
HUBBLE SPACE TELESCOPE

(NASA-TM-107962) HUBBLE SPACE
TELESCOPE. UPDATE: 18 MONTHS IN
ORBIT (NASA) 19 p

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UPDATE: 18 Months in Orbit

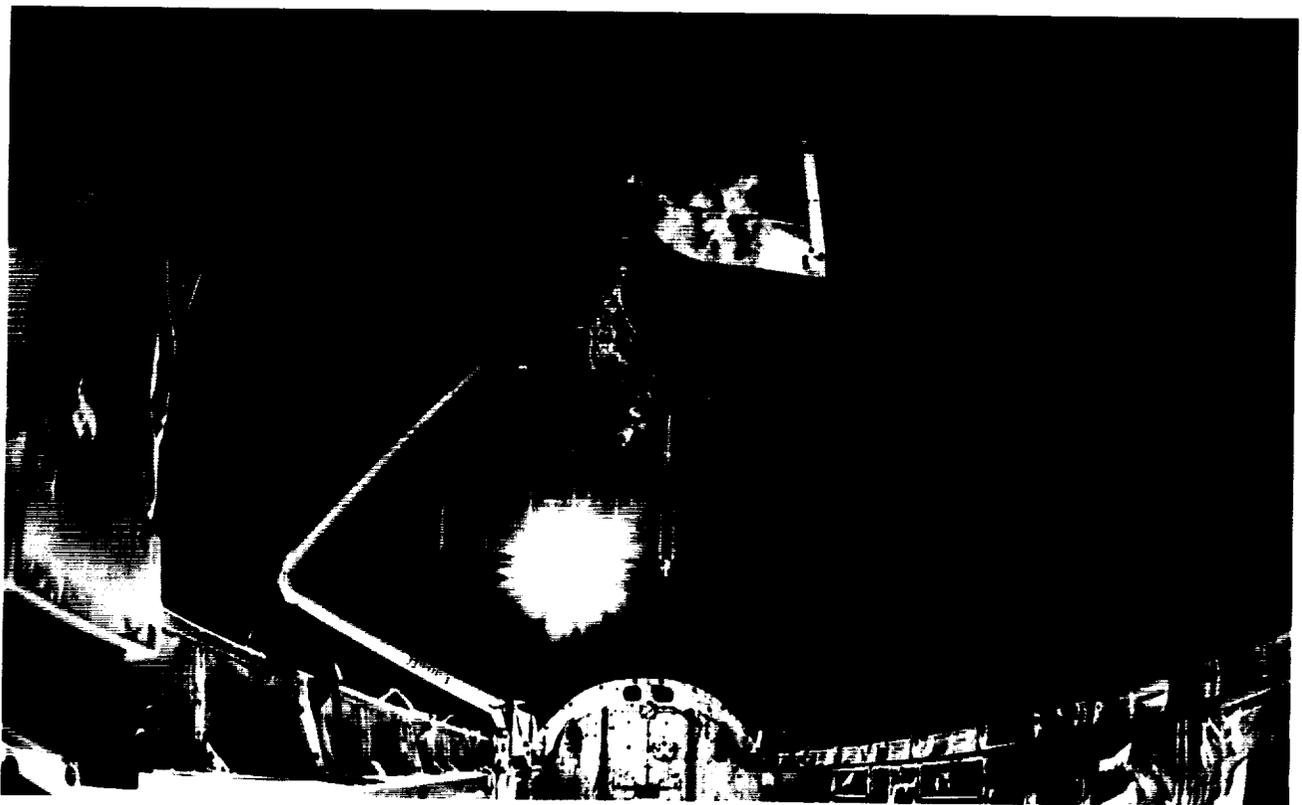


ORIGINAL PAGE
COLOR PHOTOGRAPH

"From our home on the Earth, we look out into the distances and strive to imagine the sort of world into which we are born. Today we have reached far out into space. Our immediate neighborhood we know rather intimately. But with increasing distance our knowledge fades rapidly, until at the last dim horizon we search among ghostly errors of observations for landmarks that are scarcely more substantial.

The search will continue. The urge is older than history. It is not satisfied and it will not be suppressed."

— *Edwin P. Hubble*
(1889-1953)



ORIGINAL CONTAINS
COLOR ILLUSTRATIONS

HUBBLE SPACE TELESCOPE

ORIGINAL PAGE
COLOR PHOTOGRAPH

In April 1990, Space Shuttle *Discovery* launched Hubble Space Telescope — perhaps the most ambitious scientific mission NASA has ever undertaken.

Then, in June 1990, came the disappointing news of spherical aberration in the HST primary mirror. Many concluded prematurely that the project had no future.

But now, after 18 months in orbit, HST is in routine operation and has surprised its early critics by producing results at the forefront of science. Regular Shuttle servicing missions should permit the telescope to achieve its original scientific goals over a planned 15-year observing lifetime.

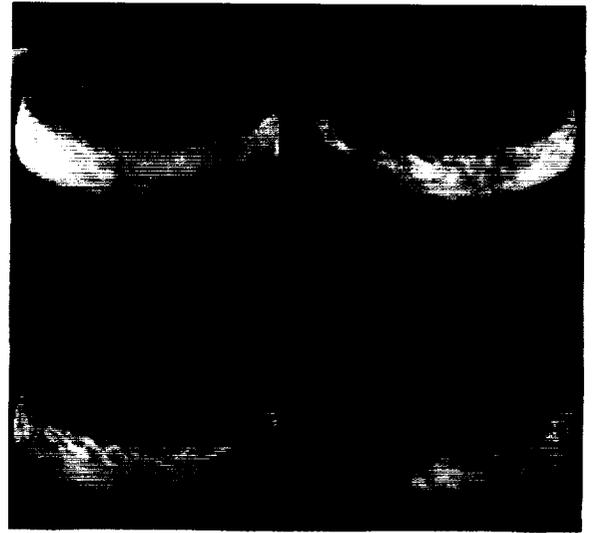
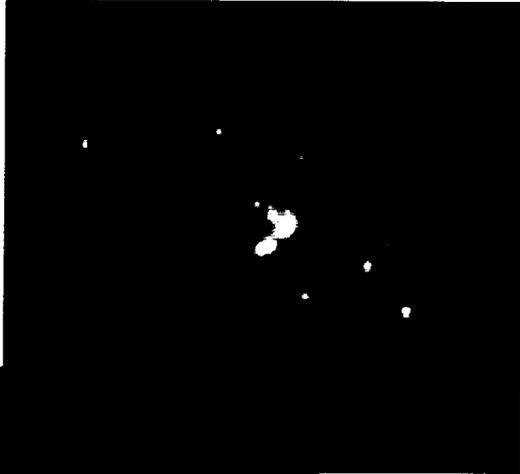
UPDATE: 18 Months in Orbit

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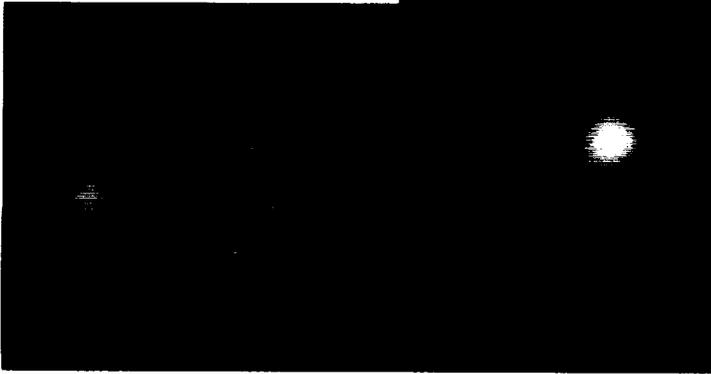
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The First 18 Months

