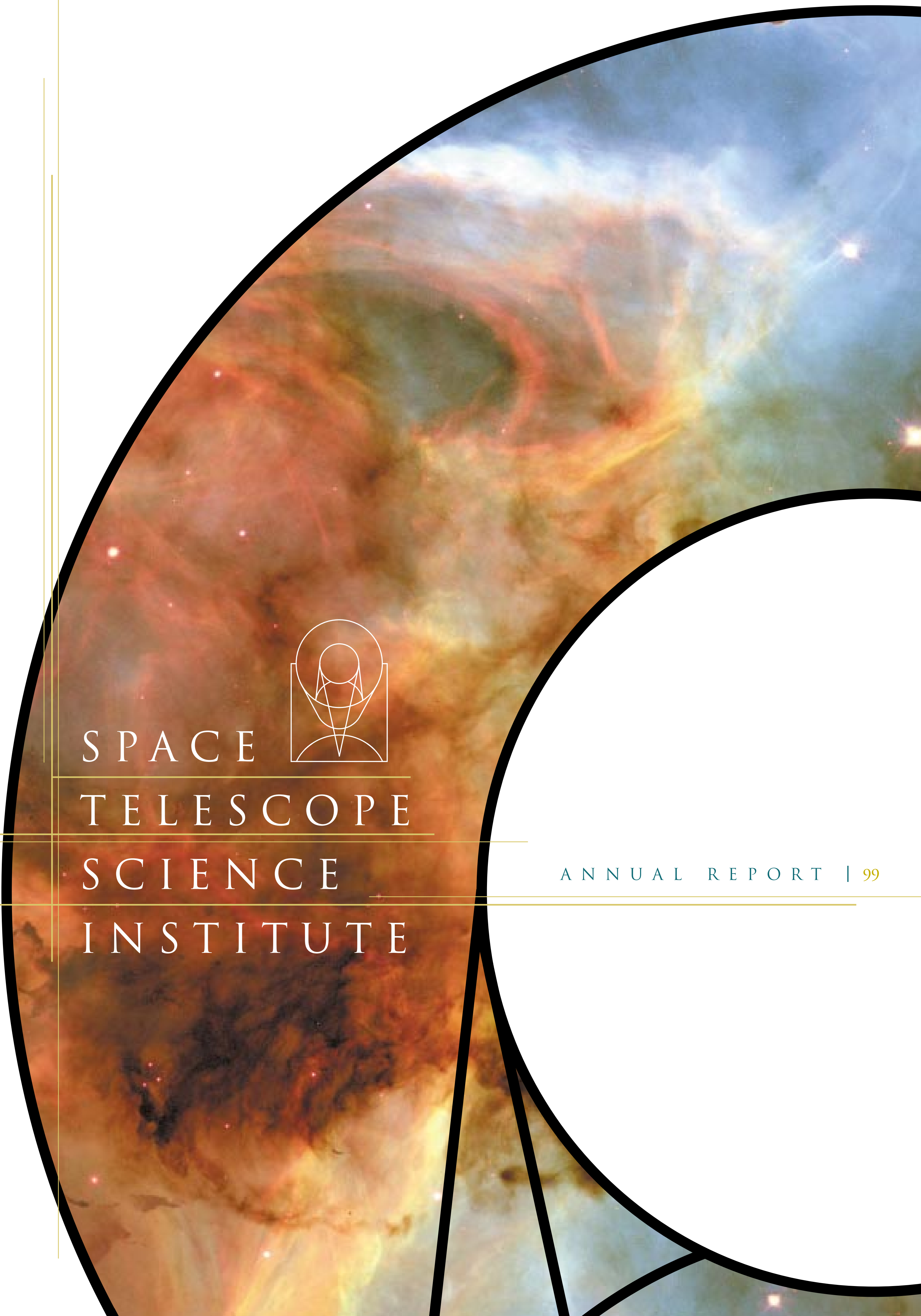


SPACE TELESCOPE SCIENCE INSTITUTE

ANNUAL REPORT | 99

DIRECTOR'S FORWARD

THE LAST YEAR OF THE MILLENNIUM, 1999, saw the Hubble Space Telescope experience major highs and one major low. On the high side, the science results continued to be superlative, including the successful conclusion of the key project to measure the expansion rate of the Universe and its age. A well-cited study of important discoveries placed Hubble number one in importance for space science missions since the space age began; an update shows Hubble still in the lead. Public interest in our mission remains strong. The Institute web pages receive about 3.5 million hits per month, only 0.5 million less than CNN. The staff at the Institute remains excited about the mission 10 years after it was first launched.

On the low side, we lost a fourth gyroscope since the second servicing mission in early 1997, which led to a loss of science observations for about one month. This deep low was offset by the high of the servicing mission in December, when seven heroic astronauts restored the Hubble to a condition even better than it was in before the fourth gyroscope failed. A power control unit had developed a loose contact, but in the course of replacing equipment the astronauts unexpectedly also made that problem disappear. Sometimes even delicate space instruments benefit from a little jostling! The astronauts' exploits capped an excellent year for the Hubble program.

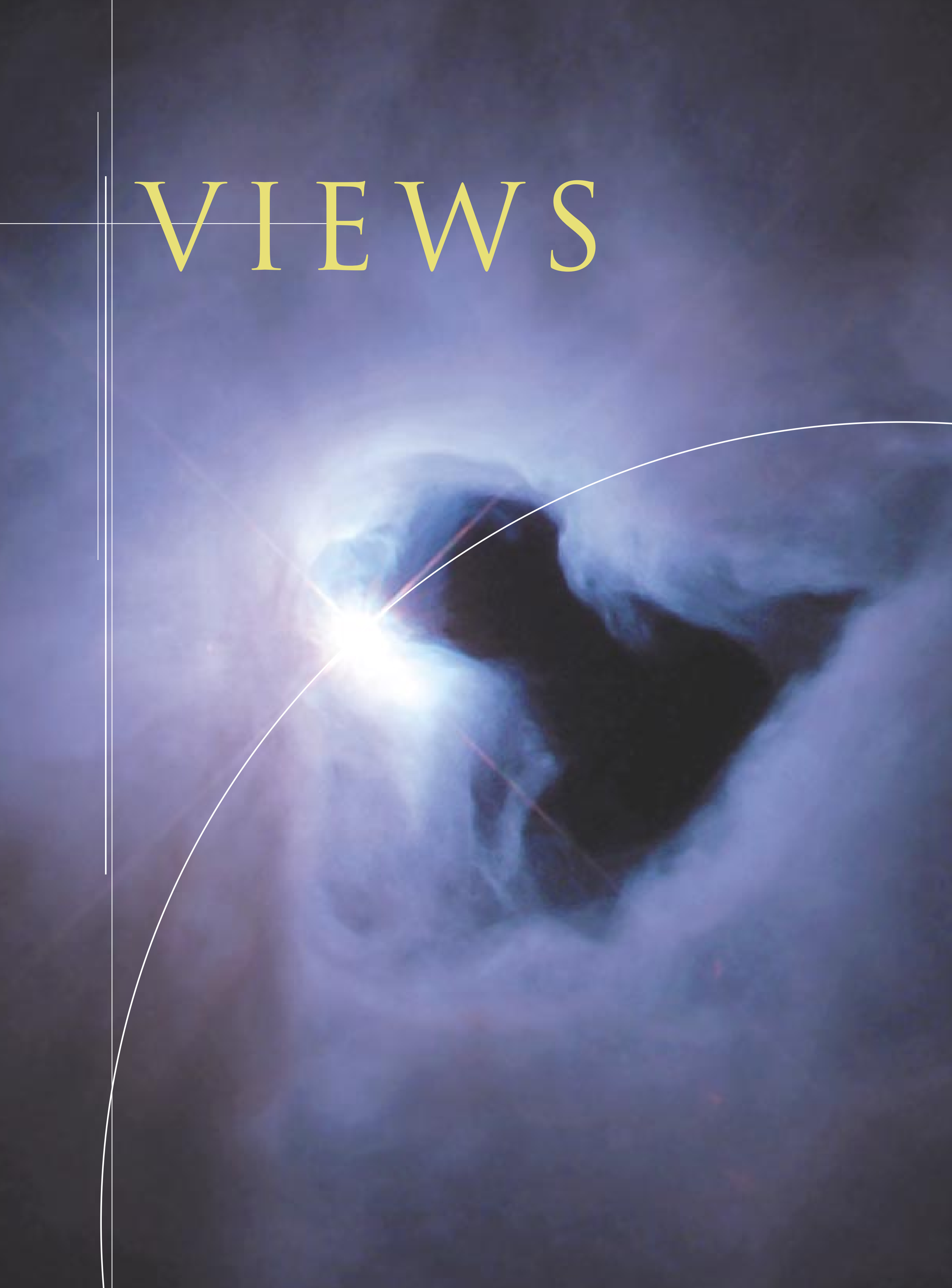
A well-cited study of important discoveries placed Hubble number one in importance for space science missions since the space age began.

