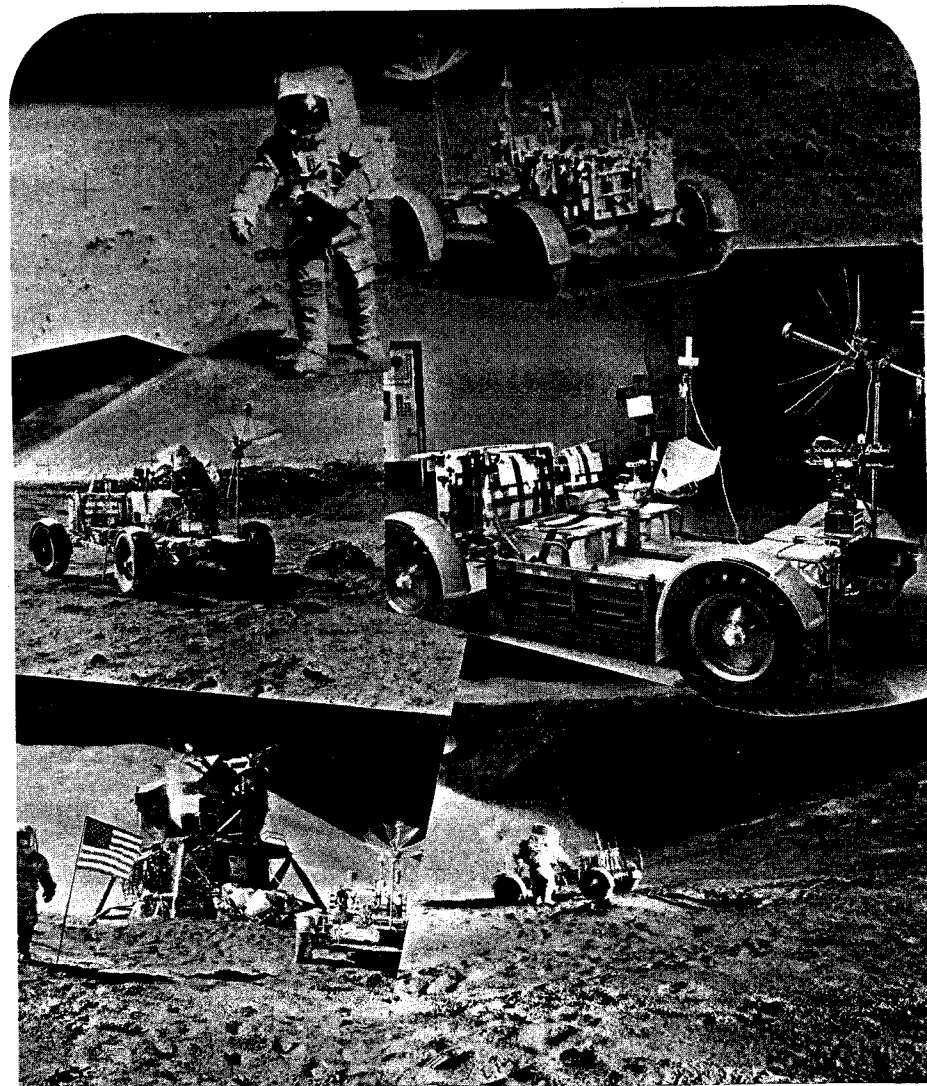




1972



LUNAR ROVING VEHICLE

APOLLO XVII

BOEING

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SPECIFICATIONS

WEIGHT	462 pounds (209 kg) Earth weight (not including unloading systems) 77 pounds (35 kg) moon weight
TOTAL LOADED WEIGHT	1600 pounds
LENGTH	122 inches (310 cm)
WIDTH (to center of wheels)	6 feet (183 cm)
WHEEL BASE	90 inches (230 cm)
GROUND CLEARANCE	14 inches (35.5 cm)
TURNING RADIUS	10 feet (305 cm)
MAXIMUM SPEED	8.7 mph (14 kph)
POWER SUPPLY	Two 36-volt primary silver-zinc batteries
RANGE	Up to a cumulative distance about 57 miles (92 km)
TRACTION DRIVE	Four ¼-hp DC series-wound motors
NAVIGATION SYSTEM	
BEARING TO LM	±6 degrees at 5 km
RANGE TO LM	±600 meters at 5 km
TOTAL DISTANCE TRAVELED	±2%
STATIC STABILITY	Up to 45 degrees in pitch and roll with full load

BACKGROUND

Lunar Roving Vehicle (LRV)-3 will be aboard Apollo 17 when it is launched to the moon on December 6, 1972. This will be the last of three vehicles built by The Boeing Company under a contract from the National Aeronautics and Space Administration's Marshall Space Flight Center.

LRV-3 is a near duplicate of the vehicle that provided moon transportation for the crews of Apollo 15 and 16. No major changes have been made in the vehicles. Several minor changes have been incorporated. LRV-3 will be equipped with the same seat belt design that proved successful on Apollo 16. An electrical cable has been installed to accommodate a new Surface Electrical Properties (SEP) experiment the astronauts will conduct, and new fender extension stops have been installed on all four fenders.

Other minor changes include the addition of an index ring to the azimuth alignment dial on the low gain antenna and a change to the aft pallet latch.

The 460-pound vehicle (without unloading system) will carry two astronauts, scientific equipment and lunar samples collected during their lunar exploration. The mission commander will operate the vehicle much as he would an earth car, using a T-shaped hand controller somewhat like an aircraft or spacecraft "stick" rather than a steering wheel. The vehicle is able to move both forward and backward at variable speeds.

The LRV is deceptive in appearance. It looks like a simple, familiar vehicle. In reality it is a specialized spacecraft designed to function safely in space conditions of vacuum, wide temperature variances and over difficult terrain. It has been built to the exacting specifications of all Apollo program hardware, and has been subjected to a rigorous test program to qualify it as a manned spacecraft.

Reliability is obtained through simplicity in both design and operation and through redundancy. For example, there are two complete battery systems, each sufficient to power the vehicle. The Lunar Roving Vehicle is normally steered by both the front and rear wheels; however, if one steering mechanism fails, it will be disconnected and the vehicle can complete its mission using only the remaining steering system.

The vehicle's power source will be two 36-volt silver-zinc batteries. These are nonrechargeable batteries of plexiglass cell construction. Silver-zinc plates operating in potassium hydroxide electrolyte are used. Each battery is designed for a capacity of

115 ampere hours and contains 23 cells. The case material is magnesium. Each battery weighs 59 pounds.

