

14.3.2 Loss of Laser Altimeter Altitude Data

The laser altimeter exhibited two anomalous conditions during the mission:

- a. Altitude data became intermittent after revolution 24 as the result of a decrease in the laser output power.
- b. Beginning with revolution 38, the photomultiplier tube high-voltage power supply was held in the idling (minimum-voltage level) mode until after the laser fired, thereby causing the receiver to miss the return pulse from the lunar surface (**Fig. 14-37**). No altitude data were obtained after this anomaly occurred.

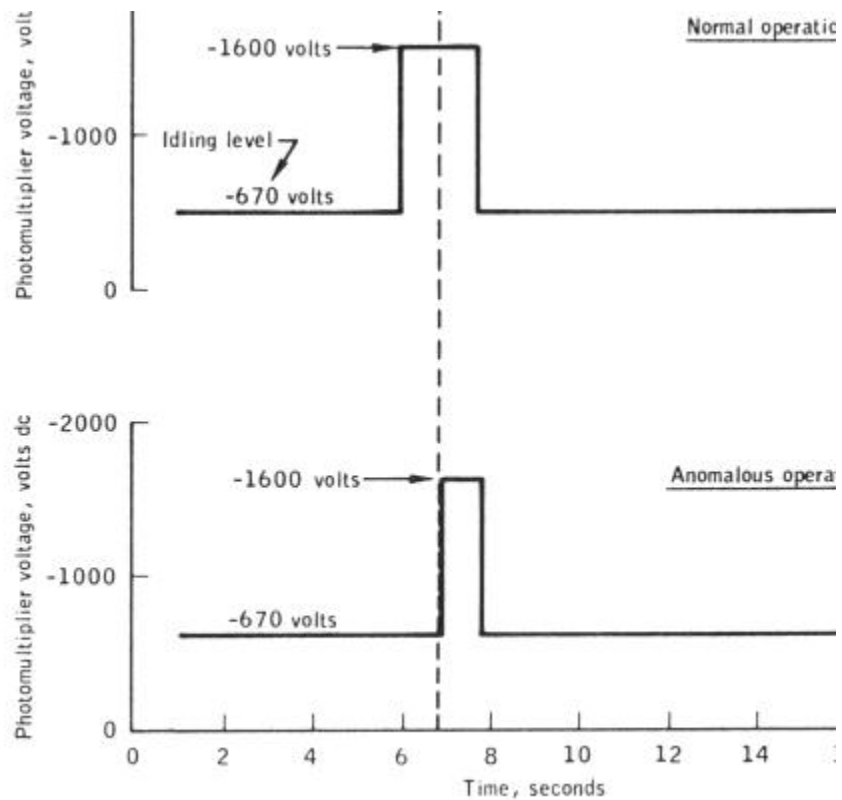


Figure 14-37.- Comparison of photomultiplier power supply volt.

The photomultiplier tube power supply anomaly was duplicated when a relay which had been removed from a flight unit because it had an audible "buzz" was installed in the prototype altimeter. The relay serves no function in flight, but is a safety precaution for ground personnel working on the altimeter (**Fig. 14-38**). The relay contacts close when the altimeter is turned off, discharging the high voltage stored in the pulse forming network capacitors.

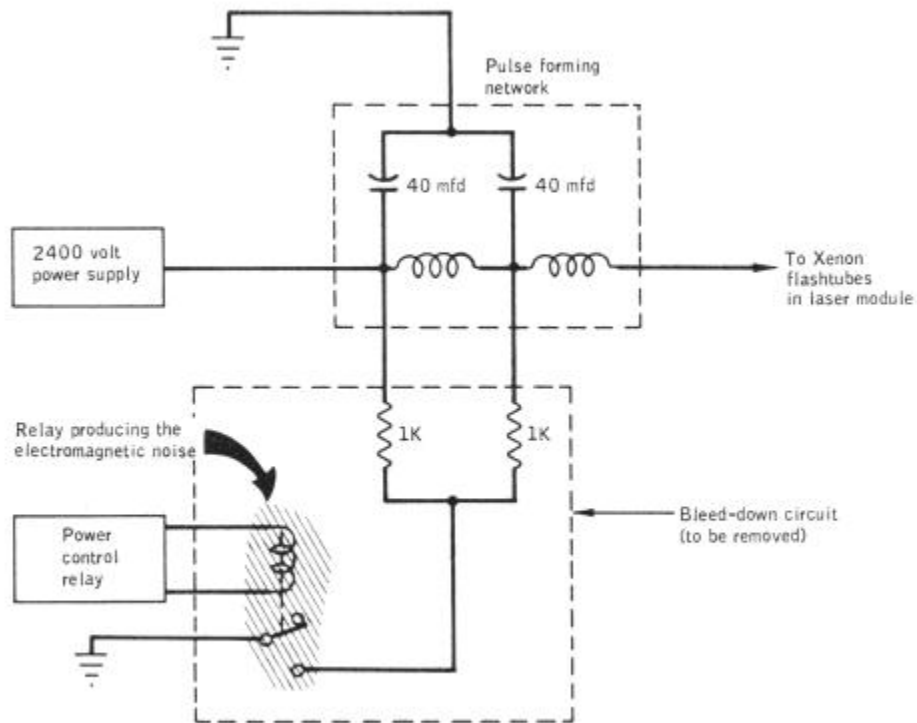


Figure 14-38.- Pulse forming network bleed-down circuit.

It is suspected that the audible "buzz" is accompanied by electromagnetic interference that is coupled into the video amplifier in the laser receiver (**Fig. 14-39**). The video amplifier is a principal element in the automatic gain control circuit which controls the output of the photomultiplier tube power supply. The electromagnetic interference from the relay can thereby result in the automatic gain control holding the power supply in the idling mode until the pulse forming network is discharged in firing the laser. The relay and resistors that comprise the bleed-down circuit will be removed from the remaining flight altimeters.

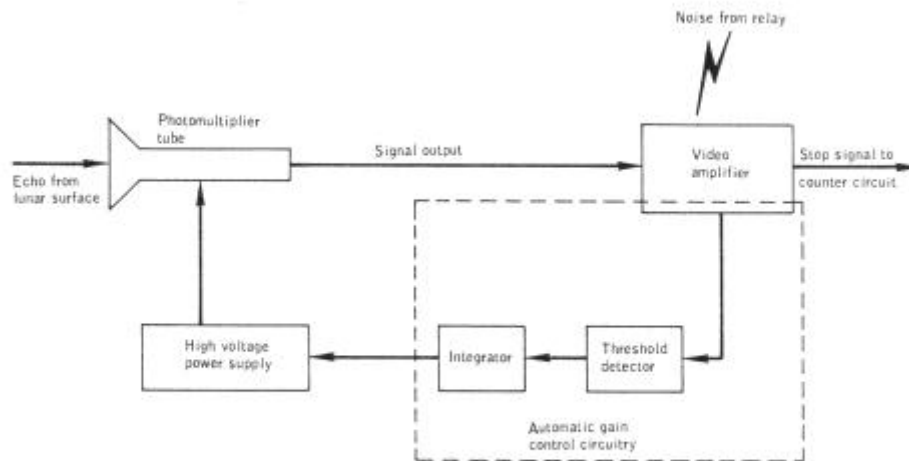


Figure 14-39.- Laser receiver circuitry.

The cause of the low output power anomaly has not been isolated. A review of the manufacturing records has established that the flight unit was the same as the qualification unit with regard to parts, processes, and manufacturing methods. Investigations indicate that the fault most likely occurred in the laser module.

An automatic power compensation circuit will be incorporated into the remaining flight units. The circuit will increase the pulse forming network voltage by about 50 volts each time the laser power falls below an established threshold value as sensed by a photodiode. Design feasibility tests have been completed on a breadboard circuit. The results show that the circuit will maintain the power output at a level sufficient to provide proper ranging.

This anomaly is closed.

14.3.3 Slow Deployment Of Mapping Camera

The extension and retraction times of the deployment mechanism subsequent to the first extend/retract cycle were two to three times longer than the preflight nominal time of approximately 1 minute 20 seconds. Also, the camera could not be fully retracted after the final deployment. During the transearth extravehicular activity, an inspection of the mapping camera and associated equipment showed no evidence of dragging or interference between the camera and the spacecraft structure, the camera covers, or the cabling.

The first extend and retract cycle times were 1 minute 20 seconds and 1 minute 17 seconds, respectively. The second retraction required 2 minutes 30 seconds and the third retraction and fourth extension required slightly more than 4 minutes. The second and third extensions occurred while the telemetry, system was in the low-bit-rate mode;

therefore, these deployment times are not obtainable. Subsequent extensions and retractions required 2 to 4 minutes.

Load tests show that a restraining force of 250 pounds would increase the deployment time to 1 minute 45 seconds. With one of the two extend/retract mechanism motors operating, the 250-pound restraint would increase the deployment time to 2 minutes 25 seconds.

Voltage tests show that 12 volts to the motors (28 volts dc nominal rating) would result in deployment times of approximately 4 minutes. Had this occurred during the mission, however, the indicator which shows that power is applied to the motors would have displayed a partial barberpole during deployment operations. The barberpole indicator is connected in parallel with the motors and, since the position is voltage-dependent, it can be used to approximate the voltage levels to the motors. During the flight, a full barberpole indication was always observed.

Apparently, the problem first occurred sometime between the first and second retractions. During this period, a 4-second service propulsion system firing was performed for lunar orbit circularization. An evaluation of vibration test data indicates, however, that the circularization firing was probably not a factor in the anomaly. An investigation is being made to determine if there is mechanical interference between the camera and the reaction control system plume protection covers.

This anomaly is open.

14.3.4 Gamma Ray Spectrometer Calibration Shifts

During the mission, the gamma ray spectrometer experienced a downward gain shift of approximately 30 percent, but this was compensated for by commanding the high-voltage step function from the command module. The drift decreased with time at an initial rate of 1 percent per hour and a final rate of 0.4 percent per day. Near the end of the mission, the gamma ray spectrometer was operating in a relatively stable state at 824.8 volts (high voltage step 6). (A step 4 voltage of 777.8 volts was the normal position in preflight operation.) The spectrometer to be flown on Apollo 16 was aged at flux rates representative of those encountered in lunar operation. The unit has stabilized after having experienced a gain change of approximately 8 percent.

