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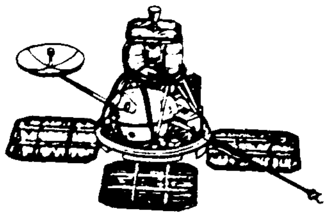
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION TELS WO 2-4155
WASHINGTON, D.C. 20546 WO 3-6925

FOR RELEASE: THURSDAY A.M.
July 27, 1967

RELEASE NO: 67-192



PROJECT: LUNAR ORBITER E

(To be launched no earlier than Aug. 1, 1967)

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7/21/67

NEWS

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FIFTH AND FINAL
LUNAR ORBITER
LAUNCH PLANNED

The United States will attempt to launch the fifth and final Lunar Orbiter, completing the launch series of the highly successful photographic spacecraft within one year.

Lunar Orbiter E is scheduled for launch from Cape Kennedy, Fla., by the National Aeronautics and Space Administration within the period Aug. 1-3. The first Lunar Orbiter was launched Aug. 10, 1966.

In one year, the Orbiters have been major contributors to the nation's effort to learn about the Moon's surface, and have acquired a wealth of photographic detail which will stand as the definitive source of lunar surface information for many years.

The first three Lunar Orbiter missions were in direct support of the Apollo and Surveyor lunar landing programs; they identified at least eight areas in which potential manned landing locations exist.

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The fourth Orbiter mission completed a broad photographic survey of the Moon's front face, yielding telephoto pictures of 99 per cent of the entire area with ten times finer resolution than the best existing telescope views. For most of the area covered, the pictures contain a hundred-fold increase in discernible detail.

Now Lunar Orbiter has been given the complex assignment of photographing areas of potential interest to:

----the Apollo and Surveyor landing programs;

----future Apollo Applications Programs; and

----science by photographing at close range sites of outstanding interest identified from the broad higher altitude survey completed by Lunar Orbiter IV.

The 860-pound Orbiter will be launched by an Atlas-Agena D vehicle on a flight to the vicinity of the Moon which will take about 89 hours. When successfully injected on its translunar trajectory, it will be designated Lunar Orbiter V.

During its 14-day photographic mission, the spacecraft will revisit five potential Apollo landing sites previously viewed by Lunar Orbiters I, II, and III, to supply additional telephoto coverage of some promising areas. It will also look at several locations being considered for future Surveyor landings. Some 20 per cent of the available film load will be devoted to these targets.

The largest part of the Mission Five film budget is assigned to targets of primary interest to science. Low-altitude telephoto pictures of the 36 science sites promise to permit more detailed interpretation of lunar surface phenomena than has been possible before.

Finally, additional apolune photography of the Moon's hidden side is planned to raise the total of hidden side coverage to more than 95 per cent. Cartographic quality pictures of approximately 60 per cent of the far side were acquired by Lunar Orbiters I through IV, and Mission Five is scheduled to fill a coverage gap between 104 degrees and 143 degrees West longitude with enough overlap to coordinate the pictures with previous photography.

Hidden side telephoto pictures will be taken to the highest latitudes feasible, and wide angle photography will include the Moon's polar regions.

Photography on the Moon's front face will have sufficient resolution to show surface features as small as six feet across in the telephoto pictures and as small as 50 feet in the wide angle coverage.

Most of Lunar Orbiter E's front face photography will be accomplished from a low perilune orbit much like those flown by the first three spacecraft in the series. It will be a high inclination, nearly polar orbit of 85 degrees like that in which Lunar Orbiter IV is currently operating.

The low point (perilune) of the orbit intended for Lunar Orbiter E is about 60 miles and the apolune (high point) about 930 miles. At those altitudes the spacecraft will require three hours and 11 minutes to complete one circuit of the Moon.

The photographic flight plan is an ambitious one which assumes that all spacecraft systems, ground support systems, and the operations team will be able to operate at maximum efficiency. Once photography begins on Aug. 6 there will be picture taking sequences on almost every orbit. Priority readout of some of the pictures will occur throughout the photographic part of the mission, although the schedule requires a final readout to return to Earth all photographs to be taken.

The full photographic flight plan requires more than 70 camera-pointing maneuvers by Orbiter E, where only 50 were required by the Lunar Orbiter III flight plan.

In addition to its principal photographic assignment, Lunar Orbiter E, like its predecessors, will monitor proton radiation and meteoroids in the vicinity of the Moon. Detection equipment on the four Orbiters flown thus far has recorded a total of nine meteoroid punctures.

The most notable radiation measurements were recorded by Lunar Orbiter I which clearly measured the effects of a series of solar flares which took place after its photography was complete.

Meteoroid and radiation measurements are used primarily for spacecraft performance analysis since the hermetically sealed camera package potentially could suffer damage from a meteoroid hit or the photographic film could fog from solar proton radiation.

Orbiter E, like its predecessors, will add to and refine the definition of the Moon's gravitational field. The low altitude, high inclination orbit is expected to yield more selenodetic information than the higher altitude orbit originally flown by Lunar Orbiter IV.

On the first day of the planned launch period, Aug. 1, Orbiter's launch window is between 4:09 and 8 p.m. EDT. On each succeeding day of the period the window opens about two hours later.

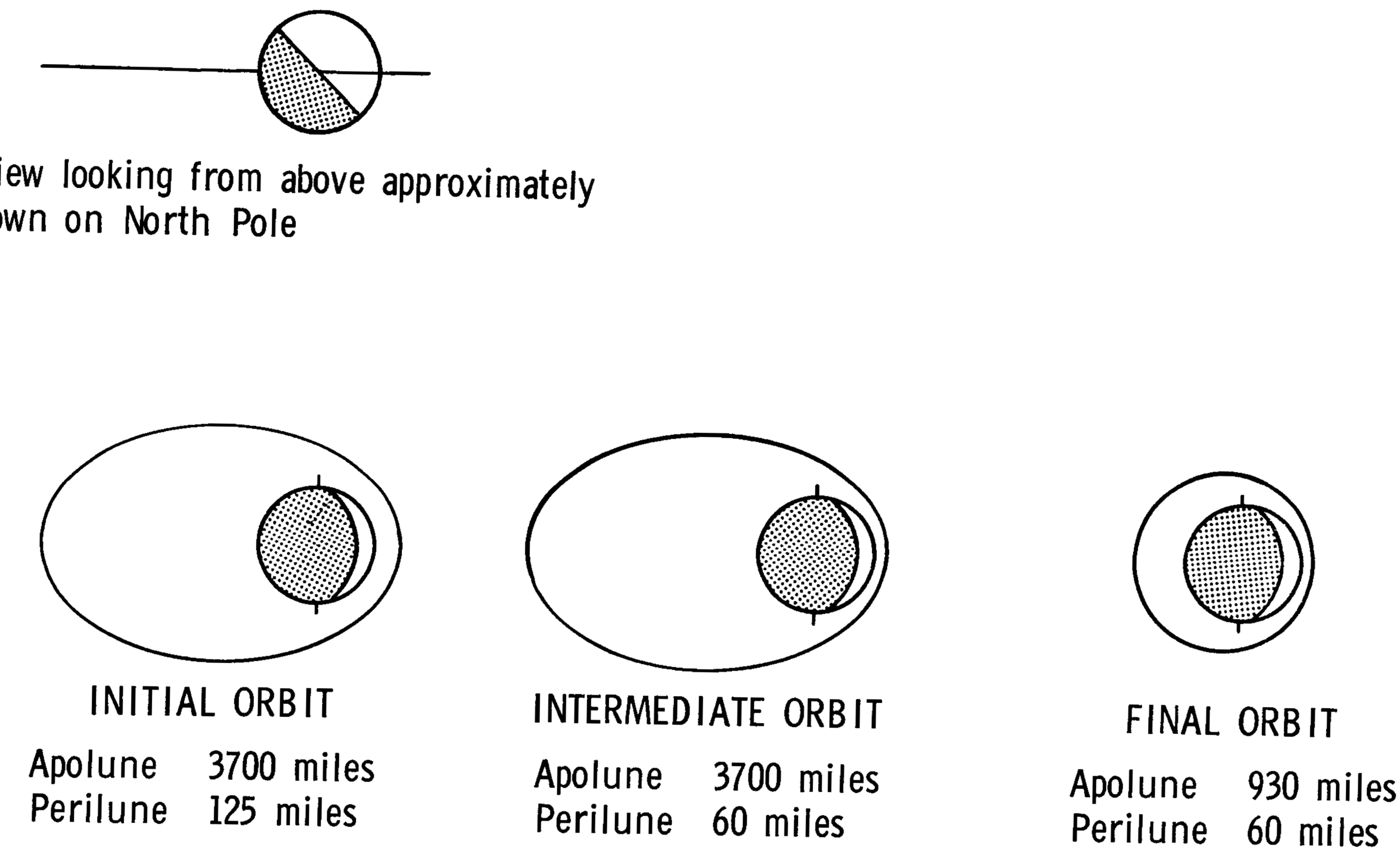
During its jouney to the Moon, the spacecraft will be oriented to the Sun and the Southern hemisphere star Canopus, except when it is executing one or possibly two mid-course maneuvers.

