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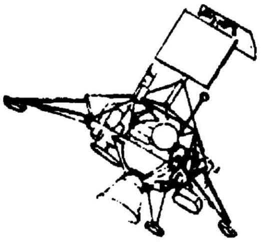

PROJECT: SURVEYOR D
(To be launched no earlier
July 13, 1967)

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NEWS

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NASA PREPARES
TO LAUNCH
FOURTH SURVEYOR

The United States is preparing to launch Surveyor D, another lunar soft-landing spacecraft, the fourth of the series of seven Surveyors planned for lunar missions.

The launch by the National Aeronautics and Space Administration is planned from Complex 36 at Cape Kennedy, Fla., during the five-day period July 13-17. The launch vehicle is an Atlas-Centaur.

Like the three previous Surveyors, Surveyor D's mission will be to perform a soft-landing in the Apollo area of interest on the Moon and take television pictures of the lunar surface around its landing site.

Like Surveyor III, this spacecraft will carry a surface sampler to dig into the lunar surface under the eye of the television camera.

Although the Surveyor D mission is basically similar to that of Surveyor III, there are some differences.

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Most important is the target landing site for Surveyor D. It will be aimed to soft-land in Sinus Medii (Central Bay) at almost the dead center of the front face of the Moon at 1° 20' West longitude and 0° 25' North latitude.

In general, the Sinus Medii area is considerably rougher than the sites of the two previous Surveyor landings but verification of a site in the center of the Moon's visible face is required by the Apollo program to provide a variety of landing site options.

Surveyor D's soft landing will be further complicated by the fact that it will approach the Moon at a greater angle to the vertical than its predecessors, thus requiring a larger gravity turn during the crucial terminal descent sequence. Surveyor D will approach the Moon at the beginning of its descent at an angle of 36 degrees from vertical; Surveyor I's angle of approach was only six degrees and Surveyor III's was 25 degrees.

Other differences from previous Surveyor missions:

--Altas-Centaur 11 has a one-burn capability in its second stage. This is the last of the direct ascent Centaurs and is similar to the Surveyor I Centaur but unlike the two-burn Centaur which launched Surveyor III into a parking orbit from which it was sent to the Moon.

--Modifications have been made in this Surveyor's landing radar electronic logic circuitry to prevent a repeat of III's three-bounce landing that occurred when the three vernier engines were not cut off just prior to the first touchdown. See page 8.

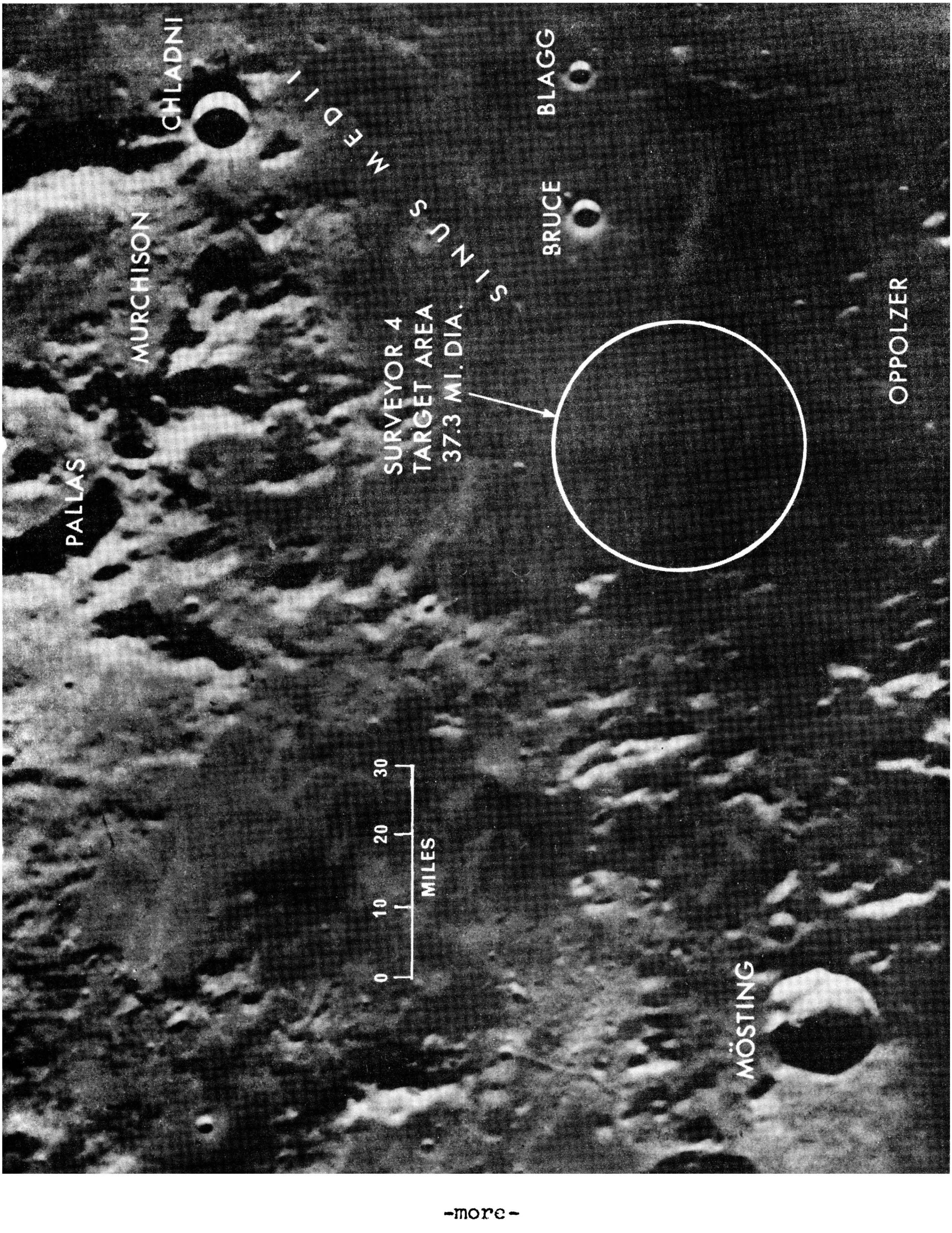
--A small magnet will be attached to a footpad in view of the television camera to determine if there is magnetic material on the lunar surface. See page 19.

The Surveyor D flight will take about 65 hours from lift-off to lunar landing. A large solid propellant retrorocket and three small vernier rocket engines under radar control will slow Surveyor from a lunar approach speed of about 6,000 miles per hour to about three miles per hour. The engines cut off at the 14-foot mark and the spacecraft free falls to the lunar surface, touching down at about 10 miles per hour.

On the first day of the launch period, July 13, the launch can occur between 7:03 a.m. EDT to 7:07 a.m.

The Surveyor D target site is a 37-mile diameter circle in Sinus Medii about 190 miles north of the large crater Ptolemaeus.

At launch, Surveyor D will weigh 2,290 pounds. The retromotor, which will be jettisoned after burnout, weighs 1,463 pounds.


PALLAS
MURCHISON
CHLADNI
SINUS MEDII
BRUCE
BLAGG
SURVEYOR 4
TARGET AREA
37.3 MI. DIA.
OPPOLZER
0
10
20
30
MILES
MÖSTING

After expenditure of liquid propellants and attitude control gas, the landed weight of Surveyor on the Moon will be about 625 pounds.

In addition to data provided by the TV camera and surface sampler, Surveyor D will also provide data on the radar reflectivity, mechanical properties, and thermal conditions of the lunar surface.

Surveyor I soft-landed on the Moon June 2, 1966, and returned 11,150 high-quality photographs of the lunar terrain. It survived eight months on the lunar surface during which time it withstood eight cycles of extreme heat and cold. Surveyor II was launched Sept. 20, 1966, but the mission failed when one of the three vernier engines failed to ignite during an attempted midcourse maneuver.

Surveyor III soft-landed on the Moon Apr. 19, 1967, returned 6,319 photographs and provided 18 hours of operation of the surface sampler.

The Surveyor program is directed by NASA's Office of Space Science and Applications. Project management is assigned to NASA's Jet Propulsion Laboratory operated by the California Institute of Technology, Pasadena. Hughes Aircraft Co., under contract to JPL, designed and built the Surveyor spacecraft and the surface sampler.

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NASA's Lewis Research Center, Cleveland, is responsible for the Atlas first stage booster and for the second stage Centaur, both developed by General Dynamics/Convair, San Diego, Calif. Launch operations are directed by Kennedy Space Center, Fla.

Tracking and communication with the Surveyor is the responsibility of the NASA/JPL Deep Space Network (DSN). The DSN stations assigned to the Surveyor program are Pioneer, at Goldstone in California's Mojave Desert; Robledo, Spain; Ascension Island in the South Atlantic; Tidbinbilla near Canberra, Australia; and Johannesburg, South Africa. Data from the stations will be transmitted to the Space Flight Operations Facility in Pasadena, the command center for the mission.

(END OF GENERAL RELEASE; BACKGROUND INFORMATION FOLLOWS)

SURVEYOR BACKGROUND

Surveyor I performed the first fully-controlled soft landing on the Moon on June 1, 1966, after a 63-hour, 36-minute flight from Cape Kennedy.

Surveyor I landed at a velocity of about 7.5 miles per hour at 2.45 degrees south of the lunar equator and 43.21 degrees West Longitude in the southwest portion of Oceanus Procellarum (Ocean of Storms).

During the six weeks following the perfect, three-point landing, the spacecraft's survey television camera took 11,150 high-resolution pictures of the lunar surface for transmission to Earth receiving stations. Resolution in some of the closeups was one-half millimeter or about one-fiftieth of an inch. These pictures showed details of the lunar surface a million times finer than the best Earth telescope photos.

From the pictures were derived the representative colors of the Moon's surface, an accurate view of the terrain up to one and one-half miles surrounding the Surveyor, the effect of landing a spacecraft upon the lunar surface and pictorial evidence of lunar environmental damage to the spacecraft itself. A section of the mirrored glass radiator atop one of the electronic equipment compartments was shown to be cracked in a photograph taken during the second lunar day.

The spacecraft also took a number of pictures of the solar corona (the Sun's upper atmosphere), the planet Jupiter and the first magnitude stars Sirius and Canopus.

The television pictures showed that the spacecraft came to rest on a smooth, nearly level site on the floor of a ghost crater. The landing site was surrounded by a gently rolling surface studded with craters and littered with fragmental debris. The crestlines of low mountains were visible beyond the horizon.

By July 13, Surveyor I's 42nd day on the Moon, the spacecraft had survived the intense heat of the lunar day (250 degrees F), the cold of the two-week-long lunar night (minus 260 degrees F) and a second full lunar day. Total picture count was: first lunar day -- June 1 to June 14 -- 10,338; second day -- July 7 to July 13 -- 812. The total operating time of Surveyor I (time during which signals were received from the spacecraft) was 612 hours.

Despite a faltering battery not **expected** to endure the rigors of the lunar environment over an extended period, Surveyor continued to accept Earth commands and transmit TV pictures through the second lunar sunset. It received and acted upon approximately 120,000 commands during the mission.

Communications with Surveyor I were re-established at intervals through January 1967 but no TV pictures were obtained after the July 1966 activity. Important Doppler data on the motion of the Moon were acquired during the final months of Surveyor operations.

On Feb. 22, 1967, at 12:24 a.m. EST, Surveyor I was photographed on the surface of the Moon by Lunar Orbiter III.

