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This ATM contains the reports on two (2) tests performed to determine astronaut capability to align the ASE Mortar Box Assembly (MBA)/ geophones to the required limits of azimuth accuracy without a sophisticated sighting mechanism. In this aspect, both tests satisfy the requirements of delta PDR RFC 07-13 and CDR RFC 07-02.

These tests also answer one item found in CDR RFC 07-03, that relating to geophone vertical alignment.

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T & E Report No. 41

Introduction

A preliminary series of tests were performed to determine the feasibility of alignment of the geophones to form a line wherein the last (third) geophone would be within $\pm$ 3° of the line formed by the first two geophones using a flag or flags.

The second objective of the test series was to determine the feasibility of aligning the mortar box assembly (MBA) so that its line-of-fire would be within $\pm$ 3° of the geophone line using the MBA antenna and the edge of the mortar box itself as an aiming device. This objective could not be tested due to winds which caused a continuous oscillation of the MBA antenna; however, this portion of the test will be performed in the Bendix Human Factors Lab at a future date.

Equipment and Facilities

A long area (approximately 375 feet) was selected as a preliminary test bed. This area was substitute location in that it was a grassy field. Ground conditions (i.e., mud) prevented performing the tests on a grass free area at this time. In addition to the deployment area, the following items were used to perform the tests:

a. Engineering model geophones and cable.
b. Mission & Crew Engineering's Central Station mockup.
c. M & C Engineering's Geophone Marker Flag(s) (see Figure 1).
d. M & C Engineering's MBA with antenna.
e. Surveyor's transit.
f. Tape measure.
g. Protractor device to measure verticality.

Subjects

Two experienced Bendix engineers served as subjects for this test; performing their tasks under shirt sleeve conditions.

Test Conditions

The tests were performed outdoors at approximately 2:00 P.M. with a fairly extensive cloud cover prevalent. This served, of course, to reduce ambient illumination conditions; however, the exact amount of illumination was not measured.

Task Sequence

The task sequence followed by the subjects and support personnel was:

a. Subject walked 10 feet from central station and emplaced first geophone.
b. Support personnel checked and recorded accuracy of vertical emplacement.
c. Subject walked 150 feet and emplaced second geophone.
d. Subject checked (visually) horizontal alignment and emplaced marker flag.
e. Support personnel checked and recorded accuracy of geophone vertical alignment. Subject walked 150 feet and after visually checking horizontal alignment, emplaced third geophone.
f. Support personnel measured and recorded accuracy of vertical alignment of geophone.
g. Transit operator measured and recorded accuracy of horizontal alignment of geophones.

Results

The first subject to deploy the geophones emplaced all three from a standing position with 0° of error (i.e., vertical to within less than 30 minutes). After emplacement of the third geophone, horizontal alignment checks revealed that there was a misalignment of 18 minutes which is considerably well within the $\pm 3^{\circ}$ requirement. It was discovered at this time that the strain of cable deployment had misaligned the verticality of the number 2 geophone (see Figure 2). Measurement of this geophone revealed that it had been pulled toward the last geophone such that it now registered 30° from the vertical.

The second subject then emplaced all three geophones in a similar manner (i.e., standing emplacement). The first geophone was 2° off vertical while the other two were accurately aligned vertically (less than 30 minutes off vertical). While deploying the cable during this series, the subject played out some cable prior to walking off to deploy the next geophone with the result that vertical alignment was not disturbed.

Azimuth alignment accuracy checks after emplacement of the final geophone revealed an error of 10 minutes. A second flag was then used at the site of the first geophone with the result that the error was reduced 50% (i.e., 5 minutes).

The flags used were tested with both sides (i.e., all orange on one side, orange with white diamonds on the reverse side) visible at one time or another to the subjects. Subjective evaluation by both subjects indicated that the one color scheme is preferrable. The diamond markers on the flag tended to disturb the subject during performance of alignment functions. Another comment received pertaining to the flags and their design was that the horizontal dimension (along the top) could be reduced to some, as yet, undetermined dimension; however, it is desirable to have the maximum vertical dimension compatible with final flag design constraints.

Finally, the flags were emplaced approximately 4 inches from the geophones and in-line with each. Confirmation of this distance as being sufficient is requested from the Experiments group. Some attempts were made to measure MBA alignment tests after the geophone cable was deployed and the accuracy checked. However, as was mentioned earlier, the high winds precluded this test. There are a few items which are noteworthy that were discovered during these attempts. These are:

a. The astronaut will not be able to easily manuever the MBA using the EHT and then check alignment. It will be faster and more accurate for him to perform this task by using the MBA antenna as a handling device.

b. The suited astronaut will require two flags (one at the first and second geophones from the central station) for alignment of the mortar box.

c. With two aiming (marker) flags, the MBA antenna and edge of the mortar box, the probabilities of alignment to within $\pm 3^{\circ}$ of the geophone cable look pretty high. However, this is speculation and future tests will reveal the adequacy of this technique. This would preclude the necessity for use of an auxiliary device if these presumptions are upheld by tests.