At a point about 2,500 miles from the Moon's surface, the liquid fuel retroengine will fire to slow the spacecraft so it will be captured in the Moon's gravitational field. As a satellite of the Moon, Lunar Orbiter will enter an initial elliptical orbit whose distance from the Moon will vary from 125 to 3,700 miles.

The initial orbit will be nearly polar, inclined 85 degrees to the Moon's equator. The spacecraft will require eight hours 22 minutes to make a complete circuit of the Moon in the initial orbit. Much of the farside coverage will be obtained from this orbit.

Two orbit adjustments are planned to lower the spacecraft into the final orbit from which it will complete most of its photography. In the first maneuver, the perilune will be lowered to about 60 miles, and in the second, the apolune will be brought down to about 930 miles. The final photographic orbit should have a period of about three hours and 11 minutes.

Photography is scheduled to begin Aug. 6, and will be completed Aug. 19. Final readout of all pictures taken will be Aug. 27.



LUNAR ORBITER E ORBIT DESIGN

NASA will distribute lunar site photographs to members of the scientific community for interpretive studies. The U.S. Geological Survey will employ 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 Co., Seattle, as prime contractor. Eastman Kodak Co., Rochester, N.Y.(camera system); and Radio Corporation of America, Camden, N.J.(power and communication systems); are the principal subcontractors to Boeing.

NASA's Lewis Research Center, Cleveland, is responsible for the launch vehicle and Kennedy Space Center, Fla., will supervise the launch operation. Prime vehicle contractors are General Dynamics, Convair Division, San Diego, 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 (DSN), operated by NASA's Jet Propulsion Laboratory, Pasadena, Cal. DSN stations, located at Goldstone, Cal.; Madrid, Spain; and Woomera, Australia, will participate in the mission.

Photographic data gathered by Lunar Orbiter's fifth mission will flow from each DSN station to the Army Map Service, Washington, D. C., for reassembly and duplication. Some material will be reassembled and printed at NASA's Space Flight Operations Facility and at the Langley Research Center to support preliminary screening activities. Photographs and video tape records of sites of primary interest to the Apollo program will be sent to NASA's Manned Spacecraft Center for evaluation and detailed analysis.

(END OF GENERAL RELEASE; BACKGROUND INFORMATION FOLLOWS)

LUNAR ORBITER PROJECT

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 photographs of the lunar surface enroute to crash landing and destruction on the Moon.

Surveyor I, launched May 30, 1966, achieved a successful soft landing on the Moon's surface. It measured important surface properties--for example, how much weight the lunar crust will support--and transmitted 11,150 close-ups of the Moon's surface from its position on the Sea of Storms (Oceanus Procellarum).

On Aug. 10, 1966, Lunar Orbiter I was launched and during the succeeding days demonstrated its remarkable versatility as a flying photographic laboratory. Final tallies show that it photographed about two million square miles of lunar surface, including 16,000 square miles over prime target sites in the Apollo zone of interest on the front face of the Moon. It provided the first detailed scientific knowledge of the lunar gravitational field and topographic and geological information of direct benefit to the Apollo program and to scientific knowledge of the Moon.

On Oct. 29, 1966, after making 527 revolutions in 77 days of orbiting the Moon, Lunar Orbiter I was ordered to fire its velocity control engine for 97 seconds. At 9:30 a.m., EDT, it impacted the hidden side of the Moon. This was done to eliminate any possibility that Orbiter I could interfere with the Orbiter II mission by inadvertently turning on its radio transmitter.

Lunar Orbiter II, launched Nov. 6, 1966, flew an even more successful photographic mission, providing wide angle and telephoto coverage of more than 1.5 million square miles of the Moon's surface not covered by Orbiter I, including 15,000 square miles of primary site photography in the Apollo zone.

By July 15, 1967, Lunar Orbiter II had completed more than 1,960 orbits, and is continuing to add to the scientific understanding of the lunar gravitational field through careful tracking.

Lunar Orbiter III, following the program timetable of a flight every three months, was launched Feb. 4, 1967, to obtain photographs confirming the earlier photography completed by Orbiters I and II. As a result of its successful mission, NASA's Office of Manned Space Flight announced the selection of eight sites suitable for landing the Project Apollo Lunar Module.

In a remarkable historic first, Lunar Orbiter III flew over the landing site of Surveyor I and made a series of pictures showing a man-made artifact standing on the lunar surface.

As of July 15, 1967, Lunar Orbiter III had completed more than 1,080 orbits of the Moon. It is tracked from time to time to provide further data for gravitational field studies, and its meteoroid and radiation detectors remain in operating condition.

Surveyor III was launched April 17, 1967, and bounced to a landing on the lunar surface April 19. It extended the work of its predecessor by mechanically sampling the texture of the Moon's surface material. The precise location of the Surveyor III landing site was established through photographs of the area made by Lunar Orbiter III's telephoto lens two months earlier.

On May 4, 1967, Lunar Orbiter IV left Cape Kennedy on an ambitious mission to photograph as much as possible of the Moon's front face with its telephoto lens and to add to existing coverage of hidden side areas as well. By the time its photographic mission was completed June 1, it had acquired telephoto pictures of 99 per cent of the Moon's front face. The pictures provided scientists ten times better resolution than the best existing telescope views, and for most of the area covered contained a hundredfold increase in discernible detail.

In conjunction with its three predecessors, Lunar Orbiter IV raised to more than 60 per cent the total cartographic quality coverage of hidden side topography. Analysis and interpretation of the wealth of photographic detail returned by Orbiter IV will occupy seientists, mapmakers and planners of future missions for months to come.

As of July 15, Lunar Orbiter IV had completed 220 circuits of the Moon.

All three operating Orbiters are used as tracking targets by the NASA Manned Space Flight Network stations, providing a valuable method of exercising and evaluating the tracking network and the Apollo Orbit Determination Program.

Lunar Orbiter and Surveyor data are being used together to gain a detailed understanding of selected areas of the lunar surface in order to make a safe manned landing possible.

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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 860 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 18 and one-half feet across the antenna booms and 12 feet, two inches across the solar panels.