Instruments are used to measure the amount of discharge of electrical power from the storage batteries. Unlike the charge-discharge indicator on the dashboard of the standard automobile, these instruments, called ampere hour integrators, will perform a bookkeeping function. They will accumulate a total amount of current drawn from the batteries and relay the information to a display console located between the seats of the LRV.

The LRV will carry a total weight of 1,140 pounds (earth weight), which will include the two astronauts and their life support systems (400 pounds for each man and his equipment) plus 340 pounds of scientific experiments, astronaut tools, and lunar soil and rock samples. This is over twice its own weight. In comparison, the average family automobile can carry only about half its weight.

The operational lifetime of the lunar vehicle on the moon is 78 hours during the lunar day. It can make any number of sorties up to a cumulative distance of 57 miles or 92 kilometers.

The LRV is designed to negotiate, from a standing start, step-like obstacles one-foot high with both front wheels in contact. It also will be able to cross, from a standing start, 28-inch crevasses, even if both front wheels rest across the crevasse. The fully loaded vehicle will be able to climb and descend slopes as steep as 25 degrees. A parking brake will hold the LRV on slopes up to 35 degrees.

The side-by-side seating for the crew is designed to make both front wheels visible to both astronauts. They will navigate with a dead-reckoning navigation system which will tell them direction and distance to the Lunar Module at any point during their sortie, and will report the total distance traveled at any time on the excursion. The navigation system was built by Boeing's Aerospace Group Electronics Organization.

Eight LRV test units were built, leading to the manufacture of the first flight model. The units included: a full-scale mockup, which was used in development of the vehicle's design; LM-LRV test unit which was used to determine if the LRV's weight might cause stresses or strains in the LM's structure; two one-sixth weight units for developing and testing the mechanism which is used to ease the vehicle from the LM to the lunar surface; a

mobility test unit to prove the drive system; a normal Earth-gravity unit for astronaut training built by Delco Electronics; a vibration unit which was tested to uncover any potential weaknesses in the LRV's structural design, and a qualification unit which was tested under conditions of vacuum, vibration, high and low temperature and given electrical and drive system testing to prove the moon car design is fitted to the conditions expected on the lunar surface.

Program management, engineering, final assembly and testing were performed at The Boeing Company's Space Center near Seattle, Washington. The first flight model LRV was delivered to NASA on March 14, 1971, two weeks ahead of schedule and less than 17 months from formal signing of the contract awarding the assignment to Boeing. The other two units were also delivered ahead of schedule.

This is believed to be the shortest development, design, qualification, and manufacture cycle of any major item of equipment for the Apollo space program. In comparison, the extremely complex command and service module and the lunar module took 52 and 66 months, respectively, from contract award to delivery of the first flight article. The astronauts' portable life support systems took 70 months, and their spacesuits 60 months.

The Lunar Roving Vehicle more than doubles the time the astronauts are able to spend on the moon's surface during exploration. By riding instead of walking, the explorers expend less energy and use their limited oxygen and cooling water supply at a slower rate than they would on foot. In addition, the new spacesuits and life support system allows increased lunar surface stay time.

Design and development were under the direction of the NASA-Marshall Space Flight Center, Huntsville, Alabama. Boeing's major subcontractor was General Motors Delco Electronics Division's Santa Barbara Operation in California. The Delco Electronics portion of the LRV work centered on the vehicle's mobility subsystem which included the wheels, suspension, traction and drive system.

CREW STATION

Crew station equipment includes the seats, footrests, inboard and outboard handholds, armrest, floor panels, seat belts, fenders and toeholds (see sketch).

The two seats are tubular aluminum frames spanned by nylon. They are folded flat onto the center chassis and unfolded somewhat like a lawn chair by the astronauts after the vehicle is deployed on the lunar surface. The seat back and seat bottom are designed to support the astronauts' portable life support system (PLSS).

The footrests also are folded against the center chassis floor until the LRV is deployed. They are held in the stowed position by Velcro straps and lifted into position by the astronauts. Side restraints also are provided.

A pair of inboard handholds, located between the seats, are constructed of one-inch aluminum tubing and are used to support the astronauts as they board the vehicle. The handholds also contain receptacles for an accessory staff and a low-gain antenna for the lunar communication relay unit (LCRU).

The outboard handholds and center armrest provide stability and comfort for the astronauts when they are seated. The armrest, made of fiberglass, supports the astronaut's arm while he is manipulating the hand controller.

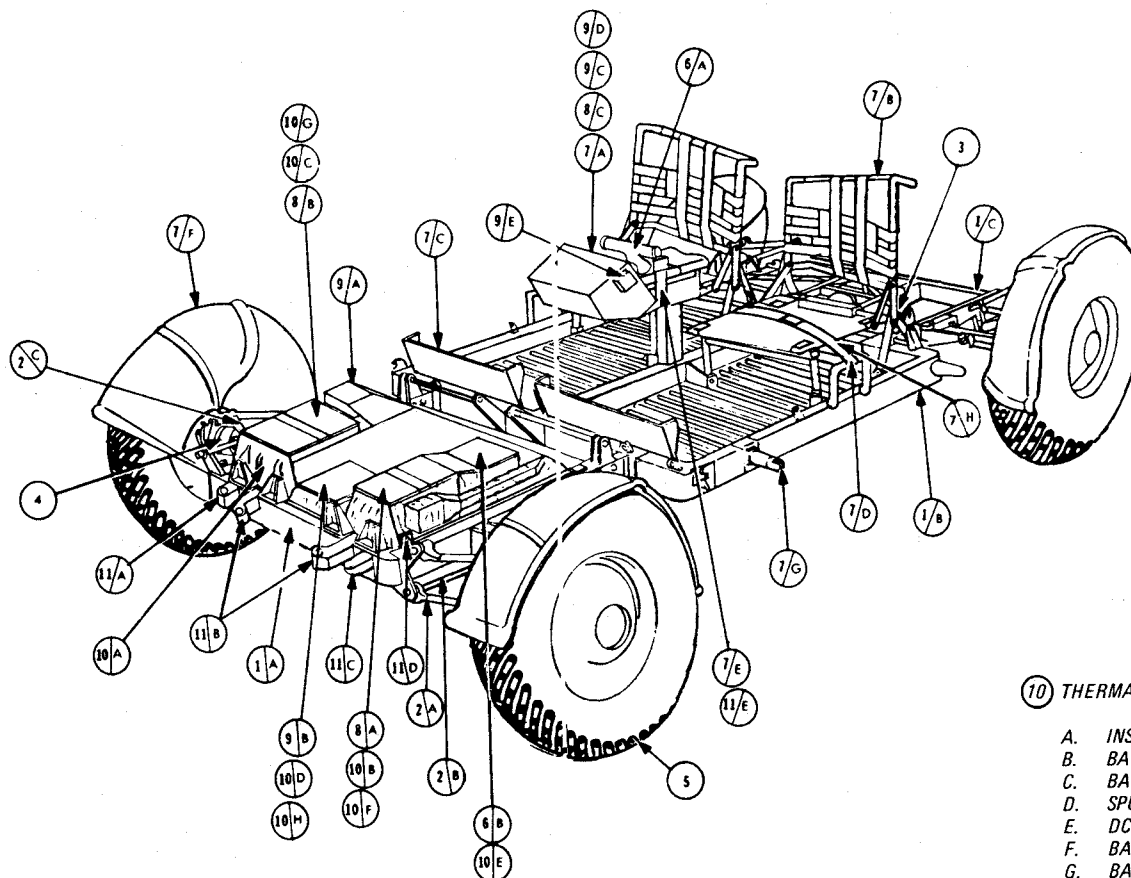
Floor panels in the crew station area are beaded aluminum panels which can support the full lunar weight of the astronauts when standing.

