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* CREW TRAINING MANUAL

LUNAR COMMUNICATIONS RELAY UNIT

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FOREWORD

This LCRU Crew Training Manual is provided by RCA to the NASA Manned Spacecraft Center under Contract NAS 9-10660. The document is in response to SE-C-0043A, paragraph 5.3e.

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1.1 INTRODUCTION

The Lunar Communications Relay Unit (LCRU) is the principal communications link between the EVA's and the manned space flight network (MSFN), during extended extra-vehicular activity on the lunar surface. The LCRU provides the capability of two way voice communications between the crew and flight controllers, transmission of crew biomedical data, PLSS subsystem status, LCRU subsystem status, and color television transmission. The LCRU also provides relay of commands to the Ground Commanded Television Assembly (GCTA), and enables the flight controllers to remotely operate several LCRU configurations when in the TV RMT mode. The LCRU may also be employed along with the LM communications systems when the crew activity is in close proximity to the LM spacecraft. In the LM/LCRU configuration the LM is used for normal voice/data transmission and the LCRU for television.

The following list summarizes the telecommunication functions:

- o Duplex voice of astronauts via VHF AM to LCRU and LCRU to MSFN via S-Band
- o Telemetry data (PLSS and LCRU) to MSFN via S-Band
- o Television, GCTA to LCRU via hardline, to MSFN via S-Band
- o Flight controller's voice MSFN to LCRU via S-Band, and LCRU to astronauts via VHF AM.
- o Command data MSFN to LCRU via S-Band, and hardline LCRU to GCTA

1.2 FUNCTIONAL DESCRIPTION

The LCRU is comprised of the subassemblies shown in figure 1-5. The VHF group consists of an omni antenna, triplexer, VHF/AM transmitter, and VHF receiver. The S-Band section is comprised of two groups, one group employs a low gain helical antenna, diplexer, S-Band PM transmitter (dual modulator), and PM S-Band receiver. The other group is composed of a high gain deployable parabolic antenna, diplexer, S-Band FM-PM (dual modulator) transmitter and PM S-Band receiver.

1.2 (Continued)

A down link signal processor (DLSP) conditions the baseband signals for transmission over the S-Band links for each individual mode. The uplink signal processor (ULSP) conditions the ground controller's voice for transmission over the VHF link.

A detailed functional configuration is shown in figure 1-6. The EVA voice and data are received on the VHF link and combined with the LCRU status data (29 VDC bus voltage and radiator temperature). The composite voice and data are then conditioned for use in four modes. The S-Band links employed with the low gain antenna include the PM1/WB mode (the path employing the 1.25 MHz SCO) and the baseband PM1/NB mode.

The S-Band links employed with the high gain antenna include the PM2/NB mode, FM/TV mode, and the TV RMT mode. Note that upon command received from the GCTA the 1.25 MHz SCO and/or the FM/PM transmitter may be turned on or off when the LCRU is in the TV RMT mode. This enables power management of the LCRU during periods requiring no television transmissions.

The up-link signal from MSFN may be received over either S-Band group, except that the 70 KHz command subcarrier is available only via the high gain transceiver group. The received signal from MSFN is processed to separate the up link subcarriers (124 KHz for voice, 70 KHz for commands) from the S-Band carrier. The voice signal is processed to enable modulation of the VHF transmitter and provide operation via VOX.

1.3 MAJOR COMPONENTS

The LCRU Subsystem is comprised of four major components: LCRU Unit, Battery, Low-Gain Antenna, and High-Gain Antenna as outlined in the following paragraphs.

1.3.1 LCRU Unit

The LCRU Unit is a rectangular assembly 22 x 16 x 6 inches pressurized to 7.5 psia. The earth weight of the unit is 55 lbs; the effective lunar surface weight is 9.2 lbs. The predominant exterior features of the unit include a protective thermal blanket, radiating mirrors, a control panel, power/signal connector, S-Band antenna connectors, VHF omni antenna, and battery access compartment (Figure 5-1). An exploded view of the LCRU with bottom cover removed, Figure 5-1A, shows the packaging of the VHF RF equipment, the S-Band equipment, control panel, signal processing, and battery compartment. The LCRU Unit, being the principal assembly, is composed of sub-assemblies as described in the subparagraphs below.

1.3.1.1 Thermal Controls

The LCRU employs a passive thermal control system which comprises three elements as follows:

(1) Thermal blanket to insulate the unit from external environment.

(2) Secondary surface radiating mirrors, 196 sq. in. area, to reflect undesired solar heat and emit undesired heat generated within the LCRU

(3) Change of phase (wax) material to absorb excess heat and stabilize unit temperature via an absorption-discharge cycle (melt-freeze mode of wax).

The thermal blanket is configured to allow modification of the thermal control by the amount of radiation surface exposed to deep space.

(1) Zero exposure - blanket fully enclosed

(2) Total exposure - blanket fully open

(3) Partial exposure - blanket open either 35% or 65% as marked on blanket panels.

1.3.1.2 RF Electronics Equipment Group

The LCRU RF electronics equipment group includes the telecommunications equipment transmitters, receivers, diplexers and signal processing. The antennas associated with the VHF or S-Band equipment are covered separately.

1.3.1.2.1 VHF AM Transceiver

The VHF transceiver provides the RF interface between the astronauts and the LCRU. The receiver and transmitter are coupled to the antenna by means of a triplexer. The receiver operates at a center frequency of 259.7 MHz over an RF input range of -88 to +6 dbm. The receiver provides for reception of the amplitude modulated voice and four EMU subcarriers from EVA-1. At RF input levels below -88 dbm data dropouts and degradation of voice will occur. The receiver employs squelch quieting for low level RF inputs, the squelch range is between -106 dbm and -118 dbm.

The VHF transmitter is amplitude modulated 70% and VOX operated by the ground controller's voice. The transmitter delivers 320 milliwatts CW at a frequency of 296.8 MHz. The VHF transceiver is energized in all LCRU modes, but it would not be utilized in the TV RMT mode.

1.3.1.2.2 S-Band Transceivers

The S-Band transceivers provide the RF interface between the LCRU and the ground controller. Transceiver Number 1 contains a PM/PM transmitter and a PM receiver coupled to the LGA via a diplexer. The transmitter, which contains two selectable modulators, delivers a nominal RF power of 6 watts. Modulation scheme is selected by the S-Band mode switch. PM1/WB mode provides the EVA voice and data sub-carriers as a frequency modulated signal on a 1.25 MHz subcarrier, with the 1.25 MHz S.C. phase modulated onto the 2265.5 MHz carrier. PM1/NB mode provides the EVA voice and data subcarriers as a direct phase-modulated signal onto the 2265.5 MHz carrier. The modulation information in either mode is as follows:

- o Voice either EVA_1, or EVA_2
- o 3.9 KHz subcarrier, EVA_2 EKG data
- o 5.4 KHz subcarrier, EVA_1 EKG data
- o 7.35 KHz subcarrier, EVA_1 PLSS status
- o 10.5 KHz subcarrier, EVA_2 PLSS status
- o 14.5 KHz subcarrier, LCRU temperature and voltage status

The receiver in S-Band transceiver number one accepts the common LM/LCRU uplink carrier of 2101.8 MHz. The 124 KHz uplink subcarrier is phase demodulated from the S-Band carrier, and the receiver then frequency demodulates the controller's voice from the subcarrier. The receiver has a sensitivity of -97 dbm for a nominal SNR of 30 db. The receiver has a dynamic range of -97 dbm to -65 dbm. Audio Quieting is provided by a primary squelch circuit which triggers on out-of-band noise at a nominal -101 dbm. Audio Subcarrier squelch is also employed to maintain quieting in the absence of the 124 KHz subcarrier, as would be the case for the uplink mode using the LM voice 30 KHz uplink subcarrier. The subcarrier squelch is active from -65 dbm down to a level overlapping the primary squelch.

The S-Band transceiver number two contains a FM/PM transmitter and a PM receiver coupled to the HGA via a diplexer. The transmitter contains two selectable modulators and delivers a nominal 8 watts. Modulation scheme is selected by the S-Band mode switch. PM2/NB is identical in characteristics to PM1/NB except for RF power output. FM/TV provides EVA voice and data as a frequency modulated signal on a 1.25 MHz subcarrier which is combined with baseband video from the television camera. The FM/TV mode

1.3.1.2.2 (Continued)

will contain video only when the television camera has been commanded ON by the ground controller or astronauts.

The TV RMT mode provides flexibility beyond FM/TV since it allows for video and voice-data transmission, video transmission alone, or stand-by. In standby no transmission is executed, but up-link reception is available to accept commands from the ground controller.

The PM receiver in S-Band transceiver number 2 is identical to number 1 except a 70 KHz subcarrier circuit is provided to handle up-link commands to the GCTA. The 70 KHz output SNR is greater than 10 db for an RF input of -97 dbm.

1.3.1.2.3 Signal Processor

The LCRU contains two signal processors; one handles down link telecommunications and the other, up-link. The down-link signal processor provides the interface between the VHF receiver and selected S-Band transmitter. The voice and data demodulated by the VHF receiver are processed as a composite baseband signal to match the transmission requirements as follows:

- o PM1/NB - Set level to deviate narrow band PM transmitter to match MSFN baseband requirements
- o PM1/WB - Set FM level on 1.25 MHz S.C., and set level of S.C. to deviate wide band PM transmitter to match MSFN 1.25 MHz I. F. and baseband requirements
- o PM2/NB - Same as PM1/NB
- o FM/TV - Set FM level on 1.25 MHz S.C., set level of video, set level of composite video/subcarrier to match MSFN demodulator and baseband requirements
- o TV RMT - Same as FM/TV

The down-link signal processor contains the two 1.25 MHz subcarrier oscillators as an integral portion of the pre-modulation processing circuits. The 14.5 KHz subcarrier which carries the LCRU status data and the associated time share commutator are included in the signal processor. The LCRU status data is combined with received EVCS data, and the composite EVCS/LCRU baseband is set to the pre-modulation level required for transmission.

The up-link signal processor provides the interface between the S-Band receiver and VHF transmitter. The received baseband voice is processed to drive the VHF transmitter to 70% amplitude modulation. The processing includes VOX, automatic gain control to maintain modulation level, and a nominal 12 db of clipping.

The VOX threshold is a nominal 18 db below the nominal level of the ground controller's voice. Below VOX threshold the VHF transmitter is keyed OFF, and above threshold it is keyed ON. The VOX attack time is less than 10 milliseconds; release is a nominal one second.

1.3.1.2.4 Instrumentation

The LCRU is instrumented with a visual monitor to display the 29 VDC bus voltage, thermal radiator temperature and S-Band received signal strength (AGC). The LCRU contains voltage busses of 16.8, 10, 14, and 29 VDC, but only the 29 VDC bus is monitored since the primary purpose is for battery status. The temperature and voltage are also telemetered during data transmission on the 14.5 KHz subcarrier in all modes except when the 1.25 MHz SCO is commanded off in the TV RMT mode. The instrumentation characteristics are as follows:

Item	Range	TLM	Meter
Voltage	25 to 33 V	±0.3 VDC	±0.5 VDC
Temperature	35° F to 120° F	±5° F	±10° F
AGC	-65 o -105 dbm	N/A	±5 db

The telemetered status of bus voltage and radiator temperature are identified by the time duration of signal as follows:

Voltage - 20 seconds nominal

Temperature - 10 seconds nominal

A pressure sensor is located within the LCRU pressurized compartment to verify 7.5 psia pressure prior to prelaunch MESA installation.

1.3.1.2.5 Voltage Regulators

The LCRU contains a DC-DC converter which is employed when operating on external power from the LRV. The converter operates over an input range of 32 to 44 volts DC and provides two outputs: 28.5 and 16.5 volts D.C. In addition the LCRU employs a redundant low voltage regulator which operates from the 16 volt bus to provide regulated 14 and 10 VDC.

The bus lines usage for each subassembly is identified in the following table:

	29V	14V	10V
S-Band transmitters	x		
S-Band receivers		x	
VHF transmitter		x	
VHF receiver		x	x
Down-link signal processor		x	x
Up-link signal processor		x	

1.3.2 Battery

The LCRU internal power source is a 19 cell primary battery of the silver-zinc type utilizing a potassium hydroxide electrolyte. The battery weighs 9 lbs (1.5 lbs moon weight), and has a rectangular case 4.7 x 9.4 x 4.65 inches, which is pressured to 8 lbs differential. This 8 psid is maintained in the presence of a vacuum by venting through a relief valve. The battery shown in Figure 4-5 contains a spring loaded handle for easy removal and installation. The rear end of the battery contains mounting alignment pins, a pressure relief valve, and a push-pull connector which mates with the battery compartment connector when the battery is pushed into place. Installation of the battery in the LCRU housing is shown pictorially in Figure 4-6.

The battery capacity is rated at 400 watt hours at an operating temperature between 35° F and 130° F. The battery delivers a nominal 29 volts at a nominal current of 3.10 amperes and is tapped to provide 16.8 volts at 0.75 amperes.

The unit is normally stored dry with a shelf life capability of three years. After activation, the wet stand life is limited to 21 days, 8 hours.

The battery terminal voltage when a load is first applied will be a nominal 33 volts. After the initial discharge period, the battery voltage will maintain a plateau voltage of 29 volts. The last 30 to 45 minutes of battery life will exhibit a degradation in terminal voltage as shown in Figure 4-6A.

1.3.3 Low Gain Antenna (LGA)

The low gain antenna is employed for voice-data telecommunications in mobile operation on the LRV, in stopped LRV operation when HGA is not deployed, or in the handcarry configuration. The antenna is designed with a helical feed, cup type reflector and right hand circular polarization. The unit has a nominal bandwidth of 200 MHz to cover the transmit and received frequencies and a power handling capability of 25 watts. The antenna gain is nominally 10 db on boresight for both transmit and receive. The off axis gain is as follows:

Transmit:	8 db over 30° cone
	6.5 db over 60° cone
Receive:	6 db over 60° cone
	-5 db over 120° cone

The mechanical configuration of the antenna is shown in Figure 4-3. The overall length, less mounting staff, is 9.32 in.; the feed diameter 1.54 inches; and the reflector diameter 5.13 in. The antenna weight is 0.65 lbs; with positioning mechanism, cable and staff the total weight is 2.45 lbs. The antenna contains a thermal coating of white paint.

The antenna is pre-assembled prior to stowage as shown in Figure 4-3. Installation of the assembly on the LRV/LCRU requires insertion of the staff into the LRV left inboard handhold and mating the blue color coded RF connector with the LCRU LGA connector using the alignment mark. The antenna elevation (lunar surface to earth) is set by unlocking the elevation adjustment lock, tilting the antenna at pivot point to desired elevation angle, and re-setting the lock. The elevation angle scales in 10° increments from 0 to 90° are marked in red on pivot assembly rotor. The Azimuth adjustment is executed by rotation of staff handle about the staff axis. The spline adjustment, made by pushing the staff downward and rotating, should not be used since the pointing increments are too coarse.

The antenna is removeable from the staff for use in the handcarry mode. Depressing the release button unlocks the antenna from the staff. The antenna is then withdrawn from the staff while maintaining pressure on release button. The antenna then may be mounted

1.3.3 (Continued)

in the castellated receptacle located in the top right front corner of the LCRU unit as shown in Figure 4-16. The antenna cable may be coiled as shown and fastened with the velcro. Adjustment of antenna elevation in handcarry is same as described previously. The azimuth adjustment requires removal of antenna stem from splines and resetting as desired.

1.3.4 High Gain Antenna

The high gain antenna is employed for television useage when operating the LCRU at a fixed site. The antenna is of the deployable type designed with a cup-helical feed, three foot parabolic rib-mesh reflector and right hand circular polarization. The antenna has a nominal bandwidth of 200 MHz to cover the transmit and receive frequencies and a power handling capability of 20 watts. The antenna gain is nominally 24 db on boresight, 23.5 db over a 5^{o} cone and 20.5 db over a 10^{o} cone.

The mechanical configuration of the antenna is shown in a fully stowed state in the exploded view of the stowage container, figure 4-2. The antenna is fully assembled to its mast, with its cable and optical sight pre-assembled. In the stowed state, the unit is folded at the hinge plate. The antenna assembly weight is nominally 10 lbs (1.7 lbs moon weight).

The antenna assembly mechanical details are shown in Figure 4-4, the mast is shown in unfolded state and parabolic reflector is closed.

The lower end of the mast contains a tapered shaft which fits into a hole on the left side of the LRV bumper. An alignment indicator is marked in red to allow for ease of insertion. The bayonet collar is rotated clockwise to lock mast in place. The mast extension lock wheel provides a friction lock on the telescoping mast. When unlocked, the mast may be extended to a height suitable for easy viewing of the sighting device. The lock wheel unlocks with counter clockwise rotation, and locks clockwise.

The antenna dish unfolds from its stowed state by pivoting at the hinge plate joint. A spring loaded lock located at the hinge plate maintains the antenna in the upright position.

The deployment collar is used to open the parabolic reflector. CCW rotation (nominal 30°) unlocks deployment collar, and a slight pull back on the collar deploys the reflector to full open position. The collar when rotated CW locks the reflector open. Directional arrows on collar are noted in red.

1.3.4 (Continued)

The HGA connector at the end of transmission line is marked in red. The connector is also marked with an alignment indicator to allow ease of installation at the LCRU HGA connector port (also color coded red).

Mechanical pointing of the antenna is provided by tilting of the pointing handle in azimuth and elevation. The antenna assembly is free to move about a ball joint located below the hinge plate. The ball joint tension is operated by two controls. The lock bar locks the joint from further movement. The friction knob provides a drag adjustment of the joint as desired by the operator.

The positioning handle may be employed in several configurations, dependent on earth elevation as shown in Figure 4-8. The photograph on left shows the positioning handle for normal use, for earth elevation angles of 0 to 80^{o}. The center photo shows handle in position for earth elevation fully vertical. Note that handle has been removed and relocated in a different socket available on positioning mechanism. The photo at right shows an alternate position employed when earth position requires orientation toward front of LRV.

