, 2018).

Fig. 46. Overview of Station Four looking north from the Loop Road. The cinder in the foreground is the base of Sunset Crater Volcano. This is the origin point of the Bonito Lava Flow. (Photo by author. November 4, 2018).

Fig. 47. Contact point between Sunset Crater Volcano and Bonito Lava Flow at Station Four, looking west below the Loop Road. (Photo by author. November 4, 2018).

Fig. 48. Overview of the northern portion of Station Five looking north from Forest Service road 776. The parasitic lava flow (red cinder) is visible in the background. (Photo by author. April 15, 2018.)

Fig. 49. Apollo 17 astronauts Harrison “Jack” Schmitt (left) and Gene Cernan (left) document and photograph a volcanic bomb at Station Five during the Apollo 17 EVA3, November 2-3, 1972. Note the gnomon next to the sample, mock Portable Life Support Systems (PLSS) and chest-mounted Hasselblad cameras. (SUCR Photo Archive, SUCR 1878, Colton Research Center, Museum of Northern Arizona, Flagstaff, Arizona.)

Fig. 50. Repeat photograph of Fig. 49 showing the sampled rock. A careful look at the background reveals that the natural features of this site are virtually unchanged since 1972. UTM: 454806.00 m E, 3912745.00 m N. (Photo by author. November 4, 2018).

Fig. 51. View looking south across the non-contributing half of Station Five. Forest Service road 776 (gray gravel) is just beyond the USFS easement fence. Note the cinder disruption and tracks due to OHV use. (Photo by author. November 4, 2018).

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Fig. 53. View of Station Six, looking north. The half cone (background) and southernmost portion of the Bonito Lava Flow (foreground) are both visible. (Photo by author. April 15, 2018.)

Fig. 54. Astronaut Harrison “Jack” Schmitt on the southern portion of the Bonito Lava Flow at Station Six during Apollo 17 EVA3, November 2-3, 1972. (SUCR Photo Archive, Photo 1877, Colton Research Center, Museum of Northern Arizona, Flagstaff, Arizona.)

Fig. 55. Repeat photograph of Fig. 54. (Photo by author. September 1, 2018).

Fig. 56. Astronauts D.K. Slayton (left), N.A. Armstrong (center) and J.W. Young (right), use a wide-angle mirror stereoscope at the Bonito Lava Flow. (Fig. 5 in E.D. Jackson, “Early Terrestrial Geology and Geophysics Training,” Testing and Training Collection, Box 7, Folder: Geology Field Trips-Pre Mission, n.d. (1975), NASA/USGS Astrogeology Regional Planetary Information Facility, USGS Astrogeology Science Center, Flagstaff, Arizona. NASA photograph S-64-23817.)

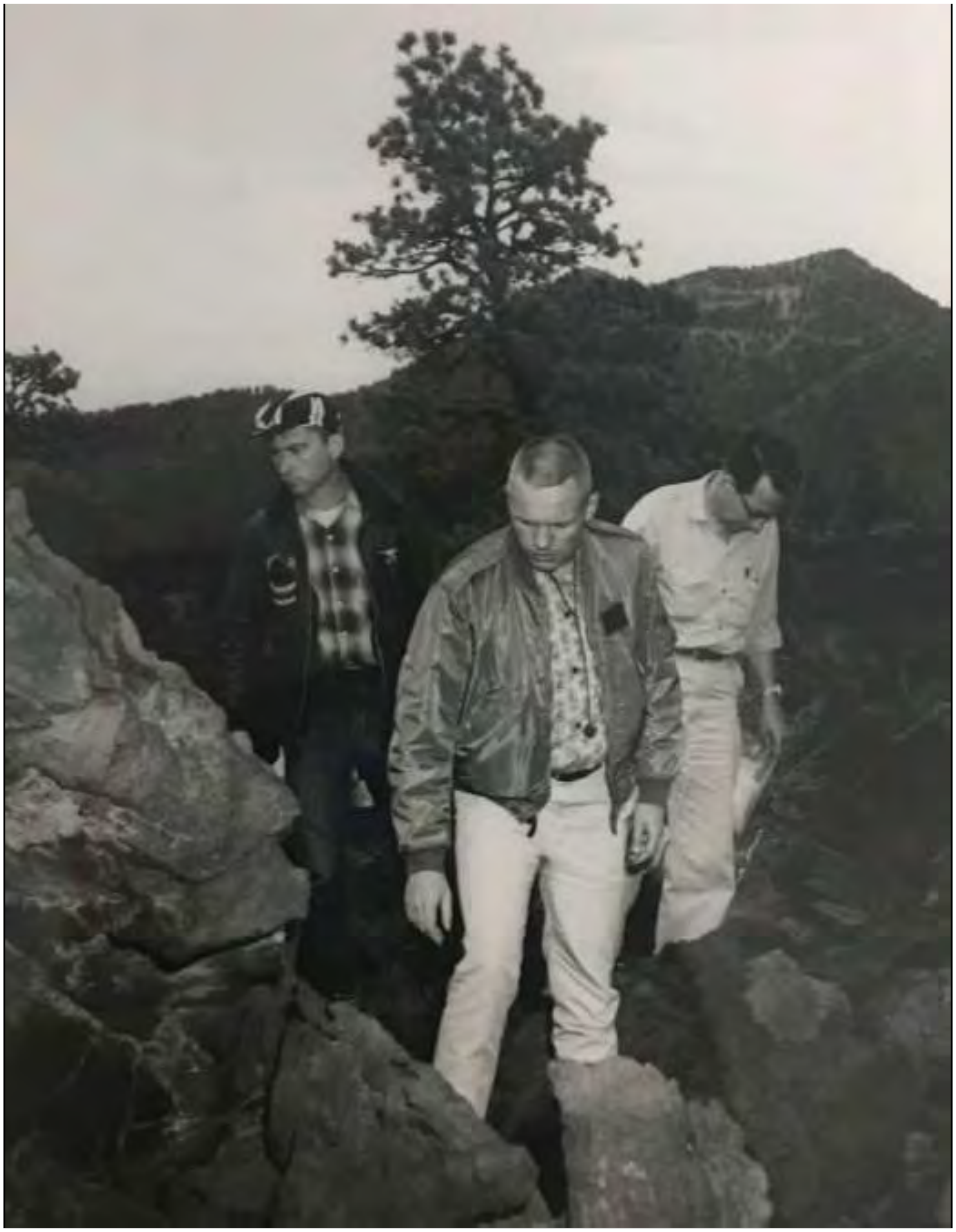


Fig. 57. Neil Armstrong and J.W. Young on the Bonito Lava Flow during geology field training, 1964. (Image from SUCR Administration Collection, Box L21, Folder: Lunar testing at Sunset Crater 1964, SUCR 24.6, Colton Research Center, Museum of Northern Arizona, Flagstaff, Arizona.)

Fig. 58. Astronauts (l-to-r) C.C. Williams, Frank Borman, and Gene Cernan on the Bonito Lava Flow with USGS geologist Dale Jackson, April 30, 1964. (Image from Schaber, open-file report, 2005. NASA photo S-64-23729.)

Fig. 59. Apollo 15 astronauts Jim Irwin and David Scott practice documenting and sampling rocks at Crater Field One, 1970. Pictured are (l-to-r) Jim Irwin, Bill Phinney (MSC/Houston), Lee Silver (Caltech and USGS) and Dave Scott. Sunset Crater Volcano is visible in the background to the north above Irwin. (Image from Schaber, open-file report, 2005. NASA photo S-70-53304.)

