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PROJECT: RANGERS C & D

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Ranger C is scheduled in the 7-day opportunity beginning Feb. 17. Ranger D is scheduled in the next opportunity beginning 30 days later.

NEWS NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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NASA READIES TWO
RANGER SPACECRAFT
FOR MOON MISSIONS

The National Aeronautics and Space Administration is preparing two spacecraft for launch on the final missions of the Ranger Moon photography program.

The eighth and ninth Rangers, designated Rangers C and D, will be launched from Cape Kennedy, Fla., by Atlas-Agena B launch vehicles. If successfully launched they will be named Rangers VIII and IX.

Plans are to launch Ranger C in the seven-day opportunity which begins Feb. 17, and if all goes well, Ranger D will be launched in the next opportunity which begins approximately 30 days later.

Objectives are to provide further scientific information on the Moon's surface as well as lunar topographical data in support of the Surveyor soft lander program and the Apollo manned landing program.

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The single experiment carried by each of the 800-pound spacecraft will consist of six television cameras that could provide more than 4000 photographs. Ranger VII returned 4,316 high resolution photographs before it impacted the Moon July 31, 1964.

Cameras on Rangers C and D will take photographs during the final minutes of 65-hour flights before hitting the Moon. The images will be converted to video signals, transmitted to Earth tracking stations and recorded on magnetic tape and 35mm film.

The specific target for each spacecraft will depend on a number of factors such as day of launch and injection conditions.

Generally, however, primary target areas will be closer to the terminator or shadow line on the Moon than were targets for Ranger VII. Pictures taken closer to the shadow line will have more contrast and better definition of detail.

With Ranger C, scientific investigators hope to photograph one of the darker maria or seas which is free of crater rays.

Ranger VII photographed a bright mare, later named Mare Cognitum, which is streaked with rays of material "splashed" from the lunar surface when the large crater Tycho was formed. Examples of darker maria are Mare Tranquillitatis and Mare Vaporium which are accessible during the first two days of the launch period.

On each day of the Ranger C launch period, primary targets are within 13 to 20 degrees of the terminator. An impact outside these margins, however, could yield valuable data.

Primary target areas for Ranger D will largely depend on the results of the Ranger C mission.

Sensitivity to light of the three cameras with f/2 apertures on the new Rangers has been increased over those of Ranger VII to allow them to function at the light levels closer to the terminator. This is done by increasing the amplification of the video signal from the three cameras. The three cameras with the larger f/1 apertures will remain the same as the ones on Ranger VII.

Management and technical direction for the Ranger Project is assigned by NASA's Office of Space Science and Applications

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to the California Institute of Technology's Jet Propulsion Laboratory, Pasadena, Calif. This includes responsibility for the spacecraft, space flight operations, tracking and communications.

NASA's Lewis Research Center, Cleveland, Ohio, with the support of the United States Air Force, is responsible for providing the Atlas-Agena launch vehicle. Goddard Space Flight Center, Greenbelt, Md., will conduct the launch.

General Dynamics/Astronautics, San Diego, Calif., manufactures the Atlas; Lockheed Missiles and Space Co., Sunnyvale, Calif., manufactures the Agena.

The Astro-Electronics Division of the Radio Corp. of America, Princeton, N.J., designed and manufactures the six-camera television subsystem.

Tracking and communication for Ranger is the responsibility of the NASA/JPL Deep Space Network with permanent stations at Goldstone, Calif.; Woomera, Australia; and Johannesburg, South Africa. Data flowing into these stations from the Rangers will be transmitted immediately to JPL's Space Flight Operations Facility (SFOF) in Pasadena for reduction and analysis. After launch, control of the mission will shift from Cape Kennedy to the SFOF at JPL.

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TECHNICAL BACKGROUND

The following background information is applicable to Ranger C and Ranger D.

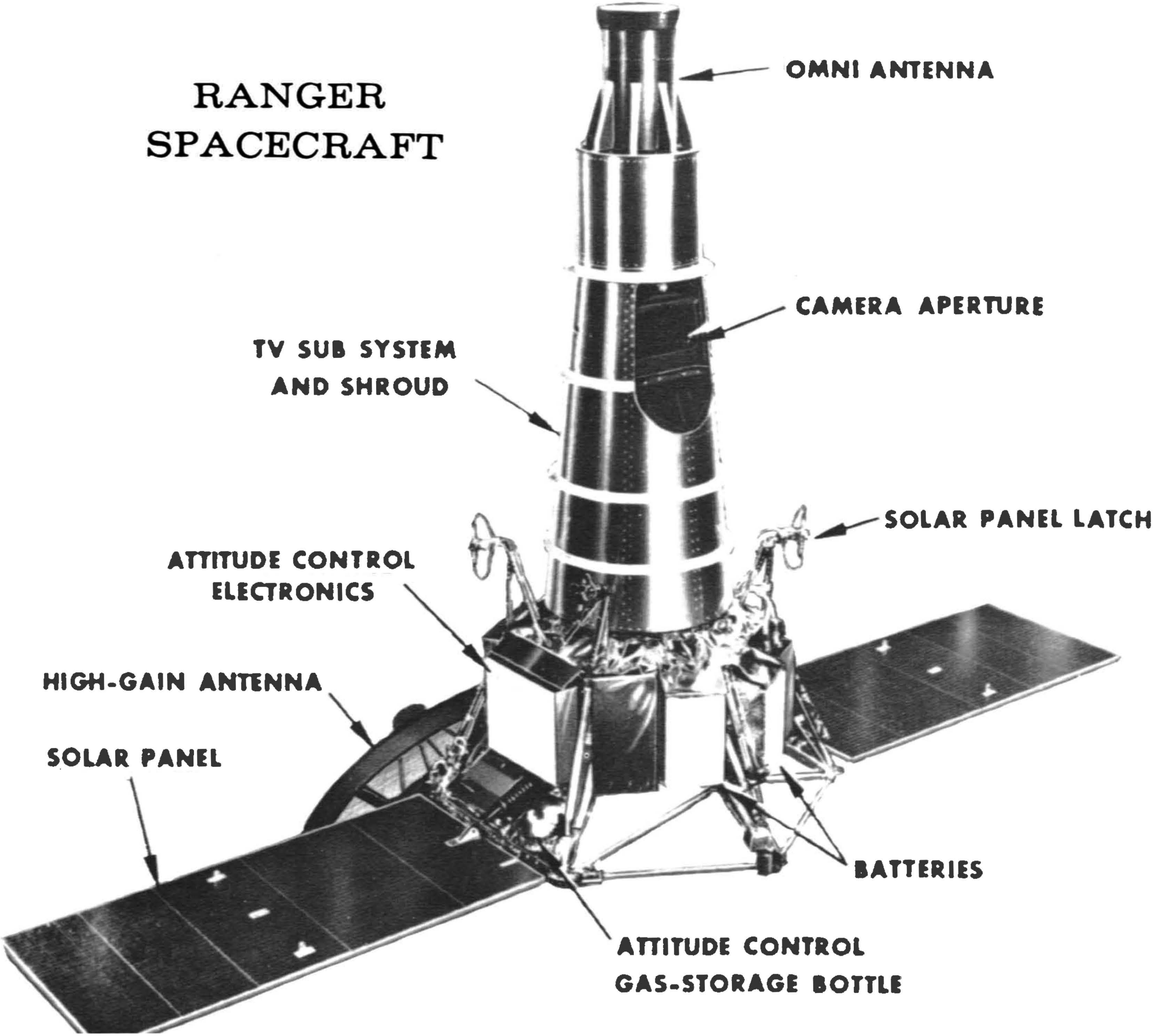
Ranger Description

The Ranger spacecraft was designed and built by the Jet Propulsion Laboratory. Industrial contractors provided a number of subsystems and components.