Conclusions and Recommendations

Based on the results of these preliminary tests, Mission and Crew Engineering feels that:

1. It is feasible and possible to accurately align the geophones such that there is a very small error in the line formed by all three under shirt sleeve conditions.

2. It is feasible and possible, under shirt sleeve conditions, to very accurately align the geophones vertically.

3. It will be necessary that the geophone cable reel carried on the thumper be almost inertia-less and that the astronaut start the rotation by hand after each geophone emplacement to prevent toppling or vertical misalignment of a previously emplaced geophone.

4. Two geophone marker flags will be necessary to both aid in geophone cable alignment accuracy (and speed) and, primarily, as an aid in mortar box alignment.

5. The dimensions on the flags across the top of the pennant shape could probably be reduced; however, the two vertically oriented sides should be as long as possible compatible with other flag (stowage) requirements.

6. The flags should be painted a solid color the equivalent of color chip No. 22246 (Orange). The alternate white markings tested on the flags were reported as distracting.

7. It will be almost impossible to deploy the geophone cable to 300 feet $\pm$ 1% accuracy in length. The subject (and/or astronaut) required approximately

24" to 30" of slack cable at the third geophone along to deploy this geophone from a standing position. The use of two feet of cable for this purpose uses up 1/3 of the total amount of available slack cable for meeting this requirement.

It is highly recommended that these tests be rerun to validate the preliminary results. The test series should be performed under somewhat better controlled conditions of illumination, terrain characteristics, suited and pressurized, etc. Also, better environmental conditions would allow the total task sequence to be performed and timed. Cable distance accuracy could also be checked to determine the margin of error which may occur during geophone deployment.

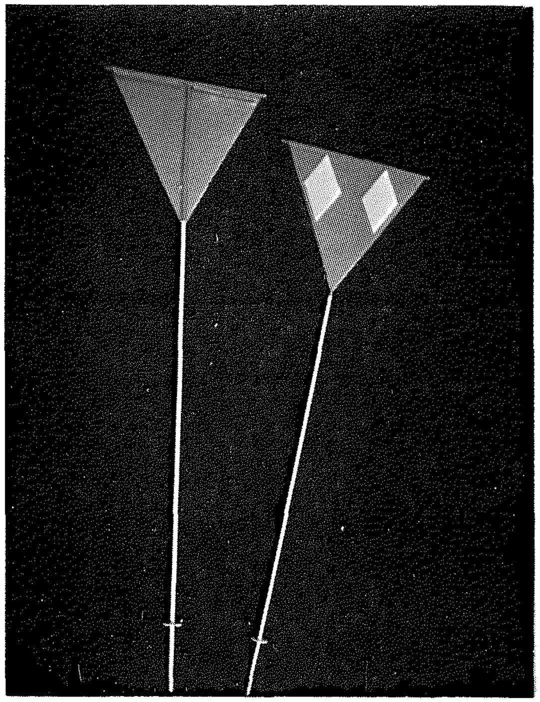

FIGURE 1.- GEOPHONE MARKER FLAGS - TWO SIDES

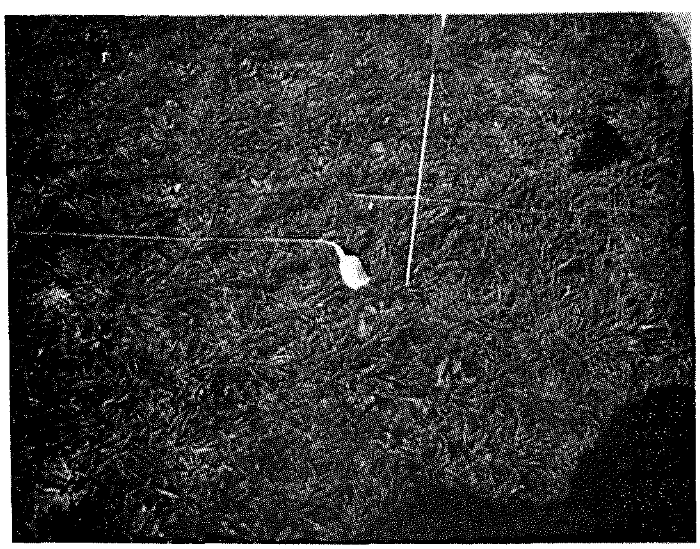

FIGURE 2. GEOPHONE VERTICAL MISALIGNMENT

T & E Report No. 42

Purpose

The final ASE geophone and Mortar Box Assembly (MBA) alignment test was performed to determine (1) if the geophones could be emplaced vertically and aligned to within ± 3° of the line formed by the emplacement of the first two out of three geophones, (2) if the MBA could then be aligned such that its line of fire (180° away from the geophone line) would be within ± 3° of the geophones, (3) if the cable length accuracy (± 1% over 300 feet) could be met and, finally (4) if alternate MBA alignment methods or techniques could be employed by the astronaut on the lunar surface which would not require him to stand in the grenade line of flight.

