NEWS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

TELS. WO 2-4155
WO 3-6925

FOR RELEASE: SUNDAY
January 7, 1968

RELEASE NO: 68-2K

PRESS KIT

PROJECT: GEOS-B

(To be launched no earlier than Jan. 10)

contents

GENERAL RELEASE----------1-9
GEOS-B SATELLITE----------10-11
GEOS-B FACT SHEET----------12-14
SCIENTIFIC OBJECTIVES----------15
GEODETIC INSTRUMENTATION----------16
Optical Beacon System----------16
Radio Doppler System----------16-17
Radio Range System----------17-18
Radio Range And Range Rate System----------18
Laser Corner Reflectors----------19
C-Band Transponder----------19
Laser Detector----------20
C-Band Passive Reflector----------20
Power Supply----------20-21
Gravity Stabilization System----------21
Satellite Clock and Memory----------22
Laser Detection Package----------23
Thermal Design----------23
DELTA LAUNCH VEHICLE----------24
Delta Statistics----------24-26
GEOS-B Nominal Flight Events----------27
PRINCIPAL INVESTIGATORS----------28
GEOS-B Team----------29
GEOS-B Contractors----------30-31

NEWS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

TELS. WO 2-4155
WO 3-6925

FOR RELEASE: SUNDAY
January 7, 1968

RELEASE NO: 68-2

GEOS-B LAUNCH SCHEDULED

The National Aeronautics and Space Administration is scheduled to launch its second Geodetic Earth Orbiting Satellite (GEOS-B) no earlier than Jan. 10 from the Western Test Range aboard a Delta launch vehicle.

GEOS-B, which will be designated Explorer XXXVI after launch, is designed to contribute to the development of a more precise model of the Earth's gravitational field (gravimetric geodesy) and to improve our knowledge of the size and shape of the Earth (geometric geodesy) by establishing the location of a set of worldwide tracking stations whose positions are known with an accuracy of 36 feet or better in a unified geocentric coordinate system.

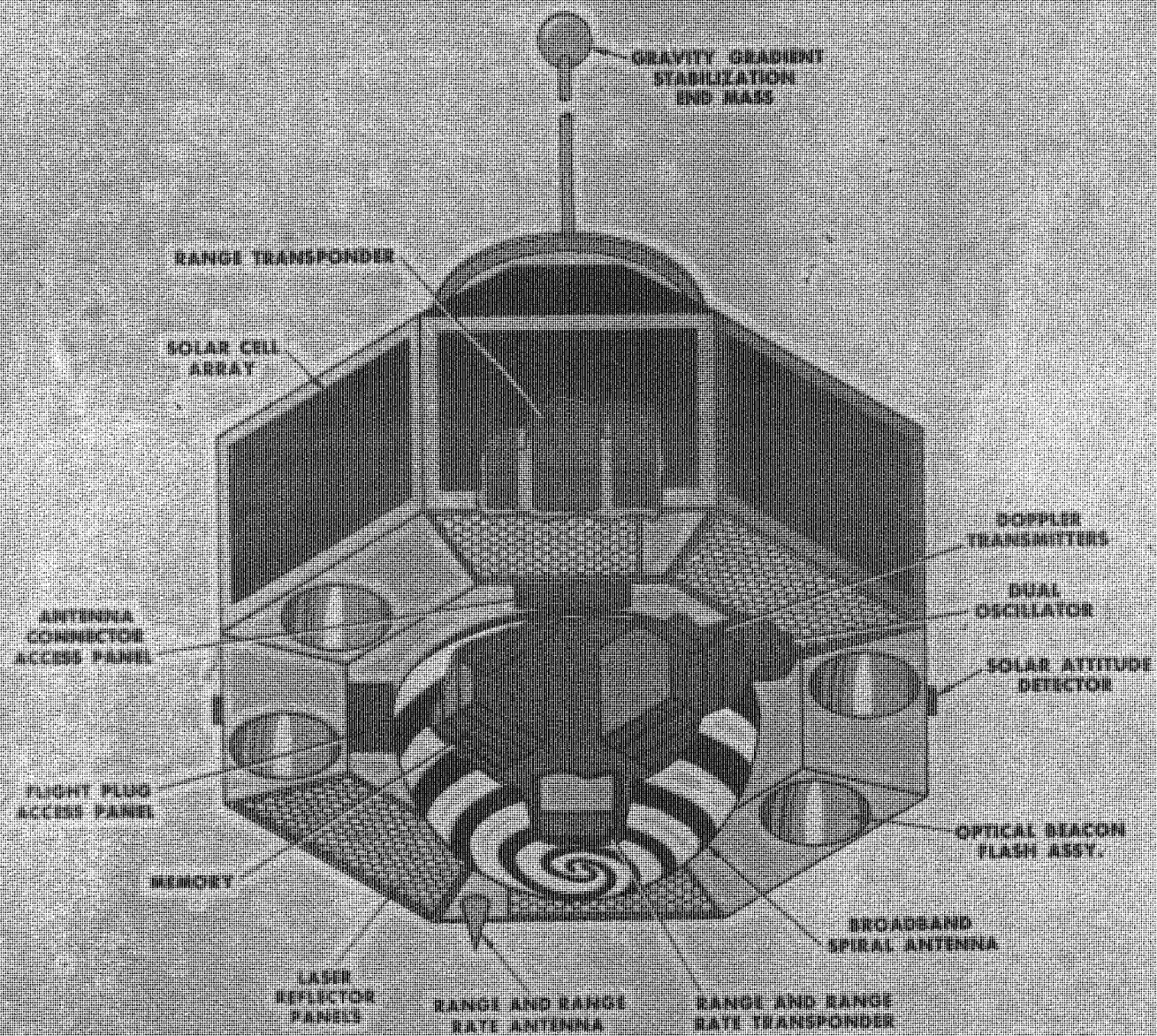
The 48-inch diameter, 460-pound spacecraft is being launched to contribute to the completion of the NASA-managed United States National Geodetic Satellite Program (NGSP).

