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ABSTRACT

This pamphlet describes the Space Telescope, an unmanned multi-purpose telescope observatory planned for launch into orbit by the Space Shuttle in the 1980s. The unique capabilities of this telescope are detailed, the major elements of the telescope are described, and its proposed mission operations are outlined. (CS)

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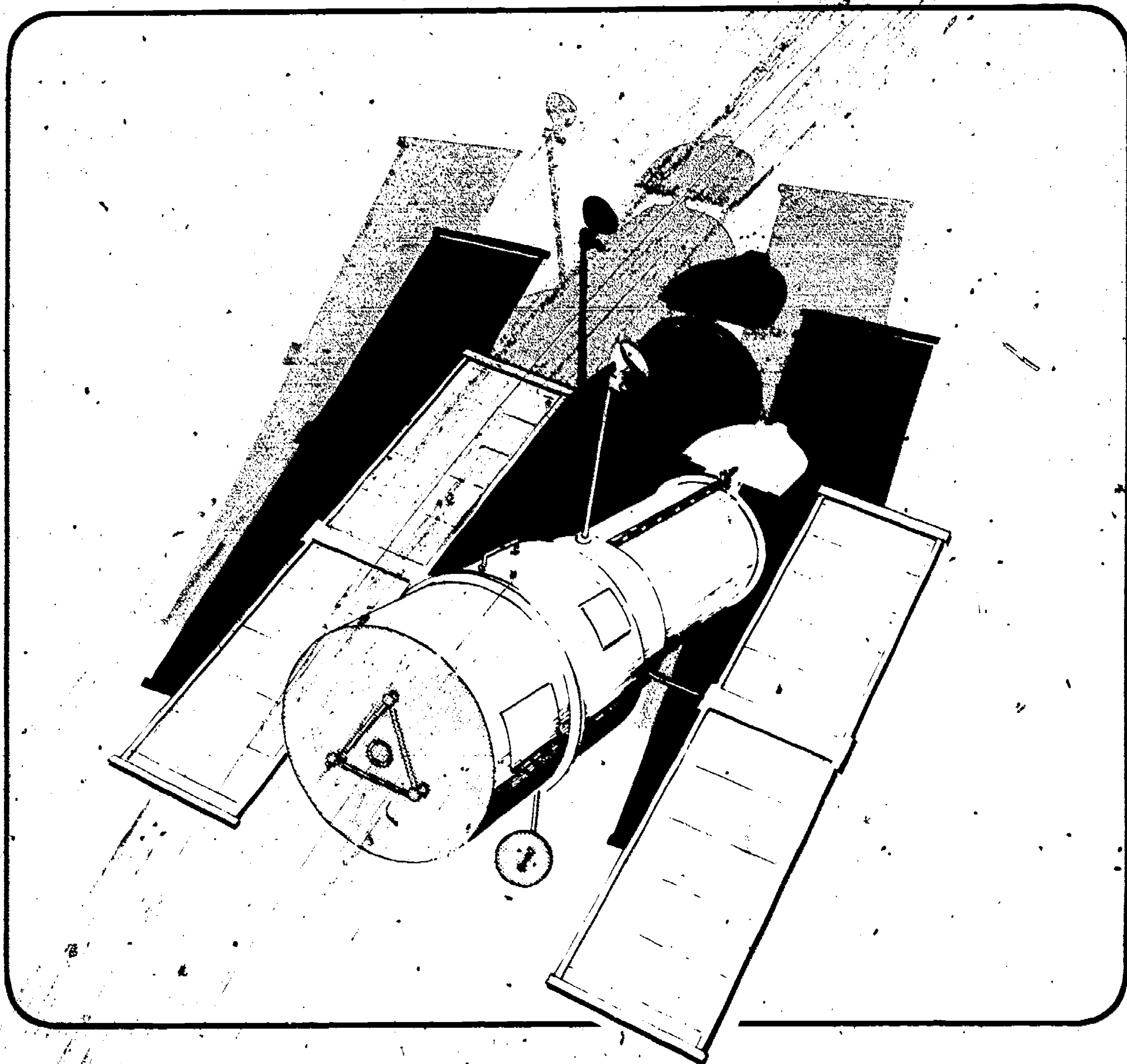
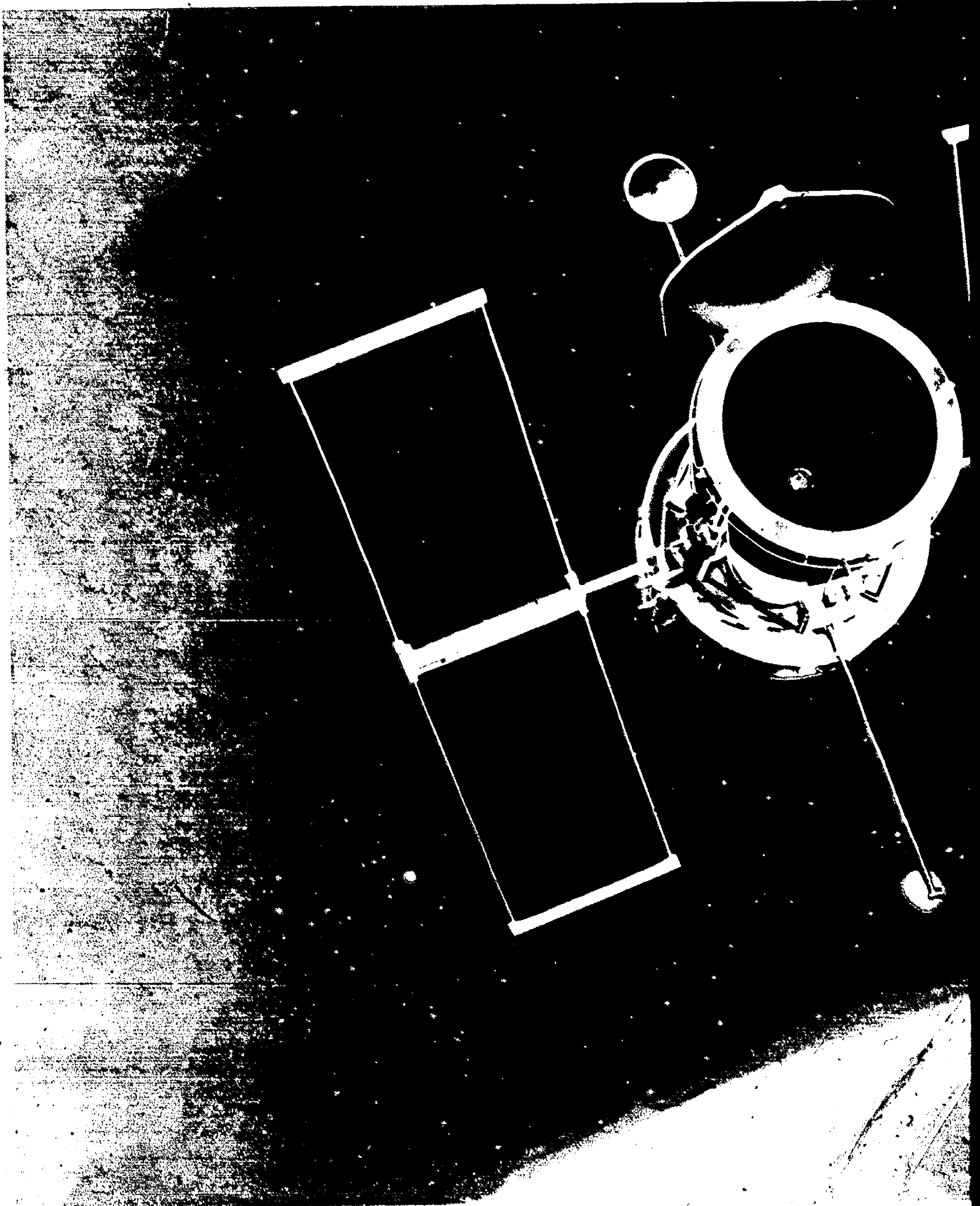
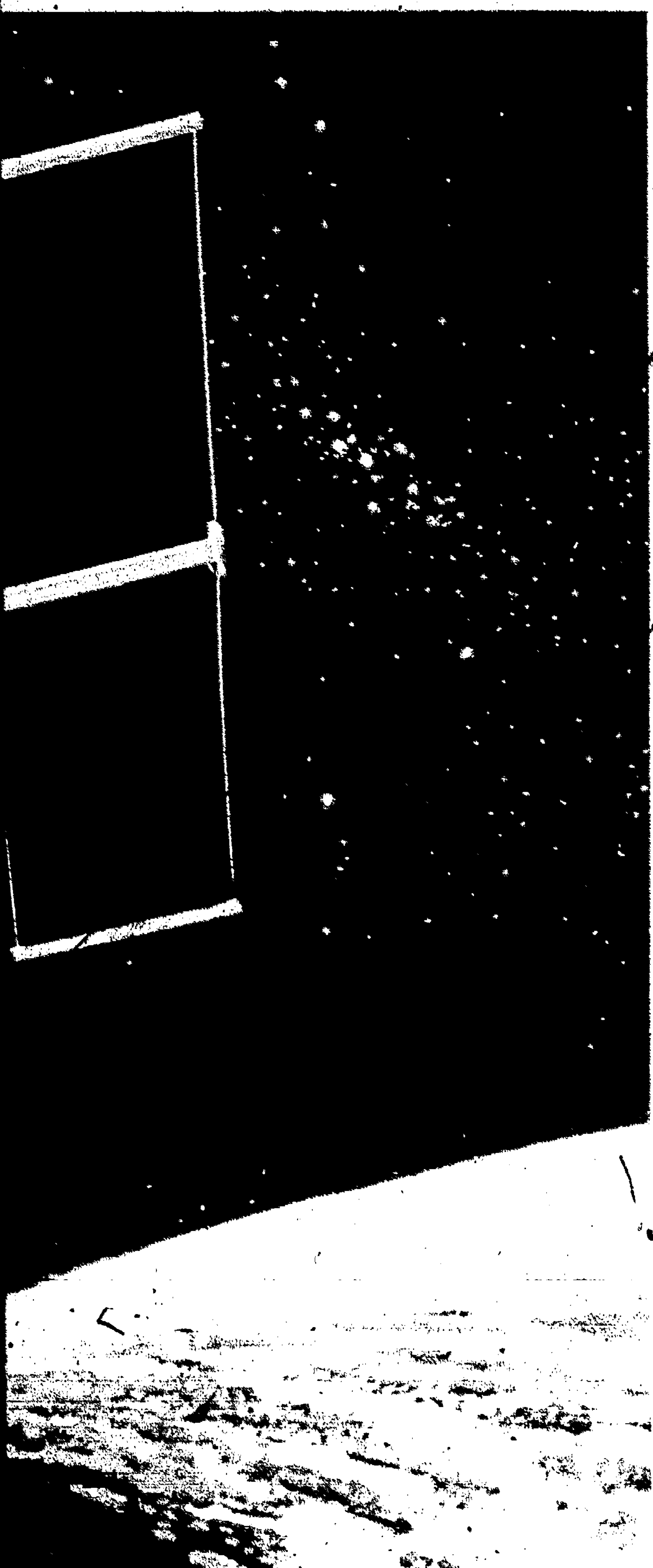