R136: Star birth in nearby galaxy



Saturn: Planet-wide atmospheric storm



Supernova 1987A: Exploding star in the Large Magellanic Cloud, a nearby galaxy

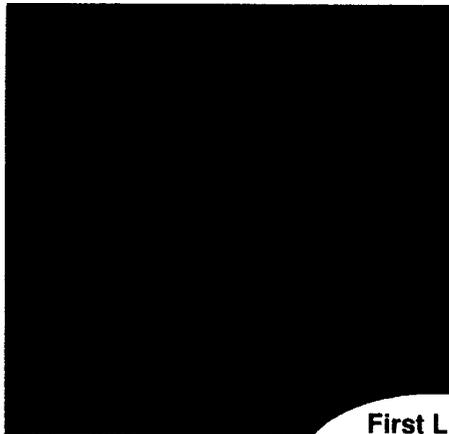
M14: Old globular star cluster in Milky Way Galaxy



Imaging Begins



First Light:
European
Faint Object
Camera



NGC 7457: Distant galaxy with black-hole candidate at center

First Light:
Wide Field/
Planetary Camera



Einstein Cross: Quasar quadruply imaged by gravitational-lens galaxy (center)



R Aquarii: Matter ejected from young, evolving star

1990 APRIL JUNE AUGUST OCTOBER



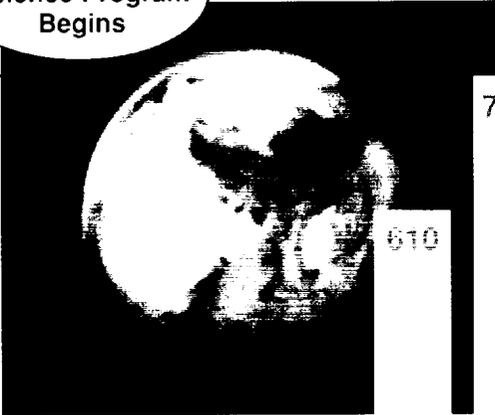
450 New
Observing
Proposals
Received

90

*Jupiter: Atmospheric
circulation patterns*

Formal
Science Program
Begins

790



710

*Mars: Finest surface
detail ever seen from
vicinity of Earth*

460

CUMULATIVE
NUMBER OF
OBJECTS
OBSERVED

360

260

**More than 1,900 observations
of nearly 900 astronomical objects**
have already been carried out by HST. Observations began with imaging but now include spectroscopy. Scientists obtain information on the temperature, composition, and motion of an object by analyzing the spectrum of radiation emitted or absorbed by the object. Observing time is in great demand by astronomers world-wide.

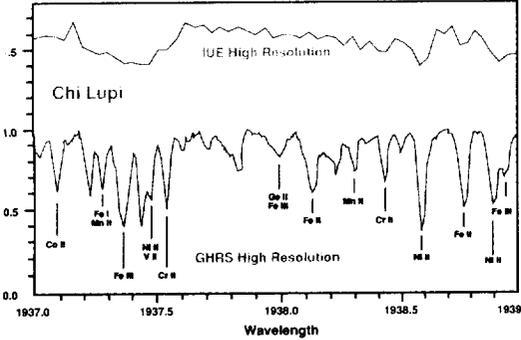
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100

30

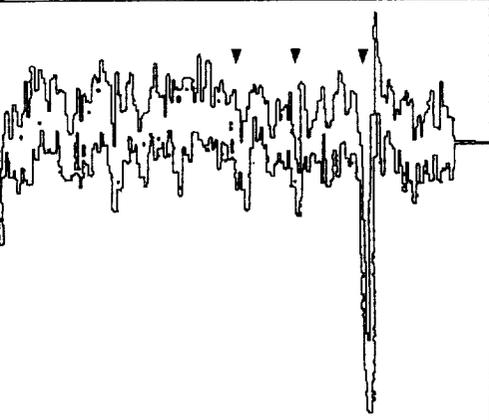
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DECEMBER 1991 FEBRUARY APRIL JUNE AUGUST OCTOBER



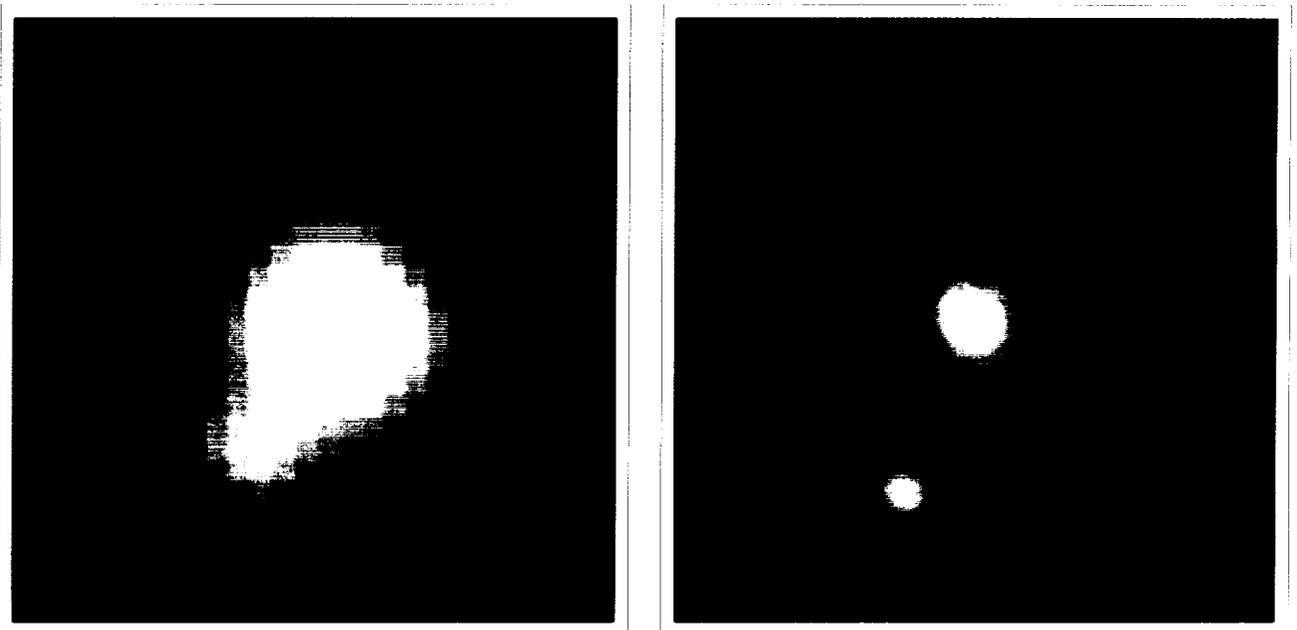
*Chi Lupi: Chemistry of stellar
atmosphere (ultraviolet spectrum)*