The seat belts are made of nylon webbing. They are designed for simple attachment and release.

Molded fiberglass fenders protect the vehicle and astronauts from lunar dust which may be churned up by the wheels. Because of space limitations, a section of each fender is retracted while the LRV is stowed in the LM. After the vehicle is lowered to the lunar surface, the astronauts extend the fender sections.

A toehold on each side of the vehicle is used to aid the astronauts as they get out of the vehicle under one-sixth gravity conditions. The toeholds are assembled on the lunar surface by dismantling two tripods which linked the LRV to the LM. One section of each tripod is inserted into the receptacles located on each side of the chassis.

Should it become necessary, the toehold also can be used as a tool to actuate a wheel decoupling mechanism.



① CHASSIS

- A. FORWARD CHASSIS
- B. CENTER CHASSIS
- C. AFT CHASSIS

② SUSPENSION SYSTEM

- A. SUSPENSION ARMS (UPPER AND LOWER)
- B. TORSION BARS (UPPER AND LOWER)
- C. DAMPER

③ STEERING SYSTEM (FORWARD AND AFT)

④ TRACTION DRIVE

⑤ WHEEL

⑥ DRIVE CONTROL

- A. HAND CONTROLLER
- B. DRIVE CONTROL ELECTRONICS (DCE)

⑦ CREW STATION

- A. CONTROL AND DISPLAY CONSOLE
- B. SEAT
- C. FOOTREST
- D. OUTBOARD HANDHOLD
- E. INBOARD HANDHOLD
- F. FENDER
- G. TOEHOLD
- H. SEAT BELT

⑩ THERMAL CONTROL

- A. INSULATION BLANKET
- B. BATTERY NO. 1 DUST COVER
- C. BATTERY NO. 2 DUST COVER
- D. SPU DUST COVER
- E. DCE THERMAL CONTROL UNIT
- F. BATTERY NO. 1 RADIATOR
- G. BATTERY NO. 2 RADIATOR
- H. SPU THERMAL CONTROL UNIT

⑪ PAYLOAD INTERFACE

- A. TV CAMERA RECEPTACLE
- B. LCRU RECEPTACLE
- C. HIGH GAIN ANTENNA RECEPTACLE
- D. AUXILIARY CONNECTOR
- E. LOW GAIN ANTENNA RECEPTACLE

⑧ POWER SYSTEM

- A. BATTERY NO. 1
- B. BATTERY NO. 2
- C. INSTRUMENTATION

⑨ NAVIGATION

- A. DIRECTIONAL GYRO UNIT (DGU)
- B. SIGNAL PROCESSING UNIT (SPU)
- C. INTEGRATED POSITION INDICATOR (IPI)
- D. SUN SHADOW DEVICE
- E. VEHICLE ATTITUDE INDICATOR

MOBILITY SUBSYSTEM

The mobility subsystem consists of the chassis and equipment and controls required to propel, suspend, brake, and steer the Lunar Roving Vehicle (see illustration).

The wheels are an open wire mesh design with a chevron tread covering 50 percent of the surface contact area. An inner frame or "bump" stop prevents excessive deflection of the wire mesh under high impact conditions.

Each wheel can be uncoupled from the traction drive system and allowed to "free wheel" on a bearing independent of the drive train. The uncoupling mechanism also can be used to re-engage the wheel with the traction drive.

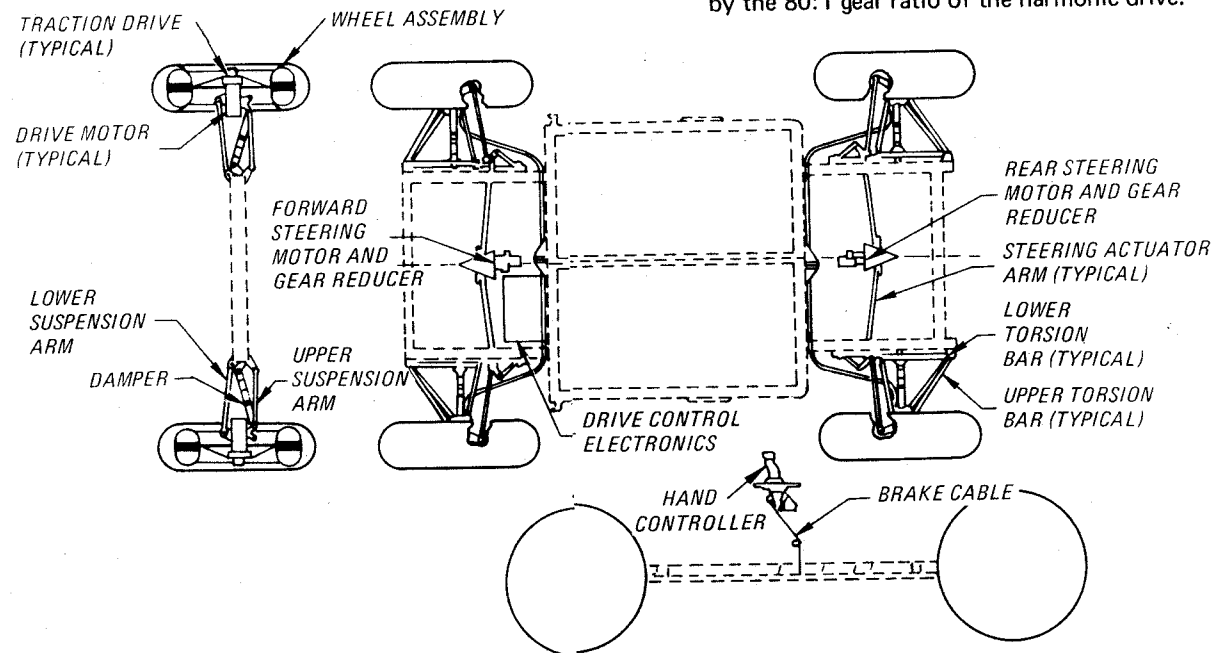
Each wheel is driven by its own separate traction drive assembly consisting of a harmonic drive reduction unit, drive motor, and brake assembly. Each traction drive is hermetically sealed to maintain a nitrogen gas internal pressure of 7.5 psia. The gas aids in transferring heat to the outer casing of the drive motor.