After transearth injection, a temporary eight-channel zero reference shift was observed. This shift disappeared when the instrument was repowered after the transearth extravehicular activity, and subsequent instrument operation was normal for about 25 hours during transearth coast. Shortly before entry, the offset shift reappeared and remained until the experiment was turned off. Normalization of the data during processing will compensate for this offset.

Tests conducted with the qualification unit verified that the change in gain was due to aging effects of the photomultiplier tube in the gamma ray detector assembly as a result of high cosmic ray flux rates in lunar operation. The zero shift appears to be associated with the run-down inhibit signal between the clock-gate module and the analog-to-digital converter (**Fig. 14-40**).

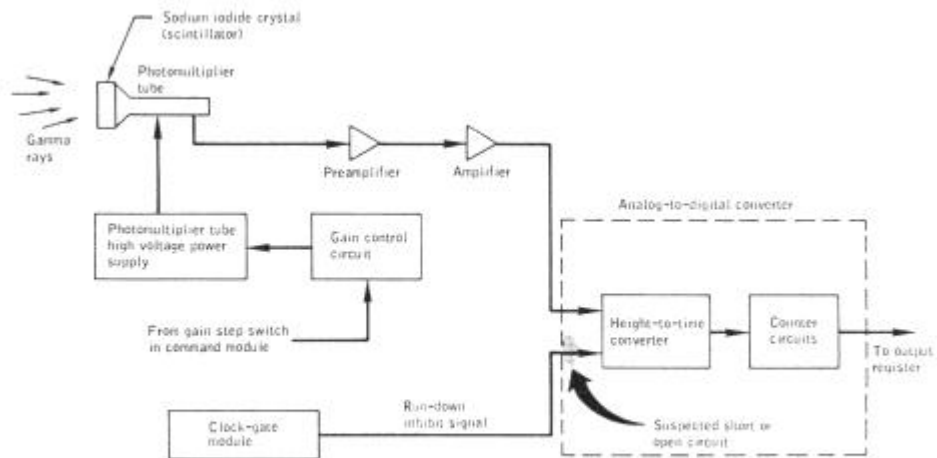


Figure 14-40.- Gamma ray spectrometer circuitry.

Absence of this signal at a particular point in the analog-to-digital converter removes a 3-microsecond offset in the pulse height analyzer. The resulting effect is an overall eight-channel offset in the spectrum. The qualification unit was partially disassembled and tests showed that either an open or a shorted wire within the pulse height analyzer can result in an eight-channel offset. An inspection of the circuit in the qualification unit disclosed no design deficiency which would cause this type of failure. Since the eight channel zero offset does not significantly impact overall data quality, no corrective action is contemplated.

This anomaly is closed.

14.4 APOLLO LUNAR SURFACE EXPERIMENTS PACKAGE AND ASSOCIATED LUNAR SURFACE EQUIPMENT

14.4.1 Problems During The Lunar Surface Drilling Operations

The Apollo lunar surface drill performed well during the lunar surface activities; however, the following problems related to drilling operations were encountered:

- a. Penetration of the surface to the full depth with the bore stems was not achieved.
- b. Releasing the bore stems from the drill adapter was difficult.
- c. Bore stem damage occurred near the first joint.
- d. Removing core stems from the drilled hole in the lunar surface was difficult.
- e. Separation of core stem sections was difficult.

Difficulty in penetrating the surface to the desired depth with the bore stems

Although the average penetration rate for the two bore stem holes was reasonable (approximately 120 inches per minute for hole 1, and 18 inches per minute for hole 2), it was necessary to stop both holes at approximately 60 percent of the depth desired.

The bore stem sections are made of a fiberglass and boron filament laminate, chosen for its optimum thermal characteristics as a casing for the heat flow experiment probe. The sections are approximately 21 inches long with tapered male and female joints. One-inch double-thread spiral lead flutes are provided on the exterior surface to transport the soil chips from the drilled hole to the surface. The depth of the flutes is 0.050 inch for about 18 inches, but the flutes almost disappear at the joint area where the wall thickness must follow the taper of the joint (**Fig. 14-41**). As a result, the volume of chip flow to the surface is slowed considerably in looser soil formations, and stalled by the packing of the chips in high-density formations.

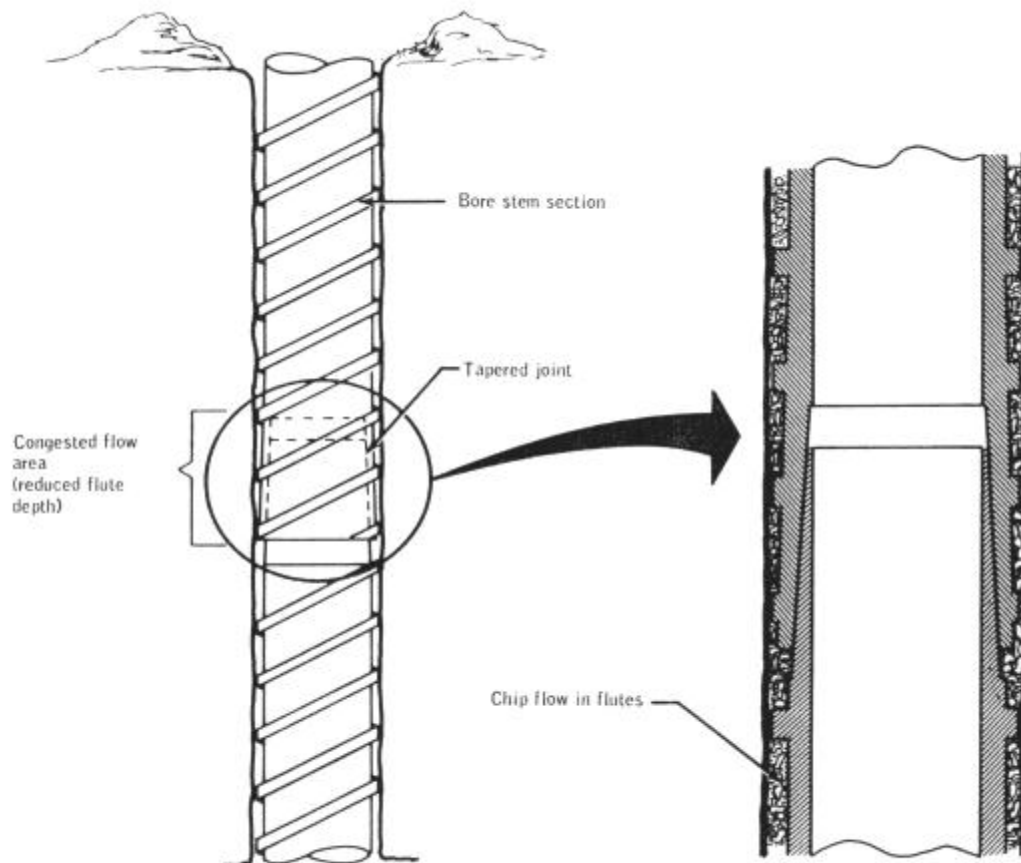


Figure 14-41.- Congestion at bore stem joints.

In order to reduce the time required, prevent damage to bore stems, and increase the probability of attaining the full depth, the following modifications and corrective actions are being implemented:

The bore stem joints will be changed from boron/fiberglass tapered joints to threaded titanium inserts which provide continuous flutes as do the core stems. The thread configuration also provides a more positive connection, precluding inadvertent separation of the joint in the hole.

The length of the first (bottom) bore stem section will be increased so that the 43-inch probe for the heat flow experiment is housed entirely in the boron/fiberglass material and the titanium joint is not in the probe region.

The length of the remaining sections will be increased by a small amount, which will reduce the number of joints for the crew to mate as well as keep the titanium away from the experiment thermocouples.

Crew training will include boring and coring experience with a soil model typical of the Hadley Rille soil characteristics as well as models of less dense soil.

This anomaly is closed.

Difficulty in releasing bore stems from drill adapter

Use of the normal procedure for releasing the lunar surface drill head from the bore stems was hampered by the bore stems turning freely in the lunar soil.

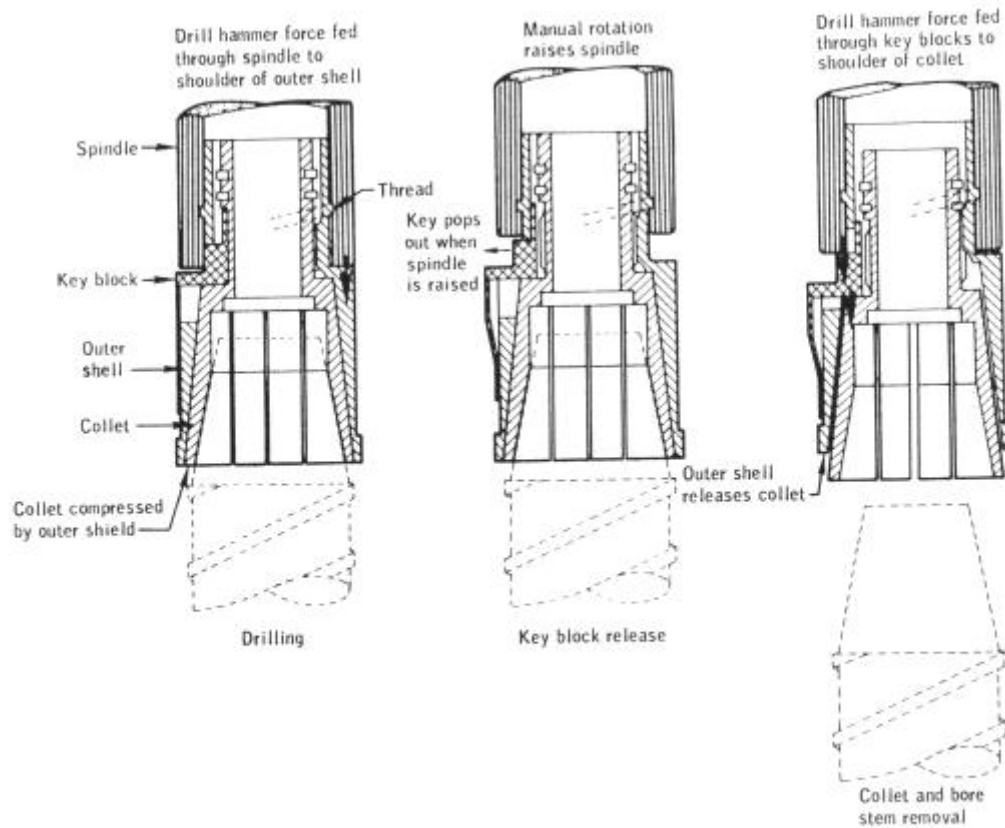


Figure 14-42.- Release of bore stem from drill.

