Bendix
Aerospace Systems Division

EASEP
Crew Systems & Operations Analyses

NO.	REV. NO.
EATM-24	
PAGE 1 OF 1	
DATE 1/8/69	

This EATM contains analyses for the deployment of the EASEP and the criteria upon which the crew systems design review for all drawings was based. This EATM is submitted in response to the documentation task requirement under Exhibit F-1, Item 43, EASEP Documentation Delivery Schedule. The reports contained in this EATM are "EASEP Crew Systems and Operations Deployment Task/Time Sequence Analyses for LRRR & PSEP", EATM-16, 3 January 1969, and "Crew Systems Criteria for Early Apollo Scientific Experiments Packages", CSO-E-1, dated 23 October 1968.

Haydon Y. Grubbs, Mgr.
Crew Systems & Operations

J. Brueger
LRRR Program Mgr.

This EATM presents the EASEP deployment task/time sequence analyses for the Laser Ranging Retro-Reflector (LRRR) and the Passive Seismic Experiment Package (PSEP). Separate and combined task/time deployment sequences for the LRRR and PSEP are included. The assumptions for the development of these task/time deployment sequences are based on current design.

Prepared by: Leslie D. Marrus
Leslie D. Marrus, P.E.
Crew Systems & Operations

Approved by: Haydon Y. Grubbs
Haydon Y. Grubbs, Mgr.
Crew Systems & Operations

J. Brueger
J. Brueger
LRRR Program Mgr.

Kai Hsi
K. Hsi
PSEP Program Mgr.

1.0 ASSUMPTIONS

In performing the analyses reported herein, certain assumptions were made, as follows:

1. The slope at all landing sites is no greater than 2°.

2. EASEP (LRRR and PSEP) deployment does not include Lunar Module (LM) Scientific Equipment Bay (SEQ) Door operations, but does include all boom assembly operations.

3. No time has been allocated for the astronaut to level the deployment site using his Extravehicular Mobility Unit (EMU) boot.

4. No rest periods have been programmed in these sequences.

5. The astronaut takes the most direct route to the deployment site as shown in Figure No. 1.

6. The nominal walking rate for the EMU-suited astronaut operating at 1/6G is 1.5 feet per second.

7. There is no time allocated for leveling the LRRR or the PSEP.

8. There is no time allocated for communication of data between the astronaut and MCC.

9. These sequences describe one-man deployment of the EASEP.

10. The Lunar Module is oriented on the lunar surface with the SEQ (Quadrant II) facing the sun (lunar east).

11. The Commander, who remains inside the LM, maintains constant voice contact with the LM Pilot while the LM Pilot is deploying EASEP.

12. The voice link between the LM Pilot and MCC, during EASEP deployment, is through the LM directly to MCC.

13. The LM Pilot is pressurized to 3.75 psi in the EMU during EASEP deployment.

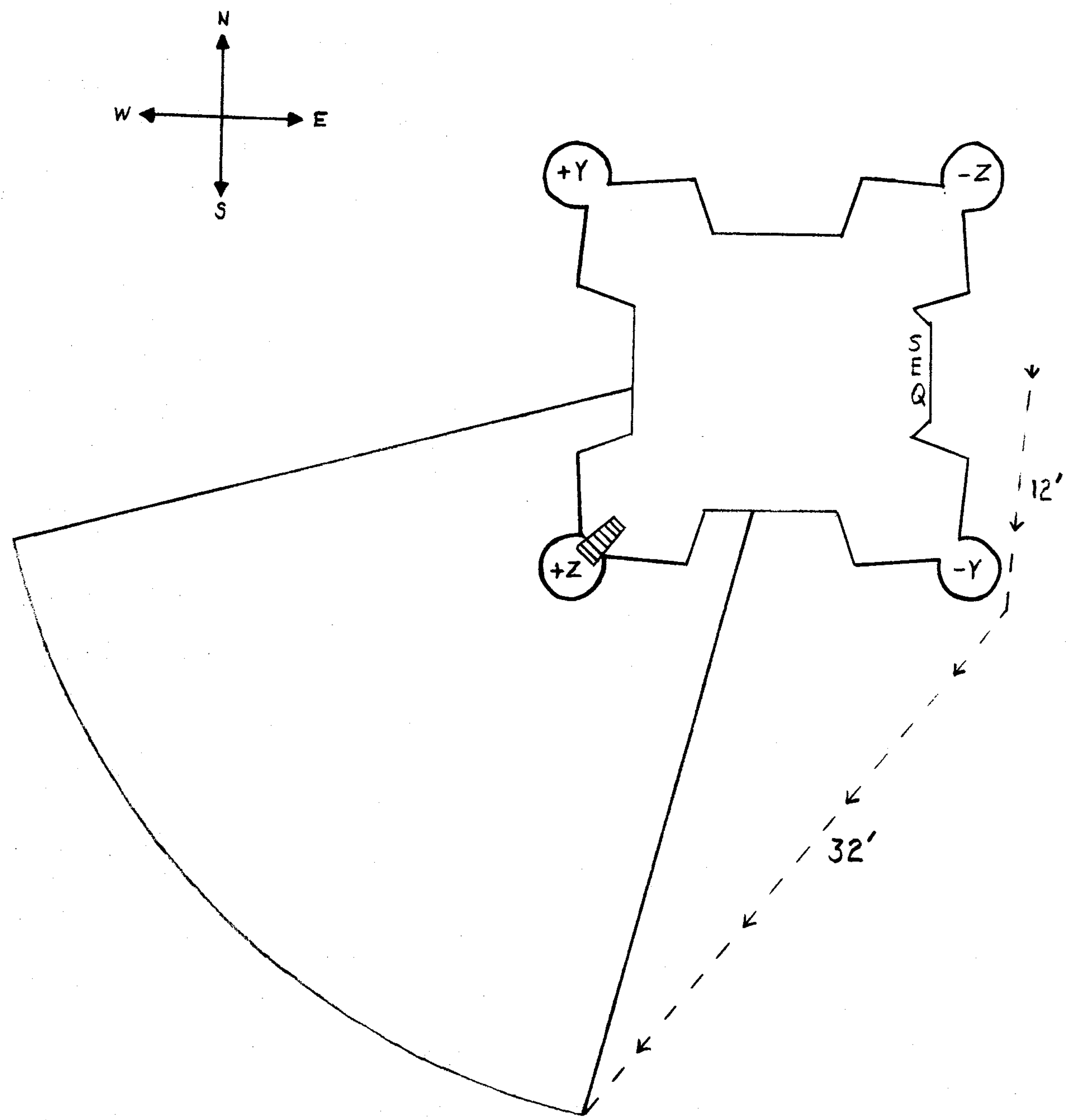


FIGURE NO. 1 - TRAVERSE TO DEPLOYMENT SITE

14. The times, in minutes and seconds, are based on part-task tests conducted with Crew Systems and Operations mockups. A whole task/time sequence deployment test is required to validate these analyses.

