July 28, 1969

Aviation Week & Space Technology

Special Report:

Apollo 11 Landing On Moon

See contents, page 15

A McGraw-Hill Publication $1.00

Apollo 11 astronauts plant U. S. flag on lunar surface

Aviation Week & Space Technology

July 28, 1969

Volume 91, Number 4

Publishing Director: Robert W. Martin, Jr.

Publisher: R. A. Hubley

Editorial Offices:
New York: 330 W. 42nd St. 10036
Phone 212, 971-3807
Washington, D.C.: National Press Building 20004
Phones: 202, NA 8-3414; 202, RE 7-6630
Los Angeles: 1125 W. Sixth St. 90017
Phone: 213, 481-7304
Dallas: 1800 Republic National Bank Tower 75201
Phone: 214, 747-9786
Houston: 1730 NASA Boulevard 77058
Phone: 713, 591-3596
Florida: Cocoa Beach, Fla. 32931
Room 915, 1980 N. Atlantic Ave. Phone: 305, 783-0400
San Francisco: 255 California St. 94111
Phone: 415, DO 2-4600
European Offices:
Geneva, Switzerland: 1 rue du Temple. Phone 32-35-63
London: 34 Dover St., London W.1, England
Phone: 01-493-1451
Paris: 90, Champs Elysees
Phone: 256-0452

Member ABP and ABC
105,869 copies of this issue printed

Cover:
Astronauts Neil A. Armstrong and Edwin E. Aldrin, Jr., plant a U.S. flag on the Sea of Tranquility 46 min. after Armstrong took man's first step on the lunar surface. Wire stiffening holds out flag in the near vacuum environment. Photo from television screen by Lawrence J. Herb, Aviation Week & Space Technology art editor.

Special Report: Apollo 11 Lunar Landing

Space Technology

Air Transport

Aeronautical Engineering

Missile Engineering

Avionics

Departmental

Editorial

Bell goes all the way with Apollo —

Apollo positive expulsion tanks were produced at Bell

From liftoff to lunar landing to splashdown these precision "liquid-squeeze" devices designed and built by Bell had a vital role in the success of the mission:

...31 of them, to be exact

2 fuel and 2 oxidizer tanks in the Command Module.

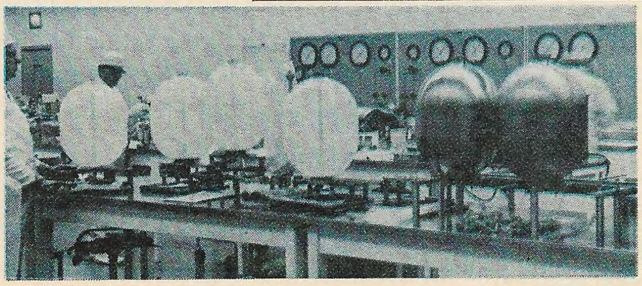
8 fuel and 8 oxidizer tanks in the Service Module.

2 fuel and 2 oxidizer tanks in the Lunar Module.

2 fuel and 2 oxidizer tanks in the Saturn S-IVB Auxiliary Propulsion System.

3 water tanks for the Environmental Control System of the Lunar Module (one for the descent stage and two for the ascent stage).

"Windows" in Apollo illustration indicate locations of the 31 Bell tanks.



Positive expulsion devices are required in space vehicles to force liquids out of tanks. They operate much the same as toothpaste is forced out of a tube. The Bell devices consist of an outer shell enclosing a flexible bladder which contains the liquid. Pressurizing gas is driven into the space between the shell and bladder forcing the liquid to flow. Other programs utilizing Bell positive expulsion tanks include Lunar Orbiter, Centaur, Minuteman, Gemini and Mercury.

BELL AEROSYSTEMS—A textron COMPANY Buffalo, New York

Proven Systems Capabilities for Aerospace • Defense • Transportation • Communications

Mankind's Giant Leap

The small step of Neil Armstrong's boot from the lower rung of the lunar module landing gear ladder to the powdery surface of the moon was indeed a giant leap for all mankind.

Man's first adventure on the lurain embodied many triumphs of technology and spirit. But its greatest significance will prove to be the watershed it marks in man's knowledge of himself and his universe. From now on, the theories that have beguiled scientists and fiction writers alike will fade swiftly into obscurity as they are submerged by the vast quantity of new facts garnered in man's accelerating exploration of the moon and the rest of his universe.

Vanished already are the horror stories of man's difficulties in operating on the moon—banished by the swift mobility, varied work and easy communications of Neil Armstrong and "Buzz" Aldrin in man's initial 2 hr. on the lurain. Gone too are the long-espoused theories on deep layers of lunar dust that would engulf both man and spacecraft—refuted by the first scuffs of man's boots and the hard, mallet-driven progress of the core-sampling drill. Going fast are many of the theories of a cold, dead moon —jolted by Armstrong and Aldrin's first observations of lunar rocks. The first 78-lb. load of rocks brought back by the Eagle crew from Tranquility base will provide more answers on the origin and composition of the moon than a century of stargazing through instruments from earth.

Less than a week after the Apollo 11 crew returned safely to earth, the Mariner satellites will start transmitting back to earth man's first close view of the Martian surface in another astonishing triumph of space age science fact over theoretical fiction.

Among the other triumphs of Apollo 11 that should be noted are:

■ **Open Program over Secrecy.** The U.S. policy of an open space program for all the world to see paid a stupendous dividend on Apollo 11 as people of almost every nation on earth were able to see man's first steps on the moon in that incredible television transmission. Never has the American image been projected brighter on such a global scale. It showed all mankind that this country is truly willing to share its triumphs, tragedies and knowledge with all who care to participate. The world owes a great debt to Stanley Lebar and his Westinghouse colleagues, who conceived and built the tiny 7-lb. television camera that transmitted so faithfully from the moon, and also to the National Aeronautics and Space Administration officials, who fought so hard to keep it on the mission.

■ **Engineers over Scientists.** One of the key differences between the U.S. and USSR space programs has been the divergent philosophies of its managers. The USSR program, dominated by the senior scientists of the powerful Academy of Sciences, has tended to overestimate the technical problems of manned spaceflight and insisted on over-testing with unmanned spacecraft or animal subjects. The U.S. program is managed by engineers backed by experience with operational development of high-speed aircraft from the X-1 to X-15. They have tackled problems such as the sound, heat and bio-medical barriers by designing and proceduring around them, while U.S. ground-bound scientist experts in these fields urged slowdowns or abandoning manned space flight. The engineering approach not only enabled the U.S. to overtake and pass the USSR in the race to put men on the moon, but is also producing far more scientific data faster than the conservative small-step programs of the scientist-dominated USSR effort. The wild gyrations of Luna 15 in lunar orbit and its ignominious crash in the Sea of Crises at the same time Astronauts Armstrong and Aldrin were broadcasting priceless data from the Sea of Tranquility offered a valid contrast in the two national philosophies.

■ **Manned over Unmanned Spacecraft.** Apollo 11 was another demonstration of the vital necessity for man in the control loop for a truly effective space exploration vehicle. Without man aboard, the lunar module would have crashed in an uncharted crater of huge boulders. Wailing would have been heard around the world on the futility of trying to land spacecraft on the lurain. With Neil Armstrong at the controls, the danger of the automatic landing site was quickly recognized. Eagle was flown manually beyond the dangerous crater to a feathery touchdown on powdery sand. In addition, the LM guidance computer became overloaded, rebelled and flashed false alarms until it was bypassed by the human brains aboard. No unmanned spacecraft could have accomplished the reconnaissance, evaluation and experimenting that Armstrong and Aldrin did in their relatively short lunar stay. Unmanned spacecraft are certainly necessary for preliminary exploration of distant planets just as Ranger, Surveyor and Orbiter blazed a trail for Apollo. But man must eventually be on board to insure the mission's operational and scientific success.

Apollo 11 also gives man his first spark of immortality. It demonstrated that he no longer need be a prisoner of his earthly home. If, at some future time, this planet becomes uninhabitable because of a nuclear war, cumulative pollution or the end of its galactic cycle, the human race now has the capacity to seek a new environment.

Man may find that his ultimate survival as a species may depend solely on his resources of space technology and his skill as a space voyager.

—Robert Hotz

We've had it up to here with Mariner.

6,118 miles from Mars, to be exact. But that was in 1965.

Now two Mariners are on their way for a closer look. A 2,000 mile flyby that should tell us a lot more about our red-skinned brother.

Then in 1971 the Mariners go again. Not to fly by, but to orbit.

1973 will be the year of the Vikings. The spacecraft which will help answer the question: "Is there life on Mars?"

But don't think that everything JPL does is out of this world. Some of our best ideas never get off the ground, such as terrestrial innovations with batteries and x-rays.

That takes the help of engineers, programmers, mathematicians, physicists and chemists who think both way out and way in.

If that sounds like you, you may send your resume in confidence to Wallace Peterson, Supervisor, Employment.

Immediate openings exist in: Spacecraft Structural Design, Temperature Control Materials & Processing, Application of Microelectronics & Transistors, Guidance & Control Systems, Electro Optics, Propulsion Systems Analysis, Space Vehicles Design—Trajectory Design & Systems Analysis, Systems Design & Integration, Deep Space Support Systems, Electromechanical Spacecraft Instrumentation, Scientific Programming and TV Image Processing.

JET PROPULSION LABORATORY

California Institute of Technology
4812 Oak Grove Dr., Pasadena, Calif. 91103
Attention: Professional Staffing Dept. 7

"An equal opportunity employer." Jet Propulsion Laboratory is operated by the California Institute of Technology for the National Aeronautics and Space Administration.

Man in a space station

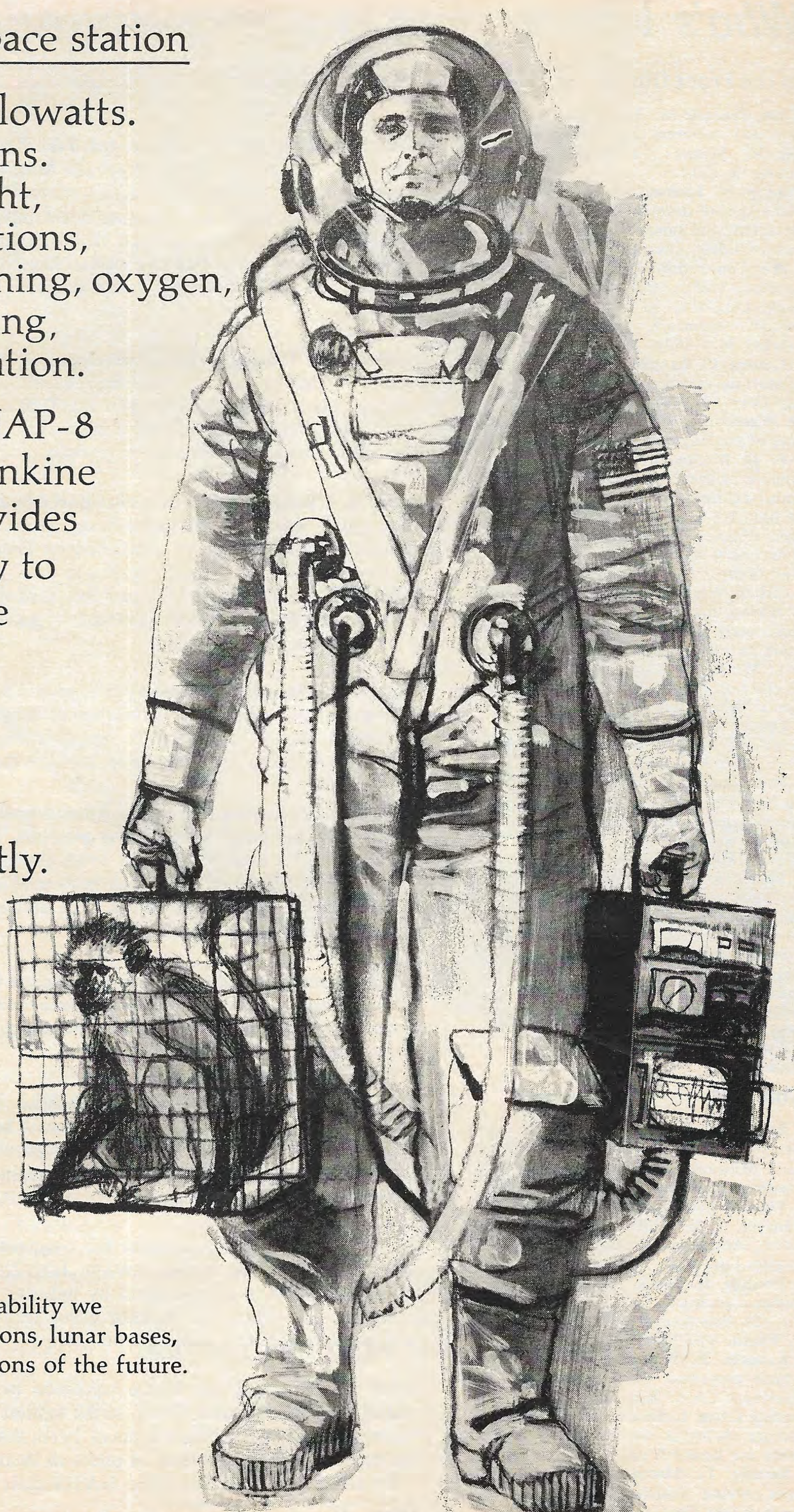
He needs kilowatts.
By the dozens.
For heat, light,
communications,
air conditioning, oxygen,
food recycling,
experimentation.

NASA's SNAP-8
Mercury Rankine
System provides
them. Plenty to
run a twelve
man space
station for
years.

Completely.
Independently.
Efficiently.
Reliably.
Simply.

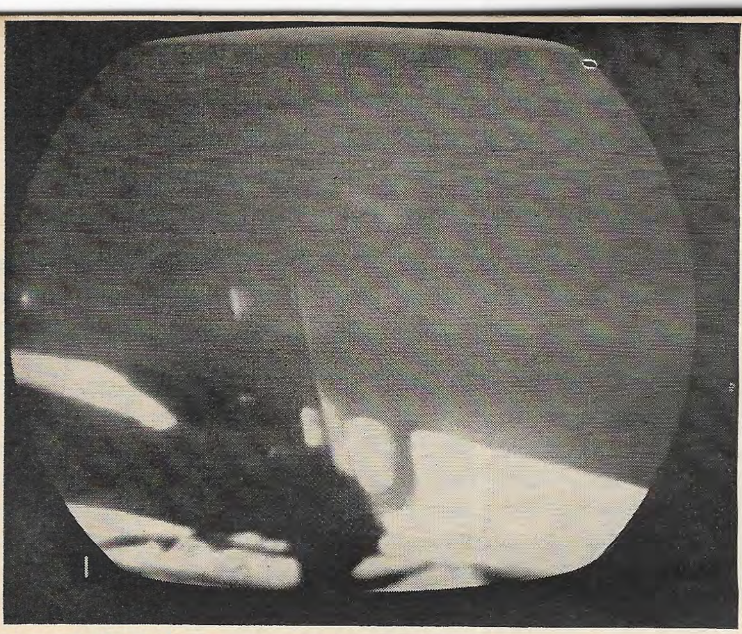
And it's
ready for
application
now.