The design concept continues that used in earlier Rangers and Mariner planetary spacecraft of a basic unit capable of carrying varying payloads. This unit, or bus, provides power, communication, attitude control, command functions, trajectory correction and stabilized platform for mounting scientific instruments.

The Ranger bus is a hexagon framework of aluminum and magnesium tubing and structural members. Electronics cases are attached to the six sides and a high-gain, dish-shaped antenna is hinged to the bottom. The midcourse maneuver motor is set inside the hexagonal structure with the rocket nozzle facing down. The bus also includes a hat-shaped, omni-directional antenna which is mounted at the peak of the conical television system structure.

RANGER SPACECRAFT



Two solar panels are hinged to the base of the hexagon and are folded during launch. The panels provide 24.4 square feet of solar cell area and will deliver 200 watts of raw power to the spacecraft. There are 4,896 solar cells in each panel.

Two silver zinc batteries provide power for the bus during launch, prior to opening the solar panels and during the midcourse and terminal maneuvers when the panels do not point towards the Sun. The batteries each provide 26.5 volts for nine hours operation. A single battery is capable of providing power for launch, midcourse and terminal maneuvers.

The TV system will carry two batteries to operate the cameras for one hour and to provide a nominal 33 volts.

Ranger is five feet in diameter at the base of the hexagon and 8.25 feet high. With the solar panels extended and the high-gain antenna deployed, the spacecraft is 15 feet across and 10.25 feet high.

Six cases girdling the spacecraft house the following;
Case 1, Central Computer and Sequencer and command subsystem;
Case 2, radio receiver and transmitter;

Case 3, data encoder (telemetry);

Case 4, attitude control, (command switching and logic, gyros, autopilot);

Case 5, spacecraft launch and maneuver battery;

Case 6A, power booster regulator, power switching logic and squib firing assembly;

Case 6B, second spacecraft launch and maneuver battery.

Two antennas are on the spacecraft:

(1) The low gain, omni-directional antenna transmits during the launch sequence and the midcourse maneuver only and serves as a receiving antenna for commands radioed from Earth through the flight.

(2) A dish-shaped, high gain directional antenna is used in the cruise and terminal modes. The hinged, directional antenna has a drive mechanism allowing it to be set at appropriate angles. An Earth-sensor, mounted on the antenna yoke near the rim of the dish-shaped antenna, keeps it pointed at Earth. During midcourse maneuver the directional antenna is moved out of the path of the rocket exhaust and transmission is switched to the omni-antenna.

Midcourse Motor

The midcourse maneuver rocket is a liquid monopropellant engine weighing 46 pounds including hydrazine fuel and nitrogen gas which provides pressure. The fuel is held in a rubber bladder inside a pressure dome. On the command to fire, nitrogen under 300 pounds of pressure per square inch is admitted inside the pressure dome. This squeezes the rubber bladder containing the hydrazine which is forced into the combustion chamber. Because hydrazine is a monopropellant, it needs a starting fluid to begin burning and a catalyst to maintain combustion. The starting fluid, nitrogen tetroxide, is forced into the combustion chamber by a pressurized cartridge to ignite the fuel. Burning is maintained by the catalyst, aluminum oxide pellets which are stored in the combustion chamber. Burning stops when the valves turn off nitrogen pressure and fuel flow.

Attitude control of the spacecraft during the midcourse motor burn is accomplished by four jet vanes which protrude into the rocket exhaust. The vanes are controlled by an autopilot linked to gyros.

The midcourse motor can burn for periods of as little as 50 milliseconds and can alter velocity in any direction in increments of 1.2 inches per second up to 190 feet per second. It has a thrust of 50 pounds for a maximum burn time of 98.5 seconds.

Communications

Aboard the spacecraft are three radios: the three-watt receiver/transmitter in the bus and two 60 watt transmitters in the television section of the payload. The television units will transmit, during the picture-taking sequence, the images recorded by the six TV cameras. One transmitter will handle the two full scan (wide angle) cameras; the second will transmit for the four partial scan (narrow angle) cameras.

Telemetry will provide 110 engineering measurements (temperatures, voltages, pressures) on the spacecraft including 15 data points on the TV system, during the cruise portion of the flight. When the cameras are turned on, additional engineering measurements on the TV system performance will be transmitted.

The communications system for the bus includes: data encoders which translate the engineering measurements for transmission to Earth and a detector and decoder, in the command subsystem, which translates incoming commands to the spacecraft from a binary form into electrical impulses. Commands radioed to the spacecraft are routed to the proper destination by the command subsystem. A real time command from Earth immediately actuates the designated relay within the command decoder thus executing the command. Stored commands are relayed to the Central Computer and Sequencer in serial binary form to be held and acted upon at a later time.

The TV system includes separate encoders to change the television images into analog form for transmission.

Stabilization System

Stabilization and maneuvering of the spacecraft is provided by 12 cold gas jets mounted in six locations and fed by two titanium bottles containing five pounds of nitrogen gas pressurized at 3500 pounds per square inch. The jets are linked by logic circuitry to three gyros in the attitude-control subsystem, to the Earth sensor on the directional antenna and to six Sun sensors mounted on the spacecraft frame and on the backs of the two solar panels. There are two gas jet systems of six jets and one bottle each. Either system can handle the mission in the event the other system fails.

The four primary Sun sensors are mounted on four of the six legs of the hexagon and the two secondary sensors on the backs of the solar panels. These are light-sensitive diodes which inform the attitude-control system when they see the Sun. The attitude-control system responds to these signals by turning the spacecraft and pointing the longitudinal or roll axis toward the Sun. The spacecraft is turned by squirting the nitrogen gas regulated to 15 pounds per square inch pressure through the gas jets.

Computation and issuance of commands is the function of the digital Central Computer and Sequencer. All events of the spacecraft are contained in three CC&S sequences. The launch sequence controls events from launch through the cruise mode. The midcourse propulsion sequence controls the midcourse trajectory adjustment maneuver. The terminal sequence provides required commands as the Ranger nears the Moon.

The CC&S provides the basic timing for the spacecraft subsystems. This time-base will be supplied by a crystal control oscillator in the CC&S operating at 307.2 kilocycles. The control oscillator provides the basic counting rate for the CC&S to determine issuance of commands at the right time in the three CC&S sequences.

Television Subsystem

The 380-pound television package, designed and built by RCA's Astro-Electronics Division, Princeton, N.J., is shaped like a truncated cone 59 inches high, 27 inches wide at the base, and 16 inches wide on top. It is mounted on the hexagonal base of the Ranger spacecraft bus. It is covered by a shroud of polished aluminum with a 13-inch opening near the top for the television cameras. The shroud is circled by four one-inch-wide fins designed to supply proper thermal balance by absorbing solar heat during the cruise mode.

The television subsystem consists of two wide-angle and four narrow-angle television cameras, camera sequencers, video combiners, telemetry system, transmitters, and power supplies.