Spectroscopy
Begins

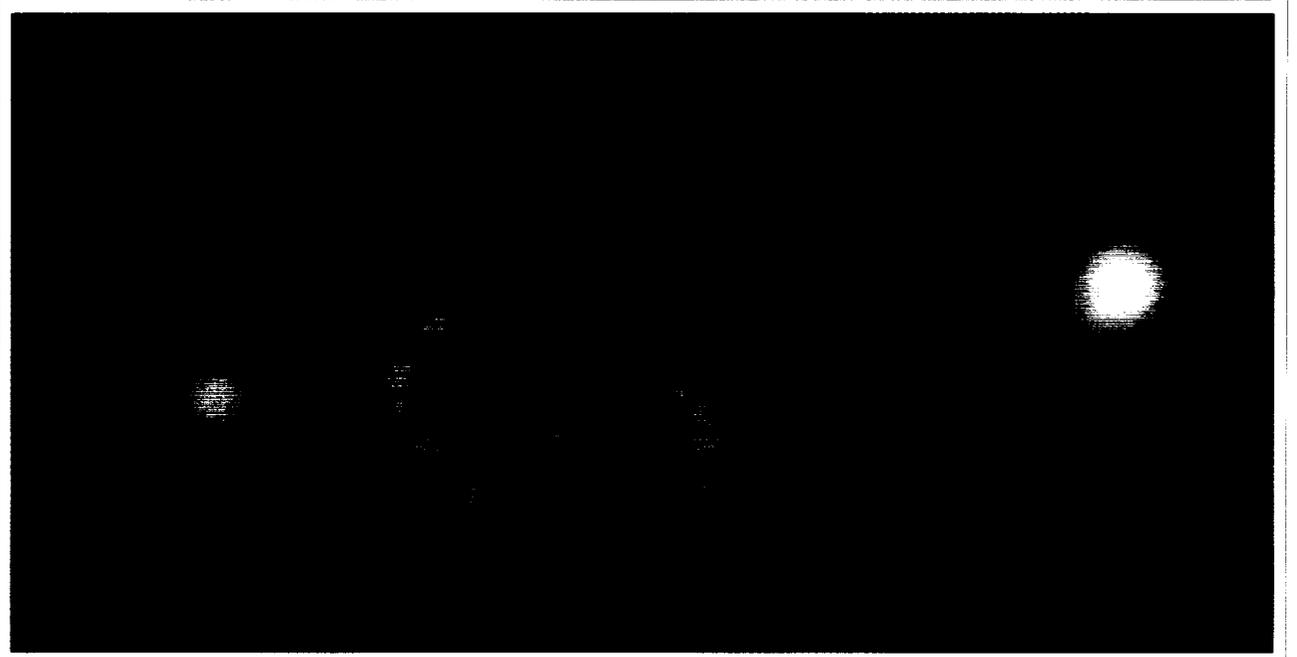


*Intergalactic gas: Surprising number of
clouds found near Milky Way Galaxy
(ultraviolet spectrum)*

“I Thought It Was Broken”



Pluto and its close satellite Charon, barely distinguishable as separate bodies in a ground-based image (left), are clearly separated in the HST image (right). Because Charon is half the size of Pluto, this system is often called the “double planet.”



Ring of gas around Supernova 1987A, shown in this HST image, was ejected many thousands of years prior to the blast. In combination with spectroscopy by NASA’s International Ultraviolet Explorer satellite, HST measurements of the ring’s angular size yielded the distance to the supernova.

Q: What's the real story with HST? I thought it was broken.

A: Hubble Space Telescope is the most capable optical telescope available to astronomers today, despite the mirror problem. It is producing images and spectral observations that place HST programs at the forefront of astronomy.

Q: How is that possible?

A: First of all, HST has greater clarity of view than any ground-based optical observatory, both because of the substantial light-gathering power of its 94-inch mirror and because of its location in space above the distorting effects of Earth's atmosphere. In addition, its location in space permits HST to observe ultraviolet radiation that does not penetrate the atmosphere.

Q: But what about the mirror problem?

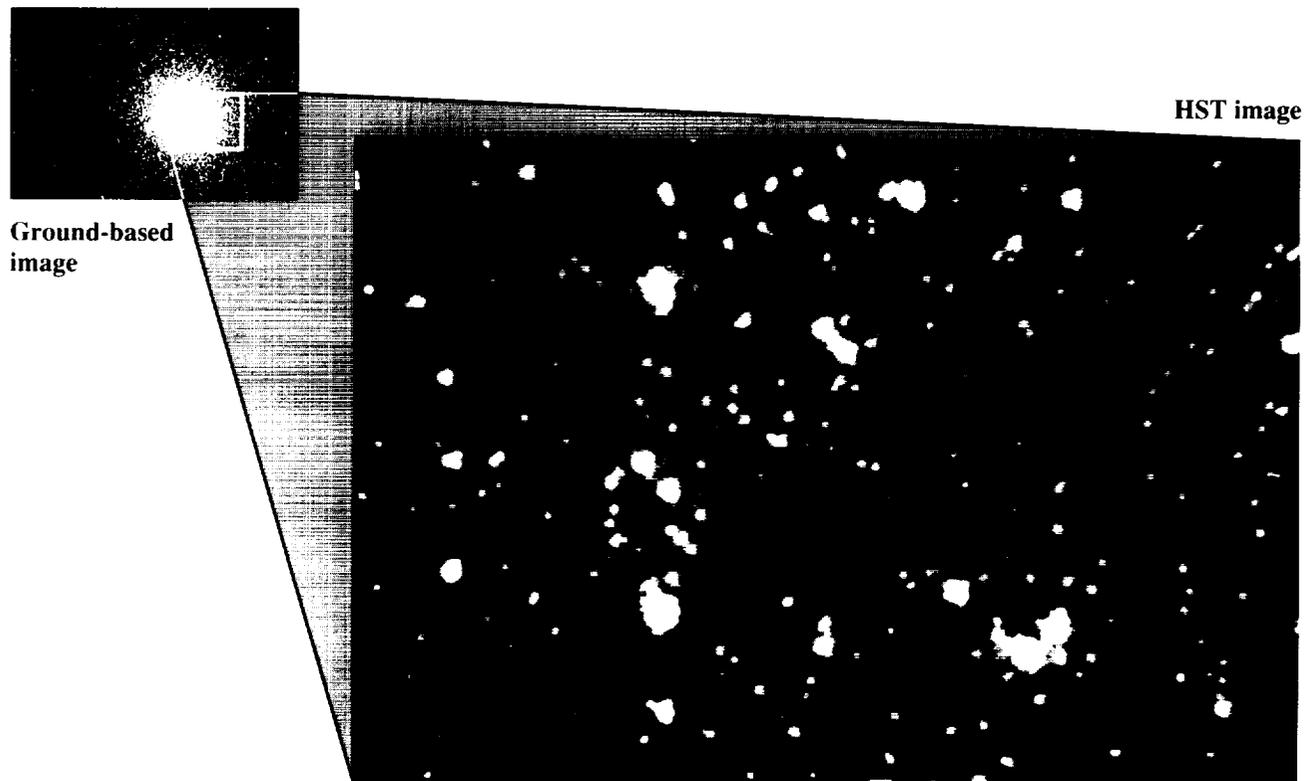
A: Because the mirror was so perfectly polished — albeit to a slightly incorrect shape — the effects of the spherical aberration can often be removed by computer processing. Many processed images reveal breathtaking detail never before seen from the ground.

Q: What is the long-range future of Hubble Space Telescope?

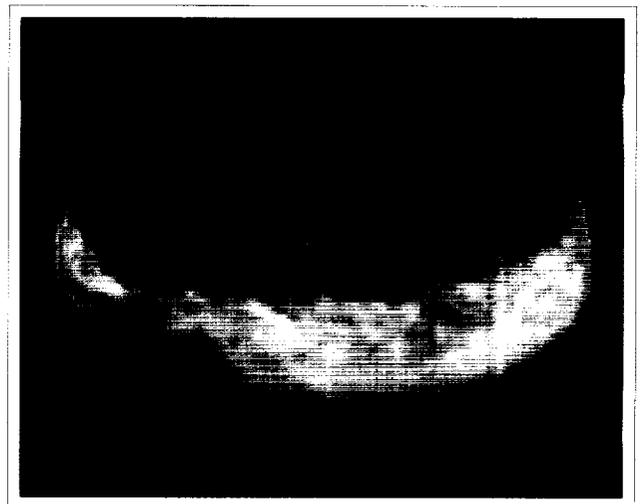
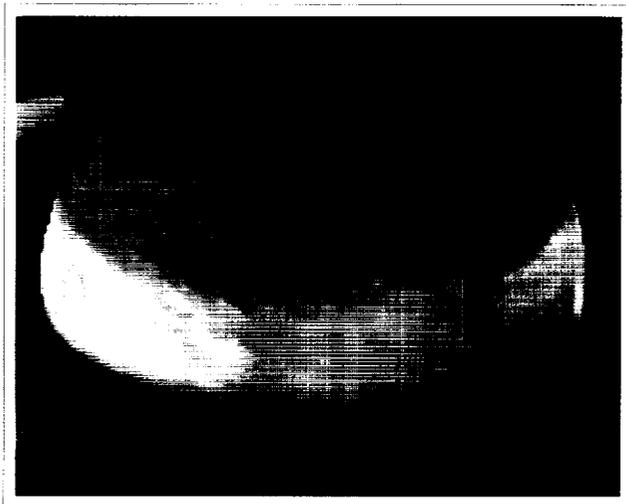
A: Bright. Through Shuttle servicing missions, which were planned from the beginning, we can achieve the capabilities intended for HST early in the observatory's 15-year mission lifetime. Over this period, HST should be able to achieve its original scientific objectives.