The NGSP, designed to satisfy the nation's requirements in satellite geodesy, is a coordinated undertaking involving NASA, Department of Commerce (Coast and Geodetic Survey) and the Department of Defense as well as many non-governmental scientists and organizations.

Scientists in other nations as well as in the United States are participating in the NGSP. Among the nations with participating scientists or organizations are: Federal Republic of Germany, France, Greece, Switzerland, the United Kingdom and The Netherlands. All results from the NGSP will be made available to the world scientific community.

The six geodetic systems on GEOS-B are: (1) flashing-light beacons emitting a combined candle power of 6,620 candle-seconds-per-flash, to be photographed against a background of stars, (2) corner cube quartz reflectors to pinpoint the satellite's position by reflecting a laser beam, (3) three radio transmitters for determination of the line of sight velocity of the satellite using the Doppler shift principle and the Navy TRANET tracking equipment, (4) a radio transponder which can be used to provide the distance from the satellite to an interrogating ground station of the Army SECOR network, (5) range and range-rate transponders for simultaneous determination of satellite-to-ground station range and line of sight velocity using the NASA Satellite Tracking and Data Acquisition Network (STADAN),

GEOS B SPACECRAFT



System, and (6) C-band transponder systems at STADAN stations to be used for calibration and experimentation to determine the applicability of the C-band radar tracking system to satellite geodesy.

GEOS-B will be gravity gradient-stabilized by means of an extendable 60-foot boom.

It will be launched into a 921-by-691-mile orbit, inclined 74 degrees to the equator and will complete a revolution every 112.4 minutes.

During the past decade, largely because of satellite techniques, knowledge of the shape and gravitational field of the Earth has been advanced as much as in the centuries since the Greek postulation of a spherical Earth about 600 B.C.

With satellites as tools, scientists have determined that the flattening of the Earth at the poles is less than had previously been believed, that the Earth is somewhat pear-shaped, that the equator is elliptical instead of circular, and that the surface gravity of the Earth has several "hills" and "valleys" which are as much as 100 feet to 300 feet higher or lower than the average.

The differences in gravitational force causing the above-mentioned variations in the shape of the Earth are very small, somewhat more or less than one-thousandth of one per cent. Although minute, these variations caused by an uneven distribution of the Earth's mass, are enough to cause a satellite to deviate from a perfect elliptical path by hundreds of feet. By measuring these deviations of the satellite with the various tracking instruments, the large scale changes of the Earth's gravity field can be determined.

The provision of accurate control points for the connection of continental and local datums to a single unified world reference system is important to the location of land masses in relation to one another and the production of accurate maps. The existence of accurate maps is of primary importance to such sciences as geology and geography as well as of immense technological importance to those areas of the world where natural resources remain to be developed.

Gravimetric satellite geodesy has already had great impact on:

--Our knowledge of the location and meaning of the variations of mass within the Earth;

--Our knowledge of the strength of the materials in the interior of the Earth and the way they deform when forces are applied to them.

GEOS-B will allow continued improvement in the accuracy of laser-ranging measurements begun earlier using GEOS-I and other satellites. It is believed that ultimately laser ranging may become accurate enough to measure the small horizontal motions of large continental land masses which have been postulated.

Looking beyond GEOS-B there are many potential future applications of the techniques of satellite geodesy.

Movement along faults (cracks in the Earth) hundreds or thousands of miles long, is measured in inches each year by ground instrumentation. By means of laser reflectors on GEOS spacecraft, measurements could be made in relations to worldwide motion, including movements associated with earthquakes which may be on the order of yards horizontally and vertically, occurring in a few minutes, hours or days. Such satellite measurements may be instrumental in forecasting earthquakes.

Satellite geodesy in the future is expected to be of increasing importance to oceanographers and glaciologists.

As science and technology advance and provide an expanding potential for the economic exploitation of marine resources, there is an ever-increasing demand for accurate mapping and positioning information. Positioning information is very important in the location and relocation of objects on the bottom of oceans for salvage operations and for offshore oil well drilling or mining operations.

Measurements of the ocean surface, which varies with the rotation of the Earth, lunar gravitational pull, large ocean currents (such as the Gulf Stream), and other influences, are important in the field of physical oceanography.

Although oceans cover 70 per cent of the surface of the Earth, less than 5 per cent of the ocean bottoms have been accurately mapped. Underwater hydrographic mapping can be tied in with the common coordinate system attained by satellites.

