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NEWS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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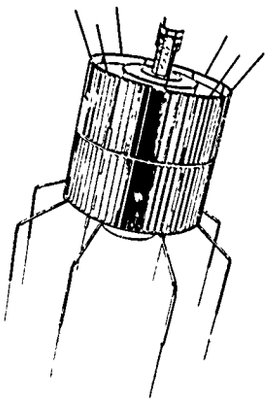

PROJECT: ATS-C

(To be launched no earlier than Nov. 3)

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APPLICATIONS TECHNOLOGY SATELLITE-C

The third in a series of five Applications Technology Satellites (ATS) directed toward the development of experiments and concepts in the useful applications of space and related space technology is scheduled for launching Nov. 3 from Cape Kennedy, Fla.

The 1,574-pound ATS-C (805 pounds after insertion into orbit) will carry nine major experiments: Color Spin-Scan Cloud Camera (SSCC); Omega Position Location Experiment (OPLE); Self Contained Navigation System (SCNS); Mechanically Despun Antenna; Image Dissector Camera (IDC); Very High Frequency (VHF) and Microwave (SHF) Transponders; Resisto Jet, and Reflectometer.

A number of engineering experiments related to the function of various spacecraft systems also will be conducted.

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ATS-C (ATS-III in orbit) will be launched by the National Aeronautics and Space Administration on an Atlas-Agena Rocket. It will be put into a synchronous (stationary) orbit over the South Atlantic Ocean.

Five of the major experiments will be tested in space for the first time. They are the SSCC, IDC, OPLE, SCNS and the mechanically de-spun antenna.

The SSCC will picture for meteorologists their first full disk of the Earth, high resolution color photographs from the synchronous, stationary orbit (22,300 miles). They are expected to be equal to pictures which could be taken by a 35-mm camera at the same altitude.

Each photo will include portions of five continents (North and South America, Africa, Europe and Antarctica) if the spacecraft is placed in proper orbit at 47 degrees West longitude over the Atlantic Ocean near the mouth of the Amazon River in South America. Resolution of the photos will be 2.2 miles at picture center.

Meteorologists hope to obtain cloud height information from the color prints at sunrise and sunset each day by studying the changes in coloring of the clouds at those times. The photos may also be useful in determining the width and location of ocean currents such as the Gulf Stream. In addition, such meteorologically important information as soil moisture content may be apparent through pictures showing green vegetation as opposed to brown deserts.

The OPLE system will test for the first time a method of locating fixed or moving remote surface or air platforms via a synchronous satellite from a controlling ground station. The link established for location can then be used to retrieve data sensed locally by the platform and to send commands to it.

Each OPLE location operation utilizes signals from three of the ground stations of the Navy's Omega surface-to-air navigation system which emits continuous signals.

In the normal operation of the Omega system, signals from three stations would be received aboard a ship or aircraft and a phase comparison between the signals made. The phase comparison would be the basis for a computation of the location of the ship or aircraft. The phase comparison and location computation would be done on the ship or aircraft.

In the case of OPLE, the Omega signals are received by a moving or fixed platform which then transmits them via the VHF transponder of the satellite to the ATS ground station. Phase comparison of the Omega signals is then made at the ground station, as is computation of the position of surface or air platform. This location information may be transmitted back through the satellite to the platform if necessary. The advantage of the system is that the rather complex and bulky equipment for phase comparison and location computing can be located at a convenient center or station rather than at the platform.

OPLE will be able to interrogate such platforms for meteorological or oceanographic information such as water temperatures, wave heights, air temperatures and define information on wind or current velocity.

One of the more promising potential applications of the system is its possible use in navigation and air traffic control, especially in the coming era of supersonic aircraft.

Six OPLE packages are expected to be operating at the time of the ATS-C launch. Fixed stations will be at NASA's Goddard Space Flight Center, Greenbelt, Md.; Saint Cloud, Minn., and Winkfield, England. A mobile van will be operating on the Eastern Seaboard and a mobile van will operate within a 50-mile radius of Goddard. The sixth package will be aboard a Coast and Geodetic Survey ship, the Discoverer, operating out of Miami, Fla.

Within a few months, OPLE packages are slated for aircraft, balloons and bucys. Additional fixed stations are planned for Bermuda and the Grand Canary Islands.

The Self Contained Navigation System (SCNS) has applications for both manned and unmanned spacecraft. By using this system for orbital attitude determination, a spacecraft would not need tracking stations on the planetary body it might be orbiting.

To determine the orbit of ATS-C, baseball-sized steel balls will be ejected from the spacecraft while optical sensors on board observe their position against a star background. With the aid of an on-board computer, the spacecraft can determine its own orbit to within five miles and its attitude (all three axes) within 10 seconds of arc. Such information could be transmitted back to Earth, in the case of an unmanned spacecraft circling another planet, or it would be immediately available to astronauts in the case of a manned spacecraft.

The mechanically de-spun antenna experiment has been designed to provide higher quality communications (voice, TV and facsimile) than has been possible with previous communications satellites.

Because this antenna receives ground signals 10 times more effectively than previous antennas, lower power transmitters can be used on the ground. This results in less interference with commercial microwave links on Earth.

The VHF experiment will permit high-quality, two-way voice communications between the ground and aircraft which are thousands of miles away.

VHF experiments will be conducted between Goddard and various domestic commercial airlines including PAA, United, American, TWA and Eastern. Discussions are underway with British Overseas Airways Corp., Air France, Air Italia (Italy), Lufthansa (Germany) and Air India, all of which have expressed an interest in participating.

Experiments will also be conducted with a German research ship, the Meteor, which is based at Hamburg, Germany.

Also, meteorological data such as cloud cover pictures, weather maps and charts will be sent via the VHF frequency, from one central point to remote stations scattered over about one third of the world.

The microwave experiment will permit transmitting television (color and black-and-white), voice, telegraph and digital data to several ground stations simultaneously. The United States ATS stations are at Rosman, N. C.; and Mojave, Calif. Other participating stations are at Nova Scotia, Canada; Goonhilly Downs and Chilbolton, England, and Pleumeur-Bodou, France.

ATS-C will be the first spacecraft to carry an Image Dissector Camera (IDC). Engineers are interested in seeing how this electronic scanning, as opposed to mechanical scanning, camera will perform in space. It is believed that the IDC will be more suitable for less stable, spinning platforms, in that it can repeat scan lines immediately rather than mechanically continue line-by-line scans. Such a camera would be able to correct itself should one or more of the 1,328 lines-per-picture be garbled.

The IDC will take black-and-white meteorological pictures of more than 40 million square miles with a resolution of about 4.5 miles at picture center.

Two more spacecraft (ATS-D and E) remain in the program. Both of these satellites use a gravity gradient stabilization control system and will be placed into synchronous orbits. The two spacecraft will be launched within about the next 18 months.

The ATS program is directed by NASA's Office of Space Science and Applications with Goddard responsible for project management.

NASA's Lewis Research Center, Cleveland, is responsible for the Atlas-Agena launch vehicle. Launch operations are directed by NASA's Kennedy Space Center's Unmanned Launch Operations, Fla.

Hughes Aircraft Co., Culver City, Calif., is responsible for the spacecraft and integration of spacecraft experiments. General Dynamics/Astronautics, San Diego, Calif., developed the Atlas booster and Lockheed Missile and Space Corp., Sunnyvale, Calif., developed the Agena vehicle.

BACKGROUND AND TECHNICAL INFORMATION FOLLOWS

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THE ATS PROGRAM TO DATE

The first Applications Technology Satellite was launched into a synchronous orbit over Christmas Island in the Pacific Dec. 7, 1966. All of its meteorological communications and scientific experiments continue to operate and return data to Earth. The satellite has exceeded its test objectives.

ATS II, launched last April 5, is in a highly elliptical orbit, is tumbling, and will be turned off next month. The flight failed when the Agena did not re-ignite. The satellite was intended to achieve a circular orbit of some 7,000 miles. The spacecraft and its communications, meteorological and scientific experiments are returning useful information.

ATS II's orbit, which ranges from 115 miles to 6,900 miles, made it impossible to conduct the primary experiment of stabilizing on the Earth with a gravity gradient control system. Satellites using the gravity gradient require a circular orbit.