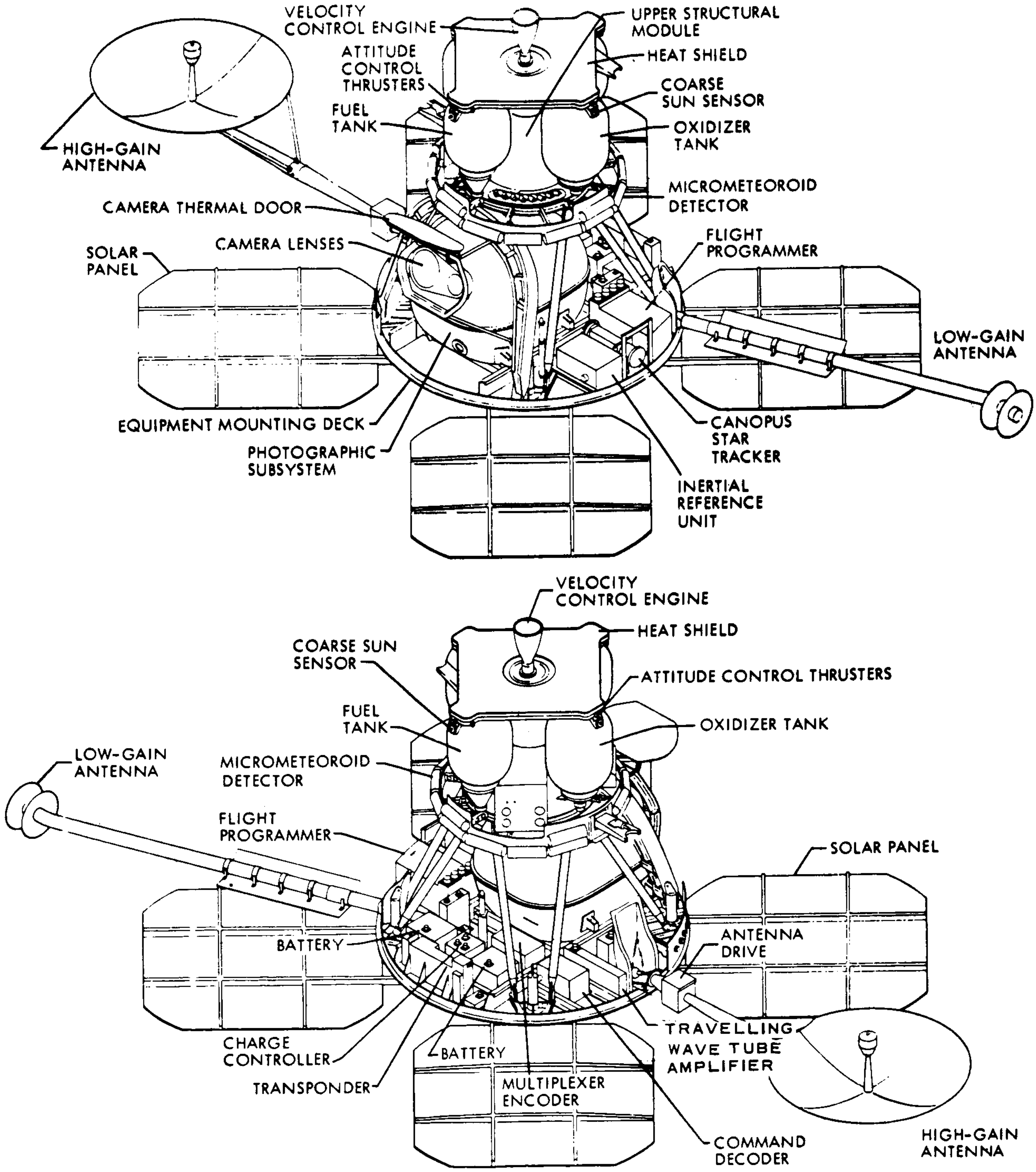
The primary structure consists of the main equipment mounting deck and an upper section supported by trusses and an arch.

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.

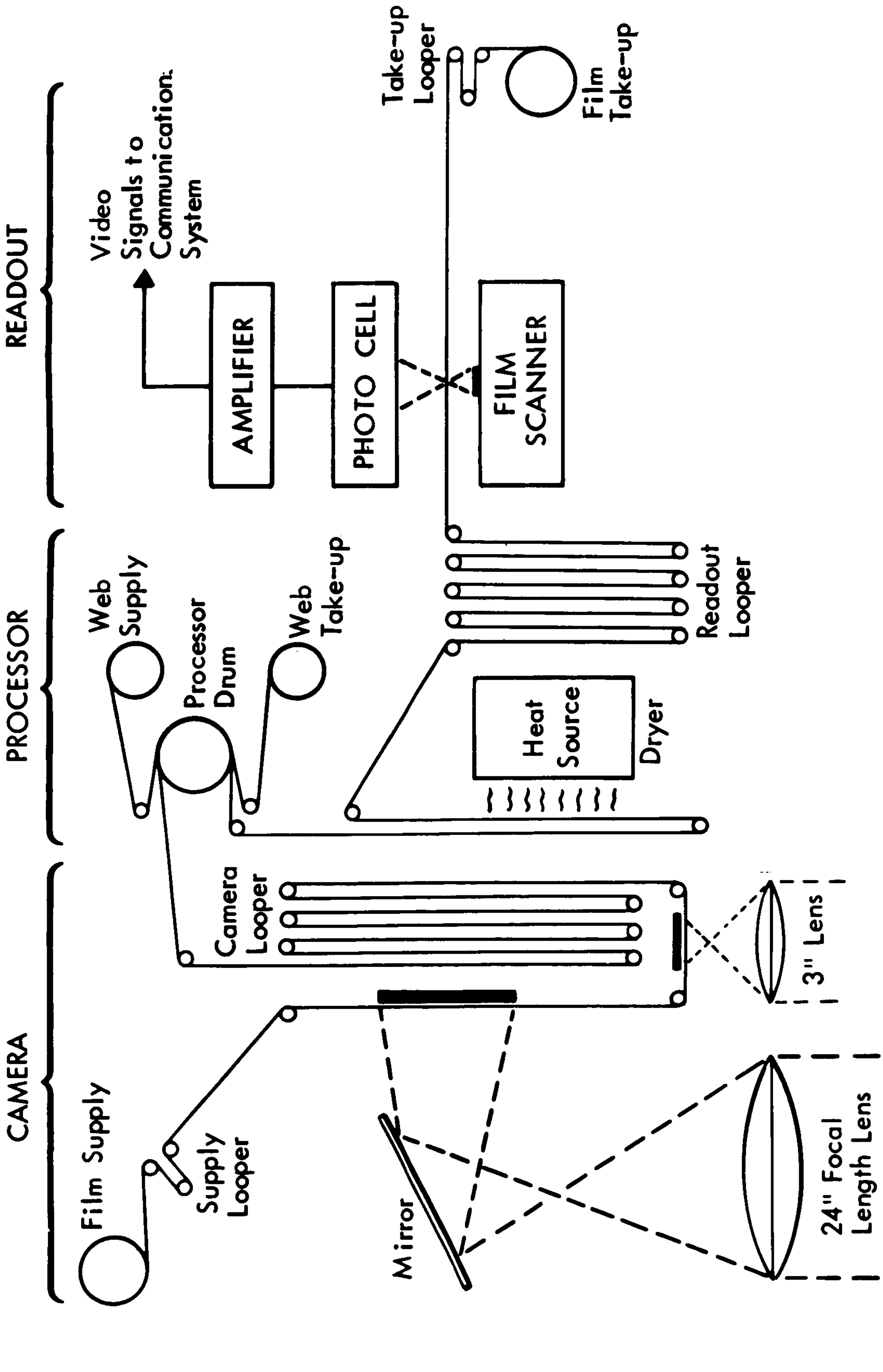
The lower section houses the camera, communications and electrical system equipment, the inertial reference unit, the Sun sensor, and the Canopus star tracker.

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 wide angle and the other for telephoto photography. The cameras 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.



LUNAR ORBITER SPACECRAFT



PHOTOGRAPHIC SUBSYSTEM

The wide angle 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 telephoto lens is a 24-inch f/5.6 Paxoramic specially designed and built by Pacific Optical Co. 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 260-foot roll of 70-mm SO-243 unperforated film, sufficient for at least 212 dual exposure frames. The supply spool is shielded against ionizing radiation from solar flares.