In the area of glaciology, it is important to be able to monitor glacial and ice sheet growth and motion, such as the great ice sheets of Antarctica and Greenland. Increased knowledge of movements is essential to better understanding to long term climatic change.

Scientists believe that monitoring of the great icecap movements to an accuracy to three or four yards via geodetic satellites as well as by automated stations on the icecaps could be effective in providing long term (possibly years in advance) forecasts of general iceberg populations constituting a hazard to shipping.

Overall responsibility for the GEOS-B is under NASA's Office of Space Science and Applications.

GEOS-B was designed and built by the Johns Hopkins University, Applied Physics Laboratory, Howard County, Md. APL is also responsible for engineering services through the launch operation, preflight testing, coordination with NASA on the interface between spacecraft and launch vehicle, and engineering checkout in orbit.

During the engineering checkout phase (one month after launch), APL's operational role includes injecting flash sequences into the satellite memory system, verifying that system's performance and transmitting the signal from its Maryland ground station to extend the spacecraft's gravity gradient boom when it has the desired end pointed toward Earth.

The Goddard Space Flight Center, Greenbelt, Md., is responsible for the Delta launch vehicle and spacecraft-vehicle integration. Also assigned to the Geodetic Operations Control Center at Goddard is responsibility for coordination and communications between GEOS project management and the scientific experimenters and other participants.

After orbit is achieved and satellite instrumentation has been turned on, Goddard will be responsible for the project's integrated tracking and control effort. All tracking information, visibility computations, flash sequence control and computations, housekeeping telemetry and data reduction will be accomplished by and/or coordinated by the Geodetic Operations Control Center. The Center will prepare daily flashing-light schedules for injection into the satellite's memory system by ground signals from the primary NASA STADAN control station at Rosman, N.C.

In-flight optical and radio ranging support to be provided by Goddard includes STADAN's Range and Range Rate, interferometer (Minitrack) and optical camera (MOTS) facilities and the laser tracking facilities.

The Smithsonian Astrophysical Observatory (SAO), Cambridge, Mass., will support the optical tracking with its worldwide network of Baker-Nunn camera stations.

Additional optical tracking will be provided by camera teams of the Coast and Geodetic Survey, U.S. Air Force and the U.S. Army Corps of Engineers' Army Map Service, AMS. Radio ranging or tracking systems to be operated for GEOS include the Navy Doppler Tracking Network (TRANET); the AMS's Sequential Collation of Range (SECOR) stations; and NASA Range and Range Rate and C-band radar systems

Principal scientific investigators in the GEOS-B project represent Ohio State University, Columbus; University of California, Los Angeles; Smithsonian Astrophysical Observatory, Cambridge, Mass.; Department of Defense; Goddard Space Flight Center; and NASA's Wallops Station, Wallops Island, Va.

-end-

THE GEOS-B SATELLITE

GEOS-B is a compact, 460-pound satellite with an eight-sided aluminum shell topped with a truncated pyramid. It is 48 inches wide and 32 inches high. GEOS-B has the same configuration as GEOS-A, which was launched in November 1965. The satellites differ mainly in that GEOS-B contains:

a. Two C-band transponders each with its own cavity-mounted helix antenna for use in range radar calibration and for experimentation to determine the accuracy of the system for geometric and gravimetric geodesy invesitgations.

b. A C-band passive radar reflector to provide calibration data on the fixed-time delay of the C-band transponder.

c. A telemetry system with one 76-channel and one 38-channel commutator and three 9-channel solar array monitor accumulators. GEOS-A's telemetry system has two 35-channel commutators.

d. A laser detector to determine whether laser signals arrive at the spacecraft at predicted power levels, and the frequency and depth of modulation of the beam.

e. Two heat pipes as part of the thermal design of the spacecraft.

The satellites are essentially the same in all other respects. The range transponder, however, is of improved design, and the laser reflector has a larger surface area.

Each of the spacecraft's 16 side surfaces carries a panel of solar cells. The solar cell arrays are designed to provide maximum solar cell power output and minimum daily average fluctuations in the satellite's exposure to sunlight as it orbits the Earth. A solar attitude sensor is mounted below each equatorial solar cell panel and on the antenna hemisphere, and two on the top of the satellite. These sensors provide information on the satellite's orientation relative to the Sun.

A 60-foot boom of silver-plated beryllium-copper extends from the top of the satellite to provide gravity gradient stabilization of the satellite so that the optical beacons, radio antennas and laser reflectors point earthward at all times.

A magnetically anchored eddy-current damper on the end of the boom provides the dumbbell configuration required for stabilizing the satellite by gravity gradient, and removes residual oscillations of the satellite following boom extension. The boom can be retracted or extended to different lengths by means of a motor located inside the satellite.

Contained in the satellite are the instruments for making geodetic measurements: the C-band transponders, the radio Doppler system, the range and range-rate transponder, the range transponder, and the optical beacon system. Also included are the clock and memory, command system, telemetry system, electromagnet, and three independent power supplies wired to their associated solar cell arrays.

Two heat pipes are mounted across the bottom of the satellite between the three transponder packages. Vector magnetometers for measuring the satellite orientation with respect to the Earth's magnetic field are also mounted in the satellite.