The 123-foot long gravity gradient rods on ATS II extended as planned, but they were severely damaged when the satellite passed through high velocity at perigee.

A brief resume on the success of the major experiments aboard ATS I follows:

Microwave Communications (SHF)

More than 3,000 hours of tests have been conducted with this experiment.

High quality color television pictures have been received at stations at Rosman, N.C.; Mojave, Calif.; Cooby Creek, Australia, and a station near Tokyo, Japan.

Many tests have been made of the multiple access mode, which means that all of the stations participated simultaneously.

Good quality meteorological pictures are still being received daily using the wide-band mode of this experiment.

Very High Frequency (VHF) Communications

ATS I was the first satellite which permitted two-way voice communications (VHF) between aircraft and the ground.

Increased air travel over long flights using higher performance jet aircraft, makes this experiment especially applicable over oceans and sparsely populated areas.

The first of these tests began Dec. 19, 1966, with standard, off-the-shelf, antennas and associated electronic equipment. Initial voice quality of these tests was good and has since improved with the introduction of especially designed antennas and electronic equipment. Several commercial airlines now have the new equipment.

More than 1,000 hours of VHF tests have been conducted. These two-way voice tests have been held with United, American, Pan American, Trans World and Eastern airlines, and with Japanese and Australian air carriers.

The VHF channel on ATS I has been used in several tests with U.S. Coast Guard cutters operating several hundred miles at sea where reliable communications are not always possible.

In October, 1967, the satellite was used to support Coast Guard cutters operating in the Antarctic, and a team of Coast and Geodetic Survey personnel on Pitcairn Island in the Pacific.

Some of the tests were conducted between Goddard and airplanes thousands of miles away. Several tests were run when planes were taxiing on Mid-Pacific Islands.

Spin Scan Cloud Camera

The spin scan camera on ATS I has photographed the whole Earth's disk (about 39 per cent of the globe) from 55 degrees north to 55 degrees south latitudes on a daily basis since Dec. 11, 1966.

More than 3,000 pictures have been taken. These pictures, made in the green portion of the solar spectrum make it possible to resolve cloud elements or geographical features measuring about two miles across, from a synchronous altitude of 22,236 miles.

With the wide range of light and dark sensitivity of the camera system, it is possible to detect thin clouds as well as very bright thick clouds. Because of the synchronous orbit, movies of weather motion have been possible from these photos.

These movies have shown the life cycle of a large variety of storm systems, such as major disturbances and their associated jet streams, large areas of convection or massive air motion affecting cloud patterns in the tropics as well as typhoons and families of typhoons in the Pacific. The destructive hurricane Beulah in the Atlantic also was photographed by this camera.

In a two-week period in September, ATS I photographed the beginnings of hurricane Sarah in the eastern Pacific and its eventual death north of Wake Island.

The high resolution capability of ATS I pictures makes it possible to see and study individual cloud "streets" or corridors and other mass air motion phenomena.

As a result of pictures transmitted from ATS I, it is now possible to measure the rate of motion of cloud systems and individual clouds to a high degree of accuracy, within about three miles per hour.

When the altitude of these clouds can be determined accurately by infrared measurements, or color photography, these photos form the basis of a system to measure the winds in the troposphere, the highest layer of the Earth's atmosphere at which temperatures decrease with increasing altitude. "Numerical" long-range forecasting, associated with large-scale use of computers in preparing data, also would become possible with the availability of new information about winds in the troposphere.

The ATS I camera has photographed many meteorological phenomena, including:

Large scale air motion systems in the tropics. The cirrus clouds from these systems are carried on strong jet-like currents to high latitudes;

Cloud systems in the equatorial regions show that, in the upper troposphere, strong winds cross the equator from one hemisphere to the other and return, revising old theories that this phenomenon did not exist;

East-west wave motions in the tropical cloud systems appear to be trapped near the equatorial belt;

An equatorial dry zone, with minimum cloud activity, straddles the equator. It has remarkable persistence extending over several months;

Movies of a squall line formation from which tornadoes developed over Belvidere, Ill., early this year show the clash of northward flowing warm air and cold air flowing southward;

Studies show that wind on the surface of the sea can be measured within 15 per cent of its actual velocity in areas of "sun glint" or bright reflection of sunlight from the water surface;

Many hurricanes and typhoons have been tracked from birth to death. Air motions within the storm and movements of these storms are being studied;

Photos taken of the Moon have been used to calibrate the camera's light sensitivity;

The reflecting properties of clouds, as viewed from a variety of angles, are being studied.

The main advantage of the Spin Scan Cloud Camera over previous meteorological cameras, is its ability to return cloud cover pictures virtually continuously, locating weather phenomena accurately over specific points on Earth.

A second feature is the ability to make time-lapse movies, assembled from these photos.

Weather Facsimile Experiment (WEFAX)

Good quality weather facsimile pictures, maps and charts, are being received daily by several low cost Automatic Picture Transmission (APT) stations in the United States, Toronto, Canada, and Pacific area.

This experiment is scheduled for a minimum of one hour daily. During the hurricane season, this experiment was scheduled for an additional 10 minutes as a part of the hurricane watch.

The WEFAX experiment also supported the Line Island Experiment on the atoll of Palmyra, about 1,000 miles south of Hawaii last March and April.

The Line Island experiment was a short term field research program to study, on a daily basis, cloud cover pictures in the area where tropical storms are born.

ATS I pictures were radioed to Mojave, Calif. Using the ATS I WEFAX experiment, the photos were sent back to ATS I and relayed to an Automatic Picture Transmission (APT) station on Palmyra.

THE SPACECRAFT

Spacecraft Structure

ATS-C is a spin stabilized spacecraft. It is a cylindrically-shaped, lightweight structure with a large adaptable volume for mounting various types of experiments.

It is six feet long, five feet wide and weighs about 1,574 pounds at spacecraft separation from the Agena. After apogee motor burnout, the spacecraft will weigh 805 pounds.

ATS-C's primary structure is composed of two main subassemblies: the aft structure sub-assembly and the center structure sub-assembly.

The aft structure is composed of a circular thrust tube, 13 inches long and 29 inches in diameter, an intermediate bulkhead, aft ring frame, and eight radial ribs.

The center structure includes a sheet metal center thrust tube, 19 inches long and 29 inches in diameter, eight longitudinal members, and 16 sheet aluminum longitudinal stiffeners.

An annular-ring honeycomb shelf, attached by screws to the forward end of the center thrust tube, provides a mounting surface for electronic units. The outer edge of the shelf is longitudinally supported by eight struts extending from the outboard corner of the ribs.

The spacecraft is equipped with a 360-degree forward solar panel and eight aft, 45-degree segmented solar panels. The forward panel supports the Sun sensors, axial jets, and the eight 5-foot-long VHF experiment whip antennas.

The integrated triple-mode repeater, VHF repeater, and Mechanical Array Control Electronics (MACE) package are situated about the center thrust tube and attached to the stiffeners.

The forward shelf is used as the mounting platform for all telemetry and command packages and the main electrical wiring harnesses. This shelf is an important structural item, serving to stabilize the circular shape of the forward solar panel and the outer stringers.

The apogee kick motor is contained within the thrust tube, aft of the mechanically despun antenna and is mounted with the nozzle extended aft of the 360-degree panel.

The mechanically despun antenna is mounted on the cruciform structure within the forward end of the thrust tube.

The two nitrogen spin-up system tanks are mounted between the forward assembly ribs while four hydrogen peroxide tanks and two hydrazine tanks are mounted about the center section thrust tube.

All tanks are symmetrically positioned to improve balancing operations.

Thermal Control Subsystem

Thermal control of the ATS-C spacecraft relies completely on the passive balance of energy coming from the Sun on the spacecraft and re-radiation of infrared energy to space.

The external properties of the solar panels control the average temperature of the spacecraft.

Based on the known thermal properties of the solar absorption and infrared emittance of the panels, and the spinning mode of the spacecraft, solar panel temperatures are expected to vary from 55 to 85 degrees Fahrenheit (F) during normal operation, over a range of Sun angles between 65 degrees and 115 degrees.