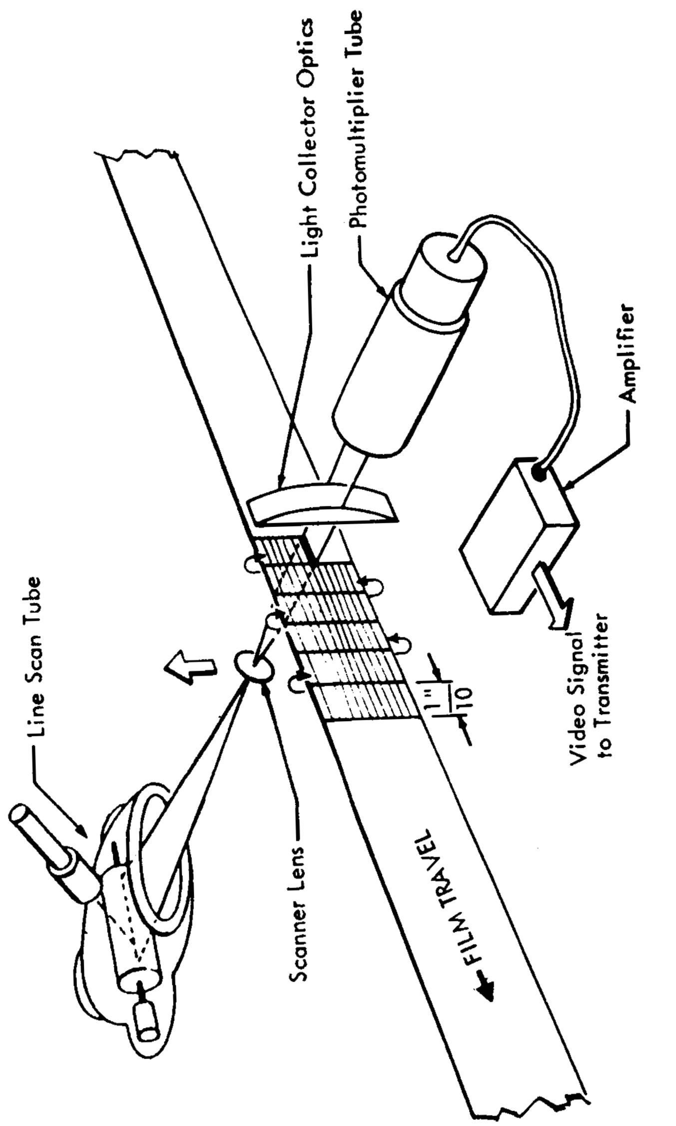
Along one edge of the film is a band of pre-exposed data, primarily resolving power charts and densitometric gray scales, which will be read out along with the lunar images captured by the spacecraft.

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.

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 wide angle 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 (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.



FILM SCANNER

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 servo-mechanism 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.

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 readout process is to begin.

Photo Readout Process

Readout 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 readout 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 readout 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 23 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 requires 43 minutes to scan the 11.6 inches of film which correspond to a single exposure by the two lenses.

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.

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 is occupied with readout.

Readout occurs 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 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 -- 2,714 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 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 regulate the amount of current to the battery while it is being recharged, and a shunt regulator to keep the solar array output from exceeding a safe maximum voltage.

During the first weeks of its mission, Lunar Orbiter E will operate in full sunlight on nearly every orbit, and its charge controller has been selected to provide a charge rate correctly proportioned to the light conditions.

Orbiter E will also carry a voltage booster to permit use of the Image Motion Compensation equipment for photography when the solar panels are not closely aligned with the Sun, a condition which will occur at times during the mission.

Attitude Control System

During the course of its mission, Lunar Orbiter E will be called on to perform accurately a very large number of attitude changes. The precision with which it can point its cameras lies at the heart of its success and versatility as a flying photographic laboratory.

The current record is held by Lunar Orbiter IV which acted correctly on 7,067 commands and performed 670 separate attitude maneuvers. The mission planned for Lunar Orbiter E should be somewhat less demanding.

Orbiter's 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 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. The programmer memory periodically brought up-to-date by ground control, but the device can operate 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 the 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 senses 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.

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.

Twelve 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. A combination of eight coarse and fine Sun sensors views through the equipment mounting deck which forms the bottom surface of the spacecraft.

All Sun 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 is 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 from 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 active maneuvering program dictated by the nature of the mission requires an increase of about 10 percent in the quantity and pressure of nitrogen carried in the storage bottle aboard the spacecraft. A similar increase was used on Lunar Orbiter IV. The nitrogen bottle of Lunar Orbiter E will carry 16 pounds of gas at a pressure slightly above 4,100 psi. The system has been thoroughly checked and approved for operation at the increased pressure.

[illegible] of the nitrogen is budgeted for use in attitude control changes, for which it is regulated down to a pressure of 19 psi. About four pounds are assigned to the velocity control system to be used in pushing fuel and oxidizer from storage tanks into the velocity control engine.

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Velocity Control System

In the Orbiter E mission, at least four and possibly five changes in spacecraft velocity will be required after the launch vehicle has completed its work.

The first will be a midcourse correction planned for about 20 to 30 hours after liftoff. Since launch vehicle targeting for Mission V has been expressly designed for the high inclination orbit to be used, the mid-course correction should be relatively small.

Sufficient fuel will be aboard to permit a second mid-course correction if required.

The most critical velocity change will come after 89 hours of flight, as Lunar Orbiter E nears the Moon.

There the velocity control engine must execute a precision firing maneuver to slow the Orbiter enough to allow it to enter an orbit about the Moon.

Two further velocity control maneuvers are planned to adjust the high point (apolune) and low point (perilune) of the initial orbit to attain the path selected for the major part of the Orbiter E's photographic mission.

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 totalling 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 unsymmetrical 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 a dozen or more 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 is 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 executive 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 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 is used 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 Orbiters are equipped with a passive temperature control system to carry away heat generated by the energy used in operation and to limit the amount of heat absorbed when the spacecraft is in direct sunlight.

The elliptical, near-polar orbit planned for Lunar Orbiter E will expose the spacecraft to virtually constant sunlight for the first 30 days of its flight. The low perilune from which photographs will be made will subject it to more heat radiated from the Moon than Orbiter IV experienced.

For these two reasons, special steps have been taken to allow the spacecraft to reject more solar heat than its predecessors.

All sides of the spacecraft are well insulated, except the equipment mounting deck which forms the bottom of Lunar Orbiter.

The mounting deck forms a heat sink to dissipate heat generated by equipment inside the spacecraft.

Most of the mounting deck area is coated with a special white reflective paint. Additional protection was provided for Lunar Orbiter IV by cementing to the painted surface a number of small mirrors, each one inch square.

For Lunar Orbiter E, the number of mirrors has been increased to a total of 529. By reflecting sunlight falling on the deck, the mirrors compensate for the added heat loads to which the spacecraft is exposed.

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 between the upper and lower decks is covered with a multi-layer thermal blanket composed of alternating layers of aluminized mylar and dacron cloth. The highly reflective aluminized mylar effectively prevents solar heat from reaching the inside of the spacecraft.

During flight from the Earth to the Moon, Lunar Orbiter's temperature inside the thermal blanket varies between 40 and 75 degrees F. In lunar orbit, spacecraft internal temperatures will be around 75 degrees F.

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

LUNAR ORBITER TASKS

Lunar Orbiter E's primary objective is to obtain photography of scientifically interesting sites on the Moon, including landing sites accessible to Apollo, Surveyor and early Apollo Applications Program missions.

The spacecraft will fly a distributed multi-site type of mission which will include broad survey photography of portions of the Moon's hidden side.

Much of the mission is intended to enlarge scientific understanding of lunar surface features by obtaining telephoto pictures of selected sites to support more detailed analysis and interpretation than has hitherto been possible. Some of the science sites to be photographed were selected on the basis of Lunar Orbiter IV's frontside survey; interest in others was confirmed by that flight.

The goals of increased scientific knowledge of the Moon were stated in 1963 by the President's Scientific Advisory Committee:

> "...The central problems around which scientific interest in the Moon revolve concern its origin and history and its relationship to the Earth and the solar system. The Moon is a relatively unspoiled body, its surface not having been subject to wear and tear or erosion by an atmosphere and water. Hence a study of its surface may tell us its history, its age, whether it was formed when the solar system was formed, whether at some time it was separated from Earth or whether it was captured by Earth at some time in its history. Answers to these questions may profoundly affect our views of evolution of the solar system and its place, as well as man's, in the larger scheme of things..."

In pursuit of those goals, the Apollo, Orbiter, Surveyor and Ranger programs have been carried forward as an integrated effort to explore the Moon with manned and unmanned spacecraft.

The first three Lunar Orbiters had as their prime objective the location and confirmation of sites suitable for early manned Apollo and unmanned Surveyor landings.

In April, 1967, NASA announced selection of eight candidate Apollo landing sites which had been identified from Orbiter photography.