At the Institute, preparations for the future drove much of our activity. In 1999, as described in this Annual Report, we formulated a plan to operate Hubble for about two-thirds of the cost of the current operations. This plan will free up resources to support the Next Generation Space Telescope. Our Low-Cost Operations plan will be phased in over the next six years or so. We then reorganized the Institute to highlight tasks needed for the new mission and to strengthen the science culture that underpins our service to the community. At the same time, we supported NASA's third visit to Hubble to repair the failed gyroscopes and upgrade important systems.

Our Annual Report contains three major sections—*Views*, *News*, and *Reviews*—followed by two science essays and a list of Institute science publications. This content is organized to engage both the casual reader and the reader who wants in-depth knowledge about the way we carried out our work. I would be pleased to have feedback on what you like and do not like about the Annual Report, and what we could add to make it more interesting for you. In keeping with the thrust of our new age (see *Views*), your remarks will be most helpful if sent electronically to svwb@stsci.edu. We hope you find our 1999 Annual Report most enjoyable.

Steven Beckwith
Baltimore, Maryland | *28 February 2000*

VIEWS



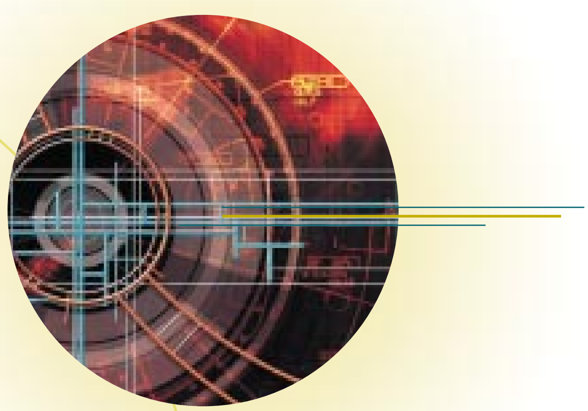
THE IMPACT OF WWW.STSCI.EDU.

THE DAWN OF THE NEW MILLENNIUM coincides with a societal shift from industry to service, from capital and equipment to knowledge. We are moving into the information age, where success will depend more on intelligence than physical strength. It was not very long ago that the most important attribute for survival was immunity to disease followed closely by strength and coordination; now, success in life's competition will depend more on IQ and EQ[1].

As communication pathways expand to encompass the civilized world and knowledge becomes the new coin of the realm, our horizons grow from those of the tribe, the state, and the nation to encompass the entire world. And this shift has happened in one generation.

As communication pathways expand to encompass the civilized world and knowledge becomes the new coin of the realm, our horizons grow from those of the tribe, the state, and the nation to encompass the entire world.

[1] 'Emotional intelligence,' deemed an essential attribute of managers and leaders.



We are a necessary link in the chain from concept to proof. The services we provide guarantee highly efficient use of the telescope time and data quality that is both very good and very uniform.

The gateway to astronomical research with Hubble is not a long ride up a high mountain; it is the click of a mouse at www.stsci.edu.

For astronomers, the new millennium marks the era of 'desktop astronomy.' One hundred years ago, important advances in astronomy came primarily from private, often individual improvements to telescopes and personal commitments to long-term observation of the skies. Stamina mattered—success often only followed many long nights at the eyepiece. Craftsmanship mattered—some telescopes and most instruments were fashioned by the hands of the astronomer who would use them. Technique mattered, too, since the quality of data depended very much on the skill of the data gatherer. Before the development of relativity and quantum mechanics, the most important theory was Newtonian mechanics, which was not difficult for observers to master and apply as they plied their trade on mountaintops.

We now have a generation of astronomers whose success owes little to physical stamina, craftsmanship, or even technique in the gathering of data. One of my colleagues derisively refers to these young scientists as 'keyboard astronomers,' although that term applies equally well to her (and to me) these days. As often as not, the breakthroughs are made by teams working with computers rather than by rugged individuals working at telescopes. We have all become more specialized. The theories are esoteric and require a great deal of effort to master. Data analysis requires enormous investments of time, as the data rates are climbing almost exponentially. Just as in industry, we now outsource most work not requiring our core scientific training—engineering, electronics, software, and even observation planning.

The Space Telescope Science Institute has been the leader in supporting this new culture in astronomy. NASA provides the hardware; we provide the software. Our experts assist astronomers in the planning and execution of their programs, including the preliminary data processing and all the calibration. We are a necessary link in the chain from concept to proof. The services we provide guarantee highly efficient use of the telescope time and data quality that is both very good and very uniform. If our Institute did not exist, some other organization would have to supply the same services: history's most complex telescope requires a large number of talented specialists.

The gateway to astronomical research with Hubble is not a long ride up a high mountain; it is the click of a mouse at www.stsci.edu. Through this electronic gateway, you can learn all you need to know to propose an idea, find the status of your program, and retrieve the data to your desktop. You can also find out what the competition is up to! The Internet lets you work with collaborators across the globe, sharing ideas and data, preparing presentations, and writing papers. Finally, you can publish the new insights gleaned from your (remote) observations on the preprint server at Los Alamos and submit the manuscript to a refereed journal for archival purposes.

NASA's decision with the European Space Agency (ESA) nearly 20 years ago to vest Hubble operations in a separate institute run by scientists was prescient. Now, NASA routinely outsources science operations to institutes run by the science community—Chandra and the Space Infrared Telescope Facility are the most recent examples—so that it can concentrate on its own strengths: innovative technology for space, new missions, and the future of the space program as a whole. Building space hardware requires a mindset different from supporting science operations. It means focusing on a few important goals and paying exquisite attention to detail to minimize the risk of failure in space.