The Space Telescope is an unmanned multi-purpose optical telescope observatory planned for launch into Earth orbit by the Space Shuttle in the 1980s. The Marshall Space Flight Center, Huntsville, Ala., is NASA's lead center for management of the Space Telescope project.

Why Astronomy ?

Astronomy deals with the most fundamental issues that face reasoning man: how did my world come into being, what is the order of the universe, what role does my world play; and what is its future?

Answering these questions is the challenge to the astronomer, the theologian and the philosopher. The astronomer seeks to learn and understand the laws governing the structure and evolution of his universe by observation and interpretation.

For more than a century, astronomers have dreamed of viewing the sky through a telescope in space outside the Earth's obscuring atmosphere. While it may have been a dream for Oberth, the German scientist who first mentioned the possibility in 1923, and even for those who discussed it extensively in the late 1940's and early 1950's, today it has become a reality.

Relatively small telescopes are already in orbit, such as NASA's International Ultraviolet Explorer and Orbiting Astronomical Observatory.

But now NASA is developing a much larger and more sophisticated instrument called the Space Telescope, a multi-purpose unmanned optical telescope in Earth orbit, scheduled to become operational in the 1980s.

The astronomer's capacity for observation will be tremendously enhanced by the Space Telescope, envisioned today as mankind's eye to the universe for the next 20 years.

Some may wonder why we need to look to the stars. Why, other than curiosity, should man strive to examine the far reaches of the cosmos? We look because the missing pieces in the puzzle of the universe are out there. We want to know how it began, how it grew, how it is changing, and what is its ultimate fate.

The scale of distances to even the nearest stars is so great as to prevent the present generations of man from visiting them for study. This means that the astronomer is only an observer—not an experimenter. He cannot punch, squeeze, melt, or perform operations on the objects of his study, but must learn only from observing what nature is doing.

Fortunately, the same vastness of scale that prohibits our travel also allows a richness of conditions to apply and a host of different observable phenomena to occur. For example, we can study regions of ionized gas that are so rarefied as to surpass the best vacuums achievable on the Earth; and we can study collapsed stars, so dense that all of the Earth could be compressed with equal density into a sphere only 1,000 feet in diameter.

The profusion of observable objects can also be used to advantage. Although most of the phases of the evolution of a star like our Sun are very long compared with the total lifetime of men on the Earth, by observing individual stars in different phases of their changes, the astronomer can accurately picture the Sun from cradle to grave. Even though the universe is abundant in its phenomena and subjects, the observational nature of this science means that the astronomer's "eyes" are only as good as his imagination and success in conceiving and realizing new ways of observing.

The view of a serene universe, composed of stars and systems of stars (galaxies), has given way in the past 20 years to a picture of a violent universe, filled with many cataclysmic events accompanying the origin of galaxies and the death of stars. We now know of quasars, neutron stars and possibly black holes, each of which gives off signals of its nature and existence with no regard for the sensitivity of the eyes of the most intelligent species, or for the properties of the atmosphere, of the third planet of a rather common star.