In the bore stem drilling position, the key blocks are restrained inside, and the spindle drives against the shoulder of the adapter outer shell (**Fig. 14-42**). The operational sequence to release the bore stem from the adapter includes the following steps:

With the bore stem held stationary, the power head is rotated by hand 90 degrees counterclockwise. This moves the spindle and adapter shoulder about 1/4-inch apart and releases the spring-loaded key blocks outward.

With the key blocks in the outward position, pulsing the power head transfers power from the spindle through the key blocks to the collet shoulder, thus moving the collet about 1/4-inch, and releasing the bore stem.

In development ground tests, the soil friction usually kept the bore stem from turning in this operation. When there was insufficient friction from the soil, the bore stem was grasped with the gloved hand. On Apollo 15, the soil did not hold the bore stem, and the core-stem wrench was used to hold the bore stems for this operation.

The single-purpose core stem wrench is fitted to the 0.983-inch- diameter titanium core stem, but the 1.088-inch throat will admit the 1.075-inch-diameter bore stem. The softer bore stem (boron-fiberglass laminate) can be deformed and present some difficulty in wrench removal, with possible damage to the bore stem. A wrench to fit both bore and core stems will be provided.

The change of the bore stem joint, discussed in the previous anomaly, will result in the elimination of the present bore stem drill adapter. The bore stem will thread into the power head spindle adapter in the same manner as the core stems on Apollo 15 and a spindle thread reducer will be provided to fit the core stems. In addition, the training models and procedures will be updated to reflect equipment changes.

This anomaly is closed.

Bore stem damage near the first joint

The probe would not go to the bottom plug of the bottom bore stem in hole 2, but stopped at a point about 6 inches above the first joint. Examination of photographs and heat flow probe data indicate that, near the end of the bore stem drilling operation, the first joint was separated when the drill and drill string were moved vertically (up and down) in an attempt to improve the drill penetration rate. Easier penetration (for approximately 6 inches) was reported by the crew, but it resulted from the bottom of the second section apparently performing more in a coring manner (**Fig. 14-43**) with the lunar soil entering the second section of the bore stem.

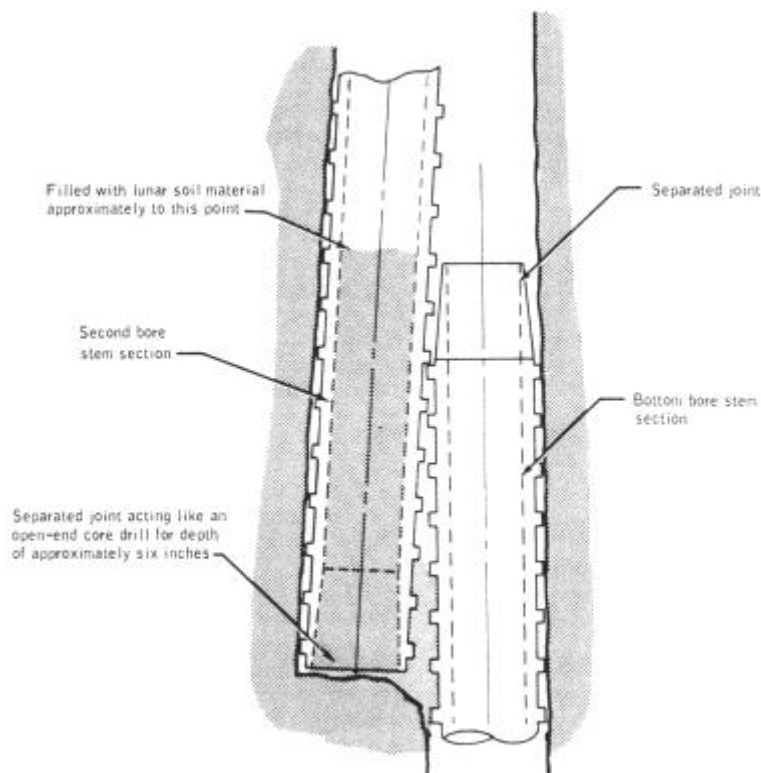


Figure 14-43.- Bore stem joint separation.

The change from boron/fiberglass to threaded titanium in the bore stem joint will prevent a repetition of such a separation.

This anomaly is closed.

Difficulty in core stem removal from the drilled hole in the lunar surface

Friction of the compacted soil in the drill flutes can build up substantial forces against core stem removal in a deep hole in some soil formations. This was illustrated in premission and drill development experiences.

Interference from the compacted material in the drill flutes can be reduced and core stem removal eased by pulsing the power head when at the bottom of the hole without upward and downward motion of the drill stem. Ground tests have indicated that the best results are obtained when the power head is pulsed just before the power head is removed to add each core stem section. The tendency to auger, as reported by the crew, is also reduced by pulsing the power head before each new core stem is added.

To assure maximum core return and minimum core disturbance for this mission, and without having the benefit of some of the experience from later ground tests, the crew did not pulse the power head. In addition, the core stem string was left in the ground for several hours before the crew returned for its final removal. The core stem string was removed with considerable physical effort, but a very complete core was recovered.

A mechanical assist (modified jacking mechanism) will be mounted on the treadle for easier core removal from difficult formations. Training and procedural changes will be implemented so that the drill motor will be pulsed before the addition of each core stem.

This anomaly is closed.

14.4-1.5 Difficulty in separation of core stem sections

The sections of the core stem string could not be separated using the vise and wrench because the vise had been mounted on the pallet backward. The six section core stem string was removed from the core hole as a single unit and brought to the vise on the lunar roving vehicle. Three sections were separated individually with hand friction on one side of the joint and the wrench on the other side. The remaining three sections were returned to the earth in one piece.

The configuration of the core stem vise is the same as that of the core stem wrench head. The vise is mounted on a bracket on the lunar roving vehicle aft chassis pallet, located on the right hand side of the vehicle. The core stem wrench head is similar to the conventional pipe wrench head, with one fixed jaw and one pivoted jaw. The throat width is not adjustable and is designed to fit the outside diameter of the core stem.

As mounted, the vise would hold the core stem so that the joint could be tightened by rotating the wrench on the adjoining section. However, the vise would not hold in the opposite direction so that the joint could be loosened and separated (**Fig. 14-44**). Working on the inboard side of the vise, the core stem could have been held properly for loosening; however, there is insufficient clearance on the inboard side of the vise for

wrench rotation, and the distance to the other side of the lunar roving vehicle is greater than the length of a core stem section.

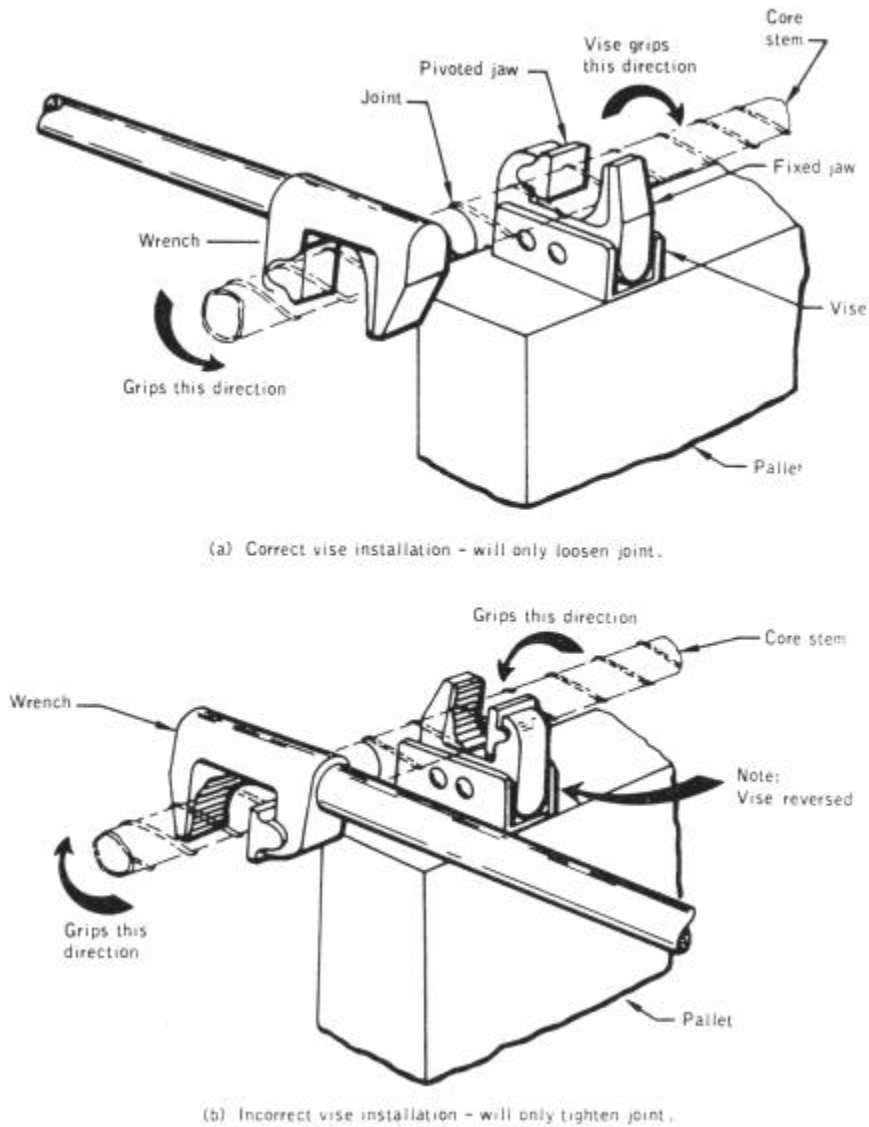


Figure 14-44.- Installation of core stem vise on rover pallet.

The installation drawing of the vise was in error and has been corrected to assure correct orientation of the vise for Apollo 16. The training vise was installed backward from the erroneous drawing, but correct for loosening the stems.

This anomaly is closed.

14.4.2 Central Station Rear Curtain Retainer Removal Lanyard Broke

To remove the retainer for the central station rear curtain, added for Apollo 15, it was necessary to remove two retaining pins (**Fig. 14-45**). The two pins, a universal handling tool fitting, and the curtain retainer are joined by a three-section lanyard. When the universal handling tool was inserted in the fitting and raised to remove the first pin, that section of the lanyard broke. When an effort was made to remove both pins simultaneously by inserting the handle under the lanyard joining the two pins, that part of the lanyard broke. The pins and retainer were then removed by hand.