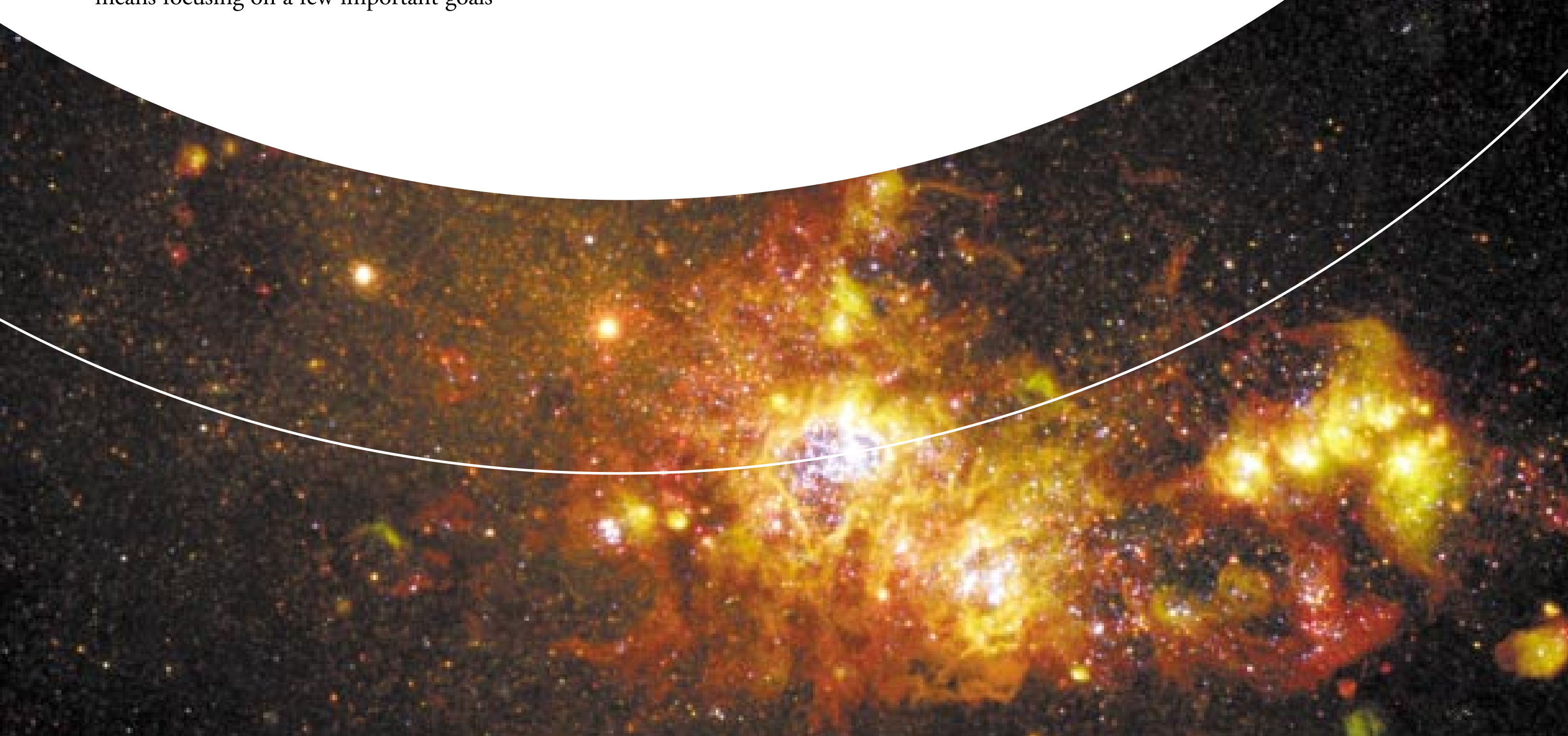
Software, on the other hand, is amenable to change and experimentation throughout the life of a space mission. We continually improve the science operations of Hubble, upgrading software, reacting to changes in the instruments, and evolving the nature and style of the science that the telescope supports. Software builders need a culture of change and improvement where experimentation with new ideas does not pose risks to the health of the project. Whimsy is tolerated and sometimes even encouraged.

We are also a fully international institute, with many of the key positions held by employees of ESA. European contributions to the Hubble mission are an essential part of our culture.

Because both the 'hard' and 'soft' cultures play special roles in big science, our relationship with NASA and ESA is symbiotic. Our partnership will grow stronger as we develop the Next Generation Space Telescope together. Learning a lesson from Hubble, we will work closely with the space agencies during the development phase to ensure that the operational impacts of hardware decisions are known early on. We will help discover tradeoffs where the mission can be optimized by placing a greater or lesser burden on fixed hardware or malleable software.

We hope to put more planning flexibility in the hands of astronomers, perhaps allowing them to use the Next Generation Space Telescope like a ground-based telescope, enabling them to look at the observations in nearly real time and to adjust the scientific program depending on preliminary results. By sequencing observations as events, instead of scheduling in absolute time, it should be possible to repeat failed observations within hours rather than months, as is often the case with Hubble.

We are also attentive to the future of astronomy using telescopes in space. We believe that space observations will play an increasingly important role in the future of our science. As Hubble has demonstrated, the advantages of space are enormous even for fields that are traditionally the domain of ground-based instruments. Increasing utilization of space for basic research epitomizes the opportunities of the information age and heralds a new culture of astronomy. The Institute will help astronomers place the signatures of their imagination on this new era.



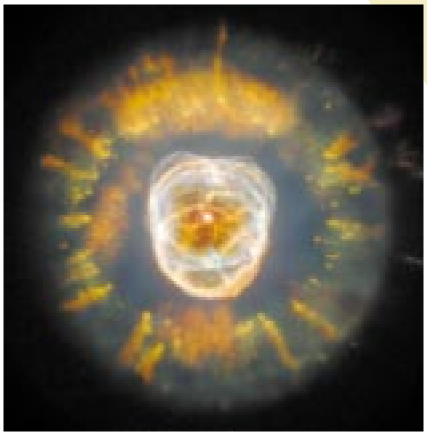
NEWS

HUBBLE HEROS HOLIDAY HIT

On the last human space flight of the 20th century, the shuttle Discovery and her seven-member crew of astronauts blasted off from Kennedy Space Center's launch pad 39B at 7:50 P.M. on December 19 on a critical mission to repair the Hubble. Eight and half minutes later Discovery achieved orbit, and two days later the crew captured the ailing telescope. Over the next three days, the astronaut crew carried out all scheduled repair work. They replaced all six gyroscopes, and installed a new computer, a refurbished Fine Guidance Sensor, a radio transmitter, and a spare digital data recorder. The heroic crew worked a total of 24 hours and 33 minutes outside Discovery.

The Observatory Verification program began at the moment of Hubble's release from Discovery and proceeded according to plan. Over the Christmas and New Year period, the Hubble spacecraft was reconfigured to resume operations under control of its new computer and using the new gyroscopes. All science instruments were successfully re-commissioned. To demonstrate that Hubble was back in business, astronomical images were taken of the Eskimo nebula and a distant cluster of galaxies. Then the Cycle 8 General Observer science program was immediately resumed.

Astronaut preparing to install Rate Sensor Unit 1 (gyros) during Servicing Mission 3A.



In Hubble's first glimpse of the heavens following the successful December 1999 servicing mission, the telescope captured a majestic view of the planetary nebula, NGC 2392, nicknamed the Eskimo Nebula. This image shows an outer disk of material embellished with a ring of comet-shaped objects with their tails streaming away from the central, dying star. The bright central region shows a bubble of material being blown into space by wind emanating from the star.

