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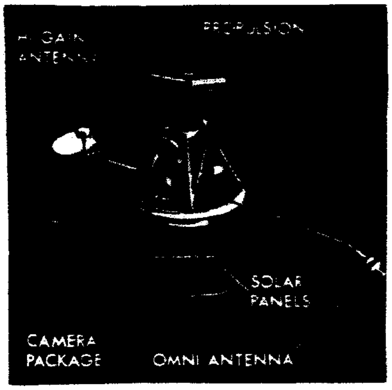
LUNAR ORBITER



PROJECT: LUNAR ORBITER A

(To be launched in a period from Aug. 9 through 13.)

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NEWS NASA
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LUNAR ORBITER
FLIGHT SET
FOR AUGUST

The United States is preparing to launch the first in a series of photographic laboratory spacecraft to orbit the Moon.

Lunar Orbiter spacecraft are planned to continue the efforts of Ranger and Surveyor to acquire knowledge of the Moon's surface to support Project Apollo and to enlarge scientific understanding of the Earth's nearest neighbor.

Lunar Orbiter A is scheduled for launch from Cape Kennedy, Fla., in a period from Aug. 9 through 13. The 850-pound spacecraft will be launched by an Atlas Agena-D vehicle on a flight to the vicinity of the Moon which will take about 90 hours.

If successfully launched, this first of five Lunar Orbiters will be named Lunar Orbiter I.

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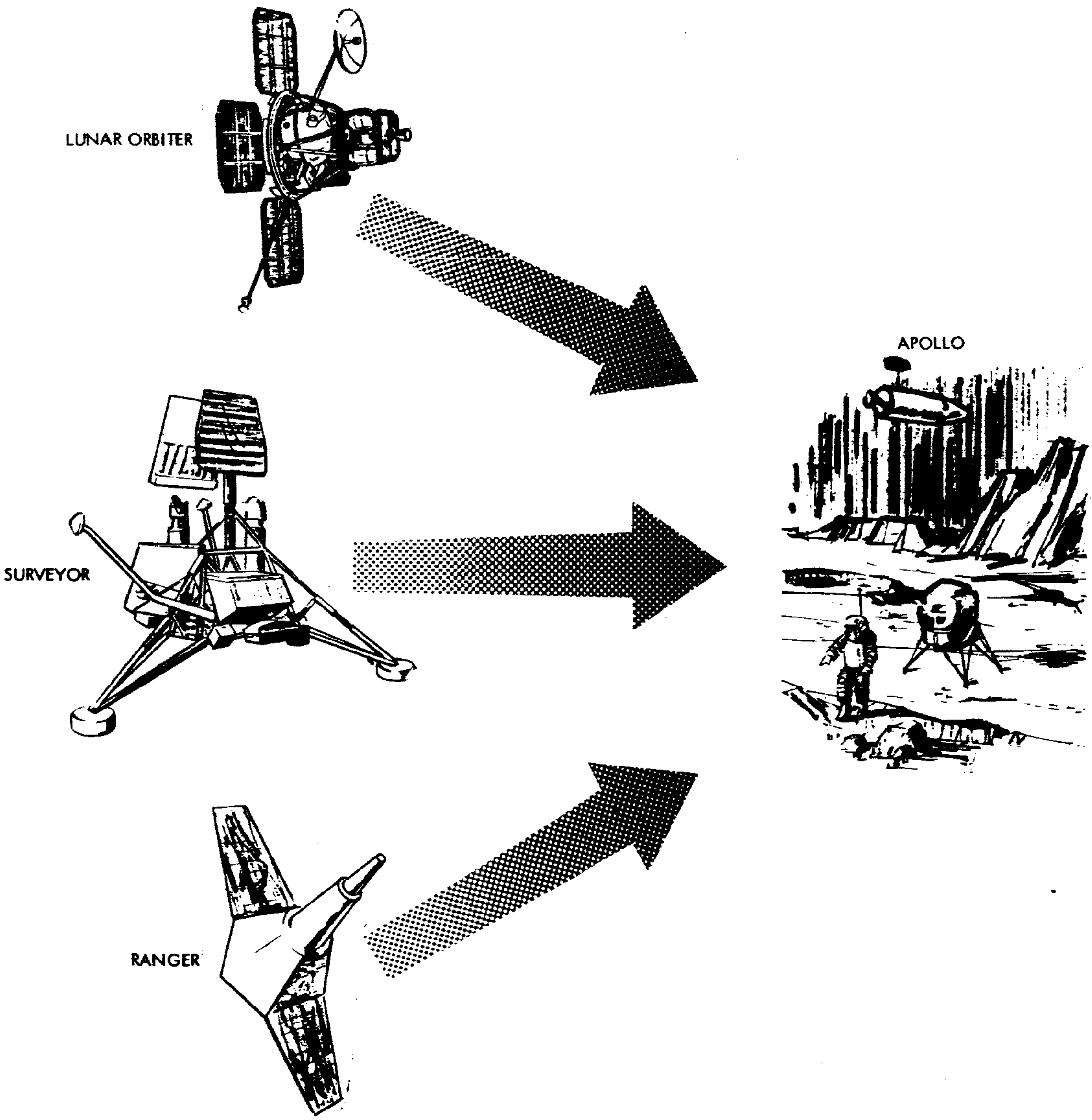

THE LUNAR EXPLORATION PROGRAM

The basic task of Lunar Orbiter A is to obtain high resolution photographs of various types of surface on the Moon to assess their suitability as landing sites for Apollo and Surveyor spacecraft.

About a month prior to its scheduled launch, Orbiter's photo targets were revised so that, in two consecutive orbits, it will attempt to photograph Surveyor I on its landing site. Prior to loss of contact with Surveyor I on July 13, its solar array and high gain antenna were positioned to cast the largest possible shadow on the lunar surface to aid in catching Orbiter's photographic eye.

In addition to its photographic task, Orbiter A will monitor the meteoroids and radiation intensity in the vicinity of the Moon. Since the spacecraft's hermetically sealed camera package could potentially suffer damage from a meteoroid hit or from space radiation, this information will be used primarily for spacecraft performance analysis.

Orbiter A also will provide precise trajectory information for use in improving the definition of the Moon's gravitational field.

On the first day of its planned launch period, Aug. 9, Orbiter's launch window is 12:07 to 4:43 p.m. EDT. On each succeeding day of the period, the window opens approximately two hours later.

During its journey to the Moon, the spacecraft will be oriented to the Sun and the Southern hemisphere star Canopus, except when it is executing one or possibly two mid-course correction maneuvers.

At a point about 550 miles above the Moon, a liquid fuel retro engine will fire to slow down the spacecraft to permit it to be captured by the Moon's gravitational field. As a satellite of the Moon, the Lunar Orbiter will enter an initial elliptical orbit about 1150 by 125 miles.

Orbiter will be tracked precisely by the Deep Space Network for three to eight days--depending on the day of launch--before its retro rocket will be fired again to place it in its ultimate photographic orbit. It is desired to adjust the lowest point of the final orbit (perilune) to 28 miles above the lunar surface. The highest point of the orbit (apolune) will remain at 1150 miles.

Then, for a period of seven days, as the Moon revolves beneath it, the spacecraft's camera will record on film views of nine selected locations in far greater detail than they have been viewed through Earth-based telescopes.

Up to four exposures will be transmitted to Earth by radio after each site is photographed, except when locations are too closely spaced to allow time for the readout process.

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All of Lunar Orbiter's photographs will be transmitted to NASA Deep Space Network stations after site photography is finished. They will be received in reverse order from which the pictures were taken.

From launch to complete read-out of all photography will require about 35 days. At least 30 more days will be required for a preliminary analysis of the pictures.

NASA will disseminate lunar site photographs to members of the scientific community for interpretive studies. The U.S. Geological Survey will employ the Lunar Orbiter photographs as basic material in its efforts to derive a more detailed understanding of the physical processes which played a part in the formation of the lunar surface as it exists today.

The Lunar Orbiter program is directed by NASA's Office of Space Science and Applications. The project is managed by the agency's Langley Research Center, Hampton, Va. The spacecraft are built and operated by the Boeing Company, Seattle, Wash., as prime contractor. Eastman Kodak Company, Rochester, N.Y., (camera system) and the Radio Corporation of America, Camden, N.J., (power and communications systems) are the principal subcontractors to Boeing. NASA's Lewis Research Center, Cleveland, is responsible for the launch vehicle and the Kennedy Space Center, Fla., will supervise the launch operation. Prime vehicle contractors are General Dynamics/Convair, San Diego, Cal., for the Atlas and Lockheed Missiles and Space Co., Sunnyvale, Cal., for the Agena.

Tracking and communications for the Lunar Orbiter program are the responsibility of the NASA Deep Space Network, operated by the Jet Propulsion Laboratory, Pasadena, Cal. DSN stations at Goldstone, Cal.; Madrid, Spain; and Woomera, Australia, will participate in the mission. Photographic data gathered by Lunar Orbiter will flow from each DSN station to the Eastman Kodak Company, Rochester, N.Y. for reassembly processing, thence to the Langley Research Center, for preliminary evaluation.

END OF GENERAL RELEASE; BACKGROUND INFORMATION FOLLOWS

LUNAR ORBITER SPACECRAFT

The Lunar Orbiter program was announced by NASA in August, 1963, as one of three major projects for unmanned exploration of the Moon in advance of Project Apollo.

In the following two years, three Ranger spacecraft, carrying television cameras, returned a total of 17,259 close-up photographs of the lunar surface en route to crash landing and destruction on the Moon.

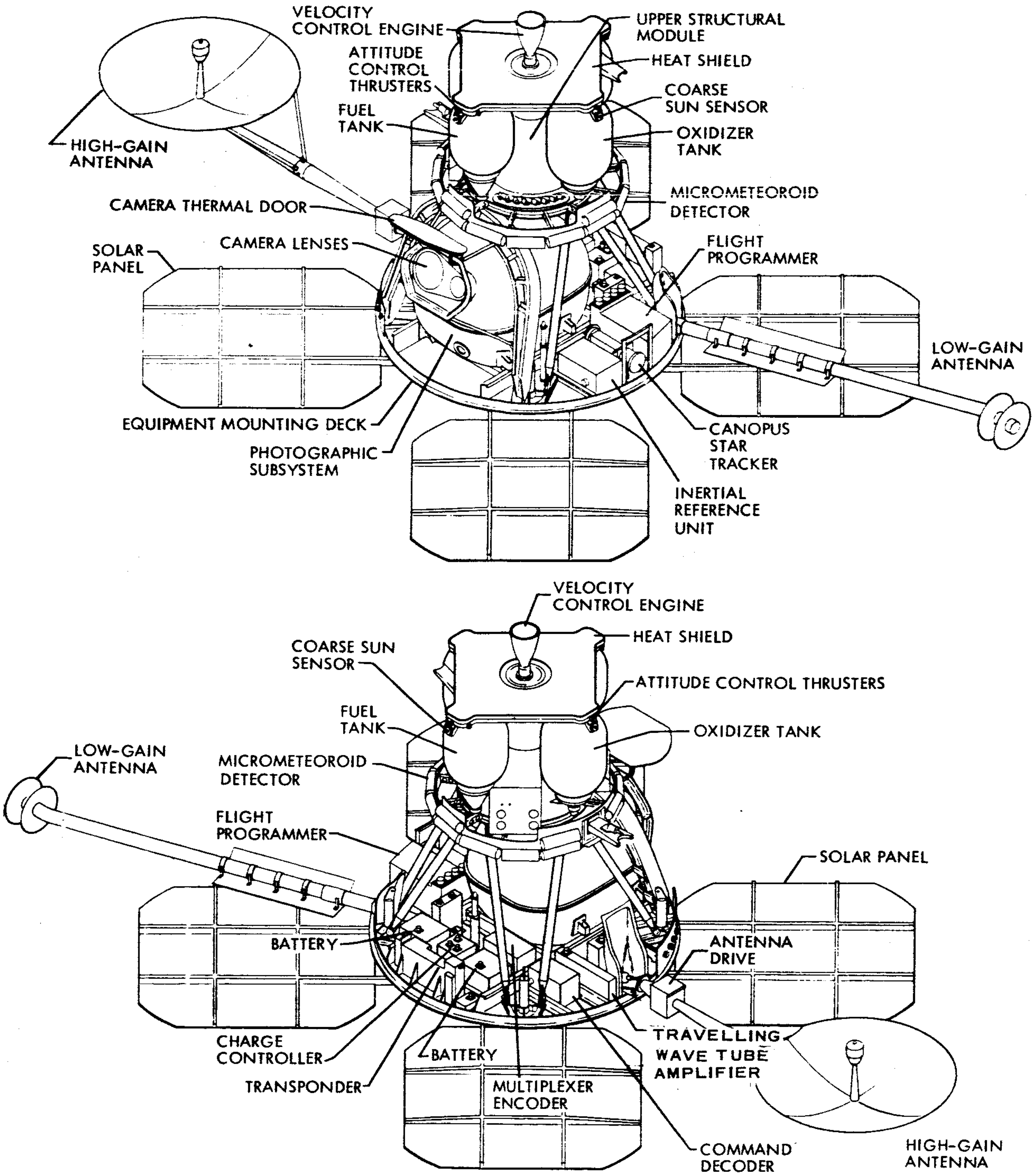
Surveyor I, launched last May 30, went on to achieve successful soft-landing on the Moon's surface. It has since measured important surface properties -- for example, how much weight the lunar crust will support -- and transmitted 11,237 close-ups of the Moon's surface from its position in the Sea of Storms.