In Fact,
Hubble Space Telescope is the most powerful optical telescope in the world today: it offers unmatched ability to image fine detail and to study ultraviolet radiation from astronomical objects.

Achievements Amid Challenges



Star Regeneration in 47 Tucanae. In the cores of old globular clusters like 47 Tucanae, thousands of stars are crowded into a region less than one light-year across. Could these ancient stars ever be regenerated by stellar mergers or collisions? Ground-based telescopes have not been able to answer this question; their images of such cluster cores (top left) are smeared out by atmospheric turbulence. But in the core of 47 Tucanae, HST's clear view from space (above) has revealed dozens of hot blue luminous stars radiating away energy so rapidly that they cannot have survived since the birth of the cluster itself. These observations provide the first convincing evidence of recent star regeneration in old clusters.



HST images of Saturn, recorded at quarterly intervals of the planet's 10-hour rotation period, show successive quadrants of the surface. Hundreds of such images, computer processed to bring out fine detail, were assembled into a 1991 film to illustrate the progress of a giant storm across Saturn's turbulent atmosphere.

Q: Have you had to meet other challenges, besides the mirror?

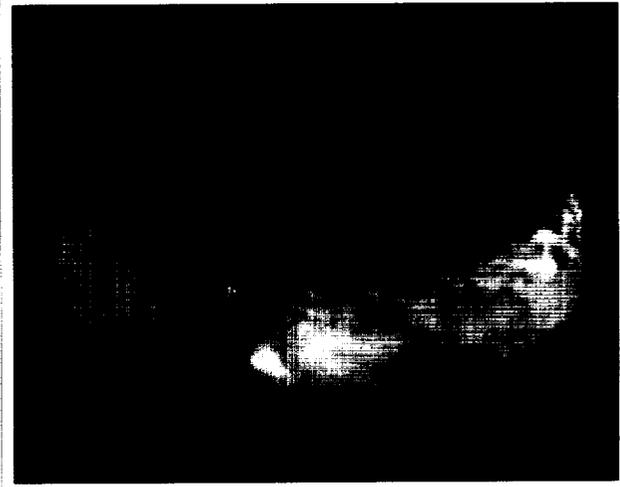
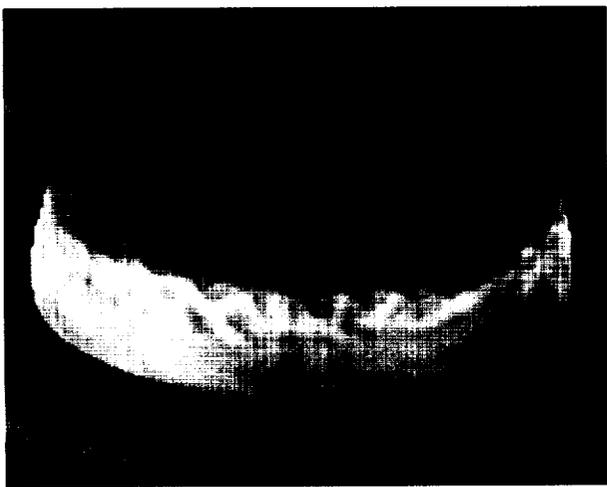
A: Yes — which is not surprising for a complex system with 400,000 different parts. For example, the solar-power arrays supplied by the European Space Agency make HST "jitter", or shake, every time the spacecraft orbits into and out of daylight. But we have fixed most of the problem by writing special computer programs for the HST pointing system.

Q: Is HST especially vulnerable to malfunctions?

A: Quite the opposite. HST, as well as being serviceable in space, was designed to provide high redundancy and extensive backup capabilities. For example, two gyroscopes used for pointing control have stopped functioning; but we've activated two spare gyros to continue normal operation, and another spare is still available. Overall, very few of HST's reserve capabilities have been needed so far.

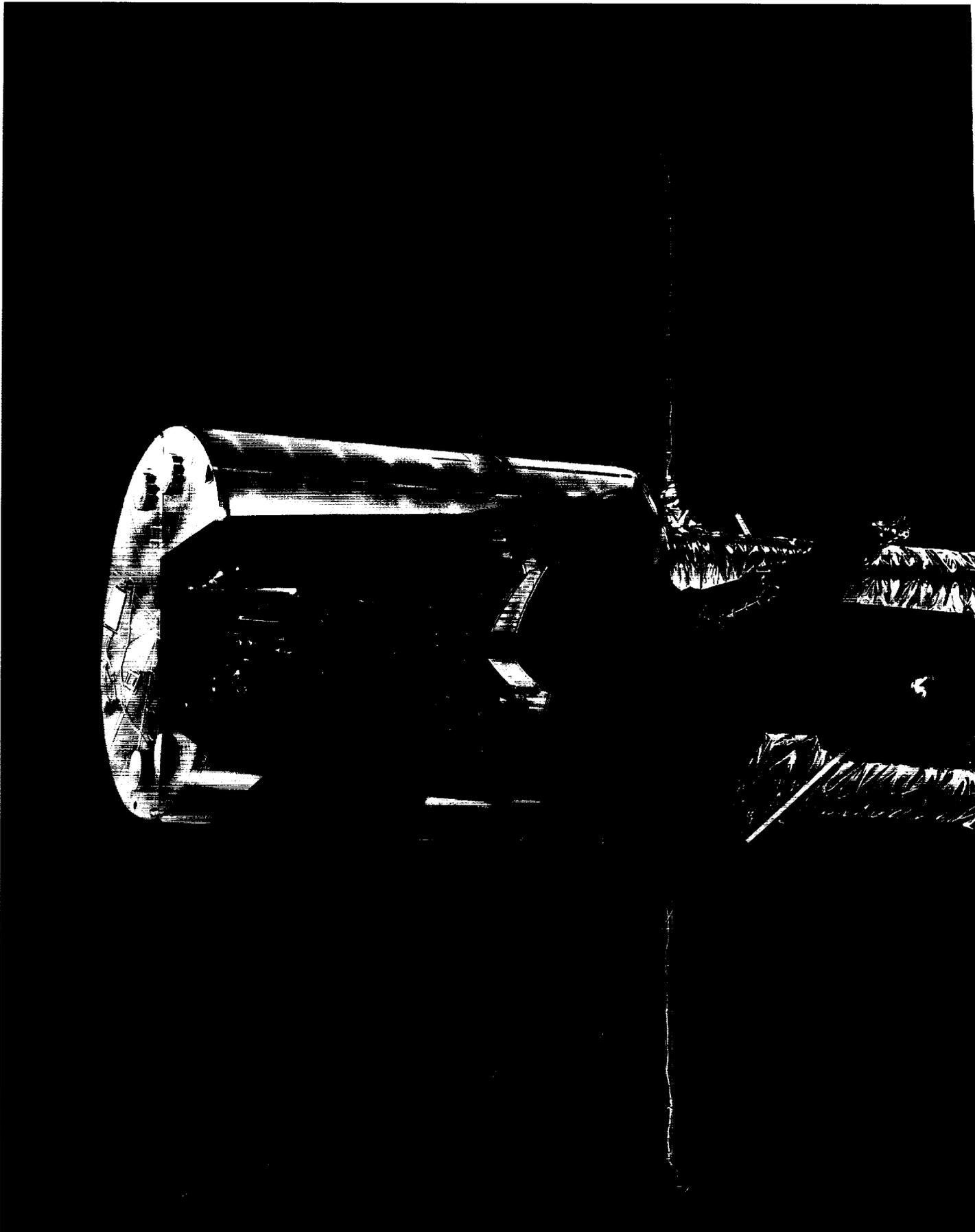
Q: So the capability for forefront science remains high?