The fourth Orbiter mission completed in May, 1967, was designed to serve general scientific needs and to prepare the way for future orbital and landing missions. Its telephoto survey of 90 per cent of the Moon's front face will stand for many years as the definitive source of lunar surface information.

Lunar Orbiter E will build upon the results of its predessors in five major ways:

--- It will revisit five candidate Apollo landing sites to extend coverage obtained on the first three Orbiter missions and to look more closely at some peripheral areas which appear promising;

--- It will sample with near-vertical photography a number of sites potentially suitable for candidate landing sites in the Apollo Applications Program. The sites combine landing areas which appear reasonably smooth with nearby features of scientific interest.

--- It will photograph a number of sites which lunar scientists consider of high interest, although many lie in rugged areas unsuited to early manned landing and exploration.

--- It will survey areas of interest for potential Surveyor landings; and

--- It will add to the hidden side coverage obtained by Orbiters I through IV to raise from 60 per cent to a possible 95 per cent the Lunar Orbiter telephoto and wide angle photography of the Moon's far side.

Lunar Orbiter E will contribute to three additional areas of scientific inquiry though the following 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.

Information obtained from the selenodesy experiment will increase knowledge of the Moon's gravitational field obtained through detailed tracking of Orbiters I through IV. Lunar Orbiter E will fly in a high inclination orbit like Orbiter IV, but the lower perilune planned for the mission will be more sensitive to small gravitational effects and hence a more useful contributor to selenodesy.

Prior to the Lunar Orbiter program, detailed knowledge of the Moon's gravitational field did not exist. After four successful missions, it is now possible to predict orbital lifetimes accurately and to operate spacecraft with confidence in orbits closely approaching the surface of the Moon.

Meteoroid and radiation data are gathered primarily for spacecraft performance analysis but also are of considerable scientific interest.

Lunar Photography

Lunar photography is Orbiter's principal assignment, and the Orbiter E mission has been built around the requirement to obtain high quality photographs of selected locations on the lunar surface in detail far exceeding that visible through the best Earth-based telescopes.

The Orbiter E flight has been planned to yield a maximum of scientific information about the lunar areas to be photographed.

NASA engineers expect to operate the Orbiter E camera in a variety of modes depending on the particular target. There will be some single frame photography and some in fast or slow sequences of four or eight frames.

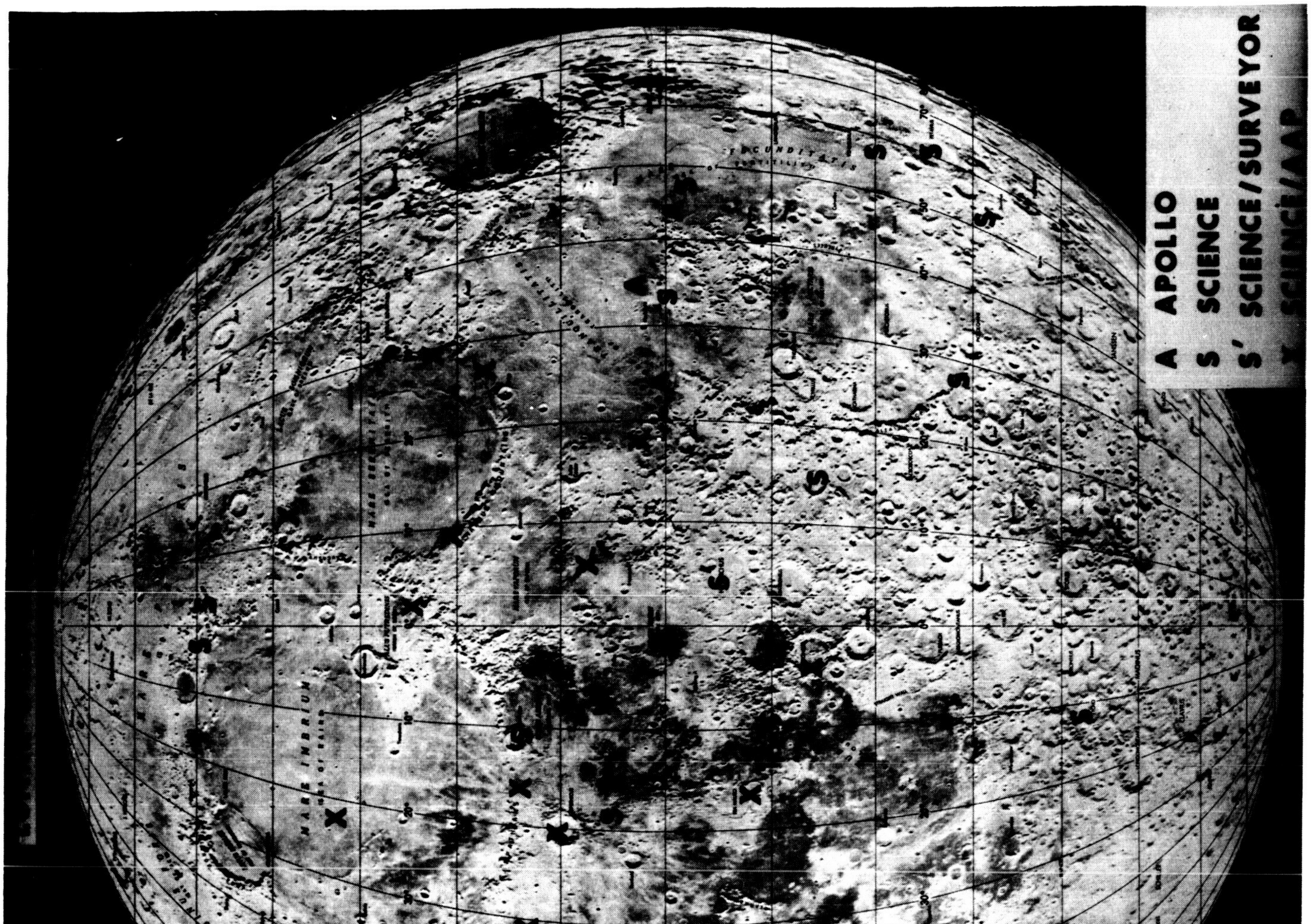
Most of the site photographs will be taken from a near vertical position over the target, but in several instances oblique pictures of the lunar surface are scheduled. A few obliques will be made with the camera pointing from east to west, providing a panorama of a potential Apollo landing area as it might be viewed from an approaching manned spacecraft.

Over the Apollo zone, a series of stereoscopic telephoto pictures is scheduled, to aid the Apollo site selection group in measuring slopes and ridges in potential landing areas.

On the Moon's hidden side, the camera will be operated from near the apolune of the orbit in an overlapping fashion similar to that used on the Lunar Orbiter IV survey mission.

During the first picture taking orbit, the spacecraft is scheduled to expose 16 frames in two eight-frame rapid sequences, one covering the region between the North Pole and the Equator and the second between the Equator and South Pole. After four additional frames are taken on succeeding orbits, enough exposed film will be accumulated to begin priority readout.

From that point in the mission, the number of exposures scheduled will vary with the targets to be photographed.


A APOLLO
S SCIENCE
S' SCIENCE/SURVEYOR
MARE IMBRIUM

As on previous flights, Lunar Orbiter pictures will be taken shortly after sunrise on the Moon, with light falling on the surface at a shallow angle to bring out the best detail. As the Moon turns beneath the spacecraft, succeeding areas to be photographed come into view of the camera on every orbit.

The hidden side photography will be made just before lunar sunset to achieve a comparably good lighting angle.

Targets on the front face of the Moon will be photographed on the ascending node of the orbit as the spacecraft is moving from south to north above the lunar surface.

On the majority of orbits during the photographic phase of the mission, Lunar Orbiter will process and transmit to Earth one or more frames of photographic coverage.

After completing photography, which on this mission will consist of 213 frames, a final picture readout will begin. Present schedules call for taking the first pictures on Aug. 6, the final frame on Aug. 19, and finishing final readout by Aug. 27.