Fig. 60. Apollo 15 astronauts Jim Irwin (left) and Dave Scott (left) training at Crater Field One, 1970. The USGS simulated LRV “Grover” is in the background near the elevated LM ramp. This image was taken facing northeast. (Image from Schaber, open-file report, 2005. USGS photo F117045.)

Fig. 61. Apollo 15 astronauts Jim Irwin (left) and Dave Scott (right) train in the USGS LRV simulator Grover on one of the Cinder Lake crater fields, 1970. (Image from Schaber, open-file report, 2005. NASA photo AP15-S70-53283.)

Fig. 62. Astronaut James B. Irwin trenching lunar soil during an Apollo 15 moonwalk. (July 31-August 2, 1971, NASA AS15-92-12424.) Available from: https://spaceflight.nasa.gov/gallery/images/apollo/apollo15/html/as15-92-12424.html

Fig. 63. Apollo 15 astronaut James Irwin with the Lunar Roving Vehicle. (July 31, 1971, NASA photo AS15-86-11603.) Available from:
https://spaceflight.nasa.gov/gallery/images/apollo/apollo15/html/as15-86-11603.html

Fig. 64. Astronauts Eugene Cernan and Harrison Schmitt train in the USGS LRV Grover at Station Six during the Apollo 17 EVA3, November 2-3, 1972. (SUCR Photo Archive, Photo 1884, Colton Research Center, Museum of Northern Arizona, Flagstaff, Arizona.)

Fig. 65. Eugene Cernan pilots the Lunar Roving Vehicle during an Apollo 17 EVA, December 11, 1972. Before driving on the moon, Apollo 15, 16 and 17 astronauts trained using simulated LRVs in the district. (NASA photo AS17-147-22526). Image available from: https://spaceflight.nasa.gov/gallery/images/apollo/apollo17/html/as17-147-22526.html

Fig. 66. Astronaut Harrison H. Schmitt holds a lunar rake used for sampling small rocks during an EVA for Apollo 17. Schmitt and other astronauts practiced sampling with these tools in the district. (December 11, 1972. NASA photo AS17-134-20426.) Image available from: https://spaceflight.nasa.gov/gallery/images/apollo/apollo17/html/as17-134-20426.html

Fig. 67. Eugene Cernan took this picture of Harrison Schmitt using a lunar rake to sample the surface during EVA on December 12, 1972. Note the gnomon in the foreground. The photography and sampling practices shown here were practiced first in and around Sunset Crater Volcano. (NASA photo AS17-145-22157) Image available from:
https://spaceflight.nasa.gov/gallery/images/apollo/apollo17/html/as17-145-22157.html

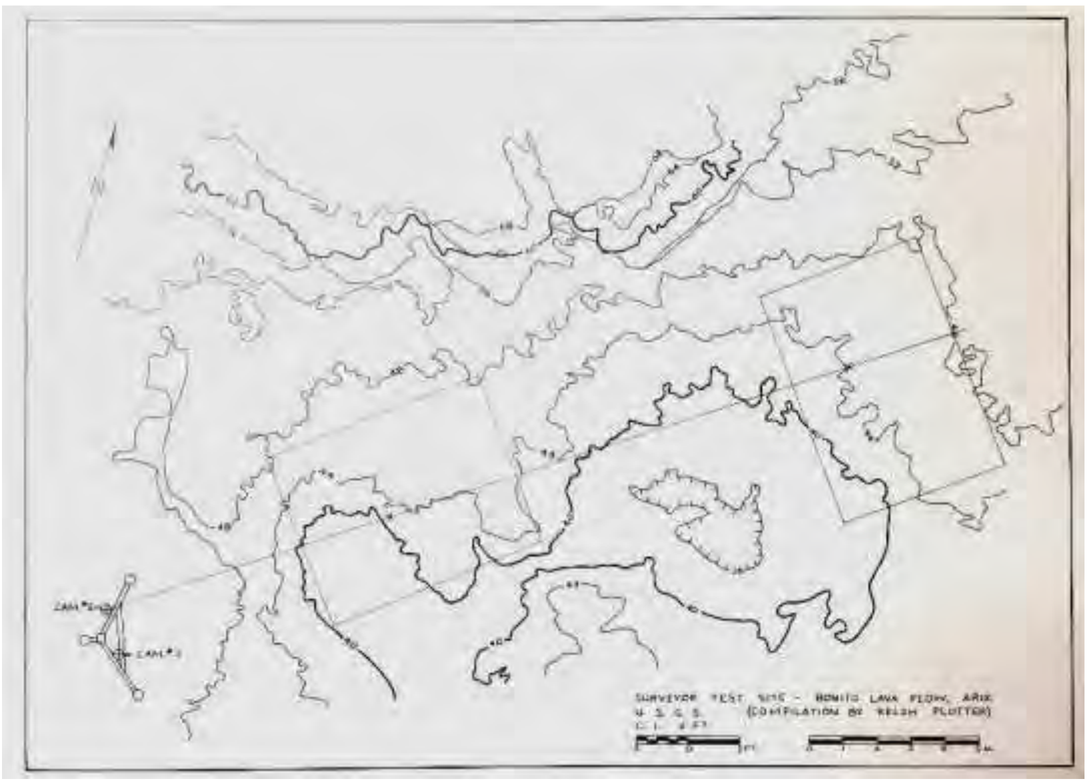


Fig. 68. Map of the Surveyor camera test site on the Bonito Lava Flow. (Uncatalogued USGS Image, USGS Astrogeology Regional Planetary Information Facility, USGS Astrogeology Science Center, Flagstaff, Arizona.)

Fig. 69. Suited test subject John Hendricks next to the “Explorer” LRV at Cinder Lake Crater Field One along with SPE personnel (l-to-r), Dick Wiser, Bill Tinnin and Putty Mills. (Image from Schaber, open-file report, 2005. USGS photo P726c, F126845c.)

Fig. 70. Suited subjects Tim Hait and David Schleicher test tools at Cinder Lake Crater Field One with a mock Lunar Module in the background. The ramp was necessary to simulate the

actual high of the Lunar Module. (Image from Schaber, open-file report, 2005. USGS photo P463, F11067199.)

Fig. 71. Repeat photo of Fig. 70. Some erosion of the LM ramp is evident. (Photo by author. July 21, 2018).

Fig. 72. Suited test subject Tim Hait drives a core sample tube into the rim of a crater at Cinder Lake Crater Field One. Note the prototype tool carrier in the foreground. Astronauts used similar tool carriers during Apollo 12-14 moonwalks. (Image from Schaber, open-file report, 2005. USGS photo P564, F36819c.)

Fig. 73. Suited test subject with lunar hand tool carrier. (Uncatalogued USGS Image, USGS Astrogeology Regional Planetary Information Facility, USGS Astrogeology Science Center, Flagstaff, Arizona.)