The surface of the satellite oriented toward Earth is rimmed with eight trapezoidal panels. Mounted on these panels are the flashing light assemblies of the optical beacon system, laser corner reflectors, laser detector, C-band passive reflector, and C-band antennas. Between two panels is a four-inch high conical antenna for the S-band range and range-rate equipment. A 24-inch diameter fiberglass hemisphere projects from the center. Painted on it are the broadband spiral antenna for the Doppler system, the range transponder, command receiver, and the telemetry system.

GEOS-B FACT SHEET

Launch:	Jan. 10, 1968
Apogee:	921 miles
Perigee:	691 miles
Inclination:	74 degrees retrograde
Lifetime:	18 months operation in orbit
Weight:	460 pounds
Main Structure:	Octahedron topped by a truncated pyramid, 48 inches across flats and 32 inches high.
Appendages:	Extendible boom, 30 feet long; conical antenna, 4 inches high; broad-band spiral antenna painted on 24-inch diameter hemisphere.
Geodetic Instrumentation:	1. Optical beacon system 2. Radio Doppler system 3. Range transponder 4. Range and range-rate transponder 5. C-band transponders (two) 6. Laser corner reflectors
Command System:	Dual command receiver, dual command logic, and power switching circuitry, providing 32 ON and 32 OFF commands.
Clock and Memory:	The clock in synchronism with WWV controls timing markers broadcast on 162 and 324 MHz doppler system frequencies and 136 MHz telemetry frequency. Through the memory it controls the timing of the optical beacon flashes. The redundant memory is a serial-operation, fixed-program special purpose computer with a capacity of 65 digital words of 21 bits each. It programs the flashing of the optical beacons and checks the operation by counting the flashes that occur.

Power Systems:

Three independent solar cell/ nickel cadmium battery power systems:

1. Main Power System: 2304 N/P solar cells; one battery of 8-12 ampere-hour, nickel-cadmium cells.

   Voltage: 10.7 volts nominal.

   Power: 16 to 20 watts.

2. Optical Power System: 1344 N/P solar cells; one battery of 11-12 ampere-hour, nickel-cadmium cells.

   Voltage: 14.7 volts nominal.

   Power: 9 to 12 watts.

3. Transponder Power System: Same as Optical Power System.

Telemetry System:

Five basic units: (1) one 76-channel and one 38-channel (PAM) commutator that modulate two sub-carrier oscillators that, in turn, phase modulate the telemetry transmitter, (2) two 8-channel pulse duration modulation (PDM) sub-commutators, (3) three 15-bit tell-tale registers, (4) telemetry time marker, and (5) three nine-bit solar array monitor accumulators. The telemetry transmitter radiates 400 milliwatts at 136.32 MHz, transmitting time markers and telemetry functions on command. The TM transmitter provides the tracking signal for the STADAN minitrack stations.

Stabilization Systems:

1. Magnetic stabilization: Electromagnet

2. Gravity-gradient stabilization: Extendible 60-foot boom with magnetically anchored eddy current damper end mass.

Attitude Sensors:	1. Three vector magnetometers. 2. Eleven solar aspect sensors.
Solar Science Electron Detector:	Two units to measure electron density.
Thermal Design:	Two heat pipes and multilayer insulation.
Tracking Stations:	1. Stations of the world-wide Space Tracking and Data Acquisition Network (STADAN) operated by the Goddard Space Flight Center (GSFC). (Minitrack and optical tracking) 2. Navy's radio-Doppler TRANET Stations. 3. Smithsonian Astrophysical Observatory (SAO) Optical Network. (Baker-Nunn Cameras) 4. Coast and Geodetic Survey and Army Map Service Optical Cameras (BC-4). 5. Army mobile geodetic ground stations for use of radio range transponder (SECOR). 6. NASA, Navy, Army and Air Force C-band Radars. 7. GSFC Range/Range Rate Facilities. 8. U.S. Air Force Geodetic Stellar Cameras (PC-1000) 9. Foreign observatories.

SCIENTIFIC OBJECTIVES

The primary objectives of GEOS-B are:

a. To connect geodetic datums to establish one world datum and to adjust all local datums to the common center-of-mass of the Earth so that positions of geodetic control stations will have a relative accuracy of ± 10 meters or better in an Earth center-of-mass coordinate system.

b. To provide a more precise definition of world wide variations of the Earth's gravitational field.

The secondary objectives are:

a. To improve positional accuracies of satellite tracking sites and to calibrate tracking equipment.

b. To compare and correlate results obtained from the various geodetic systems on the spacecraft.

c. To calibrate the ranging accuracy of certain specified ground based radars for their evaluation as geodetic instrumentation systems.

GEODETIC INSTRUMENTATION

Optical Beacon System

Four xenon or "electronic" flash tubes emitting a combined candlepower of 6620 candle-seconds per flash will permit the GEOS-B satellite to be photographed against the stellar background. Photographs made by cameras of the Smithsonian Astrophysical Observatory, the Air Force, the Army Map Service, NASA's Minitrack Optical Tracking System (MOTS), the Coast and Geodetic Survey, and other facilities can be checked against numerous stellar tables including a star map of SAO containing over 260,000 stars, which are measured to an accuracy of 1 second of arc.