Readout of a complete frame -- one wide angle picture with a telephoto picture centered within it -- takes about 43 minutes. Under some operating conditions, Lunar Orbiter spacecraft have been able to read and transmit as many as three frames per orbit. For readout it is necessary to have the spacecraft in sunlight with its high gain antenna pointed at one of the Deep Space Net receiving stations.

Selection of the target sites to be photographed by the fifth Lunar Orbiter was made by a NASA Surveyor-Orbiter Utilization Committee. The selection was based on a consideration of scientific interests and on the requirements of the Apollo, Surveyor, and Apollo Applications programs. The committee worked from recommendations drawn up after extensive consultation among experts from NASA's Planetology Subcommittee, the Lunar Orbiter, Surveyor, Apollo and Apollo Applications Programs, Bellcomm, the U. S. Geological Survey, University of Arizona, and NASA Headquarters.

The five potential Apollo landing sites to be revisited during the Lunar Orbiter E mission are listed in the following table. The Roman numerals refer to the previous Orbiter mission on which each was a prime target site.

Site	Coverage Frames	Mode	Site Center Longitude	Site Center Latitude	General Description
I P-1	10	2 westerly obliques + 8 stereo telephoto	42°56' E	1°00'S	A portion of a promising dark mare area in the easterly part of the Apollo zone of interest. It lies on the west edge of the Mare Fecunditatis.
II P-2	9	1 westerly oblique + 8 stereo telephoto	34°14'E	2°4'N	This area appears to be a volcanic complex in southeastern Mare Tranquillitatis where craters have been subdued by volcanic material or where craters are generally absent.
II P-6	9	1 westerly oblique + 8 stereo telephoto	23°51'E	0°45'N	One of the smoothest areas found during evaluation of previous Orbiter photography. It lies in the southern part of Mare Tranquillitatis near the crater Moltke.
II P-8	8	8 stereo telephoto	1°06'W	0°25'N	An area located in the central part of Sinus Medii. Diffuse rays and crater fields appear to cover the central area. Low ridge structures are also present. The darker areas are of particular interest.
III P-11	8	8 stereo telephoto	36°11'W	3°30'S	An Oceanus Procellarum area east of the crater Flamsteed. It is about 110 miles east of the Surveyor I landing site.

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By far the larger part of Lunar Orbiter E's photo budget -- 168 frames out of 213 or 79 per cent -- will be devoted to sites of primary interest to science. A number of the sites are potential areas of interest for projected missions in the Apollo Applications Program.

Forty-two specific locations have been scheduled for scientific photography, ranked in order of priority.

Those of highest priority will receive more intensive coverage of at least four and in some cases eight frames of near-vertical photography. The fast coverage mode of camera operation will be used, providing a generous overlap in the pictures taken. One site will be covered by four exposures in the slow mode which reduces the amount of overlap and increases the area covered.

In the highest priority group are such well-known lunar features as:

-- Copernicus, of which the outstanding oblique views made by Lunar Orbiter II remain a highlight of lunar photography;

-- Aristarchus, a site in which Earth-based infrared measurements showing a very high thermal anomaly have aroused unusual interest;

-- Hipparchus, a candidate Surveyor site at 4°05' East and 4°45' South;

-- Tycho, a fresh rayed crater that throws linear rays over the entire front face of the Moon;

-- Hyginus rille, a large feature in which very fresh craters of volcanic origin are aligned along a sunken valley;

-- Cobra Head, an unusual feature at 49°30' and 25°09' North which is the source of the Vallis Schroteri, a narrow valley within a valley; and

-- Harbinger Mountains, a complex volcanic area with sinuous rilles.

The second priority group of science sites will be less intensively photographed, although several oblique views are scheduled. They include the Alpine Valley, which was photographed in the near-vertical mode by Lunar Orbiter IV; the Altai Scarp; and the crater Messier.

Third in scientific priority is a group of sites which will be principally covered with single frame near-vertical photography, although it contains five locations scheduled to receive fast sequences of four frames each. An oblique photograph of the North Pole region is included in the third priority group.

Selenodesy

Major uncertainties about the detailed nature of the Moon's gravitational field were dispelled by the scientific contributions of Lunar Orbiters I, II, III, and IV, and as a result operations in lunar orbit can now be conducted with considerable confidence.

Although we now possess enough knowledge of the lunar gravitational field to operate spacecraft freely in lunar orbit, there is a requirement for much more detailed study and Lunar Orbiter E, like its predecessors, will be tracked with care in its high inclination, low altitude orbit.

The Moon, according to the best existing analysis, is relatively "smooth," that is, its gravitational field does not appear to possess large or unusual variations. It is sufficiently non-uniform to produce small changes in the track of any satellite around it, and these small changes, suitably evaluated by complex computer programs, permit scientists to deduce from tracking data further information about lunar gravity.

Selenodetic analysis of the tracking data of Lunar Orbiters I through IV has yielded a description of the lunar gravity field which will be used in making operational lifetime predictions for managing the mission of Lunar Orbiter E. Post flight analysis of the tracking data of Lunar Orbiter E will, in a long range sense, contribute to future manned and unmanned missions near the Moon.

Principal investigator for the Lunar Orbiter selenodesy experiment is Dr. 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

Orbiter E will carry 20 pressurized-cell detectors to obtain more 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.

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 occured. 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 the supply reel is 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 measures the dosage at the film supply reel and the other the dosage at the storage looper.

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 launch vehicle will boost Lunar Orbiter E from Launch Complex 13 at Cape Kennedy for an approximate parking orbit of 115 miles before injecting the spacecraft on its trajectory to the Moon.

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 error less than 42 mph.

Early tracking data from African and Australian sites will provide a good indication of the vehicle performance and an estimated spacecraft velocity shortly after spacecraft injection, but final numbers will not be available until the Deep Space Network stations have tracked Orbiter for some time.

Atlas-Agena Statistics

Total height on pad	105 feet
Total weight on pad	279,000 lbs.

	Atlas	Agena
Height	68 feet	23 feet
Diameter	10 feet	5 feet
Weight (at liftoff)	261,000 lbs.	15,600 lbs.
Propellants	RP-1 (11,530 gal.)	unsymmetrical dimethyl hydrazine (UDMH) 585 gal.
	LOX (18,530 gal.)	inhibited red fuming nitric acid (IRFNA) - 745 gal.
Thrust	391,000 lbs.	16,100 lbs. at altitude
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 Division, San Diego, Calif.	Lockheed Missiles & Space Co., Sunnyvale, Calif.

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DEEP SPACE NETWORK

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

Permanent stations include four sites at Goldstone, in the Mojave Desert, Calif.; two sites in Australia, at Woomera and Tidbinbilla near Canberra; Robledo and Cebreros sites, near Madrid, Spain; and Johannesburg, South Africa. All are equipped with 85-foot-diameter antennas except the site at Goldstone which has one 210-foot-diameter antenna.

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 Engineering Corp. JPL also operates the Robledo and Cebreros sites under an agreement with the Spanish government. Technical support is provided by Bendix.

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 Council of Scientific and Industrial Research and the National Institute for Telecommunications Research.