General

The concept of geophone and MBA alignment procedures previously developed was such that the astronaut performing the required tasks on the lunar surface would be required to stand in the grenades line of flight to align the MBA to the bearing formed by the geophones. Under this concept, the astronaut would emplace and implant the geophones, return along the line performing the required thumping operations and then retrieve, emplace and align the MBA. During the performance of the alignment procedures, the astronaut could only check to confirm accuracy of deployment by standing in front of the MBA and sighting back along the MBA using the edge of the box and the ASE antenna as points for alignment. Some concern had been expressed about this task and the vulnerability of the astronaut in the event of stray signals or any other malfunction which could fire the grenades or launch the MBA. Therefore, alternate means for performing this alignment were selected for testing. These alternate techniques are:

1. Use an aiming stake some distance in front of the MBA which would not interfere with the grenade launch and still be useable. Under this scheme, the geophones would be emplaced first and the MBA aligned to them.

2. Use an aiming stake and the MBA antenna as indicators but emplace the MBA first and align the geophones to those points using a flag at the 2nd geophone only.

3. Use the MBA antenna and a flag at the second geophone as aiming points, emplacing the MBA first.

4. Use the MBA antenna and two flags (one at the first and one at the second geophones), emplacing the MBA first.

5. Incorporate a flag at the MBA antenna and a flag at the second geophone, emplacing the MBA first.

Alternates (2) through (5) would not require the astronaut to stand in the MBA's line of fire to check accuracy of alignment; whereas the first concept does require him to do so. However, alternate #1 was the technique first envisioned so it was decided to perform one series of alignment tests using that concept. As alternate schemes, it was decided to test concepts #1 using two flags (one at each of the geophones nearest the central station) and #5. The details on each of these series will be discussed below as well as the site used, equipment, subject, results, and conclusions and recommendations.

Site

A long (340 foot) wide area unencumbered by trees, grass, weeds (see Figure #1) immediately adjacent to the Bendix Aerospace Systems Division Plant II was selected. There were two major reasons for selecting this locality--(1) ready availability of a clear area, and (2) the subject used in the tests could perform his required functions in the modified (unpressurized) A4H pressure suit.

Equipment

As aids in performing the tests, the following items were used:

a) Engineering Model geophones and cable (see Figure #2).
b) Crew Engineering model of the Central Station (see Figure #3).
c) Crew Engineering model of the MBA (see Figure #4).
d) Crew Engineering Experiment Handling Tool (EHT).
e) Two Crew Engineering flag mockups.
f) Wild theodolite for azimuth alignment checks (accurate measurement to within 0.05 seconds of arc).
g) Crew Engineering (modified) A4H pressure suit, backpack mockup and thermal overgarment (see Figure #5).

Subject

A Bendix engineer experienced in the use of the pressure suit and familiar with the deployment requirements of the ASE subsystem was used to perform the tasks. The subject operated in an unpressurized suit due to the lack of a portable air supply and communications system. The visor was open at all times and the subject wore sunglasses to reduce glare.

Test Procedures

There were three (3) series of tests performed as designated below:

Test Series No. 1 - One Geophone Marker Flag - Deploy geophones then MBA.

a) Subject instructed prior to task performance about the method to be used.

b) Subject grasped geophone cable reel and proceeded to the emplacement site of the first geophone (approximately 10 feet from Central Station).

c) Geophone lowered to ground and implanted from the standing position by stepping on it with the boot. (See Figure #6)

d) As the astronaut subject proceeded toward the emplacement site of geophone no. 2, the vertical alignment of the first geophone was checked; then, the distance between the first and second geophones was measured with a steel tape.

e) Subject reached emplacement site for second geophone, implanted it as before and emplaced a marker flag approximately 12 inches from the geophone (see Figure #7).

f) As distance between the geophones was being measured, subject proceeded toward emplacement site of last geophone.

g) Vertical alignment of second geophone was measured and recorded.

h) Subject emplaced and implanted last geophone, vertical alignment was measured, distance separation between geophones was measured and the azimuth accuracy checked and recorded.

i) Subject returned to Central Station area and retrieved MBA using the EHT (see Figure #8).

j) The MBA was emplaced and aligned using the ASE antenna and the single geophone marker flag (see Figure #9, 10, 11).

k) The MBA/geophone azimuth alignment accuracy was measured and recorded.