Now the Lunar Orbiter and Surveyor I, taken together, must be used to obtain specific kinds of information about selected areas of the lunar surface in order to make a safe manned landing possible.

Lunar Orbiter will examine such areas so that Surveyor's findings can be applied over a full-sized landing site with all topographic features of significant size located and measured. Since hummocks only 20 inches high are significant, and the Lunar Orbiter can obtain more than 3,000 square miles of high resolution (three feet) photographs on each mission, formidable demands are placed on the spacecraft's capability to gather information.

In December 1963, NASA selected the Boeing Company, Seattle, to be prime contractor for the program, and a contract was negotiated in May 1964.

Now, less than two and one-half years later, the first Lunar Orbiter is ready to fly.



LUNAR ORBITER SPACECRAFT

SPACECRAFT CONFIGURATION

The Lunar Orbiter spacecraft is a flying photographic laboratory, equipped with the necessary controls to position the camera correctly over the site to be viewed, and the means to extract the information contained in each photograph and send it back to Earth.

In flight configuration, Lunar Orbiter is a truncated cone from whose base project four solar cell panels. It carries two antennas on rods extended from opposite sides of the spacecraft, and is covered with an aluminized mylar reflective thermal blanket.

Lunar Orbiter weighs 850 pounds, and when folded for launch measures five feet in diameter by five and one-half feet tall. During launch the solar panels are folded against the base of the spacecraft and the antennas are held against the sides of the structure. A nose shroud only five feet, five inches in diameter encloses the entire spacecraft.

When the solar panels and antennas are deployed in space, the maximum span becomes 18½ feet across the antenna booms and 12 feet, 2 inches across the solar panels.

The primary structure consists of the main equipment mounting deck and an upper section supported by trusses and an arch.

In the upper section are located the velocity control engine with its tankage for oxidizer, fuel and pressurization, and the attitude control thrusters. The nozzle of the engine extends through an upper heat shield.

The lower section houses the camera, communications and electrical system equipment, the inertial reference unit, the Sun sensor, and the Canopus star tracker.

Camera System

The technological ability to compress a complete photographic laboratory within an egg-shaped pressure shell with all parts weighing no more than 150 pounds makes the Lunar Orbiter mission possible. The package itself includes two cameras--one for medium and the other for high resolution photography. The cameras will view the Moon through a protective window of quartz, which in turn is protected by a mechanical flap in the thermal blanket which covers most of the spacecraft. The flap, or camera thermal door, is opened and closed by command at the beginning and end of every photographic pass over a section of lunar surface.

The medium resolution lens is an 80-mm Xenotar, manufactured by the West German firm of Schneider-Kreuznach. It is fitted with a fixed aperture stop of f/5.6 and a between-lens shutter to provide exposure speed selections of 1/25, 1/50 and 1/100 second.

The high resolution lens is a 24-inch f/5.6 Paxoramic, specially designed and built by Pacific Optical Company. The lens weighs less than 16 pounds and operates through a focal plane shutter adjustable on ground command to the same speed selections as the 80-mm lens.

Relatively low shutter speeds are required by the exposure index of the film, which is Kodak Special High Definition Aerial Film, Type SO-243. Although its aerial exposure index of 1.6 is slow in comparison with other films, it has extremely fine grain and exceptionally high resolving power. It is relatively immune to fogging at the levels of radiation normally measured in space.

Lunar Orbiter will carry a 200-foot roll of 70-mm SO-243 unperforated film, sufficient for at least 194 dual exposure frames. The supply spool is shielded against ionizing radiation from solar flares.

Along one edge of the film is a band of pre-exposed data, primarily resolving power charts and densitometric gray scales, which will be read out along with the lunar images captured by the spacecraft.

The gray scales are very important because they contain the key to correct interpretation of the Lunar Orbiter's photographs. Specifically, they provide the photometric calibration which will make it possible to estimate slopes on the Moon's surface by measuring film densities.

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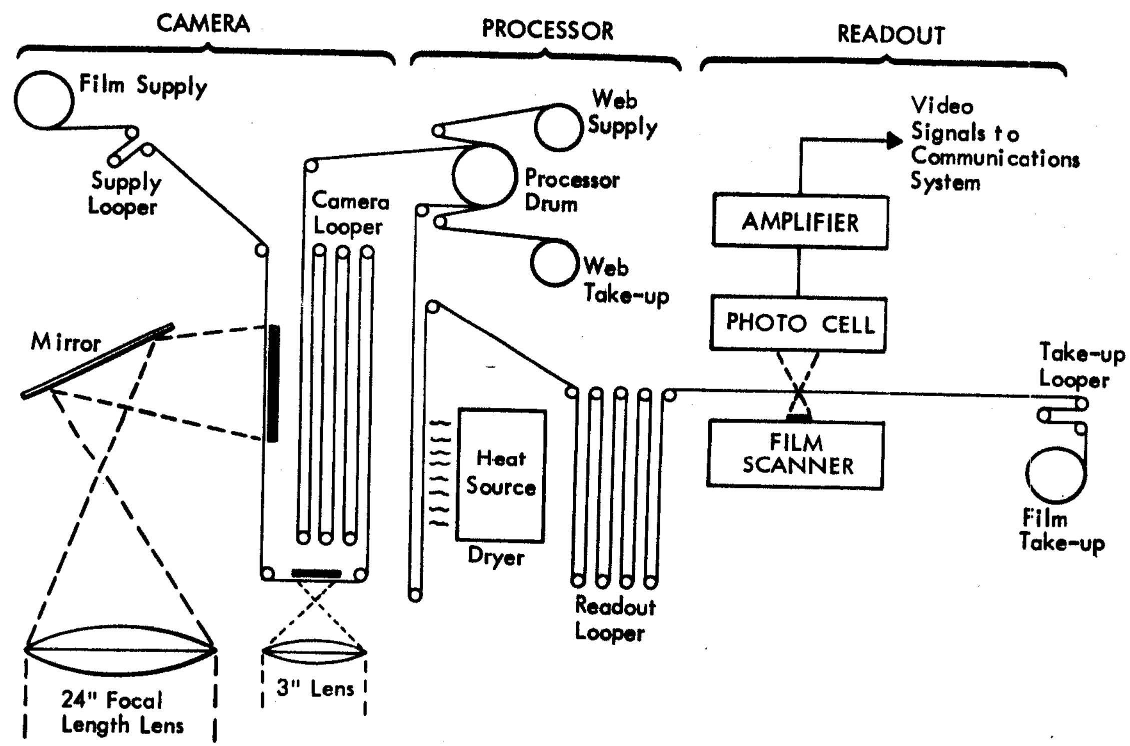


PHOTOGRAPHIC SUBSYSTEM

Photo Taking Process

Light gathered by the 24-inch lens is turned through a right angle by a mirror before it reaches the film, while the medium resolution lens passes light directly to the film. Because of the camera's mechanical design, the two simultaneous images are not placed side by side on the film, but are interspersed with other exposures.

Because the spacecraft will be moving at 4,500 mph at perilune (or lowest point in orbit about the Moon) and in view of the relatively low film exposure speeds, the camera system has been provided with a device to eliminate blurring of the image. This image motion compensation is performed by a special sensor and a mechanical drive to move the film platen slightly while an exposure occurs.

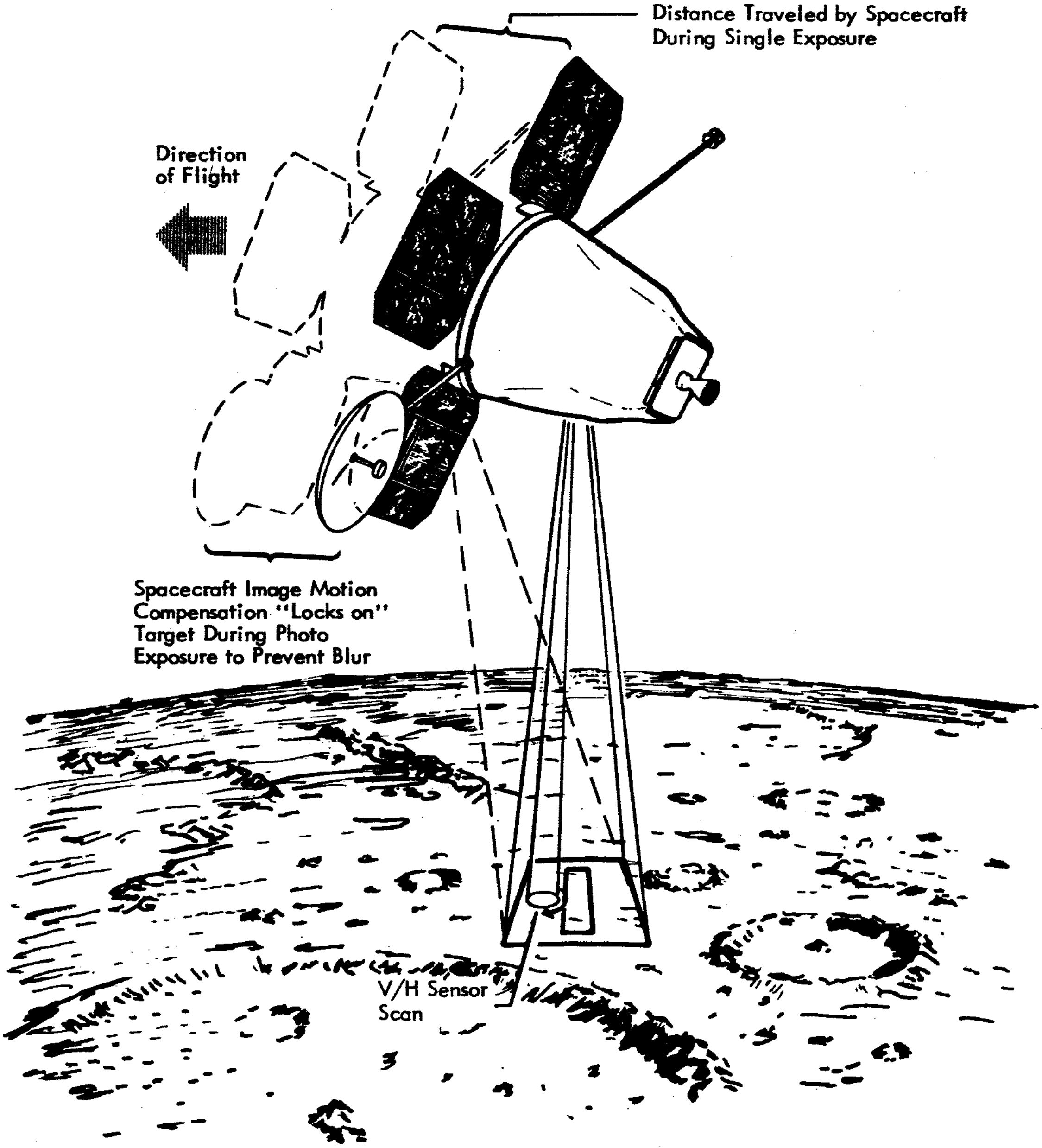
The special sensor is a vital component of the camera system. Called a V/H sensor (velocity divided by height), it electronically scans a portion of the image formed by the high resolution lens.