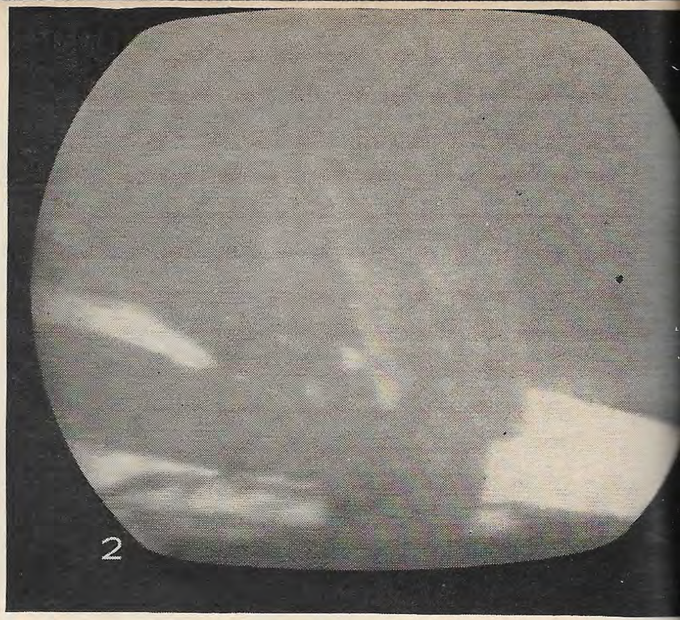
In addition—
SNAP-8 has all the
built-in growth capability we
need for larger stations, lunar bases,
and planetary missions of the future.



AEROJET
GENERAL TIRE
GENERAL

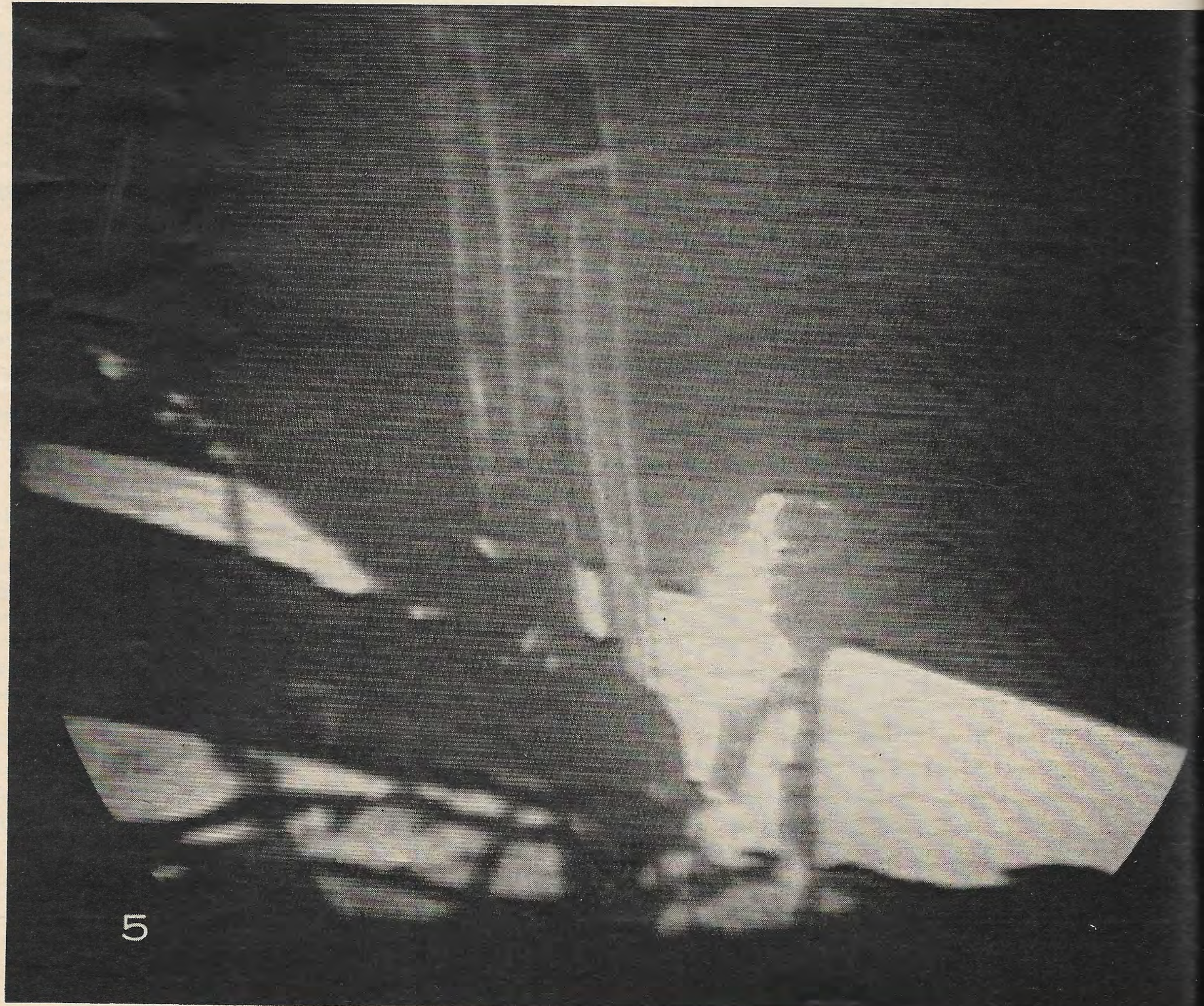
SNAP-8, developed by Aerojet-General Corporation for the National Aeronautics and Space Administration



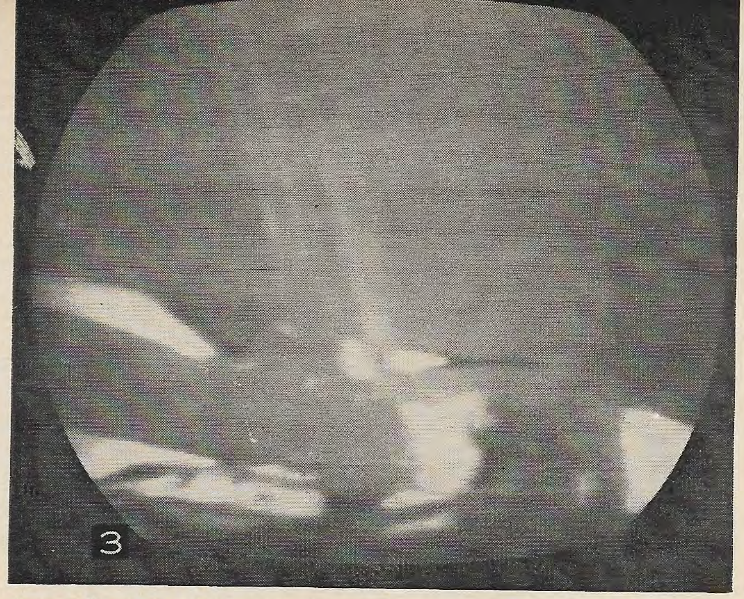


Astronaut Neil A. Armstrong's left foot drops down below last rung of the lunar module landing gear ladder (1). Then Armstrong makes the 3-ft. drop to the footpad (2). Holding on to the secondary strut, he makes his first tentative steps on the moon sur-

World Sees Astronauts Armstrong, Aldrin

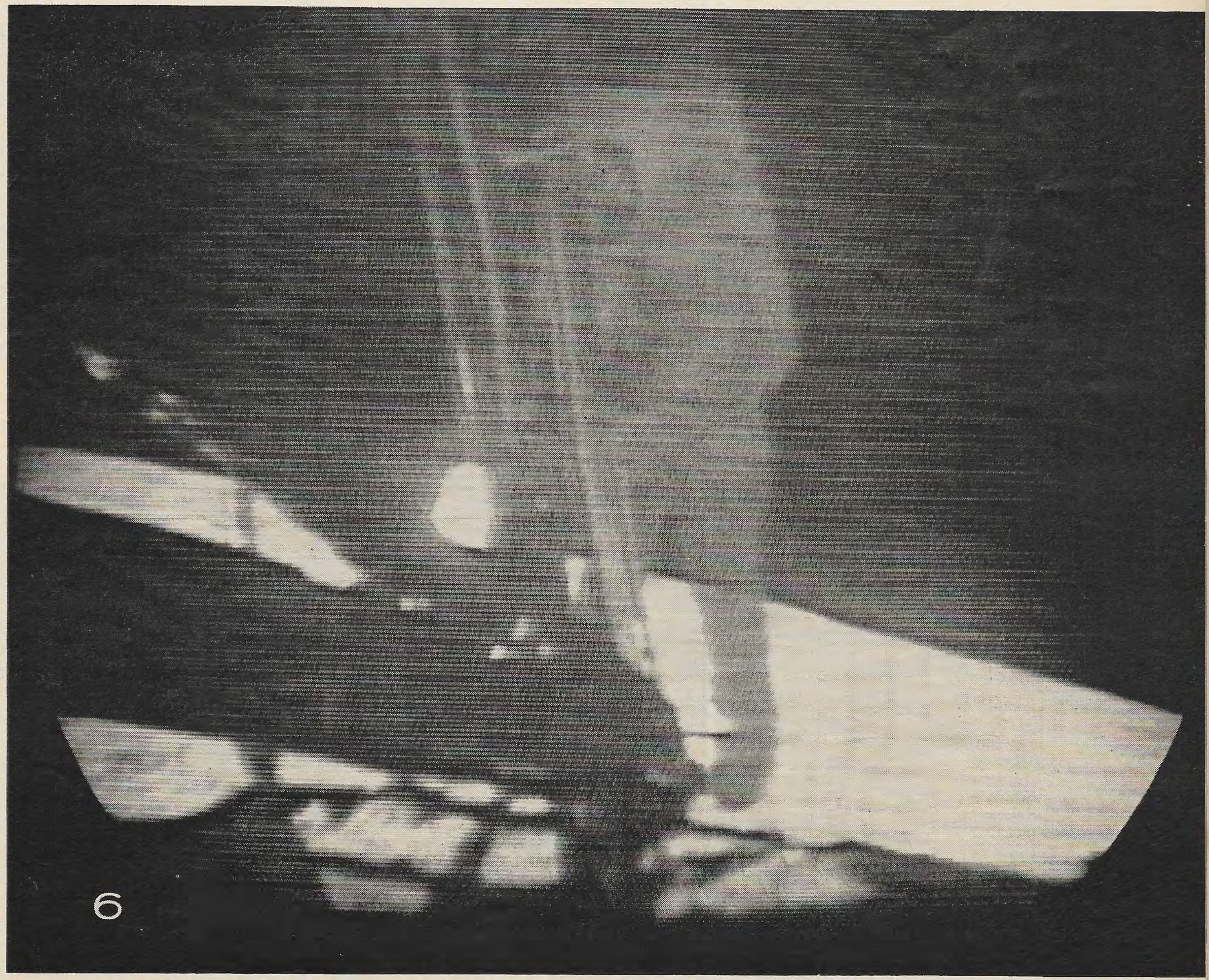


Armstrong stands at the foot of the lunar module ladder (5) watching Col. Edwin A. Aldrin, Jr., back out of the vehicle hatch to



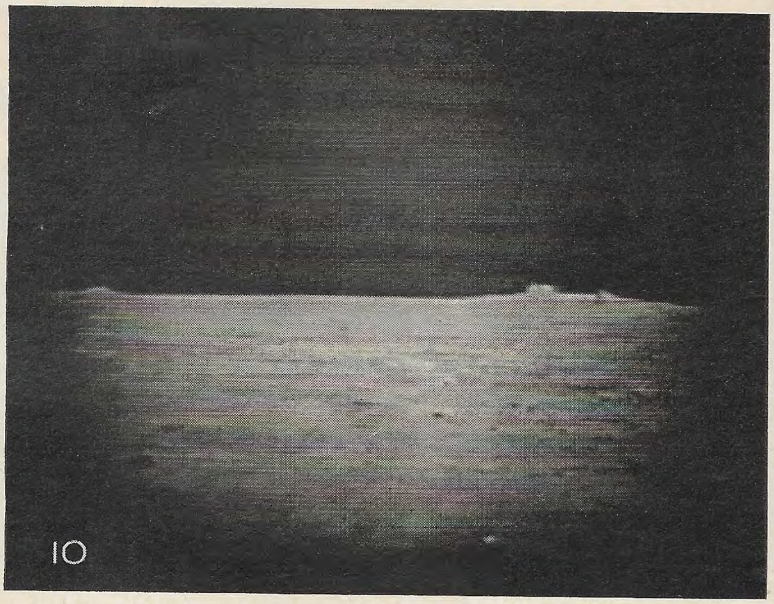
face (3), and, gaining confidence, moves away from the vehicle (4). During his initial activity, Armstrong took photographs around the vehicle and collected contingency sample of surface. (Staff photos by James H. Pickerell on CBS direct TV monitor.)