Those portions of the solar panels extending beyond the body of the vehicle structure will operate approximately 20 degrees F cooler than the remainder of the panel during normal conditions.

During the maximum period when the spacecraft is in the Earth shadow, 72 minutes, the solar panels are expected to drop in temperature to a minimum of minus 80 degrees F.

Temperatures of the electronic and payload subsystems mounting surfaces are dependent on the mode of spacecraft operation. The expected temperatures at the major equipment attachment points during normal orbital operation is 70 degrees F, plus or minus 30 degrees F.

During a solar exlipse, the electronics and payload will cool less rapidly than the solar panels and to a less severe minimum temperature.

For the maximum eclipse, the electronics and payload mounting surface temperature will drop to a minimum of 20 degrees F.

The apogee kick motor temperatures between launch and apogee will vary from 70 to 90 degrees F. depending on solar orientation during this phase of the mission.

After the apogee motor fires, the high motor temperatures of 700 degrees F. cause heat to soak back into the spacecraft resulting in some localized structural temperature maximums of 200 degrees F. occurring for one half to one hour after motor firing.

Cooling to normal orbital temperature is completed about six hours after apogee motor burnout.

Reaction Control Subsystem

ATS-C has three types of reaction control subsystems. The satellite uses a cold gas nitrogen subsystem for spinning up the spacecraft at separation to the required 90 revolutions per minute (rpm). In order to conduct the self-contained navigation experiment, the spacecraft will spin up to 100 rpm using either hydrogen peroxide or hydrazine subsystem jets. These latter two subsystems are used also for initial longitude positioning, orbital inclination and eccentricity adjustments, and to keep the satellite on station at a point directly above the equator.

Spin-up of the spacecraft is accomplished through blowdown (expulsion) of gaseous nitrogen through nozzles which are located in a plane near the spacecraft center of gravity.

A maximum design system of pressure of 3,450 pounds per square inch (psi) is available for spin-up with a lift-off pressure of approximately 3,145 psi planned to achieve a spin speed of 90 rpm. Final loading pressure depends directly on the final roll moment of inertia of the spacecraft and will be adjusted accordingly. Peak thrust of the system is 75 pounds through a nozzle of about 0.19 inch with blowdown to five per cent of initial thrust in approximately 16 seconds.

ATS-C contains two independent five pound thrust control jet subsystems, an "A" and "B" unit. The A system contains two tanks and will be filled with hydrazine propellant. The four tanks in the B system will be filled with hydrogen peroxide propellant.

Together, the two systems can provide an effective velocity increment of about 800 feet per second (fps).

The A, or hydrazine jet subsystem, is an experimental reaction control system which has never been used in space.

The hydrazine tanks will be partially filled with propellant, up to a maximum of 40 pounds which is 75 per cent of capability, and then pressurized with Nitrogen to 200 psi initially.

A 40-pound hydrazine load in the system makes it capable of delivering an effective velocity increment of about 330 fps.

The tanks of the B system are filled to about 59 per cent of capacity with hydrogen peroxide and then pressurized with nitrogen to 200 psi at 70 degrees F.

The hydrogen peroxide system, using jets delivering two-and-one-half to five pounds of thrust, is expected to control the spacecraft in an orbital environment for at least three years.

Command and Telemetry Subsystems

The command and telemetry subsystems will provide ground control of the spacecraft as well as send experiment and basic "housekeeping" data to ground receiving stations.

All spacecraft command sequences are initiated at Goddard and transmitted to the spacecraft from Rosman, N.C., and Mojave, Calif.

The command portion of the telemetry and command subsystem is redundant, consisting of two command receivers, two command decoders, and two command regulators. The receivers and decoders are cross-strapped so that each receiver can operate with each decoder.

Commands are transmitted to the spacecraft at a frequency of 148.26 megahertz (MHz) using eight bits for decoder address and another eight bits for the command. The command subsystem can handle up to 256 redundant commands. At the desired time of execution, an audio tone is transmitted to the spacecraft.

The telemetry portion of the telemetry and command subsystem consists of two transmitters, two encoders, signal conditioning units, and two regulators. One transmitter operates at 136.47 MHz and the other at 137.35 MHz. The two transmitters are cross-strapped with the two encoders.

The telemetry transmitters and command receivers are connected through a diplexing arrangement to a single turnstile antenna. The antenna is constructed of eight quarter-wave whips placed at 45-degree intervals around the spacecraft circumference.

The dipoles are fed from a balanced (not grounded) line. Thus, each of the eight whips tends to act independently as a monopole and the gain is essentially uniform in all directions.

Electrical Power Subsystem

This subsystem consists of an upper and a lower solar array and two independent nickel-cadmium battery packs. Initially, it supplies about 185 watts of power. This is expected to drop no lower than 125 watts even after three years in orbit, despite the degradation caused by radiation on the solar cells. Most non-peak electrical loads can be sustained by this lower power level.

Each of the solar arrays contains 11,000 solar cells to give the spacecraft a total of 22,000 solar cells to power the spacecraft while in Sunlight. These are negative-on-positive cells which are protected against much of the space radiation damage by fused silica covers measuring 30 thousandths-of-an-inch thick.

Each of the two battery packs contains 22 cell units which provide a total storage capability of 12 ampere-hours. This is sufficient to operate the spacecraft when it is eclipsed from the Sun or when transient peak loads are required.

The two solar arrays and two battery packs are divided into separate power subsystems which can be paralleled into one unit on command. Each main solar array directly powers spacecraft systems and maintains the voltage between about 25 and 33 volts. The upper limit is maintained by a voltage limiter and the lower by a battery discharge control circuit.

All experiment payloads and major electrical units are powered by 25-volt regulators which automatically disconnect the payloads from the spacecraft if they draw more than the prescribed current. A few high current transient loads, such as the spacecraft spin-up system and the apogee motor ignition squibs, are not regulated in this manner. These units are automatically disconnected after firing to insure against short circuit. All of these systems can be reset by the VHF command system.

ATS GROUND STATIONS & TRACKING

Command sequences are initiated at Goddard and transmitted to one of the two ATS ground stations for ultimate transmission to the spacecraft.

The primary ATS ground station is at the Rosman, N.C. facility which has an 85-foot dish antenna. The other is at the Mojave, Calif. facility which has a 40-foot parabolic antenna.

In addition to command equipment, these stations have Super High Frequency (SHF) and Very High Frequency (VHF) communications equipment as well as improved range-and-range-rate (R&RR) equipment for orbit determination purposes.

The R&RR equipment at the ATS ground stations was designed to send and receive signals through the SHF, or microwave, transponder on the spacecraft. The high-power and broad bandwidth of this transponder provides a R&RR signal with a high signal-to-noise ratio.

As a result, range of the ATS-C can be determined with a resolution of about five feet in range and approximately one third inch per second in range rate.

Range is a measure of distance from a fixed ground point to the moving spacecraft, and range rate is the rate of change of this distance from the point.

ATS-C will also be tracked by the world-wide STADAN (Space Tracking And Data Acquisition Network) during the early phases of powered flight. Assisting STADAN, during the transfer orbit, will be a NASA portable station at Cooby Creek, Australia, a Japanese station near Tokyo and the Ahmedabad, India, station which recently became operational.

Participating Stations

Stations other than the United States which plan to participate in the ATS-C experiment include Mill Village, Nova Scotia, Canada; Goonhilly Downs and Chilbolton, England; Pleumeur-Bodou, France, and Gothenburg, Sweden.

ATS-C EXPERIMENTS

Meteorological Experiments

Multicolor Spin Scan Camera System — Univ. of Wis. and GSFC

It is believed that color photographs will yield a significantly greater amount of meteorological information over the black and white prints which have been taken in the past.

The color photographs taken by the Gemini astronauts show that there is a substantial amount of additional information in color contrast over brightness contrast. The brightness range for the same scene in black and white offers much less contrast.

The possibility of locating ocean currents from the color of its biological life will be investigated. The Gulf Stream, as an example, is aqua while the ocean is blue.