The four harmonic drive reduction units transmit power to each wheel. Input torque to the harmonic drives is supplied by the four 1/4-horsepower electric drive motors. The harmonic drive reduces the motor speed at the rate of 80:1 and allows

continuous application of power to the wheels at all speeds without requiring gear shifting. Each traction drive also contains an odometer pickup, which transmits nine pulses to the navigation system signal processing unit for each wheel revolution.

The drive motors are direct-current series, brush-type motors, which operate from a nominal input voltage of 36 VDC. Speed control for the motors is furnished by pulse-width modulation from the drive controller electronic package. Each motor also forms the king-pin for the LRV's steering system. In addition, each motor is instrumented for thermal monitoring. A temperature output from a thermistor in the motor is transmitted and displayed on the control console. A thermal switch at each motor will close when its upper operating temperature is approached. This switch provides an input signal to a caution and warning system to actuate a warning panel mounted on top of the control console.

Each traction drive unit is equipped with a mechanical brake actuated by a cable connected to a linkage in the hand controller. Braking is accomplished by moving the hand controller rearward. This action deenergizes the drive motor and, through a linkage and cable, forces brake shoes against a brake drum which stops the rotation of the wheel hub. Braking is aided by the 80:1 gear ratio of the harmonic drive.



The chassis is suspended from each wheel by a pair of triangular arms connected between the LRV's chassis and each traction drive. Loads are transmitted to the chassis through each suspension arm to a separate torsion bar for each arm. Vertical travel of the wheel and its rate of travel is limited by a damper connected between the chassis and each upper suspension arm. The deflection of the suspension system and wire wheels allow 14 inches of chassis ground clearance when the LRV is fully loaded and 17 inches when unloaded.

The suspension system can be rotated approximately 135 degrees to allow the LRV to be folded into a compact package and stowed in the LM.

Both the rear and front wheels of the vehicle can be steered. The LRV has a turning radius of 122 inches. Steering is controlled by moving the hand controller left or right from the neutral position. The movement energizes separate electric motors for the front and rear wheels. The farther the hand controller is moved, the farther the wheels turn.

Maximum travel of the steering linkage results in an outer wheel angle of 22 degrees and an inner wheel angle of 50 degrees. Steering rate is 5½ seconds lock-to-lock. With both sets of wheels steerable, the vehicle has excellent responsiveness.

The front and rear steering assemblies are mechanically independent of each other. Provision is made to steer with either set of wheels (or both sets). In the event of a steering malfunction, one set of wheels may be disconnected mechanically, and the mission can continue using the active steering system.

The hand controller provides speed, steering, and braking commands. Tilting the controller forward of the neutral position proportionally increases forward speed. Reverse power is applied when the controller is tilted backwards past the neutral position and a reverse inhibit switch on the hand controller is thrown by the driver. Tilting the controller left or right of the neutral position initiates steering commands in the direction the controller moves. Braking is initiated when the controller is pulled backward (the controller handle will travel aft about three inches). At approximately three inches, a spring-loaded catch will engage the handle to lock it in the "park" position. Forward and reverse power is cut off when the braking action begins.

A "turn left" command releases the parking brake.

CONTROL AND DISPLAY CONSOLE

The Control and Display Console is divided into two main parts (see illustration on page 13): navigation on the upper section of the panel and controls for switching and monitoring of electrical loads on the lower section.

ATTITUDE INDICATOR—provides indications of LRV pitch and roll. This instrument indicates PITCH upslope (U) or downslope (D) within a range of ± 25 degrees. The damper on the side of the indicator can be used to damp out oscillations. To read roll angles, the indicator is rotated forward, which exposes the ROLL scale to the left crewman. This indication is read by the crew and reported to the Mission Control Center during navigation update. The vehicle attitude data is used by MCC to correct sun shadow device readings if the LRV is not level.

HEADING INDICATOR—displays the LRV heading with respect to lunar north.

BEARING INDICATOR—shows bearing to the LM.

DISTANCE INDICATOR—reports distance traveled by the LRV in increments of 0.1 kilometer. This display is driven from the navigation signal processing unit which, in turn, receives its inputs from the third-fastest traction drive odometer to compensate for wheel slippage.

RANGE INDICATOR—shows the distance to the LM.

SUN SHADOW DEVICE—determines the LRV heading with respect to the sun. This heading can be compared with the gyro heading at regular intervals as a check against gyro drift. When lifted into position, the device casts a shadow on a graduated scale. The point at which the shadow intersects the scale is transmitted by the crew to the Mission Control Center during navigation updates.

SPEED INDICATOR—shows LRV velocity from 0 to 20 km/hr. This display is driven by the odometer pulses from the right rear wheel.

GYRO TORQUING SWITCH—adjusts the navigation gyro to correct the HEADING indication during navigation update. Moving the switch RIGHT moves the heading scale counterclockwise; with the switch in LEFT, the scale rotates clockwise.

NAV POWER CIRCUIT BREAKER—is used to route power from the main busses to the navigation subsystem. The power distribution system is designed to provide power for the navigation system from either battery simultaneously to preclude power loss in the event of failure of one battery. With this circuit breaker in open position, there will be a loss of speed indication. However, the other navigation displays will remain intact.