Take Man's First Steps on Lunar Surface

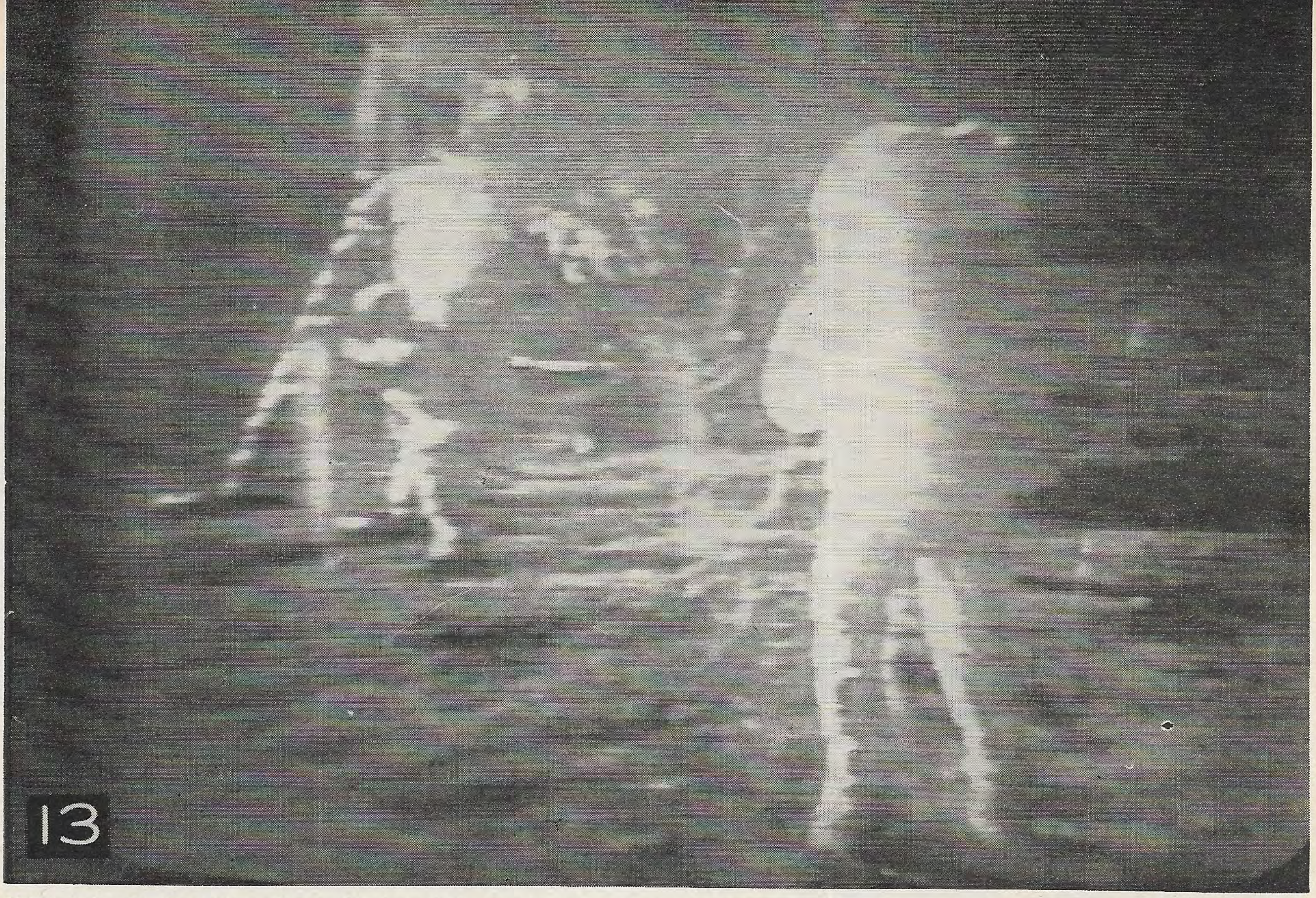


warn him in case his backpack should foul in the narrow opening. Aldrin descends the ladder (6) for drop to footpad.

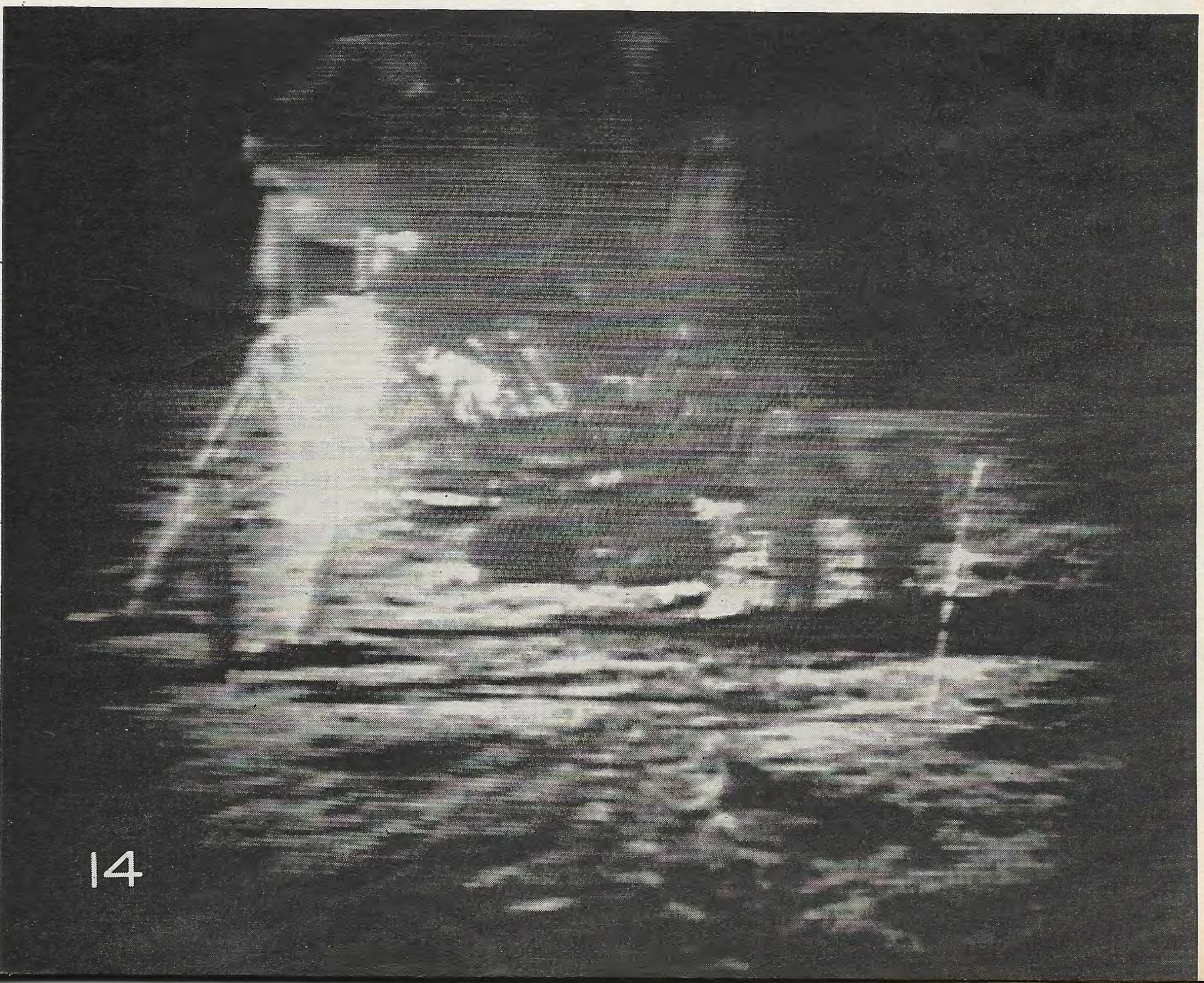
Inscription on plaque signed by President Nixon and the astronauts that was attached to descent stage and left on moon is read by Armstrong with Aldrin alongside (7). While Armstrong moves TV camera, Aldrin unstows solar wind experiment gear (8).

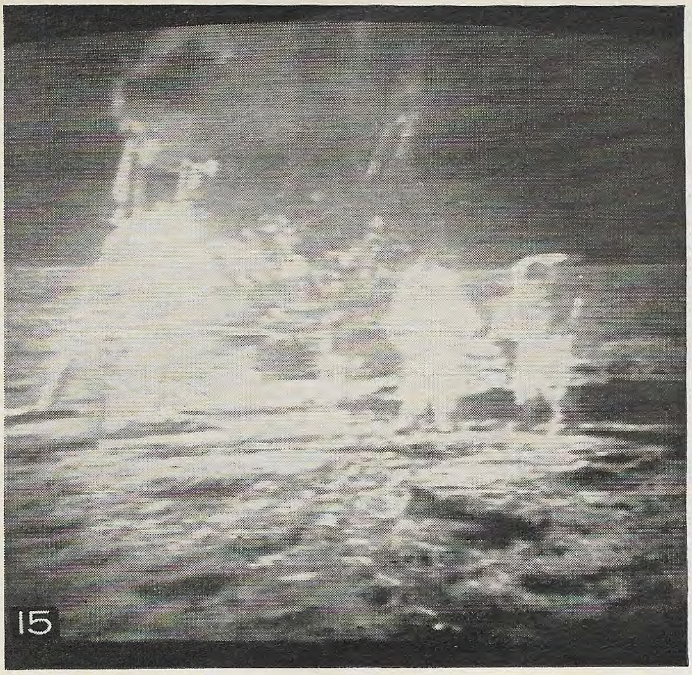


Armstrong pans TV camera in 360 deg. circle to show small craters (9) boulders (10, 11) and lunar module shadow (12). In sequence, views are to north and northeast, west, and finally south where lunar module shadow falls. In hill beyond shadow are pair of 20 X 40 ft. craters 6 ft. deep. Tripod-mounted camera was placed about 50 ft. from lunar module with ladder leg to right and modularized equipment stowage assembly (MESA) at center.

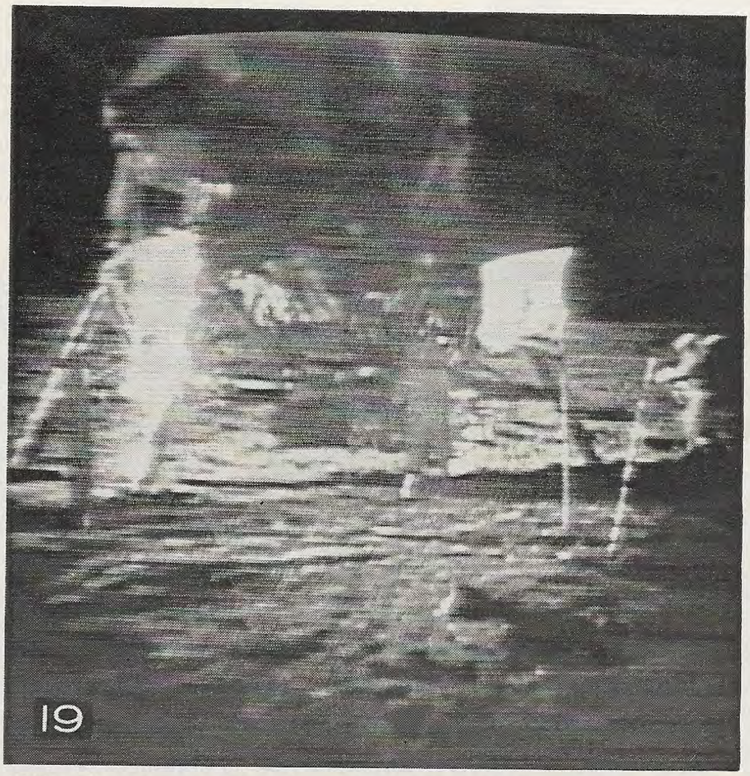


Aldrin extends aluminum sheet of solar wind experiment as Armstrong returns from camera tripod (13). Both then move into shadow of lunar module to begin unstowing U.S. flag (14). Telescoping handle of contingency sample collector is stuck in surface after use at right. Nozzle of lunar module descent engine is at center, clearing surface by approximately 1 ft.

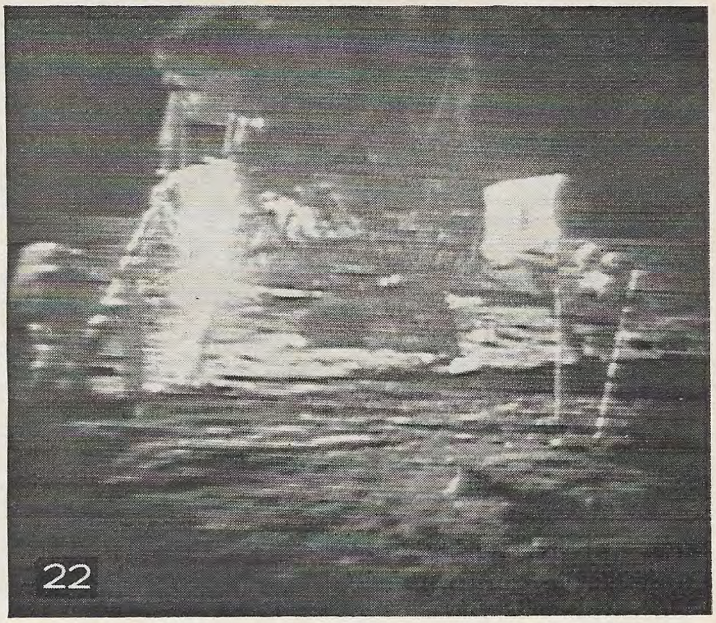




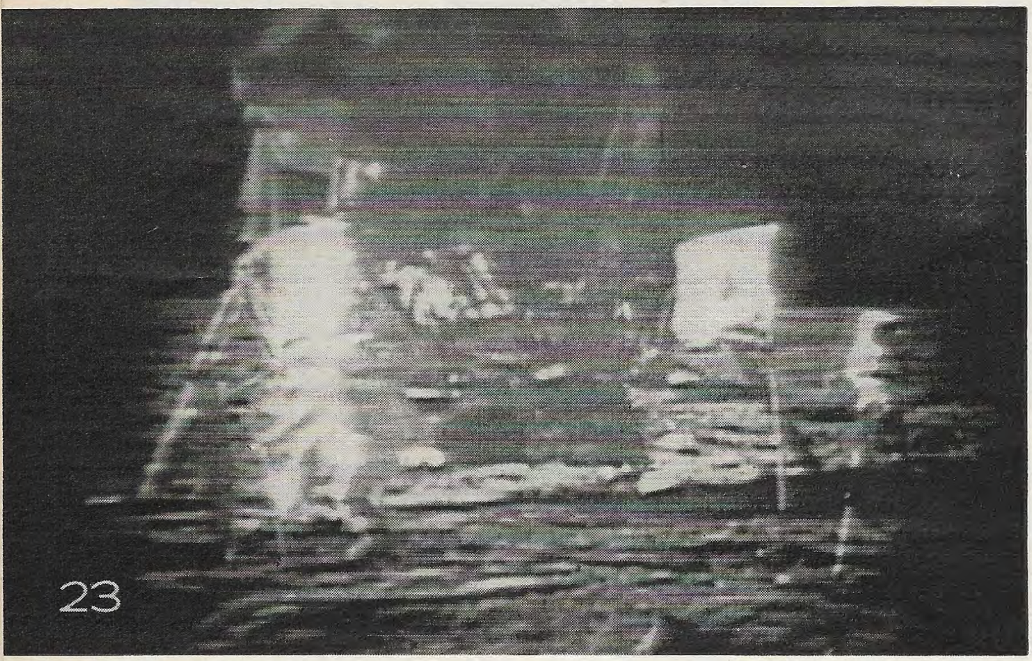
Both astronauts walk from lunar module carrying flag (15) and begin deployment (16). After conversation with President Nixon, Aldrin (17) provides display of suit mobility with a snappy salute. Aldrin is standing at right and Armstrong is in front of lunar module. Flag was stiffened with wire so that it would remain extended in windless near vacuum environment of the moon. Sunlight reflecting off wrapping of landing gear leg in left foreground produces white overexposure area on TV picture.