LRRR
DEPLOYMENT SEQUENCE

		Task Time	Cumulative Time
1.0	REMOVE EASEP PACKAGE NO. 2 (Total Time = 1:53)		
1.1	Open SEQ Bay Door.	00:00	00:00
1.2	Retrieve EASEP Package No. 2 deployment lanyard.	00:10	00:10
1.3	Walk 10 feet from LM, deploying lanyard.	00:07	00:17
1.4	Pull EASEP Package No. 2 deployment lanyard to release Package No. 2 tie-downs, extend boom assembly, and to lower Package No. 2 to the lunar surface.	00:25	00:42
1.5	Discard EASEP Package No. 2 deployment lanyard.	00:02	00:44
1.6	Walk to EASEP Package No. 2.	00:04	00:48
1.7	Use two hands to pull in opposite directions to release deployment lanyard from EASEP Package No. 2.	00:10	00:58
1.8	Remove boom assembly pull pin to separate EASEP Package No. 2 from boom attachment assembly and discard pull pin.	00:05	01:03
1.9	Retrieve EASEP Package No. 2 deployment lanyard.	00:05	01:08
1.10	Walk 5 feet back from EASEP Package No. 2, deploying lanyard.	00:04	01:12
1.11	Pull EASEP Package No. 2 deployment lanyard to restow boom assembly.	00:20	01:32
1.12	Walk to SEQ Bay Compartment II.	00:07	01:39
1.13	Restow EASEP Package No. 2 deployment lanyard.	00:10	01:49
1.14	Close SEQ Bay Door.	00:00	01:49
1.15	Walk to EASEP Package No. 2.	00:04	01:53
2.0	TRAVERSE TO DEPLOYMENT SITE (Total Time = 0:55)		
2.1	Use carry handle to lift EASEP Package No. 2 from lunar surface.	00:05	01:58
2.2	Walk to -Y landing gear pad.	00:08	02:06
2.3	Survey lunar surface to select suitable EASEP Package No. 2 deployment site.	00:10	02:16
2.4	Walk approximately 32 feet from LM to selected EASEP Package No. 2 deployment site.	00:22	02:38

LRRR
DEPLOYMENT SEQUENCE

		Task Time	Cumulative Time
2.5	Lower EASEP Package No. 2 to lunar surface on E-W axis so that LRRR will be directed toward sub-earth point when EASEP Package No. 2 is in the deployed position.	00:10	02:48
3.0	DEPLOY LRRR (Total Time = 1:38)		
3.1	Grasp deployment handle and associated release ring to release deployment handle pull pin.	00:03	02:51
3.2	Pull deployment handle to extend deployment handle six inches to first detent position and to partially release LRRR array.	00:05	02:56
3.3	Discard deployment handle release ring and attached pull pin.	00:02	02:58
3.4	Regrasp deployment handle with left hand to steady EASEP Package No. 2 and, using right hand, grasp array tilting handle, pull outward, rotate handle 45^{o}, and continue pulling array tilting handle outward to extend array tilting handle 9.5 inches to detent position and to complete release of LRRR array.	00:15	03:13
3.5	Observing array tilt angle indicator and pointer, use array tilting handle to set in array tilt angle for actual LM landing site, while using deployment handle to steady EASEP Package No. 2.	00:10	03:23
3.6	Partially release outward tension on array tilting handle and check to ensure that array is locked in place.	00:05	03:28
3.7	Release array tilting handle and allow array tilting handle to spring back into stowed position.	00:03	03:31
3.8	Regrasp deployment handle, depress trigger on deployment handle to release first detent, pull deployment handle to extend deployment handle an additional 27 inches, and use deployment handle to control descent of EASEP Package No. 2 as it rotates to the lunar surface.	00:15	03:46
3.9	Use deployment handle to embed EASEP Package No. 2 mounting tabs in lunar surface.	00:20	04:06

LRRR
DEPLOYMENT SEQUENCE

		Task Time	Cumulative Time
3.10	Observing shadow cast by EASEP Package No. 2 gnomon on partial compass rose for actual LM landing site, use deployment handle to align EASEP Package No. 2 to within $\pm 5^{\circ}$ of LRRR centerline, and release deployment handle.	00:20	04:26
4.0	<u>TRAVERSE TO LM</u> (Total Time = 0:20)		
4.1	Return to LM.	00:20	04:46

PSEP
DEPLOYMENT SEQUENCE

		Task Time	Cumulative Time
1.0	REMOVE EASEP PACKAGE NO. 1 (Total Time = 2:03)		
1.1	Open SEQ Bay Door.	00:00	00:00
1.2	Retrieve EASEP Package No. 1 deployment lanyard.	00:10	00:10
1.3	Walk 10 feet from LM, deploying lanyard.	00:07	00:17
1.4	Pull EASEP Package No. 1 deployment lanyard to release Package No. 1 tie-downs, extend boom assembly, and to lower Package No. 1 to the lunar surface.	00:25	00:42
1.5	Discard EASEP Package No. 1 deployment lanyard.	00:02	00:44
1.6	Walk to EASEP Package No. 1.	00:04	00:48
1.7	Use two hands to pull in opposite directions to release deployment lanyard from EASEP Package No. 1.	00:10	00:58
1.8	Walk to rear of EASEP Package No. 1.	00:03	01:01
1.9	Remove boom assembly pull pin to release deployment handle, to release and rotate PSE gnomon, and to separate EASEP Package No. 1 boom attachment assembly from boom assembly.	00:07	01:08
1.10	Walk to front of EASEP Package No. 1.	00:03	01:11
1.11	Retrieve EASEP Package No. 1 deployment lanyard.	00:05	01:16
1.12	Walk 5 feet back from EASEP Package No. 1, deploying lanyard.	00:04	01:20
1.13	Pull EASEP Package No. 1 deployment lanyard to restow boom assembly.	00:20	01:40
1.14	Walk to SEQ Bay Compartment I.	00:07	01:47
1.15	Restow EASEP Package No. 1 deployment lanyard.	00:10	01:57
1.16	Close SEQ Bay Door.	00:00	01:57
1.17	Walk to EASEP Package No. 1.	00:06	02:03
2.0	TRAVERSE TO DEPLOYMENT SITE (Total Time = 0:55)		
2.1	Use carry handle to lift EASEP Package No. 1 from lunar surface.	00:05	02:08
2.2	Walk to -Y landing gear pad.	00:08	02:16

PSEP DEPLOYMENT SEQUENCE

		Task Time	Cumulative Time
2.3	Survey lunar surface to select suitable EASEP Package No. 1 deployment site.	00:10	02:26
2.4	Walk approximately 32 feet from LM to selected EASEP Package No. 1 deployment site.	00:22	02:48
2.5	Lower EASEP Package No. 1 to lunar surface on E-W axis.	00:10	02:58
3.0	<u>DEPLOY PSEP</u> (Total Time = 3:21)		
3.1	Walk to rear of EASEP Package No. 1.	00:03	03:01
3.2	Grasp deployment handle, pull to extend handle to 30 inch working height, and rotate handle 90° to lock it in place.	00:10	03:11
3.3	Walk to front of EASEP Package No. 1.	00:03	03:14
3.4	Grasp carry handle with left hand.	00:03	03:17
3.5	Use right hand to remove and discard first solar panel-restraining pull pin.	00:10	03:27
3.6	Remove and discard first solar panel support bracket-restraining pull pin.	00:05	03:32
3.7	Grasp first solar panel support bracket, rotate bracket forward, lift bracket upward to release and remove first rear support bracket pull pin, and discard bracket/lanyard/pull pin.	00:20	03:52
3.8	Grasp carry handle with right hand.	00:03	03:55
3.9	Use left hand to remove and discard second solar panel-restraining pull pin.	00:10	04:05
3.10	Remove and discard second solar panel support bracket-restraining pull pin.	00:05	04:10
3.11	Grasp second solar panel support bracket, rotate bracket forward, lift bracket upward to release and remove second rear support bracket pull pin, and discard bracket/lanyard/pull pin.	00:20	04:30
3.12	Use carry handle to rotate EASEP Package No. 1 to the lunar surface.	00:10	04:40
3.13	Use deployment handle to embed EASEP Package No. 1 mounting tabs in lunar surface.	00:20	05:00