The six cameras, located near the top of the television tower, are designated F (for full-scan) and P (for partial-scan) cameras. Of the two F cameras, one has a 25mm, f/1 lens and field of view of 25 degrees. The other camera has a 75mm, f/2 lens with a field of 8.4 degrees.

Cameras P-1 and P-2 have 75mm, f/2 lenses with 2.1 degree fields of view while P-3 and P-4 have 25mm, f/1 lenses with 6.3 degree fields.

All cameras have high-quality lenses with five elements and metallic focal plane or slit-type shutters. This shutter is not cocked as in conventional cameras, but moves from one side of the lens to the other each time a picture is taken. The exposure time is 1/500 of a second for the P cameras; 1/200 of a second for the F cameras.

The six-camera assembly weighs 59 pounds. It is mounted so that the cameras are pointed at an angle of 38 degrees from the roll axis of the spacecraft.

All the cameras have a fixed-focus but will be able to take pictures from about 1100 miles to within one-half mile from the Moon's surface.

Behind each of the camera shutters is a vidicon tube one inch-in-diameter and 4.5 inches long. The inside of the face plate of the tubes are coated with a photo-conductive material that acts in much the same way as tubes in commercial television cameras. When a picture is taken the light and dark areas form an image on the face plate. This image is rapidly scanned by a beam of electrons capable of differentiating light and dark areas by their electrical resistance -- high resistance being a light area; low resistance, dark.

The image projected on the face plate of the F cameras is .44 inches square, while the P camera vidicon face plates use only .11 inches square. The F camera pictures are scanned 1152 times by the electron beam, but because they occupy a smaller area, the P cameras are scanned only 300 times.

The scan lines, each containing information about some part of the picture, are converted into an electrical signal and amplified. The signal is then sent to one of two video combiners in the television subsystem. There is one video combiner for the F cameras and one for the P cameras. They sequentially combine the output of the cameras to which they are mated. The output of the video combiners are then converted to a frequency modulated (FM) signal and sent to one of the two 60 watt transmitters. One transmitter sends pictures to Earth from the F cameras on 959.52 mc and the P pictures are sent on 960.58 mc.

Another vital component of the television subsystem are the camera sequencers. The camera sequencer sends three types of instructions to the cameras: (1) snap shutter; (2) read-out vidicon face plate, (3) erase face plates and prepare for next picture.

To erase images on face plates special lights built around the vidicon tubes are flashed to saturate the face plate. The plate is then scanned twice by the electron beam at increased frequency to remove all traces of the previous image.

Thus, in the case of the F cameras, the camera sequencer would send instructions alternately to each camera at 2.56-second intervals. While one camera is taking a picture, reading out, and transmitting it, the other will be erasing its vidicon face plate. The camera sequencer for the P cameras sends instructions every .2 seconds in the following order: P-1, P-3, P-2, and P-4.

The TV system includes two batteries, one for each channel. Each battery weighs 43 pounds. They are made of 22 sealed silver zinc oxide cells and provide about 33 volts. The total power capacity is 1,600 watt hours per battery.

RANGER FACT SHEET

LAUNCH VEHICLE	Atlas-Agena B	
DIMENSIONS LAUNCH VEHICLE		
Total height, with Ranger spacecraft, plus shroud	100	feet plus
Atlas	66	feet
Agena B	22	feet
Ranger with shroud	12	feet
DIMENSIONS RANGER		
In launch position		
Diameter	5	feet
Height	8.25	feet
In cruise position		
Span	15	feet
Height	10.25	feet
WEIGHT RANGER		
Structure	93.1	pounds
Communications	38.1	pounds
Attitude Control and Autopilot	60.3	pounds
Data Encoder	20.1	pounds
Central Computer and Sequencer	9.7	pounds
Propulsion	45.2	pounds

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Power (Solar Panels, Launch Backup Battery, etc.)	124.0 pounds	
Miscellaneous Equipment	38.2 pounds	
Ranger Bus Total		428.7 pounds

TV SUBSYSTEM WEIGHT

Cameras	38 pounds	
Camera Electronics	48 pounds	
Video Combiner	3.1 pounds	
Sequencer	14 pounds	
Batteries	86 pounds	
Transmitters and Associated Equipment	70 pounds	
Structure and Miscellaneous	121 pounds	
TV Subsystem Total		380.1 pounds
GROSS WEIGHT		808.8 pounds

Previous Ranger Missions

Earlier Ranger spacecraft had two assignments. Ranger 1 and 2 were development launches with the mission of proving the space flight concept (launch vehicle with parking orbit and attitude stabilized spacecraft), and making deep space scientific measurements. Although the launch vehicles did not place the spacecraft in the desired orbit, Rangers 1 and 2 were deemed successful tests of the spacecraft concept.

Rangers III, IV and V, had the mission of rough landing a capsule on the Moon to return seismic information, securing medium resolution TV pictures of the lunar surface and other scientific measurements.

Ranger III was given excessive velocity by the launch vehicle and crossed the Moon's orbital path too soon. The spacecraft, however, achieved Earth and Sun lock and executed a midcourse maneuver and an attempt was made to obtain a long range photograph of the Moon. During the terminal maneuver, in the attempt to point the spacecraft's television camera at the Moon, a malfunction occurred in the Spacecraft Central Computer and Sequencer and the maneuver was unsuccessful.

Ranger IV failed shortly after injection. The failure was believed to be in the Spacecraft's control clock. The launch vehicle, however, performed excellently and tracking revealed that Ranger IV crashed into the hidden portion of the leading hemisphere of the Moon.

Ranger V also failed shortly after injection. The failure was believed to be in the switching and logic circuitry of the power system.

Ranger VI, launched Jan. 30, 1964, carried six television cameras to obtain high resolution photographs of the lunar surface. The basic spacecraft performance was excellent and the Ranger hit the Moon in the Sea of Tranquility within 17 miles of the aiming point. The television cameras, however, did not work. Warm-up of the cameras was indicated, but the systems did not go to full power.

The conclusion reached by a failure analysis team of personnel from NASA, JPL and RCA was that the most probable cause was high voltage arcing in the television systems during launch that destroyed portions of the transmitter and possibly the camera systems. It is believed that the television systems were switched into the warm-up mode during launch. This would have resulted in arcing in the critical low pressure area between 150,000 and 250,000 feet.

On that basis, Ranger was modified to cover a number of possible causes of premature turn-on of the television system.

Ranger VII was launched July 28, 1964, and hit the Moon July 31 after performing a text-book mission. It returned more than 4000 lunar photographs of exceptional quality. The resolution was 2000 times better than any photograph of the Moon made by earth-based instruments. Craters 30 inches across were visible in the final pictures. The area photographed was a mare near the Sea of Clouds. It was named the Mare Cognitum, or "sea that has become known."

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Launch Vehicle

Total lift-off weight: 280,000 pounds
Total lift-off height: 104 feet

	Atlas-D Booster	Agena-B Upper Stage
Weight	260,000 pounds	16,000 pounds
Height	66 feet	21 feet
Thrust	About 370,000 pounds at sea level	16,000 pounds at altitude
Propellants	Liquid oxygen and RP-1, a kerosene-type fuel	Unsymmetrical Dimethylhydrazine (UDMH) and inhibited red fuming nitric acid (IRFNA)
Propulsion	Two booster engines, one sustainer engine and two vernier attitude and roll control engines built by Rocketdyne Division, North American Aviation, Inc.	One engine built by Bell Aerosystems Co.
Speed	About 12,600 mph at apogee for Ranger flight	About 17,500 mph after first burn about 24,525 mph at spacecraft injection
Guidance	General Electric radio command guidance equipment; Burroughs ground guidance computer	Honeywell, Inc., inertial guidance and Barnes horizon sensors
Contractor	General Dynamics/ Astronautics, San Diego, Calif.	Lockheed Missiles and Space Co., Sunnyvale, Calif.