A: Yes. Consider scientific papers presented at the January 1992 meeting of the American Astronomical Society. Of the papers reporting space science observations — which represented 25 percent of all the observational papers — one out of four described HST results. And demand for observing time remains strong. In 1991, some 450 scientific groups submitted new proposals to use the telescope.



The storm was revealed in September 1990 by ground-based observations. The HST observing schedule was quickly modified to permit HST to track the disturbance, which by November had spread to cover most of the planet. The white areas in these images are believed to be immense clouds of ammonia ice crystals, lofted to high altitudes by violent winds.

Breakthroughs In Technology





Hubble Space Telescope, the creation of ten thousand people over two decades of inspired effort, is by far the most complex and advanced space observatory ever built. The HST project team produced major technological breakthroughs in order to meet the most demanding observing requirements in space-science history.

Support Structure:

Constructed of lightweight, low-expansion, hand-formed graphite-epoxy tubes, the structure holds HST optical components aligned within 1/10,000 of an inch during two abrupt temperature changes every 96 minutes as HST orbits into and out of sunlight.

Pointing Control System:

The most accurate ever devised for astronomy, incorporating unique, high-spin-rate gyroscopes shielded against vibration and electromagnetic disturbances caused by space radiation and solar flares — reduces pointing instability to an angle less than the width of a dime seen 200 miles away.

Ultraviolet Performance:

The ultraviolet optical system is the most capable ever launched for astronomical observations in this region of the electromagnetic spectrum. It has reflecting surfaces of unprecedented cleanliness and smoothness to maximize the amount of ultraviolet radiation available for imaging and spectroscopic analysis.

Serviceability:

This is the first NASA space mission designed for regular Space Shuttle maintenance and upgrading over a planned 15-year mission lifetime. Forty-nine types of key components, including gyroscopes, are accessible and readily replaceable on orbit to maintain and expand HST capabilities.

Current Capabilities

Q: What was HST designed to do?

A: HST was designed to provide three capabilities:

- 1** High angular resolution — the ability to image fine detail;
- 2** Ultraviolet performance — the ability to produce ultraviolet images and spectra; and
- 3** High sensitivity — the ability to detect very faint objects.

Q: What can HST currently do?

A: HST currently provides the first two capabilities. First of all, for the brighter sources:

- 1** Computer processing can be used to bring out much finer image detail than can be provided by ground-based telescopes. In addition,
- 2** Ultraviolet spectroscopy has been exceptionally productive, helping astronomers to understand the composition and dynamics of objects in our Galaxy and to map the distribution of intergalactic gas clouds.

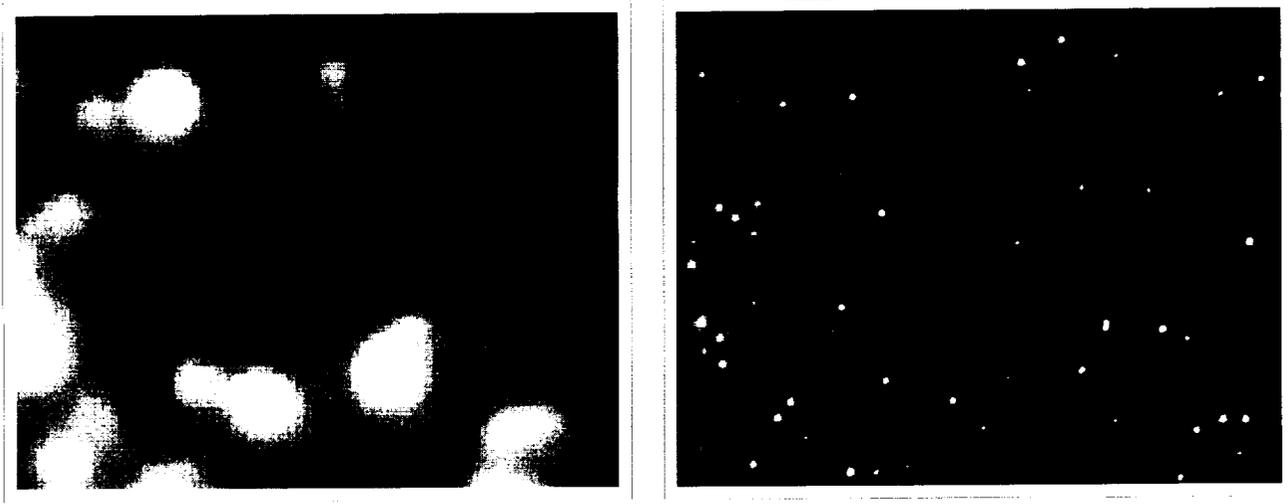
Q: How will you be able to study faint objects?

A: Computer processing can't be used for very faint objects — too much light is scattered by the aberration to permit reliable image reconstruction. But,

- 3** Corrective optics, to be provided by the first Shuttle servicing mission, will bring this scattered light back into focus, allowing HST to achieve its original design goal and reach very distant stars and galaxies.

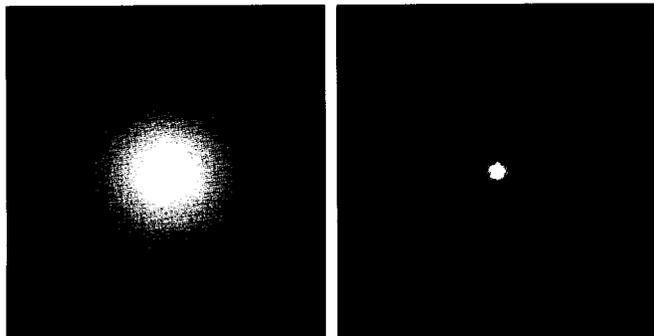
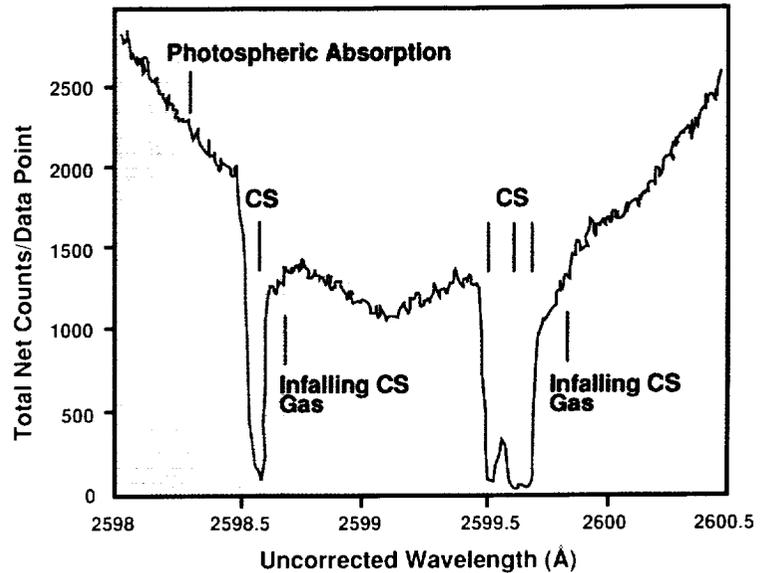
Capabilities Checklist:

- High angular resolution — ability to image fine detail.**
 - Ultraviolet performance — imaging and spectroscopy.**
 - High sensitivity — ability to detect very faint objects (after first servicing mission).**
-



1 High angular resolution of HST is illustrated by comparison of a ground-based image of the globular cluster M14 (left) and an image recorded by HST (right) after computer processing. The ground-based image is heavily blurred by atmospheric turbulence and cannot reveal individual stars in the cluster center.