Boresighting the HGA to the earth requires an optical aid since a full earth subtends an angle of less then 2^{o} when viewed from the lunar surface. Figure 4-8 shows the position of the optical sight for three antenna orientations. A close up view of the sight is shown in Figure 4-9. The sight contains an objective lens, mirrors and ground glass viewing screen. A calibrated reticle is visible at the viewing screen for centering the earth's image. A sector mask is supplied to provide blockage of the sun when earth-sun images are in close proximity. The sector mask may be rotated to the desired position by rotation of the sight hood. The mask is not required for the Apollo 15 launch site and probably will not be required for subsequent missions unless Marius Hills is selected. The mask will be removed prelaunch if it is not required. During high ambient lighting conditions on the viewing screen, the hood may be extended toward the viewer to reduce incident light. A combination filter/dust cap is provided at the objective lens. This serves the purpose of preventing dust accumulation on the objective lens and provides reduction of glare for the special case where the sun is used as a target in lieu of the earth (earth-sun angles less than 4°).

1.3.4 (Continued)

The reticle provides a nominal 18^{o} viewing angle as seen in Figure 4-10. Each scale on the reticle represents 3^{o}. The bulls-eye circle presents 3^{o} of viewing area. When the earth image is centered in the bulls-eye, the antenna is essentially boresighted, Figures 4-11 and 4-12. Typical appearance of reticle-sector mask combinations are shown for close proximity earth sun angles in Figures 4-12 to 4-14.

1.4 SYSTEM COMMUNICATIONS LINKS

The system RF links employed during an EVA sortie are shown in figure 1-1. The LMP (EVA-2) utilizes the 279.0 MHz channel for transmission of voice/data, the 259.7 MHz channel for reception of CDR's voice (EVA-1) and the 296.8 MHz channel for reception of ground controller's voice. The CDR employs the 259.7 MHz channel for transmission of voice/data the 279.0 MHz channel for reception of LMP voice/data, and the 296.8 MHz channel for reception of ground controller's voice.

The LCRU receives the 259.7 MHz signal from the CDR and relays the voice/data information to MSFN via S-Band, 2265.5 MHz. When employing television, the voice/data information is combined with the television signal on the same S-Band carrier.

The ground controller's voice and command data is sent from the MSFN to the LCRU via the 2101.8 MHz S-Band carrier. The command data subcarrier is hardlined from the LCRU to the GCTA. The voice is relayed from the LCRU to the LMP and CDR via the 296.8 MHz channel.

The LCRU is designed for use in four major configuration:

(1) Mobile (on LRV)

(2) Fixed base

(3) Remote (via ground controller) during LM ascent.

(4) Hand carry mode (Contingency)

1.4.1 Mobile

The LCRU when operated mobile with the LRV employs the link configuration shown in figure 1-2. The crew inter-communication employs the EVCS-dual mode and the EVA to earth communication employs the LCRU as relay in PM1/WB or PM1/NB mode. The S-Band link requires use of the low gain antenna (LGA) manually pointed to earth within the 60° antenna beamwidth. Television transmission is not used during mobile operation. In event of transceiver No. 1 failure, the LGA can be connected to the HGA diplexer port, and PM2/NB mode utilized.

1.4.2 Fixed

The LCRU when operated fixed base with the LRV employs the link configuration shown in Figure 1-3. The crew intercommunications employs the EVCS dual mode, and the

1.4.2 (Continued)

EVA to earth communication employs the LCRU as relay in the FM/TV mode or PM2/NB mode, (contingency). The S-Band link requires use of the high gain antenna (HGA) accurately pointed to earth within a 5° beamwidth by use of the optical sight. Deviation outside the 5° beamwidth will considerably degrade the television and voice/data transmission. If TV is not required, the LGA can be utilized in the PM1/WB mode or PM1/NB mode (contingency).

1.4.3 Ascent TV

The LCRU may be operated remotely by the ground controller during ascent of the LM spacecraft (see figure 1-4). The LCRU and LRV are deployed as indicated in paragraph 1.4.2 except that the TV RMT mode is used since the operation must be unmanned. Deployment in this case will be pre-set by the crew subsequent to their final sortie and prior to LM ingress. This mode may also be used for television transmission during and EVA in the vicinity of the spacecraft while employing the LM communications as relay for voice and PLSS status.

1.4.4 Handcarry

The LCRU may be employed in a handcarry mode for contingency use (see figure 4-16). Operation is similar to the mobile LCRU case but requires orientation of the low gain antenna (LGA) referenced to the direction of crew travel, e.g., forward orientation for frontal view of earth, rearward orientation when view of earth is behind crew. The PM1/NB mode is the optimum configuration since it will allow greater pointing in the LGA orientation.

1.5 CONTROLS AND DISPLAYS

Controls and Displays	Function	Remarks
1. Monitor Meter Switch	Selects one of three functions displayed on the monitor meter.	
POWER	29 VDC bus voltage	
RAD TEMP	Radiator temperature	
S-BD AGC	S-Band received signal strength.	
2. Monitor Meter	Provides measured display over range of 0 to 5 with five subdivisions between the major devisions	Meter face contains radio luminescent background and black pointer.

1.5 CONTROLS AND DISPLAYS

Controls and Displays	Function	Remarks
3. Monitor Meter Legend	Converts meter reading to engineering units	
°F	Value of radiator temperature	
V	Value of bus voltage	
AGC	Satisfactory range of S-BD AGC in meter units	
LIM	The permissable range of operation in meter units.	Low value in meter units denotes minimum and high value denotes maximum.

1.5 CONTROLS AND DISPLAYS

Controls and Displays		Function	Remarks
4. S-Band Mode Switch		Selects operating mode of S-Band Transceivers	
	PM1/NB	Contingency mode employed with LGA. Provides down-link voice and data and up-link ground controller's voice.	This mode useable during traverse on LRV or in hand carry mode.
	PM1/WB	Primary mode employed with LGA. Provides down-link voice and data and up-link ground controller's voice.	This mode useable during traverse on LRV, or in hand-carry mode, or fixed site when TV not required.
	FM/TV	Primary mode employed with HGA Provides down-link voice, data and television, and up-link ground controller's voice and commands to GCTA.	This mode is useable during fixed base operation only.
	TV RMT	This mode employed with HGA. Provides one of the following: (a) Down-link voice-data and television and up-link ground controller's and commands to GCTA.	This mode is useable in fixed base operation only. The various submodes of (a) through (c) are commanded by ground controller.

1.5 CONTROLS AND DISPLAYS

Controls and Displays		Function	Remarks
	TV RMT (Cont'd)	(b) Same as (a) without down-link voice-data.	
		(c) Up-link controller's voice and commands to GCTA	
5. Power Switch			
	INT	Activates LCRU from internal battery	
	EXT	Activates LCRU from LRV batteries	Requires closure of AUX PWR Circuit breaker on LRV console.
	OFF	No power applied to LCRU.	If AUX circuit breaker is closed LCRU draws small idle current in DC-DC converter. (50 MA max.)
6. Circuit Breaker			
	OUT	Opens circuit to 29 volt LCRU bus.	
	IN	Closes circuit to 29 volt LCRU bus.	Circuit breaker opens at overload current between 4 and 7.5 amperes.

1.6 THERMAL CONSIDERATIONS FOR LUNAR CREW TRAINING

Note: This thermal section is intended for familiarization of the lunar astronauts with the LCRU thermal system. It is not definitive enough, nor can it be used as a manual, for mission control personnel who must thoroughly understand the thermal problems involved and supply direction for mission thermal control.

1.6.1 INTRODUCTION

The thermal design for the LCRU consists of a combination of radiation cooling plus thermal phase change material (wax) to provide operational capability. The phase change material provides thermal design margin to accommodate for the effects of lunar dust and unexpected mission anomalies, none of which can be predicted with high degree of certainty, and to reduce astronaut manipulation of the thermal blanket for radiator control. Consideration was also given to other local influences on the LCRU including the High-Gain Antenna, TV Camera and TCU, the Lunar Rover Vehicle, and the thermal conditions during an emergency walk mode.

The LCRU is maintained within the design temperature limits under all specified worst-case environmental conditions. Cooler operation normally occurs since all worst-case conditions are not likely to occur simultaneously nor continue for an extended period. Further thermal safety margin is obtained by the LCRU radiator cover control which allows radiator opening in increments of 35%, 65% and 100%. Under worst-case hot conditions, 35% and 65% opening between sorties maintains satisfactory operating temperatures.

1.6.2 RADIATION COOLING

There are three major components to the LCRU temperature control system. The primary mode of heat rejection from the equipment is through the radiator which is located at the space-looking side (top) of the LCRU. This radiator uses second surface mirrors which allow minimum solar absorption while effectively radiating in the infrared spectrum. For some mission timelines it is impossible to provide enough radiator surface within the LCRU envelope to completely eject energy dissipated and absorbed in the unit at the upper design temperature limit. If the equipment begins an operating period at a temperature below the maximum allowable for reliable operation, a certain amount of energy can be stored by the specific heat of the components of the equipment. Due to the radiator size limitation, with radiation cooling only the steady state temperature of the equipment is higher than the operational temperature limit for high power and environmental mission time lines.

1.6.3 PHASE CHANGE MATERIAL AND RADIATION THERMAL CONTROL

Utilizing the combination of radiation cooling plus heat capacitance of the equipment does not provide an adequate amount of cooling under high equipment powered up conditions plus hot case lunar environment time lines. The lunar thermal environment uncertainties include the effect of lunar dust on the radiator, the orientation of the radiator during a traverse, and the changing lunar and solar inputs onto the equipment during the mission. Consideration of these factors has resulted in a design in which radiation cooling is supplemented by wax which provides change of phase cooling. The radiation panel is mounted directly on top of a 3/4 in. thick wax package located on the top of the LCRU. There are two additional wax packages located as shown in Figure 5-2. One is between the pressurized electronics compartment and the battery, and the second is located external to the equipment case. The wax changes phase from solid to liquid at a temperature low enough to maintain the equipment within its operational limit. Once all the wax has been liquified the energy dissipated is again limited by radiation cooling, which eventually reaches a steady state temperature level exceeding the operational temperature limit of the equipment under certain hot case conditions. Therefore, if the equipment reaches the maximum allowable temperature, it must be turned off to permit cooldown to a low temperature by radiation cooling.

As shown in Figure 5-1, the LCRU equipment case is completely covered by a thermal blanket to insulate the unit from the external environment. The thermal blanket can be removed from the top in two pieces. The two-piece cover allows the radiator to be completely open for radiation to space during operation and to be partially or completely closed during non-operational periods. It is important that the uncovered radiator be kept as free of lunar dust as possible for efficient performance of the radiator. Frequent cleaning with lunar dust brush during sortie is advisable if dust accumulates on the radiator. Inspection of the radiator at the end of each EVA stop is recommended, with brushing to be performed if dust accumulation is observed on the radiator surface. As a minimum, radiators should be swept clean of dust at the end of each EVA and as requested by MSFN. Since the time between operating periods is much longer than the operating period, there is a danger in over-cooling the equipment during non-operative periods. At the end of each EVA, Mission Control will give direction on radiator coverage for ensuing rest period.

Various lunar mission timelines as in Table 5-1, will subject the LCRU to different thermal conditions requiring adaptive control of the LCRU radiator thermal blanket covers. A typical control procedure which provides proper cooling under certain sun conditions for the timelines of Table 5-1 is shown in Table 5-2.

TABLE 5-1. LUNAR SURFACE TIMELINES - TYPICAL

Timeline #1

Three 7-hour EVA's (6-hour LCRU operation/EVA)

14 hours between EVA's

14 hours "TV-standby" time followed by 30 minutes of TV operation (after final EVA)

Timeline #2

One 5-hour EVA (4-hour LCRU operation), then 14 hours to next EVA

One 6-hour EVA (4-hour LCRU operation), then 13 hours to next EVA

One 4-hour EVA (3-hour LCRU operation), then 5 hours to next EVA

One 4-hour EVA (3-hour LCRU operation), then 14 hours "TV-standby" time followed by 30 minutes of TV operation (after final EVA)

TABLE 5-2. CONTROL PROCEDURE - EXAMPLE

Time	Blanket Setting
First EVA*	Open
First Rest Period	35% Open
Second EVA*	Open
Second Rest Period	65% Open
Third EVA*	Open
Standby	Open

*Sweep radiator with dust broom at end of EVA and as requested by MSFN durng EVA.

1.6.4 PARKING ORIENTATION

A factor greatly influencing thermal system performance is the orientation of the Lunar Rover Vehicle (LRV) in periods between EVA's. This is due to close coupling between the LCRU radiator and the LRV battery covers which absorb large solar inputs in certain LRV orientations. Solar heating absorbed through the instrument panel on the left end of the LCRU also imposes an orientation constraint.

Under worst-case conditions the LCRU will maintain acceptable thermal levels when the LRV is parked with the sun in the rear hemisphere of the LRV (see Figure 5-3). Because of LRV limitations however, the optimal parking angle for the LRV/LCRU is with the sun 90° from the right side of the LRV.

1.6.5 WALK MODE AND WALK-BACK CONSIDERATIONS

The LCRU radiator orientation in the hand-carried mode is vertical so that the radiator has a 0.5 view of the lunar surface in addition to space. If a walking mission is to be performed, the maximum operating time of the LCRU must be known. At low sun angles the equipment capability will not be greatly reduced in walking missions. At high sun angles, the walking time is severly reduced and would be a major factor in mission planning.

The time available for a walk sortie after the LCRU is removed from the LRV during a vehicular sortie depends on the thermal state of the LCRU when deployed from the LRV. Under worst-case conditions there is a minimum of one hour of walk mode continuous operation capability after deployment from the LRV.

Four-hour walk sorties are possible at high sun angles only if most of the sun load is eliminated from the radiator and precautions are taken to assure complete cooldown between EVA's.

The preferred walking mode is with the LCRU radiator looking away from the sun and astronaut. This is especially true at low sun angles when the sun is "looking" directly into the radiator surface and the lunar temperature is low. Both thermal blanket covers are removed for the walk mode.

1.7 OPERATIONAL LIMITATIONS AND RESTRICTIONS

1. Communications Signal Margins - The LCRU, being by necessity a lightweight portable unit, has limited communication signal margins as defined below.

   a. Down-Link Voice/Data - LGA pointing must remain within ±30° of earth. Signal degrades very rapidly beyond that point. When crew dismounts from LRV, LGA should be manually pointed directly to earth. (Rotate staff in azimuth only since elevation is pre-set during initial LRV installation.)

   b. Up-Link Voice- LGA pointing must remain within ±60° of earth. LCRU audio squelch occurs at ±60° such that no voice can be received beyond that point.

   c. EVA/LCRU VHF Range - A range of at least 500 meters is possible. Considering the effect of lunar surface roughness, which will reduce the ground relfection wave, a range of 800 meters may be possible without voice/data degradation. For extended range operation, the EVA traverse should preferably be outward from the front of the LRV to optimize the VHF antenna pattern. At extended range, if the EVA bends over such that PLSS antenna is horizontally oriented, signal degradation will occur.

      When planned exploration includes specific sorties with difficult communications paths, e.g., large obstacles, craters, etc., the particular communications profile should be evaluated prior to flight.

   d. TV Operation - HGA pointing must remain within ±2.5° of earth. This occurs when the earth's image is within the bulls-eye of the optical sight. The video signal will degrade extremely rapidly beyond that point due to the very narrow HGA radiation pattern. When working with partial image of earth, care should be exercised to estimate image center.

2. Operating Times - The LCRU battery has adequate capacity for at least 6 hours of voice/data or 4 hours of voice/data/TV. External power can be supplied by the LRV for backup power. A new battery should be installed in the LCRU prior to the 2nd and 3rd sorties to achieve maximum operating time and to ensure a battery temperature greater than 35° F (the LCRU could possibly cool down below 35° F between the sortie periods).

3. Temperature Limitations - The LCRU radiator/wax packages should maintain the upper thermal temperature at about 120° F. The LCRU can operate above this limit but with somewhat reduced reliability. The low temperature limit is 35° F since the battery voltage will be at its lower limit (27 VDC). By use of external LRV power, the LCRU can operate down to 0° F, but with somewhat reduced reliability. To obtain the necessary efficiency, the LCRU radiator must be kept free of significant dust deposits by use of the dust brush. The LCRU internal temperature is relayed on down-link telemetry and is also available on the control panel monitor meter.

   The LCRU temperature never stabilizes but will cycle between an upper limit (during sortie) to lower limit (between sorties). Proper positioning of the two radiator covers upon ground instruction will be necessary to keep the LCRU within acceptable temperature limits.

4. Voltage Limitation - Lower limit is 27 VDC. A voltage measurement is available on down-link telemetry and on the control panel monitor meter.

5. Handling Precautions - The LCRU is built as ruggedly as possible considering its weight limitations. However, a few precautions are necessary.

   a. When removing the LCRU from the MESA, the radiator mirrors are on the lower surface and could easily be damaged unless the LCRU is lifted up and over the MESA structure and work table. The LCRU is then to be rotated before being placed on the work table so that the radiator is facing up. At all other times, care should be taken to not cause damage to the radiator. No objects should be placed on the LCRU top even if the thermal blanket covers are in place. The radiator surface is identified by markings on the blanket "35%, 65%".

   b. Due to the limited circuit margins, care should be taken not to compress or strain the RF antenna cables and connectors in order not to cause high VSWR with resultant reduction of radiated power. Excessive make and break of RF connections should be avoided.

c. The LCRU electronics compartment is pressurized to 7.5 psia to prevent corona. Care should be taken not to drop the LCRU nor allow it to strike a lunar surface obstacle since a pressure leak might result.

d. Dust caps are used to protect the electrical connectors prior to connections. After the caps are removed, do not allow lunar dust to enter the connector.

e. When releasing GCTA mast lock, hold GCTA to prevent it from falling on LCRU radiator. The GCTA should be tilted away from LCRU to avoid LCRU damage.

f. Test results have shown that a possibility exists of piercing the HGA mesh with the PLSS antenna. While no electrical damage should result, this condition should be avoided if possible.

6. <u>Crew Safety Precautions</u>

a. The radioluminescant paint on the control panel is not a hazard to a suited astronaut.

b. Disconnection of used battery and replacement with spare battery should be performed with LCRU power switch in OFF position.

c. RF radiation from the LCRU antennas does not exceed the 10 milliwatts/CM^2 cautionary level except within 2.5 inches of the LGA helix and the HGA helix feed. Due to the antenna mounting positions and the physical range limitation imposed by the pressure suit, the RF radiation (long term heating effect) is not a hazard.