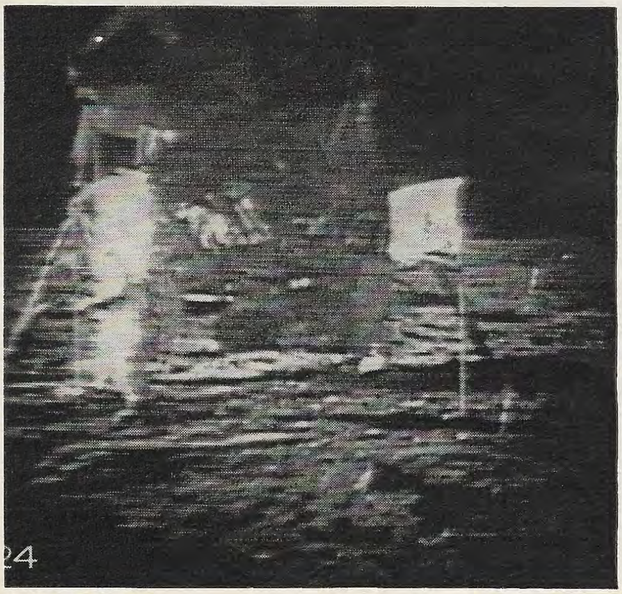


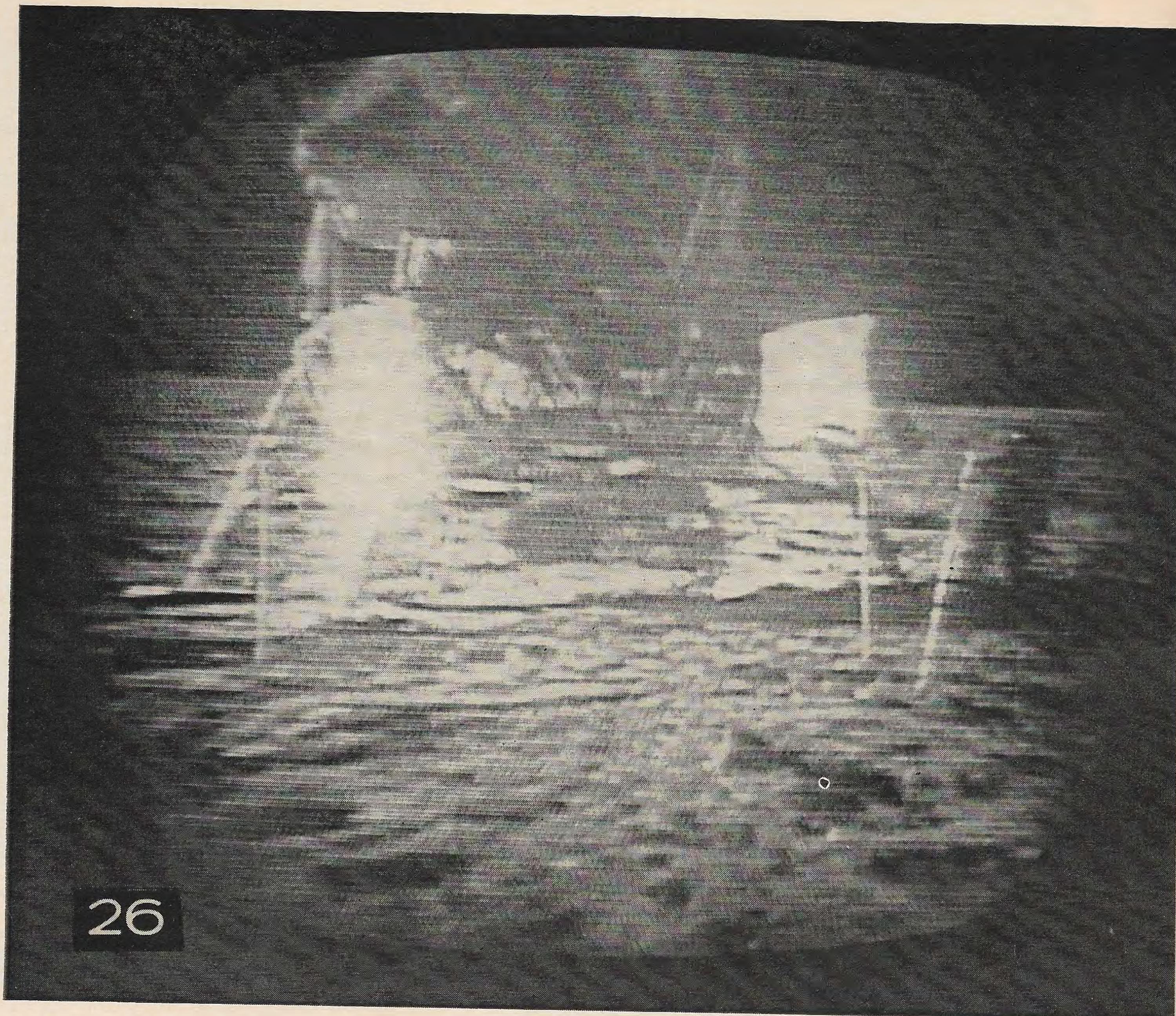
Aldrin tries kangaroo hop to evaluate the technique as a means of lunar locomotion (18). Tasks that followed this environmental activity included deployment of the passive seismometer and laser reflector experiments (19) to right rear of lunar module and inspection of the spacecraft by Armstrong (20) and later by both astronauts.



One of special tools for documented rock sample collection is used by astronaut (21). These included a large scoop for loose material and tongs for small rocks. Both astronauts took part in inspection and documented sample collection (22). Aldrin drives core sample rod into surface (23) in effort to bring back stratified layers of as much as 16 in. of lunar surface for geological analysis. Solar wind experiment sheet is then retrieved (24). Aldrin ascends (25) to complete his extravehicular activity while Armstrong completes sealing of sample return containers. Using "clothesline" hoisting device, Armstrong begins to raise No. 1 sample return box to Aldrin waiting in lunar module (26). After raising the No. 2 sample box in the same fashion, Armstrong then ascended the ladder himself and wipes lunar dust from his boots while standing on the lunar module platform (27). Astronauts have both re-entered the lunar module (28) and it, the U.S. flag and abandoned tools stand in stark loneliness on the moonscape.

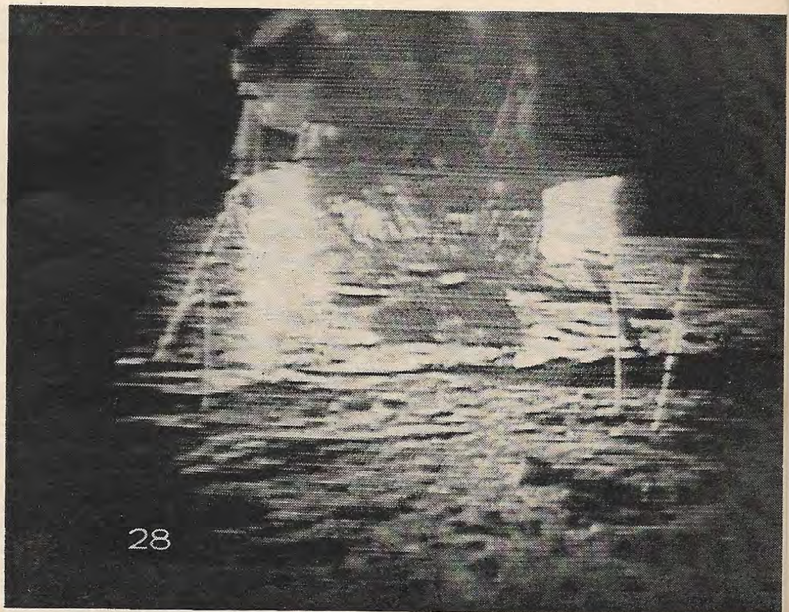




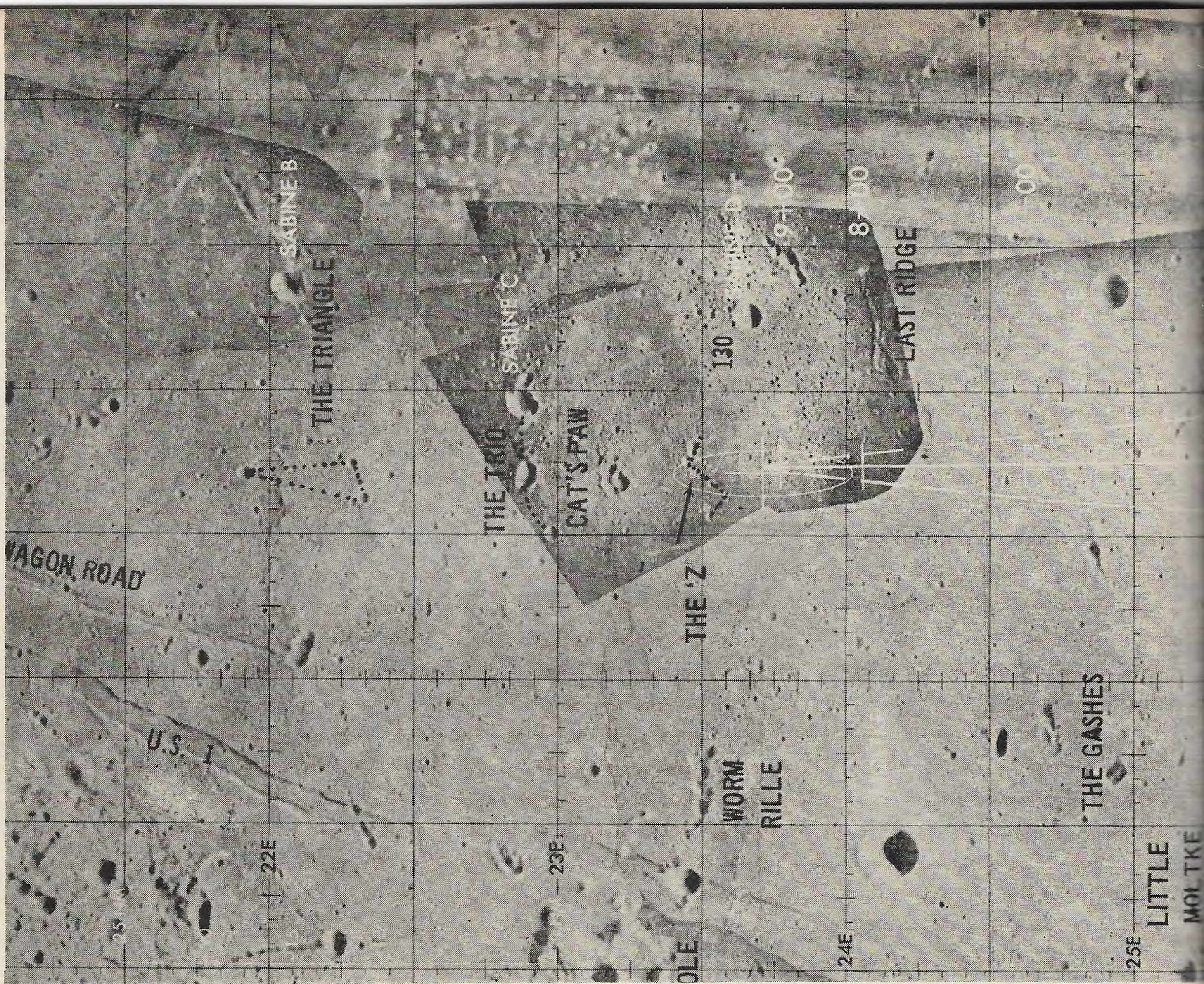


26

27



28



Mosaic of lunar surface from previous mission photos shows lunar module landing track and landing. Arrow marks actual landing

Bleak, Varied Moon Yields Wealth of

By William J. Normyle

Houston—Man's gift for vivid description captured for scientists the bleak and desolate surface qualities of the moon on the historic first landing.

Far more than on previous unmanned landings and on the two manned orbital flights (AW&ST Jan. 6, p. 24, June 2, p. 69), the crew of Apollo 11 gave the world the first human impressions of what that tortured surface really is like.

It may be some time before the impressions recorded by the first men to land on the moon, Astronauts Neil A. Armstrong and Edwin E. Aldrin, Jr., are analyzed sufficiently to settle some of the age-old arguments about the lunar origin.

Samples of the surface returned by the crew will be examined for months by scientists for clues to the geologic history of the moon and perhaps the origin of the universe.

But scientists were elated with the detailed descriptions of the lunar surface relayed by Armstrong and Aldrin during their sortie.

Highlights of the astronauts' observations, to geologists, were:

- Evidence of basaltic rock, much like that common on earth.
- Tremendous variety of rock forms within the landing area.
- Cohesiveness of the surface—described by Aldrin as clinging to a core sample tube as if it were wet.
- Sparkling, purplish rocks resembling biotites, which on earth are a species of mica commonly found in crystalline structures.
- Numerous small craters, caused both by impact and by subsurface slumping.
- Possibility of a lunar crust and mantle similar to that of the earth.
- Variety of soil properties from one location to another, and just below the surface, with interest centering on the difference in descriptions provided by the crew.

Scientists in particular are anxious to ask Armstrong for more detailed descriptions than he was able to provide while sitting in the ascent stage of the lunar module and while on the surface.

His narrative, which grew more detailed as he progressed, was cut off abruptly by the need of ground controllers to pass on data required for leaving the surface to rejoin U.S. Air Force Lt. Col. Michael Collins, orbiting alone in the command module.

Armstrong and Aldrin alternated between voluble bursts of lengthy description and long periods of silence, but the emotional effects of their landing and surface exploration were clear.

Even before they returned to a landing in the Pacific Ocean July 24 (see p. 41), the details of what they found and discovered as history's first lunar explorers were being debated.

spot, just west of crater pattern called "The Z." Armstrong reported sighting crater Sabine on takeoff.

Information to Its First Explorers

Some geologists insisted that the surface described by Armstrong in the immediate landing area showed clear evidence of volcanic activity and the presence of moisture which would indicate some possibility of a life form.

Others withheld judgment pending an analysis of the 78 lb. of lunar rock returned by the crew, and further discussions with Armstrong and Aldrin. They did not rule out the possibility of a passive moon, but admitted that the theory has lost significant support.

There was even considerable disagreement as to the exact site of the landing, although scientists at the National Aeronautics and Space Administration's Manned Spacecraft Center here quickly found the general area. They considered its location critical to new understanding of lunar morphology.

They were aided by the U.S. Geological Survey's Astrogeology Branch at Flagstaff, Ariz., where detailed surface maps had been prepared based on two previous manned lunar orbits, the flights of the five Lunar Orbiter spacecraft and the soft landings made by Surveyor.

The precise coordinates of the Apollo 11 landing position could not be immediately determined, according to geologists. Armstrong seized control of the lunar module to fly it over a field of large boulders in the middle of the preprogramed landing point to which the spacecraft was being guided by computer (see p. 36).

His landing was made about 4 mi. past the center of the target ellipse, near its southwestern edge, just beyond what has been named West Crater.

Best estimates of geologists, based largely on descriptions by Armstrong and Aldrin of the surrounding lurain and landing radar tracks, were that the lunar module touched down within about 600 ft. of that landmark, at about 0.6 deg. N. Lat. and 23.6 deg. E. Long., at 102 hr. 45 min. 40 sec. after being launched.

Large-scale maps provided by geologists only covered the center of the ellipse and did not include the subsequent landing area (AW&ST July 21, p. 80).

That is why the crew's remarks were significant in assisting in the location of the spacecraft.

Both from the cabin of the lunar module ascent stage 15 ft. above the lunar surface, and while on the surrounding lurain, Armstrong and Aldrin excitedly described their site, which they named Tranquility Base.