SYSTEM RESET SWITCH—is used to reset the BEARING, DISTANCE, and RANGE digital displays to zero. The toggle must be pulled out before operating. This feature is designed to prevent inadvertent actuation.

Switching and monitoring of electrical loads is handled in the lower section of the console. The switch and circuit breaker arrangement is designed to allow switching of any electrical load to either battery. The console has push-pull type circuit breakers (push to close) and toggle switches of a type common to Apollo spacecraft. The panel nomenclature is green against a black-dyed anodized background. The lettering contains a radioluminescent material (Promethium 147) which emits sufficient light to be read in darkness.

POWER SECTION—contains the circuit breakers that connect the batteries with the main power busses, the auxiliary outlet circuit breaker (for power to the lunar communications relay unit, or LCUR), and the circuit breakers and controlling switch for the ± 15 VDC power to the pulse-width modulators. With four main power busses, any principal load, such as a drive motor, steering motor, etc., may be connected to any battery.

STEERING SECTION—has a circuit breaker and switch for each of the two steering motors.

DRIVE POWER SECTION—has a circuit breaker and switch for each of the four drive motors.

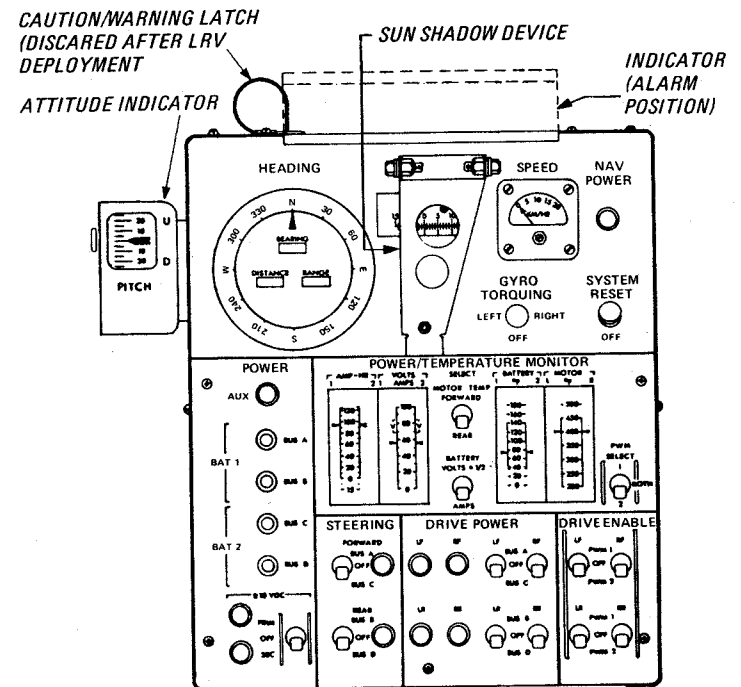
DRIVE ENABLE SECTION—contains a switch for each drive motor which permits the driver to select either pulse-width modulator (PWM) 1 or 2. (The PWMs provide speed control signals for each motor.)

The PWM select switch permits choice of PWM 1, PWM 2, or both simultaneously. (With this switch in the "both" position, the Drive Enable switches may be positioned so that some drive motors use PWM 1 and some use PWM 2.)

POWER/TEMPERATURE MONITOR—provides a status of the vehicle's electrical system and the temperatures of the batteries and motors. Pointers move across a stationary vertical scale. As a space-saving measure, battery voltage and current flow are displayed on the same meter. The position of the volts-amps switch determines which of the two is being displayed. To accommodate the scale arrangement, the volts and amps display is twice that of the actual value. Similarly, the position of the drive motor temperature select switch determines whether the forward or rear wheel motors are being monitored.

The battery amp-hour integrator meter display starts at 121 amp-hours and decreases as battery capacity is expended.

CAUTION AND WARNING SYSTEM—gives the astronauts a visual warning that one of the batteries or traction drive motors is overheating. A spring-loaded, hinged "Alarm" panel, located on top of the console, is held down by a magnet. If any of the units overheat, the circuit breaks and the panel is released.



NAVIGATION SUBSYSTEM

Components for the navigation subsystem include:

INTEGRATED POSITION INDICATOR (IPI)—Located on the control console. Displays LRV heading, bearing, and range or distance to the Lunar Module, and total distance traveled.

ATTITUDE INDICATOR—Mounted on the left side of the control console. Provides indications of LRV pitch and roll.

SUN SHADOW DEVICE—Mounted on the control console. Used to determine vehicle heading with respect to the sun.

DIRECTIONAL GYRO UNIT—Mounted on the forward chassis. Provides a stable reference for the measurement of the LRV's heading with respect to lunar north. (Lunar north is an arbitrary point on the moon which is used as a common reference for the LRV crew and Mission Control Center.)

SIGNAL PROCESSING UNIT (SPU)—Mounted on the forward chassis. Carries out digital and analog computer functions.

ODOMETER—Records wheel rotation for speed and distance computations from sensors located in each wheel.

Inputs to the navigation subsystem are: changes in LRV direction with respect to lunar north, which are obtained from the directional gyro; and odometer pulses, which report the speed and distance traveled.

Nine odometer pulses are generated for each revolution of each wheel. These signals are amplified and enter the signal processing unit where the computer selects the third-fastest wheel