Surveyor II was launched on Sept. 20, 1966, toward Sinus Medii in the center of the Moon. An attempt to perform the midcourse maneuver was unsuccessful when one of the three liquid fuel vernier engines failed to fire. The thrust imbalance caused the spacecraft to begin tumbling. Repeated attempts were made to command all three engines to fire to regain control of the spacecraft. When all attempts failed it was decided to perform a series of engineering experiments to obtain data on various subsystems concluding with the firing of the main retrorocket. The spacecraft impacted the Moon southeast of the crater Copernicus at a velocity of nearly 6,000 miles per hour.

Intensive investigation into possible causes of the Surveyor II failure by a team comprised of propulsion experts from the Jet Propulsion Laboratory, Hughes Aircraft Co., Thiokol Chemical Corp. and NASA did not result in the identification of the exact cause. As a result of this investigation, however, a number of changes in testing procedures were recommended for Surveyor III and subsequent spacecraft to provide better diagnostic capability in the vernier propulsion system during preflight testing as well as during the mission. These changes are designed to minimize the possibility of recurrence of the Surveyor II problem.

Surveyor III was launched April 17, 1967, and successfully soft-landed on the Moon April 19, 1967, on the east wall of a 650-foot diameter crater in the Ocean of Storms. The spacecraft touched down three times in the landing when its vernier engines did not cut off at the prescribed 14-foot mark but continued firing to the surface. A command from Earth shut down the enignes after the second touchdown at 2.94 degrees South latitude and 23.34 degrees West longitude. Surveyor III was equipped with a surface sampler instrument to provide data on lunar soil characteristics. The device dug four trenches, made seven bearing strength tests and 13 penetration tests during a total of 18 hours of surface sampler operation from the second day after touchdown through lunar sunset on May 3.

Operation of the television camera yielded 6,315 pictures. These included pictures of a solar eclipse as the Earth passed in front of the Sun, the lunar terrain, portions of the spacecraft, surface sampler operations and the crescent of the Earth.

Attempts to reactivate the spacecraft during the second lunar day were unsuccessful.

On Surveyor III a radar break-lock was commanded by the spacecraft landing radar's internal logic as the radar beams crossed a field of highly reflecting rocks as it neared the surface. These looked to the radar much as a field of broken mirrors would to a searchlight, giving unexpected high returns back into the radar receivers. This caused the break-lock because the radar logic circuitry is designed so as to make the radar tracking circuits select the strongest signal if several are present.

This break-lock feature is an intelligence which has been designed into the radar to enable it to ignore reflections from antenna side lobes. This is very important when the radar is first turned on and is searching for the Moon's surface from a tilted spacecraft or if the radar accidently locks onto a weak side lobe reflection initially.

It is not needed near the lunar surface when the radar is already locked on the proper reflections.

The action taken to avoid recurrence of a similar break-lock on Surveyor D and future Surveyors, is to disable the break-lock logic when the spacecraft is near enough to the Moon's surface that highly reflective rocks could be a problem. In this case, the logic will not be used below 1,000 feet.

SURVEYOR D SPACECRAFT

Spaceframe, Mechanisms and Thermal Control

The spaceframe of the Surveyor is a triangular aluminum structure which provides mounting surfaces and attachments for the landing gear, main retrorocket engine, vernier engines and associated tanks, thermal compartments, antennas and other electronic and mechanical assemblies.

The frame is constructed of thin-wall aluminum tubing, with the frame members interconnected to form the triangle. A mast, which supports the planar array high-gain antenna and single solar panel, is attached to the top of the spaceframe. The basic frame weighs less than 60 pounds and installation hardware weighs 23 pounds.

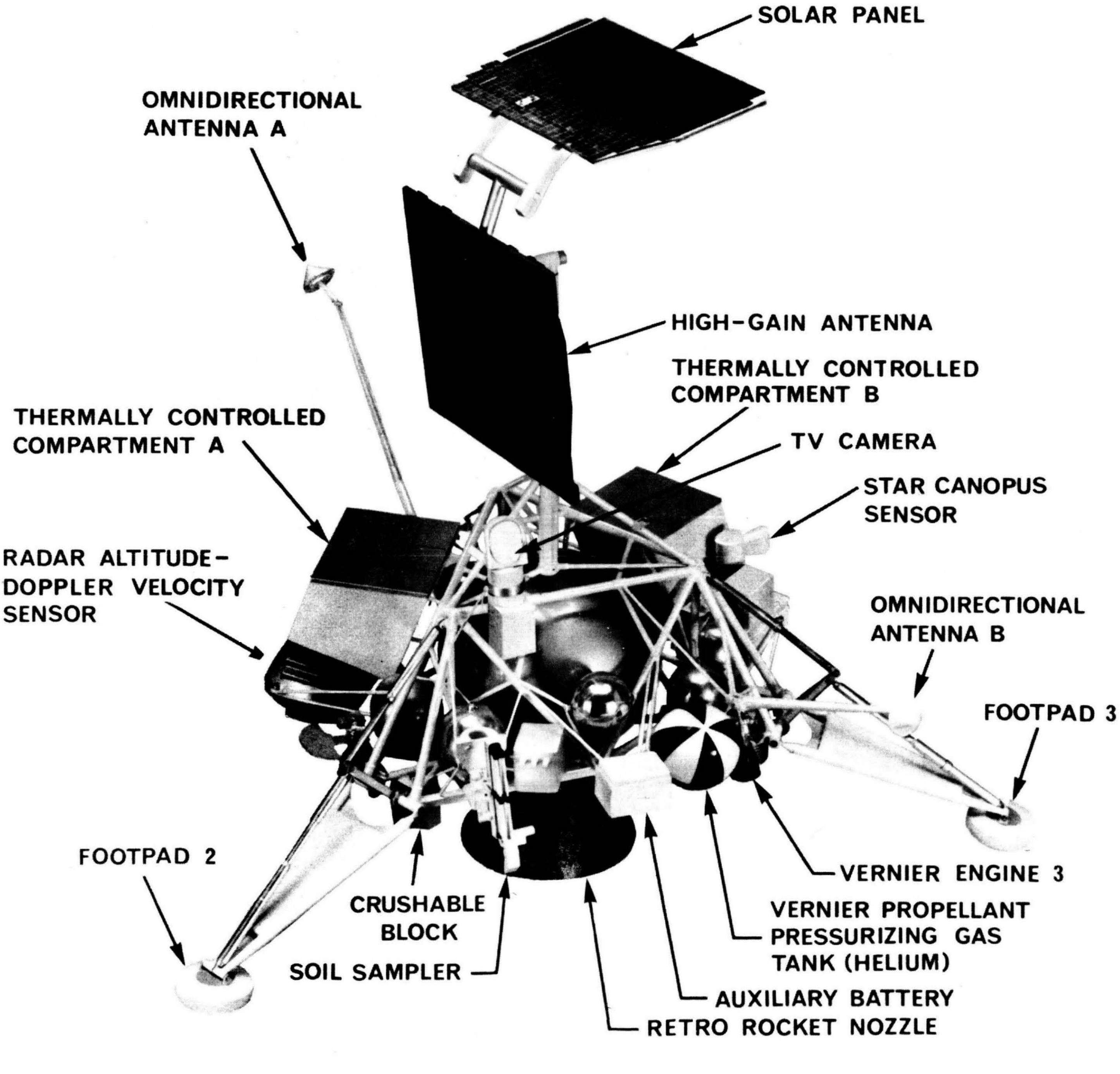
The Surveyor stands about 10 feet high and, with its tripod landing gear extended, can be placed within a 14-foot circle. A landing leg is hinged to each of the three lower corners of the frame and an aluminum honeycomb footpad is attached to the outer end of each leg. An airplane-type shock absorber and telescoping lock strut are connected to the frame so that the legs can be folded into the nose shroud during launch.

Blocks of crushable aluminum honeycomb are attached to the bottom of the spaceframe at each of its three corners to absorb part of the landing shock. Touchdown shock also is absorbed by the footpads and by the hydraulic shock absorbers which compress with the landing load.

Two omnidirectional, conical antennas are mounted on the ends of folding booms which are hinged to the spaceframe. The booms remain folded against the frame during launch until released by squib-actuated pin pullers and deployed by torsion springs. The antenna booms are released only after the landing legs are extended and locked in position.

An antenna/solar panel positioner atop the mast supports and rotates the planar array antenna and solar panel in either direction along four axes. This freedom of movement allows the antenna to be oriented toward Earth and the solar panel toward the Sun.

SURVEYOR


SOLAR PANEL
OMNIDIRECTIONAL ANTENNA A
HIGH-GAIN ANTENNA
THERMALLY CONTROLLED COMPARTMENT B
THERMALLY CONTROLLED COMPARTMENT A
TV CAMERA
STAR CANOPUS SENSOR
RADAR ALTITUDE-DOPPLER VELOCITY SENSOR
OMNIDIRECTIONAL ANTENNA B
FOOTPAD 3
FOOTPAD 2
CRUSHABLE BLOCK
SOIL SAMPLER
VERNIER ENGINE 3
VERNIER PROPELLANT PRESSURIZING GAS TANK (HELIUM)
AUXILIARY BATTERY
RETRO ROCKET NOZZLE

Two thermal compartments house sensitive electronic apparatus for which active thermal control is needed throughout the mission. The equipment in each compartment is mounted on a thermal tray that distributes heat throughout the compartment. An insulating blanket, consisting of 75 sheets of aluminized Mylar, is sandwiched between each compartment's inner shell and the outer protective cover. The tops of the compartments are covered by mirrored glass thermal radiators to dissipate heat.

Compartment A, which maintains an internal temperature between 40 degrees and 125 degrees F., contains two radio receivers, two transmitters, the main battery, battery charge regulator, main power switch and some auxiliary equipment.

Compartment B, kept between zero and 125 degrees F., houses the central command decoder, boost regulator, central signal processor, signal processing auxiliary, engineering signal processor, and low data rate auxiliary.

Both compartments contain sensors for reporting temperature measurements by telemetry to Earth, and heater assemblies to maintain the thermal trays above their allowable minimums. The compartments are kept below the 125-degree maximum with thermal swithces which provide a conductive path to the radiating surfaces for automatic dissipation of electrically generated heat. Compartment A contains nine thermal switches and compartment B, six. The thermal shell weight of compartment A is 25 pounds, and compartment B, 18 pounds.

Passive temperature control is provided for all equipment, not protected by the compartments, through the use of paint patterns and polished surfaces.

Twenty-nine pyrotechnic devices mechanically release or lock the mechanisms, switches and valves associated with the antennas, landing leg locks, roll actuator, retrorocket separation attachments, helium and nitrogen tanks, shock absorbers and the retromotor detonator. Some are actuated by command from the Centaur, and others are actuated by ground command.

A solid propellant, spherical retrorocket fits within the center cavity of the triangular frame and supplies the main thrust for slowing the spacecraft on approach to the Moon. The unit is attached at three points on the spaceframe near the landing leg hinges, with explosive nut separation points for ejection after burnout. The motor case, made of high-strength steel and insulated with asbestos and rubber, is 36 inches in diameter. Including the molybdenum nozzle, the unfueled motor weighs 144 pounds. With propellant, the weight is about 1,444 pounds, or more than 60 per cent of the total spacecraft weight.

Electrical harnesses and cables interconnect the spacecraft subsystems to provide correct signal and power flow. The harness connecting the two thermal compartments is routed through a thermal tunnel to minimize heat loss from the compartments. Coaxial cable assemblies, attached to the spaceframe by brackets and clips, are used for high frequency transmission.

Electrical interface with the Centaur stage is established through a 51-pin connector mounted on the bottom of the spaceframe between two of the landing legs. The connector mates with the Centaur connector when the Surveyor is mounted to the launch vehicle. It carries pre-separation commands from the Centaur programmer and can handle emergency commands from the blockhouse console. Ground power and prelaunch monitor also pass through the connector.