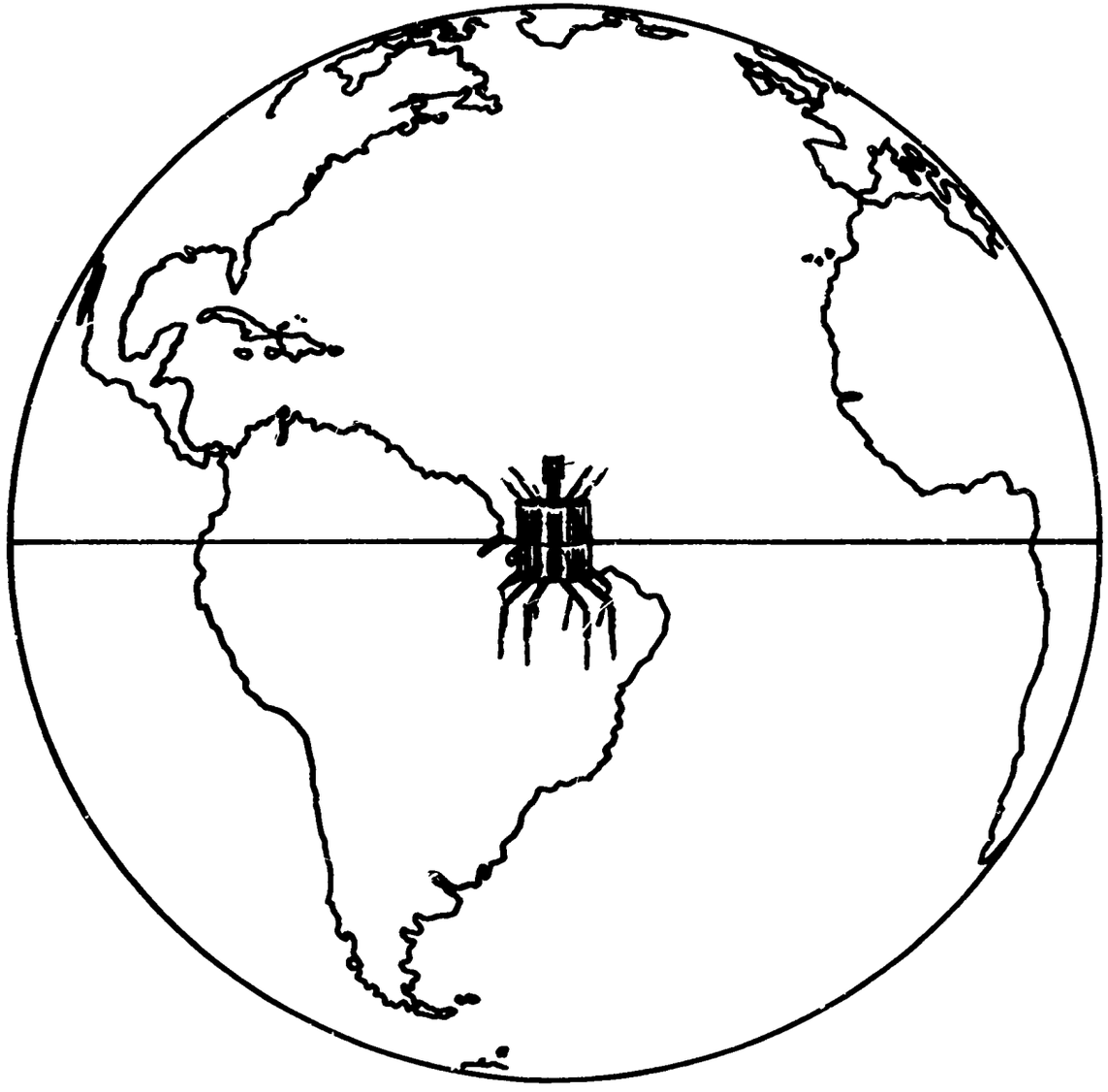
The color of the Earth, as viewed from the satellite, will vary with the time of day and with the Earth's latitude. That is, the color of the sunlight reflected from the Earth will be a function of the length of the path that sunlight traverses on passing twice through the Earth's atmosphere (up and down).

When the optical path through the atmosphere is long, the attenuation (weakening) of short wave length light (blue) is significantly greater than green and red light. Additionally, the absorption due to carbon dioxide and H20 predominates in the near infrared portion of the spectrum.

These effects are evident in the color change of clouds at sunset or sunrise. As the Sun sets the cloud color changes from white to red progressively as the blue and green components are removed. The redder a cloud is, the deeper it is in the atmosphere.

Because cloud top height determines the equivalent optical path length for a given solar angle, this effect may be used to determine cloud heights during these periods. This method of measurement cannot be used during other times of the day.

The multi-color spin-scan camera was designed specifically for operation in a synchronous, equatorial, spin-stabilized spacecraft like ATS-C.



ATS-C COLOR CAMERA COVERAGE

NASA G-68-5070.

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Unlike many other space television systems which must counteract the spacecraft spin with complex "de-spinning" or image motion compensation schemes, this system makes use of the spin to provide line scan, 2,400 lines to a picture.

Since the spacecraft will be oriented with its spin axis parallel to that of the Earth, scan will be parallel to the equator and each line will extend from horizon-west to horizon-east. Frame scan is provided by electromechanically moving the optical subassembly in a north-south direction one line-width per revolution.

The camera system consists of a high resolution telescope, three photomultiplier light detectors, multiplexer and a precision latitude step mechanism.

The latitude step mechanism combined with the spinning motion of the spacecraft provides for a scan of the complete Earth disk.

The sequence for a single picture sequence which requires about 24 minutes, is as follows: A signal from the spacecraft Mechanical Array Control Electronics (MACE) causes the latitude step mechanism to advance south at the rate of one step (one scan line) per spacecraft revolution.

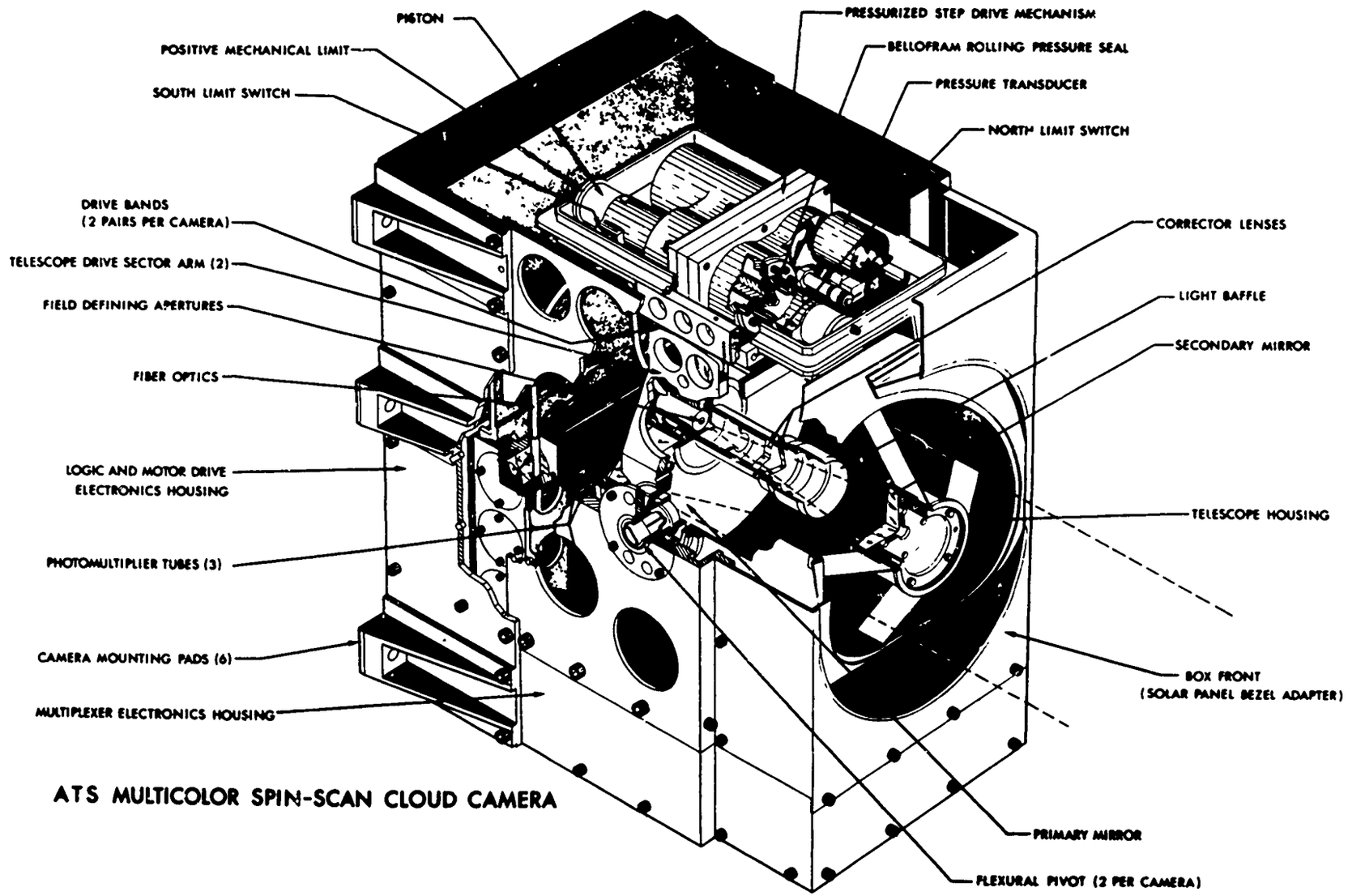
When the step mechanism has completed the required 2,400 steps, a limit switch will initiate retrace by substituting a 17-hertz oscillator output for the MACE signal and reversing the step motor phase sequence.