This means that if we are to get a complete view of the real universe we must continue to build powerful telescopes and to observe from space itself, where we see the universe as it really is—not filtered by the terrestrial atmosphere.

NEARBY GALAXY — This spiral galaxy, in the constellation Andromeda, is just barely visible to the naked eye. While it is our closest large neighboring galaxy, it is still 2.2 million light years away. The Space Telescope will enable astronomers to study this galaxy, which is very similar to our own, and other celestial objects in far greater detail than ever before.

It can be argued that astronomy is an esoteric science, justifiable only on the grounds of fundamental curiosity; however, there is further justification in its study of unique phenomena. Nature provides conditions that cannot be duplicated on the Earth and other conditions whose cost to duplicate would be prohibitively expensive for basic research.

This means that we find conditions that expand our current understanding of natural laws. The history of science shows that it is when the existing laws are put to the most demanding tests that the greatest advances in understanding occur. This raises the real possibility that fundamental processes first understood from astronomical observations can eventually be applied to aid the Earth and its population.

All types of observations are possible, from low-energy radio waves through the ultra-high-energy gamma rays; but the greatest supplier of astronomical information is still the optical telescope. Since the turbulence of the Earth's atmosphere imposes practical limitations in all but a very selected few types of observations, the only practical successor to the giant Earth-based telescope is the high-quality space telescope.

The Space Telescope Project will provide such a telescope. Launched into Earth orbit by NASA's Space Shuttle, the Space Telescope will orbit high above the hazy and turbulent atmosphere, where it will enable scientists to see the universe more clearly.

The Space Telescope is a superb system that will fully exploit the advantages of space observations. It is a natural next step in the current revolution in astronomy, a revolution that history will probably equate with Galileo's invention of the simple telescope 370 years ago.

SUPERNOVAE REMNANT — This is the Crab Nebula in the constellation Taurus. It is the remnant of a supernova, or exploding star, that first appeared in 1054 A.D. Supernovae are very rare; only six have been recorded in our galaxy in the past 2,000 years. They may flare to as much as a billion times their original brightness, fading in less than a year. The Space Telescope will study these and many other objects in the ultraviolet, visible and near infrared spectrum.

What Space Telescope Can Do

The Space Telescope's unique capability for high angular resolution imagery, large auxiliary equipment payload and efficiency of operation will make it the most powerful telescope ever built, enabling man to gaze seven times farther into space than now possible — perhaps to the outer edges of the universe.

The largest Earth-based telescopes in operation today can see an estimated two billion light years, or about 12 billion trillion miles, into space. The Space Telescope will be able to see much deeper — 14 billion light-years. Some scientists believe the universe was formed nearly 14 billion years ago — so the Space Telescope might provide views of galaxies at the time they were formed.

Studying the stars isn't merely a matter of distance, however; it is also one of clarity. All Earth-bound seeing devices have distorted vision because the Earth's atmosphere blurs the view and smears the light. The clearer images provided by the Space Telescope will enable scientists to evaluate the mass, size, shape, age and evolution of the universe more comprehensively.

With the Space Telescope, scientists will be able to look at celestial sources such as quasars, galaxies, gaseous nebulae, and Cepheid variable stars which are 50 times fainter than those seen by the most powerful telescopes. Within the solar system, they can monitor atmospheric and surface phenomena of the planets.

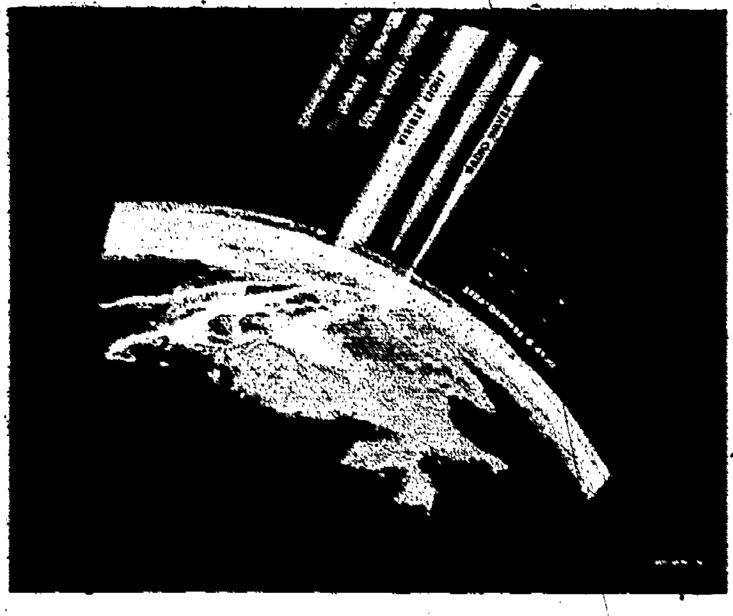
With a telescope in Earth orbit, long time exposure images more than 10 times sharper than those from the ground can be achieved.