Power Subsystem

The power subsystem collects and stores solar energy, converts it to usable electric voltage, and distributes it to the other spacecraft subsystems. The subsystem consists of the solar panel, a main battery and an auxiliary battery, an auxiliary battery control, a battery charge regulator, main power switch, boost regulator, and an engineering mechanisms auxiliary.

The solar panel is the spacecraft's primary power source during flight and during operations in the lunar day. It consists of 3,960 solar cells arranged on a thin, flat surface approximately nine square feet in area. The solar cells are grouped in 792 separate modules and connected in series-parallel to guard against complete failure in the event of a single cell malfunction.

The solar panel is mounted at the top of the Surveyor spacecraft's mast. Wing-like, it is folded away during launch and deployed by Earth-command after the spacecraft has been injected into the lunar transit trajectory.

When properly oriented during flight, the solar panel can supply about 89 watts, most of the power required for the average operating load of all on-board equipment.

During operation on the lunar surface, the solar panel can be adjusted by Earth-command to track the Sun within a few degrees, so that the solar cells remain always perpendicular to the solar radiation.

In this lunar-surface mode, the solar panel is designed to supply a minimum of 77 watts power at a temperature of 140 degrees F., and a minimum of 57 watts at a temperature of 239 degrees F.

A 14-cell rechargeable, silver-zinc main battery is the spacecraft's power reservoir. It is the sole source of power during launch; it stores electrical energy from the solar panel during transit and lunar-day operations; and it provides a backup source to meet peak power requirements during both of those periods.

Fully charged, the battery provides 3,800 watt-hours at a discharge rate of 1.0 amperes. Battery output is approximately 22 volts direct current for all operating and environmental conditions in temperatures from 40 degrees to 125 degrees F.

The auxiliary battery is a non-rechargeable, silver-zinc battery contained in a sealed magnesium cannister. It provides a power backup for both the main battery and the solar panel under peak power loading or emergency conditions.

The battery has a capacity of from 800 to 1,000 watt-hours, depending upon power load and operating temperature.

The battery charge regulator and the booster regulator are the two power conditioning elements of the spacecraft's electrical power subsystem.

The battery charge regulator couples the solar panel to the main battery for maximum conversion and transmission of the solar energy necessary to keep the main battery at full charge.

It receives power at the solar panel's varying output voltage, and it delivers this power to the main battery at a constant battery terminal voltage.

The battery charge regulator indludes sensing and logic circuitry for automatic battery charging whenever battery voltage drops below 27 volts direct current. Automatic battery charging also maintains battery manifold pressure at approximately 65 pounds per square inch.

Earth-command may override the automatic charging function of the battery charge regulator.

The booster regulator unit receives unregulated power from 17 to 27.5 volts direct current from the solar panel, the main battery, or both, and delivers a regulated 29 volts direct current to the spacecraft's three main power transmission lines. These three lines supply all the spacecraft's power needs, except for a 22-volt unregulated line which serves heaters, switches, actuators, solenoids and electronic circuits which do not require regulated power or provide their own regulation.

Telecommunications

Communications equipment aboard Surveyor has three functions: to provide for transmission and reception of radio signals; to decode commands sent to the spacecraft; and to select and convert engineering and television data into a form suitable for transmission.

The first group includes the three antennas: one high-gain, directional antenna and two low-gain, omnidirectional antennas, two transmitters and two receivers with transponder interconnections. Dual transmitters and receivers are used for reliability.

The high-gain antenna transmits 600-line television data. The low-gain antennas are designed for command reception and transmission of other data including 200-line television data from the spacecraft. The low-gain antennas are each connected to one receiver. The transmitters can be switched to either low-gain antennas or to the high-gain antenna and can operate at low or high-power levels. Thermal control of the three antennas is passive, dependent on surface coatings to keep temperatures within acceptable limits.

The command decoding group can handle up to 256 commands either direct, (on-off) or quantitative (time-intervals). Each incoming command is checked in a central command decoder which will reject a command, and signal the rejection to Earth, if the structure of the command is incorrect. Acceptance of a command is also radioed to Earth. The command is then sent to subsystem decoders that translate the binary information into an actuating signal for the function command such as squib firing or changing data modes.

Processing of most engineering data, (temperatures, voltages, currents, pressures, switch positions, etc.) is handled by the engineering signal processor or the auxiliary processor. There are over 200 engineering measurements of the spacecraft. None are continuously reported. There are four commutators in the engineering signal processor to permit sequential sampling of selected signals. The use of a commutator is dependent on the type and amount of information required during various flight sequences. Each commutator can be commanded into operation at any time and at any of the five bit rates: 17.2, 137.5, 550, 1100 and 4,400 bits per second.

Commutated signals from the engineering processors are converted to 10-bit data words by an analog-to-digital converter in the central signal processor and relayed to the transmitter. The low bit rates are normally used for transmissions over the low gain antennas and the low power levels of the transmitters.

Propulsion

The propulsion system consists of three liquid fuel vernier rocket engines and a solid fuel retromotor.

The vernier engines are supplied propellant by three fuel tanks and three oxidizer tanks. There is one pair of tanks, fuel and oxidizer, for each engine. The fuel and oxidizer in each tank is contained in a bladder. Helium stored under pressure is used to deflate the bladders and force the fuel and oxidizer into the feed lines. Tank capacity is 170.3 pounds each.

The oxidizer is nitrogen tetroxide with 10 percent nitric oxide. The fuel is monomethylhydrazine monohydrate. An ignition system is not required for the verniers as the fuel and oxidizer are hypergolic, burning upon contact. The throttle range is 30 to 104 pounds of thrust.

The main retro is used at the beginning of the terminal descent to the lunar surface and slows the spacecraft from an approach velocity of about 6,000 miles per hour to approximately 250 miles per hour. It burns an aluminum, ammonium-percholorate and polyhydrocarbon, case bonded composite type propellant with a conventional grain geometry.

The nozzle has a graphite throat and a laminated plastic exit cone. The case is of high strength steel insulated with asbestos and silicon dioxide-filled buna-N rubber to maintain the case at a low temperature level during firing.

Engine thrust varies from 8,000 to 10,000 pounds over a temperature range of 50 to 70 degrees F. Passive thermal control, insulating blankets and surface coatings will maintain the grain above 50 degrees F. It is fired by a pyrogen igniter. The main retro weighs approximately 1,444 pounds and is spherical shaped, 36 inches in diameter.

Flight Control Subsystem

Flight control of Surveyor, control of its attitude and velocity from Centaur separation to touchdown on the Moon, is provided by: primary Sun sensor, automatic Sun acquisition sensor, Canopus sensor, inertial reference unit, altitude marking radar, inertia burnout switch, radar altimeter and Doppler velocity sensors, flight control electronics, and three pairs of cold gas jets. Flight control electronics includes a digital programmer, gating and switching, logic and signal data converter for the radar altimeter and Doppler velocity sensor.

The information provided by the sensors is processed through logic circuitry in the flight control electronics to yield actuating signals to the gas jets and to the three liquid fuel vernier engines and the solid fuel main retro motor.

The Sun sensors provide information to the flight control electronics indicating whether or not they are illuminated by the Sun. This information is used to order the gas jets to fire and maneuver the spacecraft until the Sun sensors are on a direct line with the Sun. The primary Sun sensor consists of five cadmium sulphide photo conductive cells. During flight Surveyor will continuously drift off of Sun lock in a cycle less than 0.2 ± 0.3 degrees. The drift is continuously corrected by signals from the primary sensor to the flight electronics ordering the pitch and yaw gas jets to fire to correct the drift.

Locking on to the star Canopus requires prior Sun lock-on. Gas jets fire intermittently to compensate for drift to maintain Canopus lock-on and thus control spacecraft roll during cruise modes. If star or Sun lock is lost, control is automatically switched from optical sensors to inertial sensors (gyros).

The inertial reference unit is also used during mission events when the optical sensors cannot be used. These events are the midcourse maneuver and descent to the lunar surface. This device senses changes in attitude and in velocity of the spacecraft with three gyros and an accelerometer. Information from the gyros is processed by the control electronics to order gas jet firing to change or maintain the desired attitude. During the thrust phases the inertial reference unit controls vernier engine thrust levels, by differential throttling for pitch and yaw control and swiveling one vernier engine for roll control. The accelerometer controls the total thrust level.

The altitude marking radar will provide the signal for firing of the main retro. It is located in the nozzle of the retromotor and is ejected when the motor ignites. The radar will generate a signal at about 60 miles above the lunar surface. The signal starts the programmer automatic sequence after a predetermined period (directed by ground command); the programmer then commands vernier and retro ignition and turns on the Radar Altimeter and Doppler Velocity Sensor (RADVS).

The inertia burnout switch will close when the thrust level of the main retromotor drops below 3.5 g, generating a signal which is used by the programmer to command jettisoning of the retromotor and switching to RADVS control.

Control of the spacecraft after main retro burnout is vested in the radar altimeter and Doppler velocity sensor. There are two radar dishes for this sensor. An altimeter/velocity sensing antenna radiates two beams and a velocity sensing antenna two beams. Beams 1, 2, and 3 give vertical and transverse velocity. Beam 4 provides altitude or slant range information. Beams 1, 2, and 3 provide velocity data by summing in the signal data converter of the Doppler shift (frequency shift due to velocity) of each beam. The converted range and velocity data is fed to the gyros and circuitry logic which in turn control the thrust signals to the vernier engines.

The flight control electronics provide for processing sensor information into telemetry signals and to actuate spacecraft mechanisms. It consists of control circuits, a command decoder and an AC/DC electronic conversion unit. The programmer controls timing of main retro phase and generates precision time delays for attitude maneuvers and midcourse velocity correction.

The attitude jets provide attitude control to the spacecraft from Centaur separation to main retro burn. The gas jet system is fed from a spherical tank holding 4.5 pounds of nitrogen gas under high pressure. The system includes regulating and dumping valves and three pairs of opposed gas jets with solenoid-operated valves for each jet. One pair of jets is located at the end of each of the three landing legs. The pair on leg number one control motion in a horizontal plane, imparting roll motion to the spacecraft. Pairs two and three control pitch and yaw.

Television

The Surveyor spacecraft carries one survey television camera. The camera is mounted nearly vertically, pointed at a movable mirror. The mounting containing the mirror can swivel 360 degrees, and the mirror can tilt down to view a landing leg to up above the horizon.

The camera can be focused, by Earth command, from four feet to infinity. Its iris setting, which controls the amount of light entering the camera, can adjust automatically to the light level or can be commanded from Earth. The camera has a variable focal length lens which can be adjusted to narrow angle, 6.4 x 6.4 field of view, to wide angle, 25.4 x 25.4 field of view.

A focal plane shutter provides an exposure time of 150 milliseconds. The shutter can also be commanded open for an indefinite length of time. A sensing device coupled to the shutter will keep it from opening if the light level is too intense. A too-high light level could occur from changes in the area of coverage by the camera, a change in the angle of mirror, in the lens aperture, or by changes in Sun angle. The same sensor controls the automatic iris setting. The sensing device can be overridden by ground command.

The camera system can provide 200 or 600-line pictures. The 600-line pictures require that the high gain directional antenna and the high power level of the transmitter are both operating. The 600-line mode provides a picture each 3.6. seconds and the 200 line mode every 61.8 seconds.

A filter wheel can be commanded to one of four positions providing clear, colored or polarizing filters.