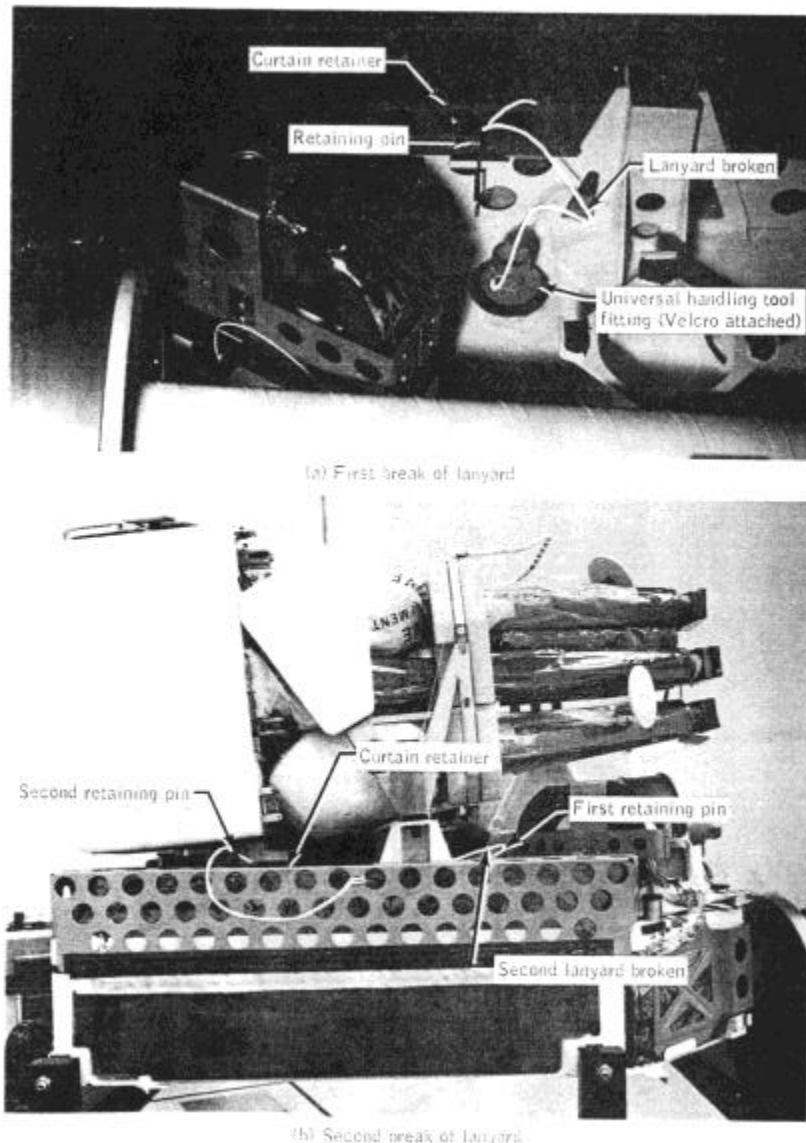


Figure 14-45.- Central station rear curtain retainer removal.

The Dacron lanyard is being changed from a 50-pound test rated material to a 180-pound test rated material with acceptance pull tests being increased to 20 pounds for

the entire system.

This anomaly is closed.

14.4.3 Intermittent Lock of Universal Handling Tool In Suprathermal Ion Detector Fitting

While carrying the suprathermal ion detector experiment from the subpallet to the emplacement site, the experiment fell off the universal handling tool at least twice. The experiment sustained no visible damage and has been operating satisfactorily.

The universal handling tool fitting on this experiment is in the highest location above the lunar surface of any of the fittings and presents an awkward position of the tool for insertion, locking, and maintaining lock in the fitting (**Fig. 14-46**).

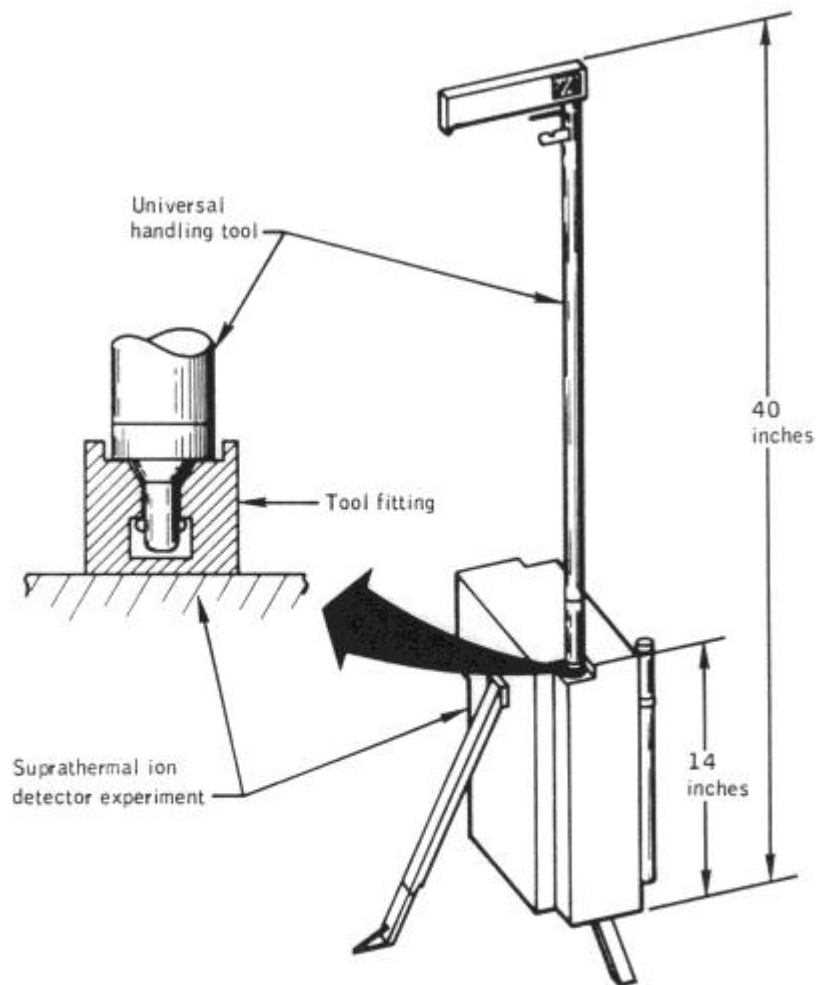


Figure 14-46.- Universal handling tool - suprathermal ion detector experiment interface.

Corrective action includes training procedures to avoid inadvertent tool-release triggering because of the position of the tool. There are no present plans for the suprathreshold ion detector experiment to be carried on future missions, and no other scheduled experiments have a similarly located fitting.

This anomaly is closed

14.5 GOVERNMENT FURNISHED EQUIPMENT

14.5.1 Television Control Unit Clutch Slippage

During the second extravehicular activity, the camera could not be elevated as the unit approached the upper or lower limits of angular travel. The condition further deteriorated during the third extravehicular activity.

Elevation control is provided to the camera cradle through a friction clutch (Fig. 14-47) which allows manual override of the ground-commanded camera positioning. The camera-cradle pivot point is approximately 3 inches below the center of gravity of the cradle with the camera mounted. As the camera moves away from the horizontal position, the unbalanced moment becomes progressively greater, and a higher torque load must be supported by the clutch mechanism.

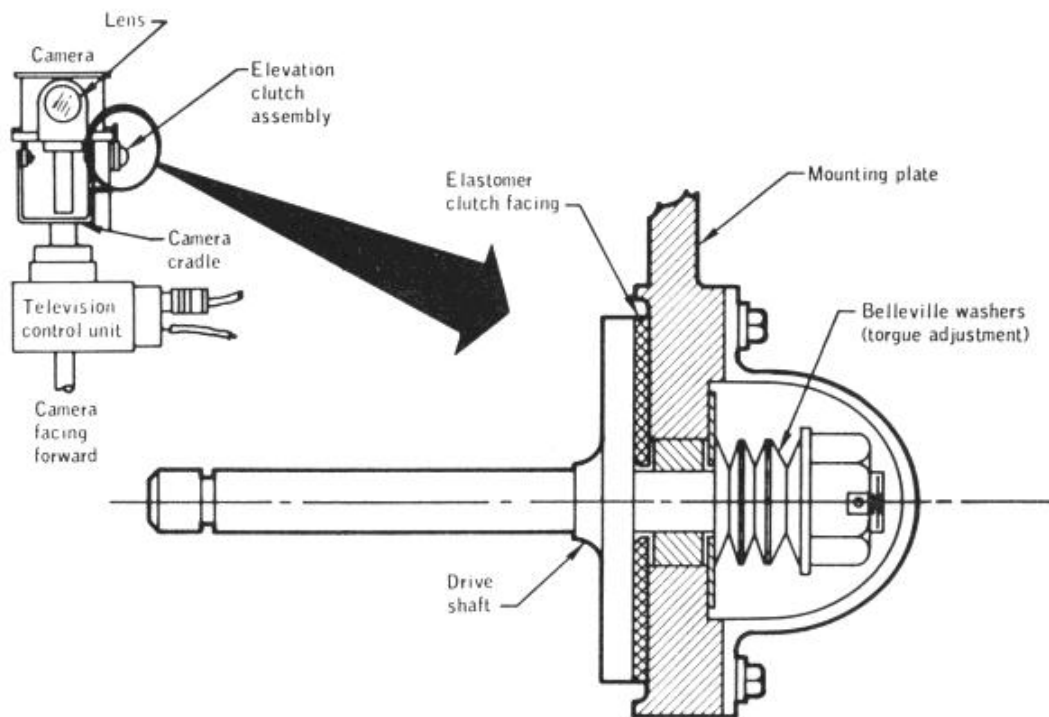


Figure 14-47.- Camera elevation control clutch.

The elastomer clutch-facing material provided the required stable friction properties in the specification and qualification test temperature range (122° F, maximum). However, the maximum temperature on the television control unit during the third extravehicular activity has been calculated as approximately 180° F. Materials specifications show that the compressive strength of the elastomer degrades rapidly at this temperature, and ground tests with flight unit 4 verify severely degraded performance with time at elevated temperature.