The tracker compares successive circular scans of a portion of the image and generates a signal proportional to the rate and direction of the motion it senses. The rate signal in turn governs the action of the image motion compensation servomechanism and the exposure interval controller, while the direction information is used to control spacecraft yaw attitude.

Special platens have been built into the camera to grip the film and hold it flat by means of vacuum while an exposure is made. The platens are mechanically driven as required by the signal sent from the V/H sensor, and their motion, although very slight, matches the speed of the spacecraft and minimizes any blur or smearing of the image.

After each exposure, the platens return to their original positions and are ready for the next picture.

After exposure, the film moves forward to a storage or buffer area between the camera and processor. The buffer region or looper is provided to take up the slack between the camera -- which can make up to 20 exposures on a single orbital pass -- and the processor. The looper is a system of pulley blocks which can be separated to store exposed film without slack. The looper can hold as many as 20 frames.



The velocity/height (V/H) sensor provides the spacecraft with velocity and height information by sampling a ring of lunar surface through the high resolution lens and comparing successive scans. The angular position change of consecutive scans with respect to time gives the velocity/height change ratio. This ratio is used for image motion compensation to "lock on" a ground target during each exposure to reduce image smear or blur. The V/H data is also used to control time between exposures, to control spacecraft yaw angle during photography, and is telemetered to aid in photograph analysis.

VELOCITY HEIGHT SENSOR

Photo Processing System

Next phase of the Lunar Orbiter's photographic system is a processor, in which the exposed film is chemically developed by the Eastman Kodak "Bimat" process.

The Bimat method uses a processing film or web whose gelatin layer has been soaked in a single developer-fixer solution of photographic chemicals. The film is slightly damp to the touch but little free liquid can be squeezed from it.

When the exposed film passes onto the processor drum and is mechanically pressed against the Bimat web, the chemical processes of negative development begin. Silver halide is reduced to silver in a few minutes, and undeveloped silver ions pass into the Bimat web material by a diffusion-transfer process. The Bimat web thereby acquires a positive image of the exposed view.

After processing is complete, the two films are separated and the used web material is reeled onto a take-up spool. No use is made of the positive images on the web.

The negative film, fully processed, passes between two chemically treated pads which remove much of its moisture, and is then fully dried by a small electric heater. When dry, the negative film is stored on a take-up reel until the electronic read-out process is to begin.

Photo Readout Process

Read-out is one of the most exacting tasks the Lunar Orbiter photographic system is required to perform.

There is no proved way of storing information which can compare in compactness with an image composed of silver grains in a gelatin emulsion on photographic film.

The read-out method used by Orbiter must capture as much as possible of the film's densely-packed information and change it into a stream of electronic signals which can be transmitted to Earth.

A film scanner, in which a flying spot of light and suitable optical elements are linked with a photomultiplier, is the heart of the read-out equipment.

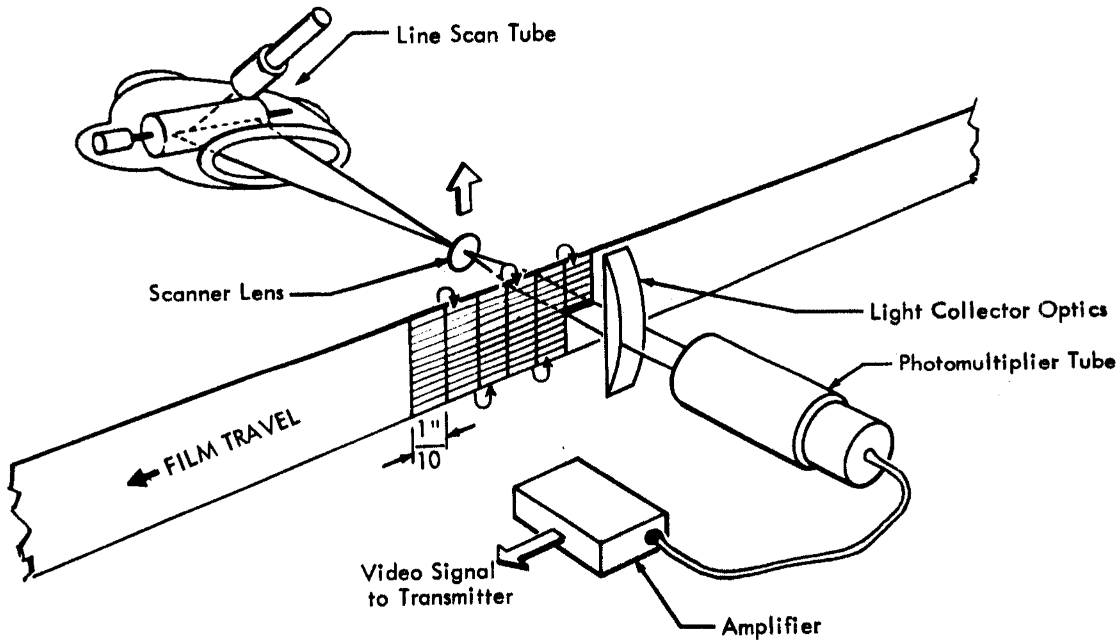
Light source for the flying spot is a Line Scan Tube developed by CBS Laboratories for film scanning applications. The tube contains an electron beam generator and a revolving drum whose surface is coated with a phosphorescent chemical.

As the electron beam moves across the surface of the phosphor, a thin spot of light is produced. The drum must be rotated to avoid burning at the electron intensities used.

The light generated by the tube is focused on the film through a scanning lens to a spot diameter of only five microns (a micron is one-thousandth of a millimeter or about 0.000039 of an inch).

The scanning lens moves the spot of light in a regular pattern across a small segment of the developed film, covering the 2.4-inch width of the image on the negative with 17,000 horizontal scans of the beam, each one-tenth of an inch long. A complete scan across the film takes 20 seconds, and when it is ended, the film advances one-tenth of an inch and the scanning lens travels over the next segment in the opposite direction.

By the process used, the Lunar Orbiter will require 40 minutes to scan the 11.6 inches of film which correspond to a single exposure by the two lenses.



FILM SCANNER

As the spot of light passes through the image on the negative, it is modulated by the density of the image, that is, the denser portions transmit less light than sections of lower density.

After passing through the film, the light is sensed by a photomultiplier tube which generates an electronic signal proportional to the intensity of the transmitted light. The signal is amplified, timing and synchronization pulses are added, and the result is fed into the communications link as the Lunar Orbiter's composite video signal for transmission to Earth.

The flow of film through the Bimat processor cannot be reversed once started because the dry film would stick to the Bimat, so a complete readout of Lunar Orbiter photographs will not begin until the final picture is taken.

Capability for earlier partial readout is provided by the looper built into the photographic system between the processor and film scanner. The priority readout looper holds four frames, which can be sent through the scanner upon ground command. Current plans call for some partial readouts during the course of the mission, when there is sufficient time between orbits on which photography is scheduled.

Before the final film readout is begun, the Bimat web film used in processing is cut so that the finished negative can be pulled backward through the processor and gradually returned to the original film supply reel. After the Bimat web is cut, the Lunar Orbiter is no longer able to obtain photographs, and the remaining portion of its photographic mission will be occupied with readout.

Readout will occur in reverse order from that in which the pictures were taken because of the inherent design of the photographic system. There is provision for repeated readout if required.

Electrical Power System

Lunar Orbiter carries a conventional solar panel-storage battery type of power system, with provisions for voltage regulation and charge control.

Primary source of power is an array of four solar panels, each slightly more than 13 square feet in area. There are 10,856 solar cells on the spacecraft panels--2714 per panel. Each is an N-on-P silicon solar cell, 0.8-in. square, protected by a blue reflecting filter.

In full sunlight, the Lunar Orbiter solar panels will produce about 375 watts of power. Total weight of the array, including the stowage and deployment mechanisms, is 70 pounds.

Energy produced by the solar panels is stored for use while the Lunar Orbiter is in shadow in a 20 cell nickel-cadmium battery rated at 12 ampere hours. The battery consists of two identical 10-cell modules; overall weight is 30 pounds.

Orbiter's electrical system voltage can vary from 22 volts when the batteries are supplying the load to a peak of 31 volts when the solar panels are operating.

The spacecraft power system includes a charge controller to prevent overloading the batteries while they are being recharged, and a shunt regulator to keep the solar array output from exceeding a safe maximum voltage.

Critical power system quantities are measured by sensors at various points, and the instrument readings will be included in the engineering and performance items telemetered to Earth.

Attitude Control System

During the course of its mission, Lunar Orbiter will be called on to perform accurately a larger number of attitude changes than previous lunar spacecraft missions have required.

Its attitude control subsystem has been designed to accomplish these spacecraft events precisely and repeatedly, while retaining enough flexibility to respond to changes ordered by ground command.

Principal elements of the attitude system are the programmer, inertial reference unit, Sun sensors, Canopus (star) tracker, an electronic control and switching assembly, and a set of reaction control thrusters.

The programmer is a low-speed digital data processing machine with a memory capacity large enough to provide 16 hours of control over a photographic mission from stored commands. It contains redundant clocks for timing mission events, and is designed to operate primarily in the stored program mode to accomplish the major mission objectives.

The programmer executes a stored program by bringing commands sequentially from its memory, completing them, and continuing to measure time until the next scheduled event. It is intended that the programmer memory will be periodically brought up to date by ground control, but the device can be operated in a real-time command mode if required.

In view of the many precise maneuvers which Lunar Orbiter must perform, the inertial reference unit is a particularly important element in the attitude control system. It has five main functions:

During an attitude maneuver, it reports the rate at which the spacecraft's attitude is changing, so that the flight programmer can send correct instructions to the reaction control jets which position the vehicle;

When photographs are being made or when the velocity control engine is in use, the inertial reference unit measures attitude errors so that the attitude control system can be directed to maintain the attitude required;

At times when the velocity control engine is firing, an accelerometer in the inertial reference unit furnishes a measurement which permits the programmer to cut off the engine at the proper instant;

While Lunar Orbiter is in cruise or coasting flight, the inertial reference unit keeps track of small oscillations which can be expected to occur and provides signals to the attitude control jets for corrective action when needed;

In lunar orbit, the inertial reference unit furnishes a memory of the positions of the Sun or Canopus whenever the spacecraft is in a position from which its sensors cannot see either one or both of the basic celestial reference bodies. Occultation is the technical term describing that condition, and it will occur during a portion of every lunar orbit. The Sun, for example, is expected to be occulted about one-fourth of the time. Inertial reference unit accuracy is important to permit rapid re-acquisition of the Sun or Canopus when the spacecraft emerges from the shadow region.

The inertial reference unit is contained in a package 7 by 10 by 7 inches, and weighs about 13 pounds. In its beryllium main frame are mounted three single-degree-of-freedom, floated, rate-integrating gyroscopes and one pulsed integrating pendulum-type accelerometer. The remaining space in the container is filled with the six electronic modules required to operate the unit and relay its measurements to the Lunar Orbiter programmer. Its power requirements are low, never exceeding 30 watts at any point in the mission.

Five Sun sensors are carried on Lunar Orbiter to provide the celestial references needed for attitude control in pitch and yaw. Four are coarse sensors, mounted under the corners of the heat shield between the propellant tanks and the velocity control engine. The fifth, a combination coarse and fine Sun sensor, views through the equipment mounting deck which forms the bottom surface of the spacecraft.

All solar sensors measure the angle of spacecraft deviation from a direct line to the Sun and generate an electronic signal in proportion to the deviation. The signal can then be used by the attitude control system to adjust the attitude of the spacecraft.

The star tracker or Canopus sensor furnishes the celestial reference for the spacecraft's roll axis. Like the Sun sensors, it measures any angle of deviation of the Lunar Orbiter from a direct line to Canopus, and provides the necessary signal to begin a corrective maneuver when needed.

The star tracker is designed to produce a series of recognition signals from which a star map can be constructed. by ground controllers. The map permits a positive determination that the tracker has locked onto Canopus rather than some other star within its field of view.