Test Series No. 2 - Two Geophone Marker Flags - Deploy geophones then MBA.

a) To economize on time relative to geophone cable deployment, the cable and first two geophones (those nearest the Central Station) were left untouched while the subject emplaced another geophone marker flag at the site of the first geophone. This was to provide an effective measure of azimuth accuracy of alignment using two flags rather than one.

b) The subject returned to the last (furthest) geophone to determine how far and in which direction he would move this instrument based on being able to see two (2) flags rather than one (see Figure #12).

c) Azimuth accuracy was checked and recorded.

Test Series No. 3 - Two Flags, One on MBA Antenna and the other at the Emplacement Site of 2nd Geophone - Deploy MBA, then geophones.

a) The subject emplaced the MBA which now had a marker flag taped to the antenna (see Figure #13).

b) He then retrieved the geophone cable reel and proceeded to the general emplacement site of the first geophone approximately 10 feet from the central station.

c) The subject then attempted to select a bearing (relative to the MBA) which would provide an adequate corridor for geophone emplacement. Upon selection of the corridor, he emplaced the first geophone at a point which would provide a line down the corridor and in-line with the MBA.

d) Geophone implantation occurred in the same manner as in test series numbers 1 and 2.

e) Vertical alignment of the geophone was checked as before while the subject proceeded to the emplacement site of the second geophone.

f) Upon reaching the emplacement site of the second geophone, the subject determined the correct point and implanted the instrument. The marker flag was placed approximately 12 inches away from and in-line with the geophone (see Figure #14).

g) As the subject proceeded to the emplacement site of the last geophone, the vertical alignment of the second geophone was measured.

h) Upon reaching the general locale of the third geophone emplacement site, the astronaut subject sighted back to the two flags (see Figure #15 and #16) to determine the exact point at which he would implant the last geophone.

i) Vertical alignment of the last geophone was checked and the azimuth alignment accuracy measured and recorded.

This terminated the tests for azimuth and vertical alignment of the geophones and the azimuth alignment of the MBA with or to the geophones.

Results

The results of these tests will be reported relative to each test series performed:

Test Series No. 1 - One flag (at second geophone), align geophones, deploy MBA to that line.

Geophone Alignment:

a) Vertical - all three geophones vertical to less than 30 minutes.

b) Azimuth - error on three geophones = 3 minutes, 51.3 seconds arc.

c) MBA to geophones - error (azimuth) = 8 minutes, 30.7 seconds arc.

Test Series No. 2 - Two flags (2 geophones nearest Central Station), align geophones then MBA to that line.

Geophone Alignment:

a) Vertical - one geophone error 1^{o}; other 2, less than 30 minutes off vertical.

b) Azimuth - error on 3 geophones = 1 degree, 1 minute, 21.7 seconds of arc.

c) MBA to geophones - error = 1 degree, 31 minutes, 48.9 seconds of arc.

Test Series No. 3 - Two flags (MBA antenna and 2nd geophone), emplace MBA, then align geophones to that line.

Geophone Alignment:

a) Vertical - all geophones less than 30 minutes off vertical.

b) Azimuth - MBA to first geophone error = 4 minutes, 15.8 seconds of arc.

MBA/1st geophone/2nd geophone error = 28 minutes, 8.2 seconds of arc.

Total error (MBA to line formed by all geophones) = 55 minutes, 24.6 seconds of arc.

By initiating the cable reel by hand prior to proceeding to the next deployment site, the subject did not place a strain on the geophone previously implanted. This precluded the vertical misalignment of any of the geophones as had occurred once in a previous test.

Distance separation between 1st and 2nd geophone was measured to be 144 feet and that between the second and third geophone to be 154 feet. Total distance, therefore, between the first and last geophone was 298 feet with one foot long pigtails at each of the first two geophones. The geophone cable measurements in the laboratory indicated that there are 144 feet of cable between the first and second geophones and 152 feet of cable between the second and third geophones, exclusive of pigtails. This provides 296 feet of cable overall. The only explanation for the difference in readings is that the pigtails were pulled to be in-line with the cable and the measurements reflect this factor. (See Figure #17) The illustration on the left indicates the geometry of the deployment as performed by the astronaut whereas, the illustration on the right indicates the measurement technique used in the laboratory and the correct deployment geometry. However, the two foot difference in length is within the $\pm$ 1% requirement.