7. Backup LCRU Modes - No redundent TV mode is available (the TV RMT mode uses the same basic circuits as the FM/TV mode), but 4 modes are available for voice and data. The LGA transmits the PM1/WB and PM1/NB modes, and the HGA transmits the FM/TV (voice included) and the PM2/NB modes. If S-Band transmitter No. 1 should fail entirely, it is still possible to have wide beam (±30°) voice/data by connecting the LGA cable connector to the HGA LCRU connector port. The PM2/NB mode (transmitter No. 2) must be used in this case.

8. <u>LCRU Interface with Back-up EVCS Modes</u> - In the event of an EVCS failure which precludes the use of the normal EVCS A/R mode, one EVCS can be switched to Mode A and the second EVCS to Mode B. In this case, the EVCS in Mode B cannot transmit to the ground or receive communications from the ground via the LCRU, but can communicate directly with the other EVCS. The Mode A EVCS can communicate directly via the LCRU with the ground and with the Mode B EVCS. "Backup Mode No. 1" puts the CDR in Mode A.

2.0 MALFUNCTION PROCEDURE

Will Provide Later

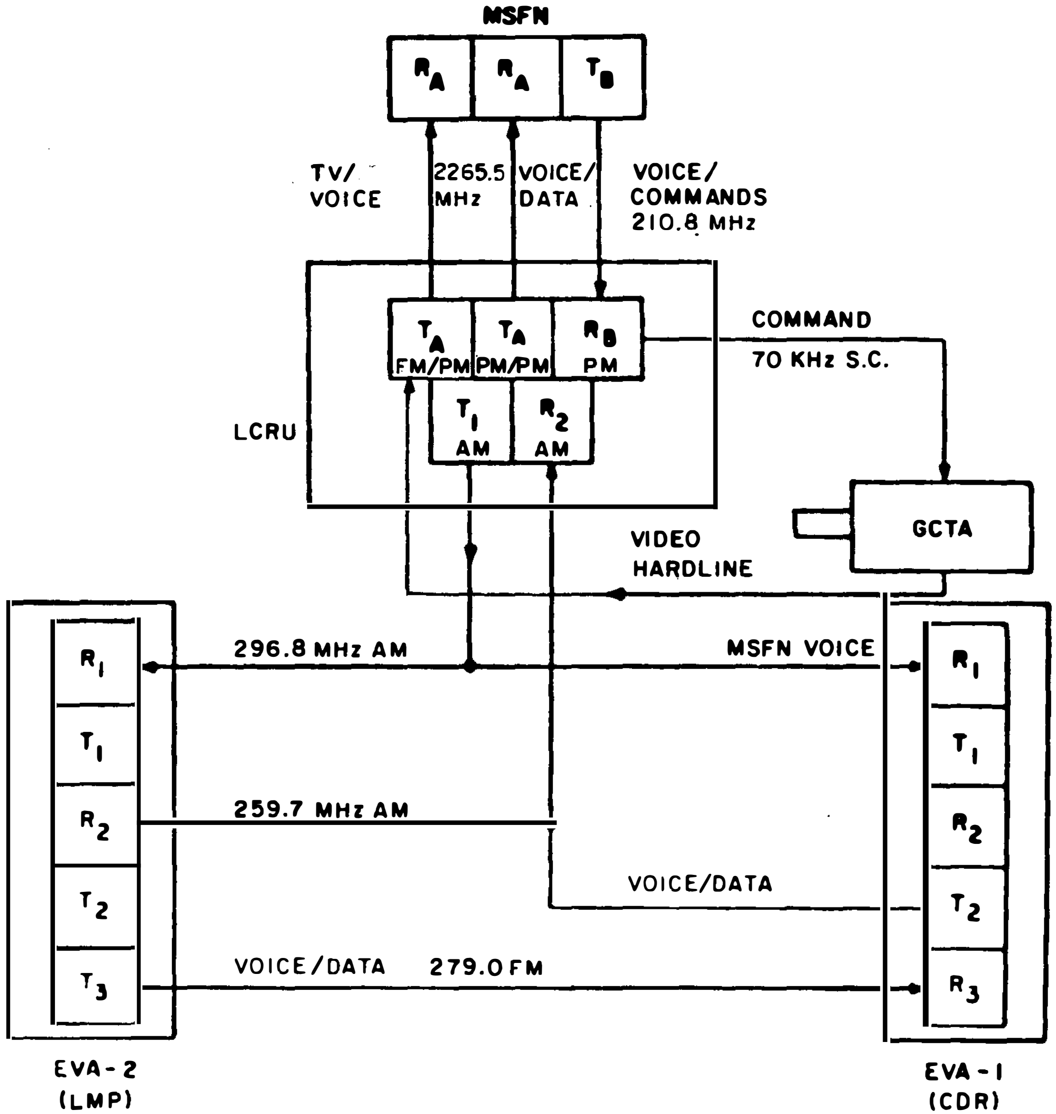

Figure 1-1. System Communications Links

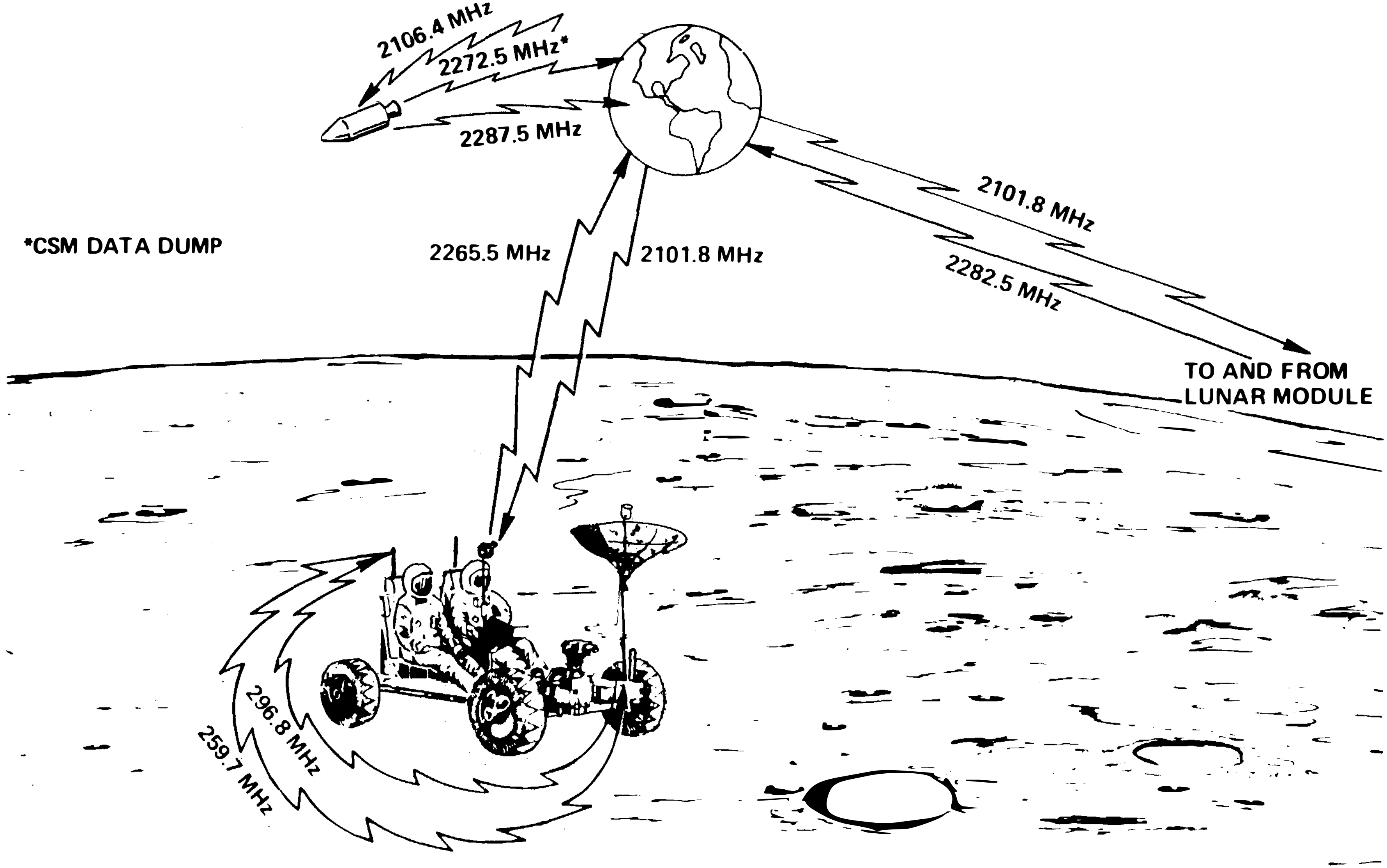

Figure 1-2. LCRU In Mobile Operation on LRV

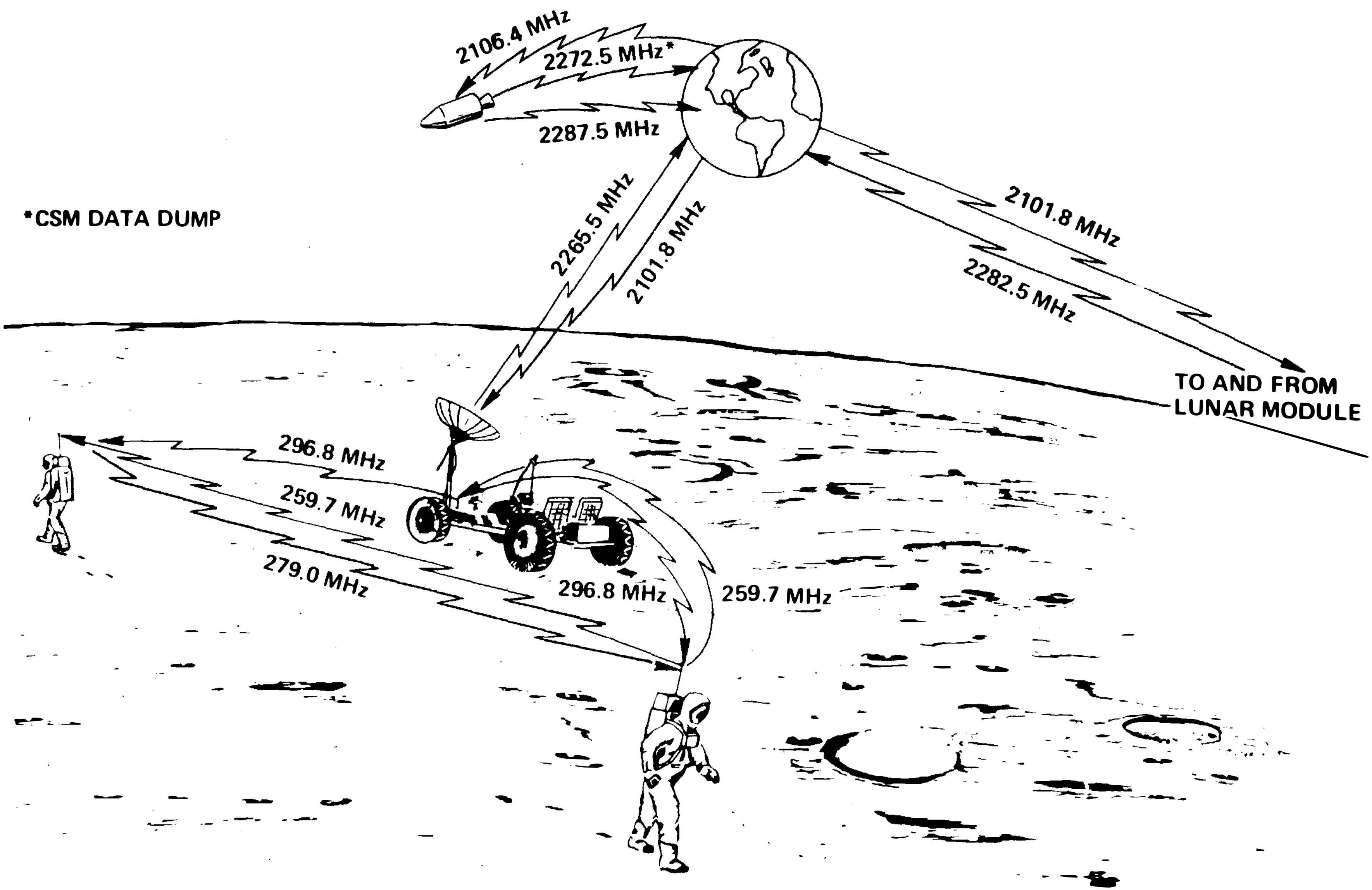

Figure 1-3. LCRU in Fixed Base Operation on LRV

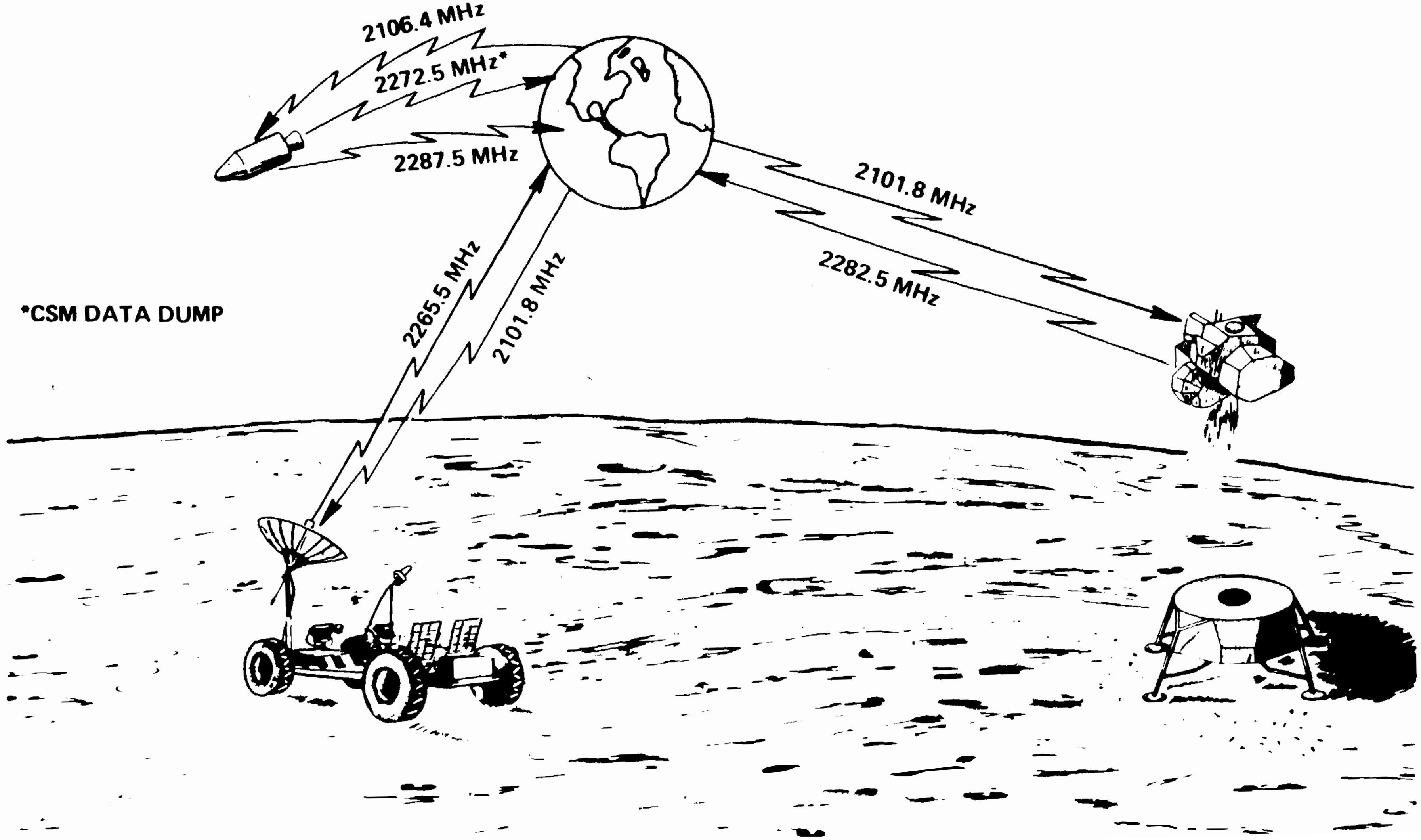

Figure 1-4. LCRU in Operation During LM Ascent