In flight, the Canopus tracker will be used for the first time after the Lunar Orbiter has passed through the Van Allen radiation belts -- some six hours after launch. It is located on the Lunar Orbiter's main equipment mounting deck, and looks outward through an opening in the thermal blanket.

All parts of the attitude control system are interlinked by a flight electronics control assembly. It contains the reaction jet valve drivers, signal summing amplifiers and limiters, Sun sensor amplifiers and limiters, signal generators, switching arrangements and other electronic circuitry required by the system.

Eight reaction control thrusters use nitrogen gas in a titanium sphere directly beneath the velocity control engine to generate the torques needed to move Lunar Orbiter in roll, pitch or yaw. Gas expelled through the thrusters is distributed through a pressure reducing valve and plumbing system according to commands issued by the programmer.

The nitrogen storage bottle, pressurized to 3500 psi, will contain just over 14½ pounds of gas at the beginning of the mission. Ten pounds of the total are budgeted for use in attitude control changes regulated at 19 psi; four remaining pounds are assigned to the velocity control system to be used in pushing fuel and oxidizer from storage tanks into the velocity control engine. The remainder takes care of leakage and a small residue.

Velocity Control System

In a typical Lunar Orbiter mission, at least three and perhaps four changes in spacecraft velocity will be required after the launch vehicle has completed its work.

Plans call for one and possibly two mid-course corrections, if necessary, but the most critical velocity changes will have to be made in the vicinity of the Moon.

There the spacecraft's velocity control engine must execute a precision firing maneuver to slow Orbiter just enough to allow it to enter an orbit around the Moon.

After several days of careful orbit tracking and computation, another firing will reduce the perilune (lowest point of orbit) to the final height from which lunar surface photographs will be taken.

To make the necessary changes and to provide a small margin of extra capability, the Lunar Orbiter carries a 100-pound thrust engine and sufficient fuel and oxidizer to make velocity adjustments totaling about 3,280 feet per second.

Lunar Orbiter's velocity control engine was developed for Project Apollo, where it will be used in the Service Module and Lunar Module for attitude control.

Nitrogen tetroxide is the oxidizer and Aerozine 50 the fuel. Aerozine 50 is a 50-50 blend of hydrazine and ununsymmetrical dimethyl-hydrazine (UDMH).

Both fuel and oxidizer are storable and hypergolic, that is, when mixed together the two liquids burn without the need for auxiliary ignition. Lunar Orbiter's four tanks divide the fuel and oxidizer to minimize changes in the spacecraft's center of gravity as propellants are consumed. About 265 pounds of usable propellants will be carried in the spacecraft tanks.

The same source of gaseous nitrogen used for the attitude control thrusters provides a positive method to push the propellants from their tanks into the velocity control engine when required. Each tank has within it a teflon bladder which exerts a positive pressure against the liquid when nitrogen is admitted to the opposite face. The tanks are pressurized to about 200 pounds per square inch.

Tank pressurization will be commanded a short time before the first midcourse maneuver. When the maneuver is to begin, the attitude control system places the spacecraft in an attitude based on ground computations and the programmer transmits an opening signal to solenoid valves on the fuel and oxidizer lines. Thrusting begins when the fuel and oxidizer mix and burn in the engine's combustion chamber.

While thrusting, the accelerometer in the inertial reference unit constantly measures the change in velocity as it occurs, and when the desired increment is achieved, the solenoid valves are commanded to close and the engine stops firing.

The velocity control system is capable of as much as 710 seconds of operation and at least four engine operating cycles.

Communications System

The Lunar Orbiter communication system is an S-band system compatible with the existing NASA Deep Space Network and capable of operating in a variety of modes.

It enables the spacecraft to:

Receive, decode and verify commands sent to the spacecraft from Earth;

Transmit photographic data, information on the lunar environment gathered by the radiation and micrometeoroid detectors, as well as information on the performance of the spacecraft;

Operate in a high power mode when photographic information is being transmitted,and a low power mode at other times;

Provide by ground command the ability to choose the transmitting power mode and to turn the transmitter off and on.

The heart of the Lunar Orbiter's communication system is a transponder basically similar to the type flown on Mariner IV.

The transponder receives a transmitted command from Earth and passes it to a decoder where it is stored temporarily. The command is then re-transmitted to Earth through the transponder to verify that it has been correctly received. When verification is confirmed, an execute signal is sent from Earth causing the decoder to pass the command along to the programmer for immediate or later use as required. The command transmission rate is 20 bits per second.

In the tracking and ranging mode, the transmitting frequency of the transponder is locked to the frequency of the signal being received from Earth in a precise ratio. The signals can then be used to determine the radial velocity of the spacecraft to an accuracy of about one foot per second. When interrogated by the Deep Space Network ranging system, the transponder signal will measure the distance between the Earth and the spacecraft with an accuracy of about 100 feet.

A low power operating mode delivers spacecraft performance telemetry and data from the lunar environment experiments (radiation and meteoroids) to Earth at 50 bits per second. Telemetry is in digital form, and has been passed through a signal conditioner, a multiplexer encoder and a modulation selector before transmission.

A high power communication mode is used to transmit photographic data in analog form and brings into use the spacecraft's high gain antenna and a traveling wave tube amplifier. Performance and environmental telemetry will be mixed with the photographic information in the transmission.

During photographic or video data transmission, the spacecraft uses a 10-watt transmitter and a high gain antenna. At other times, a one-half watt transmitter and a low gain antenna are used to conserve battery power.

A low gain antenna is hinge-mounted at the end of an 82-inch boom. It is deployed in space after the heat shield is jettisoned. The hinge is spring loaded and fitted with a positive locking latch to keep the boom in deployed position. The radiation pattern of the low gain antenna is virtually omnidirectional.

By contrast, the high gain antenna which will come into use when pictures are transmitted is quite directional, having a 10-degree beam width. It is therefore equipped with a rotational mechanism so that it can be correctly pointed toward the Earth station receiving its transmissions.

The high gain antenna is a 36-inch parabolic dish of lightweight honeycomb construction. It is mounted on the end of a 52-inch boom and is deployed after heat shield jettison in the same way as the low gain antenna. The antenna dish and feed weigh only two and one-third pounds.

A motor driven gear box at the base of the high gain antenna boom allows the boom to be rotated in one degree steps to point the antenna accurately toward the Earth receiver.

Temperature Control System

Lunar Orbiter is equipped with a passive temperature control system to carry away heat generated by the energy used in its operation and to limit the amount of heat absorbed when the spacecraft is in direct sunlight.

All sides of the spacecraft are insulated except the equipment mounting deck which forms the bottom of Lunar Orbiter. The mounting deck is coated with a special paint similar to that used on Mariner IV. The paint permits the deck surface to radiate heat much more readily than it can absorb heat from the Sun, and it thus forms a heat sink to dissipate heat generated inside the spacecraft.

On Orbiter's upper surface, the heat shield on which the velocity control engine is mounted is insulated, and the entire surface of the spacecraft within those boundaries is covered with a multilayer thermal blanket composed of alternating layers of aluminized mylar and dacron cloth. The highly reflective aluminized mylar will effectively prevent solar heat from reaching the interior of the spacecraft.

During flight from the Earth to the Moon, Lunar Orbiter's temperature inside the thermal blanket will vary between 40 and 100 degrees F. In lunar orbit, the spacecraft internal temperatures will range between 35 and 85 degrees F.

All external parts of the spacecraft are capable of withstanding full sunlight for an indefinite period.

LUNAR ORBITER TASKS

In addition to its lunar photography assignment, Lunar Orbiter A will perform three experiments:

-- Selenodesy, the study of the gravitational field and shape of the Moon;

-- Meteoroid measurements along the translunar trajectory and in orbit near the moon;

-- Radiation measurements in cislunar and near-lunar space.

The information obtained from the selenodesy experiment will be used by Project Apollo mission planners and will be of high interest to the scientific community. The meteoroid and radiation data are primarily for spacecraft performance analysis but also are of scientific interest.

Lunar Photography

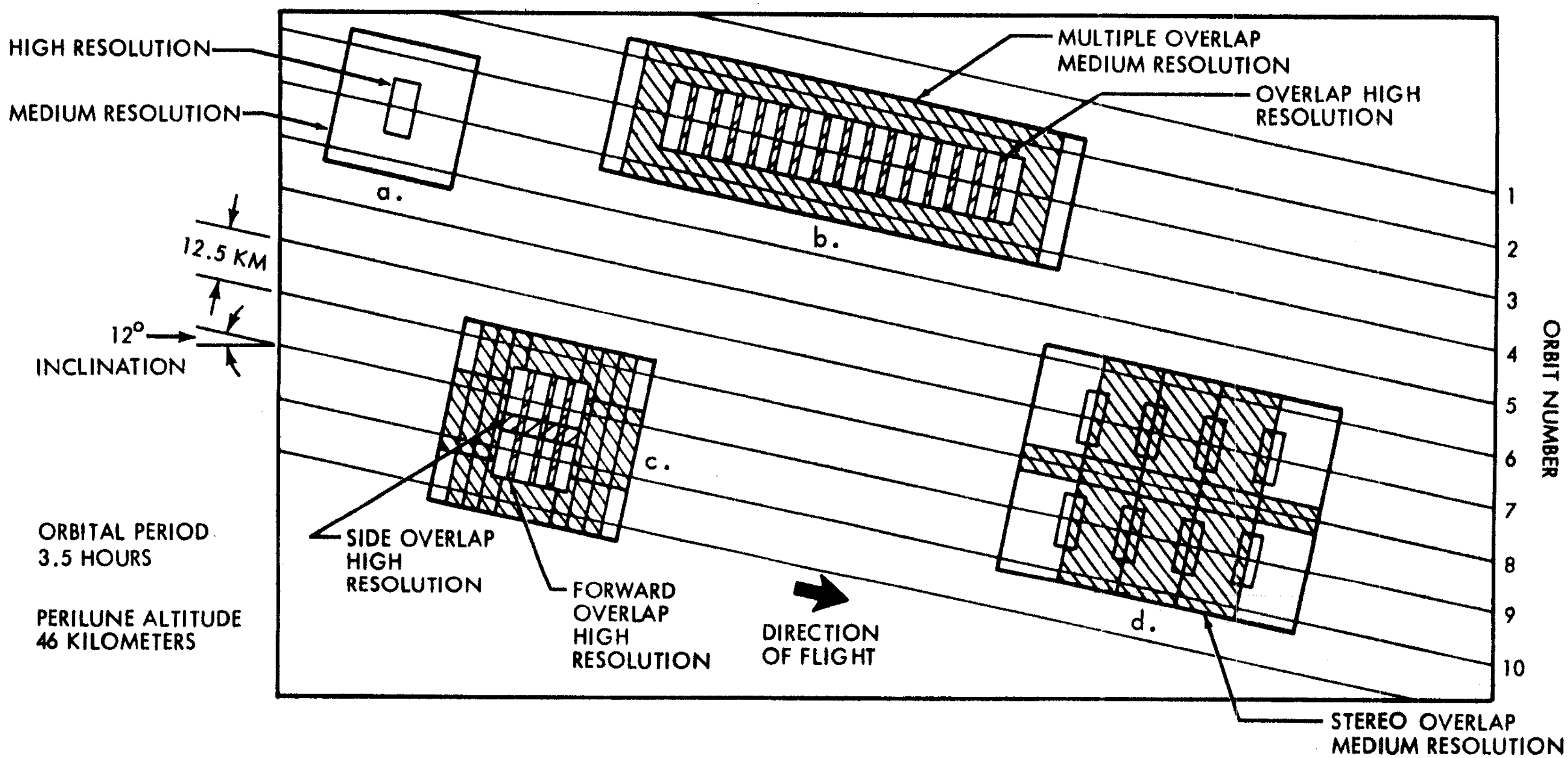
Lunar photography is Orbiter's principal assignment and the entire project has been built around the requirement to obtain high resolution photographs of large areas of the Moon's surface in such fine detail that objects as small as a card table can be distinguished.

From such photographs, in combination with Surveyor data, Project Apollo mission planners can work with confidence toward the selection and certification of suitable landing sites for Apollo's Lunar Module.

Both the spacecraft and the mission have been designed to yield a maximum of scientific information about the lunar areas to be photographed. The camera system can be employed in several different modes, and the first mission has been carefully calculated to gather the maximum of topographic information from nine selected sites grouped along the lunar equator.