It takes approximately 2.4 minutes for the stepping mechanism to return to the north latitude position. At this point another limit switch will return the step motor to the normal north-south stepping action.

The outputs of the three photomultiplier tubes corresponding to red, green and blue and a 0.5-volt reference signal are time-division multiplexed to allow simultaneous transmission on a single wideband video transmitter.

Each channel is multiplexed at the rate of 500 kilohertz (KHz) to provide a bandwidth of 150 KHz per channel. The red and green channels contain a Sun pulse for picture reproducer horizontal synchronization.

A 20-KHz tone burst of 30 millisecond duration is applied to the reference channel at the instant of camera step. This synchronizing pulse allows for accurate line count, color line sequential recording, and can be used for back-up in case of Sun sensor failure.



ATS MULTICOLOR SPIN-SCAN CLOUD CAMERA

NASA G-68-4555

Image Dissector Camera — Goddard SFC

In addition to testing the camera for engineering purposes, the meteorological pictures it takes can be used for weather prediction, correlation and research.

This camera will transmit to Earth, on a real time basis, daylight cloud cover information of the major portion of the full Earth disk, or more than 40-million square miles.

The IDC is completely electronic except for a protective lens shutter which closes over the face of the sensor when the camera is not operating.

It is mounted on board the spacecraft with the camera optical axis orthogonal (crosswise) to the spacecraft spin axis which allows the camera to view the Earth once during each rotation of the spacecraft.

The camera can be operated two different ways. In the primary scanning method of operation, the camera sweep deflection provides line scan and the spacecraft spin provides motion for vertical displacement.

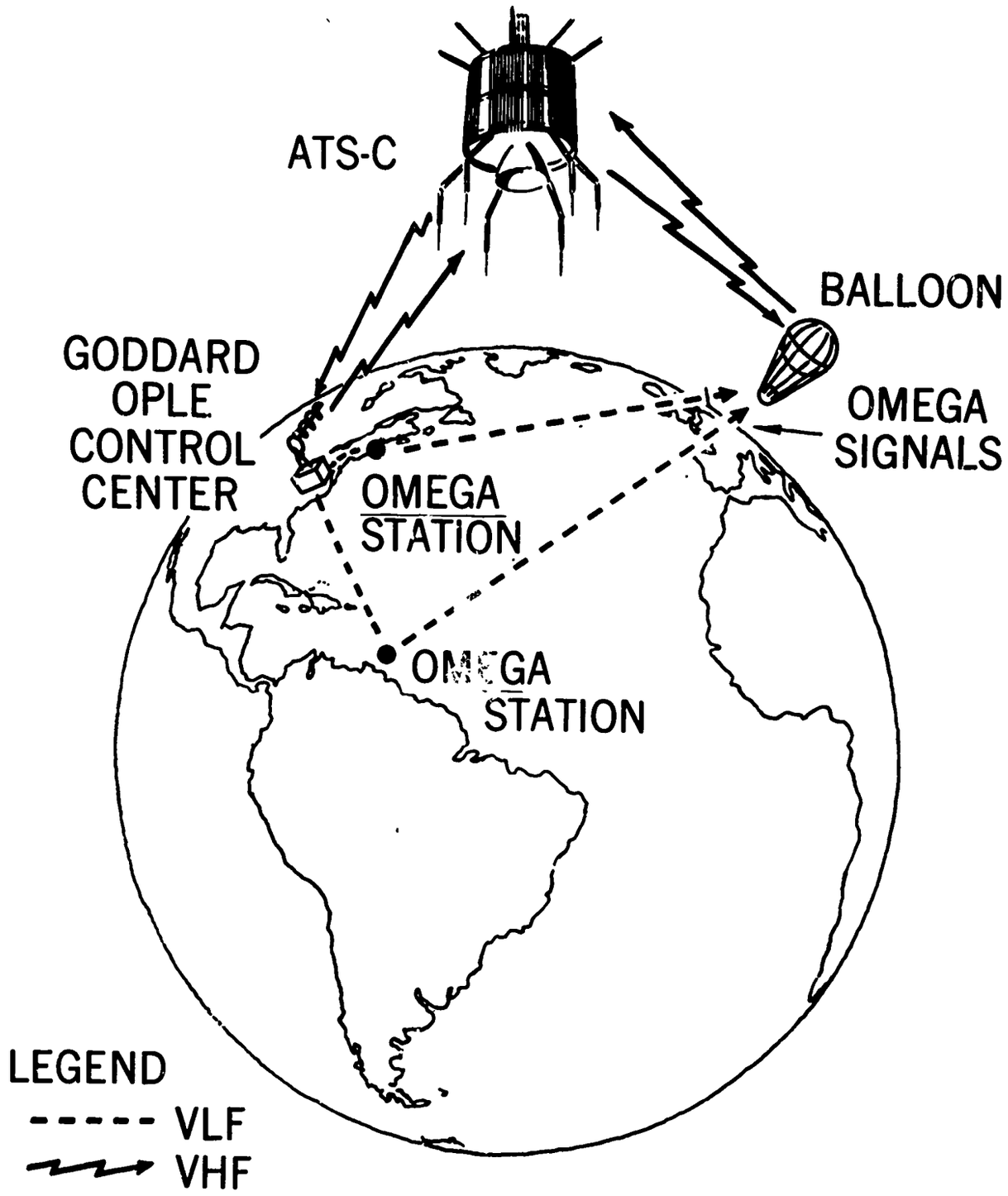
The line scan for this mode is orthogonal to the orbital plane, or in the north-south direction as scanned across the Earth. Vertical east-west displacement is achieved by initiating successive line scans at a rate slightly slower than the spacecraft spin rate.

In the secondary scanning mode, the spacecraft spin motion provides line scan in the east-west direction, while the camera sweep deflection supplies one resolution element step in the north-south direction per spacecraft spin.

Omega Position Location Equipment (OPLE) — Goddard SFC

The Omega Position Location Equipment (OPLE) experiment will demonstrate, for the first time, the feasibility locating platforms, and collecting data on a global basis employing the Navy's Omega navigation system.

OPLE was designed primarily for navigation and meteorological purposes. It can collect weather data from remote surface and airborne platforms and weather balloons to better determine wind circulation and how it affects weather systems.



OMEGA POSITION LOCATION EQUIPMENT
(OPLE)

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The OPLE system consists of a control center at the Goddard Space Flight Center, Greenbelt, Md., the ATS-C, OPLE Platform Electronic Packages (PEP), all working in conjunction with the Omega navigation network.

The entire OPLE package weighs about 45 pounds. It consists of the PEP, battery and a 3-foot, X-shaped dipole antenna.

The PEP contains a VLF and VHF receiver, decoders, a memory system timing equipment and associated electronics.