PSEP
DEPLOYMENT SEQUENCE

		Task Time	Cumulative Time
3.14	Observing shadow cast by PSE gnomon on compass rose, use deployment handle to align EASEP Package No. 1 to within $\pm 5^{\circ}$ of PSEP centerline.	00:20	05:20
3.15	Release velcroed antenna release lanyard from deployment handle.	00:05	05:25
3.16	Pull antenna release lanyard to remove antenna pull pin, and release and rotate antenna. (Steady EASEP Package No. 1 by holding handle with left hand.)	00:10	05:35
3.17	Discard antenna release lanyard.	00:02	05:37
3.18	Release velcroed solar panel deployment lanyard from deployment handle.	00:05	05:42
3.19	Pull solar panel deployment lanyard to rotate solar panels. (Steady EASEP Package No. 1 by holding deployment handle with left hand and monitor solar panel deployment.)	00:20	06:02
3.20	Discard solar panel deployment lanyard.	00:02	06:04
3.21	Grasp antenna, observe antenna tilt angle indicator and pointer, rotate antenna to elevation offset for actual LM landing site, and release antenna.	00:15	06:19
4.0	<u>TRAVERSE TO LM</u> (Total Time = 0:20)		
4.1	Return to LM.	00:20	06:39

COMBINED LRRR/PSEP DEPLOYMENT SEQUENCE

		Task Time	Cumulative Time
1.0	REMOVE EASEP PACKAGE NO. 2 (Total Time = 1:51)		
1.1	Open SEQ Bay Door.	00:00	00:00
1.2	Retrieve EASEP Package No. 2 deployment lanyard.	00:10	00:10
1.3	Walk 10 feet from LM, deploying lanyard.	00:07	00:17
1.4	Pull EASEP Package No. 2 deployment lanyard to release Package No. 2 tie-downs, extend boom assembly, and to lower Package No. 2 to the lunar surface.	00:25	00:42
1.5	Discard EASEP Package No. 2 deployment lanyard.	00:02	00:44
1.6	Walk to EASEP Package No. 2.	00:04	00:48
1.7	Use two hands to pull in opposite directions to release deployment lanyard from EASEP Package No. 2.	00:10	00:58
1.8	Remove boom assembly pull pin to separate EASEP Package No. 2 from boom attachment assembly and discard pull pin.	00:05	01:03
1.9	Retrieve EASEP Package No. 2 deployment lanyard.	00:05	01:08
1.10	Walk 5 feet back from EASEP Package No. 2, deploying lanyard.	00:04	01:12
1.11	Pull EASEP Package No. 2 deployment lanyard to restow boom assembly.	00:20	01:32
1.12	Walk to SEQ Bay Compartment II.	00:07	01:39
1.13	Restow EASEP Package No. 2 deployment lanyard.	00:10	01:49
1.14	Walk to SEQ Bay Compartment I.	00:02	01:51
2.0	REMOVE EASEP PACKAGE NO. 1 (Total Time = 2:01)		
2.1	Retrieve EASEP Package No. 1 deployment lanyard.	00:10	02:01
2.2	Walk 10 feet from LM, deploying lanyard.	00:07	02:08
2.3	Pull EASEP Package No. 1 deployment lanyard to release Package No. 1 tie-downs, extend boom assembly, and to lower Package No. 1 to the lunar surface.	00:25	02:33

COMBINED LRRR/PSEP DEPLOYMENT SEQUENCE

		Task Time	Cumulative Time
2.4	Discard EASEP Package No. 1 deployment lanyard.	00:02	02:35
2.5	Walk to EASEP Package No. 1.	00:04	02:39
2.6	Use two hands to pull in opposite directions to release deployment lanyard from EASEP Package No. 1.	00:10	02:49
2.7	Walk to rear of EASEP Package No. 1.	00:03	02:52
2.8	Remove boom assembly pull pin to release deployment handle, to release and rotate PSE gnomon, and to separate EASEP Package No. 1 boom attachment assembly from boom assembly.	00:07	02:59
2.9	Walk to front of EASEP Package No. 1.	00:03	03:02
2.10	Retrieve EASEP Package No. 1 deployment lanyard.	00:05	03:07
2.11	Walk 5 feet back from EASEP Package No. 1, deploying lanyard.	00:04	03:11
2.12	Pull EASEP Package No. 1 deployment lanyard to restow boom assembly.	00:20	03:31
2.13	Walk to SEQ Bay Compartment I.	00:07	03:38
2.14	Restow EASEP Package No. 1 deployment lanyard.	00:10	03:48
2.15	Close SEQ Bay Door.	00:00	03:48
2.16	Walk to EASEP Package No. 2.	00:04	03:52
3.0	<u>TRAVERSE TO DEPLOYMENT SITE</u> (Total Time = 1:02)		
3.1	Use carry handle to lift EASEP Package No. 2 from lunar surface.	00:05	03:57
3.2	Walk to EASEP Package No. 1.	00:02	03:59
3.3	Use carry handle to lift EASEP Package No. 1 from lunar surface.	00:05	04:04
3.4	Walk to -Y landing gear pad.	00:08	04:12
3.5	Survey lunar surface to select suitable EASEP deployment site.	00:10	04:22
3.6	Walk approximately 32 feet from LM to selected EASEP deployment site.	00:22	04:44
3.7	Lower EASEP Packages to lunar surface on N-S axis.	00:10	04:54

COMBINED LRRR/PSEP
DEPLOYMENT SEQUENCE

		Task Time	Cumulative Time
4.0	DEPLOY LRRR (Total Time = 1:43)		
4.1	Position EASEP Package No. 2 on E-W axis so that LRRR will be directed toward subearth point when EASEP Package No. 2 is in the deployed position.	00:05	04:59
4.2	Grasp deployment handle and associated release ring to release deployment handle pull pin.	00:03	05:02
4.3	Pull deployment handle to extend deployment handle six inches to first detent position and to partially release LRRR array.	00:05	05:07
4.4	Discard deployment handle release ring and attached pull pin.	00:02	05:09
4.5	Regrasp deployment handle with left hand to steady EASEP Package No. 2 and, using right hand, grasp array tilting handle, pull outward, rotate handle 45^{o}, and continue pulling array tilting handle outward to extend array tilting handle 9.5 inches to detent position and to complete release of LRRR array.	00:15	05:24
4.6	Observing array tilt angle indicator and pointer, use array tilting handle to set in array tilt angle for actual LM landing site, while using deployment handle to steady EASEP Package No. 2.	00:10	05:34
4.7	Partially release outward tension on array tilting handle and check to ensure that array is locked in place.	00:05	05:39
4.8	Release array tilting handle and allow array tilting handle to spring back into stowed position.	00:03	05:42
4.9	Regrasp deployment handle, depress trigger on deployment handle to release first detent, pull deployment handle to extend deployment handle an additional 27 inches, and use deployment handle to control descent of EASEP Package No. 2 as it rotates to the lunar surface.	00:15	05:57
4.10	Use deployment handle to embed EASEP Package No. 2 mounting tabs in lunar surface.	00:20	06:17