Photography over each of the nine selected sites has been programmed to produce overlapping pictures of most of the areas photographed by the medium resolution lens. The pictures will form stereo pairs, and well-developed techniques of photographic interpretation will be used to extract the topographic information they will contain.

The high resolution coverage, while not stereoscopic, can be analyzed by photometric methods to yield information on smaller slopes, craters and other small-scale surface features.



a. SINGLE EXPOSURE AT THE 46 KILOMETER ALTITUDE; HIGH RESOLUTION COVERAGE IS 16.6 KM X 4.15 KM, MEDIUM RESOLUTION COVERAGE IS 37.4 KM X 31.6 KM.

b. DESIGN MISSION TARGET SITE COVERAGE, 16 CONSECUTIVE EXPOSURES DURING ONE ORBITAL PASS OVER THE TARGET SITE. THE INTERVAL BETWEEN EXPOSURES (APPROXIMATELY 2.2 SECONDS) IS TIMED TO PROVIDE OVERLAP OF THE HIGH RESOLUTION FRAMES.

c. EIGHT TYPICAL FRAMES FROM A SITE EXAMINATION TYPE MISSION - CONTIGUOUS HIGH RESOLUTION COVERAGE IS PROVIDED BY RAPID EXPOSURE RATE AS IN (b) TO GIVE HIGH RESOLUTION FORWARD OVERLAP AND BY PHOTOGRAPHING ON CONSECUTIVE ORBITS (9 & 10) TO GIVE HIGH RESOLUTION SIDE OVERLAP.

d. EIGHT TYPICAL EXPOSURES FROM A SITE SEARCH TYPE MISSION - STEREO MEDIUM RESOLUTION COVERAGE IS PROVIDED BY INCREASING THE TIME INTERVAL BETWEEN EXPOSURES (APPROXIMATELY 8.8 SECONDS) TO OBTAIN 50% MEDIUM RESOLUTION FORWARD OVERLAP AND BY PHOTOGRAPHING ON ALTERNATE ORBITS (7 & 9) TO OBTAIN MEDIUM RESOLUTION SIDE OVERLAP.

PHOTOGRAPHIC MODES

To make Orbiter's photography as useful as possible, pictures will be taken shortly after local sunrise on the Moon, so that sunlight falls on the Moon's surface at a shallow angle. That lighting situation will permit the best use of photometric techniques to obtain the maximum amount of topographic and geological information from the photographs. As the spacecraft continues orbiting, the Moon turns on its axis beneath it, bringing the nine target areas successively into camera view.

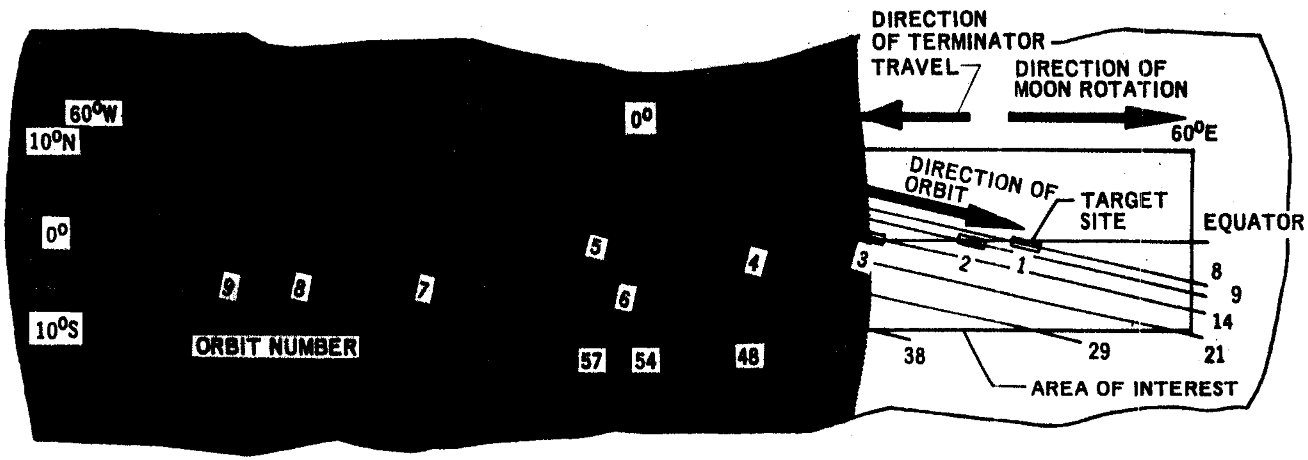
At each target site, except the last, the camera will make 16 exposures at intervals of about two and one-half seconds, producing an overlapping of medium resolution photos to supply the required characteristics for stereo viewing. The high resolution scene will be centered in the area covered by the medium resolution lens. The two pictures taken together constitute one frame.

In most cases, the target sites are separated by a few orbits, and after each photo pass, the Lunar Orbiter will process and transmit to Earth up to four picture frames. At the last site, No. 9.1, two 16-frame photo sequences will be exposed on adjacent orbits to insure a high probability of photographing Surveyor I.

Photography of each of the first eight sites will cover an area about 10 by 40 miles with high-resolution pictures and an area 23 by 56 miles with medium-resolution pictures. The coverage on the Surveyor I site will be about 18 by 40 miles of high-resolution and about 32 by 56 miles of medium-resolution.

After completing photography, which on this mission will consist of 176 frames, a complete readout will begin. This is expected to take some 14 days, because 43 minutes is needed to read out each frame and the readout can take place only when Orbiter is in the sunlight and its high gain antenna is pointing at one of the Deep Space Net receiving stations.

Selection of the nine sites to be photographed by the first Lunar Orbiter was made by a special NASA Surveyor/Orbiter Utilization Committee. The committee worked from recommendations drawn up after extensive consultation among experts from the Lunar Orbiter, Surveyor, and Apollo Programs, Bellcomm, the U. S. Geological Survey, and NASA Headquarters.



PHOTOGRAPHY OF TARGET SITES

The sites chosen represent a collective evaluation of the most promising mission targets which can be selected on the basis of current knowledge of the Moon. Among them are potential landing sites for both Apollo and Surveyor and the location of Surveyor I, as well as areas likely to provide geological evidence of value in interpreting lunar surface observations made by Ranger and through telescopes on Earth.

The sites are all within the Apollo zone of interest which is defined as plus or minus five degrees of latitude and plus or minus 45 degrees of longitude.

To aid geologists in establishing a calibration of the lunar surface, the sites include examples of three major terrain types -- maria (or seas), high-land areas, and craters. In the order in which they will be photographed, the nine sites are:

SITE	LATITUDE	LONGITUDE	GENERAL DESCRIPTION
1.	0°50'S	42° 20' E	This area covers a portion of the only promising dark mare in the Apollo target area. It begins on the floor of Mare Fecunditatis, crosses its western shoreline and included highlands near the Lubbock craters. Because of the varied features, this will be a valuable Moon surface assessment area.
2.	0° 10' S	36° 0' E	This site covers a highland area along the southern shoreline of Mare Tranquillitatis near the craters Censorinus and Maskelyne and also will be useful in assessment of the Moon's surface.
3.	0° 20' N	24° 50' E	This area is on the southern floor of Mare Tranquillitatis near the small crater Moltke and is typical of a mare area overlaid with crater ray material.
4.	0° 00'	12° 50' E	This site, an all-highland area, crosses the equator between the craters Theon Senior and Godin.

SITE	LATITUDE	LONGITUDE	GENERAL DESCRIPTION
5.	0° 25' S	1° 20' W	This area on the southwestern floor of Sinus Medii is a good example of a smooth mare with low ridge structures which are important in studying mare origin and development.
6.	4° 00' S	2° 50' W	This site begins in the crater Sporer, crosses a highland area and covers the deformed crater floor of Flammarion. This coverage will be valuable for comparative study when bearing strength data are available for various types of lunar surface.
7.	3° 45' S	22° 45' W	This area near the crater Lansberg in the eastern Oceanus Procellarum is an example of an older mare surface with low ridges, small craters and a light ray covering.
8.1	3° 0' S	36° 30' W	This area in Oceanus Procellarum east of the crater Flamsteed is an excellent example of a linear mare ridge system.
9.1	2° 21' S	43° 22' W	This area in Oceanus Procellarum covers an old crater floor just north of Flamsteed and includes Surveyor I.

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Selenodesy

A knowledge of the gravitational field of the Moon is essential to the success of the Lunar Orbiter mission and to many future operations near and on the Moon. The selenodesy experiment to be conducted with Lunar Orbiter has as its immediate goal the prediction of orbit lifetime around the Moon so that the spacecraft can complete its photographic mission.

Tracking data from Lunar Orbiter are the basic material from which the selenodesists work. By means of a complex mathematical calculation which can be handled only by electronic computers, they will be able to deduce from the tracking results some information about the nature of the lunar gravitational field.

Since the precise size and shape of the Moon are not known, the analysis will also disclose new information on how closely the Moon resembles a perfect sphere. Observations from Earth indicate that the Moon is not a true sphere, but detailed information on whether it is slightly "pear-shaped" like the Earth is not available.

It is known that the Moon exhibits small oscillations called physical librations and measurements of these barely-detectable changes support the conclusion that it is not truly spherical.

Although large gravity variations are not anticipated, a spacecraft orbit close to the Moon's surface can be sensitive to small variations over a period of time. The selenodesists hope to detect such variations during Orbiter's first few days in a high elliptical orbit.

Continuous tracking of the spacecraft during the initial orbits will provide data for making a lifetime prediction for the spacecraft at its desired photographic perilune altitude of 28 miles. If calculations predict that Orbiter cannot survive in the planned lower orbit for a sufficient period to complete the photographic mission, a higher perilune will be selected for lunar surface photography.

Estimates of several important parameters in the current model of the Moon's gravitational field are believed to be in error as much as 50 per cent. The selenodesy experiment will provide fundamental data required by the scientific community to improve our knowledge of the mass and shape of the Moon. These factors are basic to questions of the origin and history of the Moon.

In addition, the experiments will provide information of value in planning future missions to the Moon.

Principal investigator for the Lunar Orbiter selenodesy experiment is William H. Michael, Jr., Head of the Mission Analysis Section, NASA Langley Research Center. Co-investigators are Robert H. Tolson, Langley; and Jack Lorell and Warren Martin of NASA's Jet Propulsion Laboratory.

Meteoroid Measurements

Lunar Orbiter will carry 20 pressurized-cell detectors to obtain the first direct information on the presence of meteoroids in the near-lunar environment.

As the photographic system is enclosed in a thin-walled aluminum container which provides a controlled pressure and humidity environment for the operation of the camera system, a puncture of this container wall by meteoroids could result in performance degradation of this system. If such a degradation occurs, the meteoroid data could give clues to its cause.

Thus, the meteoroid information will guide designers of future spacecraft by determining what hazard, if any, should be expected from meteoroids--small particles of solid matter which move at very high speeds in space.

Meteoroids are most evident when they penetrate the Earth's atmosphere and produce the streaks of light called meteors as they burn to destruction. NASA's Explorer satellites XIII, XVI and XXIII and the three large Pegasus satellites provided direct measurements of the meteoroid population in orbits near the Earth, but similar measurements near the Moon and in translunar space have not been made.

There is uncertainty about the population of meteoroids near the Moon, based on the suggestion that it may include small particles of lunar material thrown into space by the impact of larger meteoroids on the Moon.

The 20 pressurized cell detectors mounted on Lunar Orbiter were made in the instrument shops of the Langley Research Center. Each is shaped like a half cylinder seven and one-half inches long.

The puncture-sensitive skin of each half cylinder is beryllium copper 1/1,000-inch thick. The detectors are mounted girdle-wise outside the Lunar Orbiter's thermal blanket, on brackets attached to the fuel tank deck of the spacecraft.

A total surface area of three square feet is provided by the 20 cells.

At launch, each cell is pressurized with helium gas. If a meteoroid punctures the thin beryllium copper skin the helium leaks away, and a sensitive metal diaphragm inside the half cylinder detects the loss of pressure and closes a switch to indicate that a puncture has occurred. Periodic sampling of the pressure cell switches by telemetry indicates whether any have been punctured.