The four lights, of 1,655 candle seconds each, can be flashed simultaneously in combinations or individually. The light flashes are organized in sequences of 5 or 7 flashes. The first flash will always occur at a precise Universal Time minute and to an accuracy of 0.4 millisecond relative to the National Bureau of Standards station WWV which broadcasts time and frequency standards. The interval between successive flashes in each sequence is exactly four seconds.

At the time specified the memory will generate a sequence, start command and send it to the optical beacon for execution. The memory has a capacity of 59 sequences, and a cycle time of 68 hours. A new set of light flash requests will be injected into the memory every day.

Radio Doppler System

Primary objective of the radio doppler system in the GEOS-B will be refinement of our knowledge of the structure of the earth's gravitational field. Doppler data from the satellite will also be used to help determine more accurately the precise positions of the U.S. Navy TRANET ground stations relative to the center of the mass of the earth. The TRANET network observes the satellite.

The Doppler system consists of three transmitters operating at 162, 324, and 972 MHz and an ultrastable oscillator. This instrumentation is an adaptation of equipment being used now in the Navy's navigational satellites. It has been used for geodetic research in early Navy satellites, in the ANNA-1B, and more recently in the NASA Beacon Explorer XXVII satellite launched on April 29, 1965 and GEOS-A.

The doppler technique employs precise measurement of the frequency shift of the stable radio transmissions from the satellite as observed by ground-based receivers as a function of time. The precision frequencies of the satellite transmitters are controlled by an ultrastable crystal oscillator. Using the analogy of a train whistle effect, the Doppler shift, or change in frequency or pitch, is the shift in the pitch of the signal of the train relative to the hearer. The size of the Doppler shift depends on how fast the train is going, how far the listener is from the whistle, and where the train is along the track.

Since a Doppler receiving station must measure frequency and time, the 162 and 324 MHz Doppler transmitters carry time markers consisting of bursts of phase modulations of about 0.3 second duration once a minute. The time markers are maintained in synchronization with WWV to an accuracy of 0.1 millisecond or better.

From a sufficient body of Doppler vs time measurements, the orbit of the satellite can be computed. Conversely, if the orbit has been determined, the Doppler data can be used to compute the location of the receiving station.

Irregularities in the Earth's shape, however, cause the satellite orbit to change slightly from what might ordinarily be a perfectly smooth elliptical orbit. The Doppler measurements reflect these irregularities in the orbit, and their analysis provides a better picture of the size and the shape of the Earth or geoid.

Radio Range System

The radio range system will be used primarily to determine positions by geometric means, intervisible and short-arc computations in a step-by-step fashion to extend geometric survey around the globe.

Ground station to satellite range is measured by observing the total phase shift of an accurately known modulation frequency. The shift in phase is proportional to distance and so provides a measurement of satellite range in wave lengths of the modulation frequency. The basic elements of the system are a phase-modulated ground station transmitter, a satellite-borne transponder and a ground station range-data receiver and electronic phasemeter.

Geodetic measurements are accomplished by sequential interrogation of the satellite transponder by four identical ground stations. Three of these stations are located in known positions; the fourth location is to be determined. One of the stations, the "master" station, provides timing modulation on the signal it transmits to the satellite. This timing signal is retransmitted by the satellite transponder and received at the three "slave" stations, thereby establishing a time correlation among all four stations which is used to specify the order in which each station should interrogate the transponder. Each station in turn transmits a modulated signal to the transponder, which detects the modulation and returns it on another carrier frequency to the ground station where the transmitted and received modulation frequencies are phase-compared to obtain an independent range measurement.

A sequence of four interrogations, one from each station, is accomplished in 50 milliseconds, and these sequences can be repeated at a rate of 20 a second throughout the time interval selected for observation.

The satellite trajectory is then obtained by collating and smoothing the range measurements made from the three known locations. The most accurate results are obtained when the satellite is visible simultaneously at all four stations. The accuracy of range measurement is about 10 meters.

Radio Range And Range Rate System

The range and range-rate system will be used for tracking the satellite to augment geodetic data and to provide a comparison of this system and the other geodetic measurement instruments on the spacecraft.

Modulated signals are transmitted from ground stations to transponder in the satellite where they are processed and retransmitted to the ground where a phase comparison is made between the signal originally transmitted and the one returned from the orbiting spacecraft.

This provides the range measurement. The range-rate is obtained by measuring the Doppler shift of the signal transmitted by the satellite; that is, by measuring the time required to count a fixed number of cycles of the frequency. The accuracy of this two-way Doppler data system is about the same as that obtained by the one-way Doppler system, an equivalent position error of about 10 meters.

Laser Corner Reflectors

Laser corner reflectors on the satellite will be used for measuring the satellite range at optical frequencies, which are not influenced by the ionosphere.

The corner reflectors will reflect pulsed beams of light directed at the satellite by a ground laser transmitter when the satellite is within range. The reflected light will be picked up by a telescope and amplified by a photomultiplier tube that converts the optical impulses to an electrical signal. A digital counter will record the time at which the beam of light is returned to the ground.

The total travel time of the light pulses, from ground to satellite and back to the ground, is a measure of the distance to the satellite and thus forms the basis of the satellite optical laser tracking system being studied by Goddard Space Flight Center. These time measurements, coupled with angular data, will precisely locate orbiting spacecraft and are expected to provide a very accurate method of tracking satellites.