2 Ultraviolet spectroscopy of the star Beta Pictoris by HST reveals streams of circumstellar gas (CS) falling into the star. From earlier optical and infrared observations, Beta Pictoris is known to be surrounded by an orbiting disk of matter that may be a planetary system in the process of formation. The HST ultraviolet observations probe the central regions of the system and provide new insights into its dynamics.



3 High sensitivity will be achieved through correction of spherical aberration by the first Shuttle servicing mission. The current HST image of a star (illustrated schematically at left) is broadened by the effect of the aberration. The corrected stellar image (illustrated schematically at right) will meet the HST design goal by concentrating 60 to 70 percent of the light within a small region near the image center, enabling HST to study much fainter objects.

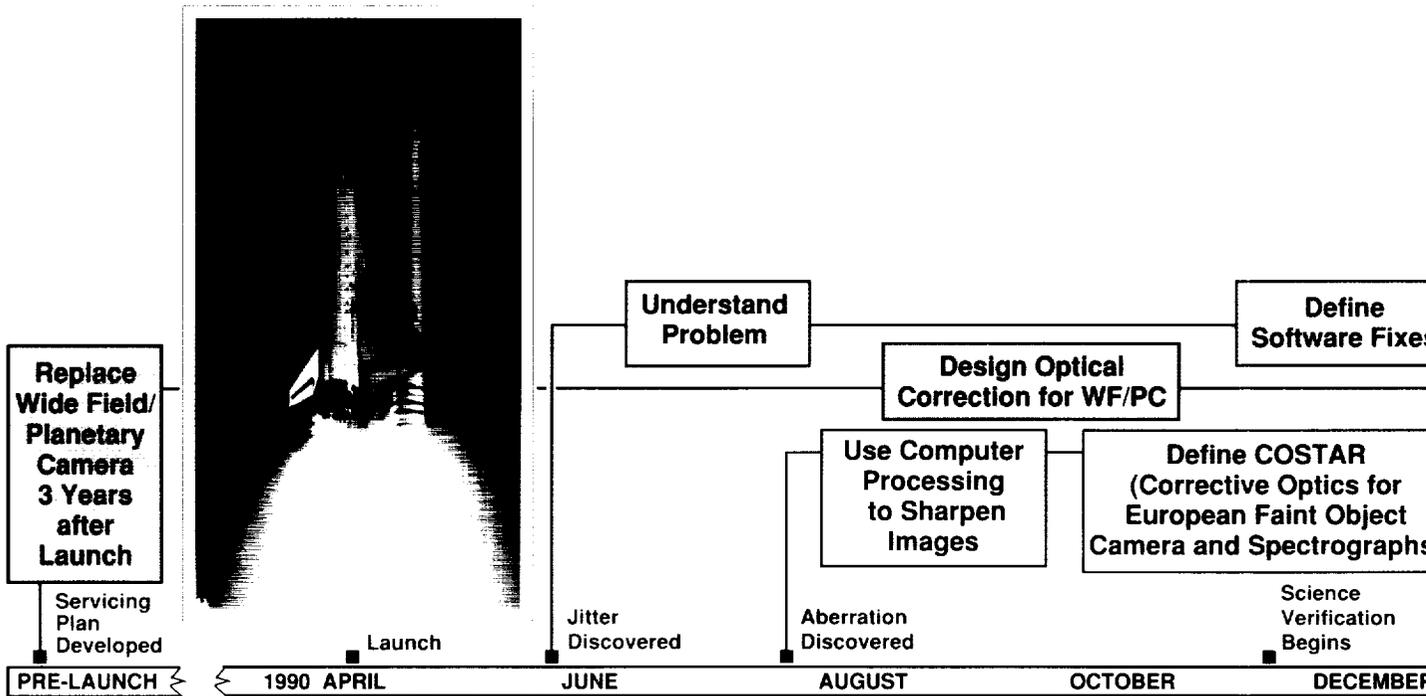
Servicing Plan

Q: *How does Shuttle servicing fit into your plans?*

A: HST is designed to be serviced by Space Shuttle crews. It has 49 different types of key components readily replaceable in space, and 74 replacement parts are available right now. We have always planned servicing missions, at roughly 3-year intervals, to maintain HST's operational capability and to upgrade its scientific performance as new technologies become available.

Q: *What will you do on the first mission?*

A: Our current baseline planning calls for replacement of the solar arrays, correction of the spherical aberration, and replacement of other components as necessary — for example, gyroscopes — in late 1993 or early 1994.