Experimenter for the meteoroid measurements is Charles A. Gurtler, Head of the Sensor Development Section of the Langley Research Center's Flight Instrumentation Division. Project Engineer is Gary W. Grew of Langley.

Radiation Measurements

The photographic film aboard Lunar Orbiter is sensitive to radiation exposure and several parts of the photographic system are shielded to reduce the possibility of damage.

To report the actual amounts of radiation to which the spacecraft may be subjected on its way to the Moon and during lunar orbits, two scintillation counters are included among its instruments. One is mounted close to the film supply reel and the other adjacent to the camera shell.

Although their primary job is to report radiation intensities which might be hazardous to the film, they will supply additional information about the radiation found by Lunar Orbiter along its flight path.

Experimenter for the Radiation Measurements is Dr. Trutz Foelsche, Staff Scientist of the Langley Research Center's Space Mechanics Division.

ATLAS-AGENA D LAUNCH VEHICLE

An Atlas Agena-D launch vehicle will boost Lunar Orbiter from Launch Complex 13 at Cape Kennedy to an approximate 100-mile-high parking orbit before injecting the spacecraft on its lunar trajectory.

The upper-stage Agena must start the spacecraft on its way to the Moon through a narrow "translunar injection point" some 119 miles above the Earth's surface. Injection velocity is 24,400 mph, plus or minus an allowable error of less than 54 mph.

The accuracy required of the launch vehicle is so great that, with no midcourse maneuver, Orbiter must not be more than 10,000 miles off its aiming point after traveling more than 221,000 miles to the Moon.

Lunar Orbiter Shroud

NASA's Lewis Research Center, Cleveland, managed development of both the shroud and the spacecraft adapter for the Orbiter vehicle.

The shroud is made of magnesium with a berryllium nose cap. Its over-the-nose design is similar to that which Lewis developed for the successful Mariner IV flight to Mars.

The spacecraft adapter is the mounting structure that supports the spacecraft, the shroud and a sealing diaphragm, provides a transition from the Orbiter to the Agena. It includes four spring-loaded plungers to push the spacecraft from Agena at separation and a V-band release mechanism with associated pyrotechnic devices. This structure is made of magnesium.

Launch Vehicle Statistics

The Atlas Agena-D Lunar Orbiter launch vehicle is under the direction of NASA's Lewis Research Center, Cleveland.

Total height on pad	105 feet
Total weight on pad	279,000 pounds

	Atlas	Agena-D
height	68 feet	23 feet
diameter	10 feet	5 feet
weight (at liftoff)	261,000 pounds	15,600 pounds
propellants	RP-1 and LOX	unsymmetrical dimethyl hydrazine (UDMH) and inhibited fuming nitric acid (IRFNA)
propulsion	2 Rocketdyne boosters, 1 sustainer and 2 verniers	Bell Aerosystems Engine
guidance	G. E. Mod III	Lockheed inertial reference package
prime contractor	General Dynamics/ Convair, San Diego.	Lockheed Missiles & Space Co., Sunnyvale, Cal.

DEEP SPACE NETWORK

The NASA Deep Space Network (DSN) consists of a number of permanent space communications stations strategically placed around the world; a spacecraft monitoring station at Cape Kennedy, and the Space Flight Operations Facility (SFOF) in Pasadena, Cal.

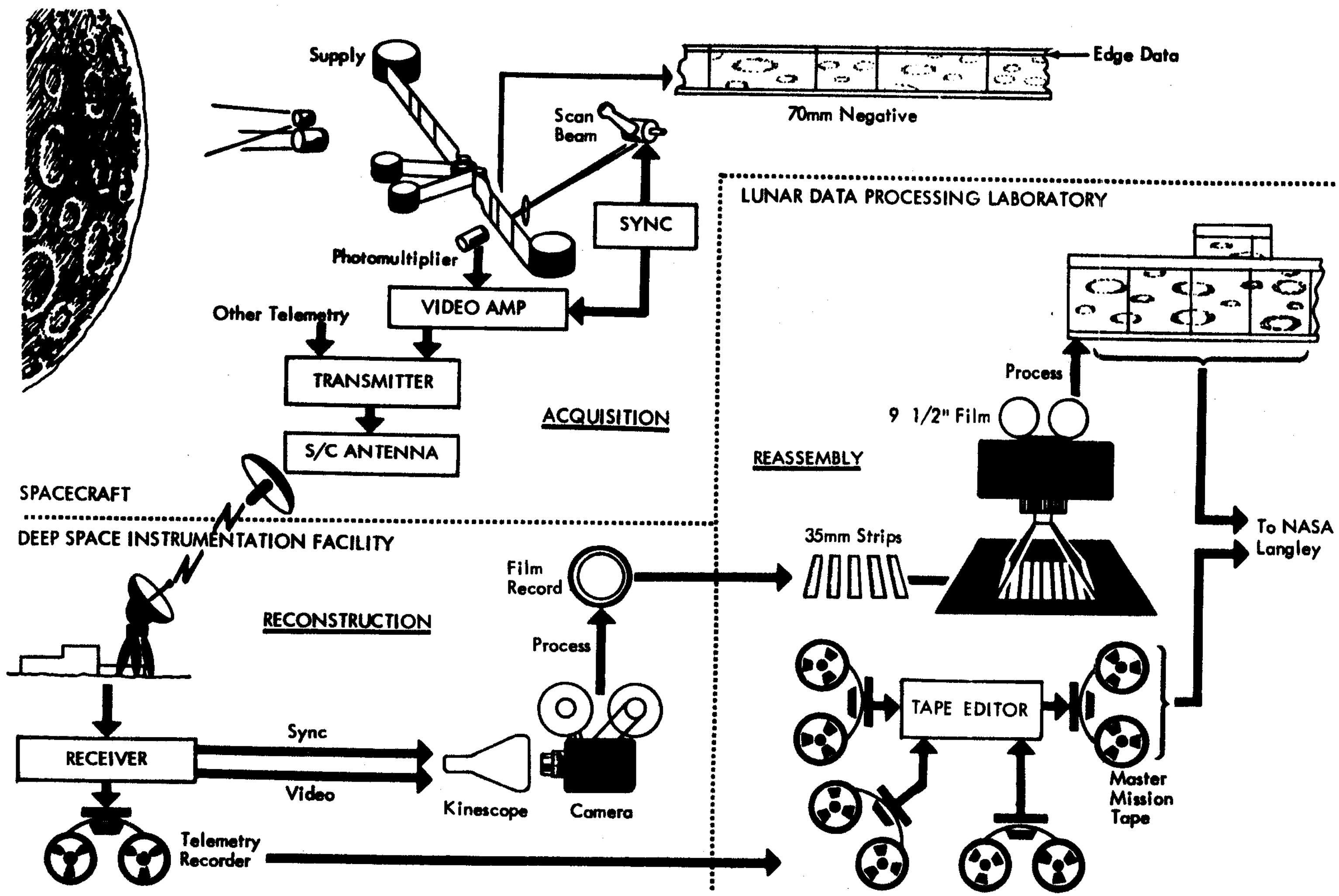
Permanent stations include four sites at Goldstone, in the Mojave Desert, Cal.; two sites in Australia, at Woomera and Tidbinbilla near Canberra; Robledo site, near Madrid, Spain; and Johannesburg, South Africa. All are equipped with 85-foot-diameter antennas except the one at Goldstone which is 210 feet in diameter. One other site, now under construction near Madrid will be known as Cebreros.

The DSN is under the technical direction of the Jet Propulsion Laboratory for NASA's Office of Tracking and Data Acquisition. Its mission is to track, communicate, receive telemetry from and send commands to unmanned lunar and planetary spacecraft from the time they are injected into orbit until they complete their missions.

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

The Goldstone DSN stations are operated by JPL with the assistance of the Bendix Field Corporation. JPL also operates the Robledo site under an agreement with the Spanish government. Technical support is provided by the Bendix Field Corporation.

The Woomera and Tidbinbilla stations are operated by the Australian Department of Supply. The Johannesburg station is operated by the South African government through the Counsel of Scientific and Industrial Research and the National Institute for Telecommunications Research.



PHOTOGRAPHIC DATA ACQUISITION, RECONSTRUCTION, AND REASSEMBLY

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

The DSN stations assigned to the Lunar Orbiter project are the Echo station at Goldstone, Woomera, and Madrid. Equipment has been installed at these stations to enable them to receive picture data from the Lunar Orbiter spacecraft. Since these three stations are located approximately 120 degrees apart around the world, at least one will always be able to communicate with the spacecraft as it travels toward the Moon.

The Space Flight Operations Center (SFOF) at JPL, the command center for the DSN stations, will be the primary mission control point. The overseas stations and Goldstone are linked to the SFOF by a communications network, allowing tracking and telemetry information to be received and displayed in real time. Key personnel for the Lunar Orbiter program will be stationed at SFOF during the spacecraft's flight. Commands will be generated at SFOF and transmitted to the DSN station for relay to the spacecraft.

Data Acquisition

The Lunar Orbiter spacecraft was designed for maximum compatibility with existing equipment installed at DSN stations. Additional equipment installed at the three Deep Space Network stations assigned to the Lunar Orbiter project includes three racks of telemetry and command equipment and four racks of equipment associated with the processing and recording of photographic information from the spacecraft.

Spacecraft tracking and ranging is accomplished by existing DSN equipment at the stations. Telemetry data, including spacecraft housekeeping information and data gathered by meteoroid and radiation sensors is routed to performance telemetry equipment and recorded on magnetic tape. The output from this equipment is fed directly to the SFOF via high speed data lines or teletype.

Video data are routed from the receiver at the DSN Station to photographic ground reconstruction equipment. A video signal is generated on board the spacecraft as the scan beam passes back and forth across the photographic negative. The signal is transmitted to Earth where it is magnetically taped and displayed line by line on a kinescope.

The face of the kinescope is photographed by special 35mm cameras at the DSN stations, converting the video information back to photographic image. Two 35mm film records are made at each DSN station. Portions of this film are processed at the station so that picture quality may be judged and corrections made, if necessary, to the spacecraft camera or readout system to improve the quality of subsequent pictures.

Each of these 35mm framelets measures approximately 3/4-inch wide by 16-3/4 inches long, and represents a portion of the original film on board the spacecraft only 1/10-inch wide and 2.165 inches long. By carefully assembling a series of these framelets, scientists will be able to reconstruct a duplicate about eight times as large as the original negative stored on the spacecraft. This work will be accomplished in the Eastman Kodak Laboratories at Rochester, N.Y.

Fourteen framelets will be edge-matched to form a composite that is photographically reduced to a 9 by 14-inch re-assembled photograph. Seven of the 9 by 14-inch composites constitute one high-resolution frame on the spacecraft negative.