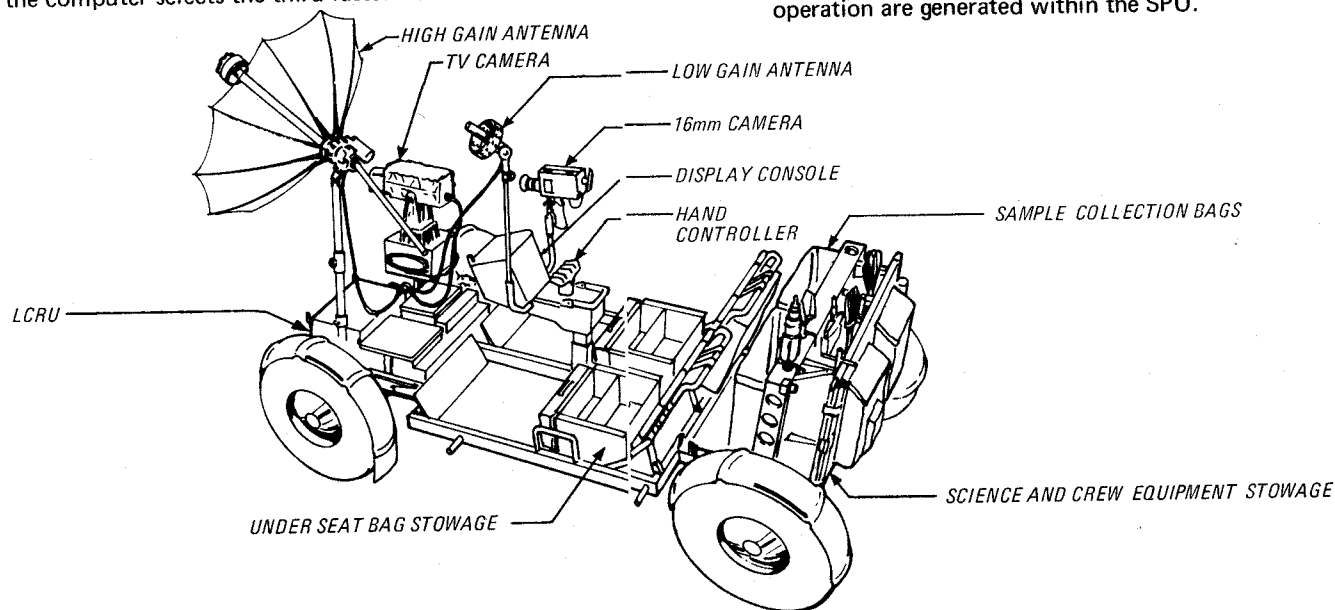
for use in the distance computation. This insures that the distance traveled display report will not be based on a wheel that is slipping or one that is decoupled and free-wheeling. In addition, the pulses from the right rear wheel enter the velocity processor section of the SPU. The information is displayed on the control console SPEED indicator as kilometers per hour.

The directional gyro is aligned by use of the torquing switch on the control console until it is aligned to lunar north. Alignment requirements for the gyro are accomplished by measuring the inclination of the LRV in pitch and roll—using the attitude indicator—and determining the heading of the LRV with respect to the sun, using the sun shadow device. This information is relayed to Earth where a vehicle heading angle is calculated. The LRV crew then torques the gyro until the heading indicator on the control console reads the same as the calculated value.

Gyro alignment is performed at the start of a lunar excursion and repeated during the excursion to correct for possible gyro drift. In addition, at the start of an excursion the digital displays (range, bearing, etc.) in the IPI are set to zero by operating the SYSTEM RESET switch.

Outputs from the navigation subsystem are: heading with respect to lunar north; bearing to the LM; range to the LM; total distance traveled; and velocity.

Power for the navigation subsystem is supplied from the LRV batteries. Voltages required for navigation subsystem operation are generated within the SPU.



THERMAL CONTROL

The LRV makes use of passive and semipassive thermal control measures to insure that it will not exceed operating temperature limits. Vehicle temperature constraint at liftoff is $70 \pm 5^{\circ}\text{F}$. Insulation and reflective coating maintains the temperature of the vehicle by controlling heat loss during boost, Earth orbit, translunar flight, and lunar landing. Batteries are maintained between 40 and 125°F , while other equipment has tolerances that vary from -30°F up to 185°F . These temperatures must be maintained through touchdown.

After touchdown, the vehicle's semipassive thermal control system also will be in operation. The requirement is to dissipate heat from operating equipment in the forward chassis area, maintain the control and display console within its operating limitations, and protect the crew station from excessive heat.

This control system utilizes insulation, radiative surfaces, thermal mirrors, thermal straps, fusible mass heat sinks, and special surface finishes.

The operating equipment in the forward chassis area includes the drive control electronics (DCE), signal processing unit (SPU), directional gyro unit (DGU), and two batteries. Passive protection is provided by a multilayered aluminized mylar and nylon netting insulation blanket with a beta cloth (polished glass) outer layer. Aluminum thermal straps connected to the SPU and DGU transfer heat away from the electronic components and store it in the batteries and fusible mass heat sinks. Thermal control of the DCE is accomplished with a fusible mass (heat sink) tank and thermal radiator attached to its upper surface.

At the end of the lunar sortie, the heat which has accumulated in the batteries and heat sinks is allowed to escape through radiation. The astronauts open fiberglass dust covers to expose fused silica thermal mirrors mounted on top of the batteries; DCE, SPU and heat sinks. The mirrors act as space radiators, thus cooling the equipment. When the batteries reach their lower limit operating temperature of approximately 45°F , the covers close automatically, which prevents additional cooling and protects against dust collection during a sortie.

All instruments on the vehicle's control and display console are mounted on an aluminum plate which is isolated from the rest

of the vehicle by fiberglass mounts. The external surfaces of the console are coated with heat-resistant paint (Dow-Corning 92-007) and the faceplate is black anodized for temperature control and to reduce reflection.

The tubular sections of the seats, footrests, handholds, and center and aft floor panels also are anodized providing a heat reflecting and radiating surface.

Heat generated by the traction drive assembly and damper at each wheel is radiated to space through the casing. Nitrogen at 7.5 psi is hermetically sealed inside each drive assembly which aids the transmission of heat from the wheel drive motors to the outer wall.

DEPLOYMENT SUBSYSTEM

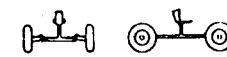
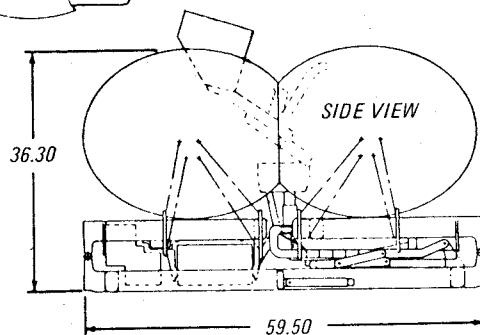
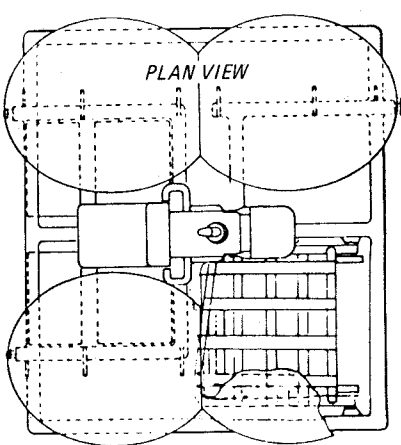
The LRV is stowed in a "nose down" position and is attached to the LM at three points during its trip from Earth to the moon. Deployment is accomplished by the astronaut sequentially pulling two nylon operating tapes, located on either side of the LM storage bay, while he stands on the lunar surface (see illustrations—pages 18, 19).

