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OPERATION LION: REPORT FOR PERIOD OF THE FLIGHT OF APOLLO 11

8 September 1969

Prepared by

Lockheed Electronics Company

for

Lunar and Earth Sciences Division

Under NASA Contract NAS 9-5191

LEC/HASD No. 645D.21.043

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PREFACE

This report has been prepared by Lockheed Electronics Company for the Geophysics Branch of the Lunar and Earth Sciences Division, by Miss Barbara M. Middlehurst and Norman C. Allen under Action Documentation 3024-AD-03-02 of the NASA Contract NAS 9-5191.

NASA CR108476

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OPERATION LION: REPORT FOR PERIOD OF THE FLIGHT OF APOLLO 11

I. INTRODUCTION

Operation LION functioned during the flight period of Apollo 11 in a way similar to that set up during Apollo 10[1,2], with only minor procedural changes. Lockheed Electronics Company under support contract NAS 9-5191 worked in cooperation with the Manned Spacecraft Center's Geophysics Branch. As established during the flights of Apollo 8 and 10, communications were handled through the Smithsonian Astrophysical Observatory Center for Shortlived Phenomena; the Center's operations are fully described in a separate report[3]. Lockheed's responsibility as prime contractor has been to maintain contact through the center with the ground-based observers; to maintain a link with the spacecraft through the Science Support Room Director and Mission Control Center; and to provide evaluation of the incoming reports of lunar changes or unusual appearances both from the ground and from the spacecraft.

II. OPERATIONAL PROCEDURES

The network of ground observing stations now has excellent potential 24-hour coverage[4]. The number of stations has increased since Apollo 10 and the rather weak longitude coverage between Hawaii

(2 stations), New Zealand (5 stations with closely similar longitudes) and Eastern Asia has been improved by the addition of three Australian Moonwatch observing stations. There are now three Hungarian observing groups. Several new groups have joined in Western Europe and the United States.

The communication train is shown below:

LION observer <---> Smithsonian CFSP <---> LION desk, Science Support Room <---> Director, Science Support Room <---> Mission Control Center <---> Spacecraft

Two-way contact by telephone linked the Smithsonian with 46 North American LION observing stations and the SSR LION desk. Commercial cable, teletype, Navy and NASCOM circuits, and telephone linked Smithsonian with observers outside North America. One line was kept free for incoming calls from Smithsonian at the LION desk at MSC for the whole time that it was manned. The LION desk in the Science Support Room was manned continuously from 20.00 on July 18, 1969, to 08.00 on July 22, 1969, jointly by representatives of the Geophysics Branch of MSC and Lockheed Electronics Company.

Three messages were given to the Director of the Science Support Room for transmission to the spacecraft, if convenient. These

were:

1. The message given in detail in Section 3 which was passed to the Apollo 11 crew.
2. Activity in Theophilus at 2027 GMT, July 19, was reported to MSC at 22.53 and a message passed to the Science Support Room Director at 00.40 GMT, July 20. No further action was taken on this alert.
3. General obscuration (loss of observable lunar detail) was reported for the central region of Mare Tranquillitatis at 10.10 GMT., July 20. This message was passed, with low priority, for the Flight Director's information at 17.27 GET, but the spacecraft crew was too busy to use the information and it was held at Mission Control.

Only one general alert to the ground-based observers was sent out, following this report from the spacecraft of an illuminated area in the region of the crater Aristarchus.

III. THE APOLLO 11 ASTRONAUTS REPORT

Reports of Aristarchus activity began to come in to the Smithsonian soon after launch and the following message was submitted by Dr. Hixon (Lockheed) to John Annexstad (NASA) at 15.45 GMT, 19 July 1969:

Priority: Pass to Apollo for information when convenient.

Location of Event: Aristarchus 23° N. 47° W.

Description and Message: During last 2 days, 6 Aristarchus Lunar Transient Events (4 independently confirmed) have been reported through Smithsonian. Request crew please observe (and if possible, photograph) Aristarchus region prior to LOI.

Source: Several observers through Smithsonian Institution (Center for Shortlived Phenomena).

This message was given to the Science Missions Manager, A. W. Patteson, passed to Lou Wade in the Mission Control Center, and finally transmitted to the crew of Apollo 11 about 18.30 GMT. At about 18.45 GMT on the first high-pass orbit, the crew of the spacecraft was in a good position to observe Aristarchus and did. The following is a preliminary transcription of the taped log of the spacecraft for a period beginning at approximately 1845 GMT on July 19, 1969:

ASTRONAUTS MENTION OF A POSSIBLE TRANSIENT EVENT AT ARISTARCHUS*

S/C - That's fine. I just want to confirm that 79:10 and we will wheeze around here in orbit.