Countdown

Launch countdown begins about seven hours before estimated liftoff time. This count allows some time for repair or replacement of equipment should there be any malfunctions during these checks.

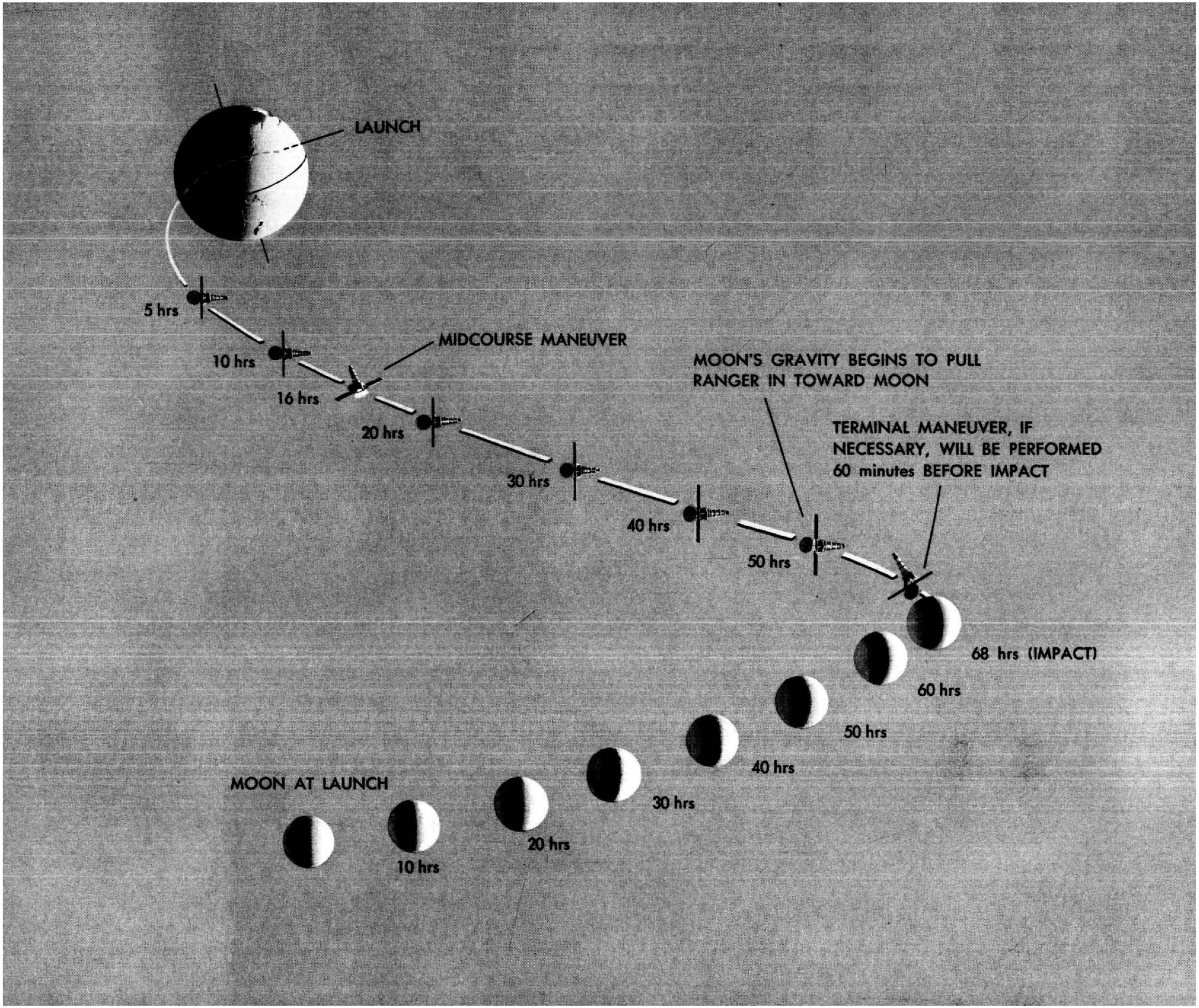
T minus 395 minutes	Start countdown
155	Start Agena UDMH tanking
135	Complete UDMH tanking
130	Remove service tower
90	Start IRFNA tanking
65	Complete IRFNA tanking
60	Evaluate countdown (built-in hold; 60 minutes maximum)
45	Start Atlas LOX tanking
7	Built-in hold (10 minutes minimum) Go/No Go status check; optimize launch time
2	Secure LOX tanking
2 seconds	Atlas engines full thrust
0	Release/Lift-off

Ranger Trajectory

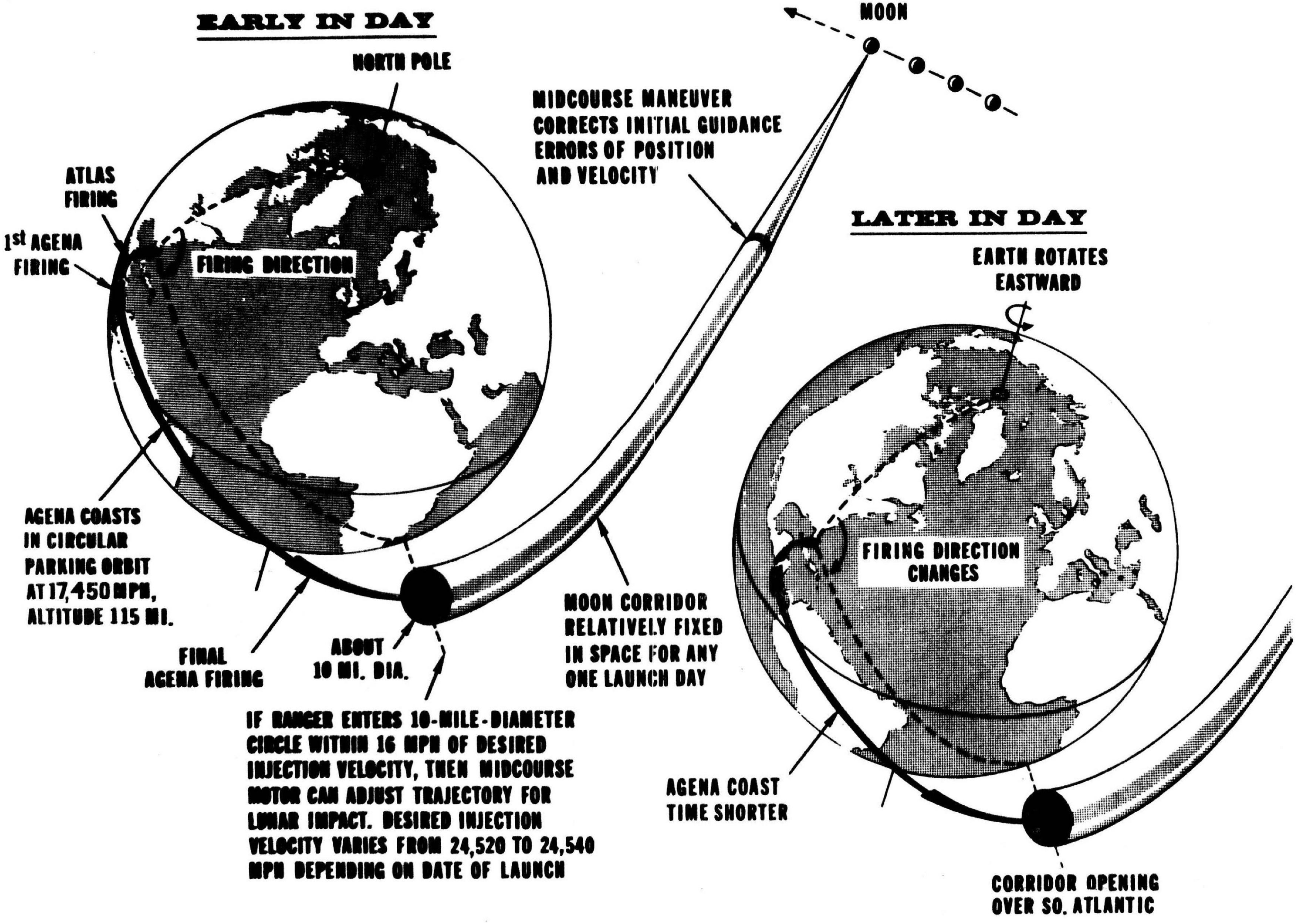
To launch a Ranger spacecraft on a trajectory from Earth that will put it on an acceptable course to the Moon requires threading the vehicle through a 10-mile-diameter target 120 statute miles above the Earth at a velocity within 16 mph of 24,470 miles per hour. If these accuracies are achieved, then a midcourse maneuver is capable of adjusting the trajectory to hit the Moon in the desired area.