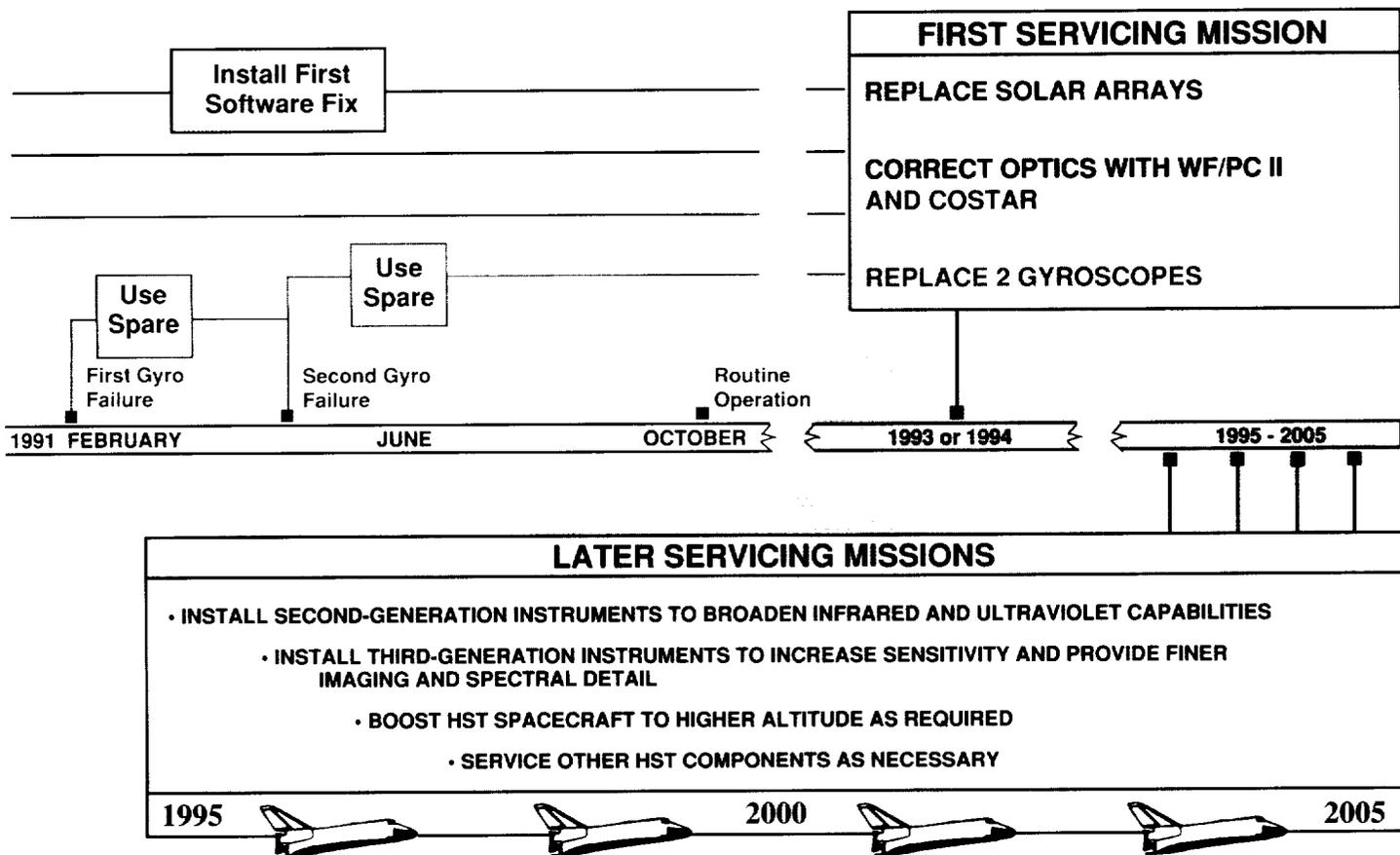


Q: *And on later missions?*

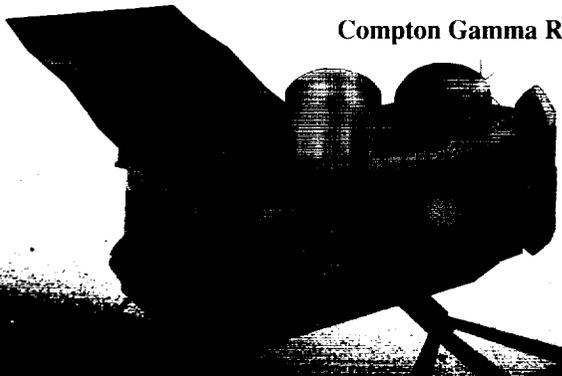
A: We'll replace remaining first-generation instruments, which represent earlier technology, with much more advanced second- and third-generation instruments to provide even greater capability, particularly for ultraviolet and infrared observations.



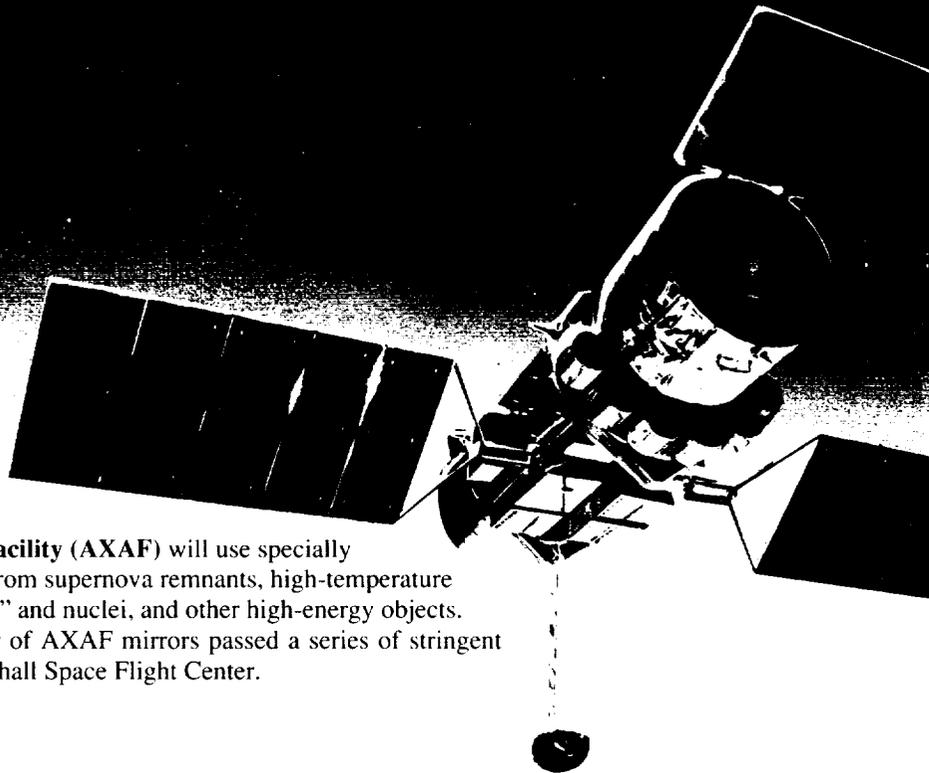
Wide Field/Planetary Camera, workhorse of the HST observing program, will be replaced by an optically corrected camera by astronauts on the first Shuttle servicing mission in late 1993 or early 1994.