The Omega navigation system was developed by the U.S. Navy following an extensive investigation of very low frequency (VLF) propagation.characteristics. It has been determined that the 10-KHz region of the VLF spectrum has a very low attenuation rate and exhibits exceptional phase stability.

These characteristics permit world-wide propagation of radio waves and allow phase measurements with a root mean square (rms) variation of less than five microseconds.

Within this frequency range the radiated energy is propagated as a guided wave in the space between the Earth and the reflecting ionosphere with an attenuation rate approximating that due to inverse spreading loss.

Near an Omega transmitter, interference between the ground wave and the single-mode transmission causes phase shifts of a considerable magnitude.

Beyond a few hundred miles from a transmitter, the single-mode propagation dominates and the signal can be used for position measurements up to a distance of at least 2,000 miles.

Frequencies between 10 and 14 KHz were chosen for the Omega system because of the high excitation of the first mode and the low interference effects at sunrise and sunset of the higher modes.

The experimental phase of the Omega program is essentially completed. At the present time there are transmitters in Aldra, Norway; Trinidad; Haiku, Hawaii; and Forrestport, N.Y., which will support the OPLE experiment.

Four more Omega stations are planned to make the system operational. These stations will radiate 10 kilowatts of power, will operate 24 hours a day, and will be positioned about 6,000 miles (statute) apart.

When Omega becomes operational, it is estimated that position error will be about one mile in the daytime and two miles at night. NASA engineers want to determine if this error will increase, and how much, with the OPLE system.

The OPLE system can receive information from as many as 40 balloons every three minutes.

During a typical interrogation period, Goddard will transmit a pre-programmed platform interrogation sequence which is relayed (VHF) via ATS-C to OPLE platforms.

The interrogation signal, which is basically a frequency-shift keyed carrier wave (CW), is received by all of the platforms in the satellite coverage area.

Each platform has a binary code address which is a series of zeroes and ones. The platform will not turn on, or send data unless it recognizes its address.

After receipt of its own proper address, the Platform Electronics Package (PEP) will turn on all of its circuitry, including a timer for the various responding PEP modes.

At the end of the interrogation sequence, the correctly addressed PEPs simultaneously transmit their assigned acquisition reference signals, initially at maximum power to enable the Goddard control center phase-lock loops to acquire and track the transmissions.

After the acquisition period, the A/R tone is modulated with meteorological or platform status data by phase-shift keying. Following the data transmission period, the A/R tone is reduced in power level and the Omega transmission mode is initiated.

In this mode, the Omega signals are received by the VLF receivers on the platforms and converted to VHF for transmission to ATS-C and then Goddard.

The A/R tone is present throughout the PEP transmission and is continuously tracked by the control center phase-lock loops to provide a constant reference signal which minimized the effect of variations in the transmission link from the PEP to the satellite and to the Goddard control center.

Weather Facsimile (WEFAX)

Weather data in facsimile format, prepared by ESSA, will be transmitted to the satellite by the ATS Mojave ground station and relayed through the satellite to special ground stations within communications range. In addition, selected spin-scan camera pictures will be transmitted via the satellite to the Automatic Picture Transmission (APT) ground readout stations.

The WEFAX experiment is designed to test satellite transmission of facsimile products, and to explore the feasibility of increasing the amount of data available to stations equipped for reception of Automatic Picture Transmission photographs from the ESSA and Nimbus satellites.

The WEFAX experiment will begin after the satellite reaches its planned position above the equator. ESSA's National Meteorological and National Environmental Satellite Centers, both at Suitland, Md., will prepare data for transmission by ATS-C and send it via landline to the ATS Mojave ground station. The WEFAX field center at Mojave will transmit the data to the spacecraft at the rate of 240 scans-per-minute. The spacecraft will relay the data via a VHF downlink directly to ground stations equipped to receive and record APT cloud-cover pictures.

APT stations in the United States, Africa, South America and Europe will be able to receive the transmissions and they have been invited to participate in the experiment. Participating stations will evaluate the quality of the transmissions, sending samples and comments to Goddard, which will conduct a systems evaluation based on these returns.

Data will be selected for transmission on the basis of value and interest to stations in the Atlantic and adjacent areas. A daily alert message giving WEFAX transmission times will be sent on meteorological teletypewriter circuits, and a monthly schedule of transmissions will be mailed to participants.

Communications Experiments

Super High Frequency (Microwave) — Goddard SFC

The primary ATS-C communications experiments will be conducted with the two microwave repeaters (receiver/transmitter) which make up the spacecraft's super high frequency (SHF) communications subsystem.

Both repeaters operate in three modes: the first two, (1) multiple-access and (2) frequency translation, are used in the microwave communications tests as described below. The third mode, (3) wideband data, is used for transmitting television pictures from the spacecraft's Spin Scan Cloud Cover (SSCC) camera to the ground.

Multiple Access Mode Tests

The basic objective of operating the microwave repeaters in the mode is to evaluate the Single Side Band (SSB) technique for multiple-access communications. This technique is a promising approach to the development of a multiple-access system where two or more ground stations use the spacecraft simultaneously. It holds such promise because it affords a maximum number of voice channels in the minimum bandwidth of the overcrowded radio frequencies.

In the multiple-access mode, the two microwave repeaters serve as telephone relays by permitting the simultaneous two-way interconnection of many ground stations. Use of both repeaters will provide for a total of 1,200 one-way or 600 two-way voice circuits when properly equipped ground stations are used.

During the multiple-station access tests, transmissions from all of the participating ground stations are collected at the spacecraft as a composite SSB signal in the 6,000 megahertz frequency range. This composite signal is converted to a Phase Modulated (PM) signal in the 4,000 MHz range by the repeater before retransmission to the receiving ground terminals.

The SSB/PM conversion technique is employed for the multiple-access tests because PM provides a constant power signal which can be amplified in an efficient manner while utilizing a minimum of weight, space and the spacecraft's onboard power. This could not be accomplished if SSB were used for the entire communications loop.

Since SSB signals are particularly sensitive to exact frequencies and power levels, precautions have been taken to insure that these two factors remain as constant as possible.

For example, the ground transmitters use ultra-stable oscillators and automatically compensate for the Doppler effect or apparent frequency shift in signals which results if the spacecraft deviates only slightly from its geo-stationary orbit.

For each degree of inclination that the ATS-C might vary from the equator, the Doppler effect might be as much as 1,200 hertz.

Frequency Translation Mode Tests

The two microwave transponders are operated in this mode to evaluate a high quality Frequency Modulation (FM) system for relaying wideband data such as color television, telegraph, digital and facsimile data. The FM system used for these tests is a refinement of the systems used on the Relay, Telstar and Syncom communications satellites.

In the Frequency Translation Mode, FM signals are received from a ground station in the 6,000 MHz frequency range and translated to FM signals in the 4,000 MHz range before re-transmission to the ground. During the translation, the signals are amplified.

The primary design criteria for the Frequency Modulation system includes meeting the specifications for color television. Wideband circuitry is utilized throughout the signal chain of the system so that the resulting usable band is 25 MHz. This meets all International Radio Consultative Committee (CCIR) recommended television standards when utilized with ground stations appropriately equipped.

Since wide band data transmissions cover a relatively wide range of frequencies, two-way simultaneous transmissions of such data will require the use of both microwave repeaters. In such a case, one ground station will use one complete channel for transmission one way while the cooperating station will monopolize the other microwave channel.

Very High Frequency (VHF) Goddard SFC

The ATS-C also carries a special communications repeater (receiver/transmitter) which operates in the Very High Frequency (VHF) range (30 to 300 megahertz). This repeater and its antenna system will be evaluated as a relay for two-way voice communications between ground stations and inflight aircraft.

Both the commercial airlines, represented by Aeronautical Radio Inc. (ARINC), and the Federal Aviation Agency (FAA) will schedule flights of their own aircraft for the VHF tests. Other countries which plan to participate include France (Air France), Germany (Lufthansa), Italy (Air Italia) and India (Air India). These airplanes will be custom equipped with VHF communications equipment for tests.