New Manager Professional Profile

Robert Hanisch

Bob Hanisch, head of the new Computing and Information Services Division—and the Institute's first Chief Information Officer (CIO)—grew up in Oshkosh, Wisconsin (the Oshkosh famous for overalls and experimental airplanes) and attended Lawrence University in nearby Appleton where he majored in physics (but spent almost as much time studying piano, both classical and jazz, in the Lawrence Conservatory). Fortunately, his brutally honest piano professor advised him that a career in science would likely be more successful than one in performance. He followed an early interest in astronomy by enrolling in graduate studies at the University of Maryland, College Park.

Initial research on comets using optical spectroscopy was dampened by the need to stay up all night in the cold. Radio astronomy, done from the warm comfort of control rooms and at reasonable hours, seemed more the thing. As it happened, the first observing experience, with the Arecibo Radio Telescope in Puerto Rico, came at the time of year when the target Coma cluster of galaxies was in Arecibo's limited viewing range at 3 A.M. So much for keeping regular business hours. Nevertheless, Bob completed his Ph.D. at Maryland on a study of the still enigmatic 'radio halo' sources in clusters of galaxies. This was followed by a short stint of teaching astronomy and physics back at Lawrence University, and then by a post-doctoral appointment at the Netherlands Foundation for Radio Astronomy in Dwingeloo, The Netherlands (the organization that operates the Westerbork Radio Synthesis Telescope).

Bob came to the Institute in May of 1984 to provide oversight for the SDAS—Science Data Analysis Software—project. Two years later he was put in charge of the project and for another eight years led this development effort and the coordination of STSDAS with IRAF from NOAO. He also took charge of the Institute's science computing support, and in 1991, when

continued on page 9

BEAMED BURSTERS | Andrew Fruchter

In the late 1960s, Air Force satellites designed to detect illicit nuclear tests discovered short bursts of extremely energetic light—gamma rays—from astronomical objects.

Over the next thirty years, many more of these bursts were recorded and analyzed, but little was learned about their nature. Then, two years ago, a small Italian satellite, Beppo-SAX, started providing accurate positions on the sky for new gamma-ray bursts. Shortly thereafter, follow-up observations from optical observatories—notably by the William Herschel Telescope, Hubble, and Keck—led to the discovery that these bursts occur in galaxies at cosmological distances.

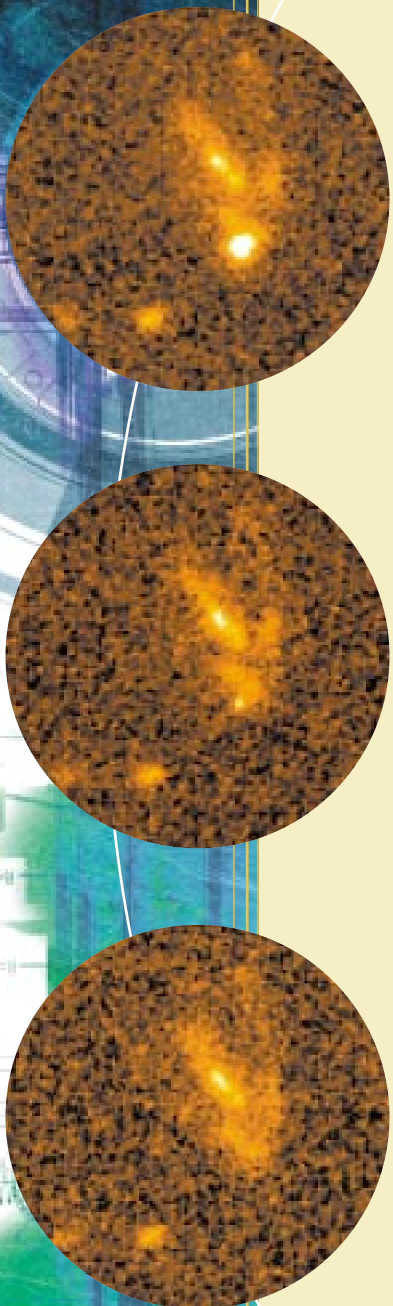
Astronomers had only begun to appreciate the enormous implications of this discovery when on January 23, 1999, Beppo-SAX detected the most powerful burst yet, GRB 990123. Within seconds, the optical transient associated with GRB 990123 became so bright that anyone with binoculars could have seen it. Yet GRB 990123 occurred in a galaxy about ten billion light years away!

GRB 990123 not only shattered its local galactic environment, but also threatened to destroy theories of the formation of gamma-ray bursts.

If GRB 990123 radiated in all directions equally, then it emitted an amount of energy equal to the rest mass energy of the Sun in the wavelength range of gamma rays alone! The implied total energy released would be so enormous as to rule out the favorite theories of burst formation, all of which relied on black holes of stellar mass. On the other hand, if the radiation were highly beamed, like the headlights of a car, the favorite theories would survive this burst.

If the bursts are beamed, the theory predicts that the rate of decay of their brightness should speed up as time passes. And indeed, this is just what the Hubble data show. Observations with the STIS CCD camera on Hubble show that the GRB 990123 burst declined with increasing speed between about two and nine weeks after the burst.

Because the Hubble results on GRB 990123 support beaming, stellar mass models of burst production may be safe—for now.



Three images of GRB 990123 and its host galaxy taken by Hubble on Day 16, 59, and 380 after outburst. The images are about 1.6 arcseconds across. In the first image, the optical transient associated with the burst is fainter by a factor of about four million than when observed at its peak, just tens of seconds after the outburst. In the second image, it has fallen by another factor of seven, and in the final frame it is essentially undetected. The drop between the first two observations is substantially larger than predicted by extrapolating the earlier data. This suggests that the light is beamed.

continued from page 7

Hubble's spherical aberration problem had been identified, led the image restoration efforts. When the Institute reorganized in 1994, Bob moved into the Data Systems Division and focused attention on the Hubble Archive. He led the Institute's efforts to expand the archive to encompass NASA's UV and optical missions, the result of which is the Multi-Mission Archive at Space Telescope—MAST—which provides access to IUE, EUVE, FUSE, and a variety of other related mission data sets.

Throughout his career at the Institute, Bob has dealt with computer systems, software development, and information management at one level or another. With the 1999 reorganization and the creation of the position of Chief Information Officer, he saw an opportunity that drew upon past experience and provided major new challenges.

Bob's research interests are complementary to his work on the Hubble/MAST archive and his position as CIO. The theme to his research is managing and locating information—data, documents, publications—all of which may be distributed at various locations on the Internet. How does one categorize this information in ways that make it easy to find from a single interface? How is this categorization, this labeling of information, done so that it imposes no restrictions on existing archives or information services? The approach Bob is taking is to build 'virtual' archives, or 'virtual' document collections, by collecting indexing information in a centralized database but leaving the data, information, or the documents at their home location. This is similar in concept of the well known Internet search engines like Altavista, Yahoo, Lycos, etc., except that the focus is on well-maintained collections within a specific discipline.

Bob led the development of the Astronomical Software and Documentation Service—ASDS—which is a distributed database of astronomical software and observatory and instrumentation manuals. Want to know what software is available for modeling emission line strengths, or what observatory has an echelle spectrograph? Just consult ASDS. Bob was one of the originators of AstroBrowse, the integrated index of astronomical data resources that provides a single interface for users to search more than 1,000 online astronomical catalogs and archives for data on given targets or sky positions. Bob is now leading a project to build a distributed database of electronic preprints that would allow departmental preprint collections to be easily put on line, would provide a common index for preprints in these collections, and would provide tracking from the preprints to the published articles.

As chair of NASA's Space Science Data System Technical Working Group, he is also leading an initiative to provide a data locating service that would span NASA's space science disciplines: astrophysics, planetary science, and space physics. A key element of this project is developing a process for translating queries from the terminology of one discipline into that of another. The information management challenge in astronomy is no less daunting than in other areas; Bob is working on ways to make the wealth of information we have as a community readily available, easily searchable, and usable by all researchers.