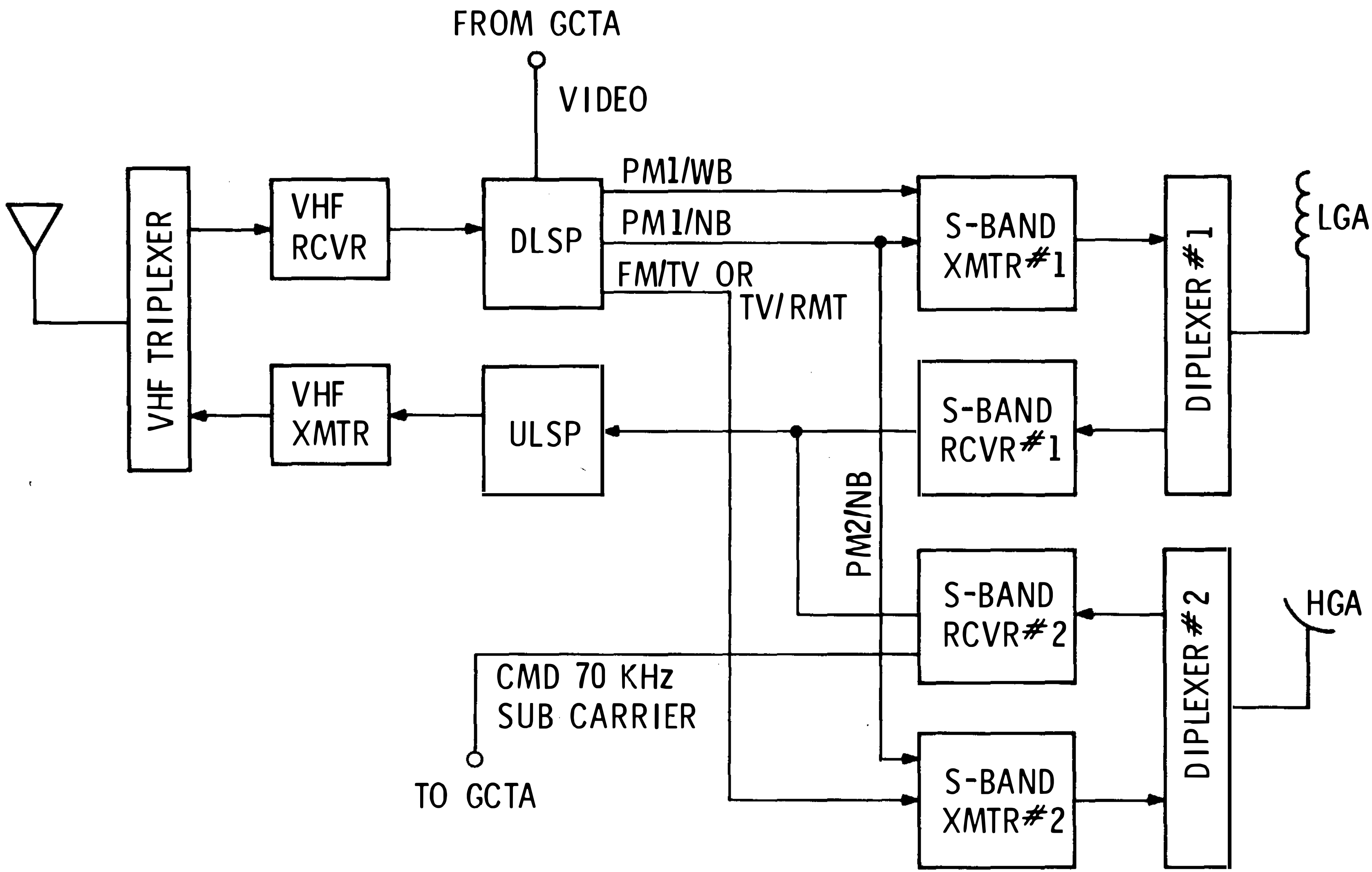

Figure 1-5 LCRU Functional Overview

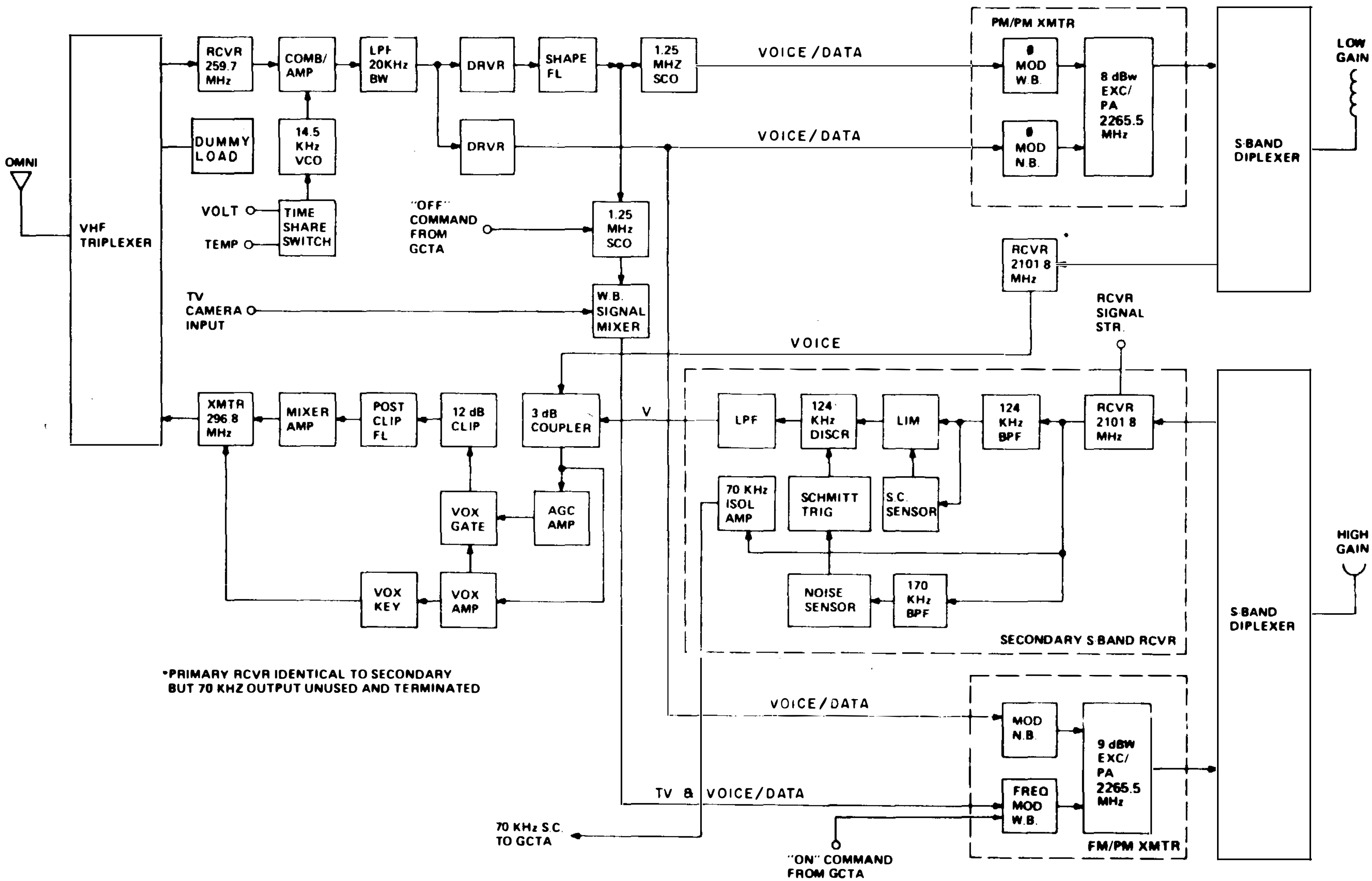

Figure 1-6. LCRU Subsystem Configuration

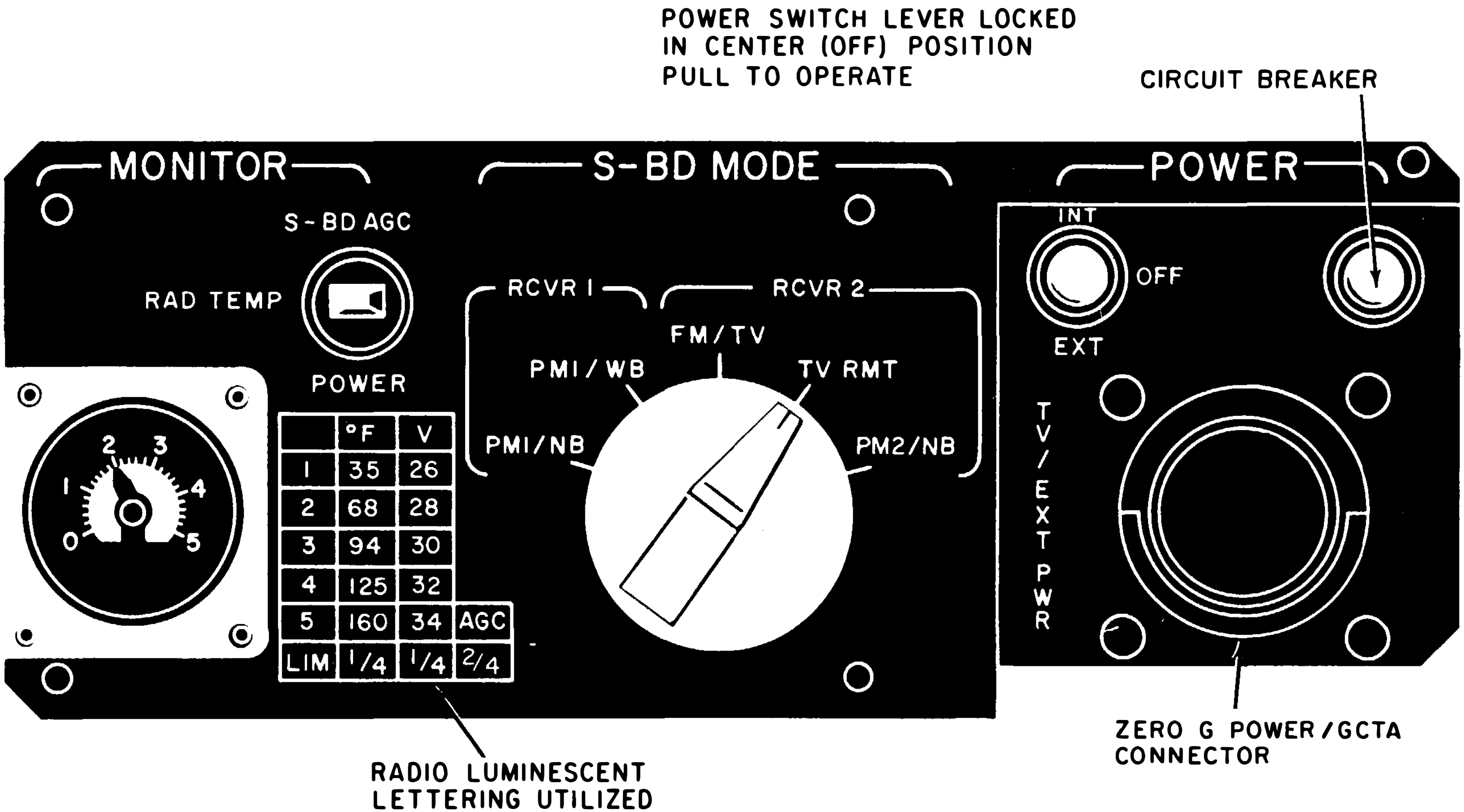

Figure 4-1. LCRU Control Panel

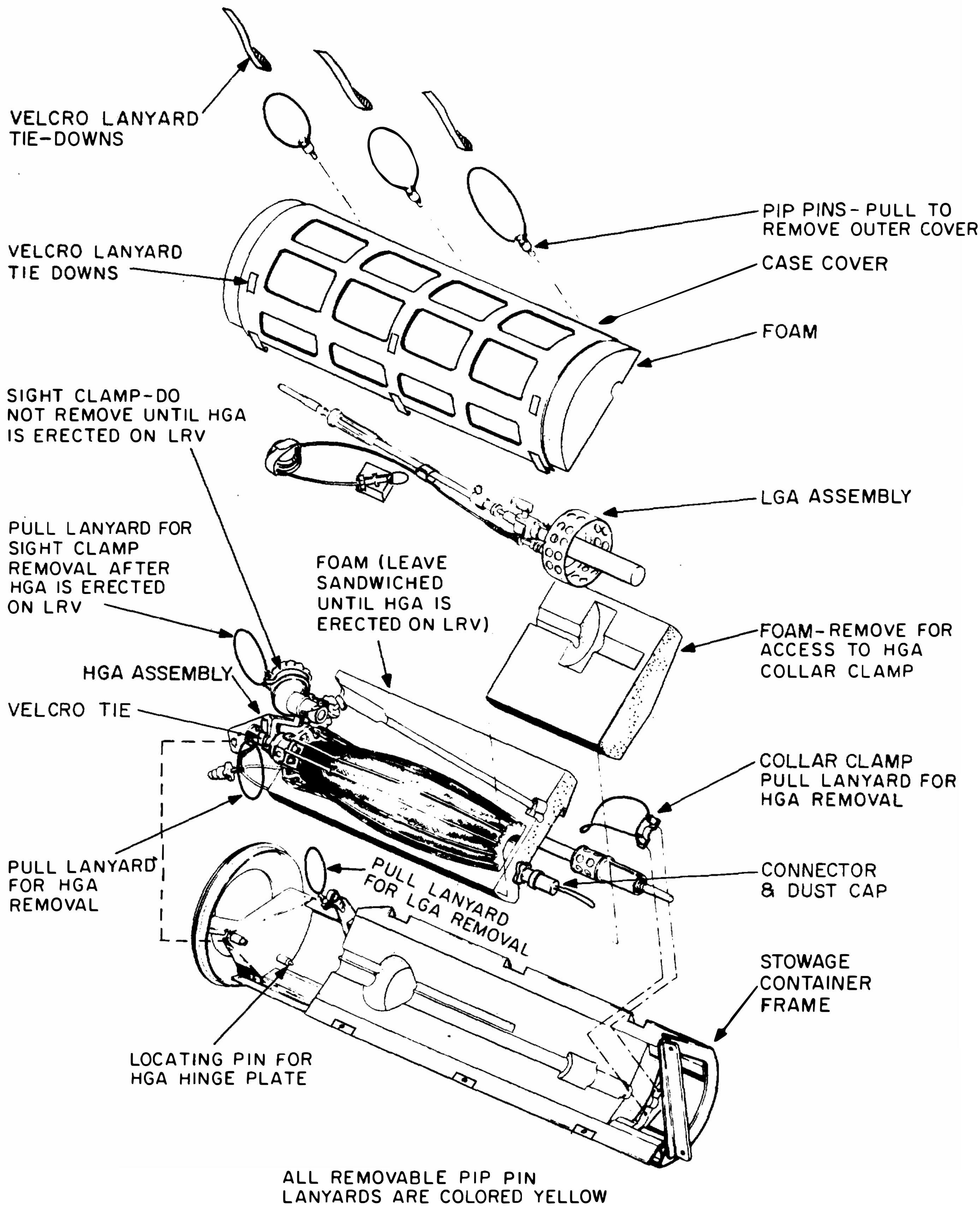

Figure 4-2. Ancillary Items Stowage Container

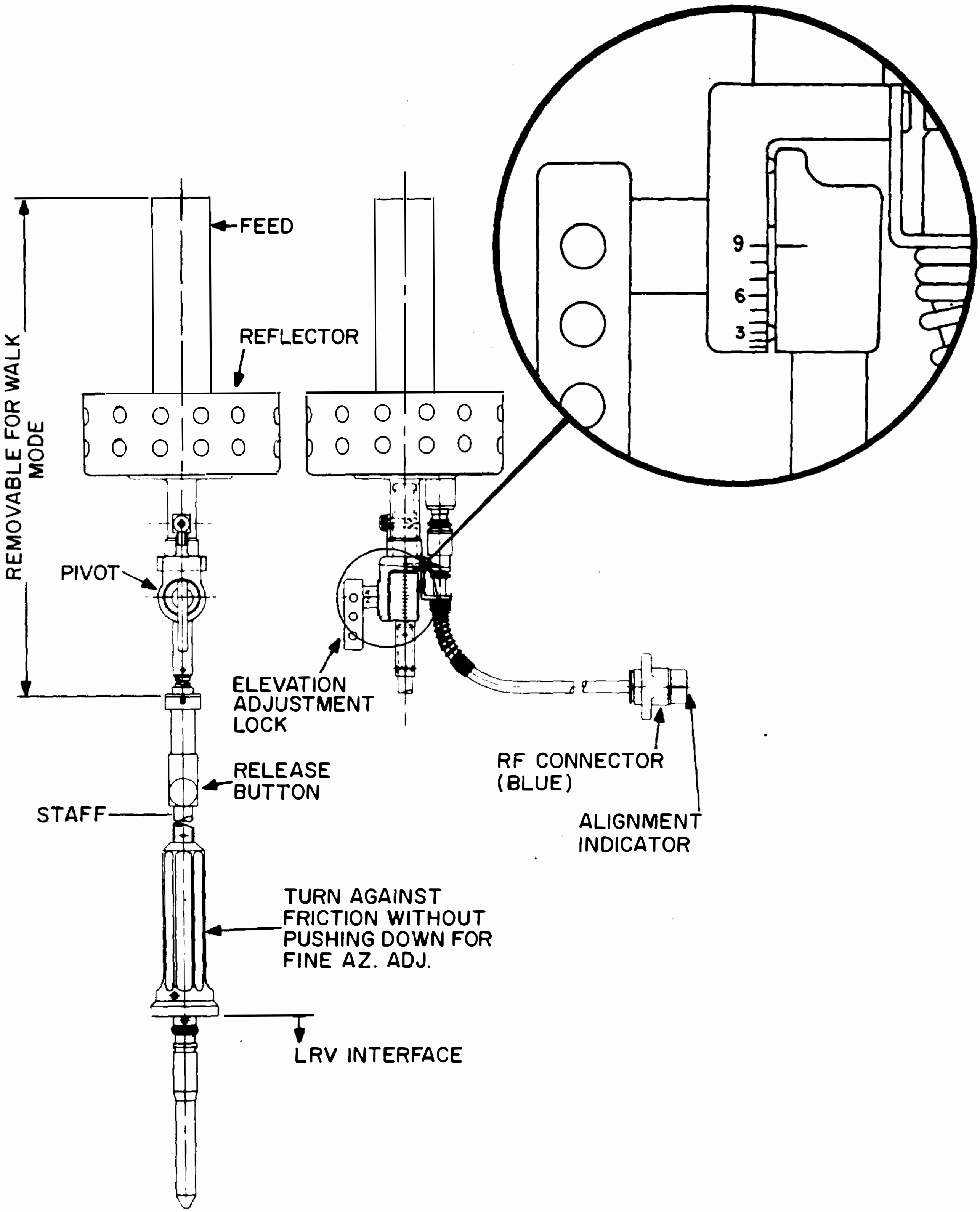

Figure 4-3. Low Gain Antenna

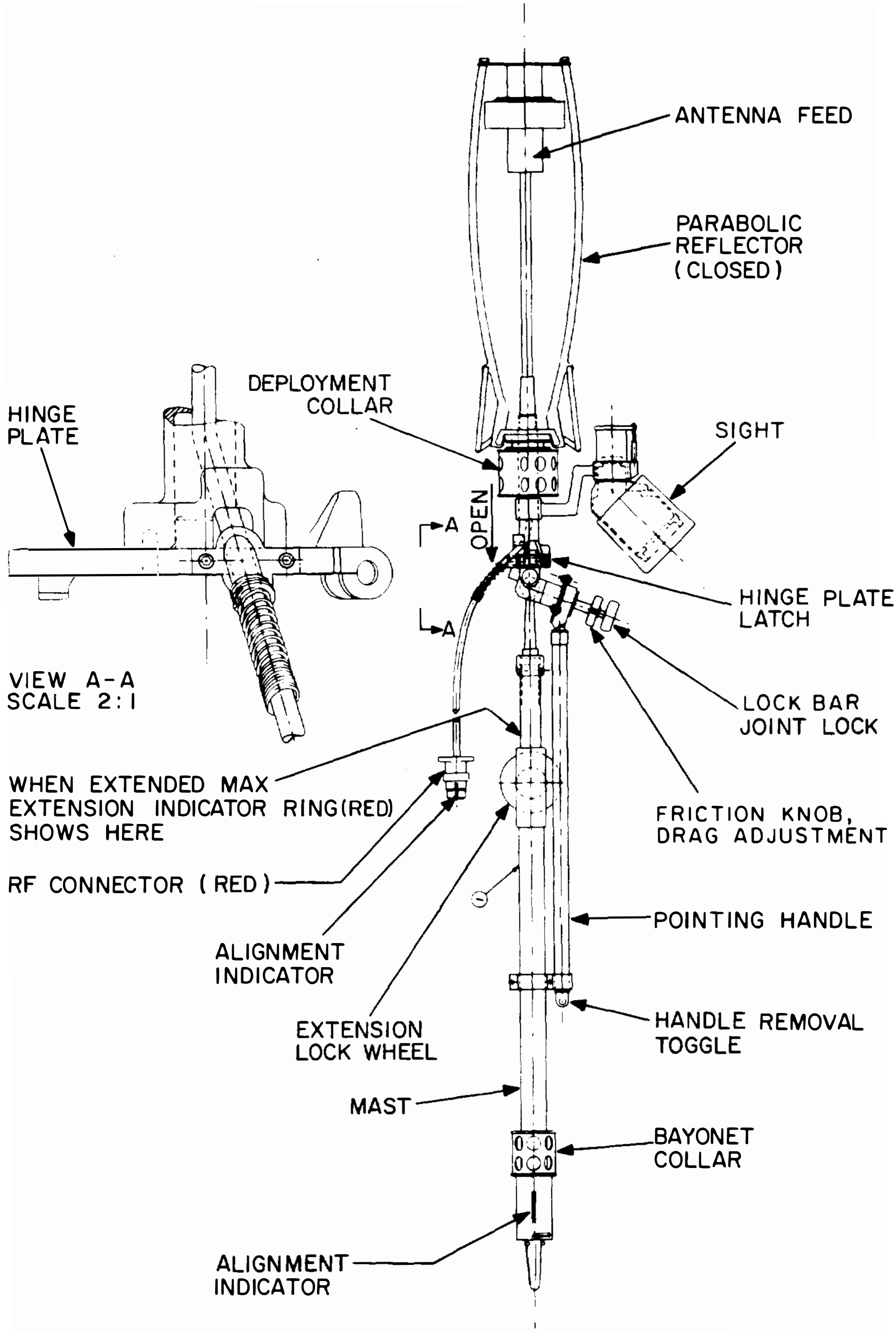

Figure 4-4. High Gain Antenna Assembly

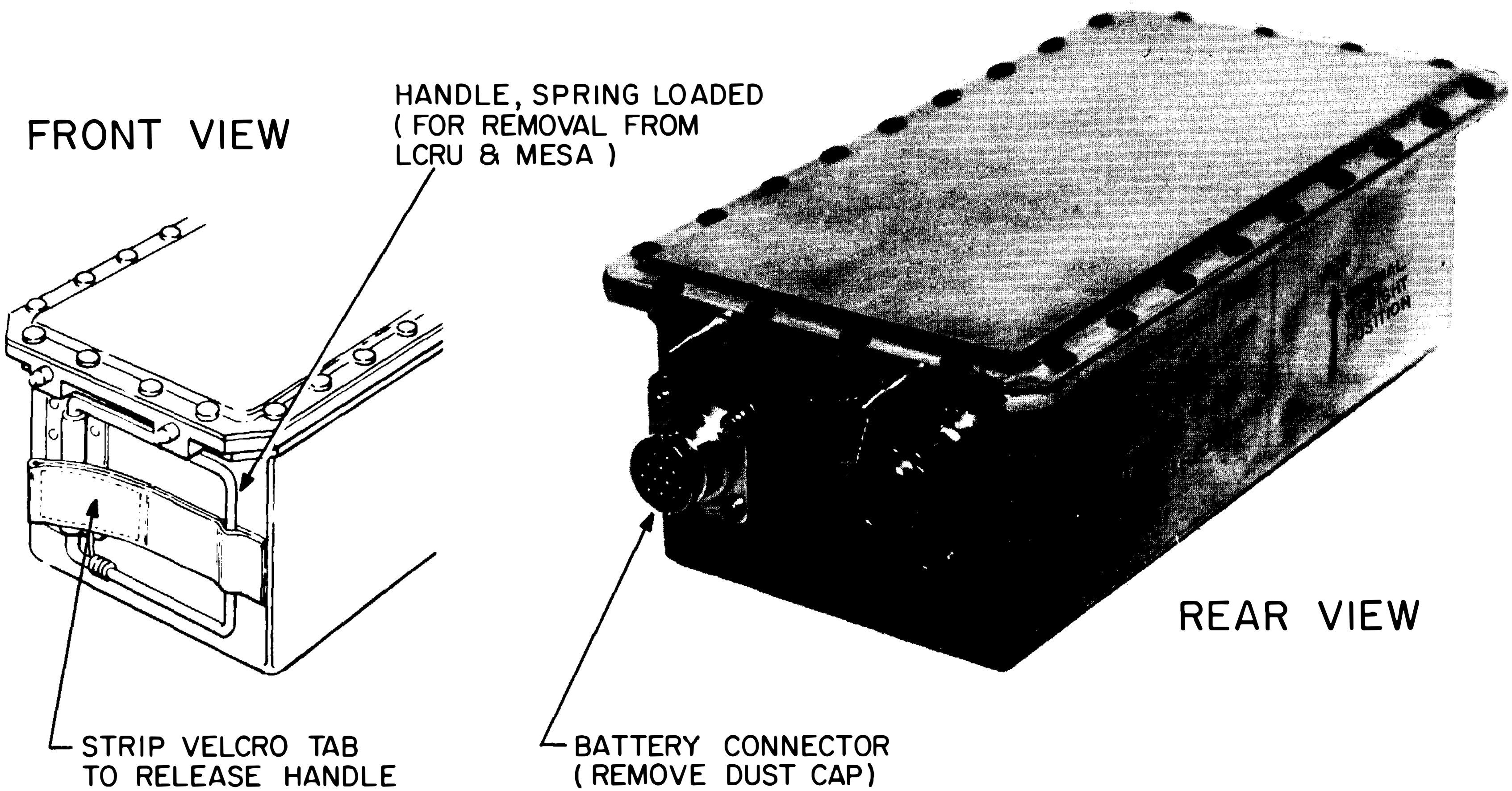

Figure 4-5. LCRU Battery

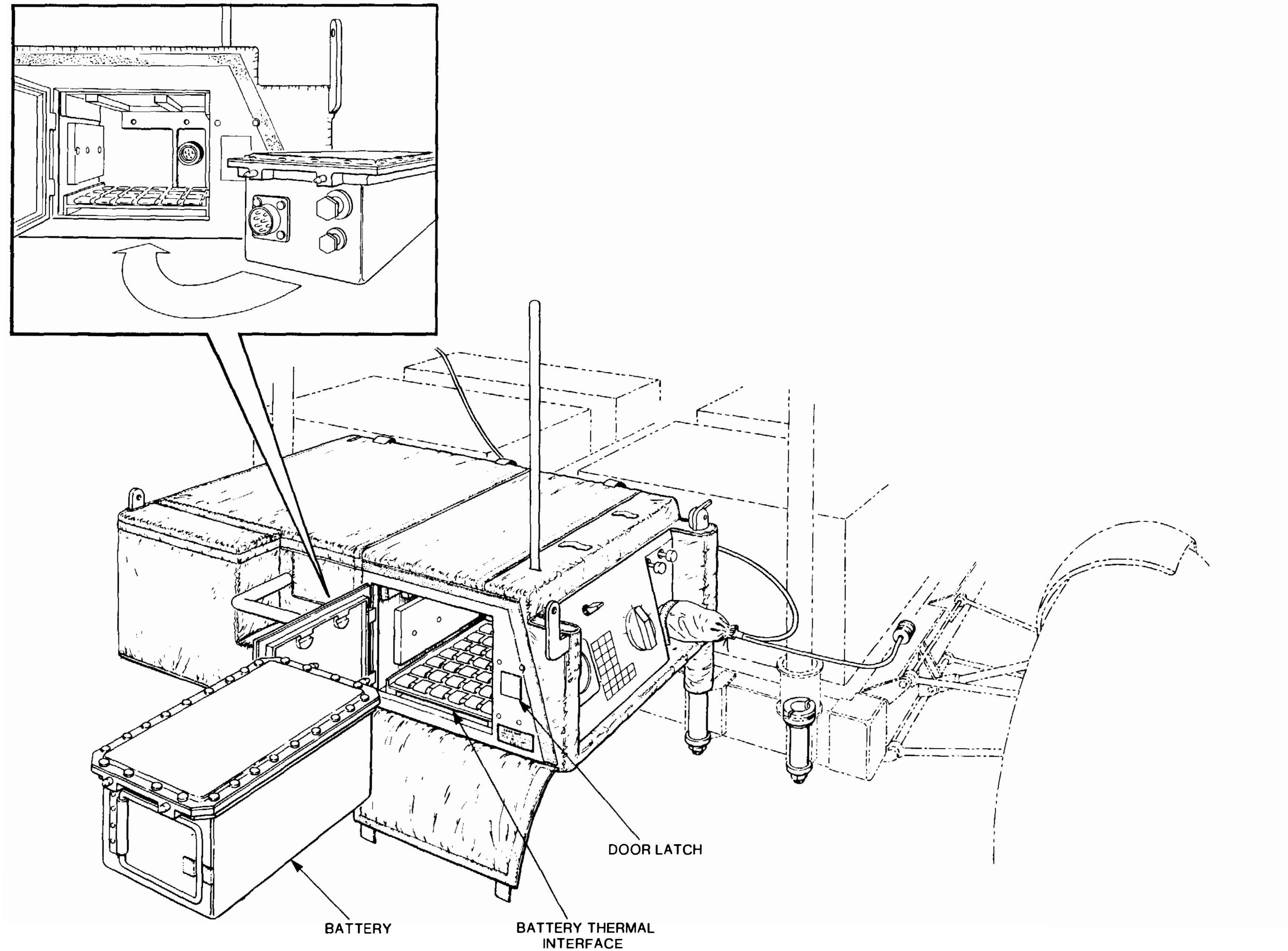

Figure 4-6. LCRU Battery Replacement

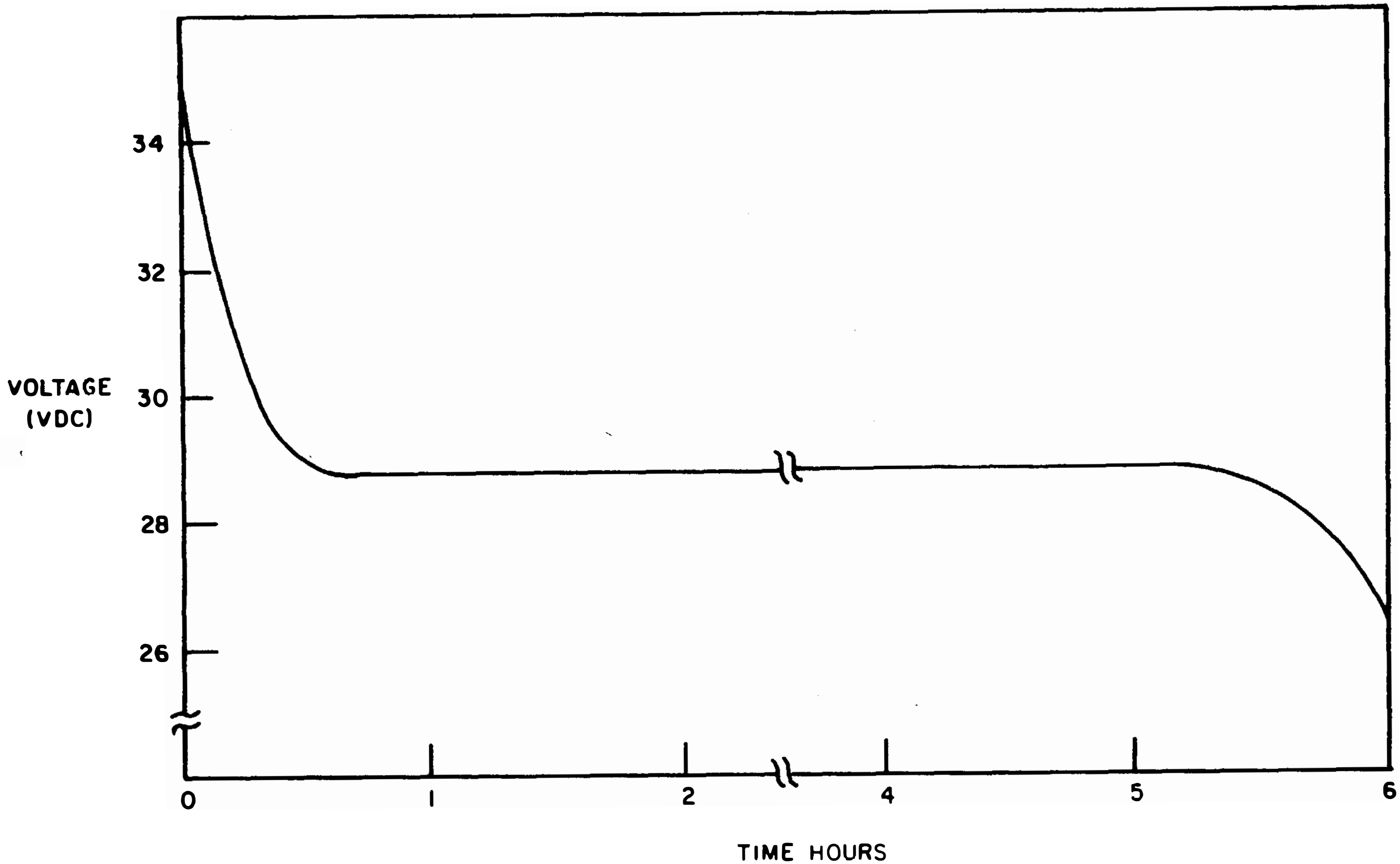

Figure 4-6A Battery Depletion Curve (Nominal Current)