The clutch is being changed to a metal-to-metal spring ring design in place of the elastomer disc. The clutch torque for Apollo 15 was set at 16 inch-pounds for ease of manual adjustment. For greater stability on Apollo 16, the new clutch is being built with a torque of 30 inch-pounds, which is still comfortable for manual positioning and is within design limits of the system, including the gear train (35 inch-pounds).

This anomaly is closed.

14.5.2 Lunar Communications Relay Unit Downlink Signal Lost

The lunar communications relay unit downlink signal was lost about 40 hours after lunar module ascent. The unit operated on internal battery power during the extravehicular traverses. Near the end of the third extravehicular activity, it was manually switched to lunar roving vehicle power in preparation for viewing ascent and for continuing television observations. The power distribution from the lunar roving vehicle to the television system is shown in figure 14-48. The lunar communications relay unit transmitter and television camera had been commanded on from the ground 13 minutes prior to the RF downlink- signal loss. The lunar communications relay unit status subcarrier had been commanded on 7 minutes prior to signal loss. The television camera was stationary and a 1-second incremental iris movement was occurring at the time of signal loss.

The flight data (**Fig. 14-49**) shows that the automatic gain control measurement began to fall followed by the video signal decay. This was followed by the decay of the lunar communications relay unit temperature measurement. The RF signal level then decreased below the ground receiver threshold as indicated by complete signal loss. The overall loss of the downlink signal within 5 milliseconds is indicative of 28-volt d-c power loss. Decay of the temperature measurement is indicative of 16.5 volt d-c power loss. The lunar communications relay unit dc-to-dc converter (**Fig. 14-48**) supplies both the 28-volt and 16.5-volt d-c power. To verify loss of 16.5-volt power, an uplink voice signal was transmitted to key the VHF transmitter on. No signal was received on the Stanford 150-foot VHF antenna which indicates that the VHF transmitter, powered from 16.5 volts dc, was inoperative.

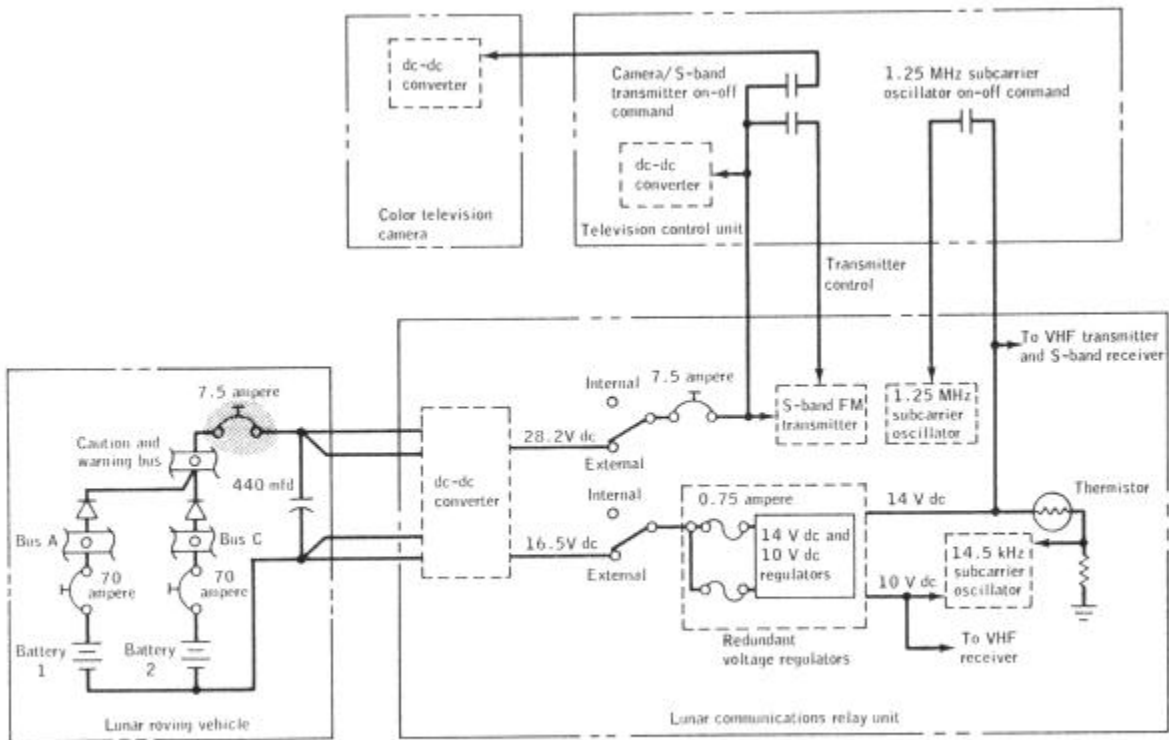


Figure 14-48.- Lunar roving vehicle/lunar communications relay unit/ground controlled television assembly power distribution.

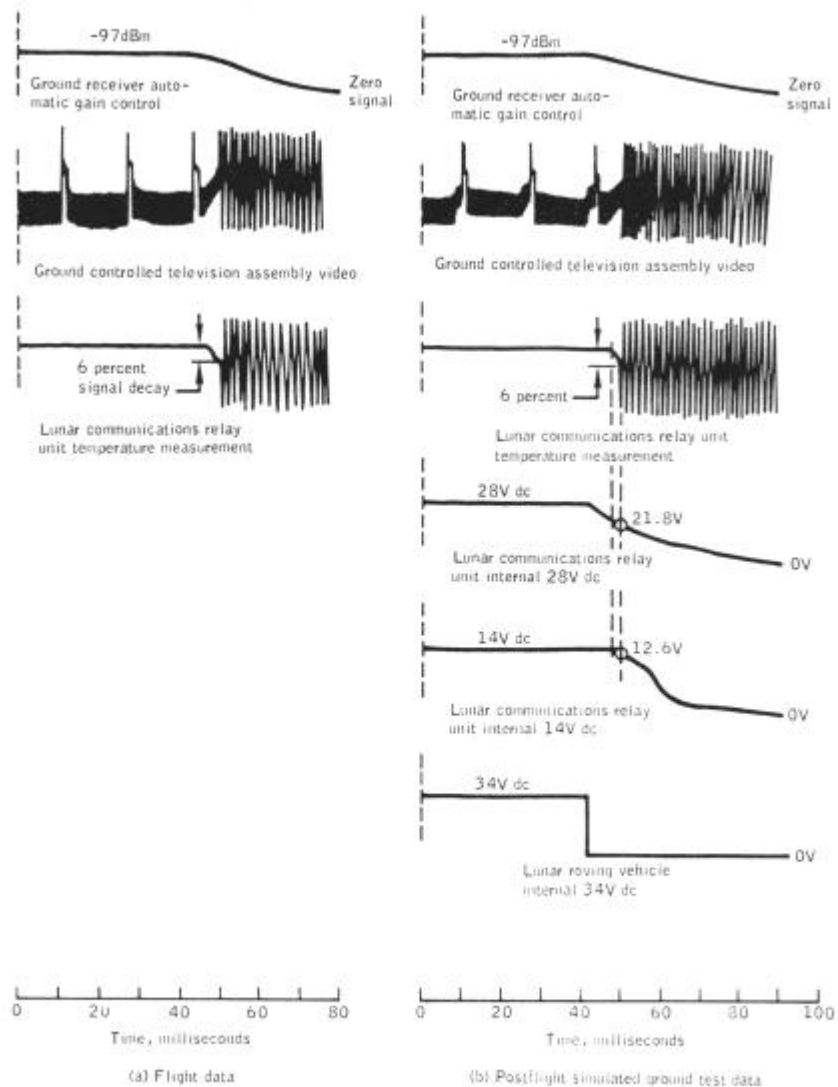


Figure 14-49.- Comparison of signal deterioration characteristics.

In laboratory tests, the fault which duplicated the flight data was the opening of the lunar roving vehicle power line prior to the 440-microfarad capacitor (figs. 14-48 and 14-49). The tests show that the decay time of the lunar communications relay unit 28-volt and 14-volt power is increased by discharging the 440-microfarad capacitor. Other induced faults resulted in shorter power decay times, affecting the received signal accordingly. The temperature measurement output (see thermistor in fig. 14-48) is proportional to the decay in 14-volt power. Consequently, the 6-percent decay of the flight temperature measurement corresponds to a 1.4-volt decay. This characteristic was duplicated when the lunar roving vehicle power line was opened. The 28-volt power decayed to 21.8

volts dc as the 14-volt power decayed to 12.6 volts. The RF transmitter power at this voltage will be decreased by 6.4 dB, and accounts for the total signal loss at this time since the ground receiver would be below its operating threshold.

The lunar roving vehicle power line has a 7.5-ampere circuit breaker forward of the 440-microfarad capacitor (fig. 14-48). Testing a 7.5-ampere circuit breaker under elevated temperatures (1800 F) and at vacuum conditions showed that the current capacity is also dependent on the connecting wire size because the wire provides a heat sink to the circuit breaker thermal element. The rover 7.5-ampere breaker used 20-gage connecting wire. Test results show that the breaker, with 20-gage connecting wire, at elevated temperatures and under vacuum conditions, will trip at 3.3 amperes. This corresponds to the calculated lunar communication relay unit load at the time of power failure.

A 10-ampere circuit breaker instead of the 7.5-ampere breaker and, in addition, a manual switch in the lunar rover circuit to override the circuit breaker after completion of vehicle activity are being provided for Apollo 16. Also, the lunar communications relay unit is being modified so that its internal 7.5-ampere circuit breaker is bypassed when operating in the external power mode.

This anomaly is closed.

14.5.3 Lunar Surface 16-mm Camera Magazines Jammed

The crew experienced film jams with the lunar surface 16-mm camera film magazines. Five out of eight magazines transferred to the lunar surface jammed, two were not used, and one successfully transported the film to completion.

Analysis of the returned magazines indicated two factors contributing to jamming.

The first magazine used had drive-spline damage and scratches on the front face, indicating that the installation in the camera was improper and that the magazine and camera were misaligned. Misalignment of the floating female spline of the camera with the male spline of the magazine caused metal to be removed from the brass male spline. In normal camera operation, the take-up claw advances one frame of film for each exposure while the metering sprocket replenishes the supply loop and removes a frame from the take-up loop, thus retaining the same amount of slack film in both loops. When the metering sprocket is not driven because of mismating, the camera claw removes film from the supply loop, which is not being replenished, and adds it to the take-up loop, resulting in the jammed condition shown in **Fig. 14-50**. Two other magazines had damaged drive splines, indicating that mismating occurred on at least three occasions. Lunar surface pictures which include the 16-mm camera show that a strip of tape that is installed for latch stowage protection was not removed prior to installation of a magazine. Leaving the tape strip in place could have contributed to the camera/magazine mismating.