COMBINED LRRR/PSEP
DEPLOYMENT SEQUENCE

		Task Time	Cumulative Time
4.11	Observing shadow cast by EASEP Package No. 2 gnomon on partial compass rose for actual LM landing site, use deployment handle to align EASEP Package No. 2 to within $\pm$ 5^{o} of LRRR centerline, and release deployment handle.	00:20	06:37
5.0	DEPLOY PSEP (Total Time = 3:43)		
5.1	Use carry handle to lift EASEP Package No. 1 from lunar surface.	00:05	06:42
5.2	Walk 10 feet east of EASEP Package No. 2.	00:07	06:49
5.3	Lower EASEP Package No. 1 to lunar surface on E-W axis.	00:10	06:59
5.4	Walk to rear of EASEP Package No. 1.	00:03	07:02
5.5	Grasp deployment handle, pull to extend handle to 30 inch working height, and rotate handle 90^{o} to lock it in place.	00:10	07:12
5.6	Walk to front of EASEP Package No. 1.	00:03	07:15
5.7	Grasp carry handle with left hand.	00:03	07:18
5.8	Use right hand to remove and discard first solar panel-restraining pull pin.	00:10	07:28
5.9	Remove and discard first solar panel support bracket-restraining pull pin.	00:05	07:33
5.10	Grasp first solar panel support bracket, rotate bracket forward, lift bracket upward to release and remove first rear support bracket pull pin, and discard bracket/lanyard/pull pin.	00:20	07:53
5.11	Grasp carry handle with right hand.	00:03	07:56
5.12	Use left hand to remove and discard second solar panel-restraining pull pin.	00:10	08:06
5.13	Remove and discard second solar panel support bracket-restraining pull pin.	00:05	08:11
5.14	Grasp second solar panel support bracket, rotate bracket forward, lift bracket upward to release and remove second rear support bracket pull pin, and discard bracket/lanyard/pull pin.	00:20	08:31

COMBINED LRRR/PSEP DEPLOYMENT SEQUENCE

		Task Time	Cumulative Time
5.15	Use carry handle to rotate EASEP Package No. 1 to the lunar surface.	00:10	08:41
5.16	Use deployment handle to embed EASEP Package No. 1 mounting tabs in lunar surface.	00:20	09:01
5.17	Observing shadow cast by PSE gnomon on compass rose, use deployment handle to align EASEP Package No. 1 to within $\pm$ 5^{o} of PSEP centerline.	00:20	09:21
5.18	Release velcroed antenna release lanyard from deployment handle.	00:05	09:26
5.19	Pull antenna release lanyard to remove antenna pull pin, and release and rotate antenna. (Steady EASEP Package No. 1 by holding handle with left hand.)	00:10	09:36
5.20	Discard antenna release lanyard.	00:02	09:38
5.21	Release velcroed solar panel deployment lanyard from deployment handle.	00:05	09:43
5.22	Pull solar panel deployment lanyard to rotate solar panels. (Steady EASEP Package No. 1 by holding deployment handle with left hand and monitor solar panel deployment.)	00:20	10:03
5.23	Discard solar panel deployment lanyard.	00:02	10:05
5.24	Grasp antenna, observe antenna tilt angle indicator and pointer, rotate antenna to elevation offset for actual LM landing site, and release antenna.	00:15	10:20
6.0	<u>TRAVERSE TO LM</u> (Total Time = 0:20)		
6.1	Return to LM.	00:20	10:40

This report is submitted as partial fulfillment of the Crew Systems & Operations effort on the Early Apollo Scientific Experiments (EASE) program.

Prepared by: Leslie D. Marrus
Leslie D. Marrus, P.E.
Crew Systems & Operations

Approved by: Haydon Y. Grubbs
Haydøn Y. Grubbs, Mgr.
Crew Systems & Operations

1.0 GENERAL

The following astronaut interface requirements are intended for use by engineering personnel in the design of the Early Apollo Scientific Experiments Packages.

The information presented contains specific criteria guidelines and restraints to be incorporated in the design for compatibility with the astronaut capability to perform in a pressurized Apollo spacesuit under 1/6-gravity conditions, in order to ensure safety and provide ease of operation.

2.0 HARDWARE DESIGN AND MATERIALS

2.1 Alignment Device

Figure 2.1-1 contains the criteria for design of a standard alignment device. The criteria provides the crewman the capability of reading a gnomon shadow cast on alignment markings for a range of sun angles from 7° through 20°. Paragraph 6.3 provides minimum criteria for alignment markings. The width of the shadow cast by the gnomon should not exceed the distance between any two alignment markings.

2.2 Leveling Device

Figure 2.2-1 contains leveling device criteria. When the bubble breaks away from the side of the outer housing the level condition is $\pm 5^{\circ}$.

The prime requirements for both the level sensor and the alignment sensor, described in paragraph 2.1 above, are that they contain a positive means of indicating an in-tolerance condition, that they are placed at a height as close to eye level as is possible, that they be positioned such that they can be observed easily by the astronaut, and that they provide the proper visual contrast. Paragraph 6.0 contains data pertinent to the design of visual tasks which should be referred to in the incorporation of level and alignment sensors.

2.3 Fasteners To Be Operated On The Lunar Surface

Fasteners utilized in the EASE design must contain the following interface features:

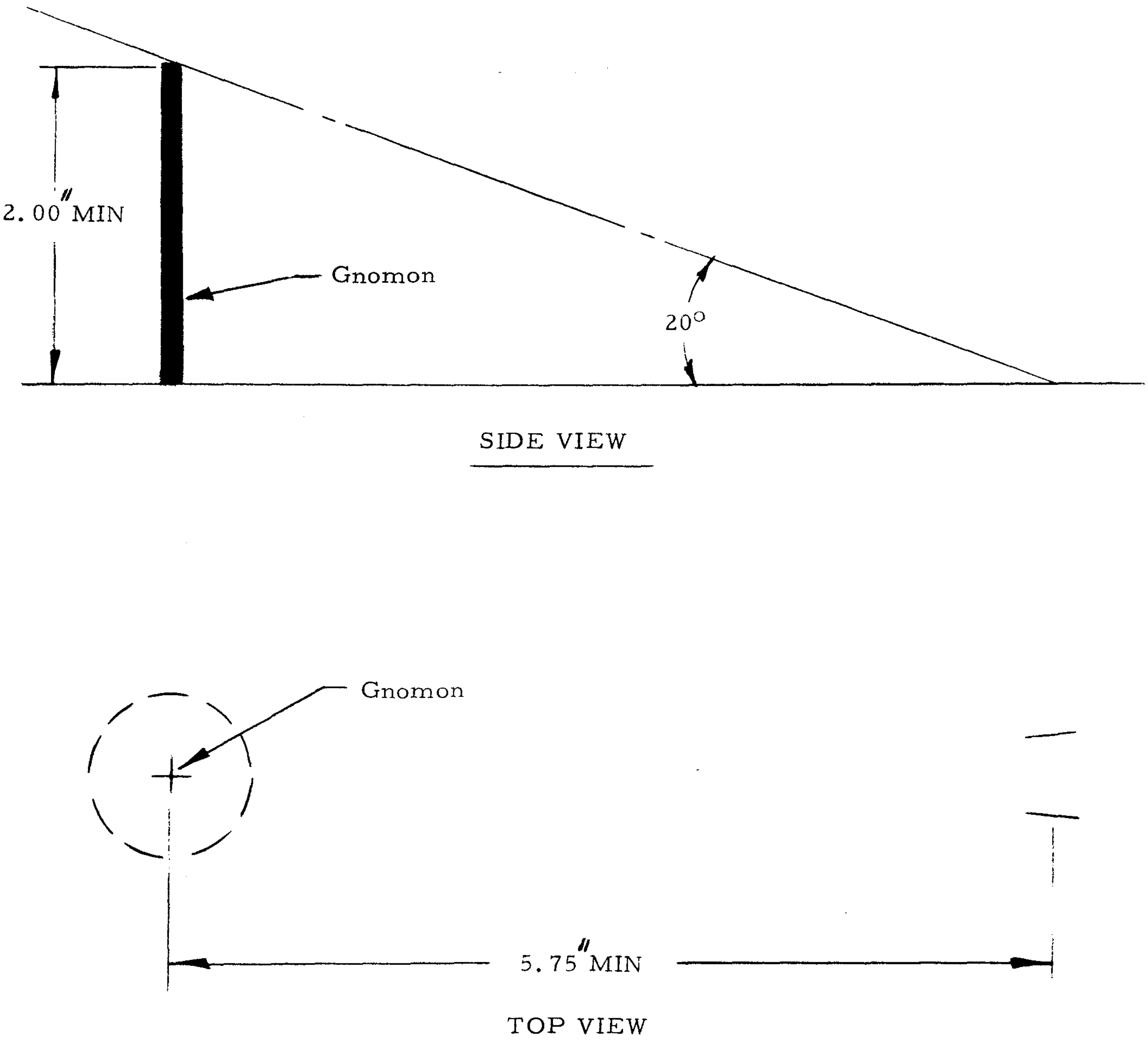


FIGURE 2.1-1
STANDARD ALIGNMENT SENSOR PATTERN

CIRCULAR LEVEL 2-16016

Manufacturer: Geier & Bluhm
594 River Street
Troy, New York

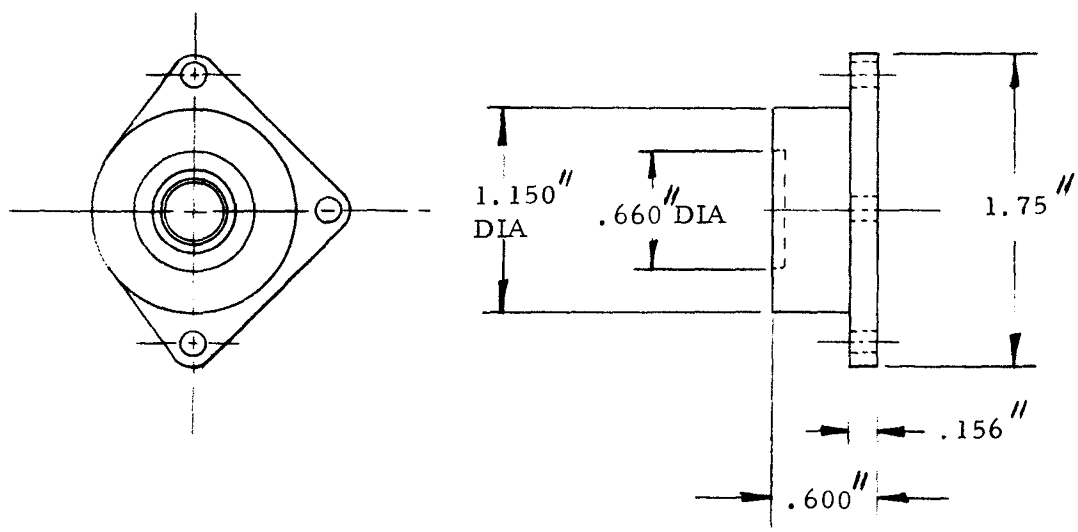


FIGURE 2.2-1

STANDARD CIRCULAR LEVEL SENSOR

(1) They must be releasable by means of an integral lanyard or handle extension.

(2) They must not require a force to release in excess of 10 in. lbs. for turn to release, 20 lbs. for a push force in the vertical direction, 5 lbs. for pull force or push force in the horizontal direction, and 5 lbs. for pull force in the vertical direction. (Astronaut capability actually allows for push or pull forces of 20 lbs. in all directions, but the lunar weight of the EASE packages does not permit forces in excess of 5 lbs. to be directed in any direction except downward.)

(3) They must provide a positive indication of release (i.e., by fastener removal).

2.4 Thermal Coatings

The thermal coating applied to the EASE subsystems affects the astronaut interface by introducing a possible source of glare (see paragraph 6.10) and because there are various operational requirements for adding markings, color-coding, etc. (see paragraphs 6.6 through 6.9).

Since markings on the thermal surfaces must provide a proper contrast, while still maintaining thermal characteristics, the following two materials should be considered since they satisfy both the thermal and visual contrast requirements:

(1) CAT-A-LAC 463-3-22246
(Thermal control lacquer - epoxy base.)

Manufacturer: Finch Paint & Chemical Company
1536 W. 288th Street
Torrance, California

(2) CAT-A-LINK 50-209
(Thermal control ink.)

Manufacturer: Wornow Process Paint Company
1218 Long Beach Avenue
Los Angeles, California

The primary difference in the two materials is that the ink is easier to apply than the lacquer.

2.5 Handles

Various handles have varied applications within the EASE design. However, these various handles can possess a standard design and be standardized in their application. Figures 2.5-1 and 2.5-2 contain a standard configuration for each handle and criteria for their utilization is contained in the following subparagraphs.

Where no muscular activity is involved (i.e., the static load applied to a handle when it is leaned on by an astronaut under 1/6G), the designer should assume that the astronaut has the capability of exerting about 50 pounds of force (the weight of the astronaut, EMU, and PLSS/OPS).

(1) "U"-Handles

Where suitcase carry or removal from the LM Scientific Equipment Bay is an astronaut task the "U" handle is the single acceptable interface. This handle is constructed from one inch diameter aluminum tubing flattened to the dimensions shown in Figure 2.5-1. The basic design requirement is that the handle allows sufficient ingress for the pressure-gloved hand.

(2) "T"-Handles

The "T"-handle has an application for which it is particularly well suited, that of lanyard pull. It is extremely important that the base leg of the "T" does not exceed the 0.75" thickness limit. This is the maximum finger separation that the glove will allow and still permit functional manipulation.

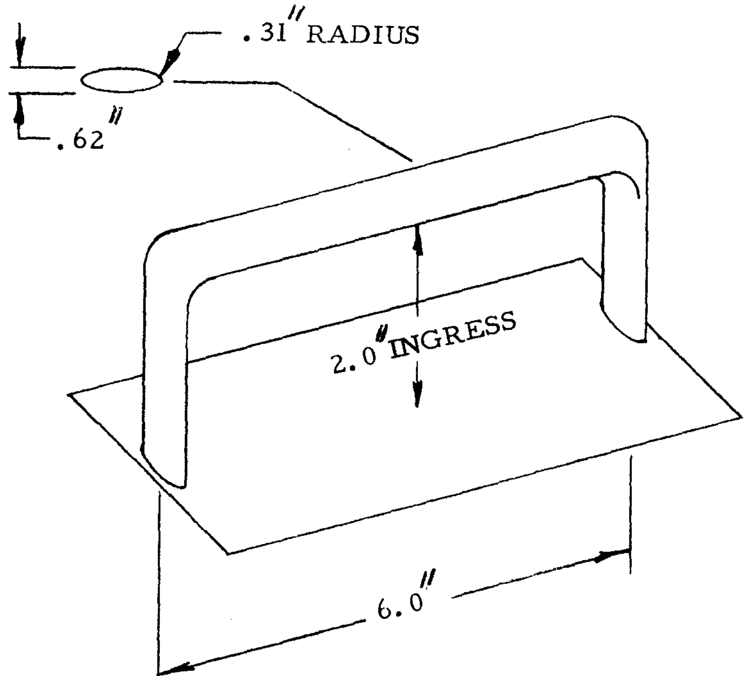
(3) Recessed Handle

These handles are suitable for lifting tasks and are convenient where packaging constraints restrict the design to close envelope tolerances. It does not permit a high degree of manipulative flexibility and therefore should be utilized for lifting and removal tasks only.