This circular target in space (injection point) remains relatively fixed each day of the firing period. The Cape Kennedy launch site, however, is continually moving eastward as the Earth rotates. Therefore, the firing angle (azimuth angle) from the launch site, and the length of time spent in a parking orbit, must change minute by minute to compensate for the Earth's rotation. Actually, the trajectory engineer computes a set of lunar trajectories for each day of a launch period.

In calculating a trajectory for a Moon flight, the trajectory engineer must include the influence on the path of the spacecraft of the gravitation pull of the Earth, Moon, Sun, Venus, Mars and Jupiter. At the same time he must satisfy numerous constraints imposed by mechanical limitations of the spacecraft, a moving launch site, photographic requirements and tracking and communication considerations.


LAUNCH
5 hrs
10 hrs
MIDCOURSE MANEUVER
16 hrs
20 hrs
30 hrs
40 hrs
50 hrs
MOON'S GRAVITY BEGINS TO PULL RANGER IN TOWARD MOON
TERMINAL MANEUVER, IF NECESSARY, WILL BE PERFORMED 60 minutes BEFORE IMPACT
68 hrs (IMPACT)
60 hrs
50 hrs
40 hrs
30 hrs
20 hrs
10 hrs
MOON AT LAUNCH

TYPICAL RANGER LAUNCH TO MOON



For example, Ranger can only be launched during a portion of the Moon's third quarter. For photographic purposes the Ranger must hit the Moon on the sunlit side visible from Earth and within 10 to 40 degrees of the terminator or shadow line. Under these conditions lighting angles will provide good contrast and shadow detail in the pictures.

The new Moon and full Moon phases are not acceptable because of attitude control requirements for the spacecraft. The spacecraft locks onto the Sun and Earth for orientation and in these periods the orientation is insufficiently accurate to provide adequate midcourse or terminal maneuvers.

In the first quarter of the Moon the sunlit side is the trailing half and there are technical limitations on target areas and satisfactory lighting angles.

This leaves the third quarter as the only acceptable lunar phase for launching.

Knowing the days of the month in which he can launch, the trajectory engineer must now determine which portion of each day is acceptable. The answer is that only a few hours of each day are useable. The fact that his launch site is moving eastward and his launch angles are limited, means he can only fire at certain times and reach the injection area above the Earth.

Other constraints imposed include the requirement that the Moon be visible to the Goldstone tracking station in the Mojave desert in California when Ranger impacts. The transit time to the Moon, controlled by the injection velocity, must conform to this requirement. The injection velocity changes, from day to day, from 24,509 mph to 24,542 mph as the Moon's distance and declination relative to Earth changes.

Further, the trajectory selected must not place the spacecraft in the Earth's shadow beyond specified amounts of time. Too much time in the Earth's shadow would chill spacecraft components and then subject them to too rapid heating when the spacecraft emerged into the glare of the Sun.

After a set of trajectories for the launch period have been computed, small errors can be expected in the actual flight trajectory due to inherent limitations in the accuracy of the launch vehicle guidance system. Guidance errors, within design limits, can be corrected by the small rocket engine carried by Ranger. This midcourse correction will be commanded at about 16 hours after launch. Prior tracking of the spacecraft will have revealed the extent of the correction required.

Additional tracking of the spacecraft after the midcourse maneuver will verify and/or determine the final portion of the trajectory and the resulting impact location. This will allow accurate calculation of the terminal maneuver (changing of attitude of spacecraft to yield desired pointing direction of camera) to be performed prior to impact.

The spacecraft will be accelerated as it nears the Moon by the lunar gravitational pull. This will slightly alter the trajectory from the original elliptical path about the Earth prior to lunar impact. The spacecraft will hit the Moon at about 5800 miles per hour.

In flight the location of the impact can only be predetermined within a circle approximately 24 miles in diameter. This circle is defined by the effects of the uncertainties of location of the Moon with respect to Earth, evaluation of tracking data, influence of Sun, Moon and planets on the trajectory, location of tracking stations, precise shape of Earth and Moon and other factors. Analysis of tracking data after the flight will considerably reduce the uncertainty of the impact location.

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Mission Description

The Atlas-Agena launch vehicle will boost Ranger to an altitude of 115 miles and an orbital speed of about 17,500 miles an hour using the parking orbit technique.

The Atlas booster engines are programmed to burn a little over two minutes, the sustainer about four and a half minutes and the verniers about five minutes. When the vehicle has reached the programmed velocity and altitude, the boosters are cutoff (BECO) and jettisoned. The radio guidance system continues to determine velocity and issues appropriate commands to the Atlas until vernier engine cutoff (VECO.)

After VECO, the spacecraft shroud is ejected. Several seconds later, explosive charges release connecting bolts, retro-rockets fire and Agena draws free of the booster adapter carrying the spacecraft.

Agena ullage rockets fire to assure that the liquid propellants will fill the propellant pumps when engine start for Agena first burn is commanded. When the vehicle reaches the proper velocity, a velocity meter will command engine cutoff.

The time for Agena first cutoff is eight minutes after liftoff. When this occurs, the vehicle is injected into parking orbit some 115 miles above Africa. Agena/Ranger coasts in this orbit at essentially the same velocity and altitude until it reaches the proper place to begin the second burn aiming Ranger for the Moon.

The Agena second burn lasts about 90 seconds until the required speed for spacecraft injection into lunar trajectory is reached. This trajectory can be visualized as a ten-mile-wide tunnel that starts in space about 115 miles above the Earth. When Ranger enters this tunnel it should be traveling about 24,525 mph. If Ranger's velocity at injection is not within 16 miles per hour of this, the midcourse maneuver cannot re-direct the spacecraft toward the Moon. This demands great precision of the Agena . For example, if the second-stage Agena engine were to fire one-tenth of a second too long, Ranger would miss the Moon by as much as 1200 miles.