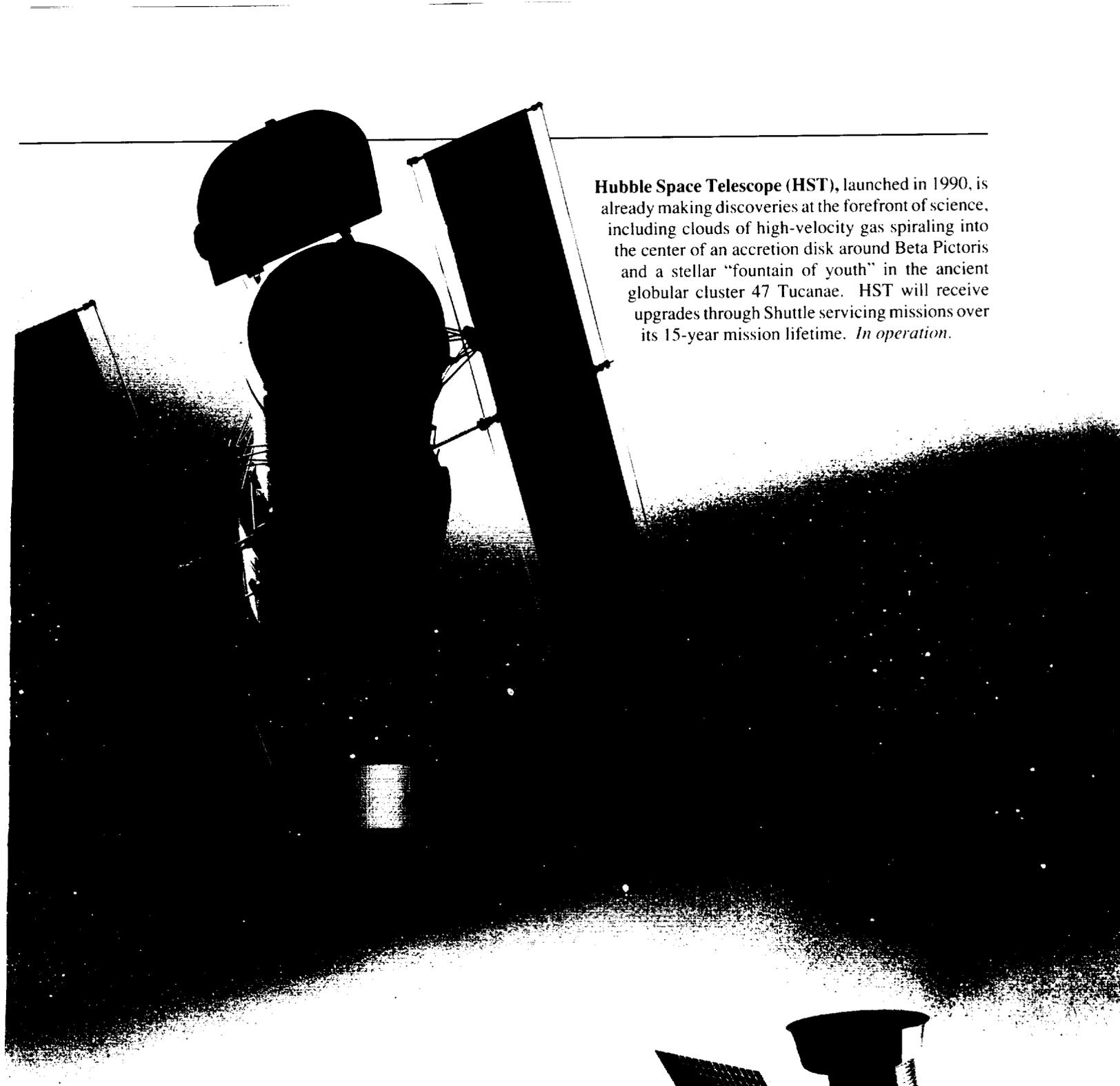
The Great Observatories



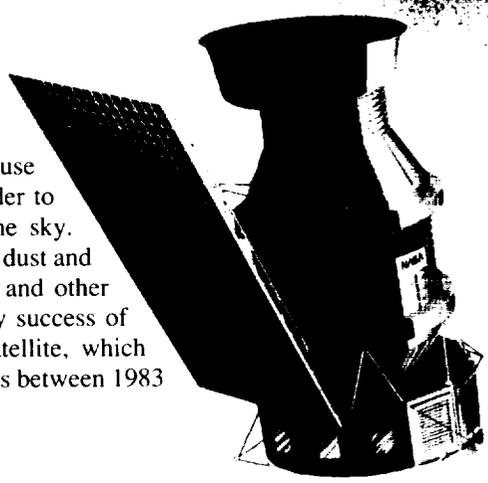
Compton Gamma Ray Observatory, launched in 1991, is now investigating the most energetic systems and violent events in the Universe. Compton has already shown that the puzzling gamma-ray “bursts” observed by earlier satellites are distributed uniformly across the sky, rather than concentrated toward the plane of our Galaxy — challenging current theories of burst origin in neutron stars and suggesting that some other mechanism must be responsible. *In operation.*



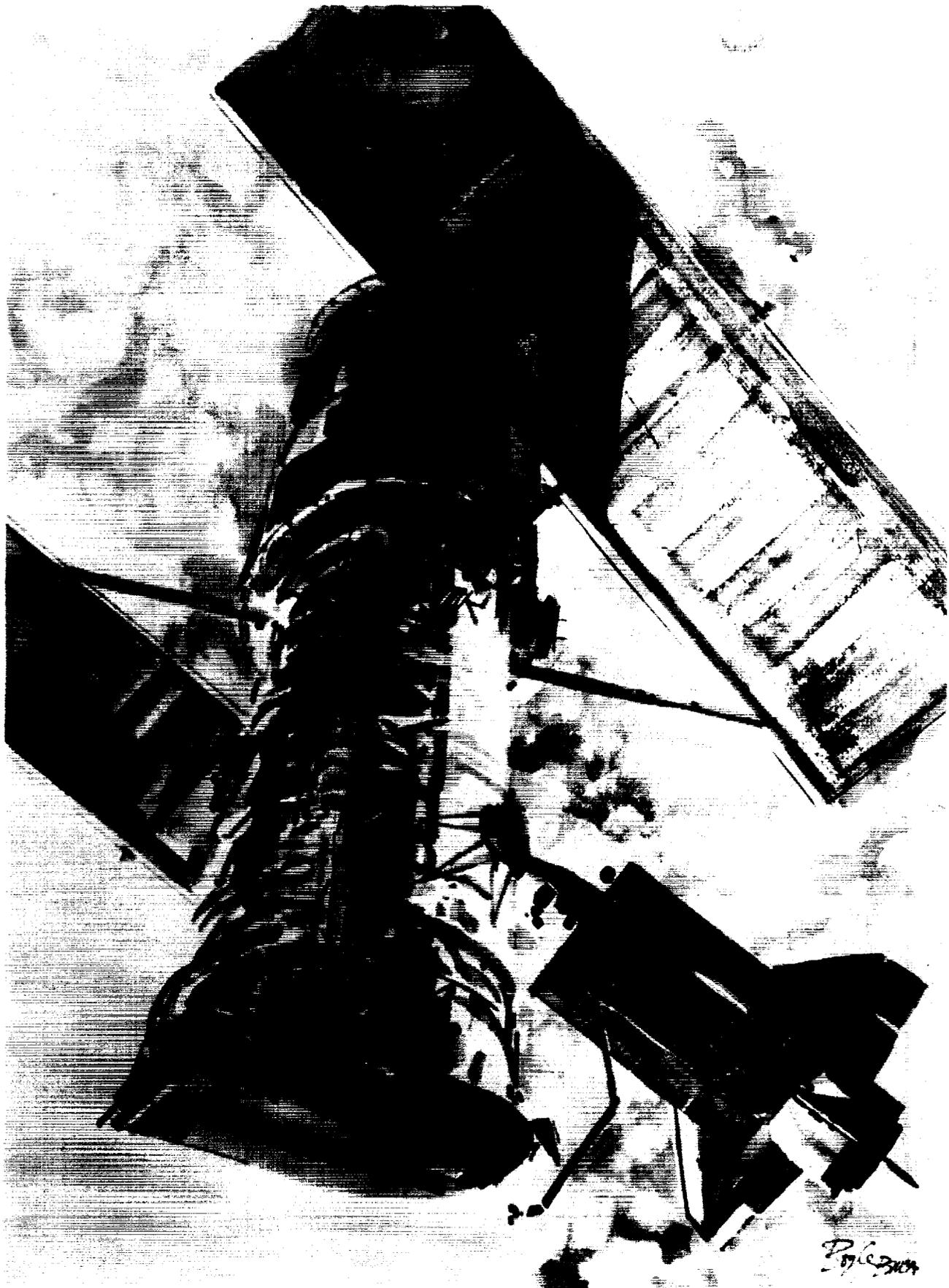
Advanced X-Ray Astrophysics Facility (AXAF) will use specially designed mirrors to image X rays from supernova remnants, high-temperature stellar atmospheres, galactic “halos” and nuclei, and other high-energy objects. In September 1991, the initial pair of AXAF mirrors passed a series of stringent performance tests at NASA’s Marshall Space Flight Center. *In development.*



Hubble Space Telescope (HST), launched in 1990, is already making discoveries at the forefront of science, including clouds of high-velocity gas spiraling into the center of an accretion disk around Beta Pictoris and a stellar "fountain of youth" in the ancient globular cluster 47 Tucanae. HST will receive upgrades through Shuttle servicing missions over its 15-year mission lifetime. *In operation.*



Space Infrared Telescope Facility (SIRTF) will use optics cooled to extremely low temperatures in order to detect millions of faint infrared sources across the sky. Particular targets include the dense, warm clouds of dust and gas that pervade star-forming regions in our own and other galaxies. SIRTF will build upon the extraordinary success of NASA's Explorer-class Infrared Astronomical Satellite, which carried out the first all-sky survey of infrared sources between 1983 and 1985. *Technology under development.*



Boyle

Space Telescope
Neil Boyle
NASA Art Program

Hubble Space Telescope,

launched in April 1990, is now in routine operation, chalking up a succession of scientific accomplishments despite a number of technical challenges.

The tracking of a rare, giant storm on Saturn, the unexpected detection of numerous clouds of hydrogen gas near our Galaxy, and the discovery of a stellar “fountain of youth” in 47 Tucanae, together with the exciting spectroscopy of Beta Pictoris, are only some of the triumphs recorded to date.

HST’s current scientific capabilities are outstanding, and its future capabilities will be even better. The first Shuttle servicing mission, in late 1993 or early 1994, will end the “jitter” caused by the solar arrays and give HST the high sensitivity needed to observe very distant stars and galaxies. Later servicing missions will install the powerful second- and third-generation instruments that have been planned from the start. With these scheduled performance enhancements, HST will be able to achieve its original scientific goals over a planned 15-year observing lifetime.

“The exploration of space. . . is one of the great adventures of all time, and no nation which expects to be the leader of other nations can expect to stay behind. . .

We choose to go to the Moon in this decade, and do the other things, not because they are easy, but because they are hard, because that goal will serve to organize and measure the best of our energies and skills, because that challenge is one that we are willing to accept, one that we are unwilling to postpone, and one that we intend to win. . .”

— President John F. Kennedy
September 12, 1962

NASA