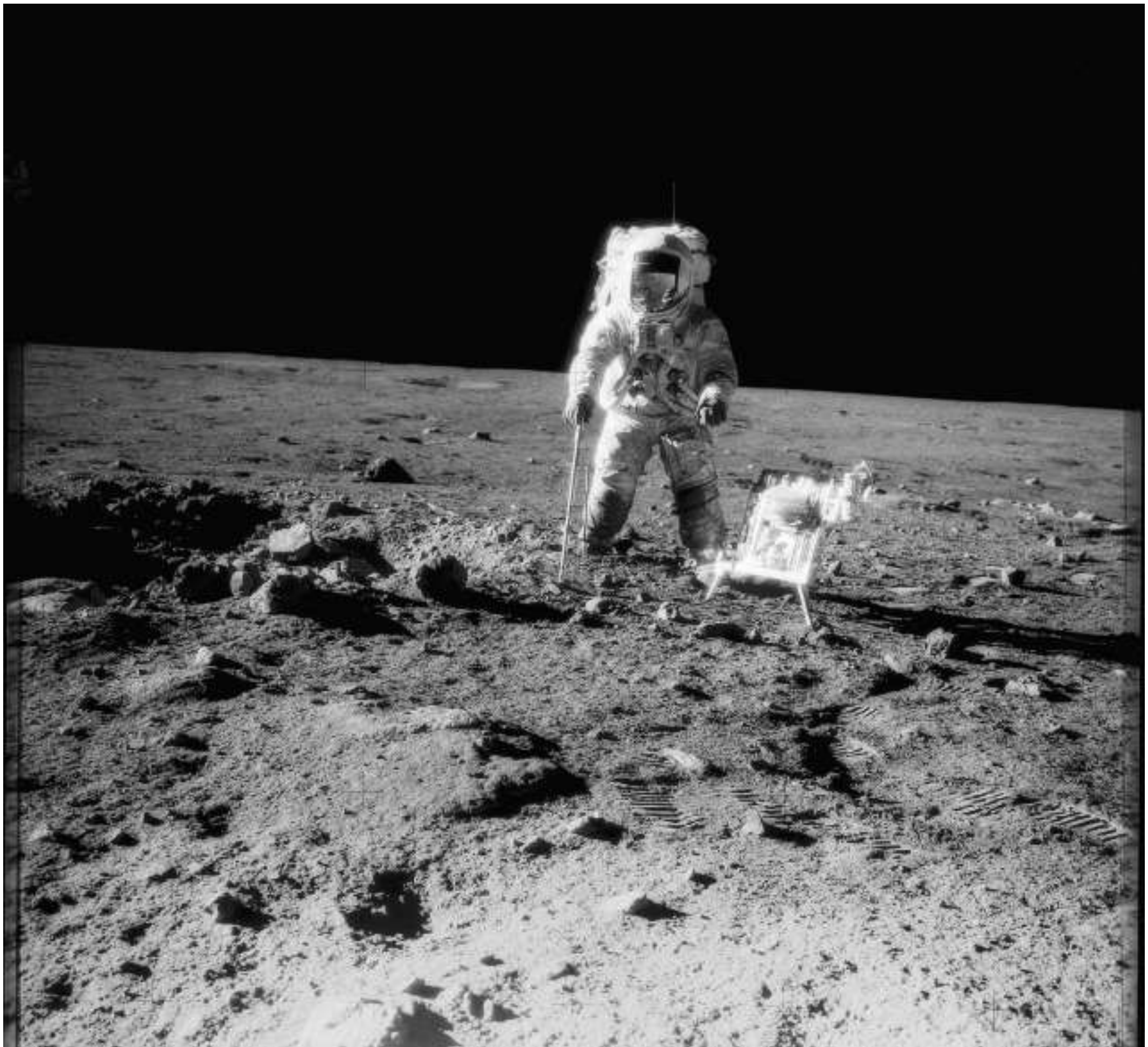


Fig. 74. Apollo 12 astronaut using lunar hand tools and a carrier similar to the one tested at Crater Field One. (November 19-20, 1969, NASA photo AS12-49-7318.) Image available from: https://spaceflight.nasa.gov/gallery/images/apollo/apollo12/html/as12-49-7318.html

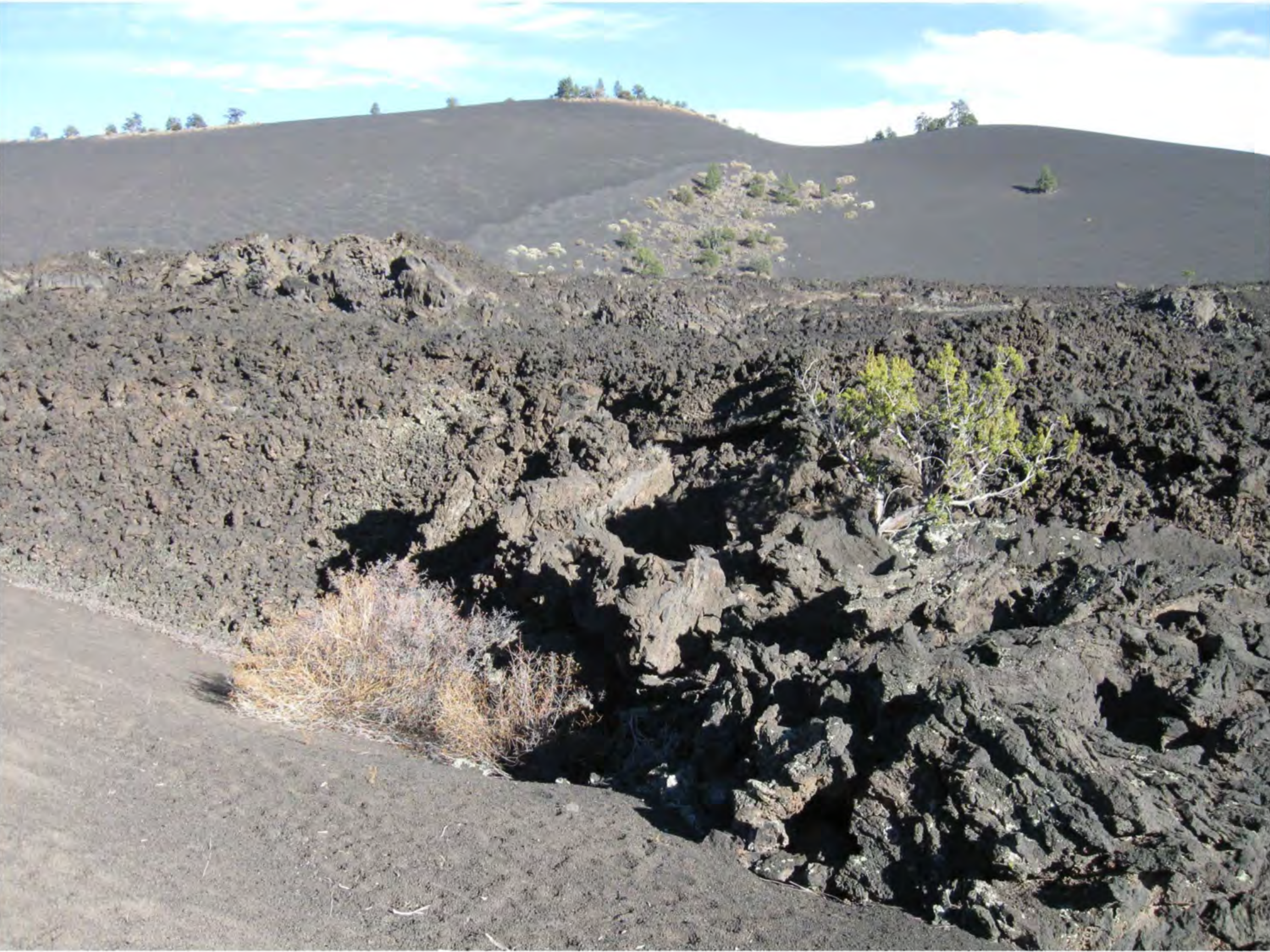
Fig. 75. Bendix prototype Surveyor Lunar Roving Vehicle on the Bonito Lava Flow, May, 1964. (Image from Schaber, open-file report, 2005.)