The spacecraft was yawed 13 deg. from the ground track on a 4.5 deg. downslope.

One of the things of primary interest to geologists was that much of the loose surface material described by the crew and probably some of that buried or half buried in the surface, were ejected there from the large and heavily rock-rimmed West Crater over which Armstrong had to navigate for a landing.

That distribution, coupled with the bright and easily identifiable rays stretching from huge craters far below the lunar equator, is expected to help geologists pinpoint surface movement caused by heavy impacts or internal lunar disturbances.

Eugene Shoemaker, a principal scientific investigator for geology, termed the landing site "a very fortunate accident."

Armstrong said the spacecraft landed in a "relatively clear crater field of elongated and circular secondary craters." He said most of the craters visible through the small triangular lunar module windows had rims, indicative of a young age. A few had no discernible rims, which could have been the result of aging or slumping.

Armstrong's own suspicion, supported here by geologists familiar with the rayed effects of the area, was that the boulder field of the landing site was ejecta from the large, rock-rimmed crater filled with debris. Armstrong had maneuvered over it to avoid a rough landing.

At first impression, Armstrong described that crater as about the size of a football field. He later said it appeared to be big enough to fit into the Astrodome, a large sports arena here.

Boulders within that crater, he said, ranged in size from 10-ft. diameter, considerably larger than those of the area in which he finally landed.

By contrast, within the field of view of the landing site, Armstrong and Aldrin described a relatively level plain without evidence of large protuberances.

There were "literally thousands of little 1- and 2-ft. craters" in the immediate area, according to Aldrin, with some angular blocks about 2 ft. in diameter resting several hundred feet ahead of the lunar module's flight path.

"The ground mass throughout the area is a very fine sand," Armstrong said, somewhat resembling silt. He also described it as similar to powered graphite on earth.

"Immersed in this ground mass are a wide variety of rock shapes, sizes, textures, rounded and angular," he added.

Armstrong said there was widespread evidence of earth-type basalt, both plain and textured.

"We are in a boulder field," Armstrong said, "where the boulders range generally up to 2 ft. with a few larger than that." Some of the boulders, he added, were fully exposed on the surface while others were either partially or almost completely buried within the surface.

To the surprise of some geologists, Armstrong said the colors on the surface were comparable to those he had described from lunar orbit before descending to the landing. These colors were predominantly ash gray. Geologists had thought that the different sun angles between orbital altitude and the surface might have given some variance to the observations.

Instead, Armstrong said with a 10-deg. sun angle there was little change.

"It's gray and it's very white, chalky gray," with some darkening in low shadows, he said.

"Some of the surface rocks in close here," he said "have been fractured or disturbed by the rocket engines [and] are coated with this light gray on the outside . . . but when they've been broken they display a dark, very dark gray interior."

As Armstrong descended the ladder to the surface, he noted that the lunar module foot pads had only made a 1- to 2-in. depression in the soil.

"Although the surface appears to be a very, very fine grained, as you get close to it it's almost like a powder . . . now and then it's very fine."

He continued: ". . . the surface is fine and powdery. I can kick it up loosely with my toe. It does adhere in fine layers like powdered charcoal to the sole and sides of my boots. I only go in a fraction of an inch . . . maybe an eighth of an inch, but I can see the footprints of my boots and the treads in the fine sandy particles."

Geologists estimate that the footprints, and those made later by Aldrin, probably would remain visible for centuries, since there is no atmosphere on the moon to disturb the imprints.

There appeared to be no difficulty in moving on the surface during any of the exercises performed by Armstrong,

Vital Lunar Material Returned to Earth

Houston—Vital cargo of the Apollo 11 spacecraft in addition to the three-man crew included an estimated 78 lb. of lunar surface material collected during the sortie of Neil A. Armstrong and Edwin E. Aldrin, Jr., and probably the most extensive collection of photographs ever returned from space.

The total collected was more than half of what the crew could have retrieved. But their time was expended by a number of chores added to their mission at the last minute, such as erecting a U.S. flag and listening to a telephone call from President Nixon.

Armstrong and Aldrin managed to fill one return container with bulk material, partly fill another with documented samples and gather some dirt in two core tubes, each 16.25 in. long.

Pending post-recovery analysis at the National Aeronautics and Space Administration's lunar receiving laboratory at the Manned Spacecraft Center here, geologists could only estimate a total returned lunar sample weight of 78 lb.

It was anticipated that, because of Armstrong's hurried activities as time was running out, samples would contain a much better variety than originally hoped.

While Armstrong sped about the surface picking as many varieties of rocks as possible in the short period available, Aldrin was driving the core tubes into the surface. He used an extension handle and hammer.

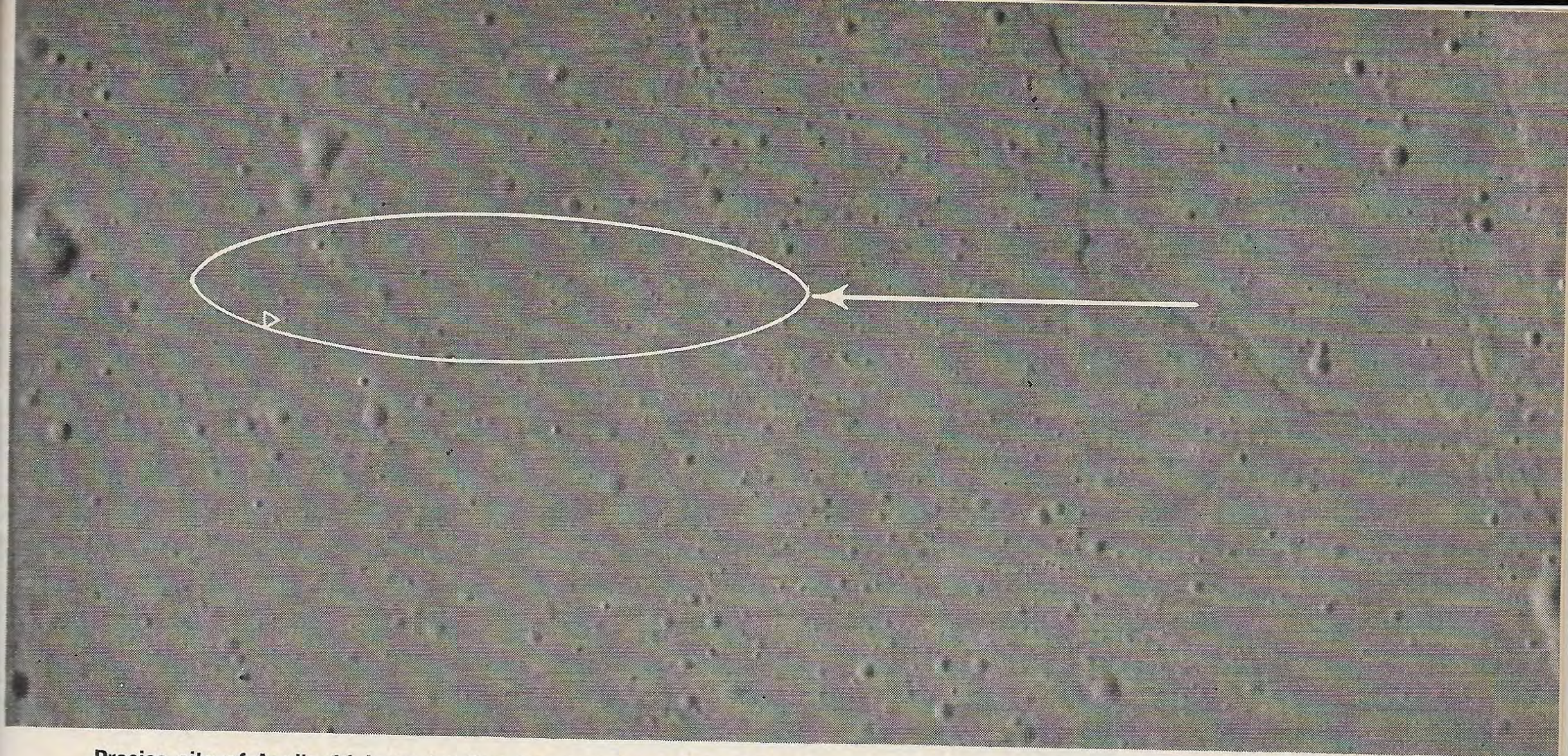
Aldrin's noticeable difficulty in driving the core sample into the surface was attributed by geologists here to a harder than anticipated subsurface material. They said a redesign of the core probably would be considered.

The larger tools were stored in a panel on the descent stage of the lunar module, along with the Westinghouse camera which Armstrong activated to televise surface activities.

Other tools were in the bay housing the early Apollo scientific package which was deployed successfully to measure lunar seismic activities and reflect laser beams from earth.

A number of tools were not carried on Apollo 11 because of limited time available for surface operation and the deletion of additional science experiments originally planned for the flight.

In addition to the television portions of the missions, the crew returned all of its film packs from one 70-mm. Hasselblad electric camera in the command module; two Hasselblad 70-mm. superwide angle cameras on the lunar module and a 35-mm. stereo closeup camera in the external lunar module storage area. They also returned two 16-mm. Maurer motion picture cameras.



Precise site of Apollo 11 lunar landing was just downrange of a crater called West Crater. Triangle inside landing area ellipse superimposed on photo from Apollo 10 mission (AW&ST June 9, p. 16) marks the touchdown point.

at first alone and later with Aldrin, and, in the final moments of surface activities alone again.

They demonstrated the ease with which men properly trained in earth simulations can perform tasks on the surface, and geologists were delighted that they can anticipate good mobility on future lunar exploration.

Armstrong performed a pilot's walk-around inspection of the lunar module and reported no sizeable cratering below the descent engine nozzle. Geologists had expected some cratering effects upon a powdery surface from the descent engine plume, but Armstrong's later description of a hard subsurface explained the lack of disturbance satisfactorily.

The engine nozzle, in fact, had about 1-ft. of clearance above the surface. Engineers had expected that the nozzle might have crushed into the surface during the descent, but there was no marked evidence of deterioration.

As he walked, Armstrong passed into the shadow of the lunar module and said it was quite dark and "a little hard for me to see if I have good footing." The contrast between light and shadow on the surface had been expected. As he moved into sunlight to photograph Aldrin's descent, Armstrong said light was sufficiently bright on the front side of the lunar module so that "everything is clearly visible."

Armstrong reported some slight difficulty in obtaining a contingency sample of the surface.

He said: "This is very interesting. It's a very soft surface but here and there I plug with the contingency sample collector"—a scoop-like device to permit him to gather surface material without bending too far forward—"I run into a very hard surface . . . it appears to be very cohesive material of some sort."

Geologists analyzing Armstrong's comments planned to ask him for more detailed description of the cohesiveness, although they now will have surface samples with which to make comparisons.

Armstrong told Aldrin—and the world watching and listening on television and radio:

"It has a stark beauty all it's own . . . like much of the high desert of the United States. It's different but it's very pretty out here."

Then he made a comment that immediately prompted discussion between the two basic schools of lunar origin—that it always has been a passive, dead body, or that it has been and still is an active sphere with considerable activity vesicles in the surface."

"Be advised," he said, "that a lot of the rock samples out here, the hard rock samples have what appear to be vesicles in the surface."

Vesicular evidence, a bead-like quality, would support a theory of an active moon, with lava flows.

Aldrin noticed some thermal effects, probably from the descent engine plume, on a secondary strut supporting the ladder. Armstrong said the effects appeared to be the most pronounced in that area although there was evidence of it elsewhere around the descent stage.

Armstrong said: "Isn't this fun?" He then advised Aldrin: "You're standing on a rock, a big rock there now."

Joining in an inspection of the lunar module, the pair noticed that the landing probe used to sense touchdown was bent back by the impact, and there was some lateral velocity during landing.

As they moved, Aldrin reported the extensive rocks strewn about the surface were "rather slippery." He said: "Very powdery surface when the sun hits. We tend to slide over it rather easily."

Some of the first surface samples collected by the pair, described by Aldrin as "very small, sparkly fragments," were purplish in color. Geologists here agreed with Aldrin's estimate that fragments could be biotites.

They normally are of a black or dark green color, but one geologist said the purplish hue described by Aldrin might be the result of lunar aridity.

The question of aridity also arose when Aldrin reported while collecting a core sample that it was dark and "almost looks wet."

Geologists connected that comment with the crew's general interpretation of surface cohesiveness, but there was no firm evidence of fluids being present. Aldrin, nevertheless, reported that the way the surface material adhered to the core tube "gave me the distinct impression of being moist."

Some geologists of the investigating team were disappointed with the inability of the crew to complete the entire collection of surface samples.

The crew collected two core samples, a full box of bulk materials and a partly filled box of what they called "a carefully documented bulk sample."

Investigators said they were satisfied that the 78 lb. of rocks probably were so diversified that they would provide excellent detail of general surface characteristics.

Mobility Unhindered by Bulky Space Suit

Astronauts' agility on moon even surprises experts familiar with gravity environment; energy requirements found reduced

By Warren C. Wetmore

Houston—Man's ability to fill a vital role in the exploration of his solar system was demonstrated by the ease with which the two Apollo 11 astronauts adapted to the unfamiliar lunar environment and accomplished their assigned tasks under a tight schedule.

"There seems to be no difficulty in moving around," Apollo 11 commander Neil A. Armstrong said shortly after he stepped from the lunar module's landing gear pad onto the powdery surface of the moon. "It's even perhaps easier than simulations of one-sixth G that we performed in the simulators on the ground. It's actually no trouble to walk around."

A few minutes later, after the first cautious steps, Armstrong was moving rapidly about with the springy, long-striding lunar lope that he adopted as the best method of locomotion.

The astronauts' agility surprised even the engineers familiar with the simulated effects of reduced gravity and the restraints imposed by pressure suits and back-packs weighing 188.44 lb., or more than the astronauts themselves.

'Easier Than Expected'

Robert E. Smylie, chief of the Manned Spacecraft Center's Crew Systems Div., concurred with Armstrong. "Doing things at one-sixth G appears easier than we expected it to be," he told AVIATION WEEK & SPACE TECHNOLOGY. "It was not that [suit] mobility was better than expected, but that the energy requirements were less." These rates are those at which the body generates heat and are a measure of the effort expended.

The evaluation of this parameter is a complicated synthesis of three independent measurements—heart rate, temperatures in the liquid-cooled garment (LCG) and the Hamilton Standard Div. of United Aircraft portable life-support system (PLSS), and the astronaut's oxygen consumption. Nevertheless, preliminary values calculated were under a 1,000 BTU/hr. average compared with 1,550 predicted; and about 1,100 BTU/hr. for Lunar Module Pilot Edwin E. Aldrin, Jr., whose pre-flight predicted heat generation was 1,250 BTU/hr.

This difference between predicted and actual values could indicate a higher lunar surface workload for the lunar module pilot. Aldrin was assigned the task of detailed evaluation of the suit/back-pack and lunar gravity constraints on his physical abilities.