Another great advantage of orbital observation is the absence of atmospheric material that absorbs the ultraviolet and infrared radiation from stars.

The crisper images of the telescope, combined with the darker sky background, will also permit much fainter objects to be detected. By concentrating the starlight into a smaller area, the contrast with the background (which is lower, due to the absence of scattered light and airglow emission) is improved, while the concentration means that the exposure times to reach a given brightness level will be reduced.

For faint object photography, the Space Telescope should be able to go perhaps 50 times fainter than the same detection system on the ground. One of its scientific instruments will use solid state imaging-type sensors of much higher sensitivity, in some respects, than photographic films. An additional fringe benefit of these sensors is the freedom

COMPARISON WITH EARTH-BASED TELESCOPES — Resolution of the Space Telescope will be 10 times better than Earth-based telescopes. It will be able to see objects that are 50 times fainter and seven times farther away than those we are now able to observe. While it is not possible to depict exactly what will be seen, the above illustration will serve as an example. At top, the tiny, hazy patch in the small circle is shown as it would be seen with an Earth-based telescope. The large circle at bottom shows the same area as it would appear with the Space Telescope.



SPACE TELESCOPE'S CAPABILITIES — Earth's atmosphere, while transparent to visible light, filters out much of the electromagnetic spectrum. Also, haze, turbulent air currents, clouds and light pollution from cities limit the usefulness of present telescopes. The Space Telescope will be able to use the entire visible portion of the spectrum, in addition to portions of the infrared and ultraviolet.

from the limited storage range of the photographic emulsion, thus permitting very long periods of observation and even fainter magnitude limits.

A further advantage for observational programs lies in the accessibility of all of the sky and almost 24 hours of observing conditions. With ground-based observatories, most optical observations are made only during twilight and dark hours and even then only when it is reasonably clear. With the Space Telescope, it will be possible to make some observations even in sunlight (although not to the faintest levels) and realize about 4,500 hours of observation per year. (Excellent ground-based observatories obtain about 2,000 hours per year.)

The Space Telescope is expected to contribute a great deal to the study of little-understood energy processes in celestial objects, the early stages of star and solar-system formation, such highly-evolved objects as supernova remnants and white dwarf stars, and the origin of the universe.

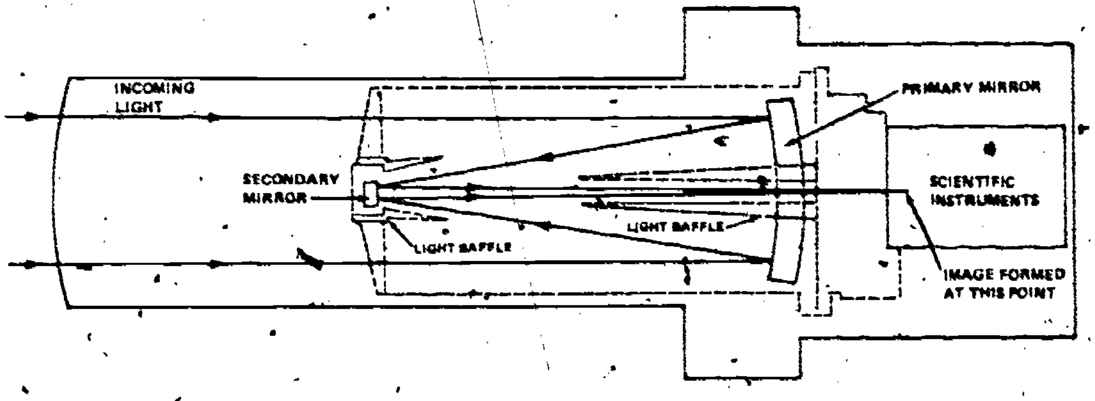
With the Space Telescope, scientists can look at galaxies so far away that they will be seen as they were billions of years ago. They should have much to reveal about the birth and growth of cosmic structures like our galaxy.

The Space Telescope may be able to search for planets that orbit other stars in the same way the Earth orbits the Sun. Data in this area will tell us about basic physical processes in the universe and indicate the chances for the existence of other life-supporting planets. It will provide a new perspective on the neighboring planets, giving continuing information about their physical conditions and atmosphere—the kind of information needed to build and equip spacecraft for further exploration.

Astronomical observations in the past have often suggested potential solutions to problems on Earth. For example, the first confirmation of nuclear fusion was from the study of the Sun. If the quasars are as intensely luminous as they appear, they have the concentrated power of millions of stars. The Sun would be pale in comparison.

Are quasars really so powerful? Can their energy principle be used on Earth? For the first time, with the Space Telescope, quasars can be seen well enough to investigate these possibilities.