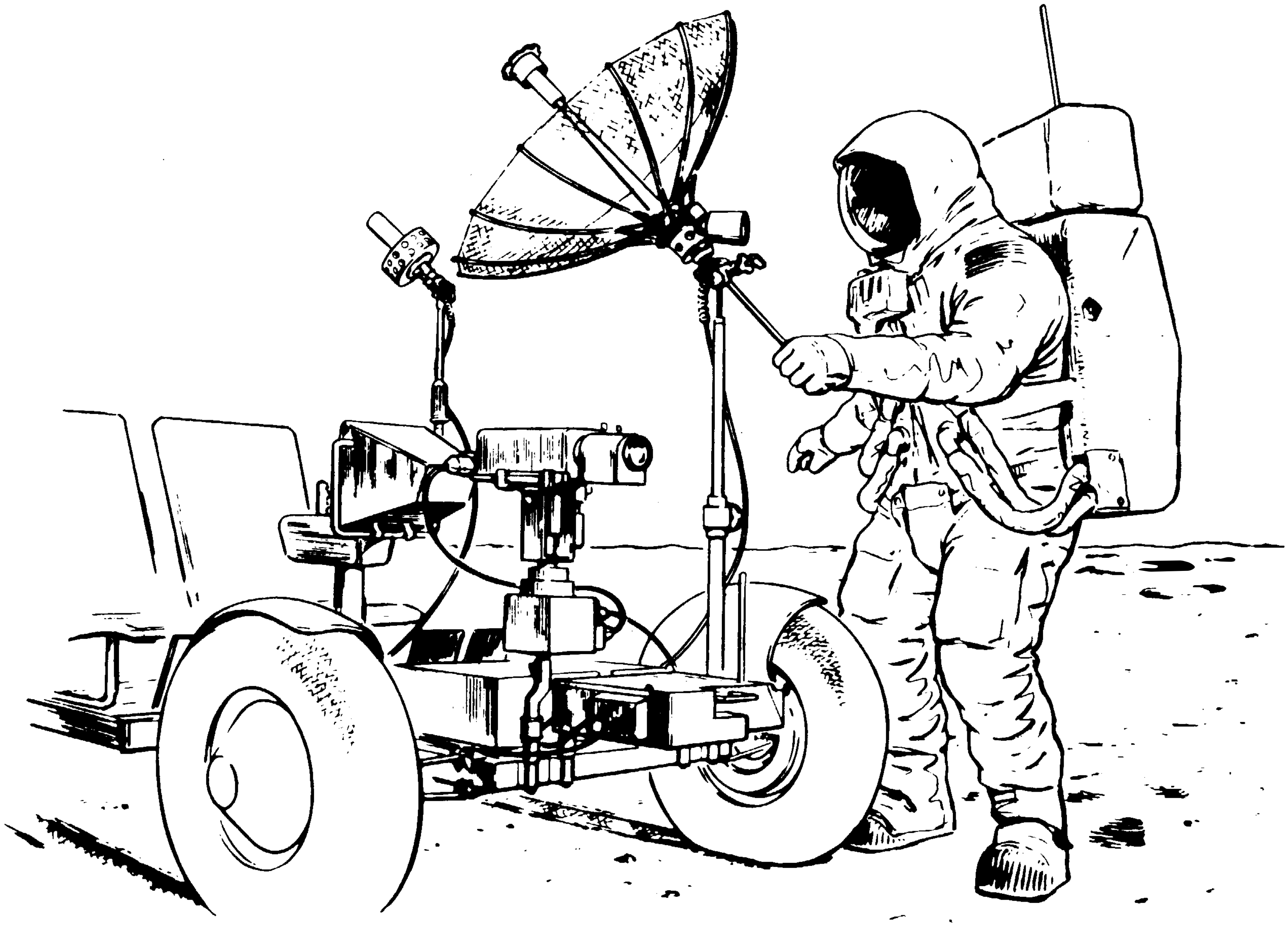

Figure 4-7. Pointing High Gain Antenna

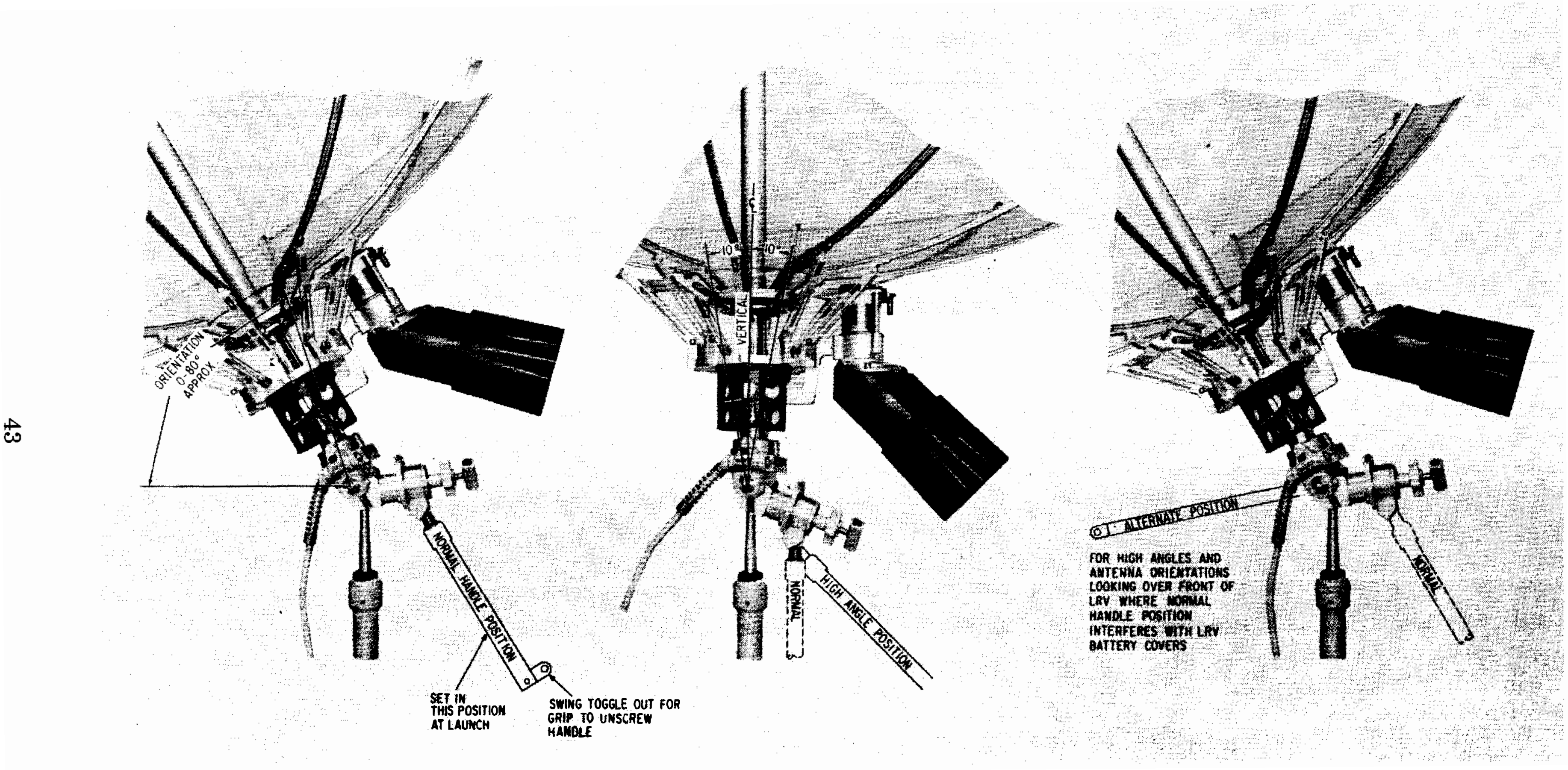

Figure 4-8. High Gain Antenna Handle Positions

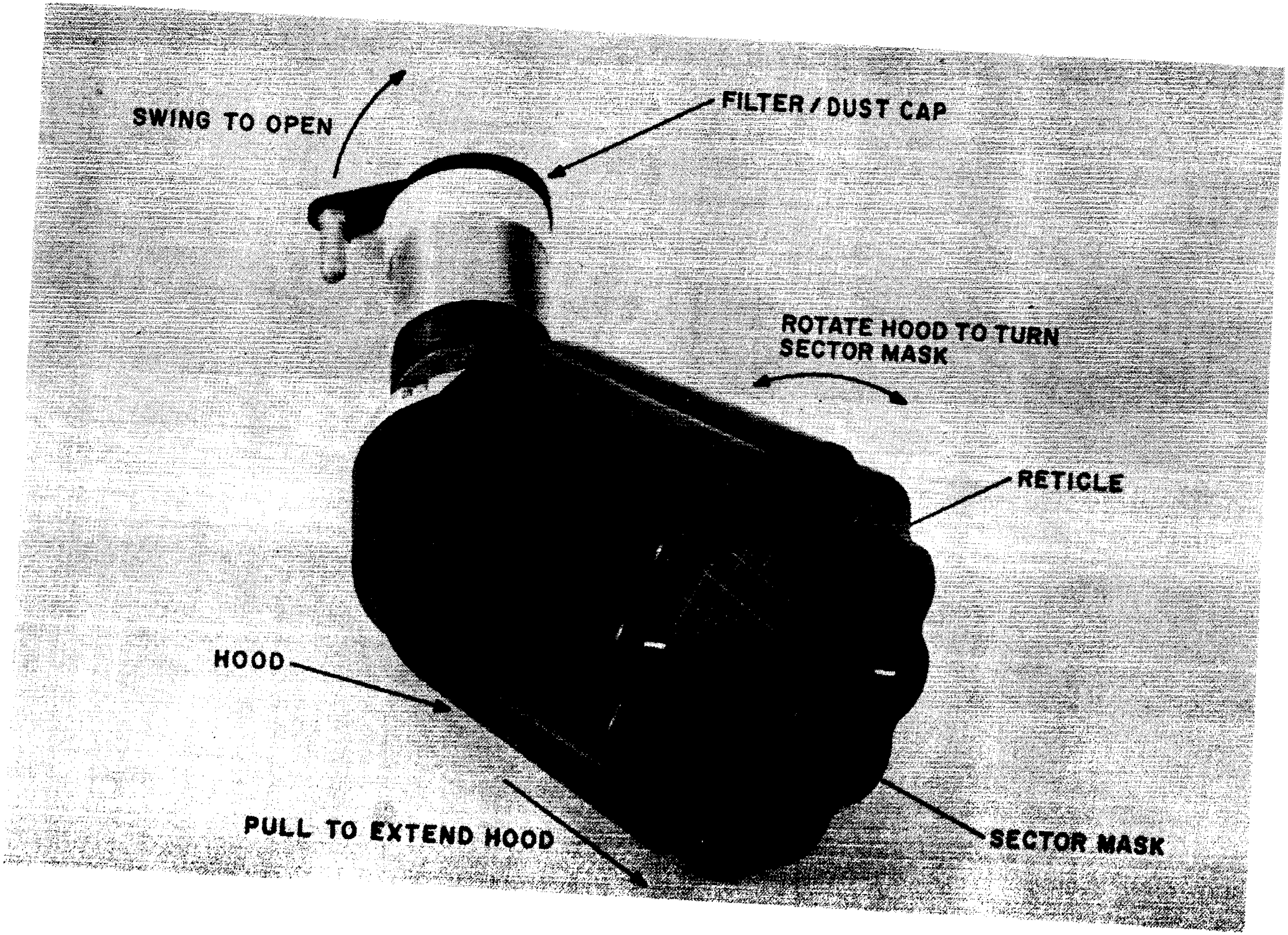

Figure 4-9. LCRU HGA Optical Sight

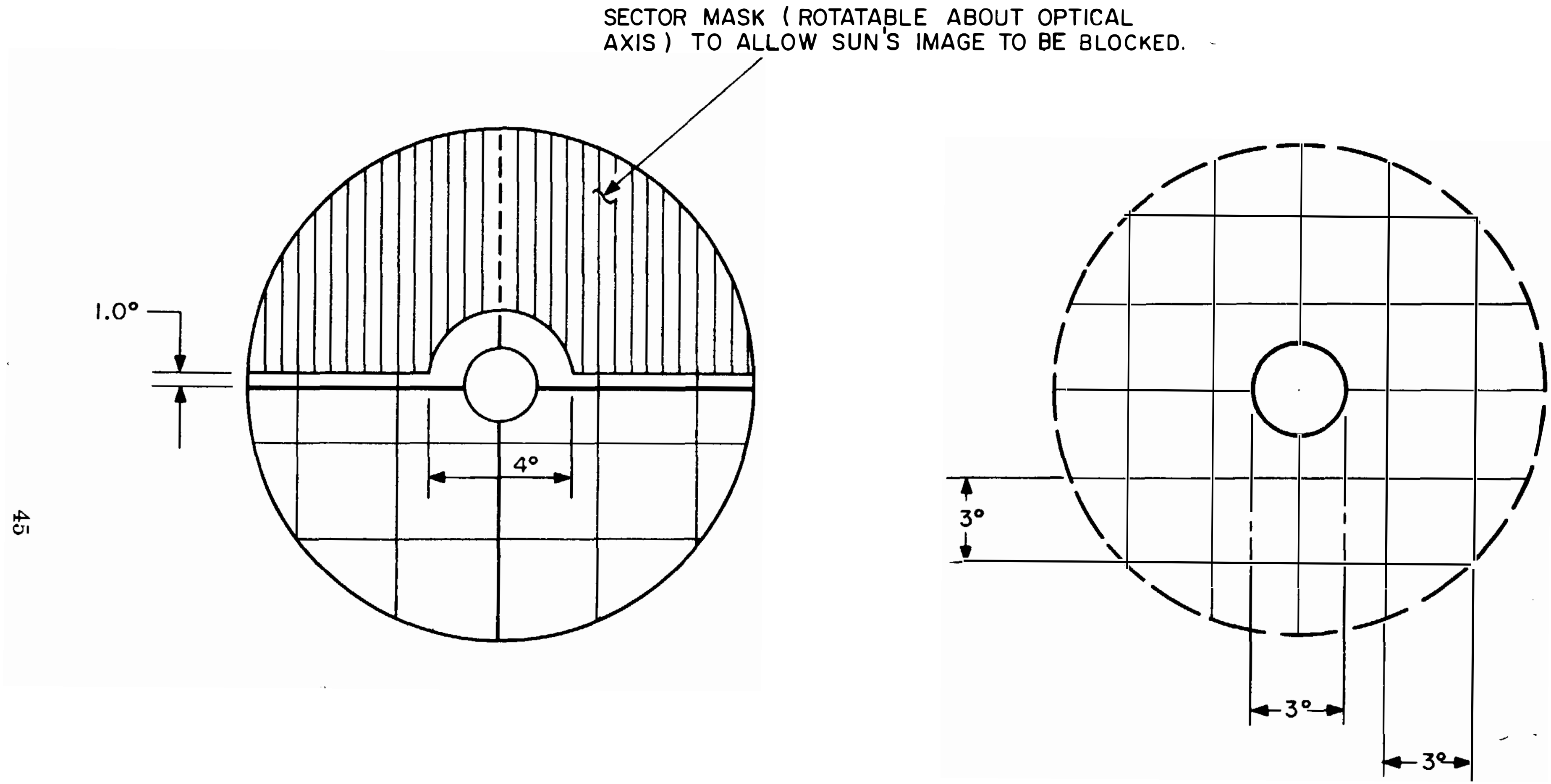

Figure 4-10. Sector Mask and Reticle

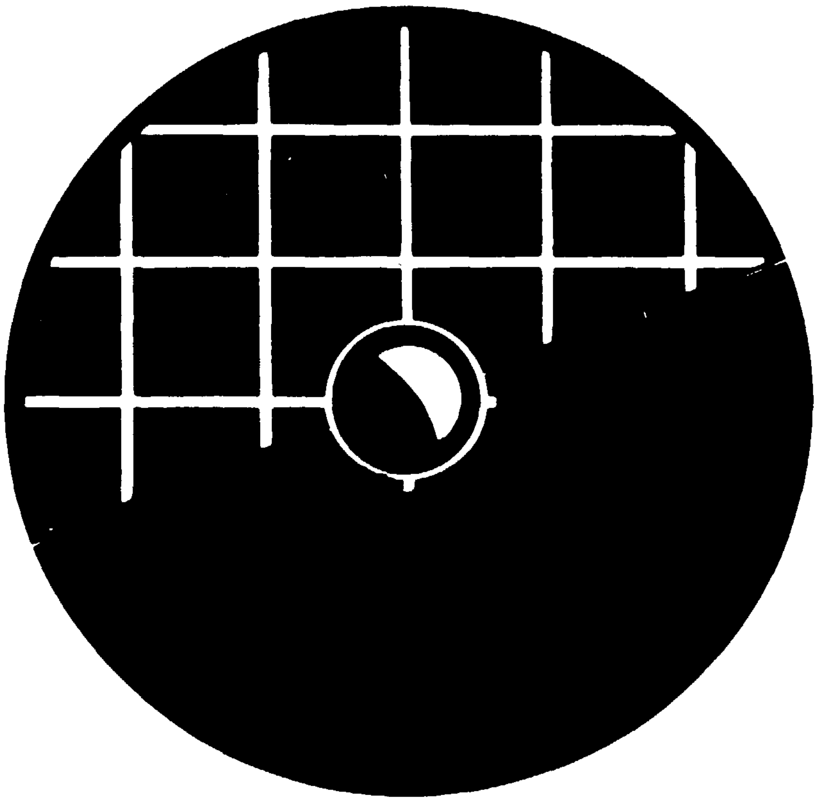

Figure 4-11. Reticle Appearance, Large Earth-Sun Angle (> 8-1/2°)
(Sector Mask not required)

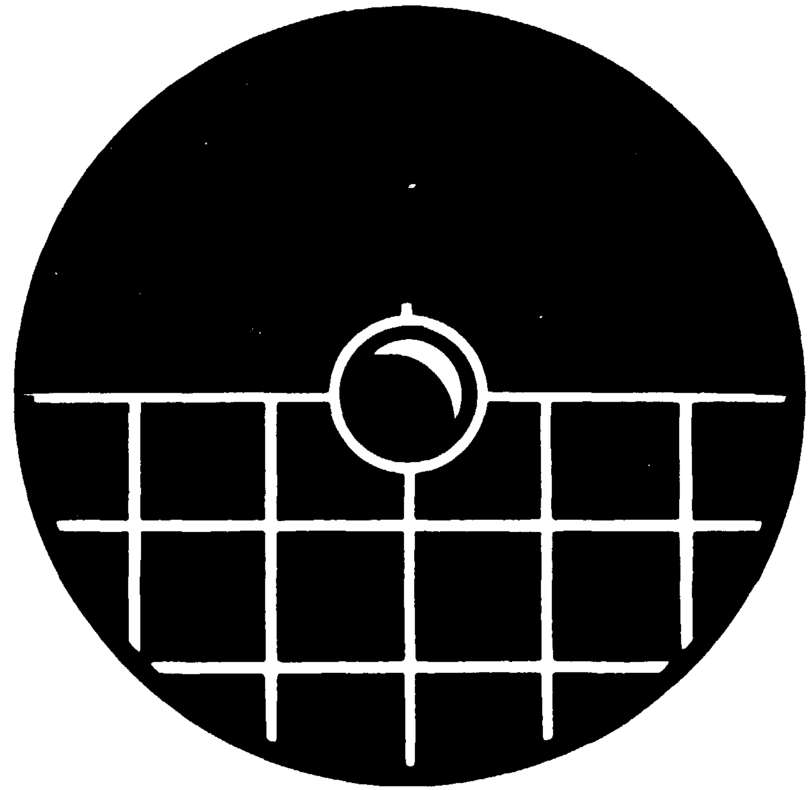

Figure 4-12. Reticle Appearance, Small Earth-Sun Angle (> 4° < 8-1/2°)
(Sector Mask blocks sun)

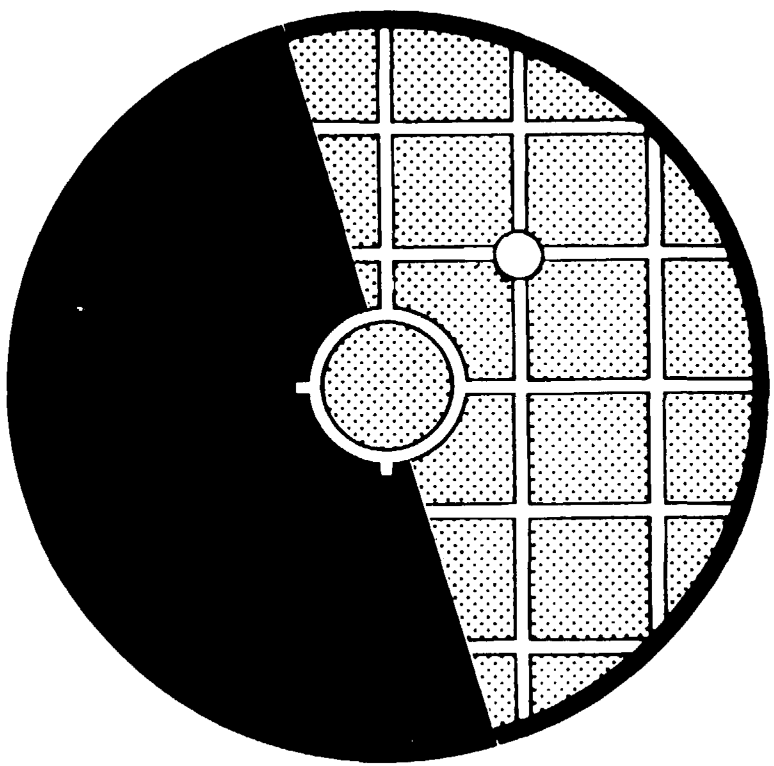

Figure 4-13. Reticle Appearance, Close Earth-Sun Angle (< 4°) (Sun filter over front lens)