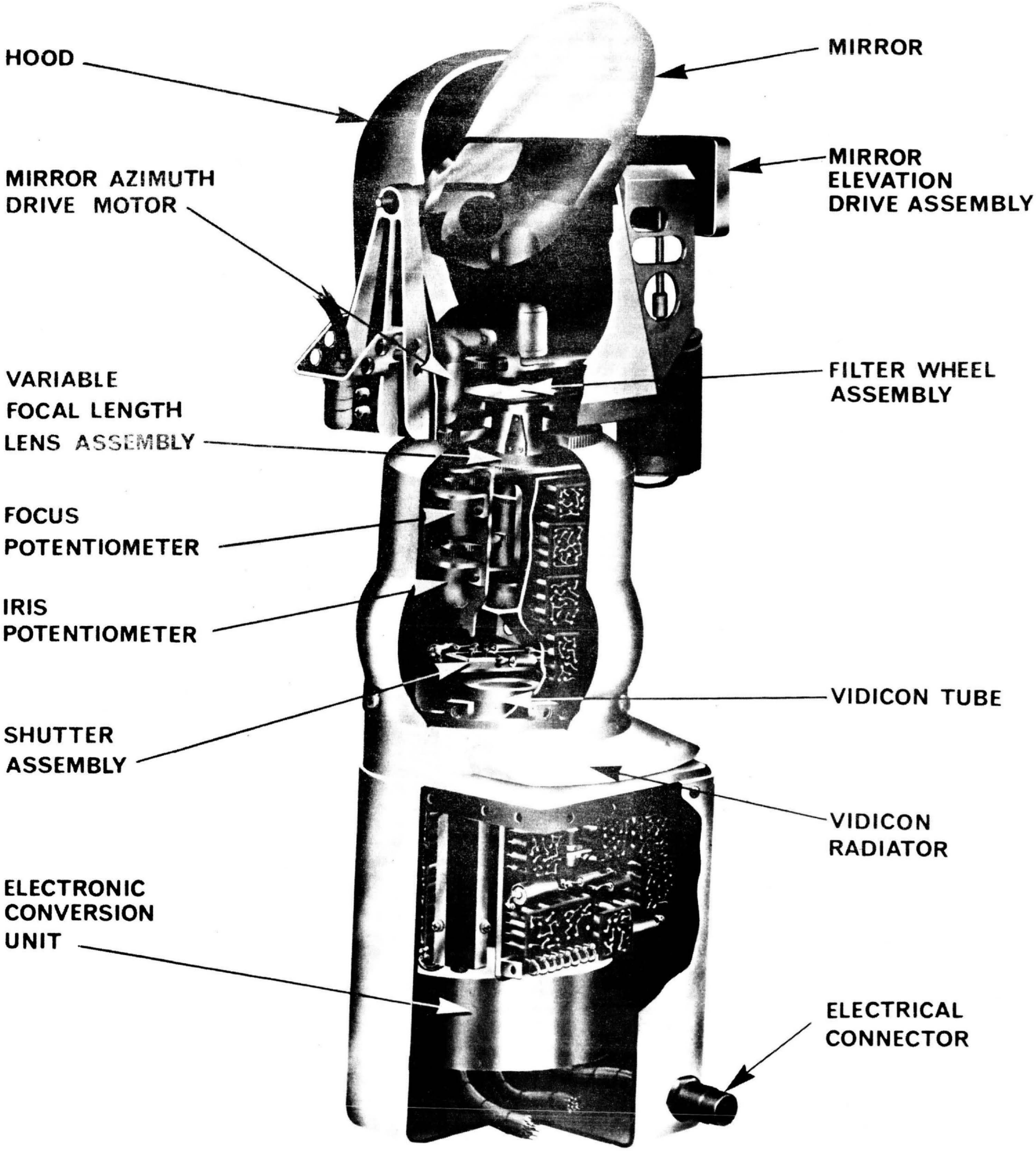
Two flat beryllium mirrors are mounted on the spacecraft frame near leg number one to provide additional coverage of the area under the spacecraft for the television camera. The larger mirror is 10 inches x 9 inches; the smaller is 3½ inches x 9½ inches.

The large mirror provides a view of the lower portion of crushable block number three and the area under vernier engine number three. The small mirror provides a view of the area under vernier engine number two.

The purpose is to provide pictures of the lunar soil disturbed by the spacecraft landing and the amount of damage to the crushable block itself.

Principal television investigator is Dr. Eugene Shoemaker, U. S. Geological Survey.

SURVEYOR SURVEY TV CAMERA



Surface Sampler Experiment

Payload of the Surveyor D spacecraft includes a surface sampler mechanism flown for the first time on the Surveyor III mission. The metal claw digger provided scientific data for determination of the bearing strength of the lunar surface and soil characteristics. The device can dig a trench to a depth of 18 inches, perform penetration tests by dropping it from various heights, and bearing strength tests by pressing down on the lunar surface.

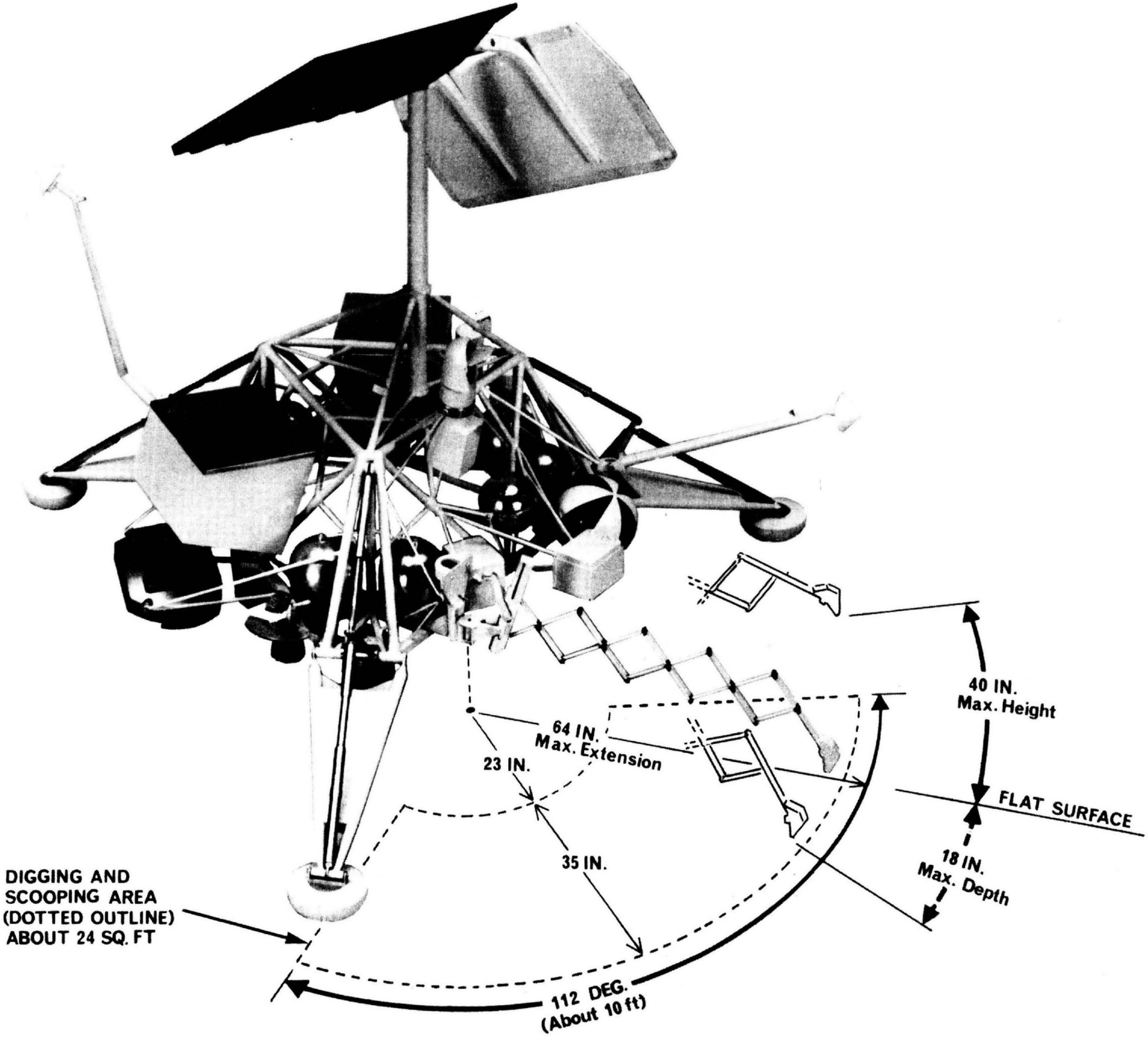
The device is a scoop about five inches long and two inches wide attached to an extendable arm hinged horizontally and vertically to the spacecraft. The flexible arm, to which the scoop is rigidly attached, is made up of tubular aluminum cross members which operate mechanically in a scissor fashion to extended, retracted, or partially retracted position by a metal tape, one end attached to the scoop and the other wound on a motor spindle at the base. Extension and retraction of the arm is controlled by commands to the motor to reel or unreel the tape. Maximum extension is about five feet from the spacecraft frame.

Two other motors, which can be operated in either direction, will allow the arm to pivot 112 degrees in a horizontal arc and to elevate or lower the scoop over a range of some 40 inches above to about 18 inches below a level lunar surface. Surface area available to the sampler totals about 24 square feet.

A fourth motor, located in the scoop, opens and closes a two-by-four-inch door on the scoop. All four motors operate on 22 volts of unregulated direct current from the spacecraft battery. They operate for either of two time periods, a single command pulsing the motor for one-tenth of a second or for two seconds. Selection of the motor to be operated, motor direction and the time period is made by ground command.

The instrument will be used in conjunction with the survey TV camera. The scoop will be positioned in view of the camera, then activated to perform picking, digging or trenching operations. Visual data combined with a determination of the force developed during the digging is expected to indicate strength, texture and cohesive characteristics of the soil.

SURVEYOR SURFACE SAMPLER MOVEMENTS



A single telemetry channel from the Surveyor will monitor the electric current being drawn by the motor in operation. By using pre-flight calibration data, this measurement can be used in analyzing the force necessary to scrape or dig the surface and break small rocks or clods.

In the event of a camera failure, where the surface sampler must be used in the blind, the force measurements will be of some, but less value, in analyzing the operation of the instrument. For maximum success of the experiment, the surface sampler is dependent upon visual data from the TV camera.