GEOS-B carries an array of cube corner prisms mounted on four of the eight flat panels on the bottom surface of the spacecraft. These prisms form the retro-reflector used for the optical laser range and angle measurements. Each prism is made of fused quartz with silvered reflecting surfaces. There are a total of 400 prisms on the spacecraft, providing a total reflecting area of 360 square inches.

The retrodirective corner reflectors conserve the narrow beamwidth of the incident light to provide maximum signal on the ground. At normal incidence, 50 percent of the light incident on the effective reflecting area will be retro-reflected within a cone 20 seconds of arc in diameter.

Three other NASA Spacecraft, Explorer XXIX, Explorer XXII, and Explorer XXVII, carry laser experiments. They are being used in the evaluation of laser techniques in deriving orbital and geodetic information.

C-Band Transponder

The C-band transponder is a new instrumentation in the GEOS satellite program. The C-band transponder will be used in range radar calibration and for experimentation to determine the accuracy of the system for geometric and gravimetric geodesy investigations.

Laser Detector

Two C-band transponders are used to provide redundancy. One has approximately 5 microseconds of internal time delay, the other just under 1 microsecond internal delay. Each transponder has its own cavity-mounted helix antenna.

The laser detector is a photomultiplier that is used to determine whether the laser beams transmitted to the spacecraft arrive at the spacecraft at the predicted power levels. It is also used to determine the frequency and depth of modulation or scintillation of the laser beam as viewed from the spacecraft. Normally it will be used about ten minutes a day. It is mounted on a bottom panel of the satellite.

C-Band Passive Reflector

The C-band reflector is used in conjunction with the C-band transponder to allow for a more precise calibration of the transponder internal time delay and to provide passive C-band tracking capabilities. The reflector is passive and will require no power.

Power Supply

Primary source of power for operating the GEOS-B instrumentation and transmitters will be 4992 N on P type silicon solar cells arranged in 16 panels on the side surfaces of GEOS. Shielding from radiation will be provided by an 0.02-inch-thick fused silica cover slide with a blue reflecting optical filter.

Three independent power supplies, each with its own bank of solar cells and nickel cadmium battery, are used to operate the GEOS instrumentation. They are (1) the main power supply, which supplies power for the radio doppler system and most of the housekeeping functions, (2) the optical beacon power supply, and (3) the transponder power supply, which supplies power to the C-band transponder, the radio range transponder, and the radio range and range-rate transponder.

This power isolation will reduce risk of damage to one section by possible failure of another and will minimize possible electrical interference among the various instruments.

Each battery is made up of 12 ampere-hour reangular nickel-cadmium cells. Cells of this type have been under test at the Applied Physics Laboratory since first used in the ANNA Satellite in 1962.

For added protection against catastrophic failures, the main power system will have a "solar only" mode. In such an arrangement, batteries can be by-passed and the loads can be operated directly from solar cell energy. The transponder power system will have a voltage sensing switch that will disconnect all loads when its battery voltage drops too low. Also every load can be disconnected from its power system by ground command.

Gravity Stabilization System

Critical to optimum use of the radio and optical beacons on GEOS-B is the gravity gradient stabilization system to keep the satellite antennas and optical beacons pointing Earthward at all times.

A passive system, it has been successfully used in stabilizing several Navy satellites and on Explorer XXIX (GEOS-I).

Attitude control will be effected two or three days after the satellite is in orbit first by magnetic stabilization and then by erection of a 60-foot silver-plated beryllium-copper boom from its housing in the top of the pyramid section of the spacecraft.

When the telemetered data from the solar attitude detectors and the vector magnetometers indicate that the satellite is magnetically stabilized with the desired end facing the Earth, the command for boom extension will be sent. A copper encased magnet on the end of the boom will remove oscillation from the boom and the satellite by transforming the oscillation energy into eddy currents and then to heat which will be dissipated into space.

The pull of gravity along the axis of the boom and satellite, although differing in infinitesimal degrees, is sufficient to keep one face of the satellite pointing Earthward forever if undisturbed. It is the same force and principle which keeps the same side of the Moon facing Earthward. The boom assembly is a motorized unit so that the boom can be extended or retracted to different lengths on command.

Satellite Clock And Memory

A satellite clock based upon the extremely precise oscillations of the ultra-stable crystal oscillator of the radio Doppler system will be used to trigger the optical beacon flashes and control timing markers broadcast from the satellite. A frequency divider, the clock functionally divides the oscillator frequency by a ratio which can be adjusted over a total range of 38.6 parts per million. This ratio will be set by ground command. The clock will be maintained in synchronism with station WWV (National Bureau of Standards) so that the timing markers broadcast on the 162 MHz and 324 MHz Doppler frequencies and the 136 MHz telemetry frequency, and the first light flash of each optical beacon sequence will always be emitted from the satellite on a precise Universal Time minute. The interval between successive flashes in each optical beacon sequence will be four seconds, and the memory will have a capacity of 59 sequences. Scientists at APL who designed the clock estimate it will be possible to keep the satellite clock in synchronism with WWV at all times to within plus or minus 100 microseconds.