A D-handle is pulled by the astronaut while standing on the LM access ladder. This retracts three pins holding the LRV to the attach points in the LM and frees the LRV for deployment. A spring-loaded pushoff rod will begin to move the folded vehicle away from the top of the LM storage bay (about 4 degrees). The lower end of the vehicle is rotated on two points formed by tripods attached to the LRV's center chassis section.

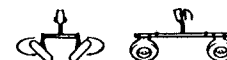
Next, the astronaut picks up the first of two operating tapes. Pulling the tape on right side of quadrant causes a cable storage drum to rotate, which releases cable. Gravity will cause the vehicle to rotate outboard after the pushoff rod has extended.

After the first 15 degrees of deployment motion, rotation of the vehicle is picked up by two support arms. This moves the rotational axis of the LRV to a point just outside of the LM storage bay. In addition, two telescoping tubes, which hold the vehicle away from the LM, start to extend.

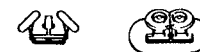
At 40 to 50 degrees of deployment motion, a cable will pull pins which unlock the forward and aft chassis sections so they can unfold. From about 50 degrees of deployment, the aft chassis section, which is under spring pressure, unfolds and latches into



STEP 1

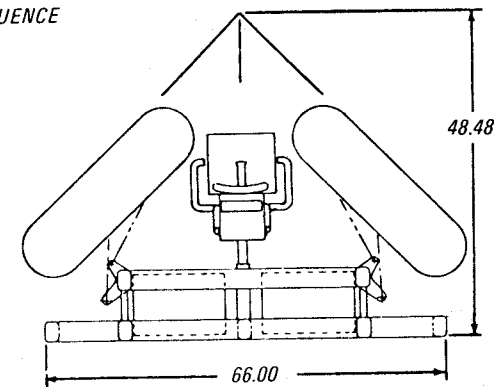


STEP 2



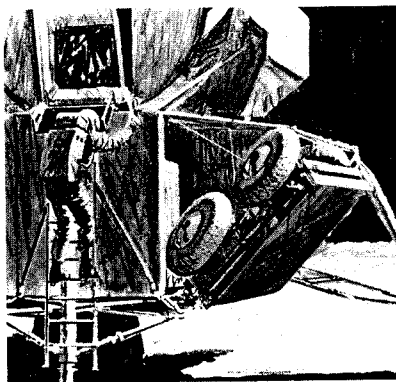
STEP 3

FOLDING SEQUENCE

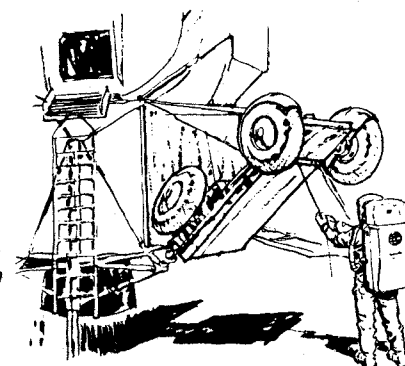
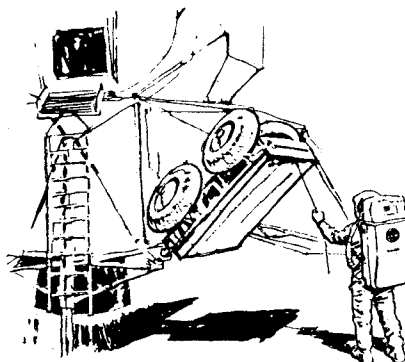


- LRV STOWED IN QUADRANT
- ASTRONAUT INITIATES DEPLOYMENT

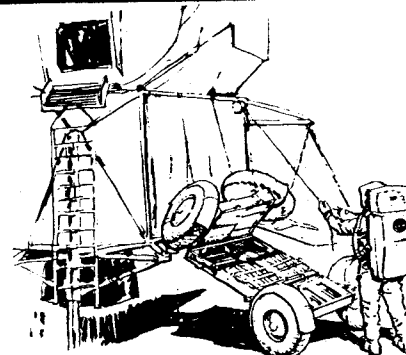
- ASTRONAUT LOWERS LRV FROM STORAGE BAY WITH FIRST REEL



- AFT CHASSIS UNFOLDS
- REAR WHEELS UNFOLD
- AFT CHASSIS LOCKS IN POSITION

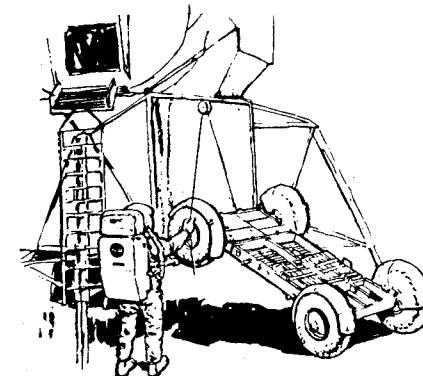


- FORWARD CHASSIS UNFOLDS
- FRONT WHEELS UNFOLD



- FORWARD CHASSIS LOCKS IN POSITION. ASTRONAUT LOWERS LRV TO SURFACE WITH SECOND REEL

- ASTRONAUT DISCONNECTS SSE
- ASTRONAUT UNFOLDS SEATS, FOOTRESTS



position. In addition, the wheels are released and torsion bars cause them to pivot and lock into position. Meanwhile, the forward chassis section has been held at about a 45-degree position.

As the astronaut continues to pull the tape, the center and aft chassis sections continue rotating until the rear wheels touch the lunar surface.

During this time, the forward chassis section is allowed to unfold and lock. Unfolding begins when the center and aft sections have rotated 73 degrees. At this point, a cam releases latches on the support arms which have served as the rotation axis. This allows the telescoping tubes to extend further and hold the vehicle away from the LM.

Finally, the astronaut pulls the second operating tape (on the left side of the LM quadrant) allowing the forward end of the LRV to be lowered to the surface. The astronauts must then disconnect the deployment hardware from the vehicle by pulling a series of release pins.

A separate deployment cable serves as a backup in the event the hinge torsion springs fail to unfold the forward and aft chassis sections.