The VHF repeater is an active frequency translation device which operates like the microwave repeaters when they are used in the frequency translation mode. Frequency Modulated (FM) signals at 149.22 megahertz are received at the spacecraft and translated to FM signals at 135.6 megahertz, amplified and retransmitted. Thus, all communications equipment at the ground stations and aboard the airplanes transmit at the higher frequency and receive at the lower one. These frequencies were selected to make maximum use of existing VHF equipment.

The antenna system for the VHF repeater is a phased-array unit which consists of eight radiating elements located around the base end of the spacecraft. This array of antennas looks like spider legs, and when electrically phased, concentrates the energy from the satellite into a beam with a pattern gain of nine decibels.

The major difference between this repeater and ATS-I is that VHF data transmitted to the spacecraft can be translated to the SHF down link as well, thereby providing much more coverage of the received signal as compared with VHF only.

In addition to tests with participating aircraft, simulated ground-to-aircraft relay tests will be conducted between two ATS ground stations. Aircraft simulation will be possible by degrading the performance of one of the participating stations. This is accomplished by using low power antennas and reducing the radiated power.

During the tests, the airborne and ground terminal performance will be evaluated to help determine how to improve ground station operation and equipment. The more efficient a ground station the less communications equipment is required aboard spacecraft and airplanes where space and weight are at a premium.

The FAA plans to use ATS-C for an evaluation of the future use of satellites for relaying very high frequency (VHF) voice communications between air traffic controllers and pilots of airplanes flying over oceanic and sparsely-populated land areas.

With presently-used high frequency (HF) communications, aircraft in transoceanic flight are sometimes unable to contact ground stations for periods lasting more than one hour due to static, interference and fading. Satellite relayed VHF should provide the capability for continuous static- and fade-free VHF communications.

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Technological Experiments

Self-Contained Navigation System — Control Data Corp.

The three balls for the experiment are three inches in diameter, stainless steel (hollow), white, highly reflective and weigh one fourth of a pound. They will be ejected, at different intervals, to a point about 26 miles from the spacecraft. In time they will gradually drift out of sight of ATS-C.

The self-contained navigation experiment is essentially a star-scanning system. It consists of the following systems:

Optics subsystem containing the Sun shade, lens, slits, reflector and photomultiplier tube;

Electronics subsystem containing the filters, amplifers and command electronics; and

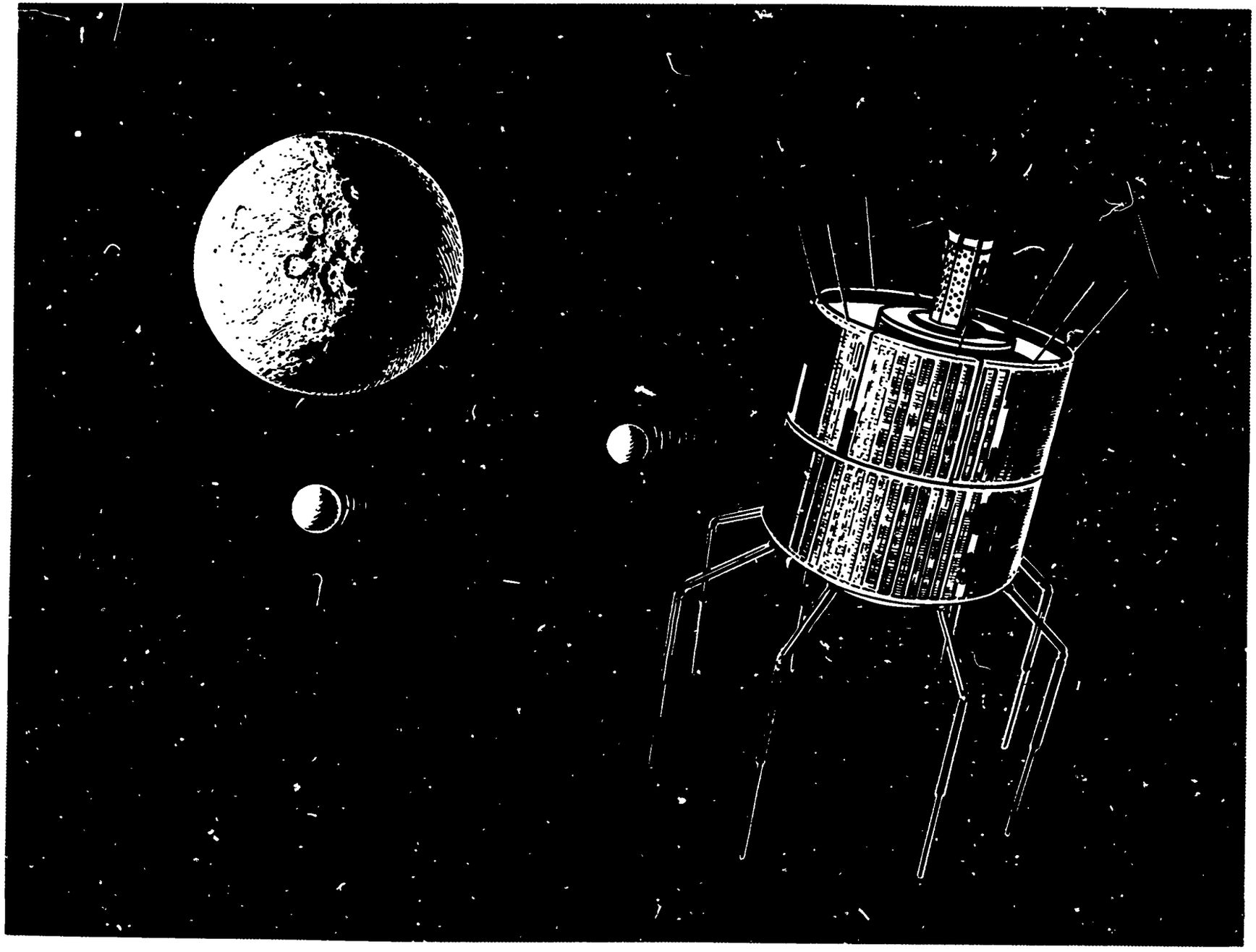
Ball ejection subsystem containing three balls, the spring loaded ejectors and the ball firing mechanism.

Objectives of the self-contained navigation experiment are:

Determine the attitude of the spacecraft using the optical star scanning system to measure the transit times of the stars in the field of view past the slits, and transmitting of these data to the ground for further processing. Three axis attitude determination will be accomplished through a solution of the equations of motion of the spinning spacecraft;

Determine the position of the spacecraft as a function of time by sighting on an ejected sphere against the star background intermittently over a period of two or more orbits; and

Determine the position of the spacecraft as a function of time by taking sightings of the Moon over several orbits.



ATS-C SELF CONTAINED NAVIGATION SYSTEM

NASA G-68-5072

Mechanical De-spun Antenna Sylvania

To provide higher antenna gain on a spin-stabilized spacecraft, a unidirectional antenna system consisting of a rotating cylindrical parabolic collimator is utilized.

The mechanical de-spun antenna has been designed to provide a highly directional transmitting (4 GH_3) and receiving gain figure of 18 decibels (db).

The earlier Syncom satellites had gain of 8 db while the electronically de-spun antenna on ATS I had a transmitter gain of 13 db.

The antenna system has been designed to operate in a space environment for minimum of one year with a five-year design goal.

The antenna system will occupy a cylindrical volume with a 10-inch diameter and a 20-inch height. The entire system, including the drive motor electronics, weighs nine pounds.

The antenna has been designed of lightweight materials with an absolute minimum of dielectric materials exposed to the space environment.

The spacecraft parabolic antenna is illuminated by linearly polarized colinear receiving and transmitting primary radiators arranged on the spin axis of the spacecraft.

A stepping motor drives the antenna at a rate synchronous with the spacecraft spin rate but of opposite direction so as to effectively despin (or stop) the antenna beam, thus illuminating the Earth's surface.

An auxiliary antenna is used to provide access to the spacecraft transponder before the time when the antenna is synchronized and phased, so that range and range-rate data can be obtained during the transfer orbit and the initial phase of the synchronous orbit.

Reflectometer Experiment — Electro-Optical Systems, Inc.

Objective of this experiment is to measure reflectance degradation of specularly reflective surface samples as a function of time in orbit, i.e., to determine how fast mirror-like surfaces will deteriorate over a period of time in the space environment.