ON-ORBIT SERVICE — The unique capability offered by Space Telescope for on-orbit servicing and uprating of its equipment, using suited astronauts, will add greatly to its value as a scientific tool. Astronomers will be able to periodically upgrade scientific instruments to the latest state-of-the-art. In event of major repairs or refurbishment, the Shuttle would be able to retrieve the Space Telescope, return it to Earth and re-launch it later.



LIGHT PATH — This schematic shows how starlight enters the open front end of the Space Telescope, is projected from the primary mirror to the secondary mirror, and is then directed to a focus inside the scientific instruments at rear. The light baffles preclude unwanted light, which may have been deflected off some part of the telescope, from reaching the image formed within the scientific instruments.

The Space Telescope System

The Space Telescope will be a long-lifetime general-purpose telescope capable of utilizing a wide variety of different scientific instruments at its focal plane.

It will weigh about 24,000 pounds (11,000 kilograms) and will have a length of 43 feet (13.1 meters) and a diameter of 14 feet (4.26 meters).

The major elements of the Space Telescope will be an Optical Telescope Assembly, a Support Systems Module and the Scientific Instruments.

The Optical Telescope Assembly will mount a 94-inch (2.4-meter) reflecting cassegrain-type telescope. A meteoroid shield and sunshade will protect the optics.

The telescope itself will have a Ritchey-Chretien folded optical system with the secondary mirror inside of the prime focus.

The primary mirror will be made of ultra-low expansion glass. The mirror will be heated during operation to about optical shop temperatures (70°F) to minimize variations from its original accuracy. Additional heat required to maintain the 70°F temperature will come from electrical strip heaters which will radiate to the back of the mirror.

The open front end of the Space Telescope will be similar to most Earth-bound telescopes and will admit light to the primary mirror in the rear of the telescope. The primary mirror will project the image to a smaller secondary mirror in front. The beam of light will then be reflected back through a hole in the primary mirror to the scientific instruments in the rear.

The pointing and stabilization control system can point the telescope to an accuracy of 0.01 arc-second and can hold onto a target for extended periods within 0.007 arc-second. (This angle is only slightly larger than that made by a dime when viewed at a distance from Washington, D.C., to Boston.) The resolving power of two point images will be about 0.1 arc-second.

The references used for pointing stability will be accomplished using precision gyros and bright field stars or "guide" stars.

The Scientific Instruments will provide the means of converting the telescope images to useful scientific data.

The instruments, and their sensors, located directly behind the telescope, will communicate images in a variety of ways. The modular instruments will fit behind the focal plane and will contain imaging systems, spectrum analyzers (to find out about atomic structure and material content of objects observed), and light intensity and polarization calibrators. Devices for exact control of temperature, direction and stability, and the equipment to generate power will be located in similar modular packages.

The apertures of the Scientific Instruments are located at the principal focus. Since stray light suppression is extremely important in reaching faint light levels, the forward end of the telescope is enclosed and well baffled, with the aperture door serving as a Sun shield.

The Scientific Instruments include two cameras, two spectrometers and a photometer.

The Faint Object Camera, provided by the European Space Agency, and the Wide Field Planetary Camera are distinguished by their fields of view, spatial resolution and wavelength range. Both instruments cover the ultraviolet and blue regions of the spectrum.

The Wide Field Planetary Camera covers the red and near-infrared regions as well. The Faint Object Camera has a very small field of view, but can use the highest spatial resolution which the Space Telescope optics can deliver. The Wide Field Planetary Camera covers a field at least 40 times larger, but with a resolution degraded by a factor of two to four.

The two spectrographs, the High Resolution Spectrograph and the Faint Object Spectrograph, provide a wide range of spectral resolutions which would be impossible to cover in a single instrument. Both instruments will record ultraviolet radiation. Only the Faint Object Spectrograph covers the visible

SUPPORT SYSTEMS MODULE — Overall size of the Space Telescope is 43 feet (13.1 meters) long by 14 feet (4.26 meters) in diameter. This illustration shows the Support Systems Module, which contains the very precise pointing and stabilization control system, communications, thermal control, data management and electric power systems, and solar panels for electrical power generation.

and red regions of the spectrum.

The fifth instrument, the High Speed Photometer, is a relatively simple device capable of measuring rapid brightness variability over time intervals as short as 0.0001 second. It can also be used to measure ultraviolet polarization and to calibrate other instruments.