The satellite memory is a fixed program, special purpose digital computer consisting of a 1,365-bit magnetic memory with timing and processing control circuits. The 1,365-serial data bits are treated as 65 digital words of 21 bits each. These bits are assigned different functions and are used to execute the message injected into the memory. This message is coded according to the bit assignments so that the flash sequence will be initiated at the desired time, the requested number of beacons will flash, and the clock rate can be set. The bits stored in the memory can initiate up to 59 flash sequences in any period up to a maximum of 68 hours. The entire memory contents are serially read out, processed, and restored once per minute.

Of the 65 memory words 59 can be used as flash sequence initiators and as such are loaded into the memory during injection with time data. Provision is also made for tailoring the intensity and duration of each flash sequence to the needs of the users. Word 60 provides for fine adjustment to the satellite clock rate; word 61 accumulates the total number of light flashes generated since the last memory load; and words 62-65 provide the "Barker Word", a permanently wired format serving to mark the beginning of each memory scan at one minute intervals.

Laser Detection Package

The spacecraft's laser detector package will be used to determine the frequency and depth of modulation or scintillation of the laser beam as viewed from the satellite. Additional laser tracking experiments will include modulated CW laser tracking and pulsed tracking investigations.

Thermal Design

GEOS-B has heat pipes as an integral part of the thermal design. The heat pipe is used in GEOS-B to minimize temperature differences between the three transponder packages.

One heat pipe, 18 inches long, is mounted between the range transponder and the C-band transponder packages, and the other, 33 inches long, is mounted between the C-band transponder and the Goddard range and range-rate transponder packages.

The pipes are made of aluminum tubing with a 1-inch outside diameter. A wick, made of aluminum screen six layers thick, is in contact with the inside diameter. The tube is evacuated and then filled with a little more than enough freon 11 to wet the wick. The tube is then sealed tight. The pipe redistributes heat in this manner: when one end of the pipe gets hot, the freon boils and evaporates, the gas moves to the cooler end where it condenses to a liquid, giving off heat in the process, and by capillary action the liquid freon is drawn back to the other end of the tube through the wick, and the cycle repeats itself.

DELTA LAUNCH VEHICLE

Delta is a launch vehicle program of NASA's Office of Space Science and Applications. Project Management is the responsibility of the Goddard Space Flight Center. Launch agency for Goddard is the Kennedy Space Center's Unmanned Launch Operations. Delta prime contractor is the McDonnell Douglas Corporation.

Delta Statistics

The three-stage, Thrust-Augmented Improved Delta for the GEOS B mission has the following characteristics:

Height: 92 feet (including shroud)

Maximum Diameter: 8 feet (without attached solids)

Lift-off Weight: About 75 tons

Lift-off Thrust: 33,500 pounds (including strap-on solids)

First Stage (liquid only): Modified Air Force Thor, produced by the McDonnell Douglas Corporation; engines produced by the Rocketdyne Division of North American Rockwell.

Diameter: 8 feet

Height: 51 feet

Propellants: RP-1 kerosene is used as the fuel and liquid oxygen (LOX) is utilized as the oxidizer.

Thrust: 172,000 pounds

Burning Time: 2 minutes, 32 seconds

Weight: About 53 tons

Strap-on Solids: Three solid-propellant CASTOR I rockets produced by the Thiokol Chemical Corp.

Diameter: 31 inches

Height: 19.8 feet

Weight: 27,510 pounds (9,170 each)

Thrust: 161,550 pounds (53,850 each)

Burning Time: 43 seconds

Second Stage: Produced by the McDonnell Douglas Corp., utilizing the Aerojet General Corp., propulsion system; major contractors for the autopilot include Minneapolis-Honeywell, Inc., Texas Instruments, Inc., and Electrosolids Corp.

Propellants: Liquid-Unsymmetrical Dimethyl Hydrazine (UDMH) for the fuel and Inhibited Red Fuming Nitric Acid (IRFNA) for the oxidizer.

Diameter: 4.7 feet

Height: 16 feet

Weight: 6½ tons

Thrust: 7,700 pounds

Burning Time: 6 minutes and 4 seconds

Guidance: Western Electric Company

Third Stage: United Technology Center FW4 Motor

Propellants: Solid

Height: 5½ feet

Diameter: 1½ feet

Weight: 600 pounds

Thrust: 5,600 pounds

Burning Time: 31 seconds

GEOS B will be the 56th flight for NASA's Delta booster. Since the first Delta launching in 1960, the reliable three-stage rocket has orbited 52* satellites out of 55 attempts.

If Delta Number 56 orbits the GEOS satellite, it will be the 23rd consecutive success for Delta and establish a new flight record for the 92-foot-tall booster. Delta orbited 22 straight satellites from 1960 through 1964.

The nominal orbital elements for the GEOS mission are an apogee (far point) of 920 statute miles, a perigee (close point) of 690 statute miles, inclination to the equator of 74 degrees, and an orbital period of 112 minutes.

Delta Number 56 will lift-off SLC-East Standard Launch Complex-Two East (Western Test Range) on a launch azimuth of 185 degrees True. The ideal launch time is between 8:45 a.m. and 9:15 a.m. (Pacific Standard Time).

Delta's current string of successes started with the GEOS I launching from Cape Kennedy, Fla., Nov. 6, 1965. That launching was also the first flight test for the Thrust Augmented Improved Delta which can orbit three times as much weight (about 1,500 pounds into Earth orbit) as the earlier Deltas used in 1960.