Aldrin investigated reaching mobility and may have kneeled at one point to extract a camera from the lunar module storage bay.

"Reaching down is fairly easy," Aldrin remarked. He may have lost his balance at this point, because he said, "Getting my suit dirty at this stage."

Aldrin also commented that there was a "slight tendency" to go off balance backwards when standing completely upright, apparently because of his heels digging into the "soft, very soft" lunar soil. An engineer noted that the astronauts have to adjust for the unbalancing effect of the 127-lb. backpack by tending to lean forward.

The center of gravity has to be kept over the heels, he said.

Although both crewmen noted that the finely divided surface soil—ground fine by eons of micrometeoroid bombardment—tended to be slippery, particularly in thin layers over underlying rocks, there were no difficulties with footing. "Traction seems quite good in this area," Armstrong remarked as he prepared to take the television camera from the lunar module storage bay.

The effect of shifting body center of gravity was investigated. "[When I] lose my balance in one direction, recovery is quite natural and very easy," Aldrin said. A NASA engineer later explained that in one-sixth gravity environment a fall would be considerably slowed. This would enable one to take several compensating steps to regain balance.

". . . Moving my arms around . . . doesn't [lift me] off the surface," Aldrin found. "I'm not quite that light-footed," he added. Arm-waving was a specific test to determine if sufficient reaction force could be generated in low gravity to displace an astronaut.

Evaluation of methods for starting from a standing position on the lunar surface was another test objective carried out by the astronauts. In this connection, Aldrin remarked: "Got to be careful that you are leaning in the direction you want to go. In other words, you have to cross your foot over to stay under where your center of mass is."

Stopping also was evaluated. "You do have to be rather careful to keep track of where your center of mass is," Aldrin reiterated. "Sometimes, it takes about two or three paces to make sure you've got your feet under you. About two to three or maybe four easy paces can bring you to a nearly smooth stop."

Agility Demonstrated

One of the most spectacular demonstrations of agility was when Aldrin, in view of the TV camera, showed broken-field running. "Like a football player, you just have to split out to the side and cut a little bit," he said. Here again, traction was no apparent problem.

The kangeroo hop—with both feet together—had been devised before the mission as a possible method of locomotion on the lunar surface. "It does work," Aldrin said after about four hops, "but it seems that your forward ability is not quite as good as it is in the . . . conventional one foot after another."

Aldrin also noted that in the restricted area around the lunar module it was difficult to say what pace would be most tiring.

He tried one and said it "could get rather tiring after several hundred feet —but this may be a function of this suit."

The ILC Industries pressure suit, with its constant-volume joints, appeared not to hamper the astronauts. They seemed quite natural going about their tasks of erecting and later furling the solar wind composition experiment, raising the U. S. flag (though there was some difficulty driving the staff into the lunar soil) unloading and carrying the bulky seismometer and laser reflector experiments, and bending to collect soil samples.

The suit's shoulder joint may even have aided Aldrin's aim as he drove the core sample tubes into the surface.

But the suit's principal zipper runs through the crotch, and this made the

---

Computer Alarm

Houston—Continuous alarm in the Apollo 11 lunar module computer because of overloading commands forced the crew into more manual guidance.

Crew requirements for data diving and landing phase of the mission July 20 became so heavy that the computer could not keep up with their demands.

Resulting overloading brought a series of alarms, but failed to interfere with the descent phase, including the critical final maneuvers. Commander Neil A. Armstrong had to switch computer programs from automatic to semi-manual to maneuver past a boulder-laden landing site to one more suitable for the lunar module.

---

astronauts appear rather straddle-legged and awkward when they moved at a slow pace.

"I'm getting a little tired of all this talk about 'bulky space suits'," Smylie said. The astronaut is not seriously constrained and can do what he needs to do." The arm mobility, he added, is "almost nude range," though the effort involved in moving the arms is greater.

When the flag was raised and after President Nixon spoke to the astronauts Aldrin had no problem in snapping a military salute.

Armstrong apparently threw a rock with no difficulty while on the surface. He commented, "You can really throw things a long way out here." Smylie and other engineers guessed that he may have thrown underhand. This would generate a lesser unbalancing force than side-arm or overhand.

Acuity Reduced

Both astronauts noted that their visual acuity was reduced considerably when they were in the shadow of the lunar module.

"It's quite dark here in the shadow and a little hard for me to see if I have a good footing," Armstrong observed shortly after descending the ladder.

This is largely because of the high optical density of the gold-coated outer visor of the extravehicular visor assembly (EVA) that is required because of the searing intensity of the direct solar rays during daytime on the lunar surface. But Armstrong was able to adapt to darkness after a moment.

"I'm standing directly in the shadow now, looking up at Buzz [Aldrin] in the window. And I can see everything quite clearly. The light is sufficiently bright, backlighted into the front of the LM [lunar module] that everything is very clearly visible."

The astronauts may have raised the lunar day visor while in the shadow. "I can't say too much for the visibility over here without the visor up," Aldrin said.

Moving from sunlight to shadow also interfered with visibility. Armstrong said: "I've noticed several times in going from sunlight to shadow that just as I go in, there's an additional reflection off the LM that, along with the reflecton off my face onto the visor, makes visibility very poor just at the transition from sunlight into shadow." He added: ". . . It takes a short while for my eyes to adapt to the lighting conditions . . ."

The suit and helmets themselves actually create their own visibility restrictions: the astronauts, standing erect, cannot see their feet because of the back-pack control boxes fixed to their chests. Each had to guide the other into and out of the small front hatch of the lunar module, with detailed instructions.

At the approximately 11-deg. sun elevation angle during the lunar surface activity, there were no problems with solar heating of the astronauts.

"In general," Aldrin said, "time spent in the shadow doesn't seem to have any thermal effects that we can feel inside the suit. There is a difference, of course, in the incoming radiation in the helmet. So I think there's a tendency to feel a little cooler in the shadow than we do in the sun."

The liquid cooling garment, in essence a suit of underwear containing tubes through which water flows near the skin, was originally developed by the British Royal Aircraft Establishment.

Worst at Noon

The worst designed case for the lunar environment is at noon, with the astronaut working in a crater. The crater would tend to focus the sun's rays on the astronaut, greatly increasing the potential heat input to the system.

The suit's multiple layers of aluminized plastic foilm, with spacers between to preclude conductive heat transfer, has reduced the input problem to about 275 BTU/hr. This is less than a man generates metabolically while standing absolutely still.

The metabolic heat produced under working conditions is a more difficult problem since it comes largely from deep within the body and must move to the skin to be dissipated. The greater heat-carrying capability of the water in the garment tubes is high enough so that, an engineer said, "We don't have to worry about getting behind on deep-body heat storage, as happened in the gas-cooled Gemini suits. We've tried, but we can't overwork the system on maximum cooling—the test subject tires out first."

Armstrong began his lunar surface activity with the coolant water diverter valve set for minimum cooling. The 45-deg. water coming from the porous-plate sublimator in the back-pack is mixed with warmer water from the garment to achieve a temperature of 75-80 deg. An engineer here said Armstrong prefers to be slightly warm in his suit.

Aldrin, on the other hand, began with maximum cooling—all water coming directly from the sublimator—which may have induced his greater metabolic heat rate. After a few minutes he informed Houston: "I'm a

Code Signal Slowed Armstrong Lunar Activity

Houston—High pulse rate of Astronaut Neil A. Armstrong during the final phase of lunar surface activity prompted Mission Control Center here to transmit a pre-arranged code phrase instructing him to slow down.

Armstrong's electrocardiograph telemetry showed that his heart rate went to the high 140s during the abbreviated 10-min. period allowed for collecting the documented rock sample. He was moving rapidly in an attempt to obtain as many rocks as possible, although thorough documentation was impossible.

Flight surgeons became concerned when they saw that his heart rate leveled in the 140s and showed tendencies to go even higher.

Subsequently, he began hauling the sample containers on the pulley-and-line lunar equipment conveyor up to Edwin E. Aldrin in the lunar module, Armstrong's heart rate peaked at 160 beats/min. He appeared to be hauling strenuously on the conveyor line.

At this busy point, the capsule communicator, Bruce McCandless, radioed: "Neil, this is Houston. Request an EMU check, over." The EMU is the extravehicular mobility unit—pressure suit and back-pack.

Armstrong gave the check, which indicated that all was well with the system and that he had 54% of his oxygen remaining. This is well above the emergency line. Houston already had a continuous telemetry read out of these data, but responded a bit later by telling both astronauts what they already knew: "Your consumables remain in good shape." This may have been another code phrase reassuring the astronauts that the concerns of the surgeons were allayed.

This was the first time that mission controllers had requested a check of the extravehicular mobility unit. But, the astronauts had been transmitting them periodically, as they are called for in the extravehicular activity schedule in conjunction with brief rests, perhaps as a code that they were feeling well.

Aldrin's peak extravehicular pulse rate was 125. Both astronauts averaged in the 90-100 range, which was higher than expected and up until the closing minutes may be attributable to excitement. When Armstrong finally ascended the lunar module ladder, he sounded short of breath.

Dr. Willard Hawkins, the NASA flight surgeon on the extravehicular activity shift at Mission Control, later said Armstrong's pulse rate never approached a critical level.

little cool. I think I'll change the diverter valve . . . I'm on intermediate now, Houston, and I show 3.78 [PSI. suit pressure], no flags [warning signals on the backpack control unit], and 74 [pc. oxygen supply remaining]."

The latter was a check of the control unit indicators specified periodically during the surface excursion, in conjunction with a brief rest. It served as a check for the seven housekeeping parameters telemetered to earth: oxygen tank pressure; liquid-cooled garment inlet temperature; oxygen inlet temperature, which also is the sublimator temperature; temperature rise in the liquid cooled garment; feedwater pressure to the sublimater, and battery voltage and current. Astronaut heart rate is transmitted over another telemetry channel.

The portable life-support system actually performed a bit above specification, according to John C. Beggs, portable life-support system program manager for Hamilton Standard. The sublimator was cooling the garment water about 2 deg. lower than expected, perhaps as a result of the 0.3 psi. increase in feedwater pressure. Oxygen entering the suit also was 1 deg. lower in temperature. Other parameters were on their predicted values.

The consumables, with the exception of battery power, were well above the expected quantities at the end of extravehicular activity. In 2 hr. 40 min. of PLSS operation, only about half of the 1.1-lb. supply of oxygen was used. Leak rates of the suits were said to have been exceptionally low. Armstrong had 5-5.5-lb. of feedwater remaining from an initial load of 6.8 lb.

The astronauts probably could have gone about another hour on the lunar surface with this surplus. It was the result of the lower metabolism level, since the backpack is designed for an average of 1,600 BTU/hr. and peaks of 2,000 BTU/hr.

Armstrong's Piloting Reflexes Avert Rocky Landing for Eagle

Houston—Trained reaction of a veteran pilot to a critical situation enabled Astronaut Neil A. Armstrong to override a guidance computer and manually prevent a landing of the lunar module on a boulder-strewn field on the moon.

As he monitored the guidance and navigation system of the Grumman Aircraft Engineering Apollo 11 lunar module, Armstrong abruptly switched landing programs. He toggled a switch to null out the descent rate and aim for a new landing point.

Engineers monitoring the guidance consoles at the National Aeronautics and Space Administration's Manned Spacecraft Center here later said they were startled by the unexplained change in the sink rate of the lunar module.

They noted that the AC Electronics Div. guidance and navigation system suddenly was switched from an approach phase mode, used prior to touchdown, to a semi-automatic mode. This indicated that Armstrong had assumed manual control of his attitude.

Final Phase

Armstrong later explained:

"Houston, that may have seemed like a very long final phase. The automatic targeting was taking us right into a football field-sized crater, with a large number of big boulders and rocks for about 1 or 2 crater diameters around us."

To null out his rate of descent, Armstrong went directly from Program 64, which is the approach phase, to Program 66, which permits total attitude to be handled manually.

He took over command at about 450 ft. altitude during a descent of about 3 fps. to the landing site. Pulsing the toggle, Armstrong commanded the Raytheon guidance computer to thrust the Marquardt reaction control jets to effect lateral translation.

That imparted a 10-15 fps. forward velocity, permitting the spacecraft to skim over the pre-programed landing site.

The normal sequence from 50,000 ft. is to punch up Program 63 to initiate powered descent with the TRW engine. Program 63 enabled the lunar module to brake toward the high gate of the approach, with Armstrong first commanding the engine to fire for 15 sec. at 10% thrust, equal to about 1,050 lb.

Armstrong then throttled the engine to 40% of rated thrust through 50,000-ft. altitude, manually yawing toward a window-up configuration to provide a view of the landing site.

The horizon and the landing area came into view at about 19,000 ft. as Armstrong ordered Program 64 into the computer.

Normally, Armstrong and Aldrin would have been observing spacecraft parameters on their panel indicators through braking, approach and landing phases.

Instead, Armstrong looked out his window and saw the huge, boulder-strewn crater lying directly in his path. By switching to the semi-automatic mode, Armstrong committed himself to abandoning the automatic landing sequence.

With manual attitude, the guidance and navigation system controls only the rate of descent in 1 fps. increments introduced by a toggle switch. Complete manual control would have been provided by Program 67, but Armstrong did not select that mode.

Result of Maneuver

All engine parameters, including chamber pressure, thrust position, commanded voltage and computer computations, agreed perfectly, according to TRW engineers. This also involved a 32-sec. firing at full thrust. The result of the maneuver was to add a total of 38 sec. burn time to the engine. Armstrong landed the Eagle lunar module with an average of 3% of his 18,000 lb. of propellant left in four tanks. Normally, the crew in practice has left 5.5-6% of propellant.

A low-level light normally comes on in the cabin at 5.6% propellant quantity, indicating 110 sec. of flight remaining. The pilot then must designate his landing within 60 sec. of that time.

There were no indications of any significant hovering time by Armstrong as he changed his landing zone and went on to another. As in simulations, he landed at about 1 fps. sec. vertical velocity.

Engineers here were puzzled that Armstrong's position during initiation of the powered descent phase was about 4 mi. beyond the planned point.

Navigational errors are one of the major problems remaining in space

Memorable Quotes

Houston—Memorable quotes from the Apollo 11 mission included:

- **Lunar module lands on moon.** Eagle (Neil Armstrong)—"Houston, Tranquility Base here. The Eagle has landed [102 hr. 40 min. ground elapsed time, 3:12 p.m., CDT, July 20]."
- **Armstrong steps onto moon.** "That's one small step for man. One giant leap for mankind [109 hr. 24 min. 20 sec., 9:56.20 p.m., July 20]."
- **Lunar module takes off from moon.** Capsule communicator (Astronaut Ronald E. Evans)—"Roger, our guidance recommendation is PGNCS [primary guidance, navigation and control subsystem] and you're cleared for takeoff." Eagle (Edwin E. Aldrin)—"Roger, understand, we're No. 1 on the runway [124 hr. 22 min., 12:54 p.m., July 21]."