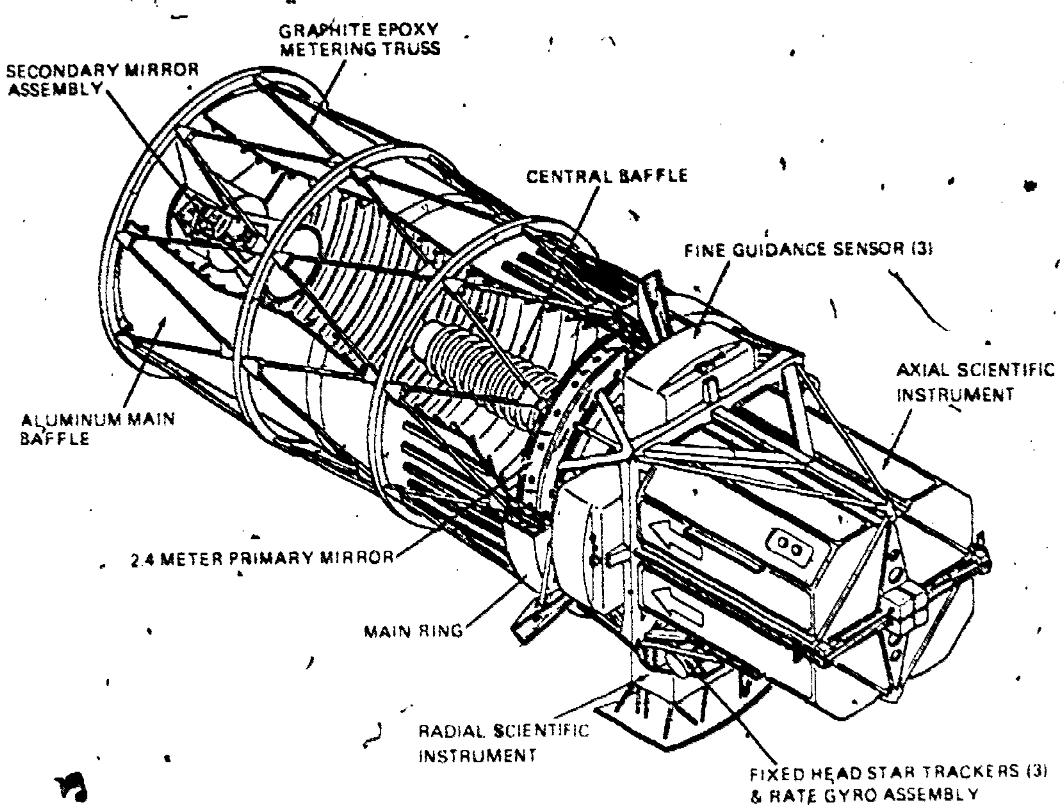
It is expected that competition for new instruments may be opened every few years to guarantee that the Space Telescope instrument payload represents the best possible configuration.

The Support Systems Module will enclose the Optical Telescope Assembly and Scientific Instruments and also provide all interfaces with the Shuttle Orbiter.

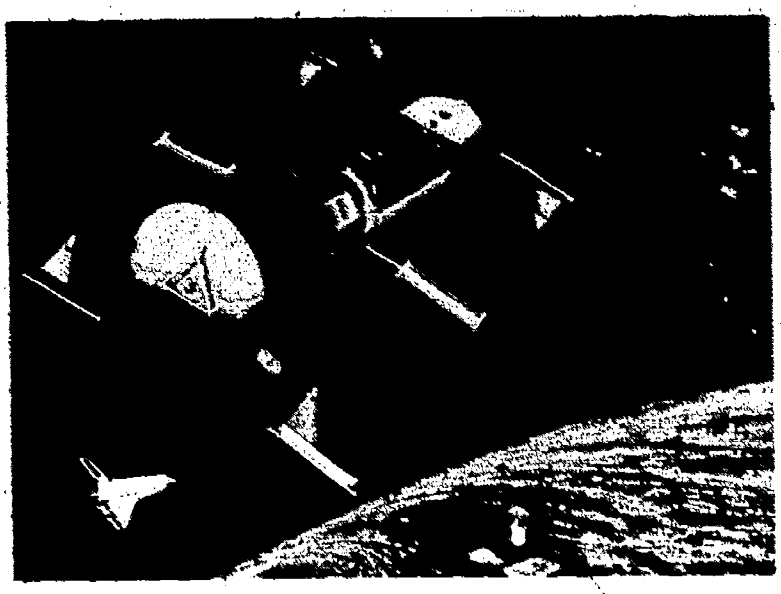
The module will contain a very precise pointing and stabilization control system, the communications system, thermal control system, data management system and electric power system.

Electrical power to operate the telescope will be provided by batteries which are charged by the two solar panels during the Sun side of its Earth orbit.

Images received by the telescope will be transmitted to Earth by telemetry.



OPTICAL TELESCOPE ASSEMBLY — This is a cutaway view of the Optical Telescope Assembly, which fits inside the Support Systems Module. Light is projected by the 94-inch (2.4 meter) primary mirror to the secondary mirror, and from there back through a hole in the primary mirror for analysis by several scientific instruments, including a Faint Object Camera, Faint Object Spectrograph, High Speed Photometer and Wide Field Planetary Camera.