Fig. 76. Apollo 17 astronaut Harrison “Jack” Schmitt (left seat) and an unidentified passenger drive a prototype Bendix Lunar Roving Vehicle at on the Cinder Lake crater fields, 29-30, 1969. (Image from Schaber, open-file report, 2005. USGS photo P916c, F116929.)

Fig. 77. USGS Branch of Astrogeology conducts their first spacesuit test on the access road within the North Bonito Lava Flow Test Area in June 15-20, 1964. The suited test subject (either Gene Shoemaker, G. Phillippi, or J. Harbour) is visible in front of the support van holding a prototype lunar staff for taking pictures. The general characteristics of the site are evident here including the sharp distinction between the cinder hill and a'a lava flow. (Photo by Paul Long. Image from Schaber, open-file report, 2005).


Fig. 78. Suited test subject climbing a portion of the Bonito Lava Flow while engineers carry communications cables, June 15-20, 1964. (Photo by Paul Long. Image from Schaber, open-file report, 2005).

Fig. 79. A suited test subject with prototype lunar staff on the northern edge of the Bonito Lava Flow, June 15-20, 1964. (Photo by Paul Long. Image from Schaber, open-file report, 2005).




SUCR 17
SITE
OVERVIEW
11-6-2017

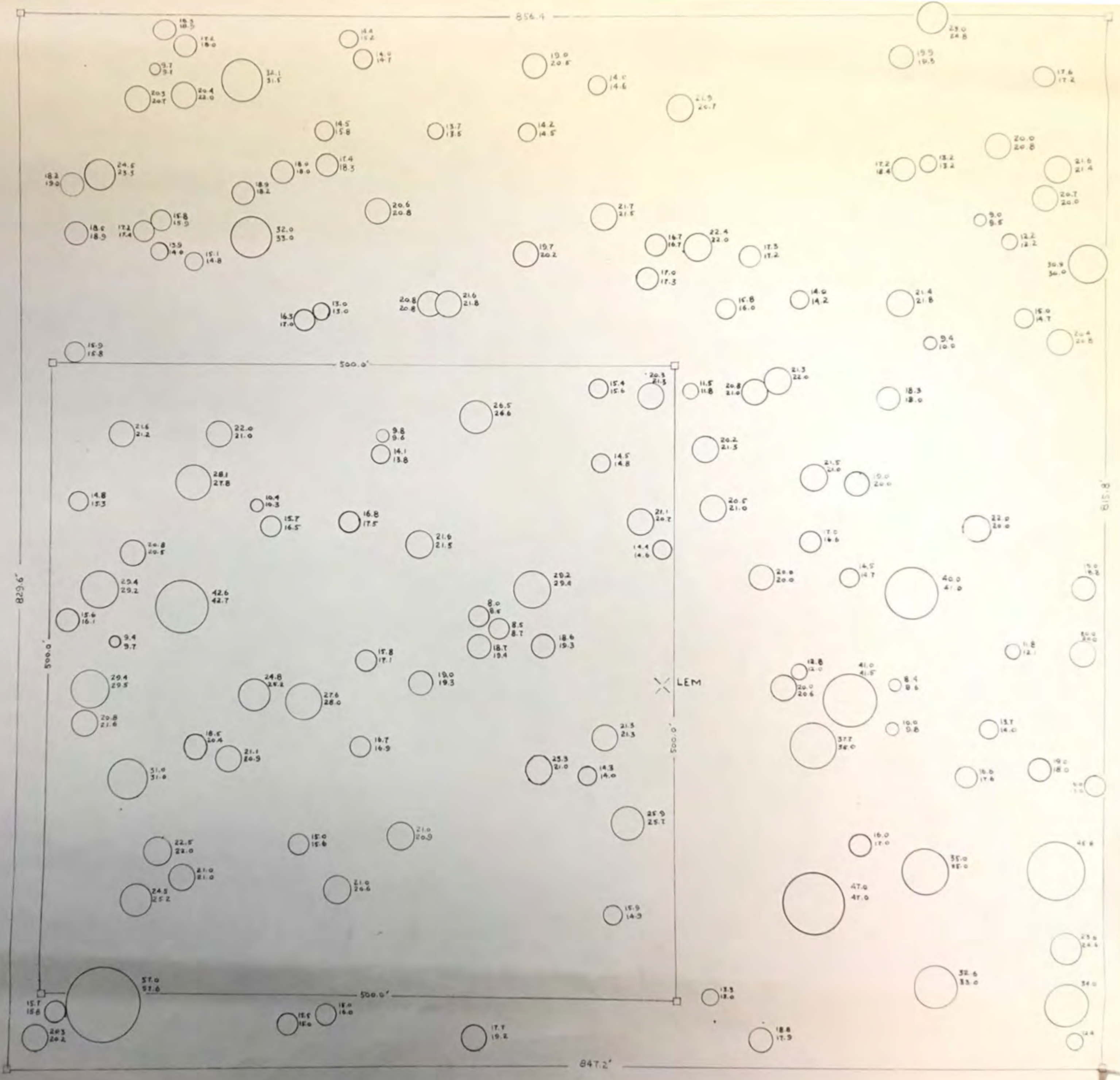

CK
CASE

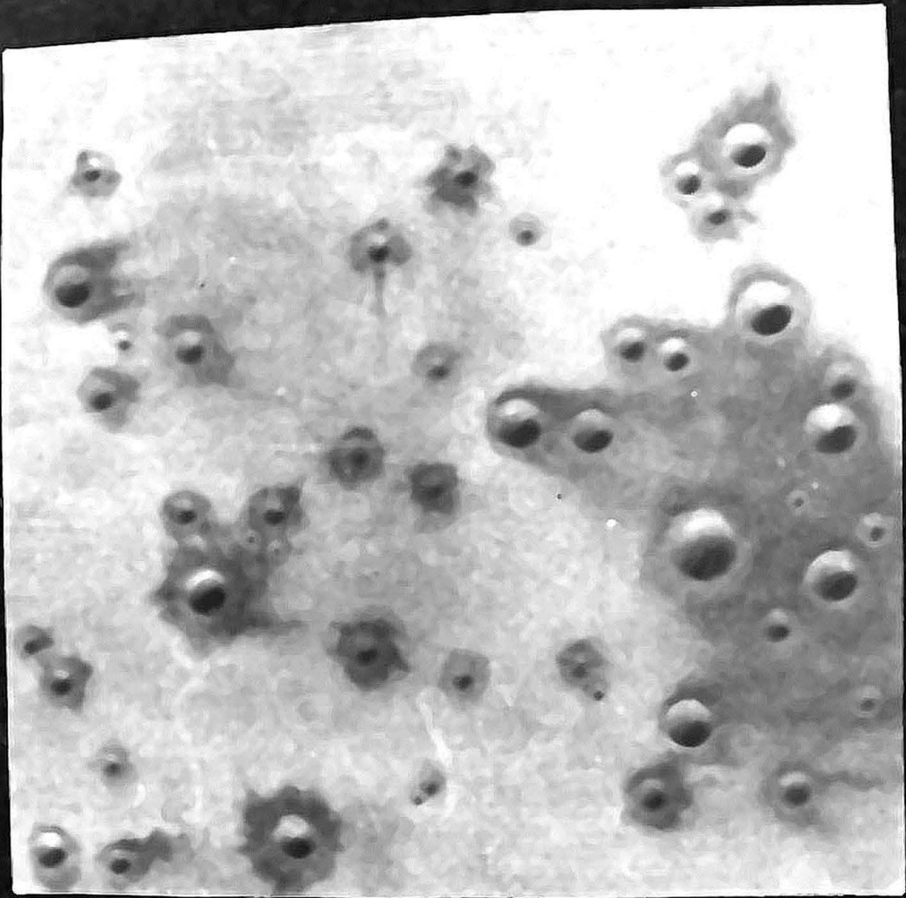
CINDER LAKE CRATER FIELD

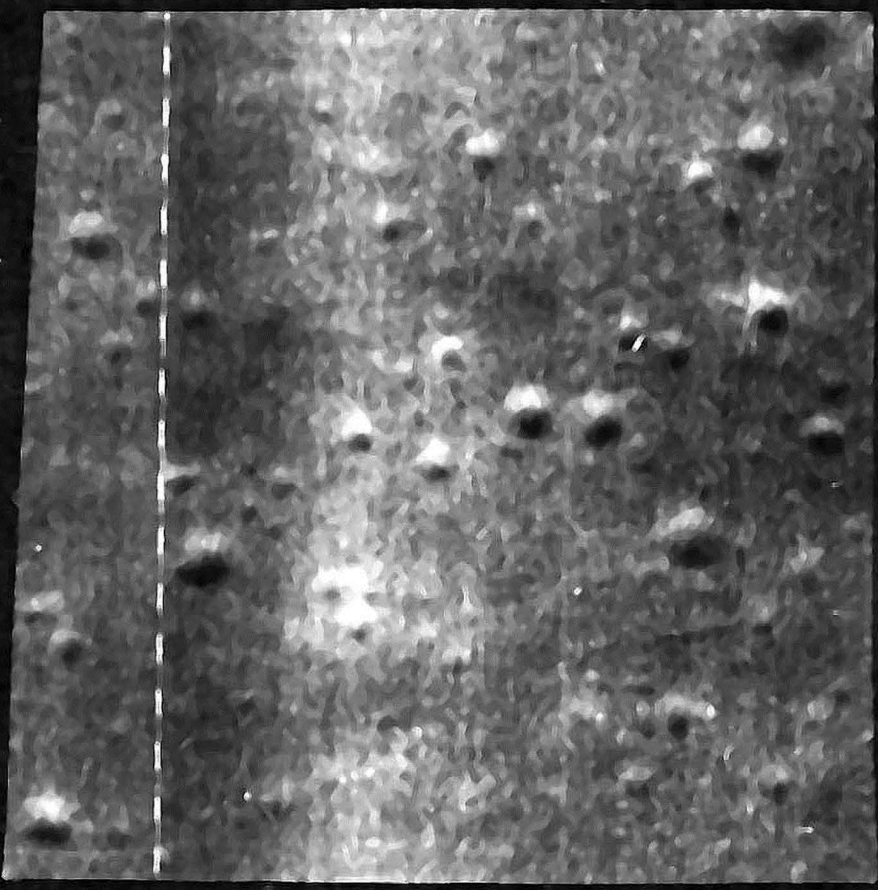
1967

SCALE 1" = 50'

1ST NUMBER INDICATES N-S DIAMETER
2ND " " E-W "