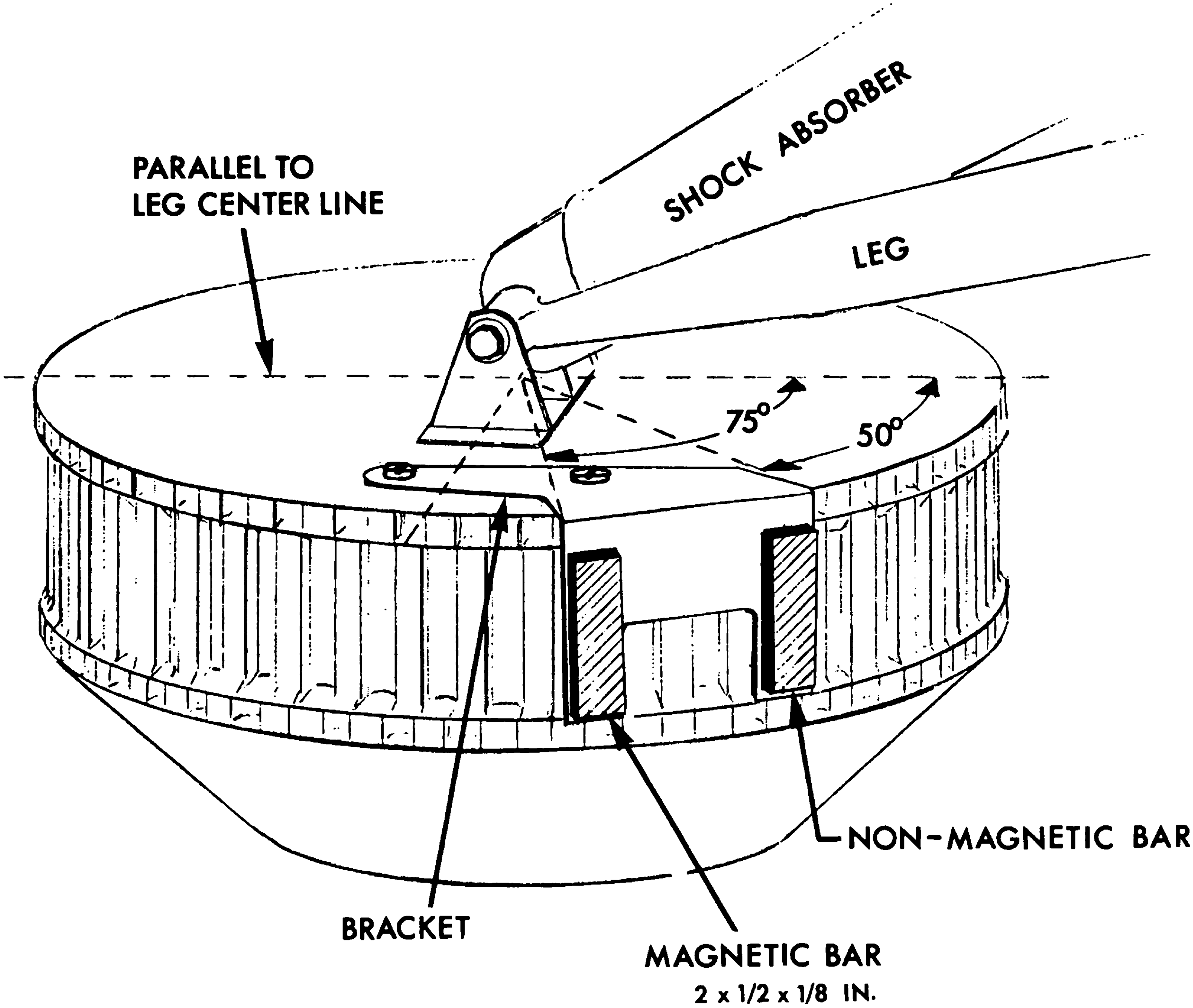
The scoop, arm, motors, and housing for the device total about 8.4 pounds. The instrument's electronics unit, located in a separate thermal-control compartment, weighs about 6.3 pounds.

Principal scientific investigator for the surface sampler experiment is Dr. Ronald F. Scott of the California Institute of Technology. The instrument was designed and built by the Hughes Aircraft Company.

Magnetic Test

The purpose of this test, utilizing a small magnet attached to a footpad, is to determine whether magnetic particles are present in the surface layer of lunar soil.

The magnet is a bar, two inches long by ½ inch wide by 1/8 inch thick, mounted vertically on footpad #2 in view of the television camera. Photographs of the bar taken at various Sun angles would show magnetic particles attracted to the magnet if there are any on the lunar surface.


SHOCK ABSORBER
PARALLEL TO
LEG CENTER LINE
LEG
75°
50°
NON-MAGNETIC BAR
BRACKET
MAGNETIC BAR
2 x 1/2 x 1/8 IN.

A second bar --nonmagnetic-- is also mounted on the footpad to serve as a control for the test by permitting a comparison of the amount of material adhering to the nonmagnetic bar, if any, with the amount adhering to the magnetic bar.

The magnet is made of an iron-nickel-cobalt-aluminum alloy. The control bar is an alloy of iron-nickel-cobalt which has a very low magnetic permeability. The two bars are screwed to a mounting bracket which is attached to the footpad. Weight of the entire assembly is about two ounces. The bars and mounting are painted dull light blue for contrast to dark lunar material.

Engineering Instrumentation

Engineering evaluation of the Surveyor flight will be augmented by an engineering payload including an auxiliary battery, auxiliary processor for engineering information, and instrumentation consisting of extra temperature sensors, strain gauges for gross measurements of vernier engine response to flight control commands and shock absorber loading at touchdown, and extra accelerometers for measurements of vernier engine response to flight control commands and shock absorber loading at touchdown, and extra accelerometers for measuring structural vibration during main retro burn.

The auxiliary battery will provide a backup for both emergency power and peak power demands to the main battery and the solar panel. It is not rechargeable.

The auxiliary engineering signal processor provides two additional telemetry commutators for determining the performance of the spacecraft. It processes the information in the same manner as the engineering signal processor, providing additional signal capacity and redundancy.

ATLAS-CENTAUR LAUNCH VEHICLE

Atlas-Centaur 11 will be the fourth in a series of operational launch vehicles designed to launch and inject Surveyor spacecraft on lunar mission trajectories. Two previous Surveyors (I and II) were launched via direct-ascent trajectories and one (III) using the parking orbit method.

The Atlas-Centaur vehicle has been developed by NASA to launch medium-weight scientific spacecraft on lunar and interplanetary missions. The vehicle has a current payload capability of about 2,350 pounds for direct-ascent missions to the Moon.

An improved Atlas, called SLV-3C, will increase Atlas-Centaur's payload capability to about 2,700 pounds for direct-ascent lunar missions. The SLV-3C Centaur vehicle, will be used initially later this year to boost the Surveyor E spacecraft to the Moon.

In addition to its Surveyor launch assignment, the Atlas-Centaur combination has been selected to launch two Mariner spacecraft on missions to Mars in 1969, three Orbiting Astronomical Observatories beginning in 1968, and two Applications Technology Satellites also starting in 1968.

Launch Vehicle Fact Sheet

(All figures approximate)

Liftoff Weight: 303,000 lbs.
Liftoff Height: 113 feet
Launch Complex: 36-A

	Atlas Booster	Centaur Stage
Weight (at liftoff)	263,000 lbs.	37,600 lbs. (less payload)
Height	75 feet (including interstage adapter)	48 feet (with fairing)
Thrust	388,000 lbs. (sea level)	30,000 lbs. (at altitude)
Propellants	RP-1 (fuel) and liquid oxygen (oxidizer)	Liquid hydrogen (fuel) and liquid oxygen (oxidizer)
Propulsion	MA-5 system (2-165,000 lb. thrust booster engines, 1-57,000 lb. sustainer engine, and 2-670 lb. vernier engines)	Two RL-10 engines
Velocity	5,560 mph at BECO 7,800 mph at SECO	23,700 mph at injection
Guidance	Pre-programmed auto-pilot thrpugh BECO	Inertial

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Atlas-Centaur Flight Sequence

EVENT		NOMINAL TIME, SEC.	ALTITUDE STATUTE MI.	SURFACE RANGE STATUTE MI.	VEL/MPH
1.	Liftoff	0	0	0	0
2.	Booster engine cutoff	144	37	51	5,560
3.	Booster engine jettison	147	39	55	5,730
4.	Jettison insulation panels	178	57	101	6,300
5.	Jettison nose fairing	205	73	147	6,930
6.	Sustainer engine cutoff	239	90	213	7,800
7.	Atlas-Centaur separation	241	91	216	7,800
8.	Centaur engine start	250	96	236	7,800
9.	Centaur engine cutoff	685	112	1,750	23,700
10.	Spacecraft separation	756	107	2,200	23,700
11.	Centaur reorientation	761	106	2,240	23,700
12.	Centaur retrothrust	996	232	3,740	23,700

(Launch vehicle mission completed at T plus 21 minutes)

Figures used are approximate but typical of potential trajectories for AC-11 depending on day of launch.

TRACKING AND COMMUNICATION

The flight of the Surveyor spacecraft from injection to the end of the mission will be monitored and controlled by the Deep Space Network (DSN) and the Space Flight Operations Facility (SFOF) operated by the Jet Propulsion Laboratory.

Some 300 persons will be involved in Surveyor flight monitoring and control during peak times in the mission. On the Surveyor I flight more than 100,000 ground commands were received and acted on by the spacecraft during flight and after the soft landing.

The Deep Space Network consists of six permanent space communications stations in Australia, Spain, South Africa and California; a spacecraft monitoring station at Cape Kennedy; and a spacecraft guidance and a command station at Ascension Island in the South Atlantic.

The DSN facilities assigned to the Surveyor project are Pioneer at Goldstone, Calif.; Robledo, Spain; Tidbinbilla in the Canberra complex, Australia; Ascension Island; and Johannesburg, South Africa.

The Goldstone facility is operated by JPL with the assistance of the Bendix Field Engineering Corp. The Tidbinbilla facility is operated by the Australia Department of Supply. The Robledo facility is operated by JPL under an agreement with the Spanish government and the support of Instituto Nacional de Tecnica Aeroespacial (INTA) and the Bendix Field Corp. The Ascension Island DSN facility is operated by JPL with Bendix support under a cooperative agreement between the United Kingdom and the U.S.

The DSN uses a ground communications system for operational control and data transmission between these stations. The ground communications system is a part of a larger net (NASCOM) which links all of the NASA stations around the world. This net is under the technical direction of NASA's Goddard Space Flight Center, Greenbelt, Md.

The DSN supports the Surveyor flight in tracking the spacecraft, receiving telemetry from the spacecraft, and sending it commands. The DSN renders this support to all of NASA's unmanned lunar and planetary spacecraft from the time they are injected into planetary orbit until they complete their missions.

Stations of the DSN receive the spacecraft radio signals, amplify them, process them to separate the data from the carrier wave and transmit required portions of the data to the command center via high-speed data lines, radio links, and teletype. The stations are also linked with the center by voice lines. All incoming data are recorded on magnetic tape.

The information transmitted from the DSN stations to the SFOF is fed into large scale computer systems which translate the digital code into engineering units, separate information pertinent to a given subsystem on the spacecraft, and drive display equipment in the SFOF to present the information to the engineers on the project. All incoming data are again recorded in the computer memory system and are available on demand.

Equipment for monitoring television reception from Surveyor is located in the SFOF.

Some of the equipment is designed to provide quick-look information for decisions on commanding the camera to change iris settings, change the field of view from narrow angle to wide angle, change focus, or to move the camera either horizontally or vertically. Television monitors display the picture being received. The pictures are received line by line and each line is held on a long persistence television tube until the picture is complete. A special camera system produces prints of the pictures for quick-look analysis.

Other equipment will produce better quality pictures from negatives produced by a precision film recorder.

Commands to operate the camera will be prepared in advance on punched paper tape and forwarded to the stations of the DSN. They will be transmitted to the spacecraft from the DSN station on orders from the SFOF.

Three technical teams support the Surveyor television mission in the SFOF: one is responsible for determining the trajectory of the spacecraft including determination of launch periods and launch requirements, generation of commands for the midcourse and terminal maneuvers; the second is responsible for continuous evaluation of the condition of the spacecraft from engineering data radioed to Earth; the third is responsible for evaluation of data regarding the spacecraft and for generating commands controlling the spacecraft operations.

TRAJECTORY

The determination of possible launch days, specific times during each day and the Earth-Moon trajectories for the Surveyor spacecraft are based on a number of factors, or constraints.

A primary constraint is the time span during each day the Surveyor can be launched -- the launch window -- which is determined by the requirement that the launch site at launch time and the Moon at arrival time be contained in the Earth-Moon transfer orbit plane. With the launch site moving eastward as the Earth revolves, acceptable conditions occur only once each day for a given plane.