Conclusions and Recommendations

The conclusions which will be set forth here must be based on certain assumptions. If these assumptions are deemed to be incorrect, the test results will be invalidated. The first of these assumptions is that the astronaut will have the flags which he will use for performing his alignment procedures in his line-of-sight as required. That is, when he emplaces the geophones and/or MBA, his line-of-sight must not be obscurred by outcroppings, depressions, rises, etc. if any accuracy is to be maintained and guaranteed. The other assumption is that the visor worn by the astronaut will pass sufficient illumination to allow him to see the flag on the MBA antenna.

Based on these assumptions, the following conclusions can be drawn:

1. The azimuth alignment accuracy of the experiment can be met without the use of an additional sighting device.

2. In order to maintain azimuth alignment accuracy, at least one flag must be used, and the broad side perpendicular to his line of sight.

3. If only one flag is used, astronaut must be capable of seeing the first geophone. If this is not possible, two flags must be used.

4. It is feasible to emplace the MBA and then align the geophones to that bearing within the required limits of accuracy if a flag is incorporated on the MBA antenna of a size sufficient to be seen by the astronaut, as in #2 above.

5. Geophone vertical alignment accuracy can be maintained while using the current implantation technique (i.e., from the standing position).

6. Deployment of the geophone cable to within the required $\pm$ 1% relative to distance appears feasible.

It is recommended that the deployment sequence for the ASE experiment indicate that the astronaut emplace the MBA first and in a position such that a bearing 180° from the MBA's line of fire will provide an optimum corridor for geophone emplacement consistent with the other ground rules. Those ground rules are that the geophone line comes not nearer to the LM than being tangent to a circle with a 200 foot radius with the LM at the center nor farther from the LM than being tangent to a circle with a 300 foot radius with the LM being the center point. The first (200 foot radius) constraint is dictated by LM ascent stage blast effects radius and the latter (300 foot radius) is dictated by astronaut safety factors in getting beyond the PLSS capability. This factor is considered in light of the ASE being deployed as the last experiment in the ALSEP mission with some expenditure in the PLSS consumables already having occurred.

The deployment sequence engendered by this recommendation would then be as follows:

1. Break 29 volt power line by rotating ASE SAFE switch to correct position.

2. Using the EHT, retrieve and emplace MBA as suggested above with antenna and flag deployed.

3. Return to central station, stow EHT and retrieve the thumper and geophone combination.

4. Emplace first geophone along the selected, desired bearing (i.e., relative to MBA and corridor).

5. Continue traverse to site of second geophone.

6. Align (visually) the second geophone along the line formed by the ASE antenna flag and the first geophone.

7. Emplace geophone marker flag approximately 12 inches from and in-line with geophones and ASE antenna flag.

8. Continue traverse to third geophones emplacement site.

9. Emplace and implant third geophone after visually aligning it with the two flags.

10. Return along geophone line and perform thumping operations.

11. Upon arrival at the central station, retrieve the Tie-Down Release Tool (TDRT) and proceed to the MBA.

12. Remove safety pin(s).

13. Activate safe switches.

14. Return to central station.

15. Using the TDRT, re-establish 29 volt power line by rotating SAFE switch 180°.

16. Return to LM.

FIGURE 1. GEOPHONE/MBA ALIGNMENT TEST SITE

FIGURE 2. ENGINEERING MODEL GEOPHONES AND CABLE

FIGURE 3. CENTRAL STATION MOCKUP WITH ERECTED SUNSHIELD

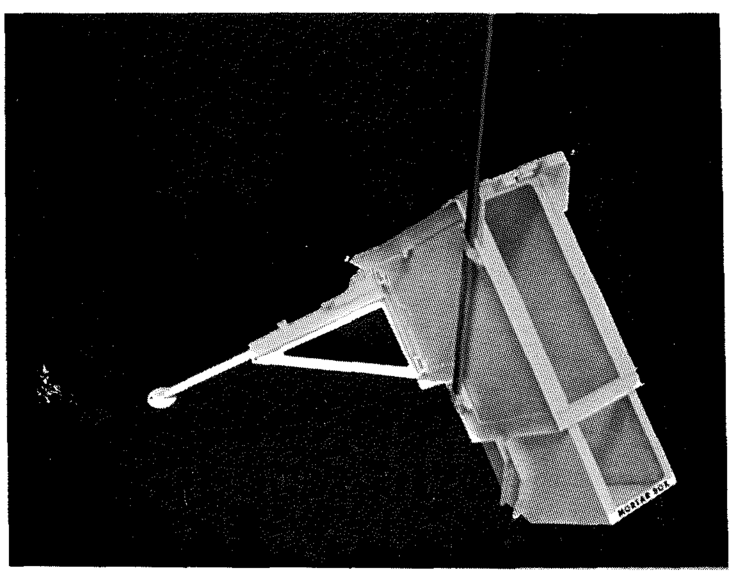

FIGURE 4. MOCKUP OF MBA

Figure 5. Suited Subject With Backpack And Thermal Overgarment

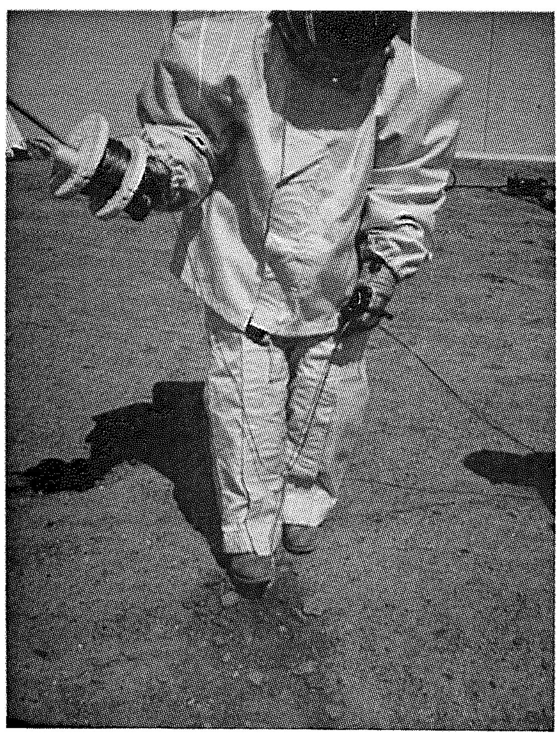

Figure 6. Geophone Implant

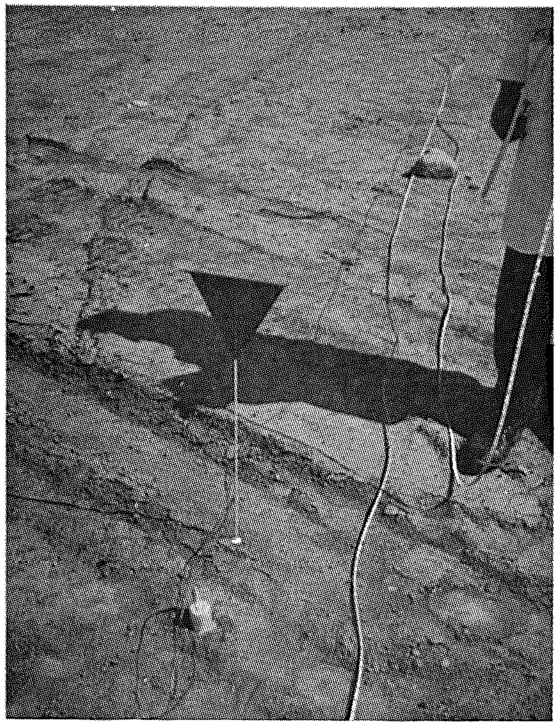

FIGURE 7. GEOPHONE & FLAG

FIGURE 8. MBA RETRIEVAL

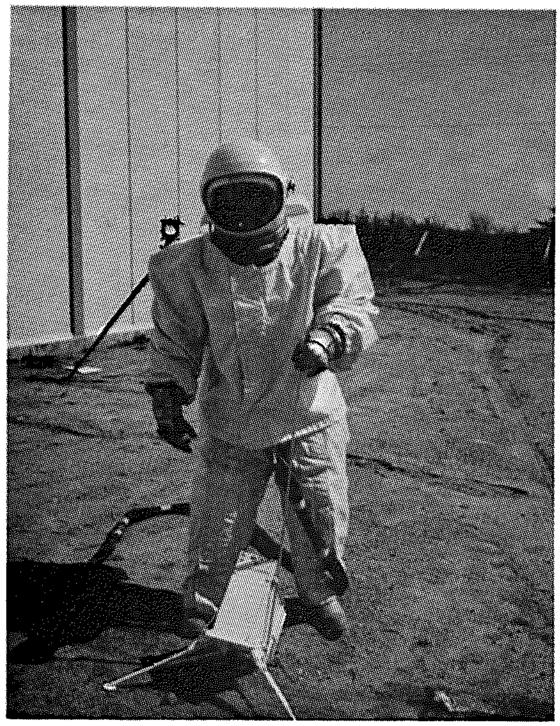

FIGURE 9. MBA ALIGNMENT
(OLD CONCEPT)

FIGURE 10. MBA ALIGNMENT
(OLD CONCEPT)