The 22* satellites orbited since 1965 include six ESSAs (weather) five Explorers (scientific), four Intelsats (communications), three Pioneers (solar scientific), two observatories (Orbiting Solar Observatory), and two BIOS (biological).

* Delta #55, which launched Pioneer VIII from Cape Kennedy, Fla., Dec. 13, 1967, also orbited a piggy-back satellite called TTS-I (Test and Training Satellite). TTS-I will be used to check out the Apollo Manned Space Flight tracking network.

GEOS B NOMINAL FLIGHT EVENTS

Event	Time	Altitude (Statute Miles)	Surface Range (Statute Miles)	Velocity (Miles Per Hour)
Solid Motor Jettison	1 Min. 5 Sec.	16	6	1,717
Main Engine Cutoff	2 Min. 32 Sec.	91	76	8,318
Second Stage Ignition	2 Min. 36 Sec.	97	83	8,287
Nose Fairing Jettison	2 Min. 40 Sec.	102	90	8,267
Second Stage Cutoff	8 Min. 40 Sec.	497	890	13,210
Third Stage Ignition	15 Min. 48 Sec.	684	2,173	12,341
Third Stage Burnout	16 Min. 19 Sec.	684	2,277	16,956

PRINCIPAL INVESTIGATORS

Results of the scientific investigations by the principal investigators will be compiled into a handbook for use in the United States Geodetic Satellite Program.

This handbook will include:

A mathematical analysis of the Earth's gravitational field as seen from satellite altitudes.

A map of the Earth that interrelates various geodetic reference points, placing these datums and isolated points on a standard coordinate system.

A discussion of the several observing techniques and an intercomparison of their effectiveness and accuracy.

The principal investigators for the geodetic satellite program are:

Dr. Ivan I. Mueller, Ohio State University -- geometrical analysis of data to locate observation points in a three dimensional, center-of-the-Earth coordinate system.

William M. Kaula, University of California, Los Angeles -- analysis of camera, Doppler and range and range-rate observations in determining the Earth's gravitational field.

Dr. Charles Lundquist, Smithsonian Astrophysical Observatory -- conducting observations to determine gravitational potential, improve knowledge of exact locations of Baker-Nunn camera positions, comparison of relations between Earth geodetic datums, and comparisons of observation techniques.

John Berbert, NASA's Goddard Space Flight Center -- observations to improve present knowledge of the accuracies of radio and optical satellite tracking systems.

GEOS-B TEAM

NASA HEADQUARTERS

Dr. John E. Naugle	Associate Administrator for Space Science and Applications
Leonard Jaffe	Director, Space Applications Programs
Jerome D. Rosenberg	Geodetic Satellites Program Manager and GEOS B Project Manager
Joseph B. Mahon	Director, Launch Vehicle and Propulsion Programs
R. W. Manville	Delta Program Manager

APPLIED PHYSICS LABORATORY

Dr. George C. Weiffenbach	Project Scientist
Ralph E. Willison	Project Engineer
Stanley J. Kowal	Payload Engineer

GODDARD SPACE FLIGHT CENTER

William R. Schindler	Delta Project Manager

KENNEDY SPACE CENTER

Robert H. Gray	Director of Unmanned Launch Operations

GEOS-B CONTRACTORS

General Electric Co. Space Technology Center Valley Forge, Pa.	Provided magnetically anchored eddy current damper for use in the gravity gradient stabilization system. Assembled and tested laser corner cube quartz reflectors which will cover fifty percent more area on the satellite than they did on GEOS-A.
Vega Precision Laboratories 239 Maple Ave., West Vienna, Va.	Fabricated and delivered two prototype and four flight C-Band transponders for GEOS-B. Provided engineering field services for C-Band transponders.
E. G. & G., Inc. Crosby Dr. Bedford, Mass.	Constructed optical beacons (four high intensity xenon flash tubes) which will provide the programmed light source for photographing the satellite against a stellar background.
DeHavilland Aircraft of Canada, Ltd. Malton, Ontario	Designed, fabricated and tested the 60-foot long beryllium copper boom used for gravity gradient stabilization of GEOS-B.
Spectrolab Div. of Textron Electronics 12484 Gladstone Ave. Sylmar, Calif.	Mounted arrays of silicon N on P solar cells and their fused silica covers.
Ryan Aeronautical Lindbergh Field San Diego, Calif	Designed and built aluminum honeycomb substrates upon which the solar cells are mounted.

Schonstedt Instrument Co. 9170 Brookville Rd. Silver Spring, Md.	Built and tested 3-axis magnetometer system used to determine the orientation of the spacecraft relative to the locally encountered Earth's magnetic field.
Matrix Research and Development Corp. 11 Mulberry St. Nashua, N.H.	Built and designed voltage regulators for 3-axis vector magnetometer system and for the solar attitude detectors.
Gulton Industries Metuchen, N.J.	Provided satellite nickel cadmium cells from which GEOS-B batteries were constructed by Applied Physics Laboratory.
Motorola, Inc. Western Center Military Electronics Div. Scottsdale, Ariz.	Designed and manufactured Goddard Range and Range Rate transponder.
Cubic Corp. 9233 Balboa Ave. San Diego, Calif.	Designed and manufactured SECOR (Sequential Collation of Range) transponder.

-end-