The launch azimuth constraint of 78 to 115 degrees is imposed by the range safety consideration of allowing the initial launch phase only over the ocean, not over land masses.

The time of flight, or the time to landing, about 61-65 hours, is determined by the constraint placed upon the trajectory engineer that Surveyor must reach the Moon during the viewing period of the prime Deep Space Net station at Goldstone in the California Mojave Desert.

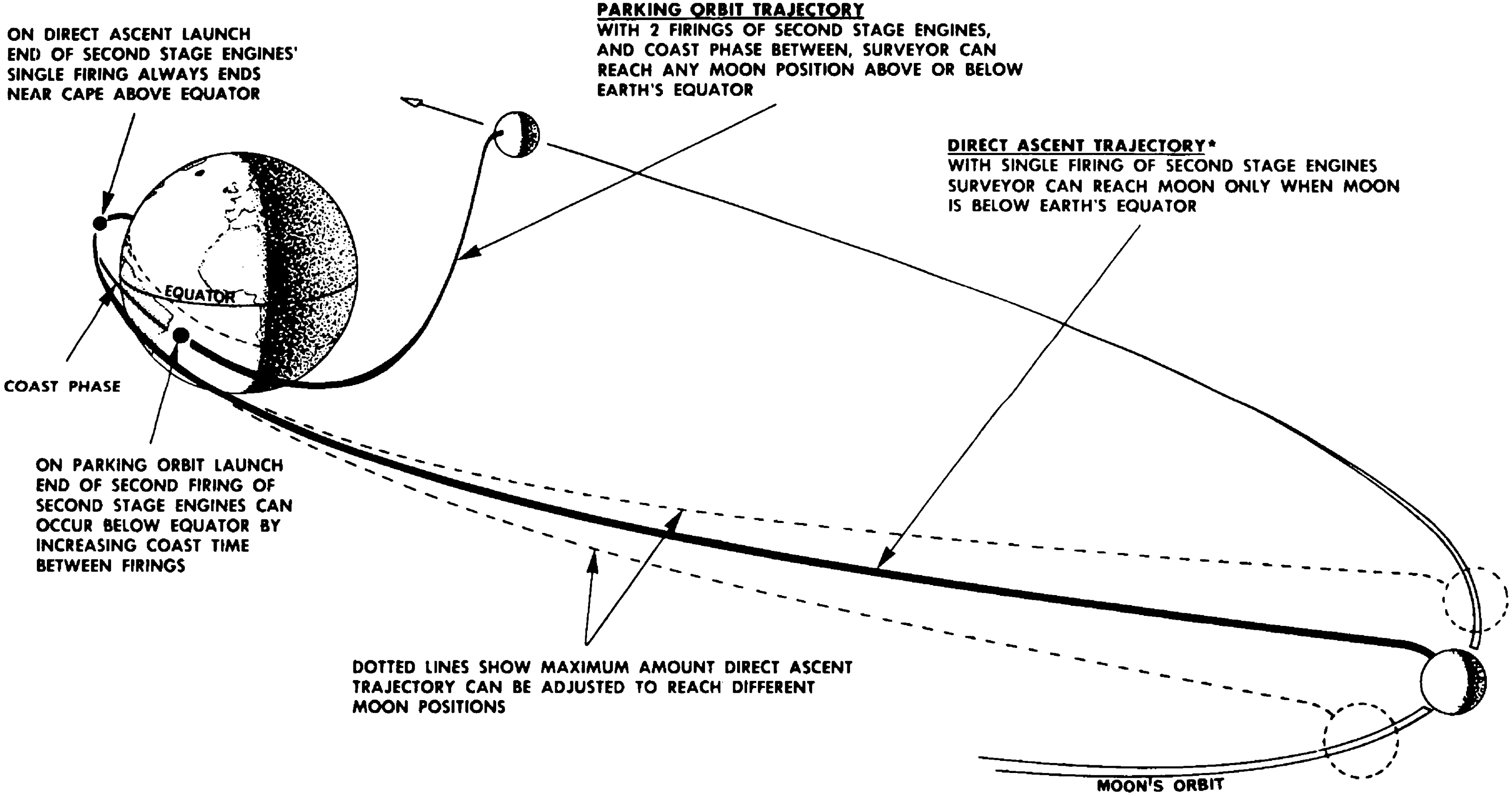
Landing sites are further limited by the curvature of the Moon. The trajectory engineer cannot pick a site, even if it falls within the acceptable band, if the curvature of the Moon will interfere with a direct communication line between the spacecraft and the Earth.

Two other factors in landing site selection are smoothness of terrain and a requirement for Surveyor to land, in areas selected for the Apollo manned lunar mission.

Thus the trajectory engineer must tie together the launch characteristics, the landing site location, the declination of the Moon and flight time, in determining when to launch, in which direction, and at what velocity.

His chosen trajectory also must not violate constraints on the time allowable that the Surveyor can remain in the Earth's shadow. Too long a period can result in malfunction of components or subsystems. In addition, the Surveyor must not remain in the shadow of the Moon beyond given limits.

SURVEYOR TRAJECTORIES TO THE MOON



*EARLY SURVEYORS WILL BE LAUNCHED ON DIRECT ASCENT TRAJECTORIES

The velocity of the spacecraft when it arrives at the Moon must also fall within defined limits. These limits are defined by the retrorocket capability. The velocity relative to the Moon is primarily correlated with the flight time and the Earth-Moon distance for each launch day.

So, a further requirement on the trajectory engineer is the amount of fuel available to slow the Surveyor from its lunar approach speed of 6,000 mph to nearly zero velocity, 13 feet above the Moon's surface. The chosen trajectory must not yield velocities that are beyond the designed capabilities of the spacecraft propulsion system.

Also included in trajectory computation is the influence on the flight path and velocity of the spacecraft of the gravitational attraction of primarily the Earth and Moon and to a lesser degree the Sun, Mercury, Venus, Mars, and Jupiter.

It is not expected that the launching can be performed with sufficient accuracy to impact the Moon in exactly the desired area. The uncertainties involved in a launch usually yield a trajectory or an injection velocity that vary slightly from the desired values. The uncertainties are due to inherent limitations in the guidance system of the launch vehicle. To compensate, lunar and deep space spacecraft have the capability of performing a midcourse maneuver or trajectory correction. To alter the trajectory of a spacecraft it is necessary to apply thrust, or energy, in a specific direction to change its velocity. The trajectory of a body at a point in space being basically determined by its velocity.

For example, a simple midcourse might involve correcting a too high injection velocity. To correct for this the spacecraft would be commanded to turn in space until its midcourse engines were pointing in its direction of travel. Thrust from the engines would slow the craft. However, in the general case the midcourse is far more complex and will involve changes both in velocity and its direction of travel.

A certain amount of thrust applied in a specific direction can achieve both changes. Surveyor will use its three liquid fuel vernier engines to alter its flight path in the midcourse maneuver. It will be commanded to roll and then to pitch or yaw in order to point the three engines in the required direction. The engines then burn long enough to apply the change in velocity required to alter the trajectory.

The change in the trajectory is very slight at this point and a tracking period of about 20 hours is required to determine the new trajectory. This determination will also provide the data required to predict the spacecraft's angle of approach to the Moon, time of arrival, and its velocity as it approaches the Moon.

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ATLAS-CENTAUR 11/SURVEYOR D FLIGHT PLAN

Surveyor D will be launched by Atlas-Centaur 11 into a direct-ascent lunar trajectory.

The primary task for Atlas-Centaur 11 on the Surveyor D flight is to inject the Surveyor spacecraft on a lunar-transfer trajectory with sufficient accuracy so that the midcourse maneuver correction required some 15 to 20 hours after liftoff does not exceed 50 meters/second or 111.85 miles-per-hour.

The Centaur stage also is required to perform a retro-maneuver to avoid impacting the Moon and to prevent Surveyor's star seeker from mistaking the spent Centaur for its orienting star, Canopus.

Launch Periods
(EDT)

Date	Launch Window Open	Close	Date	Arrival Time (Based on earliest launch time)
13	7:03 a.m.	7:07 a.m.	16	12:18 a.m.
14	7:53 a.m.	8:30 a.m.	16	10:21 p.m.
15	8:43 a.m.	10:01 a.m.	17	10:25 p.m.
16	9:43 a.m.	11:06 a.m.	18	11:42 p.m.
17	10:44 a.m.	12:08 p.m.	20	12:46 a.m.

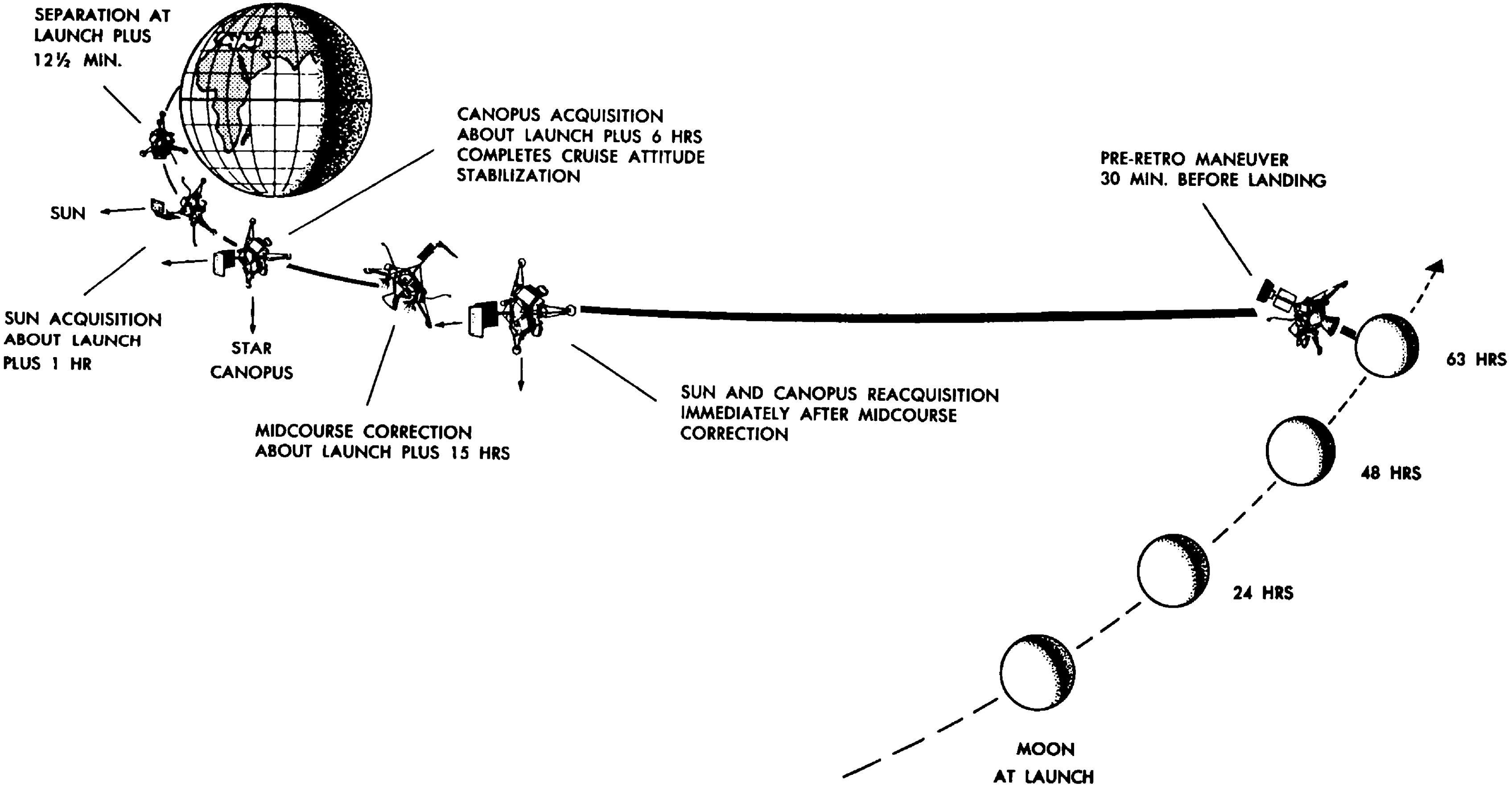
Atlas Phase

All five of the Atlas engines -- three main engines and two vernier control engines -- are ignited prior to liftoff. For the first two seconds the Atlas-Centaur will rise vertically and then roll for 13 seconds to the desired flight plane azimuth of 80 to 115 degrees depending upon time of launch.