---

* Taken from MSL GOSS Line Tape #30 at footage mark 1249.

G/C - Roger, and we've got an observation you can make if you have some time up there. There have been some lunar transient events reported in the vicinity of Aristarchus. Over.

S/C - Roger. We just went into spacecraft darkness until then _____** but not a lot. Earth shine visibility is, oh, pretty clear and looking back behind me now I can see the corona from where the sun has just set. And we will get out the map and see what we can find around Aristarchus.

G/C - O.K., Aristarchus is at Tango Echo Niner on your ATO chart. It's about 394 miles (nautical) north of track; however, at your present altitude, which is about 167 nautical miles, it ought to be over, that is, within view on your horizon, 23° north, 47° west and take a look and see if you see anything worth noting up there. Over.

S/C - We're looking ....
Roger. It would help a little bit if you could get the time of crossing 45 west.

G/C - Say again please XI.

S/C - You might give us a time of crossing of 45 west and then we will know when to start searching for Aristarchus.

G/C - Roger. You will be crossing 45 west at 77:04:10 or about 40 seconds from now. Over. Thirty seconds from now. O.K. _____ seven when we lose the S-band we'd like to get Omni Charlie from you and _____ visible _____.
Apollo XI, when we lose the S-band we would like to get Omni Charlie from you and update my last that 7704 was the time when Aristarchus should become visible over your horizon. 7712 is a point of closest approach south of it. Over.

S/C - O.K. That sounds better because we're just went by Copernicus a little bit ago.

G/C - Roger. We show you at about 27° longitude right now.

** Unintelligible interval on tape.

S/C - Righto. _____ to Aristarchus now and I can't really tell at that distance whether I really am looking at Aristarchus but there is an area there that is considerably more illuminated than the surrounding area - just has - seems to have a slight amount of fluorescence to it. A crater can be seen and the area around the crater is quite bright.

G/C - Roger XI. We copy.

S/C - Have any of the telescopes been able to see _____ work out to be about 0 phase to - well at least there is one wall of the crater that seems to be more illuminated than the others and that one, if I'm lining up with the earth correctly, does seem to put it about at zero phase. That area is definitely brighter than anything else that I can see at this moment. I'm not sure that I'm really identifying any phosphorescence but that definitely is brighter than anything else I've been able to -

G/C - XI. This is Houston. can you discern any difference in color of the illumination and is that an inner or an outer wall of the crater? Over.

S/C - Roger. That's an inner wall of the crater. No, there doesn't appear to be any color involved in it, Bruce.

G/C - Roger, you say inner wall. Would that be the inner edge of the northern surface?

S/C - I guess it would be the inner part of the west, northwest part. Yeah. The point that would be more nearly normal if you were looking at it from the Earth.

G/C - XI. Houston. Have you used the monocular on this? Over.

S/C - Standby one.
Houston. We will give it a try if we have the opportunity on next pass when we are not in the middle of lunch and trying to find the monoculars.

G/C - Roger. Copied you that time. Expect the next rev you'll probably be getting ready for LOI 2. So let's wind this up and we've got some other things to talk to you about in a few minutes. O.K.?

According to Ground Control, Apollo 11 was at an altitude of 167 nautical miles during the Rev #1 observation of Aristarchus. The horizon would appear to be at selenographic coordinate latitude of 31° 55'. Latitude of Aristarchus is 23° 42'.

Calculating the angle from spacecraft nadir places the horizon at an angle of 58° 05' from S/C nadir and Aristarchus at 56° 52' from S/C nadir. (The calculations assumed a lunar radius of 1080 stat. miles and no event site elevation correction.) The crater Aristarchus intercepts a selenographic central angle of approximately 1.5°. If there is no local dip angle to the crater rim this implies that the visual intercept would be an ellipse 2° 54' by 0° 32'.

Local Dip of the Rim of Aristarchus was investigated to see if this may have influenced ability to recognize the feature. Using contour information from LAC 39 the following elevations were determined. LAC 39 uses a reference lunar radius of 1735.4 kilometers (1nm = 1.85325 KM = 1.1516 stat. mi.).

Southern rim	west of center	5700+
	east of center	4800+
(southern rim is jagged and high on west when viewed from the south)		
Northern rim		5100
Western rim		5700+
Eastern rim		4800+

On this basis, the eastern half of the crater has a local dip to the South of between zero and 25'. This would favor Apollo 11 astronauts viewing inside of crater when they are east of longitude 47° west. Beyond that longitude, the high western rim progressively obscured the interior.