Several minutes after injection, Ranger will be separated from Agena. The Agena will begin re-orientation maneuvers before firing its lunar-miss rockets causing it to enter an elliptical solar orbit.

First Ranger Events

Some 23 minutes after launch, Ranger's Central Computer and Sequencer (CC&S) will give its first command, ordering the Ranger transmitter to full three-watt power. Until this time, the transmitter had been kept at reduced power -- about 1.1 watts. This is required during the time the launch vehicle passes through a critical region between 150,000 and 250,000 feet altitude where arcing can occur in high voltage devices and cause damage to components.

Separation from the Agena will cause the Ranger to begin a slow tumbling motion. The tumbling continues until cancelled out by the attitude control system during Sun acquisition. The yaw, pitch and roll gyros will generate signals to fire the cold gas jets to counteract the tumbling motion.

Separation of the Agena will start the mechanical back-up timer, the TV back-up clock, and release the CC&S for issuance of flight commands. During launch the CC&S will be partially inhibited to insure that flight commands will not be given inadvertently.

The mechanical back-up timer will remove an inhibit on the TV system at separation plus 30 minutes. Until this time the TV system has been inhibited from being turned on. However, the television back-up clock which is mechanized to turn on the TV at lunar encounter is still inhibited and remains so until launch plus 32 hours. About one hour after launch the CC&S will order deployment of the solar panels.

Explosive pin pullers holding the solar panels in their launch position will be detonated to allow the spring-loaded solar panels to open and assume their cruise position.

Opening of the solar panels will trip a switch to release the inhibit on the TV system as a back-up to the same function by the mechanical back-up timer.

Acquisition Modes

With the solar panels deployed, the CC&S will activate the Sun sensor system, gas jet system and command the attitude control system to seek the Sun. At the same time that the CC&S orders Sun acquisition, it will order the high-gain directional antenna extended. The drive motor then will extend the antenna to a pre-set hinge angle that was determined before launch and stored in the antenna control module.

In the Sun acquisition mode, the Sun sensors will provide signals to the gas jet system that maneuvers the spacecraft about until its long axis is pointed at the Sun thus aligning the solar panels with the Sun. A back-up command for Sun acquisition will also be given by the mechanical timer. Both the Sun sensors and the gyros can activate the gas jet valves.

In order to conserve gas, the attitude control system permits a pointing error toward the Sun of half-a-degree in each direction. It is calculated that the gas jets will fire 1/50 of a second each 60 minutes to keep the spacecraft's solar panels pointed at the Sun.

The Sun acquisition process is expected to take a maximum of 30 minutes. As soon as the solar panels are locked on the Sun, the power system will begin drawing electric power from the panels. The batteries will now only supply power in the event of a peak demand which the panels cannot handle and during midcourse maneuver and terminal sequence.

The next event initiated by CC&S is the acquisition of Earth by the Earth sensor. This will occur at about three and one-half hours after launch. The CC&S will activate the Earth sensor, (turning off the secondary Sun sensors at this point) and order a roll search. The gas jets will fire to initiate the roll. A radio command capability is provided to back up the initiation of this event.

During Earth acquisition, the spacecraft will maintain its lock on the Sun, but with its high-gain directional antenna pointed at a preset angle, it rolls about its long axis and starts to look for the Earth. It does this by means of the three-section, photomultiplier-tube operated Earth sensor mounted on and aligned with the high-gain antenna. During the roll, the Earth sensor will see the Earth and inform the gas jets. The jets will fire to keep the Earth in view of the sensor and thus lock onto the Earth. Earth acquisition requires a maximum of one-half hour.

The spacecraft now is stabilized on all three axes. There is some possibility that the Earth sensor, during its search for theEarth, may see the Moon and lock onto it, but the Deep Space Network stations have the capability to send an override command to the attitude control system to tell it to look again for the Earth. If this is not sufficient, the stations can send a hinge override command to change the hinge angle and then order another roll search. When the Earth is acquired, the transmitter is switched from the omni-antenna to the high-gain antenna by a command from Earth.

A rise in signal strength will be an indication that Earth acquisition has been achieved by the high-gain antenna.

With Sun and Earth acquisition achieved, Ranger now is in its cruise mode.

Midcourse Maneuver

The cruise mode will continue until time for the mid-course trajectory correction maneuver. After launch, most of the activity on the lunar mission will be centered at the DSN stations and at the Space Flight Operations Facility at

JPL.

Tracking data collected by the DSN stations will be sent to JPL and fed into a large scale computer system. The computer will compare the actual trajectory of Ranger with the course required to hit the target area on the Moon. If guidance errors before injection have put Ranger off the optimum trajectory, the computer will provide the necessary figures to command the spacecraft to alter its trajectory. This involves commands for roll, pitch and motor burn. Roll and pitch orient the spacecraft and motor burn controls the velocity increment required to alter the flight path and time of flight.

The first command from Goldstone will give the direction and amount of roll required, the second will give the direction and amount of pitch needed, and the third will give the velocity change needed. This data is stored in the CC&S until Goldstone transmits a "go" command.

Prior to the "go" command, Goldstone will have ordered the Ranger transmitter to switch from the dish-shaped directional antenna at the base of the craft, to the omnidirectional antenna mounted at the peak of the superstructure.

The directional antenna will not remain Earth-oriented during the maneuver.

Commands preprogrammed in the CC&S for the midcourse sequence initiate the following: the Earth sensor, mounted on the dish-shaped antenna, is turned off; the hinge-mounted directional antenna itself is moved out of the path of the mid-course motor's exhaust; the autopilot and accelerometer are powered and pitch and roll turns are initiated. During the maneuver the CC&S will inform the attitude control subsystem of the pitch and roll turns as they occur, for reference against the orders from Earth. An accelerometer will provide acceleration rates to the CC&S during motor burn. Each pulse from the accelerometer represents a velocity increment of 0.03 meters per second.

The roll maneuver requires a maximum of 9.5 minutes of time, including two minutes of settling time, and the pitch maneuver requires a maximum of 17 minutes including two minutes of settling time. When these are completed, the midcourse motor will be turned on and burn for the required time. As the attitude control gas jets are not powerful enough to maintain the stability of the spacecraft during the propulsion phase of the midcourse maneuver, moveable jet vanes extending into the exhaust of the midcourse motor control the attitude of the spacecraft in this period.

The jet vanes are controlled by an autopilot in the attitude control subsystem that functions only during the mid-course maneuver. The autopilot accepts information from the gyros to direct the thrust of the motor through the spacecraft's center of gravity to stabilize the craft.

After the midcourse maneuver has put Ranger on the desired trajectory, the spacecraft will again go through the Sun and Earth acquisition modes.

During midcourse, Ranger had been transmitting through the omni antenna. When Earth is acquired, the transmitter is switched to the high-gain directional antenna. This antenna will be used for the duration of the flight.

Ranger is again in the cruise mode. This will continue until time for the terminal maneuver.

Terminal Sequence

(In the following, the velocity, camera coverage, and distance from the Moon numbers represent one possible trajectory among many. They are close, however, to expected velocities and distances.)

It may be required, as the Ranger nears the Moon, to command a maneuver that will change the camera pointing direction to provide higher quality or coverage of a desirable area.