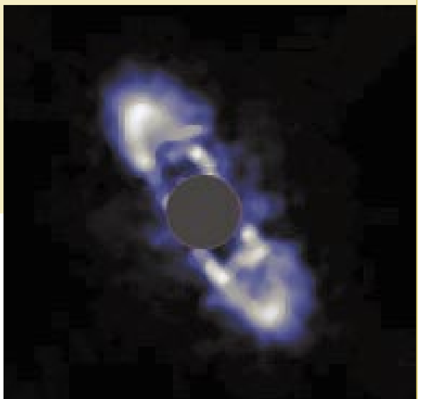
NEW EVIDENCE FOR OTHER PLANETARY SYSTEMS | Paul Kalas

Over recent years, Hubble has discovered a variety of indirect evidence for planet building around other stars. No single result is more visually compelling than this image of the star HR 4796A showing a circumstellar dust ring. The image studied by Glenn Schneider and his team was obtained by the Near Infrared Camera and Multi-Object Spectrometer (NICMOS) (Schneider et al., ApJ 513:L127-130, 1999).

HR 4796A is a young A0V star some 67 parsecs away. The star itself was artificially eclipsed by an opaque disk inside the NICMOS instrument. The faint loop is reflected starlight from a ring of dust orbiting the blocked-out star.

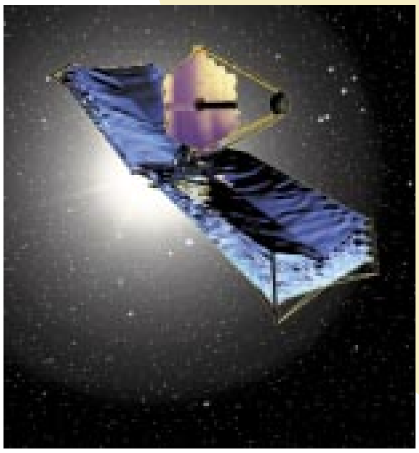
The dust ring around HR 4796A probably originates from the collisional erosion of small, unseen bodies, which may be either 'asteroids' or 'planetesimals.' Astronomers use the term 'asteroid' to refer to the small Solar System objects orbiting between Mars and Jupiter, which are highly evolved objects and may be broken parts of earlier planet-scale bodies. In theories of planet formation, they use 'planetesimal' for the hypothetical building blocks for planets.

The lack of reflected light inside of the ring around HR 4796A may mean that one or more unseen, Neptune-mass planets gravitationally sweep dust and other small bodies away from that region.



This circumstellar dust ring imaged by Hubble may be part of an extrasolar planetary system around the young main sequence star HR 4796A. The visible ring is 140 Astronomical Units (AU) in diameter and has a thickness of about 17 AU (Schneider et al.).

Two designs for the Next Generation Space Telescope. The left panel shows the Lockheed Martin concept. The team of TRW and Ball Aerospace proposed a design shown on the right. Both designs feature a large, deployed telescope shielded from the sun by a multi-layer sunshade.



NGST DESIGN TEAMS SELECTED

In spring 1999, the Next Generation Space Telescope (NGST) Project contracted with two major aerospace firms for the preliminary mission design. The Lockheed Martin Missiles and Space Company and the TRW/Ball Aerospace Company partnership will pursue two different designs for the observatory. The initial designs have much in common with the early NASA concepts for the Next Generation Space Telescope. The designs feature an 8-m diameter, deployed, primary mirror; an orbit about the second Lagrange point (L2, about 1.5 million kilometers from the Earth); and a large sunshield to permit the telescope to cool passively to below 50°K. (This low temperature will enable deep infrared observations with minimum interference from thermal background radiation.)

The chief challenge for the two teams is developing an ultra-lightweight optical telescope that can be deployed and adjusted on-orbit. The two teams have different experience and approaches. The successful design, to be picked in early 2001, may have implications beyond the Next Generation Space Telescope. The NASA Strategic Plan currently envisions a constellation of similar, slightly smaller telescopes, also deployed about L2, for detecting Earth-like planets orbiting nearby stars. Thus technology developed for NGST may be used for this Terrestrial Planet Finder.

The Next Generation Space Telescope Project is a collaboration of three international space agencies: the National Aeronautics and Space Administration, the European Space Agency, and the Canadian Space Agency. The latter two agencies will make contributions to the spacecraft, optics, and scientific instruments. For additional information, visit the NASA NGST web-site, http://ngst.gsfc.nasa.gov/.

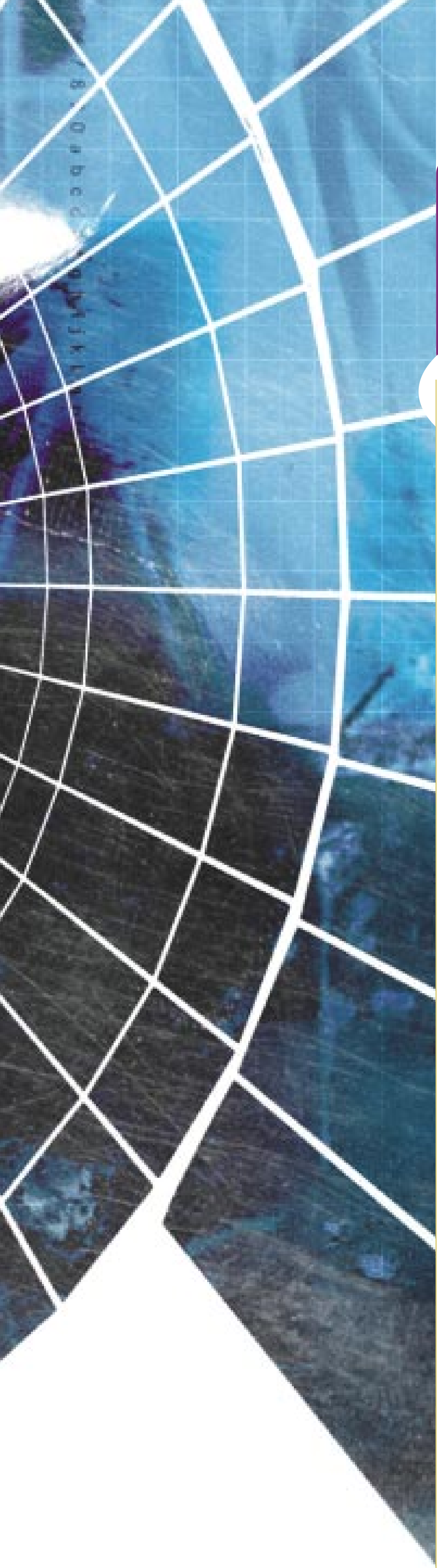
CENTENNIAL ApJ SALUTES INSTITUTE TWICE

In 1999, the American Astronomical Society (AAS) published a centennial issue of the *Astrophysical Journal* (ApJ). To select the content, the Editor-in-Chief, Helmut Abt, worked with the AAS Centennial Committee to select a jury of senior astronomers with broad interests. Each was asked to select a paper published in the ApJ or *Astronomical Journal* (AJ) during the last century that proved fundamental to the advancement of astronomy or astrophysics. Each wrote a short commentary on the selected paper to describe its impact.

Only seven of the selected papers were published in 1970 or later, but of these seven, two were first-authored by members of the Institute staff.