The western half of the crater appears to have a local dip to the North of something like 50' which would prevent viewing the inner NW crater wall beyond S/C latitude of about 35° W. Because the crater rim is fairly flat from south around to west, it is possible that this phenomena was observed on the uppermost 100 meters or so of the WNW rim.

The astronauts were "in the middle of lunch", implying that the cabin lights were on. If the lights were on, they would have had an adverse effect on the dark adaptation required to make out faint details in the scene. This combined with the fact that the spacecraft was at 45° West when the sighting was attempted, makes it understandable why the astronauts may have had difficulty in identifying exactly where the illumination was with respect to the crater.

The only other bright crater in the vicinity and in the same general direction from the high orbit point was Kepler, a much smaller

crater 10 lunar degrees to the north, at a much greater dip angle than Aristarchus. It does not seem likely that any misidentification would have been made between them, although this possibility was raised.

It has been suggested to us that the noticeable illumination, apparently strongest on the NW wall of the crater Aristarchus, was caused by the zero phase effect on earthshine reflected off the crater wall. We do not believe that "zero phase" has anything to do with the phenomenon that was reported to us at 18.45 GMT, July 19. Aristarchus was at no time collinear with the earth and the spacecraft. The only region which could have shown brightening from such a cause is the equatorial region and this did show in direct sunlight what is called the "heiligenschein", a bright diffuse area directly opposite to the illuminating body, the sun. The zero phase effect, as seen from the earth, is an increase in brightening due to the reduction in total shadowed area seen from the earth; it is a macroscopic property, that is, a property of the whole moon. But in the present case, because of the non-zero angle between the directions of the sun and the earth (or the spacecraft) as seen from Aristarchus at 18:45 GMT on July 20, further consideration of zero phase is of no interest.

The spacecraft observation was confirmed from the ground by a telegram from Bochum, Germany. Later reports from other observatories showed that activity in the same lunar region continued, at least intermittently. Positive and negative reports were received at different times for later periods from many sources; the positive reports mentioned both the general area of Aristarchus, and more specifically, the NW wall as before.

IV. THE DEBRIEFING OF THE APOLLO 11 CREW

The following questions were submitted by John Annexstad to the scientific debriefing of the Apollo 11 crew.

SAMPLE QUESTIONS - ASTRONAUT SCIENCE DEBRIEFING

LUNAR TRANSIENT EVENTS

For two days prior to LOI, the moon had been under observation by earth based astronomers. During this period of time, the crater Aristarchus appeared to be quite active. Just before LOI, the Geophysics Branch requested through channels that the astronauts view the crater for a possible event. This request was denied but reactivated during the first orbit. Since the first orbit was a high pass, the crater Aristarchus was visible to the astronauts in earthshine on their north horizon. At 77:13 GET the astronauts reported an illuminated area on the NW wall of the crater Aristarchus.

QUESTIONS (MAJOR)

1. Was the event in progress when the crater was first sighted or did it appear later?
2. Did the event appear to originate from the surface or above the surface?
3. Did the illumination appear constant or pulsative and can an estimate of the brightness be given?

QUESTIONS (SECONDARY)

1. Can you venture a guess on whether you saw earthshine, surface luminescence or gaseous luminescence?
2. Was the illuminated area difficult to identify with respect to the crater and are you certain you saw Aristarchus?
3. Was the site viewed with optics and did you photograph it?
4. Which window did you use?

The transcription of this debriefing was made available for study. As far as could be surmised, the formal list of questions was never addressed during this debriefing but the following mention of the Aristarchus sighting did come up in the discussion. It is reproduced verbatim from that report.

EXCERPTS FROM APOLLO 11 PHOTOGRAPHIC AND SCIENTIFIC DEBRIEFING

HELD IN THE LUNAR RECEIVING LABORATORY ON AUGUST 6, 1969

O'BRYANT Could you tell us why the view of the lunar surface during earthshine was so spectacular?

ALDRIN I don't know that we used the word "spectacular". We were asked to comment on the impressions that we got in the region of Aristarchus on the second** revolution. I think we all agreed that there was a considerably lighter region in the vicinity where we calculated that the crater was. I think Neil mentioned, at one time, a phosphorescence. We had the impression that there could have been some luminescence from that area.

O'BRYANT But no color change?

ALDRIN Spectacular earthshine.