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

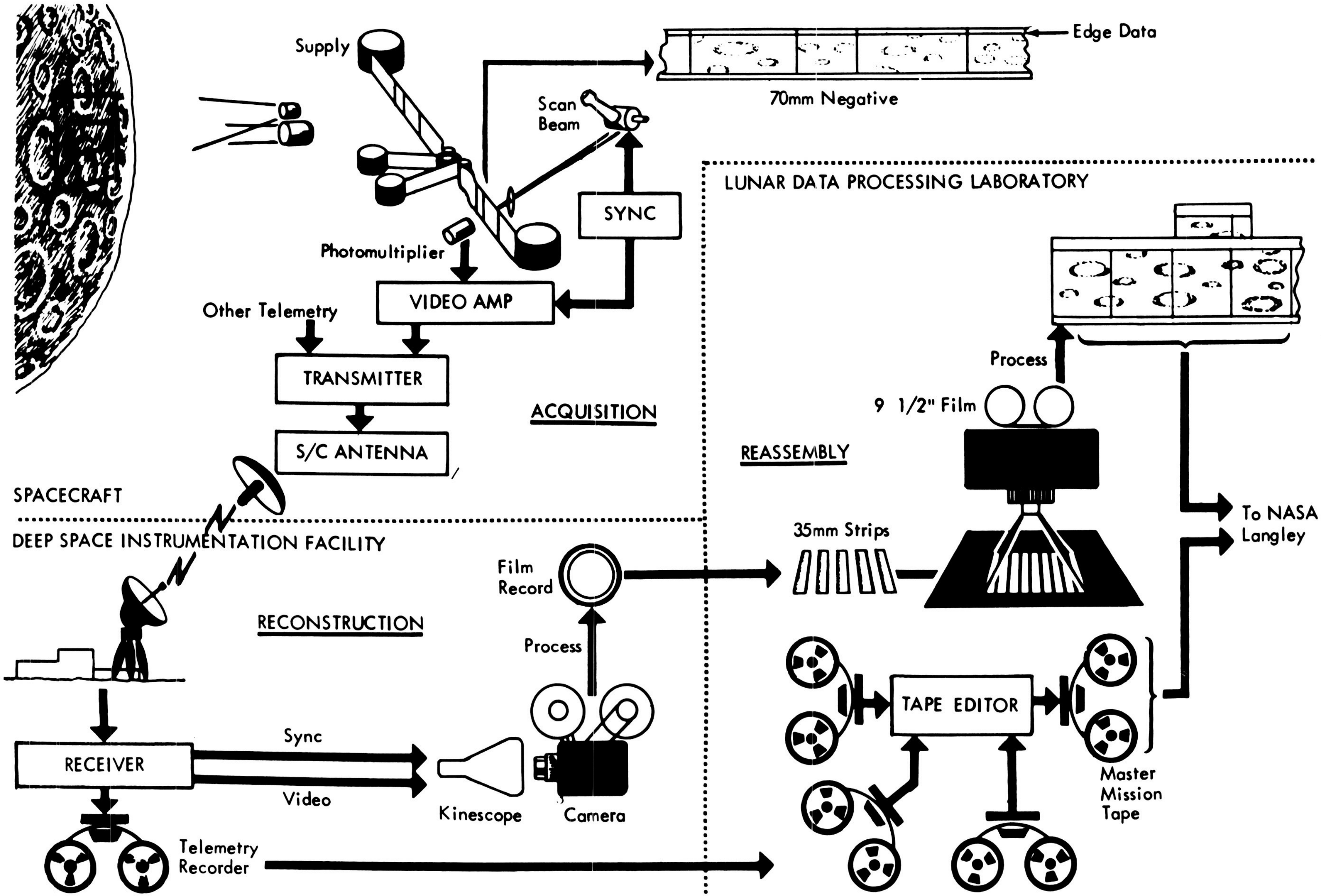
The Lunar Orbiter spacecraft was designed for maximum compatibility with existing equipment installed at DSN stations. Additional equipment installed at the three Deep Space Network stations assigned to the Lunar Orbiter project includes three racks of telemetry and command equipment and four racks of 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 seven times as large as the original negative stored on the spacecraft. This work will be accomplished at the U.S. Army Map Service, Washington, D.C.



PHOTOGRAPHIC DATA ACQUISITION, RECONSTRUCTION, AND REASSEMBLY

Data Evaluation

Although eventual reassembly and final printing of Lunar Orbiter E photography will be done by the Army Map Service Laboratories, there will be preliminary reassembly in NASA facilities at Pasadena and the Langley Research Center to provide early material for screening.

Later and more detailed evaluations of the photographs will be made by individual lunar scientists, members of the U.S. Geological Survey, and representatives of several U.S. Government mapping agencies, as well as NASA scientists.

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ATLAS-AGENA/LUNAR ORBITER E MISSION

The launch opportunity for each day in August is determined both by the relative positions of the Earth and Moon and by the Orbiter spacecraft's requirements for sunlight during its 90-hour trip to the Moon. The approximate launch times, subject to final tracking and range restrictions, for August are:

Day	Window Opens (EDT)	Window Closes (EDT)
Aug. 1	4:09 p.m.	8:00 p.m.
Aug. 2	5:56 p.m.	9:28 p.m.
Aug. 3	7:40 p.m.	10:56 p.m.
Aug. 4/5	9:22 p.m.	12:24 a.m.

Countdown Events

Event	Minus Time (Minutes)
Start Countdown	425
Autopilot System Tests	185
Atlas Battery Load Checks	185
Start UDMH Tanking	155
Finish UDMH Tanking	135
Remove Gantry	125
Start IRFNA Tanking	100
Finish IRFNA Tanking	90
Built-in Hold of 50 minutes (To meet launch window requirements)	60
Start LOX Tanking	45
Autopilot Final Test	25
Final Systems Check	25
Telemetry Final Warmup	25
Built-in Hold of 10 minutes (To meet launch window requirements)	7
Telemetry to Internal	3:30
Destruct Armed	2:30
Secure LOX Tanking	2
Atlas to Internal Power	1:40
Hold for Automatic Sequencer	18 seconds
Ignition	4 seconds
Atlas engines to full thrust	2 seconds
Liftoff	0 seconds

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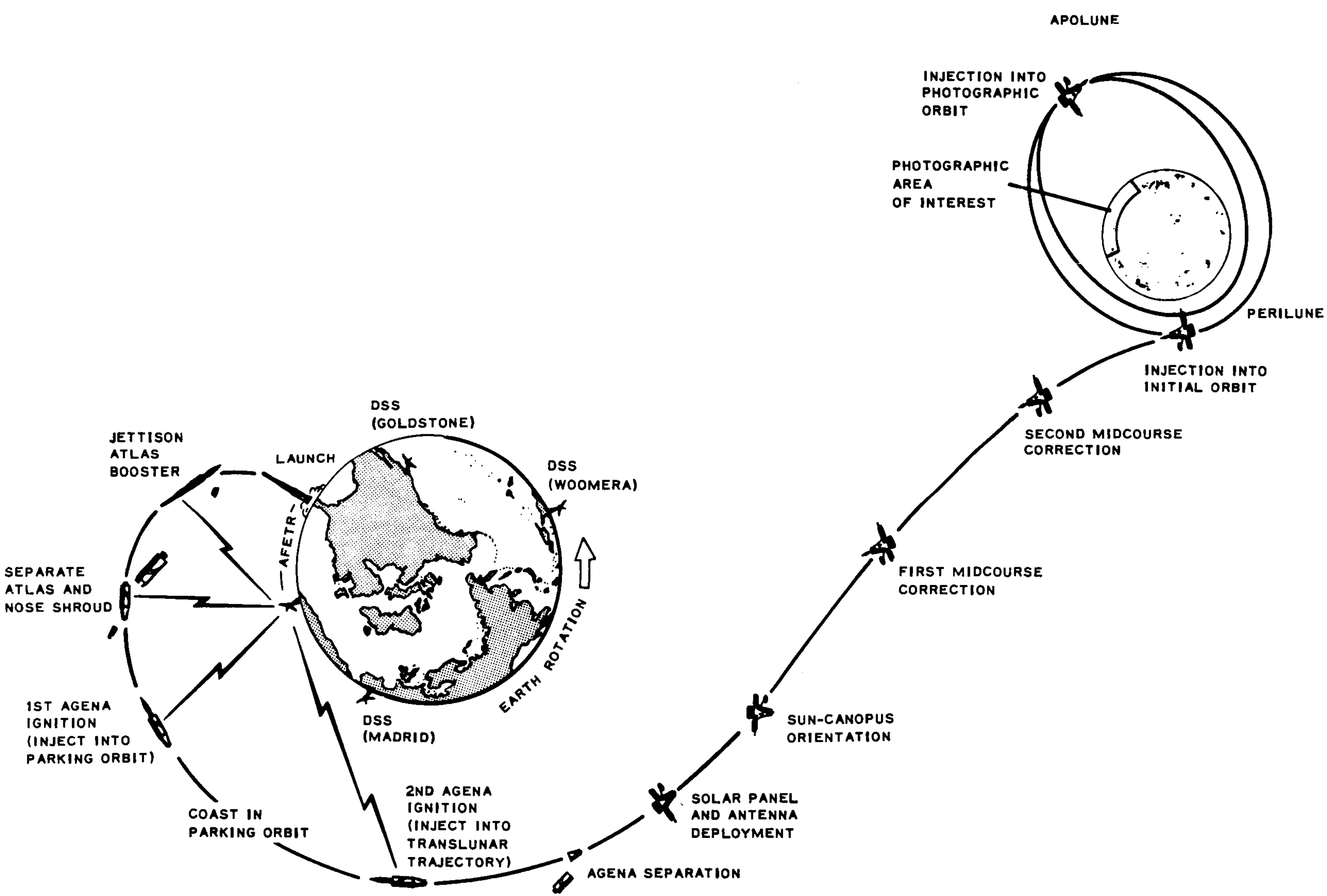
Major Flight Events

The vehicle's actual altitude and velocity during flight determine the exact times of all programmed events. For example, the Atlas booster engines will shut down (BECO) when the vehicle has achieved a velocity of 6,625 mph and a position some 50 miles downrange and 33 miles high.