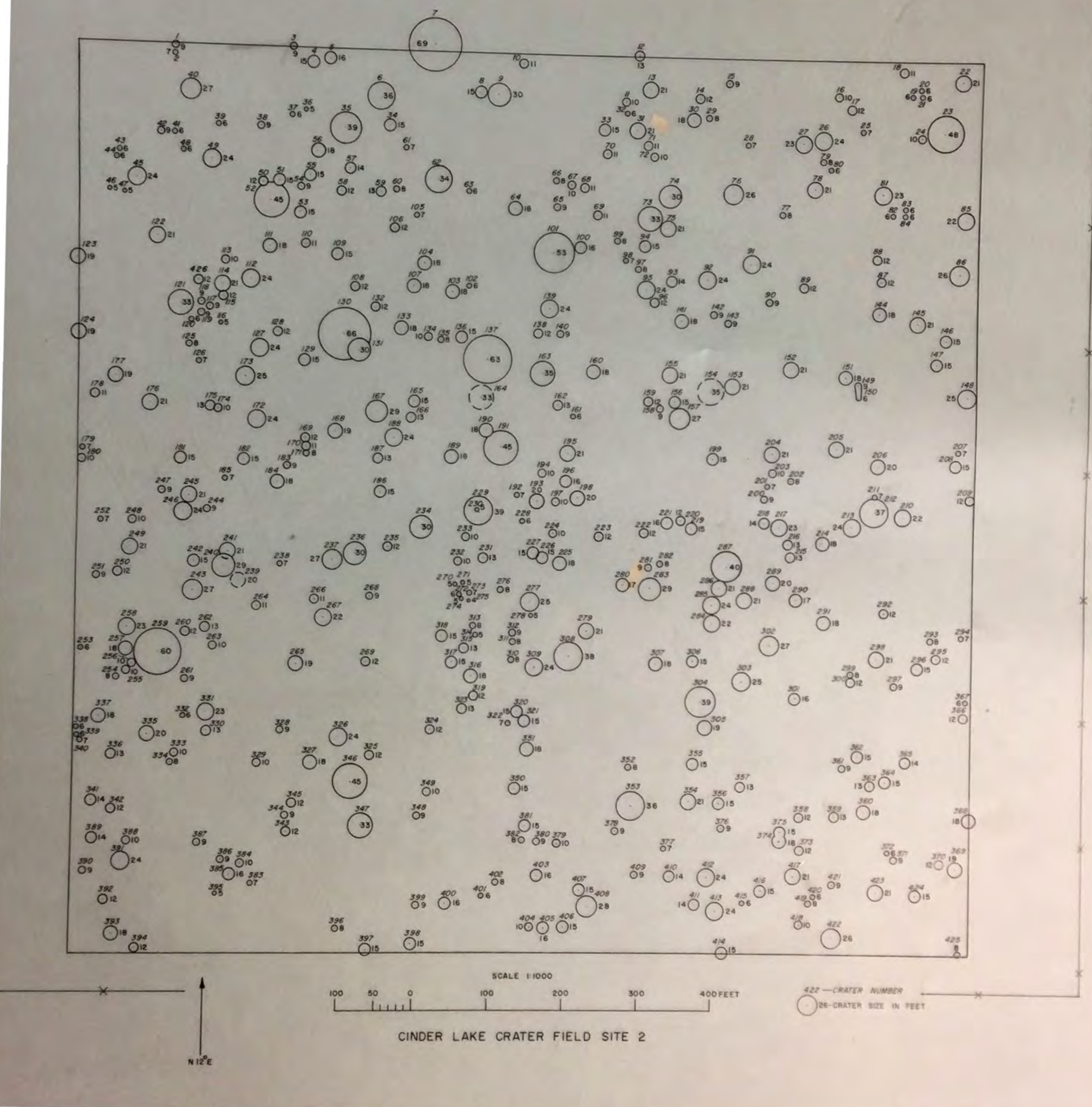






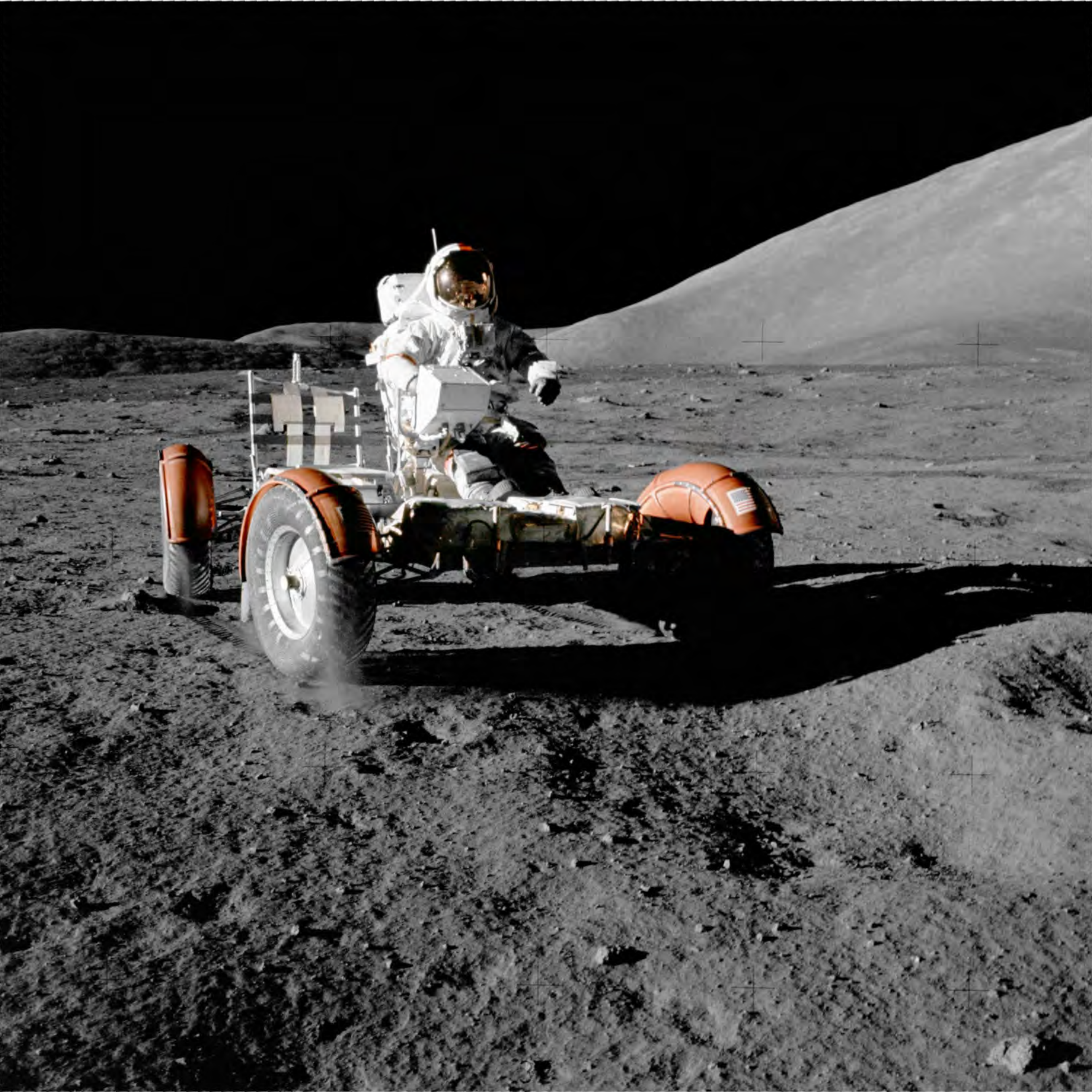

Astronaut Training Ground
NASA
During the late 1960s and early '70s, the area behind this fence was used to train astronauts for the Apollo Space Program. Craters were blasted out with explosives and rocks brought in to simulate the surface of the moon. Here, astronauts learned to walk in space suits and use equipment to prepare for lunar missions. Similar areas were created in Texas and Florida, but no longer exist.
This is the only remaining astronaut training area. Please help us protect this important part of American History