The experiment is designed primarily to obtain engineering data necessary for the design of reflecting elements of spacecraft optical systems. A secondary objective is to obtain data of scientific value relating to the degradation process.

The reflectometer has been designed to operate for a minimum of one year with a design goal of three years.

This experiment will provide measurements of both magnitude of reflectivity and spectral characteristics of reflectivity. Analysis of these data should provide considerable insight into the cause and extent of the indicated surface damage.

To further pinpoint the cause of any surface deterioration, an effort is made to separate the effects by selectively shielding certain test samples. The instrument contains some pairs of samples of different reflecting materials.

One member of each pair is partially protected from the space environment by a clear quartz shield at all times except during the very short interval when the instrument is being operated and data are being recorded. The quartz shield will effectively block the passage of most charged particles and all micrometeoroids, but will permit the passage of ultraviolet radiation.

The other members of the pair are unshielded and are exposed to all elements of the space environment.

Resisto Jet Experiment — AVCO

ATS-C's resisto jet experiment is a pressure regulated liquid ammonia electrothermal thruster system incorporating two fast heat-up resisto jet engines.

One engine will produce a thrust level of about 11 micropounds when propellant is heated as it passes through the exit nozzle. A thrust of about seven micropounds is produced during cold operation. This engine incorporates a porous plug to decrease plenum chamber pressure to engine operating pressure.

The other engine does not incorporate a porous plug and will produce a thrust level an order of magnitude greater. Operating characteristics of the system will be determined by measurement of spin reduction of the spacecraft as a result of thrust engine firings.

Ground Equipment Related Experiments

ATS-C will be used for making several tests on the ground. These tests will involve orbital evaluation; range and range rate at microwave frequencies; ranging at VHF; calibration of the Space Tracking and Data Acquisition Network; navigation experiments; propagation studies; timing experiments; geodetic experiments; and ground station evaluation.

SEQUENCE OF EVENTS

ATS-C will be launched on an azimuth of 90 degrees, and be placed in a synchroncus, stationary, equatorial orbit. In its orbit 22,300 miles above the Earth it will rotate with the globe once every 24 hours. Since the Earth turns at the same rate, it will appear to remain stationary.

The launch window opens at approximately 6:30 p.m. EST, Nov. 3 and shifts only a minute or so each day. The window is one and a half hours in length.

Launched aboard an Atlas-Agena D rocket, ATS-C will first be placed in a near circular parking orbit about 114 statute miles above the Earth by the Atlas and first burn of the Agena second stage. As the Agena and ATS-C spacecraft cross the equator for the first time, the Agena engine will be ignited for the second burn to place it in a highly elliptical orbit with an apogee slightly under the altitude of a synchronous orbit.

The maneuvering capability of the Agena will be used to orient the spacecraft so that when it is separated the thrust axis of the apogee motor will be pointing in the right direction to approximately circularize its orbit and change the inclination of the orbit to an equatorial one. Spacecraft separation occurs about 29 minutes after launch.

Apogee motor firing will occur at second apogee, about 16 hours after launch. This will occur over Brazil at the equator and 52.7° W. Longitude. The spacecraft is expected to be on station three to five days later.

The ATS-C launch will mark the last time the Atlas SLV-3 will be used with the Agena by NASA. In the future the more powerful Atlas SLV-3A will be used. This is also the last Atlas-Agena launch of an ATS spacecraft. Future ATS spacecraft will be launched with Atlas-Centaur rockets and be considerably heavier than the first three.

ATS-C also marks a final chapter in the life of Launch Complex 12 at Cape Kennedy. Following this launch it will be deactivated.

Countdown Milestones at Launch Complex 12 Cape Kennedy

Event	Minus Time (Minutes)
Start Count	415
Start Agena UDMH Tanking	155
Finish Agena UDMH Tanking	135
Start Removal of Gantry	130
Complete Removal of Gantry	100
Start Agena IRFNA Tanking	90
Finish Agena IRFNA Tanking	65
Built-in Hold of 60 minutes to meet Launch Window Restrictions	60
Start Atlas LOX Tanking	45
Built-in Hold for 10 minutes to meet Launch Window Restrictions	7
Secure Atlas LOX Tanking	2
Hold for Automatic Sequencer	18 seconds
Atlas Engine to Full Thrust	2 seconds

Launch Vehicles

Atlas-Agena-D and ATS-C

Height on pad: 109 feet

Weight on pad: 278,736 pounds

	Atlas Booster	Agena-D Upper Stage
Height:	67 feet	42 feet*
Weight:	261,219 pounds	17,517 pounds*
Propellants:	11,563 gallons RP-1	570 gallons unsymmetrical dimethyl hydrazine (UDMH)
	18,626 gallons liquid oxygen	740 gallons inhibited fuming nitric acid (IRFNA)
Thrust:	388,340 pounds at liftoff	16,000 pounds at altitude
Propulsion:	Two booster engines, on sustainer, two verniers	One regeneratively cooled engine (Bell Aerosystems)
Guidance:	Atlas autopilot and G.E. guidance	Agena IRP (inertial reference package), horizon sensors, and onboard flight programmer.
Prime Contractor:	General Dynamics Convair Division, San Diego, Calif.	Lockheed Missiles & Space Co., Sunnyvale, Calif.

* Including 19 feet of shroud and enclosed payload

Atlas-Agena Flight Events

Normal Time From Liftoff (sec)	Event Description
0.0	Liftoff
129.5	Atlas Booster Engine Cutoff (BECO)
291.22	Atlas Sustainer Engine Cutoff (SECO)
295.4	Start Agena Standard Sequence Timer
311.01	Atlas Vernier Engine Cutoff (VECO)
315.5	Atlas-Agena Separation
366.4	Agena First Burn Ignition
376.4	Nose Shroud Ejection
527.77	First-Burn Shutdown
1499.4	Agena Second-Burn Ignition
1578.7	Agena Second Shutdown
1743.4	Spacecraft Separation

THE ATS-C TEAM

The following key officials are responsible for the Applications Technology Satellite program:

NASA Headquarters

Leonard Jaffe, Director, Space Applications Programs Office
Joseph R. Burke, ATS Program Manager
Vincent L. Johnson, Director, Launch Vehicle and Propulsion Programs
J. B. Mahon, Agena Program Manager

Goddard Space Flight Center

Dr. John F. Clark, Director
Robert J. Darcey, ATS Project Manager
Don Fordyce, ATS Spacecraft Manager

Kennedy Space Center

Robert H. Gray, Assistant Director for Unmanned Launch Operations

Lewis Research Center

Dr. Abe Silverstein, Director
Dr. Seymour C. Himmel, Assistant Director for Launch Vehicles
H. Warren Plohr, Agena Project Manager
Richard P. Geye, Agena Project Engineer for ATS

Major Contractors

General Dynamics/Astronautics San Diego, Calif.	Atlas booster
Hughes Aircraft Co. Culver City, Calif.	ATS-C spacecraft
Lockheed Missiles & Space Co. Sunnyvale, Calif.	Agena D vehicle

Major Subcontractors

AVCO Buffalo, N.Y.	Resisto Jet
Control Data Corp. Minneapolis, Minn.	Self-Contained Navigation System

Electrical Optical Systems, Inc. Pasadena, Calif.	Reflectometer
General Dynamics/Electronics San Diego, Calif.	Range & Range Rate Equipment at ATS Ground Stations
ITT Industrial Labs Ft. Wayne, Ind.	Image Dissector Camera
Philco, Western Division Laboratory Palo Alto, Calif.	Integrated antenna feed system at Mojave ATS ground station
Rantec Corp. Palo Alto, Calif.	Integrated antenna feed system at Rosman, N.C., ATS ground station
Raytheon Co. Norwood, Mass.	FM and SSB communications receivers for ATS ground stations
RCA Victor Montreal, Canada	Communications receivers for ATS ground stations
Santa Barbara Research Center, subsidiary of Hughes Aircraft, Santa Barbara, Calif.	Multi-Color Spin Scan Camera
Sylvania Electronics Systems Waltham, Mass.	Mechanically De-Spun Antenna
Westinghouse Defense & Space Center Baltimore, Md.	Spin Scan Camera Black & White and color ground processing equipment.

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