Soviet Luna 15 Hard-Lands in Sea of Crises

Soviet Luna 15 unmanned spacecraft hard-landed on the moon July 21 following an unsuccessful soft-landing attempt. The device impacted in the Sea of Crises, about 500 mi. northeast of the U.S. Tranquility Base.

Return to earth was not included in the Luna 15 flight plan. No deployment of Soviet land or sea recovery forces was conducted in connection with the mission.

Four days of erratic behavior in lunar orbit preceded the hard landing.

Launched from Tyuratam July 13 (AW&ST July 21, p. 27), Luna 15 was put into initial lunar orbit at 10 a.m. Greenwich time July 17 when its engine was fired automatically on the far side of the moon. Initial orbital parameters were not announced by the Soviets, but were estimated at 540 x 150 mi. Inclination to the lunar equator was 126 deg.

On July 18 an unannounced burn brought the spacecraft down to an orbit of 126 x 34 mi. The following day the Soviets announced what they termed a correction of orbital parameters conducted at 1:08 p.m. Greenwich time. This raised Luna 15 into a 138 x 59-mi. orbit with a period of 2 hr. 3.5 min.

On July 20 at 2:16 p.m. Greenwich time the Soviets conducted what they called the second orbital correction, resulting in a 69 x 10-mi. orbit with a period of 1 hr. 54 min. The spacecraft remained at a 126-deg. inclination throughout its lunar orbital flight.

At 3:47 p.m. Greenwich time July 21, what the Russians termed a retrorocket was fired and the spacecraft impacted 4 min. later. The final burn was described in different terms from the firing which first put the spacecraft into lunar orbit.

Proton-class booster was used in the launch of Luna 15, which had an estimated gross weight in lunar orbit of 6,500 lb. This is approximately four times the estimated weight of the four previous Soviet lunar orbiters. The fuel loading was considered sufficient to carry out a soft-landing, with enough remaining payload to conduct experimentation and observation on the lunar surface.

Luna 15 was believed to have had theoretical capacity to return only a 1,000-lb. payload to earth from the lunar surface. The hypothetical half-ton load would have had to include power supply, guidance and communications equipment, leaving a relatively small capacity for equipment to collect lunar samples and for the samples themselves.

Systems tests carried out with Luna 15 are likely to be repeated in further launchings aimed at an unmanned soft landing on the moon from lunar orbit. Perfection of the technique could lay groundwork for larger spacecraft, powered by a larger booster and designed for earth return.

Flight of Luna 15 caused serious concern among National Aeronautics and Space Administration officials, who feared radio interference with Apollo 11. Luna 15 transmitted on a frequency in the 115-mc. range, whose harmonics, under certain conditions, could have interfered with the 296- and 259-mc. voice channels used by lunar module astronauts to communicate with each other and with the command module.

Soviet officials did not inform NASA of the Luna 15 experiment in advance, although they were aware of the possible conflict through previous U.S. information releases. The Russians did cooperate with astronaut Frank Borman, who was asked by NASA officials to request Luna 15 flight information by telephone from the Soviet Academy of Sciences.

flight, according to mission engineers. They said Armstrong entered the powered descent phase 4-mi. late because of a number of cumulative errors including:

- Necessity of disabling two reaction control quads during landmark tracking, leaving only one thruster operating and resulting in a later translation of several feet per second.
- Separation of the command lunar modules, with an uncertainty of exact positions.
- Initiation of the descent orbit thrust itself, behind the moon, which engineers explain could accumulate to a 9,000-fps. error in targeting.
- Possible effects of the concentrated masses below the lunar surface, which have caused changes in speeds of previous spacecraft.

In planning for Apollo 11, orbital mechanics of the lunar portion of the flight had been adjusted, it was presumed, to take the subsurface concentrations into consideration.

In effect, the increase in speed and slowdown of the spacecraft induced by the concentrations should have been accounted for, but analysts said the lunar module still was slightly off.

Similarly, the ascent phase of the flight, from the surface to lunar orbit, posed a problem for mission analysts because they were not immediately sure as to the landing coordinates.

Known coordinates were necessary to the rendezvous radar sequence so that the lunar module could more accurately orbit to the plane of the command module.

Mission engineers asked Michael Collins, orbiting alone in the command module, to locate the lunar module using auto-optics. He was unsuccessful.

Collins did track some known landmarks, and the lunar module RCA rendezvous radar was activated before ascent to locate more precisely the command module.

In addition, geologists studied small-scale maps of the landing area, from photographs on previous orbital missions, and pinpointed the coordinates with what later turned out to be close accuracy.

Following the lunar surface time (see p. 38), the North American Rockwell Rocketdyne ascent engine was fired for the first time with men on board to lift the lunar module from the surface. Systems were working so well that the TRW abort guidance system was within 1 fps. of agreement with the primary guidance.

Unlike staging during the lunar orbiting flight of Apollo 10, when a crew error left a switch in the wrong position causing gyrations, the Apollo 11 spacecraft performed in what Aldrin described as a very smooth ride.

The crew even managed, during that busy time of ascent, to identify a crater which Armstrong had approached on the surface, ranging to 80 ft. in diameter.

The ascent followed almost precisely the planned mission, only 3 min. behind schedule.

The ascent stage with Armstrong and Aldrin rendezvoused and docked with the command module and its pilot, Michael Collins, at 128 hr. 3 min. ground elapsed time. Armstrong and Aldrin, once they were docked with the command module, fathered up the lunar surface sample boxes, vacuumed lunar dust from themselves and the boxes and made the transfer to the other vehicle through the docking hatch.

The lunar module was jettisoned and left in orbit of the moon. The lunar module ascent stage used on the Apollo 10 flight had been fired off into solar orbit to test the ascent stage.

Lunar Surface Activity Time

	Ground Elapsed Time (hours, minutes, seconds)	CDT
Cabin depressurized	108:21	8:53 pm
Astronauts on portable life-support system	108:56	9:28 pm
Hatch opened	109:07:35	9:39 pm
Armstrong on porch	109:19:16	9:51 pm
Sampling equipment bay down (lanyard pulled)	109:21:10	9:53 pm
TV started	109:22:03	9:54 pm
Armstrong on foot pad	109:23	9:55 pm
Armstrong on surface	109:24:20	9:56 pm
Aldrin egress	109:40	10:12 pm
Aldrin on surface	109:42:49	10:14 pm
Plaque read	109:52	10:24 pm
TV camera moved to tripod	109:55:30	10:27 pm
Solar wind experiment deployed	110:03	10:35 pm
U. S. flag emplaced	110:09:40	10:41 pm
Aldrin tests Kangaroo hop	110:14	10:46 pm
President speaks	110:16:28	10:48 pm
Armstrong replies	110:17	10:49 pm
Bulk sample collection starts	110:23	10:55 pm
Laser experiment deployed	111:04	11:36 pm
Seismometer solar panels extended	111:12	11:44 pm
Core soil samples collected	111:14:43	11:46 pm
Solar wind experiment retrieved	111:20:22	11:52 pm
Armstrong picks up rocks	111:22:04	11:54 pm
Aldrin re-enters lunar module	111:25:07	11:57 pm
Sample box 1 up	111:31:07	12:03 am
Sample box 2 up	111:35:20	12:07 am
Armstrong climbs, wipes feet, enters	111:37:32	12:09 am
Hatch closed	111:39:15	12:11 am

Total time on portable life-support system 2 hr., 47 min., 14 sec.

Mariner 6 to Send Pictures From Mars

Los Angeles–First real-time display of pictures transmitted from near the planet Mars is scheduled for 9:35 p.m. (EDT) Tuesday, July 29, at Jet Propulsion Laboratory, Pasadena, as they are received from the Mariner 6 spacecraft about 60 million miles away.

Mariner 6 and its twin, Mariner 7, will perform a variety of photographic and scientific missions as they fly past the red planet. Each space probe will approach as close as 2,000 mi. of the Martian surface as it passes the planet. Mariner 6's closest point of encounter will occur at 1:18 a.m. EDT, Aug. 1, and Mariner 7 at 1 a.m., Aug. 5.

First ground command which will initiate a series of scientific and photographic work by automated subsystems aboard Mariner 6 will be transmitted from JPL's Goldstone Tracking Station in the Mojave Desert at 9:19 p.m. Monday, July 28. This command will inaugurate a period of 11 days of intensive work at JPL of analyzing, displaying, recording and processing data from the probes.

JPL has installed a 4.5 mc., microwave link from Goldstone to the laboratory here to provide the real-time display. The intensified 16,200 BPS transmission rate of the Mariners and the use of the 210-ft. antenna at Goldstone will enable rapid display of photos despite the roughly 60-million mi. transmission distance from Mars.

Possible Light Source

San Francisco–Laser beamed from the Soviet Union's Crimean Observatory may have been the source of the light reported seen by Apollo 11 commander Neil A. Armstrong.

Dr. James E. Faller, one of the Lick Observatory's co-experimenters in the Apollo 11 laser ranging retroreflector experiment, said his "prime guess" was that the light emanated from the Crimean Observatory's "first-class" 100-in. telescope.

The Soviet Union had been expected to try to acquire the reflector deployed by the Apollo 11 astronauts on the lunar surface, Dr. Faller said. To the best of his knowledge, he said, the lasers from Lick Observatory and McDonald Observatory in Ft. Davis, Tex., were not operating at the time Armstrong reported the light.

TV Puts Moon

Houston–Space television came of age last week as hundreds of millions of people around the world saw man take his first footstep on extraterrestrial soil.

The lunar surface camera is a 7.25-lb. unit that survived at least two deletions from the lunar module on weight grounds two years ago. The camera showed the stark panorama of the Apollo 11 landing site and the astronauts performing their mobility experiments and other lunar surface activity tasks during a record 5-hr. 3 min. 44 sec. telecast through the 210-ft. Goldstone antenna in California.

The Westinghouse camera was included in the lunar module's modular equipment stowage area (MESA) pallet on the spacecraft's descent stage. It was exposed when mission commander Neil Armstrong, standing on the lunar module float platform, pulled a lanyard and released the latch on the pallet.

Views Transmitted

The views transmitted were of the astronauts, the moon, and the lunar module after the camera had been removed from the pallet, carried some distance away, and erected on its tripod.

Quality of the black-and-white images was excellent, particularly considering that the TV channel was limited to 500 mc. bandwidth in the lunar module's S-band transmitter. The camera transmitted 10 frames/sec. compared with 30 for commercial broadcast, and had a 320-line scan, as compared with 525 for home TV. This required conversion at the ground station, with a commercial standards camera focused on a monitor, plus a magnetic disc recorder to take out the flicker.

The conversion equipment was developed by RCA Defense Electronics Products.

Handles Camera

Armstrong, who handled the camera before placing it on the tripod, even changed the fixed-focus lens. He substituted a normal lens for the wide angle initially installed when the unit was in the pallet. This created a burst of light on the screens of the receivers, since the image tube was deprived of the dark T60 filter coating incorporated in the lens.

This filter gives a 14,400:1 attenuation of light required by the fact that the image is also designed to work in the low light levels of the lunar night. But the automatic light control circuit prevented damage to the tube.

The low light-level feature permitted good visibility of the astronauts even when they were in the shadow of the lunar module. The astronauts them-

Walk Before Eyes of Millions Around World

selves experienced difficulty seeing in the shadow.

But when the astronauts went into the brilliant sunlight, their images washed out until the light control could accommodate the increased energy level.

Stanley Lebar, Westinghouse's manager of lunar TV, told AVIATION WEEK & SPACE TECHNOLOGY he would have liked to have the camera aimed completely in shadow or completely in sunlight so that the light control could function properly. The subsystem takes the average of the light falling on the camera lens to make adjustments, so if there is a large difference in the light level of various objects in the field of view the exposure is not optimum.

Operation of the light control was seen when one of the astronauts momentarily shaded the camera on its tripod. The exposure was increased electronically and then decreased when the shadow had passed.

Lebar said he noticed the camera appeared to zoom in on the scene several times, which he was unable to understand since the lens is fixed. This may have been done in the conversion equipment, he believes, with the commercial camera zooming on the monitor.

The slower scan rate of the lunar TV did result in some image smearing when the astronauts moved fast in its field of view.

Good Focusing

The good depth-of-field of the lens permitted focusing on objects from infinity down to about 20 in. Aldrin pushed his gloved hand closer than that, to show the lunar dust on his fingertips, and the image was still well in focus.

The panoramas taken by Armstrong were:

- **North to northeast**—showed a virtually featureless horizon.
- **West**—showed an angular rock in the foreground and a larger rock sunk in the sand about 10 ft. farther away.
- **South**—showed the shadow of the lunar module. Armstrong said: ". . . In the little hill just beyond . . . is a pair of elongated craters that . . . together are 40 ft. long and 20 ft. across and they're probably 6 ft. deep."

The final aiming of the camera was just about according to the flight plan. It had the edge of the lunar module on the left side of the picture, the area in front of the ladder on its right, and the pallet in the middle. Since the astronauts had no monitor, Mission Control had to give detailed aiming instructions.

After the camera was placed on its tripod about 50 ft. from the lunar module, it was left unattended to record the scene. The astronauts experienced some problems in nearly fouling the cables with their feet, indicating their restricted downward visibility in their suits.

One of the highlights of the lunar TV show was the erection of the U.S. flag on the moon.

But the full sunlight reflecting off the flag in its final position tended to wash out the stars and stripes.

The TV broadcast continued even after the astronauts had re-entered the spacecraft. It showed the jettison of the equipment designated to be left behind on the moon (see box), and was finally cut off at 2:57 a.m. CDT on July 21.

There were seven transmissions with the Westinghouse color TV camera aboard the command module, including one which was not fed to the networks. The total time was 4 hr. 23 min. in color.

The color pictures were the now-familiar shots of the earth and the moon as seen from space, plus some interesting scenes of activity inside the spacecraft as the crews went about their activities.

Lebar believed the color shows were the best yet. The reasons, he said, are the fact that the camera itself performed better than that on Apollo 10; the handling of the unit "was real professional —they didn't pan or zoom too fast"; and the higher interest content of the telecasts, which showed the crew engaged in normal tasks rather than mugging for the camera.

Engineering Use

There were some tours of the spacecraft, though, including one of the lunar module for the first time from space. Aldrin gave the first color televised physics lesson from space when he demonstrated the principle of the gyroscope in a weightless environment.

As an indication of the potential engineering applications of space television, during the lunar module show Mission Control informed the crew that the guidance engineers had noticed that the primary and abort guidance system atti-

Large Assortment of Items Left on Moon

Houston—Of all the items carried to the surface of the moon by Apollo 11, Astronauts Neil A. Armstrong and Edwin E. Aldrin, Jr., left these:

- Descent stage in which they landed, including the small plaque bearing their signatures and that of President Nixon, memorializing the first manned lunar landing.
- U.S. flag, and miniature message from foreign countries.
- Modular equipment stowage, which carried the hand tools used in geologic work (see p. 40) and the two sealed lunar surface sample containers which were hoisted up to the ascent stage by Armstrong and Aldrin on a pulley.
- Large scoop, measuring 15.5 in., with provisions for an extension by another 7.5 in. It was used to retrieve bulk samples, which filled one large box.
- Tongs, used to retrieve samples of about the size of pebbles or slightly larger. They had spring-loaded fingers attached to a 26-in. handle operated by squeezing. The tongs also can be used to pick up equipment dropped during the surface activities, so that the crewman does not have to bend too far.
- Hammer, gnomon and extension handle.