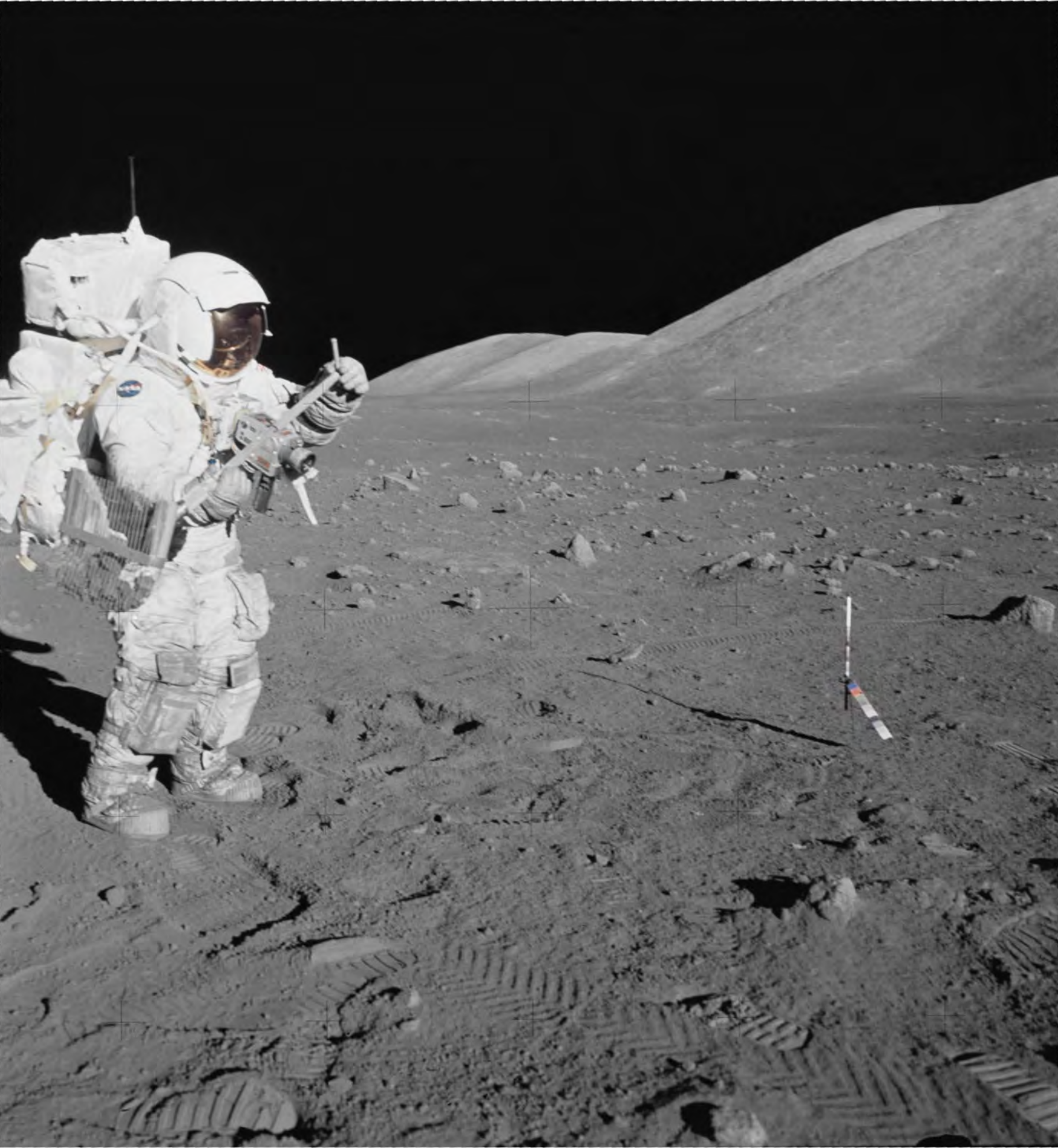
CINDER LAKE II - SECOND SHOT 7/27/68

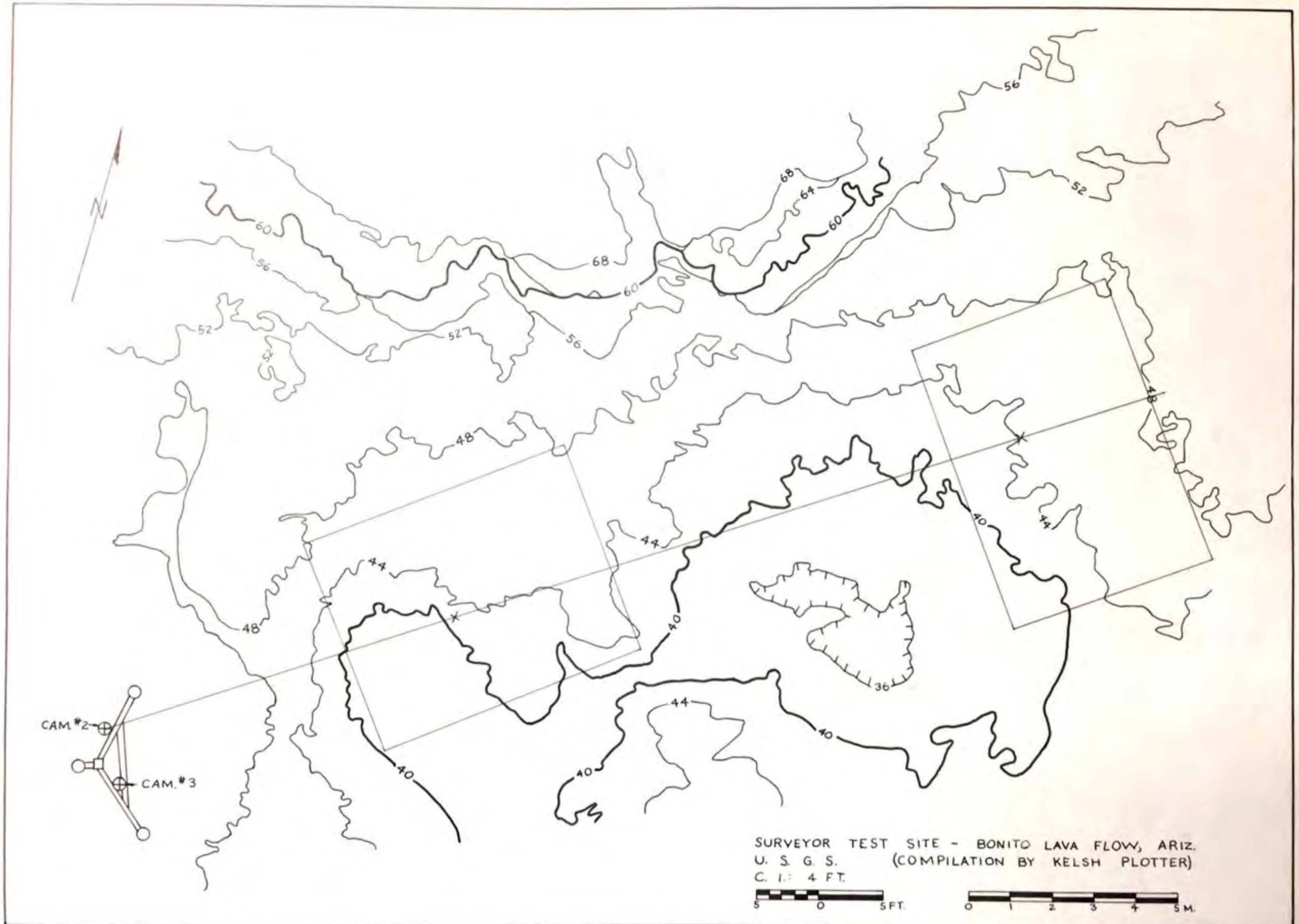


CINDER LAKE CRATER FIELD SITE 2


MOTOROLA







N
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CAM. #2
CAM. #3
SURVEYOR TEST SITE - BONITO LAVA FLOW, ARIZ.
U. S. G. S. (COMPILATION BY KELSH PLOTTER)
C. I.: 4 FT.
5 0 5 FT.
0 1 2 3 4 5 M.


5


ENGINEERING TEST MODEL
FOR
SURVEYOR
LUNAR ROVING VEHICLE
THE Bendix
CORPORATION


Bendix

UNITED STATES DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE

NATIONAL REGISTER OF HISTORIC PLACES
EVALUATION/RETURN SHEET

Requested Action:	Nomination
Property Name:	Sunset Crater-Cinder Lake Apollo Mission Testing and Training Historic District
Multiple Name:	
State & County:	ARIZONA, Coconino

Date Received:	Date of Pending List:	Date of 16th Day:	Date of 45th Day:	Date of Weekly List:
9/26/2019	10/16/2019	10/31/2019	11/12/2019	

Reference number:	SG100004595
Nominator:	Federal Agency, Federal Agency, SHPO

Reason For Review:

__ Appeal	__ PDIL	__ Text/Data Issue
__ SHPO Request	__ Landscape	__ Photo
__ Waiver	X National	X Map/Boundary
__ Resubmission	__ Mobile Resource	__ Period
__ Other	__ TCP	__ Less than 50 years
	__ CLG	

X Accept ____ Return ____ Reject 11/8/2019 Date

Abstract/Summary Comments:

Recommendation/ Criteria

Reviewer Roger Reed Discipline Historian

Telephone (202)354-2278 Date 11/8/19

DOCUMENTATION: see attached comments : No see attached SLR : No

If a nomination is returned to the nomination authority, the nomination is no longer under consideration by the National Park Service.

United States Department of the Interior

NATIONAL PARK SERVICE
1849 C Street, N.W.
Washington, D.C. 20240

IN REPLY REFER TO:

H32(2280)

Memorandum

To: Keeper of the National Register of Historic Places

From: Acting, NPS Federal Preservation Officer