During troubleshooting between extravehicular activities, the crew manually advanced the film through the aperture in all remaining magazines. The amount of manual

advancement varied from five to twenty-one frames in the jammed magazines. The film supply loop (**Fig. 14-50**) normally contains three to five excess frames. The normal procedure is to inspect the magazine for proper frame alignment in the aperture area, and manually advance the film not more than one frame, if required to obtain proper alignment. The excessive manual advancement depleted the film supply loops in all magazines.

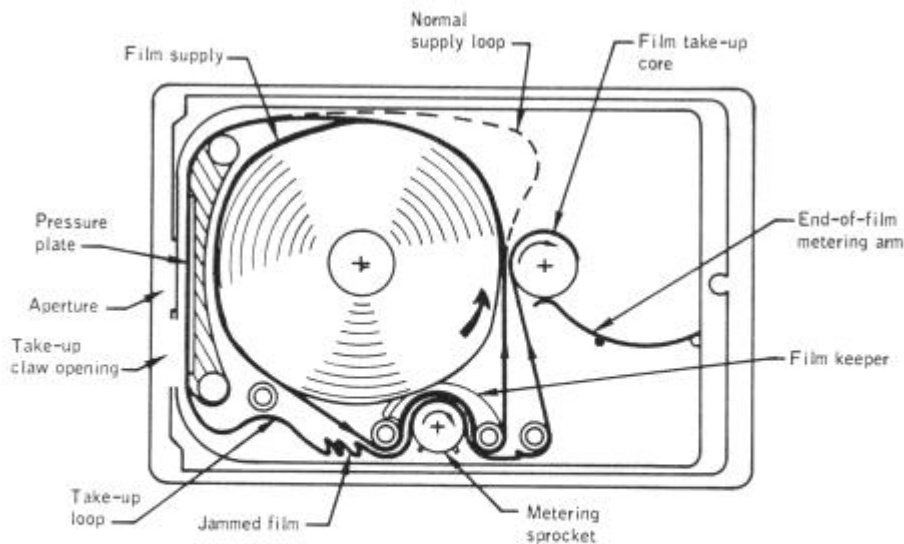


Figure 14-50.- Lunar surface 16mm camera magazine.

Hardware analysis, air-to-ground voice tapes, and crew debriefing indicate that the lunar surface camera functioned properly, and the jammed magazines resulted from procedural errors. Corrective actions are to insure adequate crew training through scheduled prelaunch briefings, stress malfunction procedures and corrective actions, and put a removal flag on the tape.

This anomaly is closed.

14.5.4 Lunar Module Pilot's 70-mm Camera Film Advance Stopped

Near the end of the second extravehicular activity, the 70-mm camera ceased to advance film. The crew reported that the camera was again operational after return to the lunar module. The camera was used again on the third extravehicular activity; however, after a short series of exposures had been made, the failure recurred. The camera was used for additional photography during the transearth phase without recurrence of the problem.

Postflight analysis of the hardware included operational testing, disassembly and

inspection, and measurement of battery charge. Operational testing with film loads indicated proper film advancement until approximately 200 cycles had been accumulated, at which time the failure mode was duplicated several times in succession. The film did not advance, although the motor was running. Disassembly and examination of the drive mechanism showed that the two set screws in the drive pinion were slipping on the motor shaft. After the last use of the camera during the mission, the crew had difficulty removing the magazine. This was caused by a rivet which had become detached from the camera magazine latch mechanism.

Corrective action is as follows: Flats will be ground on the motor shaft. A locking compound will be applied to the set screws when they are properly torqued against the flats. Also, epoxy will be applied to the tops of the screws to prevent them from backing off.

This anomaly is closed.

14.5.5 Difficult to Obtain Water From Insuit Drinking Device

After satisfactory operation during the first extravehicular activity, the mouthpiece of the insuit drinking device was displaced and the Commander was not able to obtain water during the second extravehicular activity. The Lunar Module Pilot was not able to actuate the drink valve of the insuit drinking device during either the first or second extravehicular activities.

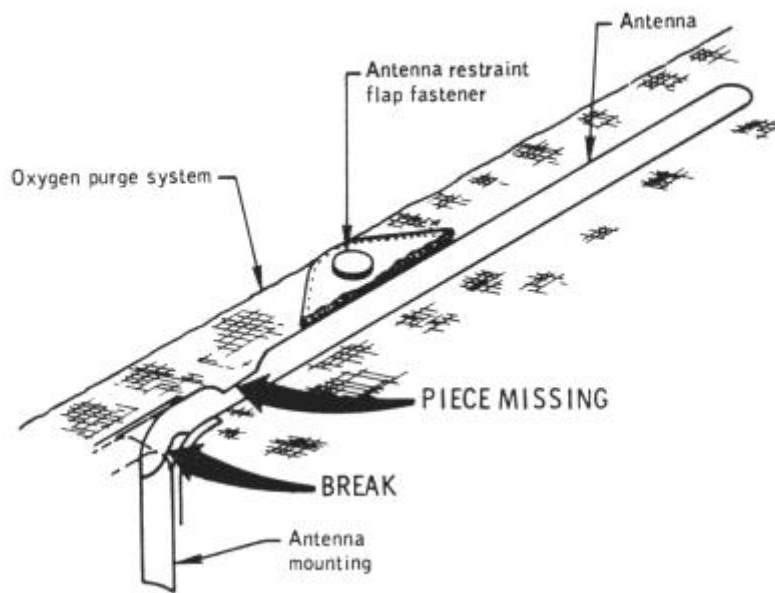
After each extravehicular activity, the insuit drinking device was removed from the suit and all of the water consumed, thus verifying proper operation of the insuit drinking device drink valve. The problem was associated with the positioning of the insuit drinking device within the suit.

Ground tests using suited subjects and other equipment configurations indicated that the existing equipment provides the optimum configuration. The tests also showed that personal experience is essential to obtaining optimum individual positioning. Crew training is to include more crew experience in making the position adjustments required for the individual's needs.

This anomaly is closed.

14.5.6 Lunar Module Pilot Oxygen Purge System Antenna Was Damaged

The crew reported that the Lunar Module Pilot's oxygen purge system antenna was broken off near the bottom during communications checkout prior to the second extravehicular activity. Previously, a notch had been observed in the antenna blade (see **Fig. 14-51**).



Antennas broken in training have shown similar flexure breaks. Observation of the notch edges of the returned antenna indicates that the notch started as a partial break in flexure, followed by material being torn out the rest of the way. Test results of the returned antenna indicated that the physical properties of the blade material were satisfactory with no excessive brittleness.

A flap which covers the entire antenna will be added for Apollo 16 to protect the antenna while the oxygen purge system is stowed and during unsuiting after extravehicular activities. The antenna will not be deployed until after egress to prevent it from being damaged inside the cabin or during egress.

This anomaly is closed.

14.5.7 Retractable Tether Failure

Both retractable tethers failed during lunar surface operations; the Commander's tether cord broke during the first extravehicular activity, and the tool clamp came off the end of the Lunar Module Pilot's tether. The Commander carried the standard 3/8-pound pull tether which consists of a case, a negator spring wound reel-to-reel on two spools, and a 30-pound cord wound on a spool mounted to one of the spring spools (**Fig. 14-52**).

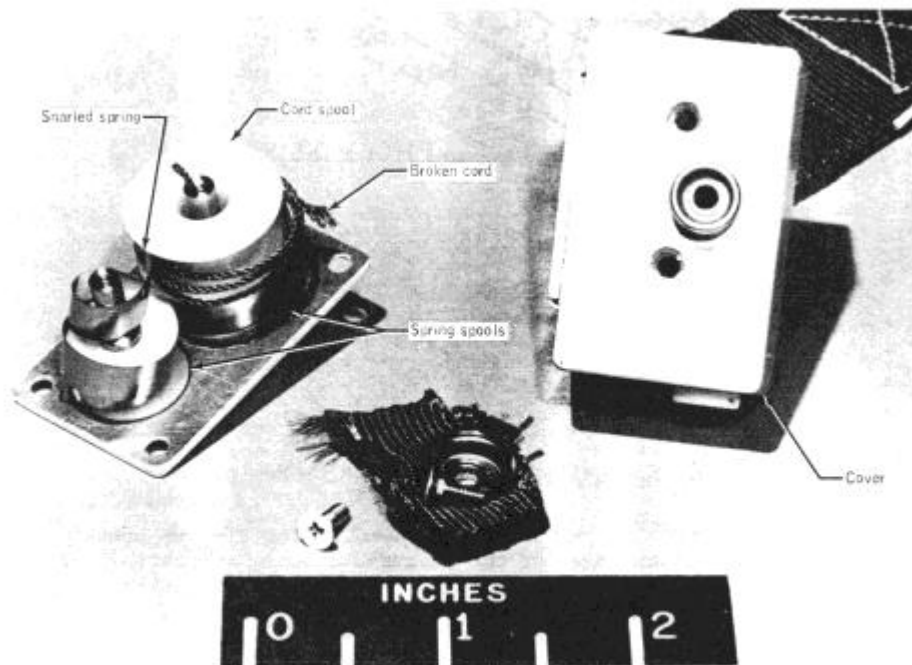


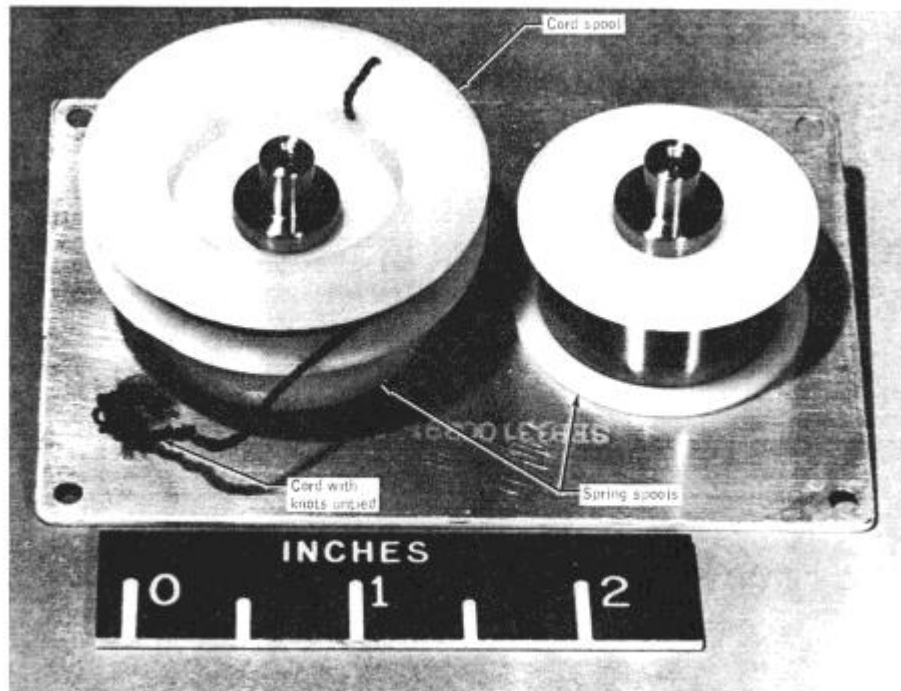
Figure 14-52.- Commander's tether (cover removed).