QUERY* Was there just a difference in brightness or a difference in color?

ALDRIN It was very difficult to discern any color in earthshine. There was a difference in intensity, perhaps in brightness, also.

QUERY* Now that Neil is back, he's the one that made the statement earlier this morning that the view of the surface in the earthshine was very spectacular; maybe he can comment on that now.

ARMSTRONG Well, I think you're referring to when the surface was illuminated by the Sun from behind, and the earthshine was on it; this was before we reached lunar orbit.

QUERY* Yes.

---

* Query denotes that identity of person asking question was not established in transcription.

** It is believed this should be "first" revolution.

ARMSTRONG We all commented on the accentuated three-dimensional aspects of that particular view, as opposed to, probably, any other views that we had seen. I think the only other accentuated three-dimensional scenes that we observed were those oblique views in the terminator area during lunar orbit, where you have marked contrast in addition to the irregular topography that you see in an oblique in the highlands area of the Moon. But this particular view, where we saw the front side of the Moon illuminated by earthlight with a solar corona in the background, was one in which a lot of detail could be seen -- a good bit more detail from that view than later views when we were in lunar orbit. I think the reason we could see such detail is that we had all the lights out in the cockpit in an attempt to have some photographic success, therefore, we had a long time to adapt our eyes to the situation. So, we had good night adaption or adaption to the illumination level that we were observing, and that was a situation that we never really enjoyed in lunar orbit.

COLLINS Also, remember that this was the first time we had seen the Moon in anything less than 200 and some thousand miles, and now we were probably 5 percent of that distance away. It was spectacular because it was so close, and it was our first glimpse of it.

ARMSTRONG We could see the full Moon, and it was roughly the size of the circular hatch window when your eye was approximately 18 inches from it; so, as you got a little bit closer, 90 percent of your view was full Moon, or 95 percent. That's pretty impressive.

QUERY In Aristarchus, with the vision that you had, did you think that there was some extra light other than what might be accounted for by ray patterns on the surface?

ARMSTRONG Let me finish this other picture with the bad sketch.

QUERY The rays show particularly bright when the illumination source is just behind you. That was the situation I believe you were in; the Earth was just behind you.

ARMSTRONG Yes. Now, I don't recall the altitude, 100 miles or 120 miles or some altitude. You're looking to the far north horizon, something like this, at 300 or 400 miles away. My impression was that, in earthlight, on other areas of the Moon we could only see crater rims and a few other things. But in this general area, there was a generally higher level of illumination. Now we're looking north. The illumination level was not sufficient for me to be able to identify just exactly where I was looking. There was an area with a generally higher level of illumination than other areas. I said on the tape that it looked fluorescent, but I'd like to withdraw that comment. I don't mean to imply that it looked like it was self-illuminated. I got the impression it was reflected light. The brightest spot, by far, was in this area, on the inner rim of this distant crater. Now, I can't confirm that it was Aristarchus.

QUERY What you said makes very good sense, though, that it's very much what would be expected from the ray or from the higher albedo in the vicinity.

ARMSTRONG So, that was significantly brighter than other places. We thought about zero phase point from earthlight and various things and tried to piece together the story; but, in retrospect, it didn't all add up completely in my mind. The bright spots in these areas did not seem to be particularly dependent on what the local slope was or on things of that nature, and this was generally a brighter area throughout. Sometimes, there were significant differences in slopes; but in many cases, there were fields and highland areas that had obvious slopes to them, yet we could not correlate these slopes with the brightness. At least, I couldn't.

Unfortunately a LION representative was not present when this discussion came up so it was not possible to dwell upon certain critical aspects of the phenomena observed at Aristarchus but the repeated stress the astronauts placed on the brightness of this area is considered most significant. It is hoped that future missions will

emphasize the description and photography of a similar sighting.

V. ASSESSMENT OF THE RESULTS

Altogether 44 positive reports were received at the LION desk from 32 observers. These reports named 14 specific sites and several less well defined larger areas. Initially, from July 16, 1969, most of the activity was reported for the region between and including Aristarchus, Grimaldi and the limb area between them, that is, generally in the NW region of the visible face. Some lesser activity was also reported early (July 19, 1969) in the opposite (SE) quadrant at Janssen and also in the Mare Crisium area (July 19, 1969). Towards the end of the mission, the region reported as active moved over to the SE quadrant more definitely and though Aristarchus sightings were reported throughout the mission, the last Grimaldi sighting was at 2045 on July 19, 1969. The first of three Theophilus reports occurred at 20.27 on July 19, 1969, the last being at 21.20 on July 21, 1969. (Temporary black patches and other phenomena were reported at various sites in Mare Tranquillitatis between 01.00, July 20 and 00.58, July 23; all the Tranquillitatis reports were from Canada.)