Subject: National Register Nomination for Sunset Crater-Cinder Lake Apollo 11 Mission Testing and Training Historic District, Sunset Crater National Monument and Coconino National Forest, Coconino County, AZ

I am forwarding the National Register Nomination for Sunset Crater-Cinder Lake Apollo 11 Mission Testing and Training Historic District. The Park History Program has reviewed the nomination and found it eligible under Criterion A, with Areas of Significance of Science, Exploration, and Invention.

The State Historic Preservation Office (SHPO) and chief local elected official(s) were sent the documentation on February 27, 2019. Within 45 days, the SHPO __ supported __ supported with comments _x_ did not respond. However, on May 7 the SHPO signed in support of the nomination. As part of the nominated boundary is located in Coconino National Forest, the Federal Preservation Officer for the U.S. Forest Service has also sent a letter of support for the nomination. Any comments received are included with the documentation.

If you have any questions, please contact Kelly Spradley-Kurowski at 202-354-2266 or kelly_spradley-kurowski@nps.gov.

United States Department of the Interior
NATIONAL PARK SERVICE
WUPATKI – SUNSET CRATER VOLCANO – WALNUT CANYON
NATIONAL MONUMENTS
6400 North Highway 89
Flagstaff, Arizona 86004

H4217

February 27, 2019

Kathryn Leonard
State Historic Preservation Officer
Arizona State Parks
1300 West Washington
Phoenix, AZ 85007

Ms. Leonard:

In accordance with the National Historic Preservation Act and the Code of Federal Regulations 36 CFR Part 60.9, we seek your review and signature as Commenting Official regarding the National Register of Historic Places nomination for the Sunset Crater – Cinder Lake Apollo Mission Testing and Training Historic District. A final draft nomination is enclosed.