After 15 seconds of flight, the vehicle begins pitching over to the desired flight trajectory which continues throughout the Atlas-powered phase of the flight.

At T plus 144 seconds, booster engine cutoff (BECO) occurs when an acceleration level of 5.7 g is sensed. Three seconds later the booster engine package is jettisoned. The sustainer engine continues to propel the vehicle and Centaur inertial guidance begins its steering functions.

SURVEYOR FLIGHT PROFILE



Atlas sustainer engine cutoff (SECO) occurs after 239 seconds of flight at an altitude of about 90 miles. Two seconds later Atlas and Centaur are separated by a flexible shaped charge which severs the interstage adapter. Eight retrorockets on the Atlas are fired to increase the rate of separation.

Centaur Phase

At T plus 250 seconds, Centaur's two hydrogen-oxygen RL-10 engines are ignited for a planned burn of 435 seconds. Centaur ignition occurs at about 96 miles altitude when the vehicle is 236 miles down range traveling at a velocity of 7,800 MPH.

After 685 seconds of flight, Centaur's propulsion system is shut down when the guidance system senses that the vehicle has attained proper velocity. Injection velocity varies with time and day of launch, but is approximately 23,700 mph.

Shortly after Centaur engine shutdown, the Centaur programmer commands Surveyor's legs and two omnidirectional antennas to extend, and orders the spacecraft's transmitter to high power. At T plus 756 seconds and an altitude of 107 miles, the programmer commands separation of Surveyor from Centaur. Three spring-loaded cylinders force the spacecraft and vehicle apart.

Five seconds after spacecraft separation, Centaur is rotated 180 degrees by its attitude control system in order to perform a retromaneuver. Unused propellants are then blown through the rocket thrust chambers to increase separation of Centaur and Surveyor -- the result is that some five hours later they are at least 208 miles apart. This eliminates the possibility that Surveyor's star tracker will mistakenly lock on Centaur. Centaur's trajectory is thereby altered to prevent it from impacting the Moon.

At liftoff plus 21 minutes, Atlas-Centaur will have completed its mission and the Centaur stage will continue in a highly elliptical Earth orbit, extending more than 257,000 miles into space and circling the Earth once each 11.3 days.

First Surveyor Events

Shortly after Centaur engine shutdown, the programmer commands Surveyor's legs and two onmidirectional antennas to extend and orders the spacecraft's transmitter to high power.

After Surveyor separates from the Centaur an automatic command is given by the spacecraft to fire explosive bolts to unlock the solar panel. A stepping motor then moves the panel to a prescribed position. Solar panel deployment can also be commanded from the ground if the automatic sequence fails.

Surveyor will then perform an automatic Sun-seeking maneuver to stabilize the pitch and yaw axes and to align its solar panel with the Sun for conversion of sunlight to electricity to power the spacecraft. Prior to this event the spacecraft main battery is providing power.

The Sun acquisition sequence begins immediately after separation from Centaur and simultaneously with the solar panel deployment. The nitrogen gas jet system, which is activated at separation, will first eliminate random pitch, roll and yaw motions resulting from separation from Centaur. Then a sequence of controlled roll and yaw turning maneuvers is commanded for Sun acquisition.

Sun sensors aboard Surveyor will provide signals to the attitude control gas jets to stop the spacecraft when it is pointed at the Sun. Once locked on the Sun, the gas jets will fire intermittently to control pitch and yaw attitude. Pairs of attitude control jets are located on each of the three landing legs of the spacecraft.

In the event the spacecraft does not perform the Sun seeking maneuver automatically, this sequence can be commanded from the ground.

The next critical step for Surveyor is acquisition of its radio signal by the Deep Space Net tracking stations at Ascension Island and Johannesburg, South Africa, the first DSN stations to see Surveyor after launch.

It is critical at this point to establish the communications link with the spacecraft to receive telemetry to quickly determine the condition of the spacecraft, for command capability to assure control, and for Doppler measurements from which velocity and trajectory are computed.

The transmitter can only operate at high power for approximately one hour without overheating. It is expected, however, that the ground station will lock on to the spacecraft's radio signal within 40 minutes after launch and if overheating is indicated, the transmitter can be commanded to low power.

The next major spacecraft event after the Sun has been acquired is Canopus acquisition. Locking on the star Canopus provides a fixed inertial reference for the roll orientation.

Canopus Acquisition

Canopus acquisition will be commanded from the ground about six hours after launch. The gas jets will fire to roll the spacecraft at 0.5 degree per second. When the sensor sees the predicted brightness of Canopus (the brightest star in the Southern Hemisphere) it will order the roll to stop and lock on the star. The brightness of the light source it is seeing will be telemetered to Earth to verify that it is locked on Canopus.

Verification can also be provided by a ground command ordering a 360 degree roll and the plotting of each light source the sensor sees that is in the sensitivity range of the sensor. (The sensor will ignore light levels above and below given intensities.) This star map can be compared with a map prepared before launch to verify that the spacecraft is locked on Canopus.

Now properly oriented on the Sun and on Canopus, Surveyor is in the coast phase of the transit to the Moon. Surveyor is transmitting engineering data to Earth and receiving commands via one of its omnidirectional antennas. Tracking data is obtained from the pointing direction of ground antenna and observed frequency change (Doppler).

The solar panel is providing electrical power and additional power for peak demands is being provided by one of two batteries aboard. The gas jets are firing intermittently to keep the craft aligned on the Sun and Canopus.

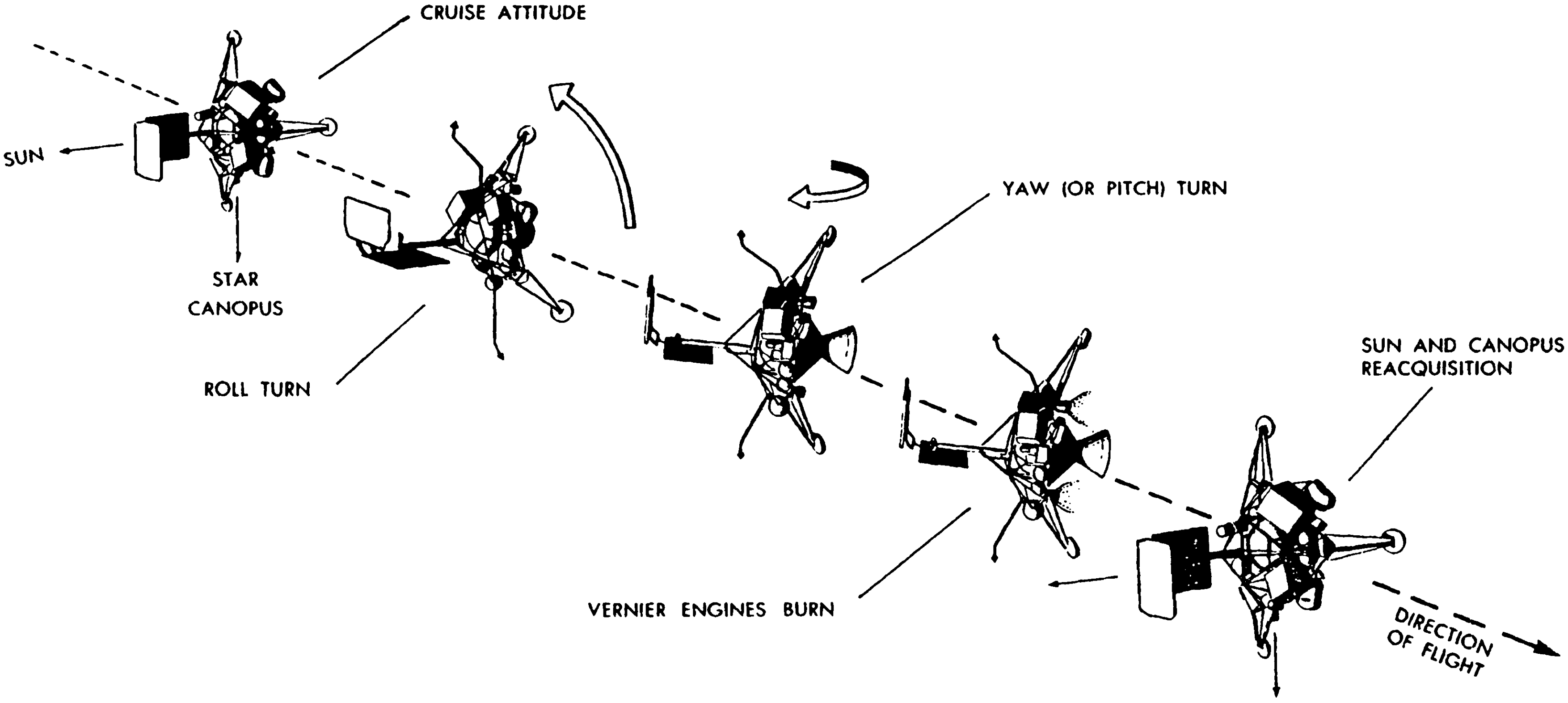
The engineering and tracking information is received from Surveyor at one of the stations of the Deep Space Net. The data is communicated to the Space Flight Operations Facility (SFOF) at the Jet Propulsion Laboratory in Pasadena where the flight path of the spacecraft is carefully calculated and the condition of the spacecraft continuously monitored.

Midcourse Maneuver

Tracking data will be used to determine how large a trajectory correction must be made to land Surveyor in the given target area. This trajectory correction, called the midcourse maneuver, is required because of many uncertainties in the launch operation that prevent absolute accuracy in plaçing a spacecraft on a trajectory that will intercept the Moon precisely at the desired landing point.

The midcourse maneuver is timed to occur over the Goldstone station of the DSN in the Mojave Desert, the tracking station nearest the SFOF at JPL.

SURVEYOR MIDCOURSE CORRECTION



The thrust for the midcourse maneuver will be provided by the spacecraft's three liquid fuel vernier engines. Total thrust level is controlled by an accelerometer at a constant acceleration equal to 0.1 Earth g (3.2 ft/sec/sec). Pointing errors are sensed by gyros which can cause the individual engines to change thrust level to correct pitch and yaw errors and swivel one engine to correct roll errors.

Flight controllers determine the required trajectory change to be accomplished by the midcourse maneuver. In order to align the engines in the proper direction to apply thrust to change the trajectory, or flight path, Surveyor will be commanded to roll, then pitch or yaw to achieve this alignment. Normally, two maneuvers are required, a roll-pitch or a roll-yaw.

The duration of the first maneuver is radioed to the spacecraft, stored aboard and re-transmitted back to Earth for verification. Assured that Surveyor has received the proper information, it is then commanded to perform the first maneuver. When completed, the second maneuver is handled in the same fashion. With the spacecraft now aligned properly in space, the number of seconds of required thrust is transmitted to the spacecraft, stored, verified and then executed.