"Evidence for the Binary Nature of Centaurus X-3 from UHURU X-Ray Observations," by Schreier, Levinson, Gursky, Kellogg, Tananbaum, and Giacconi (ApJ 172, L79, 1972) was selected by Harvey Tananbaum as marking "a watershed in the overall process of understanding of some of the least anticipated and most energetic aspects of our Universe."

"The Hubble Space Telescope Guide Star Catalog," by Lasker, Sturch, McLean, Russell, Jenkner, and Shara (AJ 99, 2019, 1990) was the most recently published paper to be included in the collection. The reviewer, William van Altena, describes the paper as "the ground-breaking article in astrometry published in either the *Astronomical Journal* or the *Astrophysical Journal* during the 1900s," and goes on to conclude that "it was the GSC that first demonstrated the need for such types of catalogs and gained overwhelming acceptance by the astronomical community and transformed astrometry from a science practiced by a few to one practiced by many."



New Manager Professional Profile

Stefi Baum

Stefi Baum, the head of the new Engineering and Software Services Division, grew up in Princeton, New Jersey. She attended Harvard University as an undergraduate, studying biochemistry and chemistry before settling on a major in physics in her senior year. She was also very active in sports, garnering ten varsity letters in four different sports. In her senior year she captained the women's lacrosse and soccer teams and led her team to victory in the soccer Nationals.

After college, Stefi spent a few years working as a data aide at the Center for Astrophysics, where she developed her love of astronomy. She started graduate school at the University of New Mexico and met her husband (Institute staff astronomer Chris O'Dea) at the nearby Very Large Array radio observatory. She then transferred to University of Maryland and arranged to do a Ph.D. jointly between Maryland and the National Radio Astronomy Observatory in Charlottesville, Virginia, combining both optical and radio astronomy observations. The year 1987 was busy for Stefi: she completed her Ph.D., moved to Dwingeloo, The Netherlands, to begin a three-year postdoc at the Netherlands Foundation for Research in Astronomy, and gave birth to the first of four children. She returned to the United States in 1990, spent one year at Johns Hopkins as a Hubble Fellow, and then joined the staff of the Institute in 1991 as an archive scientist.

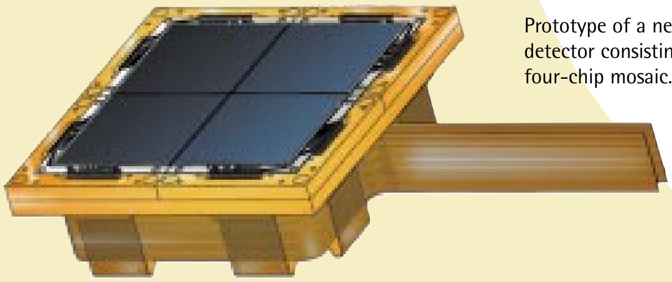
Stefi played a key role in the commissioning of the Hubble archive, co-authored the first archive manual, and edited and co-authored the first Data Handbook, which provided information on how to reduce data from all Hubble instruments. A few years later, she became an instrument scientist for the Space Telescope Imaging Spectrograph (STIS) within the Servicing Mission Office. Six months before the installation of STIS on Hubble in the second servicing mission, she assumed the role of Lead of the Spectrograph's Group, overseeing the Institute's science effort on STIS through its commissioning until it became a well integrated, calibrated, and fully supported component of the Hubble repertoire. After a brief sabbatical in 1999, she served briefly as Deputy in the Science and Engineering Systems Division before assuming the role of Head of the Engineering and Software Services Division following the reorganization. Her spare time "is completely devoted to my family; with four children between the ages of 7 and 12, all actively involved in sports, music, school, life, and growing up, our lives are filled to the brim."

Stefi's research interests are in the origin and fueling of nuclear activity in active galaxies; she has published some ninety papers on this subject in refereed journals. "Nuclear activity in galaxies is an interesting phenomenon worthy of study in its own right. But activity in galaxies can also be viewed as a beacon—allowing us to study the evolution of galaxies at redshifts where 'normal' galaxies are invisible, and providing us with insights into the nature, formation and evolution of galaxies." In her research Stefi strives to understand both the fundamental physical processes responsible for energetic nuclear activity and the origin and evolution of the galaxies that host active galactic nuclei (AGN) and the interesting environments surrounding them. Her studies include powerful radio galaxies, quasars, Seyfert galaxies, and most recently, starburst galaxies. The questions challenging Stefi include: What makes a given galaxy turn on as an AGN? Are all galaxies active at some stage in their lives, or are only a small percentage of galaxies capable of extreme nuclear activity? What determines what form activity in a galaxy will take (e.g., powerful radio source, luminous ultraviolet source, starburst instead of black hole/monster) and how is the activity related to the properties of the host galaxy or the presence or physical properties (e.g., size, spin) of a central black hole? What governs the fuel supply to the central source? How does the nuclear activity in a given galaxy evolve with time and how does that evolution affect or parallel the evolution of the host galaxy and its environment? In 1993, Stefi was honored by the American Association of University Women with the Annie Jump Cannon award, which recognizes a woman for distinguished contributions to astronomy.

NEW INSTITUTE ROLE IN ASTRONOMICAL DETECTORS

High quality detectors are important for astronomy and crucial for the Next Generation Space Telescope (NGST). Recognizing this, the Institute has adopted a proactive organizational role with respect to advanced detectors on the community's behalf.

The Institute hosted a NGST Detector Workshop in April 1999, which was attended by nearly 180 instrument designers, astronomers, and detector suppliers. A working group organized at the workshop later issued a report that relates the NGST science objectives and operational environment to desirable detector characteristics. According to the report, larger detector formats and lower noise will be important to the success of the Next Generation Space Telescope. The report also includes programmatic recommendations for assuring the availability of the needed NGST detectors.
(http://ngst.gsfc.nasa.gov/public/unconfigured/doc_597_1/Draft_6.pdf).



Prototype of a near-infrared detector consisting of a four-chip mosaic.

Following on the success of the NGST Detector Workshop, NASA's Office of Space Science asked the Institute to host a more general meeting on new detectors for space applications. This meeting will take place 26-30 June, 2000. The purpose is to bring together scientists and engineers working in wavelength domains from gamma rays to radio for the purpose of evaluating the state of the art in current and emerging detector technologies. The meeting should interest detector developers and technologists as well as scientists working on future science missions.
(http://www.stsci.edu/stsci/meetings/space_detectors/)

New Manager Professional Profile

Mario Livio

Mario Livio, the head of the new Institute Science Division, joined the Institute in 1991 as head of the Archive Branch. Prior to coming to the Institute, he completed his undergraduate studies (majoring in both physics and mathematics) at the Hebrew University in Jerusalem, his M.Sc. degree (in theoretical particle physics) at the Weizmann Institute, and his Ph.D. (in theoretical astrophysics) at Tel-Aviv University. He was a professor of physics in the physics department of the Technion-Israel Institute of Technology from 1981 until 1991.

Mario came to his career in physics via a long and winding path. As Mario himself writes:

"I was born in 1945 in Romania. When I was a few months old, both my parents had to flee Romania for political reasons, and I was left with my grandparents until the age of 5. In 1950, most Romanian Jews were pressured to leave, and I immigrated with my grandparents to Israel. I served in the obligatory military service for three years, and continued to serve for 40 days each year in the obligatory reserve military service, until I left in 1991. I was a paramedic in a special field hospital unit that could be parachuted, transported by choppers, or by marine landing boats. It was with this unit that I was in the 1967 ('Six Day') war, the 1973 ('Yom Kippur') war, and the 1982 war in Lebanon. In the Yom Kippur war, we were the only medical unit that crossed the Suez Canal."