As of August 2, 1969, a total of 78 positive reports had reached the Smithsonian Center for Short-Lived Phenomena. These described 31 different lunar sites (See Figure 1) and are reported in detail in Reference 3.

A comparison of the positive and negative reports brought to light apparent contradictions in the finds of different observers reporting for the same periods of time. An example is as follows:

July 18 : 2100 - 2300 - Brightening in Aristarchus (reported from Brazil)

July 18 : 2120 - 2140 - No TLP (reported from France)

There are several such cases but before we regard the negative evidence as contradicting the positive report, we must examine the data further. If, as reported, the brightening began at 2100 and ended at 2300, the best time for detecting it would have been during the period of greatest change. We need to know more about many observing details, such as, the contrast in levels of illumination. Also, we need the answer to such questions as: "Was it possible for all observers to keep equally vigilant watch at all times?" We believe we should pay most weight to confirmed observations, especially where two widely separated stations report similar findings.

It is too early to attempt a definitive assessment of these reports but the following interesting aspects can be pointed out here as worth further investigation.

1. The first report of activity in Theophilus was for the date of tidal maximum at this site and this report followed a long period

of inactivity. It is of interest for the tidal triggering theory that, during the mission period, tidal amplitudes at Theophilus, Tranquillity Base and Aristarchus were near the yearly maximums.

2. Several pairs of events were separated by time intervals consistent with travel times for surface waves, assuming a speed for these on the moon similar to that for terrestrial analogues. Not too much should be made of this correlation until better data are available; non-correlated pairs are also frequent.

3. Moonquakes have apparently been registered in Tranquillitatis by the lunar seismometer.[5] Much of the reported activity occurred before implantation of the seismometer. It is hoped that an opportunity to compare the records from the seismometer with LION data will be available to us in due course. The following remarks can, however, be made here. So far, none of the first three recorded quakes correlate with any known event reports, but the place of origin of the quakes is not yet released and judgement on correlations should be postponed. We have previously suggested that events may be triggered by tides (see e.g., Chapman[6], 1967; Chapman and Middlehurst[7,8], 1968) and it appears that lunar seismic activity of some kind may be in progress. Also, reports received regarding the seismic records indicate the presence of a low velocity zone, believed

to be at a depth of about 12 km which does not transmit seismic waves readily; comparison with a low velocity zone with similar properties in the earth suggests that a pocket or pockets of magma may be present at this depth. On July 25 and 26, 1969, 14 seismic events, thought to be due to landslides due to solar heating were recorded. The stability of the lunar material could have been affected by the approach to extreme values of the tidal stresses at perigee on July 25 with additional syzygy terms during days close to full moon at 09^h on July 28. This extreme tidal stress in the lunar material could have combined with the solar heating of the surface or acted alone to trigger landslides. It has been previously noted (Chapman and Middlehurst, 1968) that the celebrated lunar rolling stones are in all known cases associated with event sites listed by Middlehurst, et al (1967)[9]. It is, therefore, suggested that a combination of the effects of lunar surface heating with those of higher stress values at the tidal extremes, which occurred during the mission period, might be more effective than either factor alone.

VI. SUMMARY AND DISCUSSION OF POSSIBLE AIMS FOR FUTURE MISSIONS

During the flight of Apollo 11, we have been able for the first time to correlate (1) sightings of a transient lunar event from the

ground and from space; (2) sightings with considerable similarity in detail and timed within seconds of each other. Previously, many corroborative and independent accounts have been given but without such close timing. Further detailed knowledge of lunar activity can only be achieved following the collection of further data, in particular, permanent records. These can be of several kinds, e.g., direct photographs, spectra, and photometric traces. The operation of LION during future missions might further this aim in the following ways.

a. The taking of photographs of unusual appearances, with the Hasselblad camera by the Apollo crew, as well as by observers at ground stations.

b. The use of an objective grating (small dispersion) on the camera, and the taking of spectra with this apparatus. It is to be hoped also that ground observatories with spectroscopic equipment can either attempt to take spectra of suitable lunar sites on a routine basis during selected short periods or, following an alert through the Smithsonian, to take spectra of the site specified in the alert.

c. Ground stations with photometric equipment could monitor suspected sites of activity such as Aristarchus on a routine basis for selected short periods of a few consecutive nights, e.g., during an Apollo flight or whenever activity is suspected.

d. Records at wavelengths other than visual, e.g., radio, x-ray, infrared, microwave are desirable, and these need not be restricted to periods of the Apollo flights.