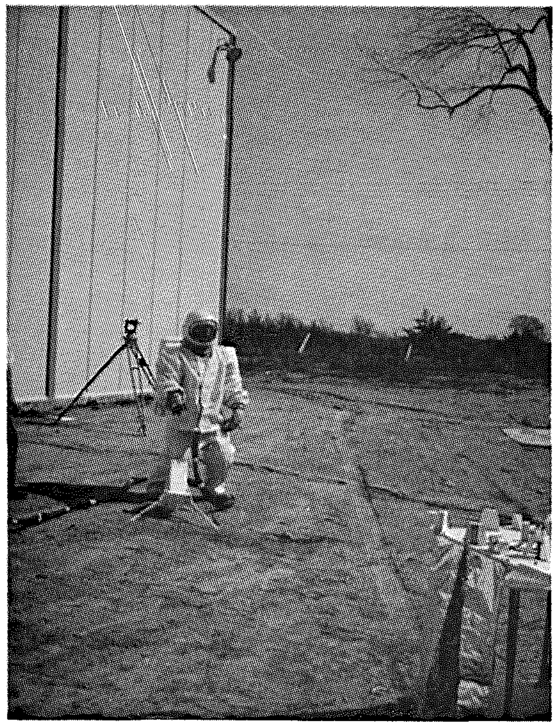

FIGURE 11. MBA ALIGNMENT
(OLD CONCEPT)