The timing of launch vehicle events also varies with the day and hour of launch. Thus, the coast period between Agena first and second burn can vary between 1,811 sec. and 634 sec.

Therefore, the following schedule of major flight events serves only as an example of AtlasOAgena events on an Orbiter mission.

Event	Velocity (miles)	Altitude (miles)	Miles Downrange	Plus Time (seconds)
Booster Engine Cutoff (BECO)	6,625	33	50	128
Jettison Booster Section	6,704	34	55	131
Sustainer Engine Cutoff (SECO)	12,650	93	400	289
Vernier Engine Cutoff (VECO)	12,630	100	462	309
Jettison Shroud	12,628	100	469	311
Atlas-Agena Separation	12,624	101	475	313
Start Agena First Burn	12,560	112	647	366
End Agena First Burn	17,445	115	1,214	519
Start Agena Second Burn	17,500	1,150	5,000	varies from 1,153 to 2,330
End Agena Second Burn	24,400	1,200	5,250	varies from 1,241 to 2,419
Spacecraft Separation		2,240		varies from 1,407 to 2,585



TYPICAL FLIGHT PROFILE

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At the correct point on the ascent trajectory the radio guidance system starts Agena's primary timer which controls all Agena events except 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.

Agena's velocity meter controls the duration of engine burn. It is preset for the velocity-to-be-gained in each trajectory and, when that velocity is gained, the engine is shut down. That is, should Agena's 16,000-pound thrust engine burn a little hotter, the time of actual engine operation will be shorter but the end effect of the desired vehicle velocity will be the same.

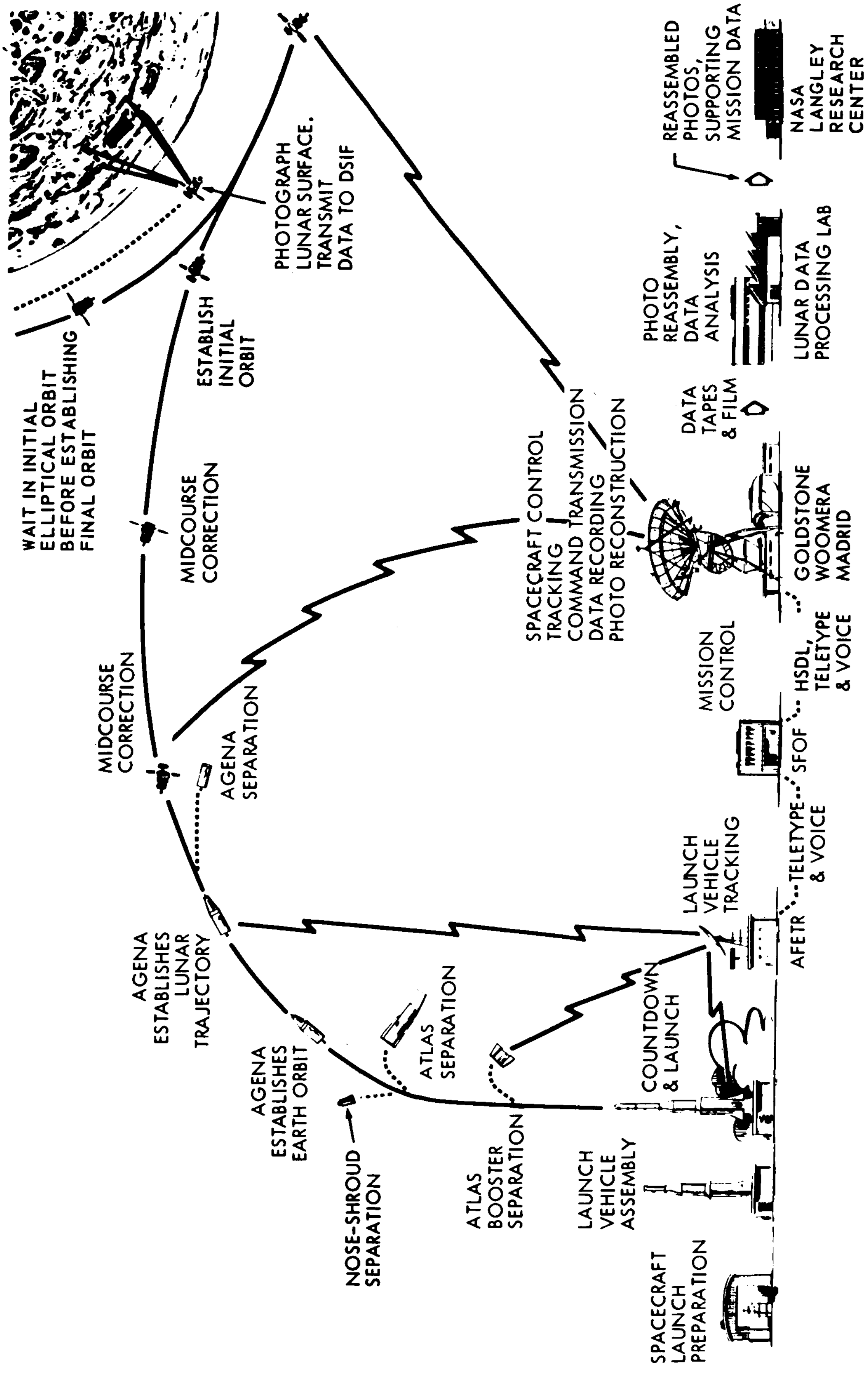
After Agena's single engine burns for the final time, the spacecraft release assembly pyrotechnic device is fired to release the V-band clamp. Four spring-loaded separation mechanisms push the spacecraft away from the Agena at slightly less than one mph and the Lunar Orbiter spacecraft will be on its translunar trajectory.

Three seconds after spacecraft separation, Agena begins a yaw maneuver which will turn it around 180 degrees in space. Then 10 minutes after separation, a signal from the primary timer fires Agena's retrograde rocket for about 16 seconds. This 137-pound thrust retrograde rocket slows Agena by 30 miles per hour to minimize the possibility that the vehicle will interfere with Orbiter or hit the Moon. With its launch job done, Agana will go into a highly eccentric Earth orbit.

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 liftoff.


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

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 20 to 30 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 flight, 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 89 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 about 10 minutes 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 an altitude of 2,500 miles above the surface of the Moon, will no longer have sufficient velocity to continue onward against the pull of lunar gravity, and will be captured as a satellite of the Moon. High point of Lunar Orbiter E's initial orbit is intended to be 3,700 miles, with a perilune or low point of about 125 miles. The orbit will be nearly polar, inclined 85 degrees to the Moon's equator. Lunar Orbiter E will require eight hours 22 minutes to complete one circuit of the Moon in its initial orbit.

After a day or more of tracking and hidden side photography in the high orbit, NASA engineers will command a firing of the spacecraft's velocity control engine to lower the perilune to about 60 miles. A similar maneuver will be scheduled later to reduce the apolune to 930 miles. The final orbit will have a period of three hours 11 minutes.

Then Lunar Orbiter E will begin its primary task of gathering detailed telephoto pictures of areas on the Moon's front face of interest to science, to Apollo, to Surveyor, and to the Apollo Applications Program.

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LUNAR ORBITER AND ATLAS-AGENA TEAMS

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

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

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