A tool clamp is attached to the external end of the cord. The Lunar Module Pilot carried the optional, somewhat larger, 1-pound pull tether of the same design.

Disassembly of the Commander's tether showed that the spring had expanded off the spool, snarled, and jammed against the case as the result of a no-load release of a slack cord (**Fig. 14-53**).

The cord had broken against a sharp edge of the spring when an attempt was made to extend the tether after the jam. The failure mode with the release of the slack cord is repeatable. Disassembly of the Lunar Module Pilot's tether showed that both the bowline and the figure-eight knot attaching the cord to the clamp had untied (**Fig. 14-53**) and this allowed the cord to retract into the housing. Changing this knot to an improved clinch knot will provide a more secure and permanent attachment. Crew training will emphasize proper use of the tethers.

This anomaly is closed.



14.6 LUNAR ROVING VEHICLE

14.6.1 Deployment Saddle Difficult To Release From Vehicle

The lunar roving vehicle deployment saddle was difficult to release from the vehicle during the final stage of deployment operations.

The causes of this problem are twofold and interrelated.

- a. The saddle-to-vehicle connection (**Fig. 14-54**) has close-tolerance interfaces to provide the rigidity required to prevent release-pin distortion and permanent binding. This design requires the vehicle/saddle interface to be completely free of stress to permit easy separation.
- b. The tilt of the lunar module to the rear and sideways, together with an uneven lunar surface, provided some stress preloading of the vehicle/saddle interface. Attempts by the crew to improve the rover position by moving and pulling on it may have aggravated this situation. The crew was aware that the interface had to be free of stress, and when this was accomplished, the saddle separated.

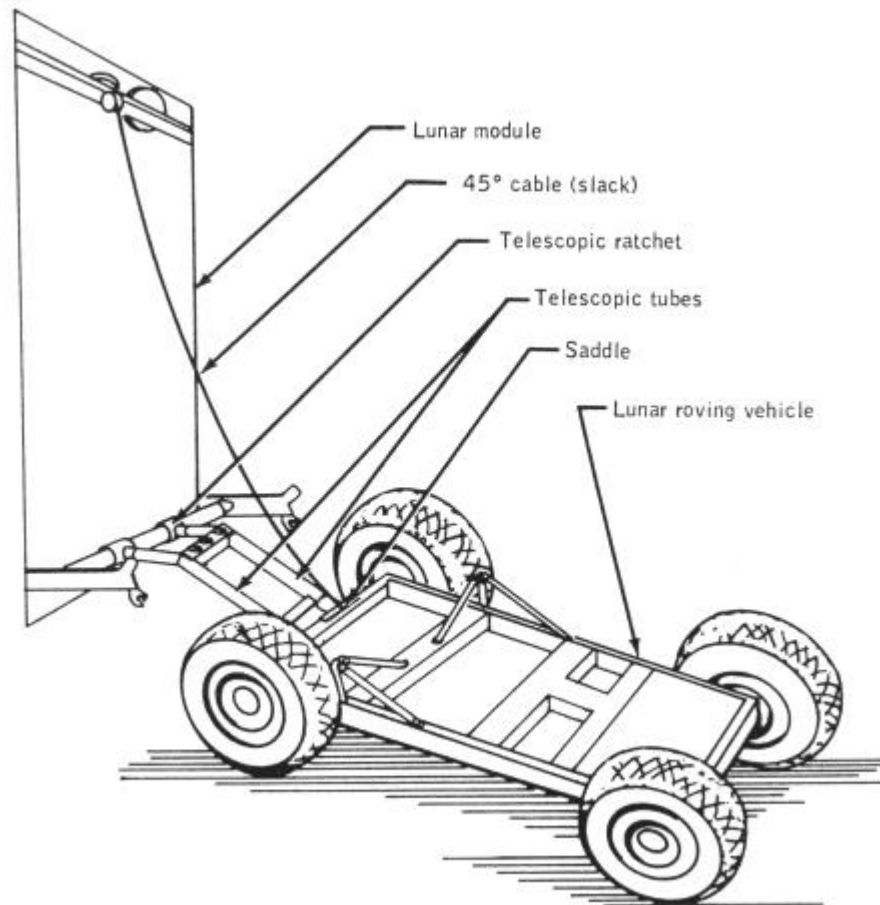


Figure 14-55.- Lunar roving vehicle deployment.

Ground tests have shown that if the partially deployed lunar roving vehicle resting on the surface but not yet detached from the saddle and lunar module, is rolled either to the left or right, the saddle/rover chassis interface will bind. The interface can be released, and the saddle dropped to the ground by one crewman adjusting the roll back to zero while the other taps the saddle with a hand tool. The corrective action is to insure adequate crew training.

This anomaly is closed.

14.6.2 Volt/Ammeter Inoperative

The lunar roving vehicle battery 2 volt/ammeter was inoperative upon vehicle activation, and remained inoperative throughout the traverses. Problems with the meter were experienced during its initial development; however, after a more rigid acceptance test program was implemented, the earlier problems were cleared. The flight problem was not duplicated during any of the ground tests. Since the instrument is not essential for the operation of the vehicle, no further action is being taken.

This anomaly is closed.

14.6.3 Front steering System Inoperative

During initial lunar roving vehicle activation, the front steering was inoperative. Electrical checks were made which verified that electrical power was being supplied to the front steering system. Unsuccessful attempts were made to manually rotate the wheels about their steering axes and to detect steering motor stall current on the ammeter. The forward steering circuit breaker and switch were cycled without any apparent effect. Consequently, the front steering was switched off for the first traverse. During preparations for the second traverse, the forward steering circuit breaker and switch were cycled and front steering was operative; however, the time that front steering capability was restored is unknown. Front-wheel wandering did not occur during the first traverse, indicating a mechanical problem. The steering continued to function properly for the second and third traverses. During the second traverse, the rear steering was turned off temporarily and wandering of the rear wheels occurred.

The most likely cause of this anomaly is motor and/or gear train binding, as indicated by the inability to drive back through the linkage and gear train by manually pushing against the wheels. Electrical causes are possible, but less likely.

The front steering system of the Apollo 16 lunar roving vehicle is currently being analyzed because of an intermittent failure of a similar nature. Manually pushing against the wheels would not always drive back through the linkage and gear train and the motor stalled at limit current for 0.8 second during a test of this condition.

This anomaly is open.

14.6.4 Lunar Roving Vehicle Seat Belt Problems

The following seat belt problems were experienced throughout all traverses

- a. The crew was trained to stow the belts, prior to egress, on the inboard handholds. However, during egress and ingress, the belt hooks would slip through the handholds to the floor area. Finding the belts after ingress was difficult because of their displacement from the proper stowage location.
- b. The belts snagged repeatedly on the ground Support equipment connector on the console support structure when displaced from the proper stowage locations.
- c. The belts were not of sufficient length to secure the hooks to the outboard handholds easily. This resulted primarily from an unexpected decrease in suit contour conformance to the seated position in 1/6g. Consequently, the crewmen's laps were several inches higher than had been anticipated.

The main causes of these problems, in addition to insufficient belt length, were insufficient belt rigidity and lack of visibility of the securing operation.

New, stiffer seatbelts with an over-center tightening mechanism will be provided for Apollo 16 to eliminate adjustment after each ingress and to provide more tightening capability.

This anomaly is closed.

15 CONCLUSIONS

The Apollo 15 mission was the fourth lunar landing and resulted in the collection of a wealth of scientific information. The Apollo system, in addition to providing a means of transportation, excelled as an operational scientific facility. The following conclusions are drawn from the information in this report:

The Apollo 15 mission demonstrated that, with the addition of consumables and the installation of scientific instruments, the command and service module is an effective means of gathering scientific data. Real-time data allowed participation by scientists with the crew in planning and making decisions to maximize scientific results.

The mission demonstrated that the modified launch vehicle, spacecraft and life support system configurations can successfully transport larger payloads and safely extend the time spent on the moon.

The modified pressure garment and portable life support system provided better mobility and extended the lunar surface extravehicular time.

The ground-controlled mobile television camera allowed greater real-time participation by earth-bound scientists and operations personnel during lunar surface extravehicular activity.

The practicality of the lunar roving vehicle was demonstrated by greatly increasing man's load carrying capability and range of exploration of the lunar surface.

The lunar communications relay unit provided the capability for continuous communications enroute to and at the extended ranges made possible by the lunar roving vehicle.

Landing site visibility was improved by the use of a steeper landing trajectory.

Apollo 15 demonstrated that the crew can operate to a greater degree as scientific observers and investigators and rely more on the ground support team for systems monitoring.

The value of manned space flight was further demonstrated by the unique capability of man to observe and think creatively, as shown in the supplementation and redirection of many tasks by the crew to enhance scientific data return.

The mission emphasized that crew training equipment must be flight equipment or have all the fidelity of flight equipment.

APPENDIX A - VEHICLE AND EQUIPMENT DESCRIPTION

This section contains a discussion of changes to the spacecraft, the extravehicular systems, and the scientific equipment since Apollo 14. In addition, equipment used on Apollo 15 for the first time is described.

The Apollo 15 command and service module (CSM-112) was of the block II configuration, but was modified to carry out a greater range of lunar orbital science activities than had been programmed for any previous mission. The lunar module (LM-10) was modified to allow an increase in lunar surface stay time and accommodate a larger scientific payload. The launch escape system and the spacecraft/launch vehicle adapter were unchanged. The Saturn V launch vehicle used for this mission was AS-510. The significant configuration changes for the launch vehicle are given in reference 1.