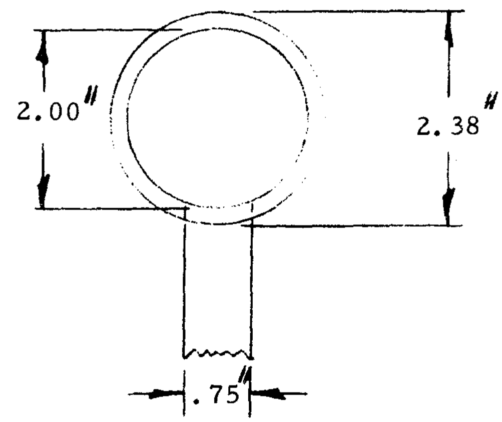
(4) Carrying Straps

There are several peculiar applications for handles in the EASE design where metal fabrication cannot be utilized due to the envelope restrictions or skin strength of the package. In these cases a fabric handle is provided which offers the same function as the "U" handle. The requirement here is for design

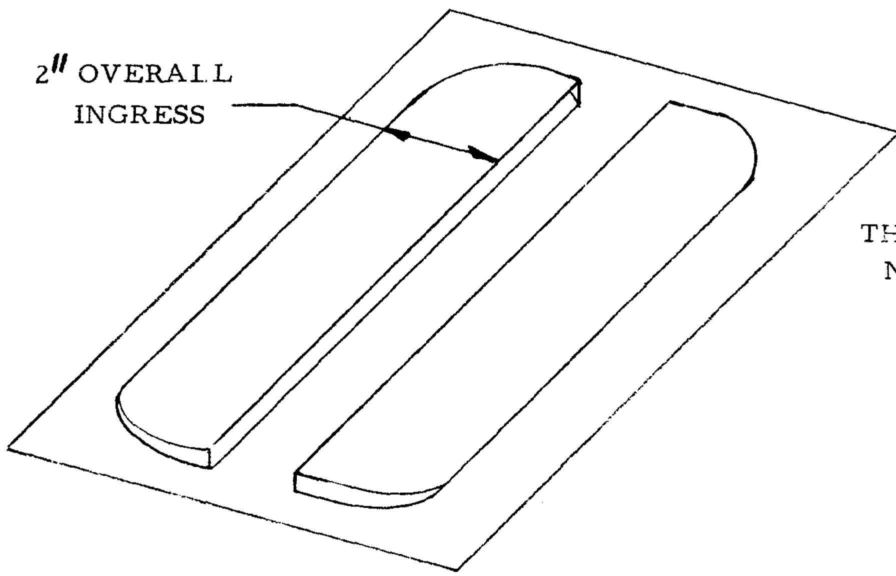
FIGURE 2.5-1



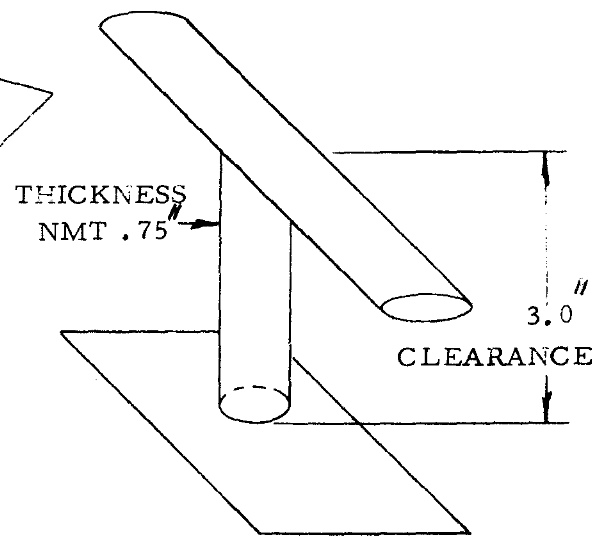
"U" HANDLES



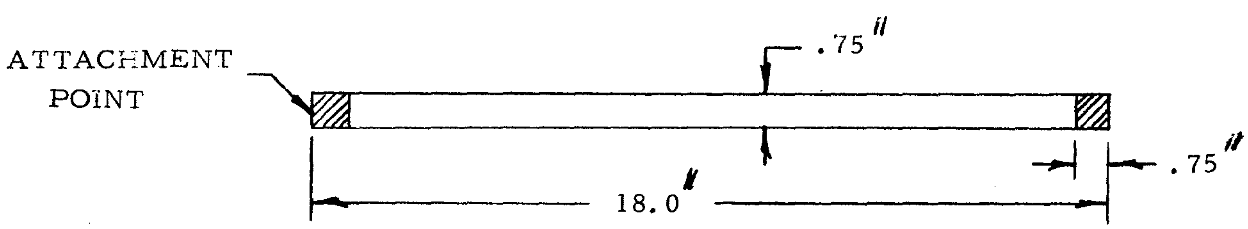
PULL RINGS



RECESSED HANDLES



"T" HANDLES



CARRYING STRAPS (FABRIC)

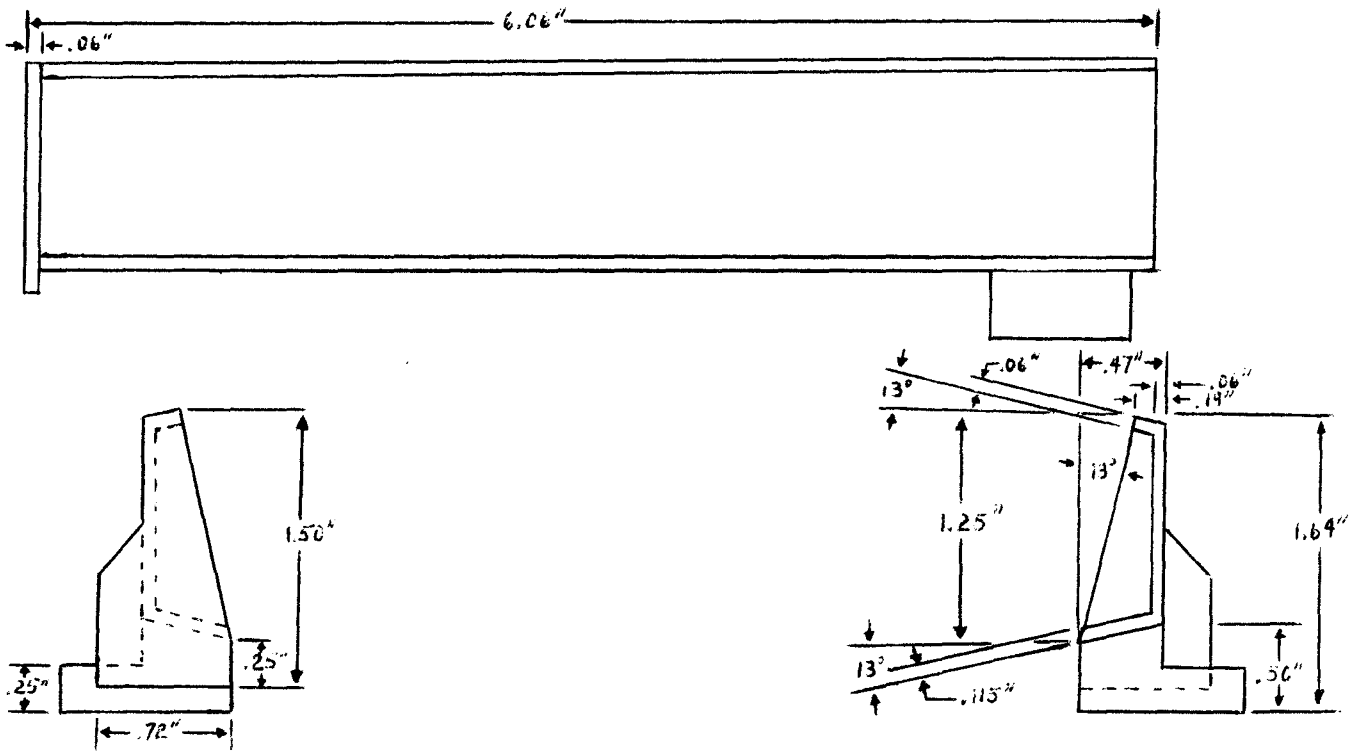


FIGURE 2.5-2

OPERATING HANDLE

of the carrying strap such that it will spring out, once it is free from the stowed position, far enough to allow gloved hand ingress within the strap loop.