Whether or not this terminal maneuver will be required will depend upon analysis of the orientation of Ranger to the surface of the Moon by personnel in the Flight Path Analysis Area of the Space Flight Operations Facility. This information will be conveyed to the team of lunar scientists and Ranger Project officials in the SFOF who will make a decision on the requirement for a maneuver.

A terminal maneuver was not required in the Ranger VI or Ranger VII mission as the cruise attitude of the spacecraft, and the camera angles, during the descent phase were satisfactory.

If it is decided to perform the terminal maneuver, a series of turn commands will be transmitted to the spacecraft from the Goldstone station at approximately 63 hours after launch. These commands will be stored in the spacecraft's central computer and sequencer.

A "go" command will be sent to Ranger from the DSN Goldstone station at one hour from impact and the CC&S will switch the attitude control system from the primary Sun sensors to the gyros and command the first pitch turn. The spacecraft's solar panels may now be turned partly away from the Sun and in that event electrical power for the bus is supplied by one of the two spacecraft batteries.

The terminal maneuver, if performed, will require about 34 minutes. It will begin when the spacecraft is approximately 3940 miles from the Moon traveling at 3400 miles an hour.

At impact minus approximately 15 minutes, the CC&S will send a command to turn on the television system for an 80-second warm up period. A radioed command for this event can be sent as a back-up. The F chain can also be commanded into warm-up by the TV back-up clock if the latter has not been inhibited.

The spacecraft will be approximately 1180 miles from the Moon and its velocity will have increased to 4400 miles an hour due to the increasing effect of lunar gravity.

At impact minus 13 minutes and 40 seconds, the camera sequencers turn the television system on to full power. This command will be backed up by another from the CC&S at impact minus 10 minutes.

At this time, when the spacecraft is 1120 miles from the Moon, the cameras will start taking pictures and transmitting them to Earth by the two 60-watt transmitters. The timing of these events is based on a nominal flight time and can be changed slightly by the effect of the midcourse maneuver on the flight time.

Television System Operation

From this point until the Ranger crashes on the Moon's surface the two wide-angle cameras, F chain, will take about 160 pictures each at intervals of 2.56 seconds.

Each of the four narrow angle cameras, P chain, will take about 975 pictures during the descent phase at intervals of .2 second.

The first pictures taken by the cameras will show areas of the lunar surface that are 180,000 and 19,000 square miles for the F cameras and 12,500 and 1,200 square miles on the P cameras.

Some of these first pictures should have resolution comparable to those taken by Earth-based telescopes. They will be vital, however, in identifying the general area being photographed. As the spacecraft approaches the Moon the pictures will decrease in area and increase in resolution.

The two F cameras are pointed at angles so that their pictures overlap slightly. The P cameras also provide additional overlapping pictures within the area covered by F cameras.

The pictures with the best resolution will be taken a few seconds prior to lunar impact. In the case of the F cameras a picture taken at impact minus 2.5 seconds the 25mm lens would record an area of 3 1/2 square miles. The 75mm lens would cover about .38 square miles. At this time, Ranger would be approximately four miles from impact.

The P camera could take the last complete picture at .2 second before impact when the spacecraft is about 1735 feet from the Moon. The P camera's 25mm lenses would provide a picture 37,500 square feet and the 75mm lenses would cover an area of 4,350 square feet.

It is impossible, however, to tell beforehand which camera will take the last picture. Because of this fact, the resulting picture resolution cannot be exactly predicted.

The pictures transmitted to Earth will be received by two 85-foot-diameter parabolic antennas at the DSN Goldstone Tracking Station. The stations have special equipment to record the pictures on 35mm film and on magnetic tape.

The recording equipment will use about 22 feet of film for the pictures from the F cameras and about 68 feet of film for the P cameras.

Photograph Recording

The lunar photographs transmitted to Earth from Ranger will be recorded redundantly at the Echo and Pioneer sites at the Goldstone station of the Deep Space Net.

Echo will be the prime recording site. The incoming data will be recorded simultaneously on magnetic tape and on 35mm film. The pictures from the F channel and P channel cameras will be recorded on separate films. Both channels will be recorded on each of two tapes.

Two tape recorders at Pioneer site will each record both channels. The Pioneer site will also record both channels on film.

Magnetic tape duplicates and working film will be prepared from the original magnetic tapes. The film together with other pertinent data such as gain settings, noise level measurements, and test polaroid pictures will be delivered to the five member scientific team in the Space Flight Operations Facility at JPL.

The 35mm films from both sites will be stored and will not be developed until the films prepared from magnetic tapes have been evaluated. A carefully controlled processing of the original films will be based on the evaluation to insure the most satisfactory results.

Deep Space Network

The Deep Space Network (DSN) consists of five permanent space communications stations, a spacecraft monitor station at Cape Kennedy, the Space Flight Operations Facility (SFOF) in Pasadena, Calif., and a ground communications system linking all locations.

The five permanent stations are at Woomera, Australia; Canberra, Australia; Johannesburg, South Africa; and two at Goldstone, Calif.

A new station near Madrid, Spain, is under construction and will go on the air later in the year.

The DSN is under the technical direction of the Jet Propulsion Laboratory for the National Aeronautics and Space Administration. Its mission is to track, 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 Goldstone DSN stations are operated by JPL with the assistance of the Bendix Field Corp. Walter E. Larkin is JPL's engineer in charge.

The Woomera and Canberra stations are operated by the Australian Department of Supply, Weapons Research Establishment. Acting station manager at Woomera is J. Haseler, and JPL's DSN resident is Richard Fahnestock. Canberra station manager and JPL DSN resident are Robert A. Leslie and Merideth S. Glenn, respectively.

The Johannesburg station is operated by the South African government through the National Institute for Telecommunications Research. Doug Hogg is station manager and Bob Terbeck is DSN resident in Johannesburg.

At Madrid, JPL will operate the newest DSN station under an agreement with the Spanish government. Donald Meyer of JPL is station manager, and Phil Tardani, also of JPL, is DSN resident in Madrid.

Since they are located approximately 120 degrees apart, DSN stations can provide 360-degree coverage around the Earth so that at least one will always be able to communicate with a distant spacecraft.

All of the stations of the DSN are equipped with 85-foot-in-diameter antennas and receiving, data handling, and inter-station communication equipment. All stations have command capability.

At the Goldstone station redundant video recording capability is provided by the use of a second 85-foot antenna and receiving and recording equipment. A 210-foot parabolic antenna is under construction at Goldstone.

Nerve center of the Net is the Space Flight Operations Facility at JPL Headquarters in Pasadena. The overseas stations and Goldstone are linked to the SFOF by a communications network, allowing tracking and telemetry information to be sent there for analysis.

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Tracking data obtained early during launch will be computed both at Cape Kennedy and at the Central Computing Facility in the SFOF so that accurate predictions can be sent to the DSN stations giving the location of Ranger in the sky when it appears on the horizon.

Scientific and engineering measurements and tracking data radioed from a spacecraft are received at one of the stations, recorded on tape and simultaneously transmitted to the SFOF via high speed data lines, teletype or microwave radio. Incoming information is again recorded on magnetic tape and entered into the SFOF's computer system for processing.

Scientists and engineers seated at consoles in the SFOF have pushbutton control of the displayed information they require either on TV screens in the consoles or on projection screens and automatic plotters and printers. The processed information also is stored in the computer system disc file and is available on command.