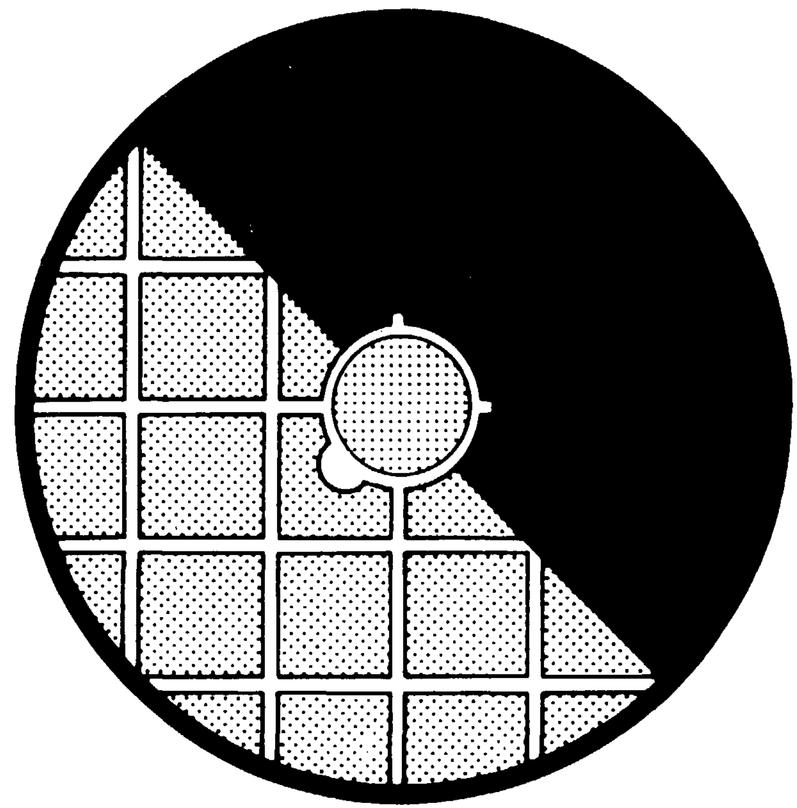

Figure 4-14. Reticle Appearance, Close Earth-Sun Angle (< 4°) (Sun filter over-front lens)

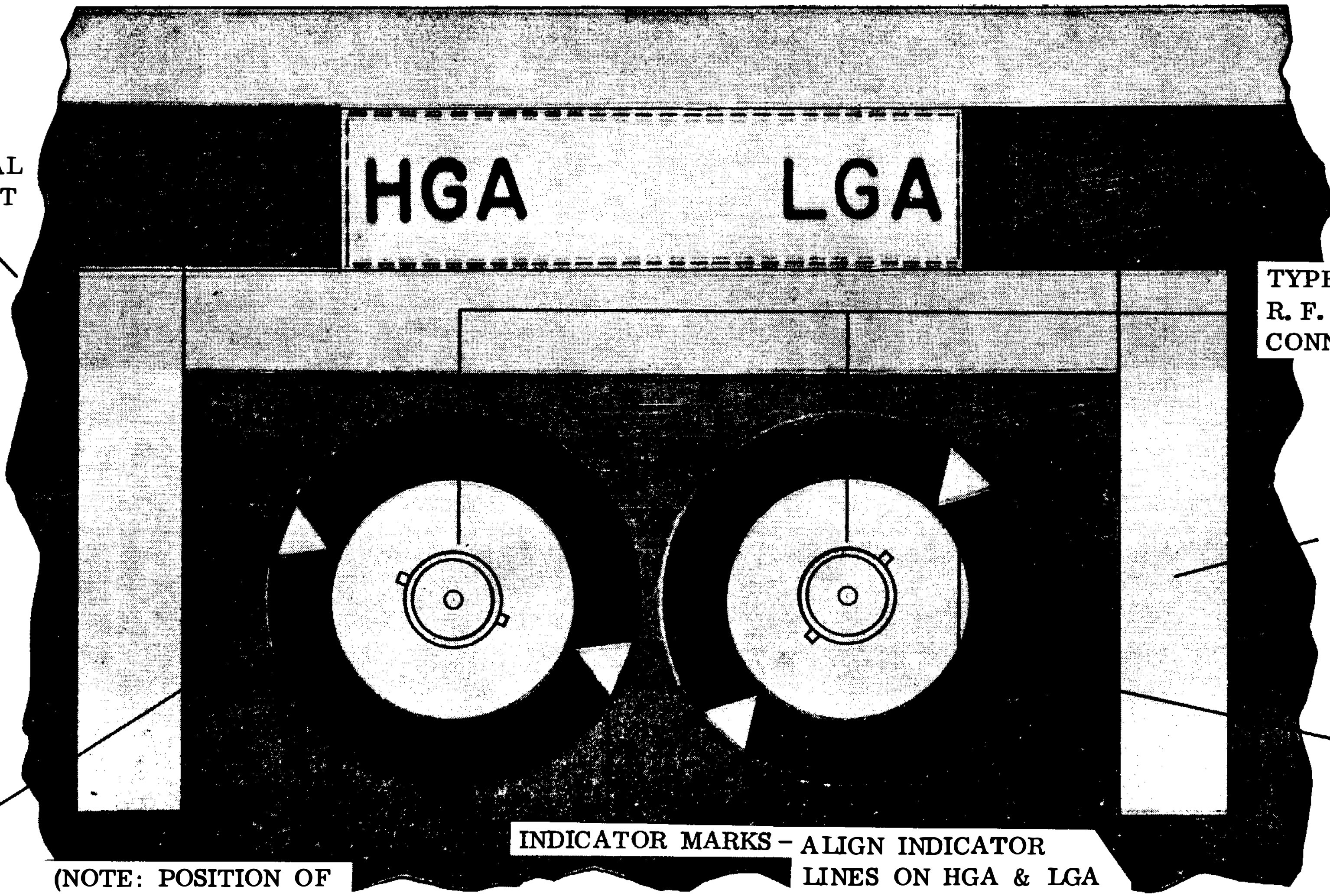

Figure 4-15. LCRU HGA & LGA Antenna Connector Inlet

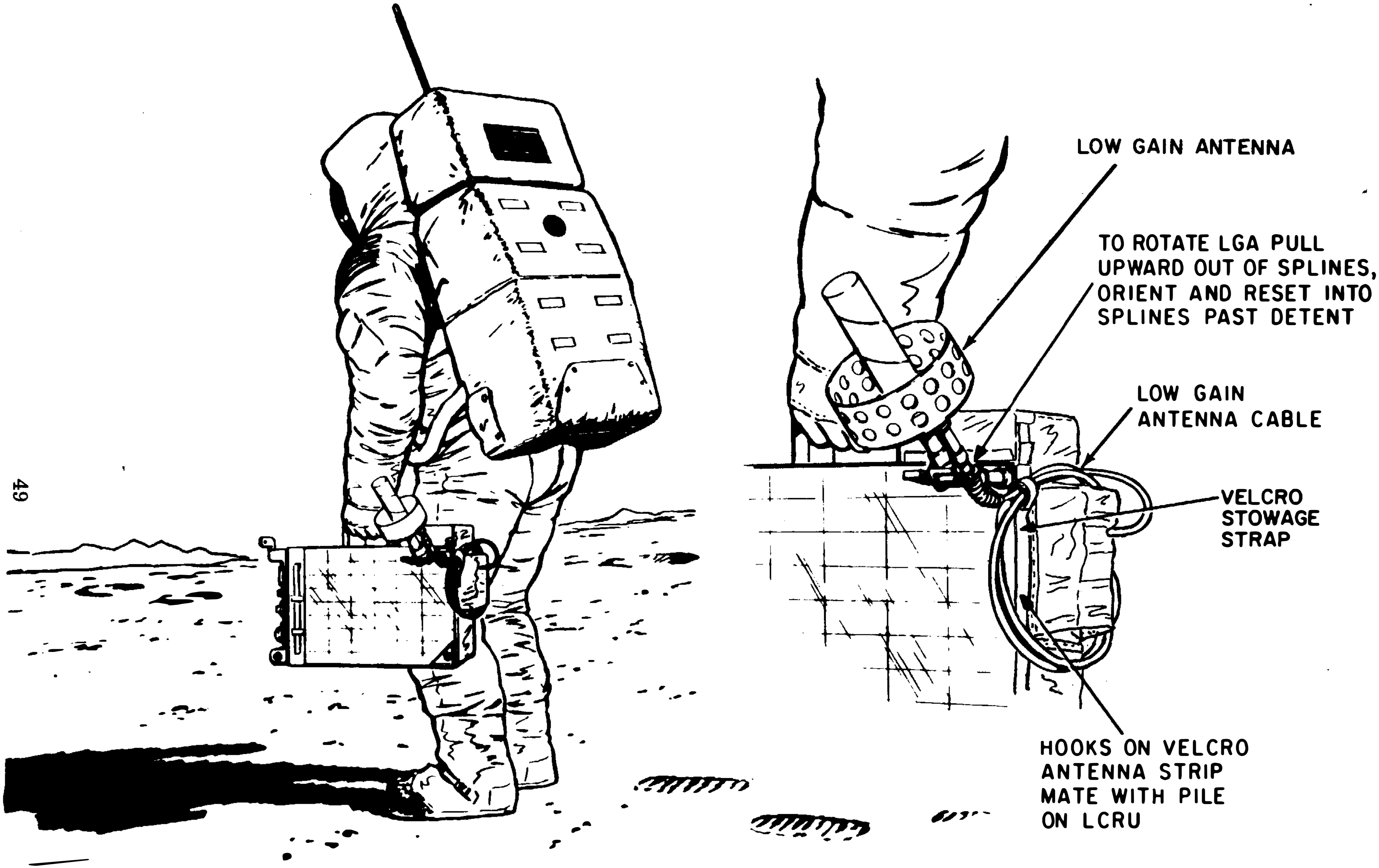

Figure 4-16. LCRU Hand Carry Mode

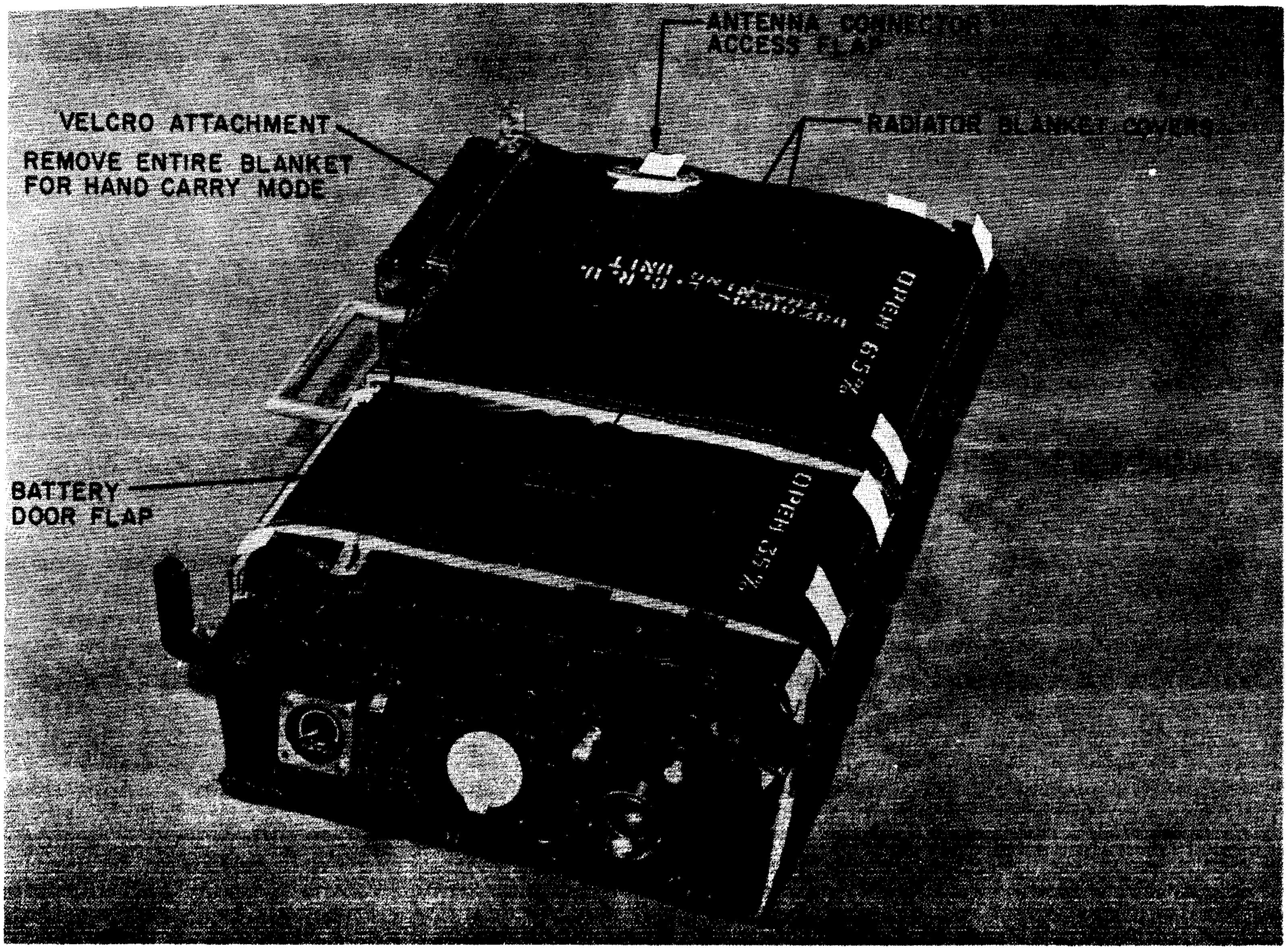

Figure 5-1. LCRU Thermal Blanket

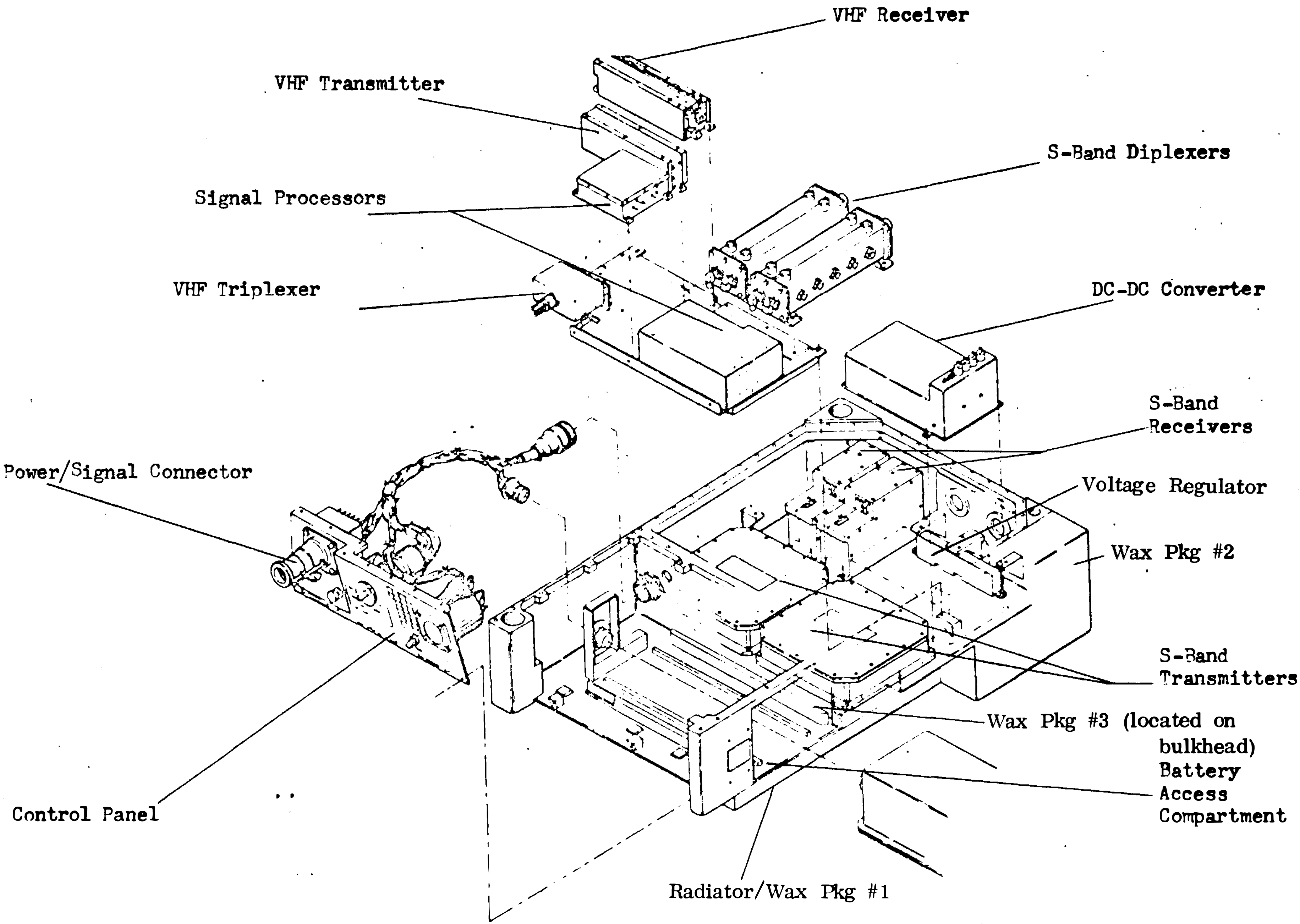

Figure 5-2 LCRU Unit (Bottom View)