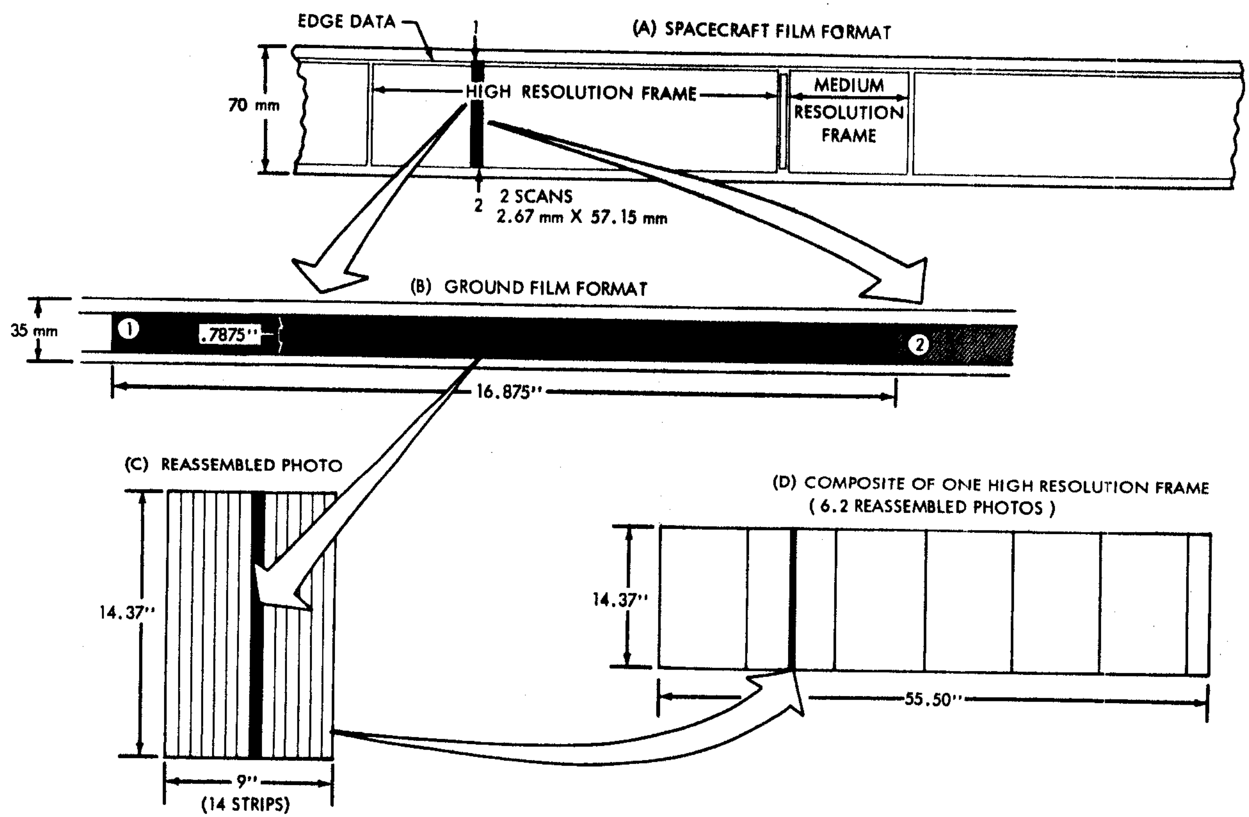


PHOTO REASSEMBLY

Data Evaluation

The photographs produced by the reassembly printer at Eastman Laboratories will be flown to the Langley Research Center, Hampton, Va., where NASA will assemble a group of experts in various areas of lunar science and space technology. Initial screening and a preliminary evaluation of the Lunar Orbiter's photographic results will be made by that group.

The evaluation team will include representatives of the Lunar Orbiter Project; NASA Headquarters; the Manned Spacecraft Center; Bellcomm; the Surveyor Project; the U.S. Geological Survey; and the USAF Aeronautical Chart and Information Service and the Army Map Service, both Department of Defense Agencies.

One primary task of the evaluation group will be a preliminary screening of the wealth of photographs to aid in the design of subsequent Lunar Orbiter missions. A parallel consideration will be a review of the photographs as a guide to future flights of the Surveyor series.

Lunar Orbiter photography will be analyzed for slope and profile information useful to Project Apollo, and preliminary terrain maps of sites which appear of interest to Apollo will be prepared.

Statistical analysis of portions of the data will be made as rapidly as possible, to expand general knowledge of lunar surface conditions, and a computer study of terrain information extracted from the Lunar Orbiter photographs will be made at the Manned Spacecraft Center.

Over a longer period of time, Lunar Orbiter photographs will be used in geological and terrain studies directed toward landing site problems, and finally, the photographs will be used for longer-term systematic geologic investigations to obtain a more comprehensive understanding of the Moon itself.

ATLAS AGENA/LUNAR ORBITER MISSION

Launch times for the August period for a Lunar Orbiter A Flight, are:

Date	Window Opens	Window Closes
Aug. 9	12:07 P.M. (EDT)	4:43 P.M. (EDT)
Aug. 10	1:43 P.M.	6:02 P.M.
Aug. 11	3:40 P.M.	7:33 P.M.
Aug. 12	5:37 P.M.	9:09 P.M.
Aug. 13	7:38 P.M.	10:46 P.M.

Countdown Events

Event	Minus Time (Minutes)
Start Count	395
Start UDMH Tanking	155
Finish UDMH Tanking	135
Start Removal of Gantry	130
Complete Removal of Gantry	100
Start IRFNA Tanking	90
Finish IRFNA Tanking	65
Built-in Hold of 50 minutes to meet Launch Window Restrictions	60
Start LOX Tanking	45
Built-in Hold for 10 minutes to meet Launch Window Restrictions	7
Secure LOX Tanking	2
Hold for Automatic Sequencer	18 seconds
Atlas Engine to full thrust	2 seconds

Atlas Flight Events

At liftoff the booster, sustainer and vernier engines on the Atlas are all operating to lift the 277,000-pound vehicle with 388,000-pounds of thrust. The Atlas vernier and booster engines gimbal and roll the space vehicle prior to pitching over to achieve the proper flight path azimuth. The roll is accomplished between two and 15 seconds after liftoff.

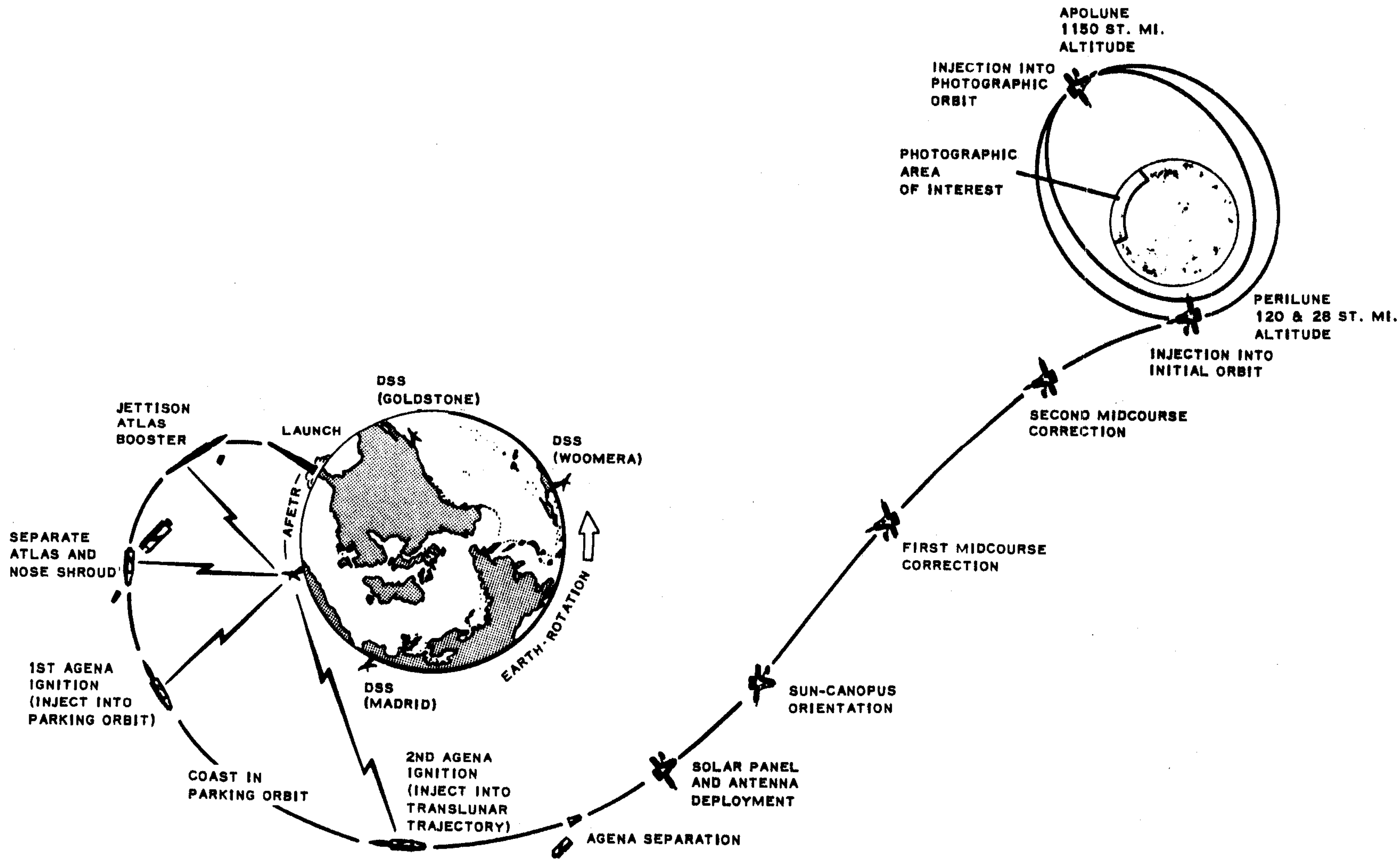
Using position and velocity radar tracking data and predetermined trajectory and targeting equations, the guidance computer computes the proper time for Atlas booster engine cutoff (BECO). At that time, a staging command is sent to the Atlas and BECO occurs.

The Atlas programmer then provides the signals necessary to jettison the booster section which occurs about three seconds after BECO. At this time, the space vehicle is about 50 miles downrange from Cape Kennedy at an altitude of about 33 miles. After staging, the sustainer and vernier engines continue to provide thrust and guidance through sustainer engine cutoff (SECO), about seven minutes after liftoff. At SECO, the space vehicle has attained an altitude of approximately 94 miles and is more than 400 miles downrange.

The vernier engines provide final attitude turn in pitch, yaw and roll to properly align the Agena and its Lunar Orbiter spacecraft axes for separation from the Atlas booster.

At the correct point on the ascent trajectory, the radio guidance system starts the Agena primary timer which controls all Agena events except Agena engine shutdown. Both parking orbit and injection conditions are highly influenced by the point on the ascent trajectory at which the Agena primary timer is started. The guidance discrete command signal to start the Agena primary timer is provided at about T+294 seconds.

Final velocity adjustments having been attained, the vernier engines shut down (VECO) about 310 seconds after liftoff.



TYPICAL FLIGHT PROFILE

About three seconds after VECO, the spacecraft nose shroud is jettisoned. Then Atlas/Agena separation occurs at an altitude of about 104 miles.

Agena First Burn

Some 40 seconds after Agena has separated from the Atlas booster, a pitchdown program begins to properly orient the vehicle longitudinal axis in pitch before Agena engine first burn.

Beginning about T+367 seconds, the sequence for starting the Agena engine includes: deactivating the pneumatic attitude control in pitch and yaw and enabling the velocity meter. One second after the engine first-burn ignition squibs are fired, Agena's engine achieves 90 per cent thrust.

Helium pressure valve squibs are fired 1.5 seconds later to allow helium to replace the propellants used, thus maintaining sufficient pressure in the tanks to assure a proper propellant heat at the propellant pump inlets.

This first engine burn should increase the velocity of the Agena and its spacecraft some 4830 mph. The exact velocity to be gained will be pre-set in the velocity meter during the flight. When the vehicle has achieved the required velocity, the velocity meter shuts down the engine (about T+535 seconds). At engine shutdown, the vehicle will be in a circular parking orbit 115 miles above the south Atlantic.

Agena must inject Lunar Orbiter toward the Moon at a point in space which remains relatively fixed. As the Earth is turning under this stationary gateway to the Moon, the actual injection time will vary with the day and hour of launch.