This major command center, designed for 24-hour-a-day functioning and equipped to handle two spaceflight missions concurrently, is manned by some 250 personnel during a mission such as Ranger.

In the SFOF's mission control area, stations are set up for the operations director in charge of the mission, the operations manager responsible for physical operation of the SFOF; the information coordinator and for representatives from supporting technical areas.

Three technical teams support mission control personnel. Space Science Analysis is responsible for evaluation of data from the scientific experiments aboard the spacecraft and for generation of commands controlling the experiments. In the case of Ranger, the sole scientific experiment will be lunar surface photographs obtained by six TV cameras.

Flight Path Analysis is responsible for evaluation of tracking data, determination of flight path and generation of commands affecting the trajectory of the spacecraft. Spacecraft Peformance and Analysis evaluates the condition of the spacecraft from engineering data radioed to Earth and generates commands to the spacecraft affecting its peformance.

Ranger Team

The National Aeronautics and Space Administration's programs for unamanned investigation of space are directed by Dr. Homer E. Newell, Associate Administrator for Space Science and Applications. Oran W. Nicks is the Director of the Lunar

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and Planetary Programs Division and Newton W. Cunningham is the Ranger Program Manager.

Vincent L. Johnson is the Director of OSSA's Launch Vehicle and Propulsion Programs Division and Joseph B. Mahon is Agena Program Manager.

NASA has assigned Ranger project managment to the Jet Propulsion Laboratory, Pasadena, Calif., which is operated by the California Institute of Technology. Dr. William H. Pickering is the Director of JPL and Assistant Director Robert J. Parks heads JPL's Lunar and Planetary projects.

H. M. Schurmeier is JPL's Ranger Project Manager. A. E. Wolfe is Spacecraft Systems Manager and P. J. Rygh is Space Flight Operations Director.

Dr. Eberhardt Rechtin is JPL's Assistant Director for Tracking and Data Acquisition and Dr. N. A. Renzetti is Ranger DSN Systems Manager.

Five lunar scientists will evaluate Ranger photographs of the Moon to determine characteristics of the lunar topography. Principal investigator is Dr. Gerard P. Kuiper of the Lunar and Planetary Laboratory of the University of Arizona at Tucson.

Dr. Harold Urey of the University of California at La Jolla; Dr. Eugene Shoemaker of the United States Geological Survey at Flagstaff, Ariz.; Ewen A. Whitaker of the Lunar and Planetary Laboratory of the University of Arizona; and Raymond L. Heacock of the Jet Propulsion Laboratory are co-experimenters.

NASA's Lewis Research Center, Cleveland, has project management for the Atlas-Agena launch vehicle. Dr. S. C. Himmel is Agena Project Manager and Ranger Launch Vehicle System Manager and George M. Bode is Ranger Project Engineer.

The Atlas, designed and built by General Dynamics/Astronautics, San Diego, Calif., is purchased through the Space Systems Division of the U.S. Air Force Systems Command. Rocketdyne Division of North American Aviation, Inc., of Canoga Park, Calif., builds the propulsion system. Radio command guidance is by Defense Division of General Electric Co. and ground guidance computer by the Burroughs Corp., Detroit.

The Agena B stage and its mission modifications are purchased directly by the Lewis Center from Lockheed Missiles and Space Co., Sunnyvale, Calif., Bell Aerosystems Co., Buffalo, N. Y., provides the propulsion system.

Launchings for the Lewis Center are directed by the Goddard Space Flight Center Launch Operations Division at Cape Kennedy. Director of the GLO is Robert H. Gray.

Thirty-seven subcontractors to the Jet Propulsion Laboratory provide instruments and hardware for Rangers A, B, C, and D. These contracts amounted to $32.5 million.

Astrodata, Inc. Anaheim, Calif.	Time Code Translators, Time Code Generators, Ground Command Read-Write and Verify Equipment
Ampex Corp. Instrumentation Div. Redwood City Calif.	Tape Recorder for Video
Airite Products Los Angeles	Midcourse Motor Fuel Tanks
Beckman Instruments, Inc. Systems Division Fullerton, Calif.	Data Monitoring Consoles for Telemetry Operational Support Equipment, Digital Measuring/Recording for Power Operational Support Equipment
Barry Controls Glendale, Calif.	Hi-gain Antenna
Bell Aerosystems Co. Cleveland, Ohio	Digital Accelerometer Modules
Conax Corp. Buffalo, N. Y.	Midcourse Propulsion Explosive Valves Squibs
Controlled Products and Electronics Huntington Park, Calif.	Structural Supports
Dynamics Instrumentation Co. Monterey Park, Calif.	DC Amplifiers
Electro-Mechanical Research Inc. Sarasota, Fla.	Subcarrier Discriminators for Telemetry Operational Support Equipment

Electro-Optical Systems Pasadena, Calif.	Power Subsystem
Electronic Memories, Inc. Los Angeles	Magnetic Counter Modules for the CC&S
Fargo Rubber Corp. Los Angeles	Midcourse Propulsion Fuel Tank Bladders
Heliotek Division Textron Electronics Inc. Sylmar, Calif.	Solar Cells
Instrument Machine Co. So. El Monte, Calif.	Pin Pullers
Link Division General Precision, Inc. Palo Alto, Calif.	Video Processing Film Converter
Mincom Division Minnesota Mining and Manufacturing Los Angeles	Tape Recorders for Ground Telemetry Equipment
Motorola, Inc. Military Electronics Div. Scottsdale, Ariz.	Spacecraft Data Encoders, Transponder, and associated Operational Support Equipment
Nortronics A Division of Northrop Corp. Palos Verdes, Calif.	Spacecraft CC&S Subsystem, Attitude Control Subsystem, and associated Operational Support Equipment
Optical Coating Laboratory, Inc. Santa Rosa, Calif.	Solar Cell Cover Slips
Ryan Aeronautical Co. Aerospace Div. San Diego, Calif.	Solar Panels
Radio Corp. of America Astro Electronic Division Princeton, N.J.	Lunar Impact Television Subsystem and associated Operational Support Equipment
Rantec Corp. Calabasas, Calif.	Directional Couplers, Diplexers, an Circulators for the RC Subsystem
Resdel Engineering Co. Pasadena, Calif.	RF Amplifiers
G. T. Schjeldahl Co. Northfield, Minn.	Thermo Shield

Skarda Manufacturing El Monte, Calif.	Structural Components
Teb Inc. El Monte, Calif.	Structural Components
Texas Instruments, Inc. Apparatus Div. Dallas	Spacecraft Command Subsystem and assocated Operational Support Equipment
Transonic Pacific Los Angeles	Transducers Voltage Controlled Oscillators
Weber Metals and Supply Co. Paramount, Calif.	Forgings
Ace of Space, Inc. Pasadena, Calif.	Electronic Chassis
Brockell Mfg. Co. Culver City, Calif.	Electronic Chassis
Dunlap and Whitehead Mfg. Co. Van Nuys, Calif.	Electronic Chassis
Hodgson Mfg. Co. La Crescenta, Calif.	Electronic Chassis
Milbore Co. Glendale, Calif.	Electronic Chassis
X-Cell Tool and Mfg. Co. Hawthorne, Calif.	Electronic Chassis
Minneapolis-Honeywell Regulator Co. Aero Division Minneapolis	Gyroscopes

In addition to these subcontractors, there were 1200 other industrial firms who contributed to Rangers A-D.

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