We therefore hope that our desire to obtain permanent records and the possible assistance that could be afforded by the Apollo crew toward this aim, may be given serious consideration in the planning of future Apollo missions, and that the cooperation between ground based observers and spacecraft crew can be continued.

During the Apollo 11 mission period, as before, the cooperation of the Smithsonian Center for Short-Lived Phenomena and of the Science Support Room personnel was invaluable and we wish to record our appreciation.

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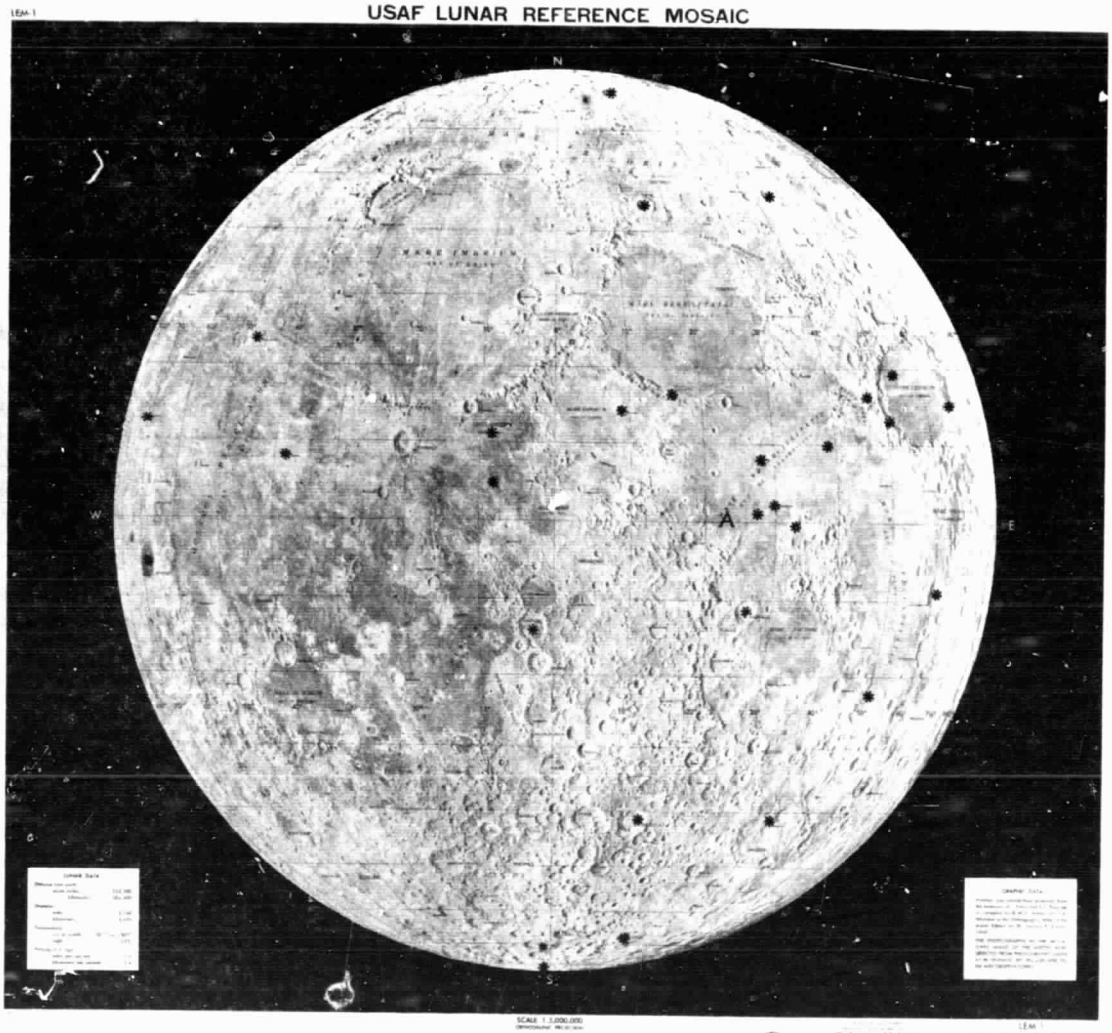
LEM-1

USAF LUNAR REFERENCE MOSAIC



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LUNAR EARTHSIDE HEMISPHERE