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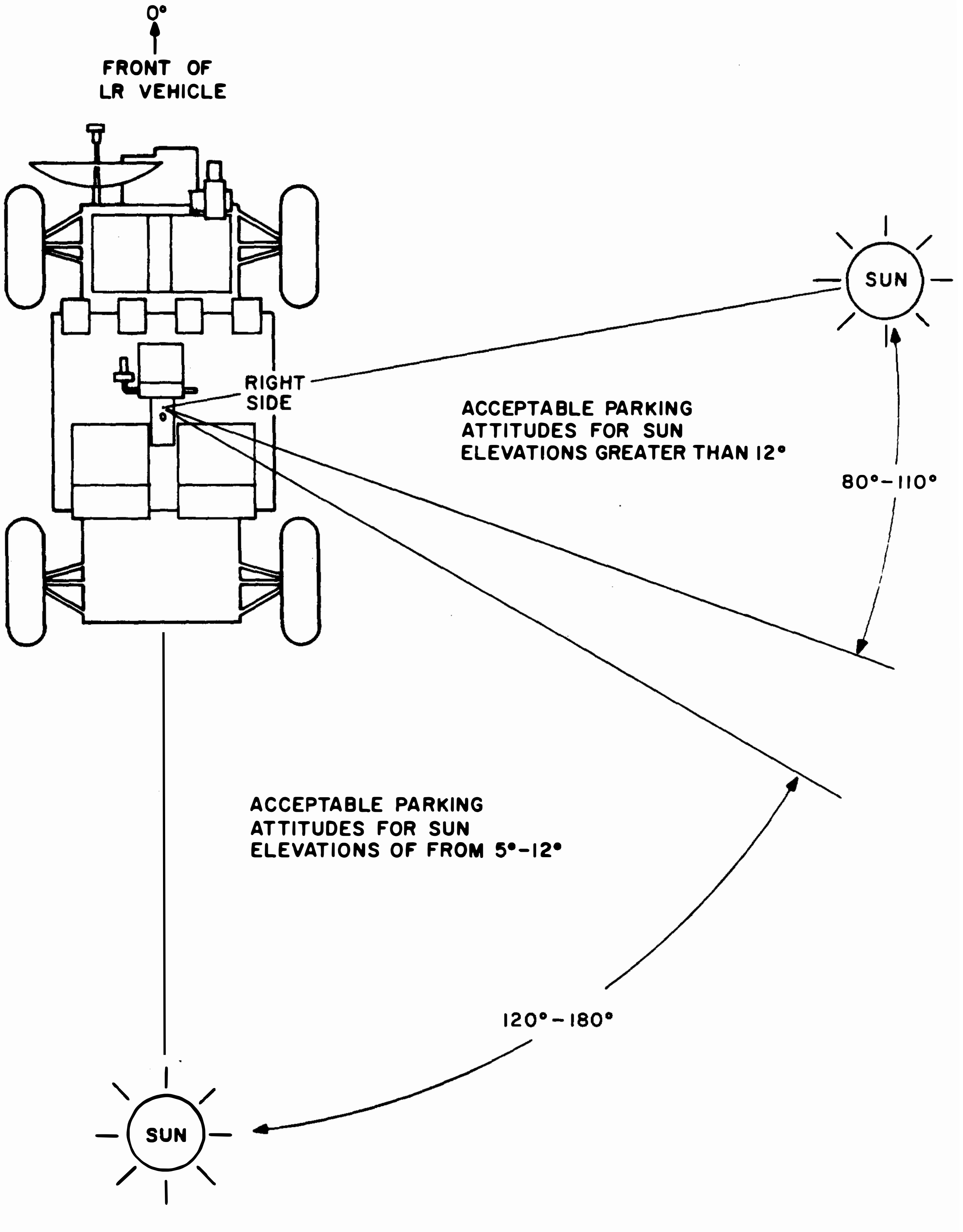

Figure 5-3. LRV Parking Attitudes

Step	Procedure	Remarks
	4.2 <u>LCRU SUBSYSTEM INSTALLATION</u>	This sequence is used to install the LCRU unit, high gain antenna, and low gain antenna.
	4.2.1 <u>MOUNT LCRU ON LRV</u>	
	<u>AT LRV</u>	
1	LCRU support locking-levers (2) Vertical position.	
2	Remove the nearest LRV velcro tie-down, and remove GCTA cable connector from LRV stowage adapter.	Leave cable in other velcro tie-downs.
3	Place GCTA connector on LRV center battery cover.	
4	Remove and discard GCTA connector stowage adapter.	
	<u>AT MESA</u>	
5	Pull Pallet No. 1 lanyard to remove pip pins (2) holding LCRU to pallet.	
6	Raise LCRU from pallet by using LCRU handle. <u>Do not remove pallet.</u>	
	CAUTION: <u>Do not strike LCRU lower surface on MESA since this surface contains the thermal radiator mirrors which are extremely fragile.</u>	
7	Rotate LCRU by the handle until the control panel faces to the right. Place the other hand under the bottom surface and place the LCRU in a horizontal position on top of the MESA table.	

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Step	Procedure	Remarks
	<u>AT LRV</u>	
8	Hold LCRU in horizontal position and lower LCRU mounting holes over locking levers and LRV support posts.	The LCRU support locking-levers do not lock in vertical position, and therefore care must be taken to not deflect the levers when positioning the LCRU mounting holes over the support posts.
9	LCRU support locking-levers (2) - 90 Degrees aft.	
10	Disconnect LCRU power cable connector from stowage adapter and pull cable for 4 inches of additional slack. Connect to LCRU. Cover connector with thermal bootie.	Dust cap on LCRU panel connector must be removed. Bootie must be squeezed to fasten velcro onto Z-G connector activating handle.
11	Remove and discard the connector stowage adapter.	
	4.2.2 <u>MOUNT GCTA ON LRV</u>	
	Refer to LRV Operations Handbook for detailed steps.	
	4.2.3 <u>MOUNT LOW-GAIN ANTENNA (LGA) ON LRV</u>	
	<u>AT MESA</u>	
1	Pull LCRU antenna container lanyards (3) to remove pip pins which hold top cover.	Do not remove pip pins which hold container to MESA.
2	Lift top foam packing along with cover.	
3	Discard top of foam packing and cover.	
4	Pull pip pin releasing LGA retaining collar.	

Step	Procedure	Remarks
5	Remove LGA.	
	<u>AT LRV</u>	
6	Set LGA Elevation to TBD degrees.	LGA elevation setting is a one-time adjustment since the RF beamwidth adequately covers pitch and roll movements during LRV traverse.
7	Mount LGA staff into LRV left inboard handhold socket.	Right inboard handhold is a procedural option.
8	Point LGA at earth by using the staff lower handhold for azimuth adjustment.	
9	Loosen LGA cable velcro around foam stowage block and uncoil cable. Attach cable to LRV console using velcro strap mounted on LRV console. Wrap cable velcro strap around LGA staff.	
10	Carry the cable connector (blue) around the LRV, over the GCTA, and connect to LCRU by rotating CW to lock. Observe alignment marks on thermal blanket and cable connector.	Thermal blanket side flap must be opened to expose RF connectors. Dust cap on cable connector must be removed.
11	Attach LGA cable to support clips (2) on right side of LRV.	
	4.2.4 <u>MOUNT HIGH-GAIN ANTENNA (HGA) ON LRV</u>	
	<u>AT MESA</u>	
1	Remove and discard antenna stowage container foam material at right end of top of HGA.	Remaining foam around HGA ribs will be removed after mounting HGA on LRV.
2	Remove pip pin at left end and pip pins (2) and collar clamp at right end.	

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Step	Procedure	Remarks
3	Remove HGA/mast.	Do not grasp HGA mesh or RF feed.
	<u>AT LRV</u>	
4	With HGA mast lockwheel outboard, insert HGA mast into LRV left bumper fitting. Attempt to rotate mast to ensure engagement of mast anti-rotational pins.	Cable slack should allow GCTA cable to be routed around and behind HGA mast bayonet collar.
5	HGA mast bayonet collar - Lock (CW) (ref. alignment marks).	
6	Remove velcro around HGA ball post. Raise HGA mast about one foot. Rotate HGA dish to vertical position assuring that hinge plate latches. Discard foam packing.	
7	Remove and discard pip pins (2) and clamp holding optical sight. CAUTION: Do not drop clamp on LCRU or LRV.	
8	Raise HGA to convenient optical sight height by using mast lockwheel.	Maximum extension of HGA is indicated by red ring on inner mast shaft.
9	Unlock HGA pointing assembly by rotating lock-bar 90 degrees CCW; set desired drag by adjusting friction knob, and point antenna toward rear of LRV at approx. 45 degrees elevation.	Four-pointed friction knob adjusts drag on ball and socket joint. Lock-bar locks joint. To adjust drag, loosen lock-bar at least CCW 2 turns and turn friction knob CW until drag will hold HGA at any angle. The drag adjustment should be a one-time setting since the lock-bar is used to lock (CW) the HGA during LRV motion.

Step	Procedure	Remarks
10	Unlock HGA dish deployment collar by rotating CCW about 30 degrees; open antenna by pulling collar back and rotating CW to lock.	10 lb. force required to pull collar back.
11	Remove HGA cable velcro and route HGA cable behind LCRU and GCTA mounting posts and connect connector (red) to LCRU rotating CW to lock. Observe alignment marks on thermal blanket and cable connector. Close thermal flap.	Dust cap on cable connector must be removed.
12	Unstow VHF antenna from top of LCRU.	
	4.2.5 INITIAL CHECKOUT	This sequence is performed only prior to the first sortie.
1	Rough align HGA toward earth and rotate sight to most convenient position.	The optical sight can be rotated over a 180 degree path to optimize the crew viewing angle. Three detents are provided at 90 degree increments but the sight may be positioned at any point between the detents if so desired.
2	Rotate the sight front sun filter/dust cap away, and center earth within the reticle circle.	For earth-sun angles less than 8 1/2 degrees, refer to 4.2.13 for instructions on using the HGA optical sight. For maximum visibility when driving LRV, the HGA maybe raised to maximum height.
3	Verify that LGA is pointing toward earth.	
4	LCRU CB--Close	
5	LCRU POWER SWITCH--INT	
6	S-BD MODE SWITCH--PM2/NB Perform voice and data check with MSFN.	
7	MONITOR SWITCH--POWER; RAD TEMP; S-BD AGC. Report (3) readings to MSFN.	
8	S-BD MODE SWITCH--TV RMT Verify GCTA properly configured for GCTA check. MSFN perform GCTA check.	

Step	Procedure	Remarks
9	S-BD MODE SWITCH--FM/TV Perform voice and data check with MSFN. MSFN perform GCTA check.	
10	S-BD MODE SWITCH--PM1/NB Perform voice and data check with MSFN.	
11	Report AGC meter reading to MSFN.	
12	S-BD MODE SWITCH--PM1/WB Perform voice and data check with MSFN.	
13	LCRU POWER SWITCH-EXT LRV AUX. POWER CB--Close Perform voice and data check with MSFN.	
14	LRV AUX. POWER CB--Open	
15	Rotate HGA lock-bar CW, and close sight dust cap.	HGA need not be placed in vertical position unless LRV driving visibility is degraded.
	4.2.6 <u>LCRU VOICE/DATA MODE (PM1/WB)</u>	This mode is used for voice/data only (no TV) during LRV in motion and stationary periods.
1	LCRU POWER SWITCH--INT (Except to EXT at beginning of each sortie.) LRV AUX POWER CB--Open (Except closed as required at beginning of each sortie.)	Voice/data relay via LM will be used during initial portion of sortie until dropout occurs. LRV Aux. Power CB is then closed to operate LCRU by external power thereby not requiring crew time to dismount LRV to place LCRU power switch to INT. At time of first LRV crew dismount, the LCRU power switch is placed to INT and the LRV AUX. Power CB is opened.
2	S-BD MODE SWITCH--PM1/WB	

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Step	Procedure	Remarks
3	Open the TBD % thermal radiator cover.	MSFN will supply instruction on which radiator cover to remove. The open radiator surface should be cleaned with the dust brush if a large amount of dust is visible; otherwise MSFN will provide notification when dusting is required.
4	Keep LGA manually pointed within ±30 degrees to earth.	
5	Before dismounting LRV for exploration stop, manually point LGA directly to earth in azimuth.	LGA elevation setting is a one-time adjustment since the RF beamwidth adequately covers pitch and roll movements during LRV traverse.
	4.2.7 <u>LCRU TV ONLY MODE</u> (TV RMT)	This mode is TV only (no voice/ data); it can be used only when the LRV is stationary and the EVA to MSFN voice link is available via the LM.
1	Open the TBD % thermal radiator cover.	
2	Rotate the HGA sight front sun filter/dust cap away, and center earth within the reticle circle. Pull out sight rear hood if necessary to lessen any background lighting glare.	
3	LCRU POWER SWITCH--INT LRV AUX POWER CB--Open	
4	S-BD MODE SWITCH --TV RMT	
5	Before moving to next stop point, rotate HGA lock-bar CW and close sight dust cap.	The dust cap need not be opened and closed between TV stops if the LRV does not produce a dust cloud.

Step	Procedure	Remarks
	4.2.8 LCRU VOICE/DATA/TV MODE (FM/TV)	This mode is used when voice/ data and TV is required, and only when the LRV is stationary.
1	Open the TBD % thermal radiator cover.	
2	Rotate the HGA sight front sun filter/dust cap away, and center earth within the reticle circle. Pull out sight rear hood if necessary to lessen any background lighting glare.	
3	LCRU POWER SWITCH--INT LRV AUX POWER CB--Open	
4	S-BD MODE SWITCH--FM/TV	
	Before moving to next stop point, perform following steps:	
5	If LCRU in-motion voice relay required, Point LGA to earth. S-BD MODE SWITCH--PM1/WB:	
6	If LCRU in-motion voice relay not required, LCRU POWER SWITCH-OFF	Use of LM relay when available will conserve LCRU battery power.
7	Place HGA in vertical position, rotate lock-bar CW, and close sight dust cap.	
	4.2.9 LCRU CLOSEOUT, POST- SORTIE 1 AND 2	This operation is to configure LCRU for cool-down cycle between sorties.
1	LCRU POWER SWITCH--OFF	
2	Clean entire radiator surface with dust brush if visible dust is present.	
3	Leave TBD % thermal radiator open.	

Step	Procedure	Remarks
	4.2.10 <u>LCRU BATTERY REPLACEMENT, PRE-SORTIE 2 AND 3</u>	Two new batteries are installed in the MESA in front of Pallet No. 1 and should be used for replacement units prior to SORTIE NO. 2 and NO. 3.
1	LCRU POWER SWITCH--OFF Open LCRU battery door access flap on thermal blanket.	
2	BATTERY ACCESS LATCH--Push Remove battery using wire handle and discard.	
3	At MESA, pull lanyard to remove battery stowage bar pip pins (2), remove and discard velcro on battery handle, and pull out new battery.	
4	Remove and discard battery connector dust cap(red) and slide battery into the LCRU and push to end of travel.	
5	Close battery access door and thermal blanket flap.	
	4.2.11 <u>LCRU CHECKOUT, PRE-SORTIE 2 AND 3</u>	This abbreviated checkout assures that the new battery and voice/data mode are operational.
1	LCRU POWER SWITCH--INT	
2	S-BD MODE SWITCH--PM1/WB	
3	Assure that LGA is pointed to earth. Perform voice and data check with MSFN.	
4	LCRU POWER SWITCH--OFF	

Step	Procedure	Remarks
	4.2.12 LCRU ASCENT TV SET-UP, POST-SORTIE 3 (TV RMT)	This sequence configures the LCRU for the TV remote control operation for viewing LM ascent stage liftoff.
1	Place LRV at TBD position away from LM.	
2	Rotate the HGA sight front sun filter away, and center earth within the reticle circle. Pull out sight rear hood, if necessary, to lessen background lighting glare.	
4	Open TBD % radiator thermal cover.	
5	Clean exposed radiator surface with dust brush if visible dust is present.	
6	LCRU POWER SWITCH--EXT	
7	S-BD MODE SWITH--TV RMT	
8	LRV AUX POWER CB--Close	
9	Standby while MSFN performs TV check.	
	4.2.13 LCRU HGA SIGHTING FOR SMALL EARTH-SUN ANGLES	
	4.2.13.1 EARTH-SUN ANGLES, 4° to 8°	
1	Rotate sun filter/dust cap away and pull out rear sight hood.	
2	Rotate sight hood so that the sector mask will cover that area of the viewing screen where sun appears when the antenna is aimed to earth.	The optical sight sector mask will be installed for mission sites with small earth-sun angles only.
3	Align earth image within circle at center of reticle using pointing handle.	

Step	Procedure	Remarks
	4.2.13.2 <u>EARTH-SUN ANGLES LESS THAN 4°</u>	
1	Rotate sun filter in front of sight, then center the sun within the reticle inner circle.	
2	If the TV picture at the ground is not acceptable, relocate the sun image at a grid reference which will be furnished by MSFN.	The sight must be in one of the three detent positions. After the crew notifies the MSFN which position he has selected, the MSFN will provide the grid reference.
	4.2.14 <u>LCRU CONTINGENCY HANDCARRY MODE</u> (PM1/NB)	This mode is used in event of LRV failure at a distance where voice/data cannot be relayed via LM. The MSFN would advise the crew on the requirement for using this mode.
1	LCRU POWER SWITCH--OFF Remove LCRU power connector.	
2	Restow VHF antenna into thermal blanket restraining loops.	
3	Remove HGA connector from LCRU.	Thermal blanket side flap must be opened to expose RF connectors.
4	Remove LGA connector from LCRU, remove cable from LRV clip attachments, and place cable on LRV.	
5	Remove upper GCTA connector and tilt GCTA outboard by releasing mast lock.	CAUTION: <u>When releasing GCTA mast lock, hold GCTA to prevent it from falling on LCRU radiator.</u>
6	Tear away and discard both LCRU thermal radiator covers.	

Step	Procedure	Remarks
7	Lift locking levers (2) on LCRU support posts.	
8	Remove LCRU and place on LRV.	
9	Remove LGA from antenna staff by pushing detent button on upper portion of staff.	
10	Coil LGA cable and use velcro to keep in place.	
11	Insert LGA into splined hole in right forward corner of LCRU and reconnect cable connector to LCRU.	
12	Pick up LCRU using its handle and place on LRV in simulated walking azimuth direction.	
13	Point LGA to earth using splined elevation adjustment and friction lever adjustment.	To rotate antenna in elevation, it must be lifted past the spline locking detent. After adjustment, push antenna back past detent.
14	LCRU POWER SWITCH--INT S-BD MODE SWITCH--PM1/NB Perform voice and data check with MSFN.	
15	During contingency handcarry traverse, LCRU may be temporarily placed on lunar surface at least 15 minutes. 4.2.15 <u>LCRU BACK-UP VOICE/DATA MODES</u> The Flight Malfunction Procedure, paragraph 2.0 should be utilized.	