A.1 COMMAND AND SERVICE MODULES

A.1.1 Structure and Thermal Systems

A scientific instrument module was installed in sector I of the service module (**Fig. A-2**). The module containing instruments for the acquisition of scientific data during lunar orbit was attached with 1/4- inch bolts to radial beams 1 and 6, to the new cryogenic tank panel, and to the aft bulkhead of the service module. The sides of the scientific instrument module were constructed of aluminum stiffened sheet, and the shelves that supported the instruments were made of bonded aluminum sandwich. A door covered the module until about 4 1/2 hours prior to lunar orbit insertion when it was pyrotechnically cut free and jettisoned in a direction normal to the X-axis of the spacecraft (**Fig. A-2**). Protective covers and thermal blankets provided thermal control for individual instruments within the module. For additional thermal control, the inside surfaces of the module were coated with a material having an absorptivity- to-emissivity ratio of 0.3/0.85; the surfaces facing the radial beams, and the radial beams themselves, were coated with a material having an absorptivity- to-emissivity ratio of 0.05/0.4. The instruments are discussed; in section A.4.2.

Because of the requirement to retrieve film cassettes from the scientific instrument module during transearth coast, extravehicular activity handrails and handholds were installed along the sides of the module and inside the scientific instrument module. A foot restraint was also attached to the module structure (**Fig. A-3**).

A.1.2 Cryogenic Storage

A third hydrogen tank was installed in sector I of the service module, as planned for all J-type missions. The isolation valve between oxygen tank 2 and 3 was moved from sector IV to the forward bulkhead to decrease its vulnerability in the event of a catastrophic tank failure. All single-seat check valves in the hydrogen and oxygen lines were replaced with double-seat valves having greater reliability. Thermal switches formerly used in the hydrogen tank heater circuits inside the tanks were removed.

A.1.3 Instrumentation

A scientific data system was integrated with the existing telemetry system (**Fig. A-4**) to provide the capability for processing, storing, and transmitting data from the scientific instrument module. The data processor, located in the scientific instrument module, necessitated changes to the data storage equipment and the introduction of a data modulator and a tape recorder data conditioner. The data storage equipment was modified to have twice the recording time of the previous equipment, and was redesignated the data recorder reproducer. The tape recorder data conditioner was added to minimize flutter-induced jitter of recorded pulse- code-modulated data.

A.1.4 Displays and Controls

Switch S30 was deleted from panel 2 and its function was incorporated into switch S29 so that both cabin fans operated simultaneously. Toggle switch S137 was added to panel 2 for hydrogen tank 3 fan motor control. The pressure and quantity outputs of hydrogen tank 3 were connected to meter displays through switches S138 and S139 on panel 2. Panels 181 and 230 were added to provide controls for the experiment equipment in the scientific instrument module. Experiment cover controls were added to Panel 278. Panel 603 (**Fig. A-5**) was added to provide umbilical connections for extravehicular activity. Panel 604 (**Fig. A-5**) was added to provide an audio warning signal to the extravehicular crewman in the event of low suit pressure or low oxygen flow.

A.1-5 Propulsion

The diameter of the fuel inlet orifice in the service propulsion system was decreased to improve the propellant mixture ratio.

A.1.6 Environmental Control System

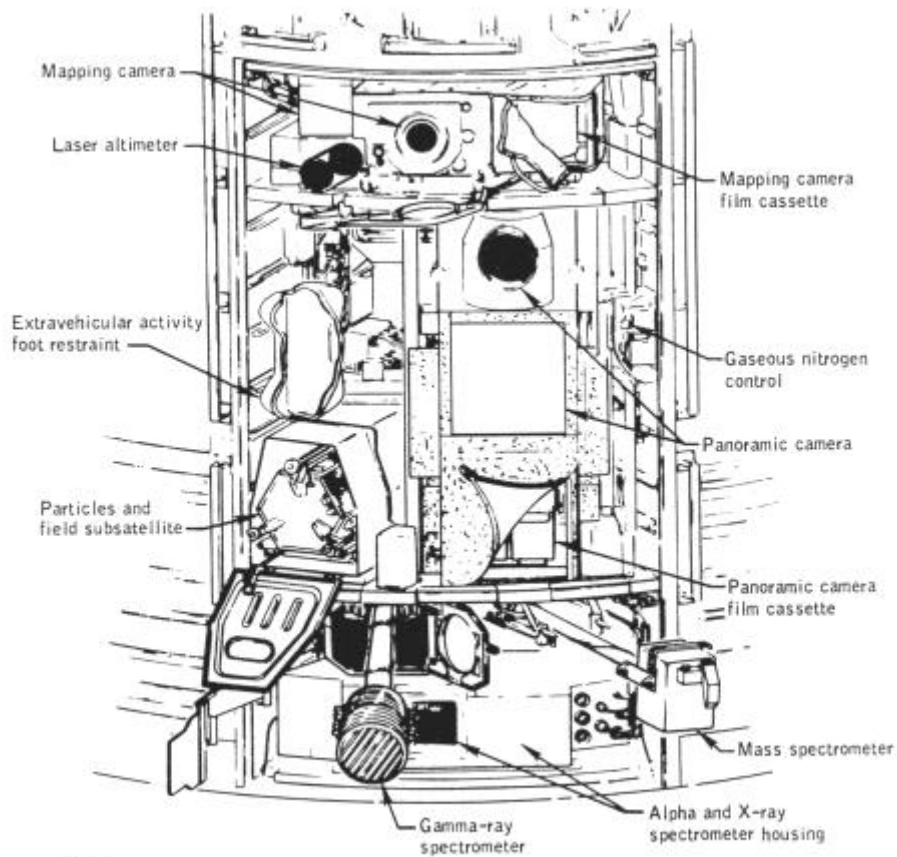
Several oxygen components were added to accommodate the scheduled extravehicular activity for retrieval of data from the scientific instrument module. The command module components consisted of a larger restrictor and filter for the higher flow rate, check valves to prevent backflow, connectors for the attachment of the umbilical, and a pressure gage.

A.1.7 Crew Provisions and Extravehicular System

The Command Module Pilot's space suit was basically the same as the Apollo 14 lunar surface suits except that the water connector and lunar module attach points had been removed. An umbilical assembly (**Fig. A-6**) was furnished to serve as a tether and provide oxygen, communications, and electrocardiogram and respiration rate measurements for the extravehicular crewman. An adapter plate mounted on the chest of the suit allowed attachment of an oxygen purge system (transferred from the lunar module). The purge valve was also brought from the lunar module to be used with the oxygen purge system. A pressure control valve was provided to maintain suit pressure at 3.5 to 4.0 psia at a flow rate of 10 to 12 lb/hr during the extravehicular activity. A suit control unit (**Fig. A-6**) was connected to the suit end of the umbilical to maintain the desired oxygen flow rate and activate the suit pressure alarm if an anomalous condition

had been sensed. An 8-foot tether was furnished for use by the intravehicular crewman stationed at the hatch (**Fig. A-5**). The tether prevented forces from being applied to his oxygen umbilical. In addition, a thermal cover was furnished to protect his communications umbilical.

An extravehicular activity monitor system was furnished to allow television and 16-mm camera coverage of the extra-vehicular crewman's activities. The components the system consisted of a sleeve mount attached to the side hatch handle and a 34-inch pole assembly to mount the cameras.



Notes:
 Mass spectrometer and gamma ray spectrometer are shown partially deployed.
 Some protective covers are not shown.

Figure A-1.- Apollo 15 scientific instrument module.

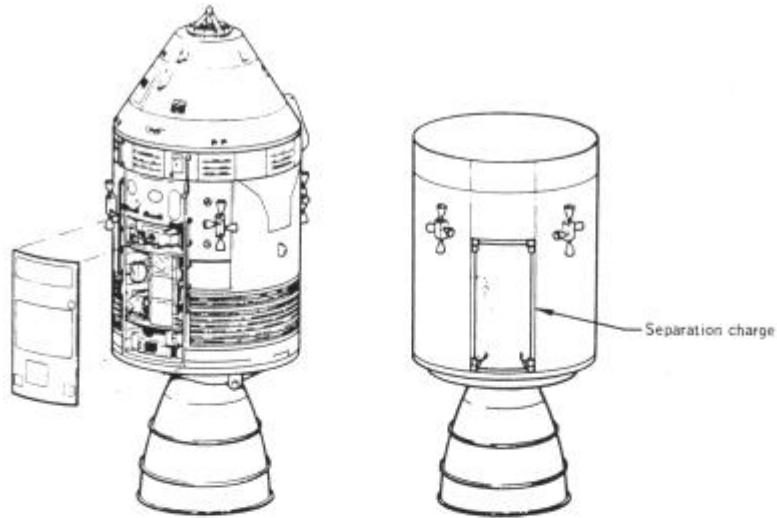


Figure A-2.- Scientific instrument module door jettison.

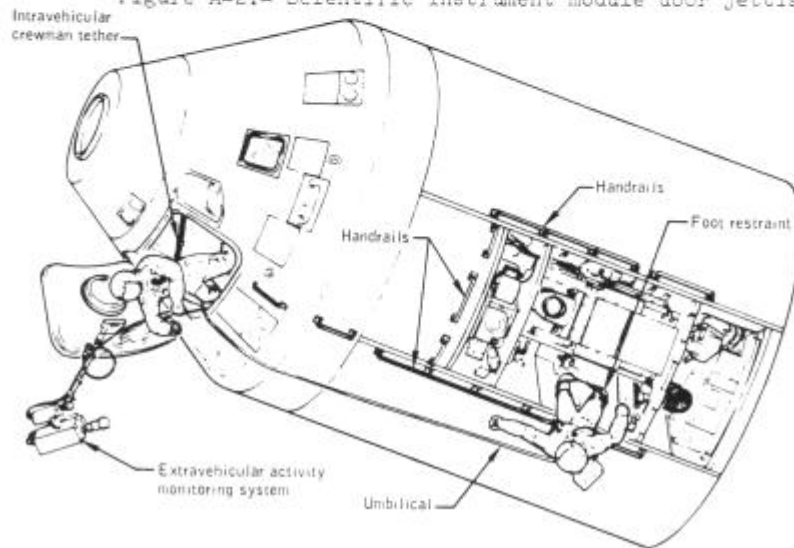


Figure A-3.- Command and service module extravehicular activity configuration