(5) Pull Rings

The pull ring is used primarily to release bonding strips or adhesive devices used for holding packages or components together prior to deployment. A secondary utilization for pull rings is in the release of pull-to-release type fasteners when the pull-to-release force is less than 5 lbs.

(6) EASE Operating Handles

Where astronaut manipulative operations such as fastener-release, package leveling and alignment, etc. are required the EASE Operating Handle is the preferred design. The modified "C" shape in cross section permits an optimal interface with a metal plate in the palm of the EMU glove, when the handle is gripped with the right hand. Figure 2.5-2 contains the appropriate configuration and dimensions.

2.6 Release Mechanisms

The inadvertent actuation of dust cover release mechanisms, etc., while the astronaut is in the immediate vicinity, could conceivably present a hazard to the astronaut. Therefore, a standardized design for release mechanisms should incorporate the following features:

(1) Pyrotechnics shall not be utilized in the design unless protected by circuitry as outlined in paragraph 4.3.

(2) Time-actuated mechanisms are recommended in preference to temperature-actuated mechanisms.

2.7 Temperature-Indication

High temperatures have two separate affects on the astronaut interface. First, high heat input to the EMU will directly increase consumption rates of PLSS consumables and, therefore, diminish excursion stay times. Second, the Apollo Block II EMU has a temperature design limit of $\pm$ 250° F. For the present design concept of the EASE program no temperatures outside this range are anticipated. However, due to the criticality of this constraint, temperature-indicating labels should be employed and the following label is recommended for this application:

Tempilabel 4B-175
(Irreversible temperature indications at 175, 200, 225, and 250^{o}F)

Manufacturer: Tempil Corporation
132 West 22nd Street
New York, New York

2.8 Elimination of Sharp Edges

Where material thickness in the design of the EASE packages prevents the provision of the minimum 0.030 inch radii on all edges and corners, which is required to ensure the integrity of the EMU, use of the following Teflon tape is recommended:

Teflon film tape, type T

Manufacturer: Connecticut Hard Rubber Company
New Haven, Connecticut

3.0 DESIGN GUIDES

3.1 Astronaut Deployment

In addition to recommendations contained in the preceding paragraphs, there are other specific recommendations that the designer should consider.

The EASE packages shall be capable of being extracted from the LM, transported to the deployment site (30 feet from the LM Descent Stage ladder and in the field of view of the two ascent stage cabin windows), and deployed on the lunar surface by one member of the flight crew.

The time required for EASE extraction from LM, transportation to the deployment site, and deployment of the packages shall be minimized consistent with mission requirements and the metabolic constraints imposed by the Portable Life Support System (PLSS) (i.e., no task requiring an expenditure rate in excess of 1600 BTU/hour for continuous operation, 2000 BTU/hour for a period of 5 minutes, or a total integrated metabolic expenditure of 4800 BTU).

4.0 SAFETY

The prime consideration in any design for the lunar environment is the reduction of hazards to an absolute minimum. This consideration should be assumed to have the highest priority.

4.1 Thermal Hazards - See paragraph 2.7.

4.2 Hazardous Voltages - N/A

4.3 Explosive Hazards

(1) No Category "A" or "B" ordnance devices will be utilized in the design of the astronaut interface.

(2) Where actuators and initiators are utilized in the design of EASE they will comply with the following requirements:

(a) They shall be Apollo approved and standardized (ASI).

(b) They shall be incorporated into the system in accordance with the latest requirements for range safety.

(c) They will be protected by at least two non-storable commands from ground.

(d) Firing circuits will be isolated in EASE and must contain protection from induction, stray voltage, and interference from other circuits in the system.

4.4 Mechanical Hazards

Sharp edges and corners and abrasive surfaces should be avoided in the design. The simple removal of all burrs and breaking of all sharp edges is not sufficient to ensure that there will be no degradation of the EMU. As a guide radii should not be less than .030 inch. The utilization of Teflon tape or similar coatings are required for surfaces where metal thickness prevents meeting minimal requirements (see paragraph 2.8). Exposure to hinging surfaces should be eliminated as should exposure to other moving parts that could conceivably pinch or cut the space suit.

5.0 ANTHROPOMETRIC REQUIREMENTS

Consideration shall be given in design of tasks to the following requirements.

(1) Movements of the arms and hands behind the torso Z axis and of the hands near the ears or back of head shall be minimized or eliminated.

(2) Tasks requiring twisting, turning or torso rotation shall be minimized or eliminated.

(3) No task shall be designed to include bending forward more than 25 degrees unrestrained or 45 degrees restrained.

(4) Equipment design will not require the astronaut to assume a kneeling or prone position on the lunar surface.

(5) Torque to be applied by the astronaut in knob turning tasks shall not exceed the forces shown in Figure 5.5-1 for the various knob diameters and grips.

(6) Dynametric forces in excess of 46 pounds for the right hand and 42 pounds for the left hand shall not be required to complete a twisting or torquing task.

(7) All equipment shall be designed so that when it is employed in the carry mode the astronaut's feet are not obscurred from his vision.

(8) Where latching or unlatching is a requirement in the EASE deployment, careful attention shall be paid to providing the optimum latch motion. If design constraints dictate that a twisting motion is necessary, it shall be in the direction of easiest wrist joint movement (adduction).

(9) Manipulative operations requiring the simultaneous use of both the astronaut's hands, other than for simple holding, shall be limited to the area between the waist and shoulders.

(10) Due to the high position and appreciable mass of the PLSS/OPS the suited astronaut's center of gravity is shifted from waist height to shoulder height and, hence, maintaining balance is a serious problem. Figure 5.10-1 contains acceptable reaching and working heights for EASE tasks that reflect the balance problem and EMU constraints.

KNOB TORQUING CAPABILITY* IN PRESSURE GLOVES (EV)

GRIP	KNOB DIAMETER	TORQUE (IN LBS.)
FINGERTIP FUNCTIONAL	.75 1.00 1.25 2.50	3.8 5.2 7.6 9.6
FINGER CURL-AROUND FUNCTIONAL	.75 1.00 1.25 1.50	3.8 5.0 7.2 11.4

* Skirt width (thickness) of all knobs: 1/2 inch. All knobs knurled. (This table will be expanded to include torque for other knob dimensions and types of grip as data becomes available.)