Agena Second Burn

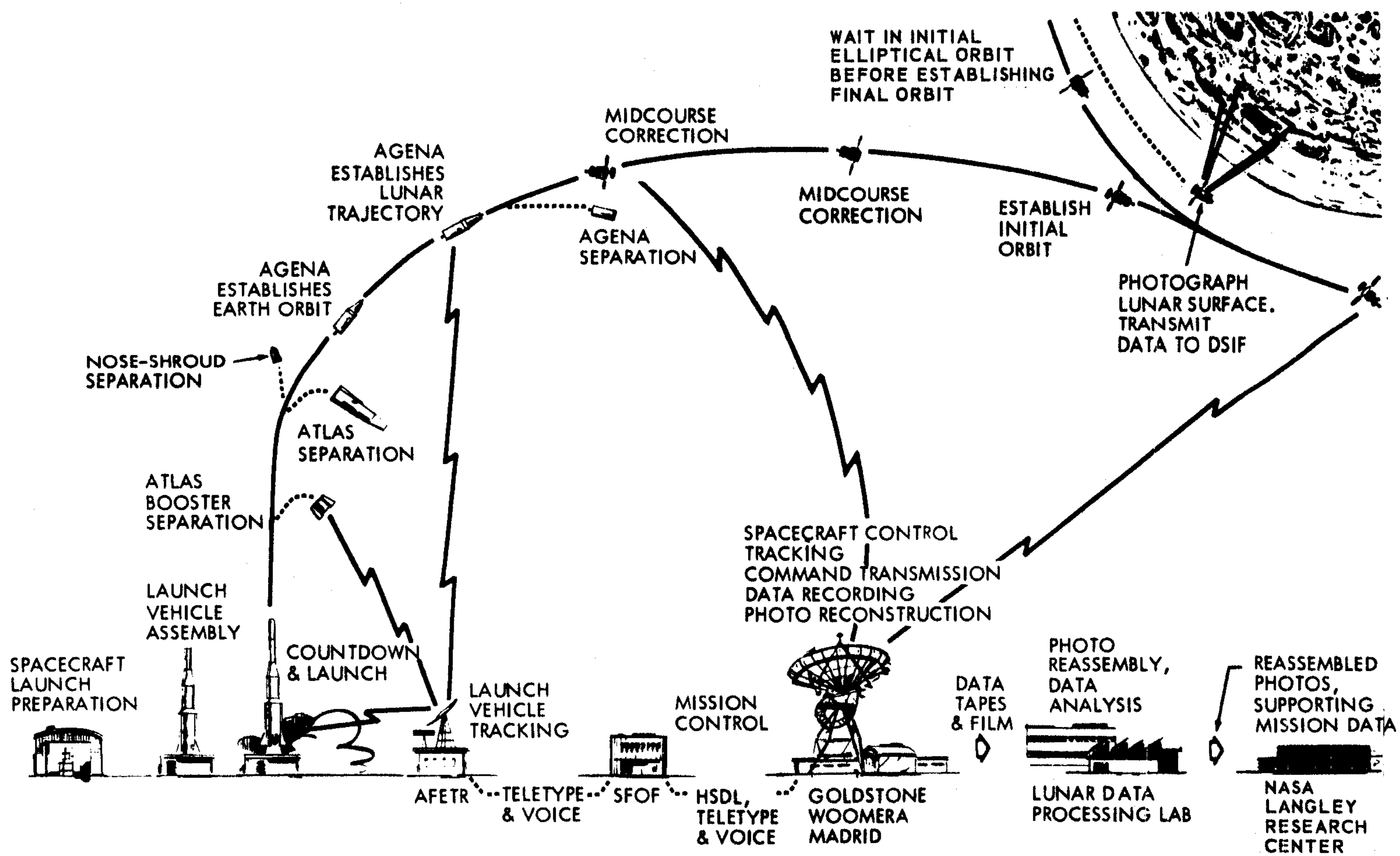
The vehicle's time in parking orbit will vary from 21 minutes to 35 minutes before the sequence is begun to ignite Agena's engine for the second time. Lunar Orbiter must be started on its coast to the Moon at a velocity of 24,400 mph, plus or minus a margin for error of 54 mph. The exact velocity to be gained will again be pre-set in Agena's velocity meter but the figure should be about 7000 mph, requiring some 92 seconds of engine thrust.

After Agena's engine shuts down for the final time, the spacecraft release assembly bolt squib is fired to release the V-band clamp. Four spring-loaded separation mechanisms push the spacecraft away from the Agena at slightly less than one mile per hour.

The Lunar Orbiter spacecraft is now on a translunar trajectory.

Three seconds after spacecraft separation, the Agena begins a yaw maneuver which will turn it around 180° in space. Then, 10 minutes after separation, a signal from the primary timer fires Agena's retrograde rocket for about 16 seconds.

The 137-pound-thrust retrograde rocket slows Agena 30 mph minimizing the possibility that the vehicle could interfere with the spacecraft or hit the Moon. Agena's job done, the vehicle will go into a high eccentric earth orbit.



SPACECRAFT LAUNCH PREPARATION
LAUNCH VEHICLE ASSEMBLY
COUNTDOWN & LAUNCH
ATLAS BOOSTER SEPARATION
ATLAS SEPARATION
NOSE-SHROUD SEPARATION
AGENA ESTABLISHES EARTH ORBIT
AGENA ESTABLISHES LUNAR TRAJECTORY
MIDCOURSE CORRECTION
AGENA SEPARATION
MIDCOURSE CORRECTION
WAIT IN INITIAL ELLIPTICAL ORBIT BEFORE ESTABLISHING FINAL ORBIT
ESTABLISH INITIAL ORBIT
PHOTOGRAPH LUNAR SURFACE. TRANSMIT DATA TO DSIF
LAUNCH VEHICLE TRACKING
AFETR
TELETYPE & VOICE
MISSION CONTROL
SFOF
HSDL, TELETYPE & VOICE
SPACECRAFT CONTROL
TRACKING
COMMAND TRANSMISSION
DATA RECORDING
PHOTO RECONSTRUCTION
GOLDSTONE
WOOMERA
MADRID
DATA TAPES & FILM
PHOTO REASSEMBLY, DATA ANALYSIS
LUNAR DATA PROCESSING LAB
REASSEMBLED PHOTOS, SUPPORTING MISSION DATA
NASA LANGLEY RESEARCH CENTER

THE MISSION

First Spacecraft Events

Thirty seconds after the Lunar Orbiter leaves Agena, a sequence of spacecraft events is commanded by the programmer, starting with solar panel deployment. Next the two antennas are released and locked in their cruise positions.

The spacecraft is then commanded to begin Sun acquisition, and the attitude control system provides the necessary torque to position Lunar Orbiter correctly. Sun acquisition should be complete about one hour and 15 minutes after lift-off.

Some six and one-half hours into the flight, and after Lunar Orbiter has passed beyond the Van Allen radiation belt, the Canopus sensor will be turned on, and the spacecraft will be commanded to begin Canopus acquisition. The Canopus tracker will view a circular band of the heavens while the spacecraft is making a complete roll, and the resulting "star map" telemetered to Earth will confirm the location of Canopus. The spacecraft will then be commanded to roll to the correct Canopus location and lock on to the stellar reference point it will use throughout its journey.

First midcourse maneuver is scheduled about 15 hours after lift-off, although the precise time for executing it will be based on actual flight events, including launch accuracy and tracking results.

A correct sequence of events derived from ground computers will be stored in the spacecraft programmer and at the selected time, Orbiter's attitude control system will position the spacecraft precisely for the velocity control engine to apply the needed thrust. After thrusting, the attitude control system returns the spacecraft to its initial orientation, reacquiring the Sun and Canopus as references.

Should a second midcourse correction prove necessary, it will be made about 70 hours after launch.

Lunar Orbit Injection

During translunar flights, trajectory information provided by the Deep Space Net tracking stations will be used in the Space Flight Operations Facility to compute the velocity change required to achieve an initial lunar orbit. On a nominal mission, lunar orbit injection will occur after 89½ hours of flight.

As the Lunar Orbiter more deeply penetrates the lunar gravitational field, a calculated attitude maneuver will point the rocket engine against the direction of flight. The correct burn time, as computed on the ground, will be placed in the programmer.

Then, at a precise instant, the rocket engine will ignite for a burn time of nine minutes and 30 seconds if the spacecraft is on its planned trajectory. Small variations from the intended trajectory are probable, and the engine burn time will be adjusted as necessary.

The slowed spacecraft, approaching a minimum altitude of 120 miles above the surface of the Moon, will no longer have sufficient velocity to continue outward against the pull of lunar gravity, and will be captured as a satellite of the Moon. High point of the orbit (apolune) is intended to be 1150 miles. Lunar Orbiter will circle the Moon every three hours and 37 minutes in its initial orbits.

Several variables will determine how long Lunar Orbiter remains in its initial orbit. One is the day on which the spacecraft is launched; if lift-off occurs on the first day in the period, the spacecraft will have to wait longer in its initial orbit before the Moon's rotation brings the photographic targets into view beneath it.

Another is the observed gravitational field of the Moon, a quantity to be determined by precise tracking of the spacecraft in its initial orbits and the analysis of the tracking data. Because very little is known about the exact size, shape and gravitational attraction of the Moon, the initial orbit may differ from the planned one, and analysis of the actual orbit achieved has a bearing on the time the spacecraft waits in a high orbit.

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Time in the high orbit will be between three and seven days.

During that period, Orbiter's camera will be used to take several engineering evaluation photographs of an area near the eastern edge of the Moon. Because they will be made from a higher altitude than photographs of the nine prime target sites, the initial engineering pictures will not have the resolution expected of the later photography.

Photographic Orbit Injection

When analysis of the Moon's gravity indicates that the necessary mission lifetime required for the low perilune orbit can be achieved, the spacecraft will be commanded to make its final major velocity change.

The maneuver will be similar to those previously performed. Instructions to the attitude control system will assure that the velocity engine is correctly aligned, and a brief engine burn will counteract just enough of Orbiter's velocity to lower the perilune to the intended final altitude of 28 miles. The apolune will remain unchanged.

In its final photographic orbit, the spacecraft will circle the Moon every three hours and 28 minutes. Its speed relative to the Moon will be about 4500 miles per hour at closest approach, or perilune.

When the maneuver is complete, the spacecraft will return to its cruise attitude oriented to the Sun and Canopus. When the Moon comes between it and either of its celestial reference points, the inertial reference unit will furnish the required orientation.

Then Lunar Orbiter will be ready for its main task--detailed photography of nine selected locations near the equator of the Moon.

LUNAR ORBITER AND ATLAS-AGENA TEAMS

NASA Headquarters, Washington, D.C.

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Joseph B. Mahon	Agena Program Manager

Langley Research Center, Hampton, Va.

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Charles J. Donlan	Associate Director
Eugene C. Draley	Assistant Director for Flight Projects
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James S. Martin, Jr.	Assistant Manager, Lunar Orbiter Project
Israel Taback	Spacecraft Manager
William I. Watson	Assembly and Integration
G. Calvin Broome	Photographic Subsystem
J. E. Harris	Power Subsystem
Royce H. Sproull	Velocity and Attitude Control Subsystem
T. W. E. Hankinson	Thermal, Structure and Mechanisms Subsystem
I. W. Ramsey	Spacecraft Testing

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Donald H. Ward	Spacecraft Launch Operations
John B. Graham	Operations Integration
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Harold Zweigbaum	Manager, Atlas Agena Operations

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Doug Hogg	JPL Station Manager, Johannesburg

Industrial Team

The Lunar Orbiter prime contractor is The Boeing Co., Seattle, Wash., which designed, built and tested the spacecraft. Major subcontractors to Boeing are the Eastman Kodak Co., Rochester, N. Y., for the camera system and Radio Corporation of America, Camden, N. J., for the power and communications systems.

Prime contractor for the Atlas booster stage is General Dynamics/Convair, San Diego, Calif., and prime contractor for the Agena second stage is Lockheed Missiles and Space Co., Sunnyvale, Calif.

The following is a list of other subcontractors for the Lunar Orbiter spacecraft:

Contractor	Product
Accessory Products Company	Quad Check Valve
Ball Brothers Research Corporation	Sun Sensor
Bell Aerosystems	Fuel Tanks
Bendix Corporation	Crystal Oscillator
Calmec Manufacturing Co.	Relief Valve
J. C. Carter Company	Propellant Fill & Vent Valve
Electronic Memories, Inc.	Programmer Memory
Fairchild Controls	Pressure Transducer
Firewel Company	Fill & Test Valves
General Precision, Inc., Kearfott Division	TVC Actuator
Gerstenslager Company	Van
ITT Federal Laboratories	Star Tracker
Marquardt Corporation	Engine
National Water Lift Co.	Hi Pressure Regulator

Contractor	Product
Ordnance Engineering Associates	Pin Release Mech. N_2 Squib Valve Shut Off Valve Propellant Squib Valve Cartridges
Radiation, Incorporated	Multiplexer Encoder Test Set
Resistoflex Corporation	Propellant Hoses
Sperry Gyroscope Company	Inertial Reference Unit
Standard Manufacturing Company	Servicing Unit - Cart Purge, Dry & Flush Unit
Sterer Engineering and Manufacturing Company	Thrusters Low Pressure Regulator
Texas Instruments, Inc.	Radiation Dosage Measurement System
Vacco Valve Company	N_2 Filter Propellant Filter
Vinson Manufacturing Co.	Linear Actuator

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