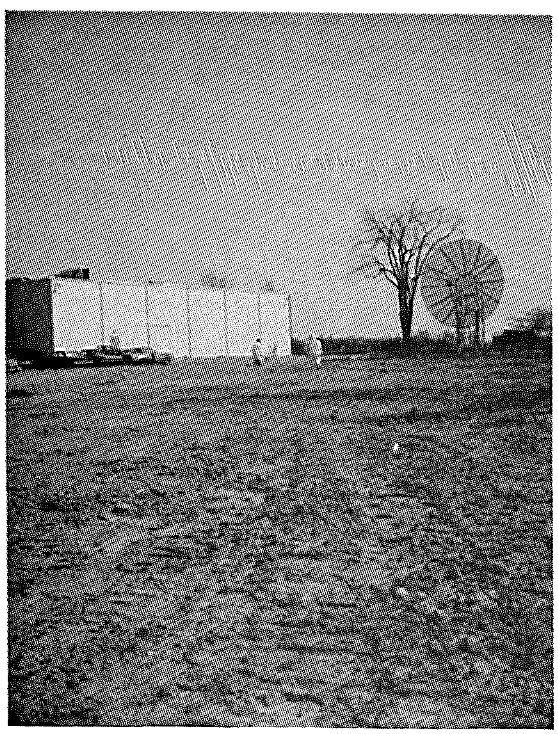

FIGURE 12. MARKER FLAGS
AT FIRST & SECOND GEOPHONES

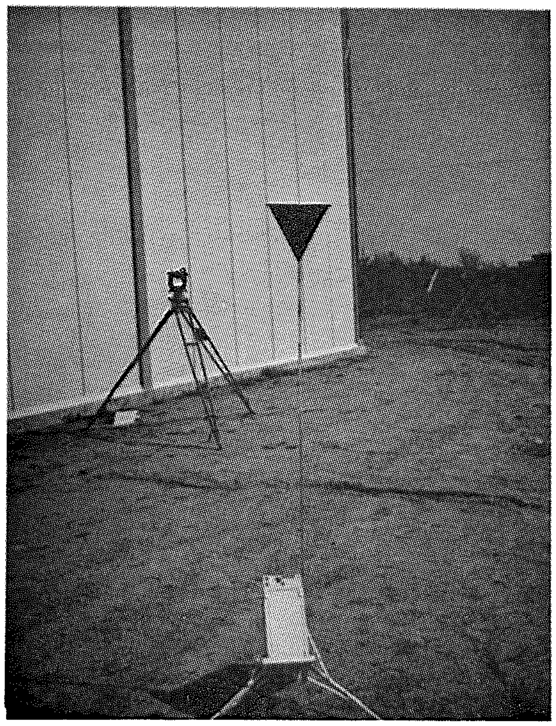

FIGURE 13. MBA ANTENNA WITH MARKER FLAG

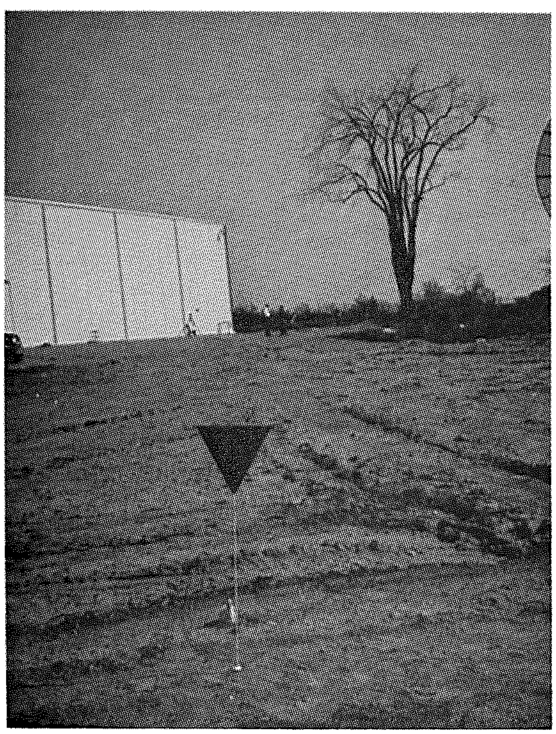

FIGURE 14. MARKER FLAGS AT MBA ANTENNA & 2nd GEOPHONE

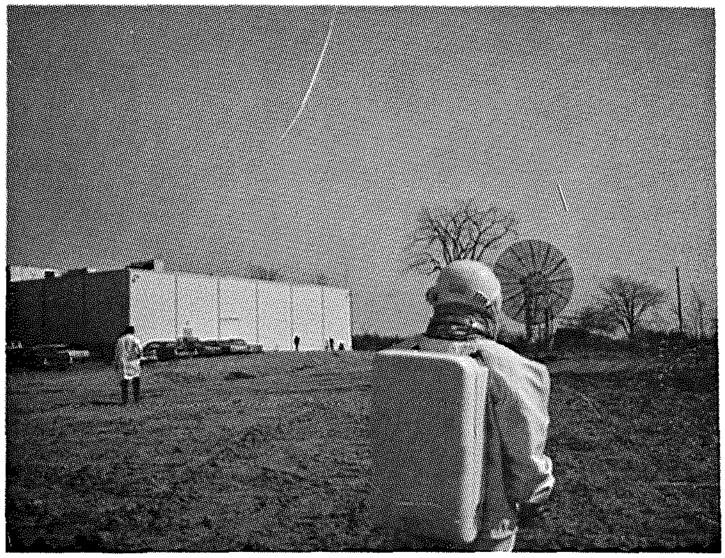

FIGURE 15. ASTRONAUT CHECKING ACCURACY PRIOR TO 3^{d} GEOPHONE IMPLANT

FIGURE 16. ASTRONAUT'S VIEW BACK ALONG GEOPHONE CABLE TO MBA.

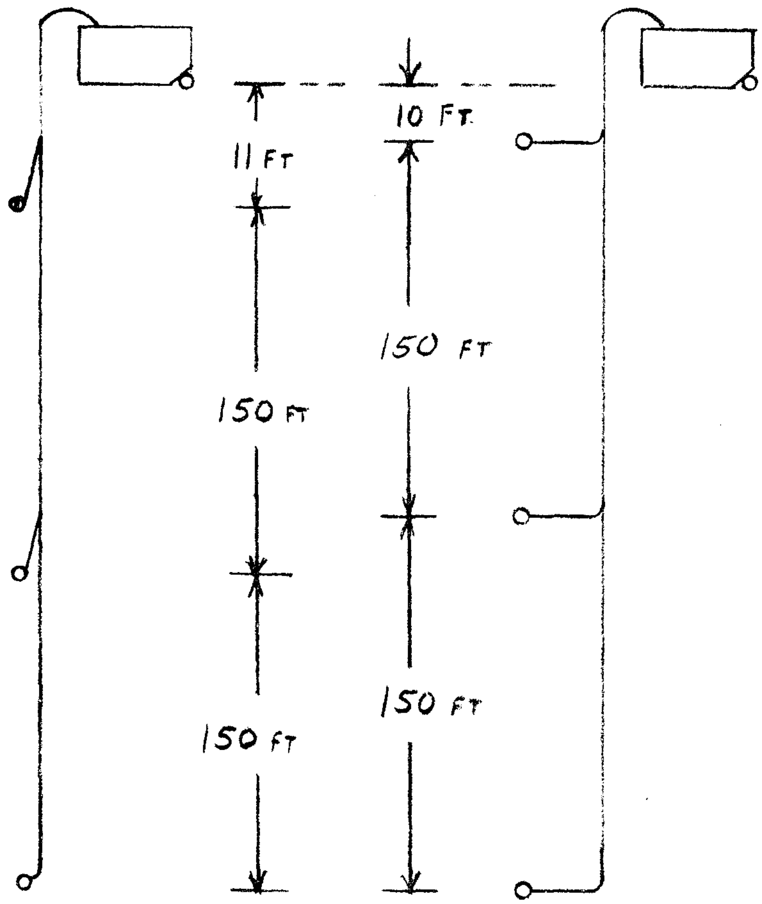

FIGURE 17. CABLE DISTANCE SKETCH TO ILLUSTRATE MEASUREMENT DIFFERENCES.