DATA ACQUISITION — The Space Telescope will be controlled remotely by ground stations. Data acquired by the telescope will be sent electronically to a computer and then converted to formats suitable for scientific analysis. NASA's Spaceflight Tracking and Data Network—which includes the Tracking and Data Relay Satellite System and ground tracking stations, and the NASA Communication Network—will be used to complete the communications link between the Space Telescope and the ground operational systems.

Mission Operations

The Space Telescope is a new concept in space-borne astronomical observatories. Its long design lifetime and the capability of refurbishment and scientific instrument replacement will enable it to operate at the forefront of astronomical research for two decades or more. Due to the Space Telescope's unique scientific importance, its operations are designed for maximum flexibility while at the same time insuring spacecraft safety and operational efficiency.

The Space Telescope will orbit the Earth at a nominal altitude of approximately 310 miles (500 kilometers) with an orbital inclination of 28.8 degrees.

The Space Shuttle will launch Space Telescope into orbit, and also serve as a base from which astronauts may make repairs by replacing modular components, including new instrument packages. Each modular package can be replaced in orbit without affecting the overall system. The Shuttle can also bring the telescope back to Earth, if necessary, for extensive maintenance or overhaul, and later relaunch it. The plan is to update the scientific instruments, on a selective basis, in orbit after about two-and-a-half years and to return the Space Telescope to Earth via the Shuttle after five years for major refurbishment.

Although in orbit, the Space Telescope will be operated in a manner similar to that of ground-based telescopes. The five instruments can be selected as appropriate for specific observations and the telescope can be pointed to targets of interest. Plans for orbital operations include a limited amount of interaction between the observer and the telescope during the observation.

There are plans to establish an independent organization, the Space Telescope Science Institute, to develop and control the science programs carried out using Space Telescope. Observers who use the telescope would go to the Institute to participate in an observation.

Principal Shuttle/Space Telescope mission operations phases will include: launch, orbital operation, deployment, checkout, on-orbit service, and re-entry.

Launch — Two reusable solid propellant boosters and an external fuel tank are required to launch the Shuttle Orbiter (carrying the Space Telescope in its cargo bay) into space. The boosters will separate and parachute into the ocean for recovery and re-use. The Orbiter will then be driven by its liquid-propellant engines.

Orbital Operation — After orbital insertion and circularization, the Orbiter will be maneuvered into the proper position and the Space Telescope will be raised in preparation for deployment.

After a preliminary checkout, the Space Telescope will be positioned in space by the Orbiter remote manipulator arm.

Checkout — As the Orbiter remains nearby for help if needed, the Space Telescope will receive an initial checkout from ground-based operators to make sure that all systems are operating properly. For the Orbiter to retrieve the telescope, the steps will be reversed.

On-orbit Service — During re-visit, the Space Telescope will be captured and positioned in the Shuttle's payload bay by the Orbiter remote manipulator arm. A crew in space suits will provide necessary service, making repairs and replacing equipment. This capability will make the Space Telescope a practical long-term reality.

Re-entry — The Space Telescope in the Orbiter's cargo bay will be isolated from the intense heat generated during re-entry. After it enters the Earth's atmosphere, the Orbiter will land like a conventional airplane. Servicing and repairs will then prepare the Space Telescope for its next mission.

The Space Telescope Team

NASA's Office of Space Science, NASA Headquarters, Washington, D.C., is responsible for overall direction of the Space Telescope program.

The Marshall Space Flight Center, Huntsville, Ala., is NASA's lead center, responsible for overall project management.

The Goddard Space Flight Center, Greenbelt, Md., is responsible for the scientific instruments, mission operations and data reduction.

The Johnson Space Center is responsible for the Space Shuttle and flight crew operations.

The Kennedy Space Center is responsible for the Space Shuttle launch operations.

European Space Agency members will provide one of the scientific instruments, as well as the solar arrays, and will participate in flight operations.

The Space Telescope prime contractors are Lockheed Missiles and Space Company, Sunnyvale, Cal., responsible for the Support Systems Module and systems engineering, and the Perkin-Elmer Corp., Danbury, Conn., responsible for the Optical Telescope Assembly.

A total of 45 scientists have been selected by NASA to participate in the design and early operational phases of the Space Telescope project in a variety of categories.

NASA will oversee the operation of an independent Science Institute responsible for conducting an overall Space Telescope science program to implement NASA policy, and detailed science planning and routine operations. The Institute will carry out NASA science objectives, solicit and select observational proposals and coordinate research and international participation.
It will determine general viewing schedules, target sequence and target availability within the context of spacecraft constraints. The Institute will also reduce and analyze data, conduct basic research, evaluate and disseminate the science data and store the data in archives.