FIGURE 5.5-1

PHYSIOLOGICAL CONSTRAINTS

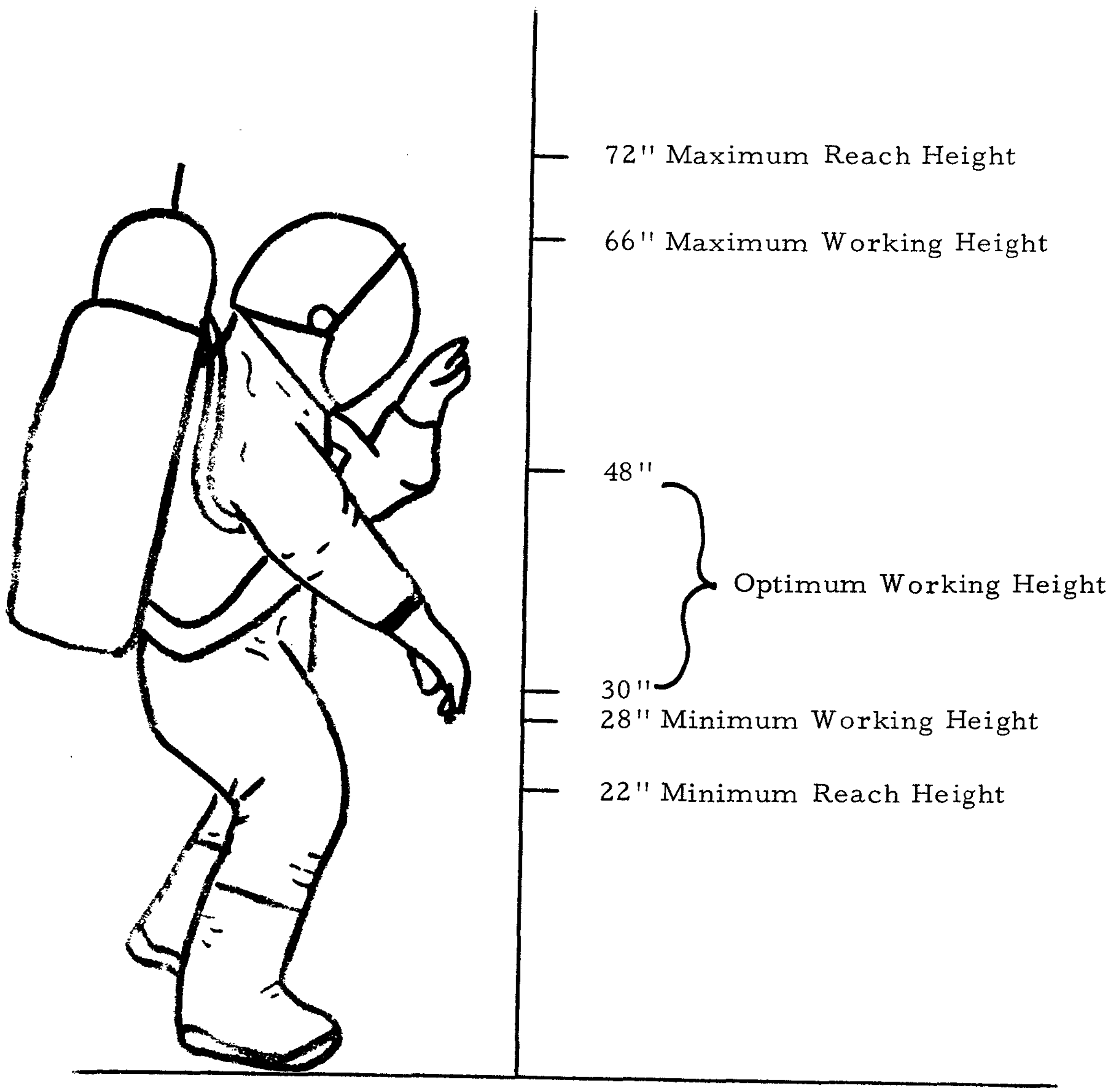


FIGURE 5.10-1
ACCEPTABLE WORKING HEIGHTS FOR EASE TASKS

6.0 DESIGN RECOMMENDATIONS FOR VISUAL TASKS

The following factors should be considered:

(1) Numerals and letters should be sized as large as other constraints permit. However, character height should be no less than 0.34 inch. The width-to-height ratio of the character should be at least two to three. The stroke width of the character should be about one-sixth of the character height. Character separation should be no less than the stroke width of the characters employed.

(2) The design of numerals and letters should be without flourishes. Block numerals and letters are preferred. Openings and breaks should be readily apparent. See Figure 6.2-1.

(3) Graduation mark height should be no less than 0.34, 0.56, and 0.78 inch for minor, intermediate, and major indices, respectively. Graduation mark stroke width should be no less than 0.14 inch. Graduation mark separation should be no less than 0.28 inch. Again, index scales should be sized as large as other constraints permit to facilitate astronaut tasks and avoid errors. The number of graduations between numbered points should not exceed four.

(4) The following numerical progressions are preferred: 1, 2, 3, 4, 5; 5, 10, 15, 20, 25; or 10, 20, 30, 40, 50.

The following numerical progression is rated as "fair": 2, 4, 6, 8, 10.

The following numerical progressions are unacceptable: 3, 6, 9, 12, 15;* 4, 8, 12, 16, 20; or 0, 2.5, 5.0, 7.5, 10.0.

*Except for bearing dials where cardinal directions are standard orienting points.

(5) Pointers and scale indices should be oriented so that the pointer is close to the index and yet does not cover numerals or graduation markings (i.e., 0.063 inch maximum). The pointer tip should be the same width as the graduation markings (i.e., 0.14 inch minimum). The pointer and scale index should be sized i.e., in depth and mounted nearly flush so that visual parallax is minimized. The pointer should be the same color as numerals and indices.

ABCDEFGHI
JKLMNOPQR
STUVWXYZ

1 2 3 4 5
6 7 8 9 0

These should be changed. Too easy to confuse! —Could be changed to:

6 and 9

or: 6 and 9

FIGURE 6.2-1
NUMERAL AND LETTER DESIGN

(6) Color contrast in order of preference, for the purpose of providing markings, etc., are as follows:

(a) Black on white.
(b) International orange on white.
(c) White on black.
(d) White on international orange.

Paragraph 2.4 recommends an international orange thermal control lacquer and an acceptable thermal control ink for the purpose of color-coding.

(7) Surfaces involved in the astronaut interface (i.e., carry handles) should be painted international orange, wherever possible, since tests have shown that a certain "graying-out" occurs under lunar lighting conditions associated with the use of the gold-plated EMU visor.

(8) Hazardous areas should be color-coded red-on-white or solid red.

(9) Physical design of modules should provide clean lines with correspondingly clear contrast. Marking or coloring of adjustment surfaces or edges will appreciably enhance contrast and simplify the astronaut's task.

(10) The gold-plated visor design attenuates 80-90% of visible transmitted light, 65% of the near I-R and far I-R frequencies, and limits UV transmittance to 5%. Even though the visor effectively attenuates the amount of transmitted light, a serious attempt should be made to minimize the amount of glare associated with EASE. Second surface mirrors should be avoided or covered while the astronaut is on the lunar surface. Similarly, solar cell and LRRR panels should be deployed following astronaut departure or provided with removable covers that are timed to self-deploy after LM descent. White, matte, thermal control paint is the preferred medium of thermal control. Gold, rather than silver, mylar should be employed where the use of a white, matte, thermal control paint is not practical.

(11) Equipment design (i.e., through the use of high reflective surfaces) and task selection (i.e., having the astronaut facing eastward toward the sun) which require the astronaut to place himself in such a position that the full intensity of the sun will fall within his range of vision should be avoided. The degree of the problem is indicated by the fact that white paper in a good reading light only reflects 20 mL, whereas the sun (when viewed from the atmosphereless lunar surface) has a luminance of the order of 700,000,000 mL.

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