The crew also left behind a variety of equipment stowed in the sample return containers on the outbound flight.

The equipment included mesh packing material, a solar wind experiment bag and support rod, a spring scale, unused sample bags, two core tube bits, two sample return container seal protectors, environmental sample container O-rings and small rods.

They left the television camera and its tripod, handle-cable assembly and bracket for attaching it to the descent stage. They also discarded the surface closeup camera—but returned its film, the conveyor used to send the surface samples up to the ascent stage, an environmental control canister and its brackets that held the portable oxygen system, three arm rests from the cabin and a bag containing urine bags.

After Armstrong and Aldrin re-entered the lunar module, and connected to its environmental control systems, they re-opened the hatch and ejected the two portable Hamilton Standard life-support systems, the stowage compartment from the left side of the cabin, which was replaced by the surface sample boxes and the remaining arm rest.

They also left behind the passive seismometer and the laser ranging retroreflector.

Lunar Scientific Experiments Furnish Data

Houston—Two of three experiments deployed by Apollo 11 astronauts have already produced a storehouse of data for scientific investigators looking into the origin of the universe.

A solar wind experiment to record sun flares unobscured by atmosphere was left on the surface for 1 hr. 17 min., retrieved by Astronaut Edwin E. (Buzz) Aldrin and returned to earth. Johannas Geiss, of University of Berne, Switzerland, said the foil reflector will be returned to Switzerland for analysis. Data should be available in several weeks.

A passive seismic experiment began transmitting data as soon as it was deployed. Among the early return of data is a recording which indicates the moon may be made up of layers—as is earth—or may be subjected to terrific bombardment by meteorites, a factor which may account for the craters of the moon.

Gary Lathan, of Columbia University, the principal investigator for the experiment, said: "We are obtaining data from an extra terrestrial body which in itself is just a magnificent experiment. We do have events which are of great interest to us, at least one which we feel is of true seismic origin."

The seismic event was recorded for a period of about 5 min. and was likened in intensity to an earthquake of a 4-5 magnitude (Richter scale) on the West Coast of the U.S. as recorded by a seismograph on the East Coast.

Additional data is expected from the seismic experiment although a heat rise in the experiment package may silence it. The package was experiencing temperatures nearing the 200-deg. range, probably beyond its tolerance. But there was hope that the package could be reactivated after it is cooled by the two-week lunar night.

C. J. Weatherred, Bendix Aerospace Systems Div., who is program manager for the early Apollo scientific experiments (EASEP) package, said tests conducted at the Bendix Ann Arbor, Mich., plant had indicated the seismic package could possibly revive after being cooled.

The third experiment, a laser ranging retro-reflector (LRRR), probably will not send back data until the beginning of the lunar night, Aug. 3. The experiment is expected to provide information on precise distances between earth and moon, on possible fluctuations in the earth's rotational rate and measurements of gravitational influences on the moon. This is done by reflecting a laser beam sent from earth directly back to its original source.

Carroll Alley, of University of Maryland, principal investigator for the experiment, explained the reasons why no data were expected back immediately:

"There is a very large background consisting of scattered light from the sun around the site at the present time. This makes it difficult to distinguish scattered laser beam photons by the reflector from the surrounding light scattered by the sun."

Lasers will be beamed to the reflector array from McDonald Observatory of the University of Texas and from the University of California's Lick Observatory.

tude indicators did not agree and requested that they be aligned.

During an early transmission, a small spot was burned in the image tube target when the camera was allowed to dwell too long on a bright light. This white mark in the camera persisted throughout the flight, as did three dark horizontal bars.

Early in the lunar TV broadcast, Armstrong could be seen rapidly photographing the lunar module and the area around it. The photography was deemed particularly important on this mission to evaluate the condition of the first landed lunar module and to document the landing site. Overlapping panoramas were taken.

A Hasselblad 70-mm. camera with a wide-angle lens was used for recording the lunar surface and astronaut activities. It was also used to photograph the experiments that were emplaced out of sight of the television camera.

The requirement for close-up stereo photography of the lunar soil structures was deleted.

Another Hasselblad, with black and white film, was in the lunar module for photography from the spacecraft as a back-up for the extravehicular activity camera.

A Maurer 16-mm. motion picture camera was in the lunar module for recording the landing and later for astronaut activities during extravehicular activity. It was operated automatically while mounted on brackets.

Quarantine Greets Apollo Crew After Safe Landing in Pacific

Houston—Apollo 11 returned to earth 195 hr. 18 min. 21 sec. after it was launched from the Kennedy Space Center. The spacecraft landed in the Pacific Ocean 13 mi. from the prime recovery ship, the aircraft carrier USS Hornet.

The spacecraft landed at 13 deg. 30 min. N. Lat. and 169 deg. 15 min. W. Long., about 900 mi. southwest of Hawaii. Because of thunderstorms, the aiming point had been moved 215 naut. mi. northeast to 13 deg. 19 min. N. Lat. and 169 deg. 9 min. W. Long.

The command module landed about 28 sec. later than had been expected. The landing had previously been computed at a ground elapsed time of 195 hr. 17 min. 53 sec.

Immediately after touchdown, rescue helicopters hovering overhead reported the command module had landed in a Stable 2 (apex down) position. But within minutes, flotation bags had been inflated and the spacecraft righted itself.

As the rescue aircraft tried to determine the physical condition of the astronauts, Michael Collins, pilot of the command module, reported: "Our condition is excellent. Take your time."

Three swimmers and two life rafts were deployed in the vicinity of the command module as quarantine procedures went into effect to preclude the possibility of contaminating the earth's biosphere with material from the moon.

One swimmer, in an anti-bacterial suit called a biological isolation garment (BIG), opened the spacecraft hatch and passed in three additional isolation garments and immediately closed the hatch.

The astronauts donned the isolation garments inside the spacecraft as the swimmer washed down the command module with a chemical decontaminant called Betadine, an inorganic iodine compound.

When the crew emerged from the spacecraft, the swimmer began scrubbing them with the decontaminant. When all three had been scrubbed, an astronaut washed down the swimmer. Then the three were transferred into a helicopter hovering overhead.

They were flown swiftly to the deck of the Hornet where they immediately entered a quarantine van for the return trip to National Aeronautics and Space Administration's Manned Spacecraft Center. There, they and their lunar samples are to remain in quarantine for three weeks from lunar liftoff.

Apollo 12 Goals Include Finding Of Surveyor 3

Houston–Apollo 12 lunar landing mission is planned to touch down close to Surveyor 3 spacecraft so that the lunar module crew can make a detailed examination of the unmanned lander and return some pieces of it to earth.

Prime purpose of such an evaluation would be to obtain baseline information that would be useful in determining the long-term effects of the lunar environment upon materials.

Knowledge of the environmental effects on the Surveyor, which landed on the moon April 19, 1967, would be of major value in designing future long term manned and unmanned space systems and extended lunar surface exploration equipment.

This baseline data would also be extremely valuable to scientists in lunar material analysis and their studies of the moon's terrain features.

Surveyor 3's location, for which Apollo 12 lunar module will be targeted for touchdown, is 2.94 S. Lat. and 23.34 W. Long. The touchdown point has been found through terrain photography from Surveyor 3 and Lunar Orbiter 3. This site—Apollo landing site 7—is in the Ocean of Storms, and is located southeast of Lansburg crater and northwest of Fra Mauro crater.

The Apollo 12 mission will provide for a lunar module stay time of from 28-32 hr.

Extravehicular activity for Apollo 12 is planned to provide for two excursions on the lunar surface by each member of the crew, with each man's total time in each excursion exceeding that of the Apollo 11 astronauts. The crew also will be permitted to range several hundred feet from the lunar module.

Initial data obtained from the extravehicular experience of the Apollo 11 crew has given mission planners here confidence that the suit and portable life support system can be used for longer duration lunar surface operations.

In the event that Apollo 12 could not launch on Nov. 14 as now planned, it would be recycled for a Nov. 16 launch aimed at a landing on site 5 in the western part of the Ocean of Storms. Landing sites 5 and 7 are mare-type areas like the Apollo 11 landing site.

The full Apollo lunar scientific experiments package, which was removed from the Apollo 11 mission, will be carried aboard the Apollo 12 mission.

Commander of the Apollo 12 crew will be Cdr. Charles Conrad, Jr. He and Lt. Cdr. Alan L. Bean, lunar module pilot, will make the descent to the lunar surface while Cdr. Richard F. Gordon, command module pilot, remains in lunar orbit.

Backup crew is commanded by USAF Col. David R. Scott. Lt. Col. James B. Irwin is lunar module pilot and Maj. Alfred M. Worden is command module pilot.

F-15 Program

U.S. Air Force has moved to strengthen and consolidate its F-15 air superiority aircraft program by grouping related activities under the commander of Air Force Systems Command.

Col. Benjamin J. Bellis will be systems program director on the F-15, reporting directly to Gen. James Ferguson, who heads Systems Command. Bellis has been nominated brigadier general. Previously, he was deputy for reconnaissance and electronic warfare.

Col. Robert M. White, who heads the system project office at Wright-Patterson AFB, will serve as deputy to Bellis.

Monitoring of F-15 activities is being transferred from the Pentagon to Systems Command, where Col. R. K. McIntosh has been named assistant to the commander of AFSC for F-15.

Space Workshop

Post-Apollo space station work will concentrate first on a dry workshop designed to evolve later into a large, 10-year earth-orbiting base.

Thomas O. Paine, head of the National Aeronautics and Space Administration, gave his approval last week to the dry workshop concept as expected (AW&ST July 14, p. 21). It will be substituted for the wet workshop.

The wet workshop was to have used a partly outfitted S-4B and its propellant to achieve orbit.

The dry workshop involves launching a McDonnell Douglas S-4B upper stage fully equipped as a laboratory but without propellant. It would be orbited on a Boeing S-1C first stage and a North American Rockwell S-2 second stage.

In a related development, NASA also issued parallel, 11-month study contracts to McDonnell Douglas and North American Rockwell to perform definition work on the proposed large space station. It would initially be for 12 men but would eventually evolve into a 50-100 man capability.

Value of each study contract is $2.9 million.

News Digest

Pacific fares conference of 15 IATA Pacific area carriers broke up in disagreement last week. The meeting in Los Angeles was postponed indefinitely. It was a continuation of a special section meeting on Pacific fares held at the IATA traffic conference at Cannes last year (AW&ST Oct. 28, 1968, p. 49). One area of disagreement concerned special, lower fares for direct flights between the U.S. West Coast and the Orient without a mid-Pacific stop.

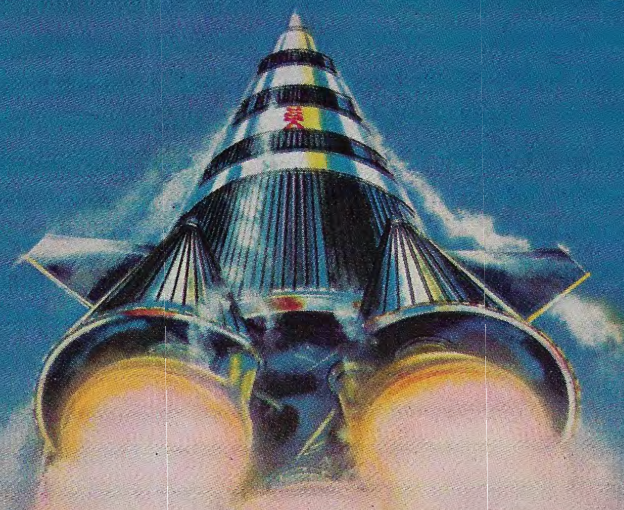
Acquisition of Air West by Hughes Tool Co. has been approved by the Civil Aeronautics Board. President Nixon, whose approval was necessary because the airline flies to Canada and Mexico, concurred in the decision. It contains a number of conditions that retain considerable authority for the CAB over operations of the airline and its relations with the rest of the Howard Hughes empire.

Two Handley Page C-10As, USAF version of the Jetstream business aircraft, are undergoing high-altitude and high-temperature operations tests. The test program calls for flights from Torrejon, Spain; Marrakesh, Morocco, and Nairobi, Kenya.

New routes for North Central, Northwest and United airlines and lifting of restrictions on some existing service of Northwest and United have been recommended in Civil Aeronautics Board examiner's initial decision in the Twin Cities-Milwaukee Long-Haul Investigation (AW&ST Nov. 4, 1968, p. 29). Among the awards North Central would get a route between Minneapolis-St. Paul, Milwaukee and New York, United would get authority between Milwaukee, Minneapolis-St. Paul, Portland, Ore., and Seattle/Tacoma, and Northwest would operate between Minneapolis-St. Paul, Milwaukee and Boston.

LTV Aerospace Corp. has formed a helicopter unit, Vought Helicopter, Inc., and signed an agreement with France's Sud Aviation to market and service Sud Alouette series rotary-wing aircraft in North America (AW&ST June 16, p. 27). Later Vought is to draw on Sud's technology to produce a line of helicopters.

Piedmont Airlines was struck July 21 by its 370 pilots, members of the Air Line Pilots Assn. The strike occurred when the local service airline moved to reduce the cockpit crew on its Boeing 737s to two men from the three-man complement that had been established on an interim basis.



THE BIG TIME:
Timing the shots.

Everything that happens during one of the Apollo moon shots is a matter of timing. And Apollo's timing is a matter for General Time Central Timing Equipment. Four basic components—a crystal oscillator (the "mainspring"), a frequency generator (the "escapement"), a time accumulator (the "hands"), and an events sequencer-programmer (the "alarm")—make this the world's most sophisticated clock...a clock that synchronizes all systems, calls the signals for a series of automatic events, provides a base for sequence programming, time correlation. In every project in which it has been used all systems have worked perfectly from launch to return; all recovered systems have functioned perfectly—with no error. *The only qualified man-rated equipment of its kind in existence.*

High reliability is built into General Time's Central Timing Equipment. For Apollo. For *any* use. Each of its modules is available separately; each can be adapted to a specific end-use. Military. Industrial. Aerospace. Communications. Meteorology. Even *your* next project. The Big Time's not too big for you!

FOR INFORMATION CONTACT

SPACE AND SYSTEMS DIVISION

GENERAL TIME
Progress in the World of Time

HIGH RIDGE PARK, STAMFORD, CONNECTICUT 06904

THE BIG TIME...Central Timing Equipment • Video Mappers • Cloud Height Indicators
Miniature Electronic Components • Oceanology • Ordnance

BIG BEN • BABY BEN • WESTCLOX • SETH THOMAS • VIDEO MAPPER • MINELCO • BRAINCON • TIME-MIST