Project Description
In 2017, Sunset Crater Volcano National Monument and Coconino National Forest began jointly researching, documenting and writing a National Register nomination for NASA's Apollo astronaut training locations on our respective lands in the Sunset Crater-Cinder lake area east of Flagstaff. The USGS – NASA Apollo astronaut training program based in Flagstaff, AZ was extensive in terms of duration and land covered during training exercises. This nomination represents one important period of time and covers one of many activity areas across the United States essential to the successful Apollo missions. Successfully listing the Sunset Crater – Cinder Lake Apollo Mission Testing and Training Historic District will preserve a unique and valuable historic resource as well as provide the visiting public with opportunities to learn about a significant piece of US history. Successful listing will also help Sunset Crater Volcano National Monument and Coconino National Forest commemorate the 50th anniversary of the Apollo 11 moon landing, a national milestone in the fields of scientific exploration and invention.

We appreciate the opportunity to consult with you on the protection of historic resources in the Flagstaff Area National Monuments. If you have any questions regarding this project or the nomination, please contact Ian Hough, Cultural Resources Program Manager, at (928) 526-1157 x222 or at ian_hough@nps.gov.

Thank you for your continued interest in Flagstaff Area National Monuments.

Kayci Cook Collins

Superintendent

Enclosure: National Register of Historic Places Registration Form

USDA United States Department of Agriculture | Forest Service | Coconino National Forest Supervisor's Office | 1824 South Thompson Street
Flagstaff, AZ 86001
928-527-3600
Fax: 928-527-3620

File Code: 2360
Date: March 5, 2019

Kathryn Leonard
Arizona State Historic Preservation Officer
1300 West Washington
Phoenix, AZ 85007

Dear Ms. Leonard,

The Coconino National Forest and the Sunset Crater Volcano National Monument have partnered to prepare a nomination of the *Sunset Crater - Cinder Lake Apollo Mission Testing and Training Historic District*. The historic district identified in this nomination played a very direct and critical role in the training of all Apollo astronauts, thus leading the United States to successfully land on the moon. The technical, scientific, and explorative achievements of the Apollo missions cannot be overstated. It is our hope that the nomination, as it corresponds with 50th anniversary of Apollo 11, will serve to further recognize and reinforce the role northern Arizona played in the success of the Apollo program.

Our partners at the Sunset Crater Volcano National Monument have led the nomination process, and at this juncture, with our complete support, they are submitting the final draft of this nomination for your review. This letter is being written in support of the nomination, and to assure all parties that Coconino National Forest is in agreement to its content.

Therefore, in accordance with the National Historic Preservation Act and the Code of Federal Regulations 36 CFR Part 60.9, we seek your review and signature as Commenting Official regarding the National Register of Historic Places nomination for the Sunset Crater - Cinder Lake Apollo Mission Testing and Training Historic District.

For any additional information, please contact Jeremy Haines, Flagstaff District Archaeologist, at (928) 527-8261, or at jhaines@fs.fed.us.

Sincerely,

Laura Jo West

LAURA JO WEST
Forest Supervisor

United States Department of the Interior
NATIONAL PARK SERVICE
WUPATKI – SUNSET CRATER VOLCANO – WALNUT CANYON
NATIONAL MONUMENTS
6400 North Highway 89
Flagstaff, Arizona 86004

H4217

March 7, 2019

Liz Archuleta
Supervisor, District 2
Coconino County
219 E. Cherry Ave
Flagstaff, AZ 86001

Supervisor Archuleta:

In accordance with the National Historic Preservation Act and the Code of Federal Regulations 36 CFR Part 60.9, we seek your review of a National Register of Historic Places nomination for the Sunset Crater – Cinder Lake Apollo Mission Testing and Training Historic District. A final draft nomination is enclosed. We are asking for your review and comments within 45 days of receiving the nomination.

Project Description
In 2017, Sunset Crater Volcano National Monument and Coconino National Forest began jointly researching, documenting and writing a National Register nomination for NASA's Apollo astronaut training locations on our respective lands in the Sunset Crater-Cinder lake area east of Flagstaff. The USGS – NASA Apollo astronaut training program based in Flagstaff, AZ was extensive in terms of duration and land covered during training exercises. This nomination represents one important period of time and covers one of many activity areas across the United States essential to the successful Apollo missions. Successfully listing the Sunset Crater – Cinder Lake Apollo Mission Testing and Training Historic District will preserve a unique and valuable historic resource as well as provide the visiting public with opportunities to learn about a significant piece of US history. Successful listing will also help Sunset Crater Volcano National Monument and Coconino National Forest commemorate the 50th anniversary of the Apollo 11 moon landing, a national milestone in the fields of scientific exploration and invention.

We appreciate the opportunity to consult with you on the protection of historic resources in Coconino County. If you have any questions regarding this project or the nomination, please contact Ian Hough, Cultural Resources Program Manager, at (928) 526-1157 x222 or at ian_hough@nps.gov.

Thank you for your continued interest and support in Flagstaff Area National Monuments.

Kayci Cook Collins
Superintendent

Enclosure: National Register of Historic Places Registration Form
Letter of Support, Flagstaff Area National Monuments
Letter of Support, Coconino National Forest

United States Department of the Interior

NATIONAL PARK SERVICE
WUPATKI – SUNSET CRATER VOLCANO – WALNUT CANYON
NATIONAL MONUMENTS
6400 North Highway 89
Flagstaff, Arizona 86004

H4217

June 18, 2019

Turkiya Lowe, Ph.D.
Acting Federal Preservation Officer
National Park Service
1849 C Street, NW
Mail Stop 7508
Washington, DC 20240

Dear Dr. Lowe:

In accordance with the National Historic Preservation Act and the Code of Federal Regulations 36 CFR Part 60.9, we seek your review and signature for the enclosed nomination for submission. The enclosed disk contains the true and correct copy of the nomination for the Sunset Crater-Cinder Lake Apollo Mission Testing and Training Historic District to the National Register of Historic Places.

In 2017, Sunset Crater Volcano National Monument and Coconino National Forest began jointly researching, documenting, and writing a National Register nomination for NASA's Apollo astronaut training locations on their respective lands in the Sunset Crater-Cinder Lake area east of Flagstaff, Arizona. The USGS-NASA Apollo astronaut training program based in Flagstaff began in 1963 and continued until 1972. All Apollo astronauts who walked on the Moon trained within the district. This nomination represents a crucial time in the Apollo program and larger Cold War Space Race. Successful listing of the district will preserve a unique and valuable historic resource as well as provide the visiting public with opportunities to learn about a significant piece of U.S. history. Successful listing will also help Sunset Crater Volcano National Monument and Coconino National Forest commemorate the 50th anniversary of the Apollo 11 moon landing, a national milestone in scientific exploration and invention.

We appreciate the opportunity to consult with you on this important piece of national history. If you have any questions regarding the nomination, please contact Ian Hough, Cultural Resources Program Manager, at (928) 526-1157 x222 or ian_hough@nps.gov.

Kayci Cook Collins

Superintendent, Flagstaff Area National Monuments

Enclosures (3):

Disc 1 of 2: National Register of Historic Places Registration Form

Disc 2 of 2: Digital images in tiff format

Nomination signature page