Deployment of the LRV is possible with the LM tilted at any angle up to 14½ degrees in any direction and with the bottom of the descent stage 14 to 62 inches above the lunar surface. The deployment time will take no more than 15 minutes under the "worst case" situation, and about five minutes with the LM nearly level.

LRV POSTDEPLOYMENT ACTIVITIES

During the first EVA the crew will descend from the LM and deploy the LRV to the lunar surface. After the LRV is on the surface, the vehicle will be visually inspected and the deployment cables and other hardware will be removed and discarded. The crew will erect the seats and place other crew station systems in operational order. One crewman will board and power-up the vehicle. He will back it away from the LM and drive it to a designated area for payload loading while the second crewman monitors and provides direction for the back-away operation. During this brief drive the driver will verify that all LRV systems are functioning.

Both crewmen will unload equipment from the LM and install it on the vehicle. A battery-powered lunar communications

relay unit (LCRU) will be mounted on the front of the chassis. An umbrella-like high-gain antenna for TV transmission and a television camera also will be mounted on the forward section of the chassis. The accessory staff and low-gain antenna for voice communications will be mounted in the inboard handholds on either side of the control and display console. Finally, the tools and experiments will be loaded on the pallet behind the seats.

Subsequent to installation of the communications equipment, the crew will confirm its operation using both self-contained power and auxiliary LRV power systems.

Prior to driving, the high-gain antenna will be positioned and locked. Since constant orientation of the high-gain antenna is not feasible while driving, TV transmission is only possible when the vehicle has stopped. However, the low-gain antenna can be oriented while driving and voice communications are possible at all times.

Prior to leaving the vicinity of the LM, the crew will calibrate the LRV navigation system as instructed by Mission Control. Mission Control will plot the route of the vehicle during each traverse, assisting the crew with periodic updates of the navigation system and confirming locations through landmark sightings.

The vehicle may be operated by either crew member during a traverse. Activities of the nondriving crewman may include movie taking, instrument monitoring, and visual observation of sites of interest, hazards, etc. At science stops, the TV camera can be used. Experiments will be deployed and scientific data gathered.

At the conclusion of each EVA, the crew will park the LRV so it can be viewed from the LM and power down all LRV systems. It will be parked with the proper heading for thermal control and the battery dust covers will be raised to permit accumulated system heat rejection to the space environment. When sufficient heat has been rejected, the covers will close automatically. The LRV then will be ready to resume traverse activities at the start of the next EVA.

APOLLO 15/LUNAR ROVER-1 PERFORMANCE

The ability of Apollo 15 astronauts to explore the moon was significantly enhanced by the use of the Lunar Roving Vehicle. Astronauts Dave Scott and Jim Irwin were able to cover a larger area, accomplish more physical work and return more information about the moon than any previous Apollo team.

Termed by the pair as a "remarkable machine," the LRV traveled faster and used less power than predicted by mission planners. During three EVA's the two astronauts drove the Lunar Roving Vehicle 17.29 miles in the Hadley Rille area. The capability to carry heavy loads and transport a television camera with them greatly expanded the scientific capability of the mission. Ground controllers became part of the exploration team and participated in the mission with directions and assistance.

The weight of lunar samples returned with LRV assistance on Apollo 15 was 170 pounds, nearly double the 92 pound record of Apollo 14.

Rover-1 averaged a speed of 9.2 kilometers per hour for the three drives. This was faster than expected by mission planners. It reached speeds of up to 14 kph during the sorties. "Mileage" was excellent. LRV-1 used about 50 percent less power than predicted.

The Boeing built navigation system proved to be accurate and reliable. The astronaut team reported the explorers did not hesitate to vary from their planned route since they had confidence the system would show them the way home. Accuracy of the system was within 0.1 kilometer over the three EVA's. That would enable the Rover to return to within 328 feet of its starting point. A side benefit and use of the navigation system was found when the crew reported the direction and distance to the Lunar Module from known lunar craters. This enabled ground control to calculate the precise location of the landing.

APOLLO 16 LUNAR ROVER-2 PERFORMANCE

On April 21, 22 and 23, 1972 Astronauts John Young and Charles Duke explored the area near Descartes crater aboard Lunar Rover 2. As on Apollo 15, use of the LRV multiplied the amount of information the moon explorers were able to gather by at least a factor of three.

Mission Commander Young reported the area was far more rugged than expected. He estimated that without the LRV for transportation he and Astronaut Duke would have been unable to accomplish more than five percent of their assignment. With the Rover they were able to fully explore the Descartes area.

Geologic samples totaling 213 pounds were gathered and

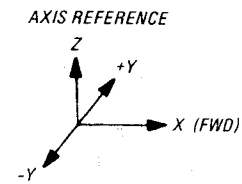
returned to earth. Among them were moon rocks of a different type than ever seen before. Scientists state the mission returned more and better data than any earlier mission.

During the first EVA the Rover traveled 4.2 kilometers or 2.6 miles. EVA number two distance was 11.5 kilometers (7.1 miles) and EVA number three logged 11.4 kilometers (7.06 miles). Total distance covered was 27.1 kilometers, or 16.8 miles. Total driving time was 3 hours and 17 minutes.

During EVA three Astronauts Young and Duke reported they set a "new lunar speed record" when the Rover hit 17 kilometers per hour, or 10.5 mph while driving down hill on their return trip to the lunar module. Young and Duke reported the LRV's handling characteristics were "excellent."

APOLLO 15 AND 16 COMPARISONS

EVA Duration (Hr: Min)			Traverse Distance (Km)	
	Plan	Actual	Plan	Actual
EVA I				
Apollo 15	7:00	6:32	8.2	10.3
Apollo 16	7:00	7:11	3.2	4.2
EVA II				
Apollo 15	7:00	7:12	14.3	12.5
Apollo 16	7:00	7:23	9.5	11.5
EVA III				
Apollo 15	6:00	4:49	10.5	5.1
Apollo 16	7:00	5:40	12.6	11.4
TOTALS				
Apollo 15	20:00	18:33	33.0	27.9
Apollo 16	21:00	20:14	25.2	27.1
LRV Driving Time:				
Apollo 15		3:08		
Apollo 16		3:17		



(DEPLOYED, EMPTY)

WEIGHT = 462 LB*

C.G. LOCATION:

X = 52.8

Y = -0.3

Z = 103.1

*INCLUDES BATTERIES
& PAYLOAD SUPPORTS,
EXCLUDES SSE