A love for astrophysics somehow emerged and persisted, with a special interest in the accretion of mass onto black holes, neutron stars, and white dwarfs. In 1999, Mario focused particularly on the topics of supernova explosions and their use in cosmology to determine the rate of expansion of the Universe, on the formation of black holes and the possibility to extract energy from them, on the formation of planets in disks around young stars, and on the emergence of intelligent life in the Universe.

Mario is a self-proclaimed 'art fanatic' who owns many hundreds of art books. Recently, he combined his passions for science and art in a popular book, *The Accelerating Universe*, which has just appeared. The book discusses the 'beauty' of fundamental theories of the Universe.

BARRY LASKER (1939-1999)

Barry Lasker, a valued Institute staff member since its inception in 1981, passed away suddenly on February 10, 1999. Barry, while still an astronomer at the Cerro Tololo Inter-American Observatory, was instrumental in AURA's original proposal to manage the Space Telescope Science Institute and in establishing the Institute.

Barry will be remembered for his intellectual leadership of Hubble's Guide Star Selection System. He oversaw the creation of the widely used Guide Star Catalog (GSC) and Digitized Sky Survey (DSS). He was a thoughtful and dedicated member of the Institute community and is remembered with great affection by his many colleagues and coworkers. He is survived by his wife Sharon and his children Zefrin and Alida.

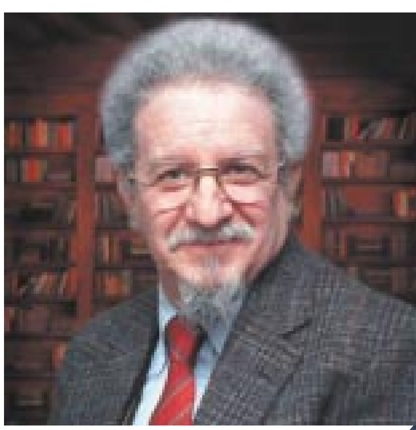
Barry's contributions to astronomy were recognized in 1999 by two major awards: the George Van Biesbroeck Prize of the American Astronomical Society (AAS), and the Maria and Eric Muhlmann Award of the Astronomical Society of the Pacific (ASP). The GSC has recently been recognized as one of the most important publications of the century in the *American Astronomical Society Centennial Issue* of the *Astrophysical Journal*.

Barry's nomination letter for the Van Biesbroeck Prize stated that "the DSS is one of the most important astronomical research tools ever created," and cited its applications spanning the entire spectrum of astronomical research, as well as its essential role in supporting Hubble observations.

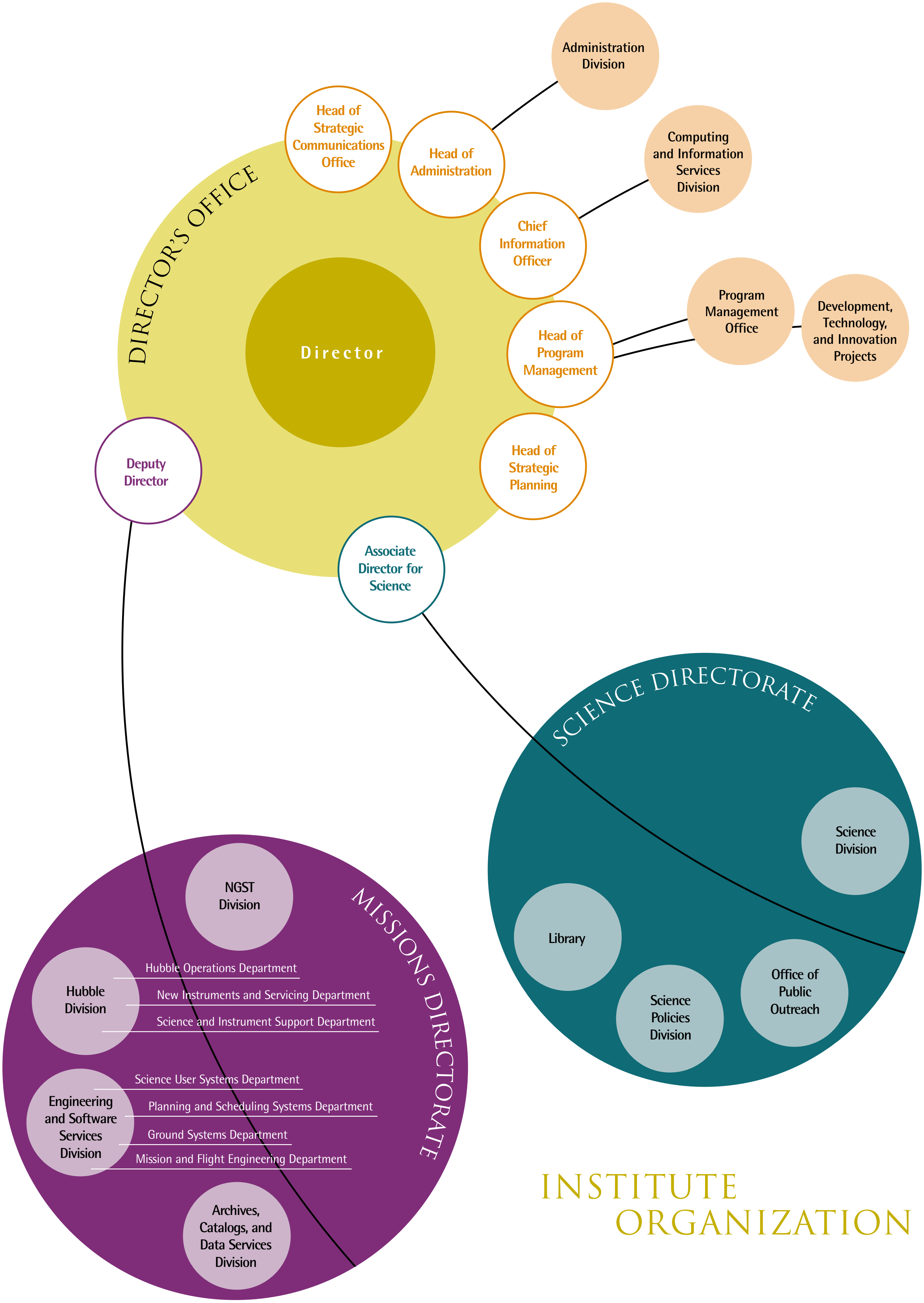
The Muhlmann Award, presented annually for significant observational results made possible by innovations in astronomical instrumentation, software, or observational infrastructure, specifically recognized the GSC and DSS work of Barry and his collaborators.

The Van Biesbroeck award was presented to Barry's wife, Sharon Lasker by AAS President Dr. Robert Gehrz during the society banquet at the June 1999 meeting in Chicago. The Muhlmann award was presented to Mrs. Lasker by ASP Secretary Prof. John Gaustad at a ceremony at the Institute in June 1999.

Barry will be remembered for his intellectual leadership of Hubble's Guide Star Selection System.



REVIEWS



INSTITUTE ORGANIZATION

DIRECTOR'S OFFICE

We are responsible for overall management of the Institute, establishing policy, organization, and strategy, and obtaining and managing resources. We conduct the external relations of the Institute, including reporting to oversight committees and soliciting and receiving advice from advisory groups. We ensure the Institute succeeds in its commitments to NASA, the scientific community, and the public.