In the event of a failure of the automatic timer aboard the spacecraft which checks out the duration of each maneuver turn and firing period, each step in the sequence can be performed by carefully timed ground commands.

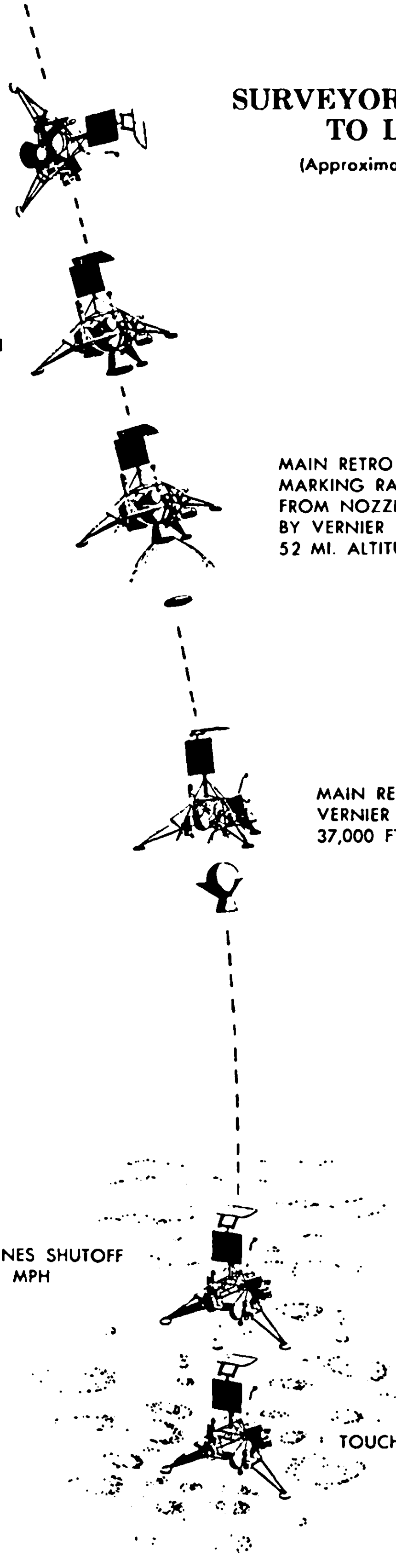
After completion of the midcourse maneuver, Surveyor reacquires the Sun and Canopus. Again Surveyor is in the cruise mode and the next critical event will be the terminal maneuver.

Terminal Sequence

The first step starts at about 1,000 miles above the Moon's surface. The exact descent maneuvers will depend on the flight path and orientation of the Surveyor with respect to the Moon and the target area. Normally they will be a roll followed by a yaw or a pitch turn. As in the midcourse maneuver, the duration times of the maneuvers are radioed to the spacecraft and the gas jets fire to execute the required roll and pitch and yaw. The object of the maneuver is to align the main retro solid rocket with the descent path. To perform the maneuvers, the spacecraft will break its lock on the Sun and Canopus. Attitude control will be maintained by inertial sensors. Gyros will sense changes in the attitude and order the gas jets to fire to maintain the correct attitude until the retrorocket is ignited.

SURVEYOR TERMINAL DESCENT TO LUNAR SURFACE

(Approximate Altitudes and Velocities Given)



With the spacecraft properly aligned, the altitude marking radar will be activated, by ground command, at approximately 200 miles above the Moon's surface. All subsequent terminal events will be automatically controlled by radars and the flight control programmer. The auxiliary battery will be connected to help the main battery supply the heavy loads required during descent.

At approximately 60 miles' slant range from the Moon's surface, the marking radar starts the flight control programmer clock which then counts down a previously stored delay time and then commands ignition of the solid propellant main retro and the three liquid fueled, throttleable vernier engines. The vernier engines maintain a constant spacecraft attitude during main retro firing in the same manner as during midcourse thrusting.

The spacecraft will be traveling at approximately 6,000 miles-per-hour. The main retro will burn out in 40 seconds at about 25,000 feet above the surface after reducing the velocity to about 250 miles-per-hour. The casing of the main retro is separated from the spacecraft, on command from the programmer 12 seconds after burnout, by explosive bolts and falls free.

After burnout the flight control programmer will control the thrust level of the vernier engines until the Radar Altimeter and Doppler Velocity Sensor (RADVS) locks up on its return signals from the Moon's surface.

Descent will then be controlled by the RADVS and the vernier engines. Signals from RADVS will be processed by the flight control electronics to throttle the three vernier engines reducing velocity as the altitude decreases. At 13 feet above the surface, Surveyor will have been slowed to three miles per hour. At this point the engines are shut off and the spacecraft free falls to the surface.

Immediately after landing, flight control power is turned off to conserve battery power.

Post-landing Events

Of prime interest to the engineers who designed Surveyor will be the engineering telemetry received during the descent and touchdown. Touchdown will be followed by periods of engineering telemetry to determine the condition of the spacecraft. Then a series of wide angle, 200-line television pictures will be taken.

The solar panel and high gain planar array antenna will then be aligned with the Sun and Earth, respectively. If the high-gain antenna is successfully operated to lock on Earth, transmission of 600-line television pictures will begin. If it is necessary to operate through one of the low-gain, omnidirectional antennas, additional 200-line pictures will be transmitted.

The lifetime of Surveyor on the surface will be determined by a number of factors such as the power remaining in the batteries in the event that the Sun is not acquired by the solar panel and spacecraft reaction to the intense heat of the lunar day and the deep cold of the lunar night.

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ATLAS-CENTAUR AND SURVEYOR TEAMS

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T. B. Norris	Centaur Program Manager

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Gen. A. R. Luedecke	Deputy Director
Howard H. Haglund	Surveyor Project Manager
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R. A. Leslie	Tidbinbilla Station Manager
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Avron Bryan	Ascension Station Manager

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Edmund R. Jonash	Centaur Project Manager

KENNEDY SPACE CENTER, FLA.

Dr. Kurt R. Debus	Director
Robert H. Gray	Director of Unmanned Launch Operations
John D. Gossett	Chief, Centaur Operations

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HONEYWELL, INC., ST. PETERSBURG, FLA.

R. B. Foster	Centaur Guidance Program Manager

SURVEYOR/ATLAS-CENTAUR SUBCONTRACTORS

Surveyor

AiResearch Division Garrett Corporation Torrance, Calif.	Ground Support Equipment
Airite El Segundo, Calif.	Nitrogen Tanks
Airtek Fansteel Metallurgical Corp. Compton, Calif.	Propellant Tanks
Ampex Redwood City, Calif.	Tape Recorder
Astrodata Anaheim, Calif.	Decommutators and Subcarrier Discriminator Systems
Bell & Howell Company Chicago, Ill.	Camera Lens
Bendix Corporation Products Aerospace Division South Bend, Indiana	Landing Dynamics Stability Study
Borg-Warner Santa Ana, Calif.	Tape Recorder
Brunson Kansas City, Kansas	Optical Alignment Equipment
Carleton Controls Buffalo, New York	Helium Regulator

Eagle-Picher Company Joplin, Mo.	Auxiliary Batteries
Electric Storage Battery Raleigh, N.C.	Main Batteries
Electro-Development Corp. Seattle, Wash.	Strain Gage Electronics
Electro-Mechanical Research Sarasota, Fla.	Decommutators
Endevco Corporation Pasadena, Calif.	Accelerometers
General Electro Dynamics Garland, Tex.	Vidicon Tubes
General Precision, Inc. Advanced Products Division Link Group Sunnyvale, Calif.	Spacecraft TV Ground Data Handling System
Heliotek Sylmar, Calif.	Solar Modules
Hi-Shear Corp. Torrance, Calif.	Separation Device
C. G. Hokanson Santa Monica, Calif.	Mob. Temperature Control Unit
Holex Hollister, Calif.	Squibs
Honeywell Los Angeles, Calif.	Tape Recorder/Reproducer
General Precision, Inc. Kearfott Systems Division Wayne, N. J.	Floated Rate Integrated Gyros
Kinetics Solana Beach, Calif.	Main Power Switch
Lear Siegler Santa Monica, Calif.	T.V. Photo Recorder
Menasco Los Angeles, Calif.	Gas Tanks

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Metcom Salem, Mass.	Magnetron Assembly
Motorola, Inc. Military Electronics Division Scottsdale, Ariz.	Subcarrier Oscillators
National Water Lift Co. Kalamazoo, Mich.	Landing Shock Absorber
Northrop/Norair Hawthorne, Calif.	Landing Gear
Ryan Aeronautical Co. San Diego, Calif.	Radar Altitude Doppler Velocity Sensor
Sanborn Waltham, Mass.	L. F. Oscillograph
Scientific-Atlanta Atlanta, Ga.	System Test Stand
Singer-Metrics Bridgeport, Mass.	F. M. Calibrator
Telemetrics Santa Ana, Calif.	Simulator
Thiokol Chemical Corp. Elkton Division Elkton, Md.	Main Retro Engine
Thiokol Chemical Corp. Reaction Motors Division Denville, N. J.	Vernier Propulsion System
Tinsley Laboratories, Inc. Berkeley, Calif.	Spacecraft Mirrors
United Aircraft Corp. Norden Division Southhampton, Pa.	Subcarrier Oscillator
Vector Southhampton, Pa.	Subcarrier Oscillator

Atlas-Centaur

Rocketdyne Division of North American Aviation, Inc. Canoga Park, Calif.	MA-5 Propulsion System

Thiokol Chemical Corp. Reaction Motors Division Denville, N. J.	LOX and Fuel Staging Valves
Hadley Co., Inc.	Valves, Regulators and Disconnect Coupling
Fluidgenics, Inc.	Regulators
General Precision, Inc. Kearfott Division Wayne, N.J.	Displacement Gyros
Honeywell, Inc. Aeronautical Division	Rate Gyros
Fifth Dimension, Inc.	Commutators
Bendix Corp. Bendix Pacific Division	Telepaks and Oscillators
Fairchild-Hiller Stratos Western Division	LOX Fuel and Drain Valves
Bourns, Inc.	Transducers and Potentiometers
Washington Steel Co. Washington, Pa.	Stainless Steel
General Dynamics Fort Worth Division Fort Worth, Tex.	Insulation Panels and Nose Fairing
Pesco Products Division of Borg-Warner Corp. Bedford, O.	Boost Pumps for RL-10 Engines
Bell Aerosystems Co. of Bell Aerospace Corp. Buffalo, N. Y.	Attitude Control System
Liquidometer Aerospace Division Simmonds Precision Products, Inc. Long Island, N.Y.	Propellant Utilization System
General Precision, Inc. Kearfott Division San Marcos, Calif.	Computer for Inertial Guidance System

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Goodyear Aerospace Division Goodyear Tire and Rubber Co. Akron, O.	Handling Trailer
Systems and Instruments Div. Bulova Watch Co. Flushing, N. Y.	Destructors
Consolidated Controls Corp. El Segundo, Calif.	Safe and Arm Initiator
Borg-Warner Controls Division Borg-Warner Corp. Santa Ana, Calif.	Inverter
Sippican Corp. Marion, Mass.	Modules for Propellant Utilization System
General Electric Co. Lynn, Mass.	Turbine
Vickers Division of Sperry Rand Corp. Troy, Mich.	Hydraulic Pumps
Edcliff Instruments, Inc. Monrovia, Calif.	Transducers and Switches
Rosemount Engineering Co. Minneapolis, Minn.	Transducers
Scientific Data Systems Santa Monica, Calif.	Computers
W. O. Leonard, Inc. Pasadena, Calif.	Hydrogen and Oxygen Vent Valves

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