In 1999, we concentrated on getting ready to operate two missions simultaneously—the Hubble Space Telescope and the Next Generation Space Telescope (NGST)—under the same overall budget that has been supporting Hubble. The Institute had been organized around a single mission, Hubble. All divisions and offices were associated with a different aspect of operating Hubble, and the added work from the Next Generation Space Telescope did not fit well into the structure. The Director's Office led several retreats of the senior managers over the summer to rethink the organizational structure and recommend ways to organize more effectively around more than one mission. Much of the rest of the year was taken up with the reorganization, which was implemented on January 3, 2000.

We created the detailed plan of development work for the ground system and operations for the Next Generation Space Telescope to enable us to carry out the science operations after launch. We submitted a proposal in September for a Cooperative Agreement with NASA to carry out this plan.

We supported NASA's mission to service Hubble in December, during which the primary goal was to replace the gyroscopes needed to point the telescope. Hubble carries six gyroscopes of which at least three are needed to make scientific observations. In January 1999, the third of the six gyroscopes failed, leaving the telescope one failure away from a complete loss of its ability to do science. NASA decided to move the servicing mission originally scheduled for mid-2000 up to October, 1999, and to split this servicing mission into two parts, the second part coming in June 2001. The 1999 servicing mission was a great success, and several additional improvements were made besides the gyroscopes, which left the telescope in a much improved state.

Hubble continues to be the most successful space science mission in NASA's history. It is a flagship mission of great importance to science and has gained widespread public acclaim for bringing science to the public at large. The preeminent place of Hubble in astronomical research is evidenced in papers, collaborations, meeting topics, and headlines. It is also reflected in young people being drawn into science, and new generations of astronomers finding employment opportunities and research directions created or inspired by Hubble. This is the living legacy of Hubble, which will continue long after the expected end of mission in 2010.

Leadership

We create the strategic vision to guide the Institute into the future. We strive to ensure that the Hubble science program remains vigorous throughout the life of the mission and that the Institute continues beyond Hubble with new initiatives.

In 1999, we reorganized the Institute, proposed a detailed plan to run the Next Generation Space Telescope, supported the servicing mission activities, and secured support for enhancing the Wide Field Camera 3 with near-infrared capabilities, an initiative we undertook in 1998.

It took several months of debate to settle on a new organization and several more months to implement the new structure. The management council, consisting of the senior managers in each division and office, did the bulk of the work through several offsite retreats. The council created three organizational models, elements of which where blended to create the new organization. Subsequently, we created a Director's Leadership Forum by selecting 40 staff members from across the Institute, representing all levels below senior management, and challenged them to recommend the best way to make the transition into a new structure. The Forum rose to the challenge and produced many detailed recommendations on how best to match the staff to the new organizational structure. Perhaps more important were the Forum's recommendations about the cultural aspects that should be preserved or eliminated as we transition to the multi-mission Institute. Cultural changes, being inherently more difficult to implement than organizational changes, are ongoing, and the Forum continues its work of suggesting ways that we can improve the culture of the Institute.

Operating the Next Generation Space Telescope will require a different approach than operating Hubble, although many elements of the current Hubble operations can be used directly for this and future missions. We built an NGST operations plan from the ground up and used this plan to determine the sequence of work during the development of the NGST observatory. We concluded that it should be possible to operate Hubble and its successor simultaneously within our current staff size, although there may be some staff growth during the 2 years around NGST launch to mitigate potential anomalies. Under Low-Cost Operations, we plan to reduce the Hubble staff from the present level. The growth of the Next Generation Space Telescope activity is supported by the reduction of staff working on Hubble. We are actively engaged in planning this transition with the goal of leveling the overall staff size changes. The future outlook, then, is for an Institute of about the same size as today, bringing in new missions to provide challenging opportunities for the vast majority of our staff.

The Director's Office worked with NASA to add a near-infrared capability to the Wide Field Camera 3, scheduled to be installed in Hubble on the fifth and last currently-scheduled servicing mission in 2003. We were successful in obtaining endorsements of the near-infrared capability from all the relevant advisory committees. The Hubble project at Goddard Space Flight Center identified a funding plan to support the additional work. Working with NASA, we have achieved final approval to add this new capability to the Wide Field Camera 3. The added capability will be vital for science in the next decade as more interest turns to the most distant galaxies, whose light is redshifted out of the visible spectrum and into the near infrared. This increased scientific interest in the early universe was stimulated in large part by the Hubble Deep Field observations conducted in recent years as a leadership service of the Institute for the astronomical community.

The Institute was founded to run the scientific operations of Hubble. NASA is largely shedding its role as an operator of space satellites, shifting the responsibility to private contractors. The Institute is at the leading edge of this wave to create outside science operations centers for new space missions. With the advent of the Next Generation Space Telescope, we are poised to move from a single-mission to a multi-mission organization. Moreover, the huge and growing library of Hubble data is becoming an increasingly important resource for new science through archival research. Our archives constitute a separate mission in their own right, and they have been given Division status in the new organization to recognize their importance. Meanwhile, we continue to examine ways to broaden our base further, including new proposals. Through these endeavors, the future of the Institute looks bright.

Program Management Office

We optimize the allocation of budget and management resources to meet the Institute's performance goals and responsibilities.

The Head of Program Management operates within the Directors Office, as in the past organization, and supervises three small groups. Our budget group and the on-site management group for the Institute's major subcontractor, Computer Sciences Corporation, remain unchanged in the new organization. Our program management group, however, has been enlarged by program managers from the various divisions and offices of the old organization. We matrix back these individuals to meet the needs of the new organization divisions and offices.

In 1999, the Institute undertook a major examination of the way we were organized and operated. We spent many months defining and understanding our goals, examining our options, and selecting an organizational architecture that best met our needs. When the new organization was agreed upon, we led the effort to complete the myriad details to implement the new organization by January 3, 2000. We worked with the newly identified division managers to complete individual staff assignments, budget reallocations, and internal management structures. We were ready to go on time.

The year 1999 was the first under our Low-Cost Operations plan, which will reduce the cost of operating Hubble by 30% over the next decade. Our budget and staff were smaller in 1999 than previous years as a result of accomplishing many of the initial savings we had identified. However, problems experienced by the Project with the instruments under development and with Hubble itself prevented NASA and us from realizing all the Institute staff and budget reductions that we had thought possible. One cost of NASA borrowing future funds to respond to these problems will be budget shortfalls for the Hubble project in the future.

In 1999, NASA rated our performance on both Hubble and the Next Generation Space Telescope excellent at 98% and 97% respectively. Our budget performance in 1999 improved to the point that we were awarded half of the amount that NASA had withheld last year for underspending with respect to our projections.

In the next year, after a settling period of at least six months, we will look at the operation of our new organization and evaluate our success in meeting the goals we set for ourselves. We expect that the downward budget pressures experienced by NASA will continue. Because new managers now supervise many of the areas identified for savings in our Low-Cost Operations plan, we will undertake a systematic review to prioritize our activities and find ways to improve our productivity. We are committed to operate Hubble more cost effectively and to implement our Low-Cost Operations plan to assure a successful future for both Hubble and Next Generation Space Telescope.

Development, Technology, and Innovation Projects

We provide a central focus to innovation and technology development activities around the Institute.

Our goals are to improve the Institute's productivity in current tasks and to expand into new activities within our AURA charter. We help formulate institute policy, evaluate proposed activities, assist in securing resources, and look for appropriate applications of new technology to insert into the Institute's improvement efforts.

Under the previous organization, each division initiated innovation and technology development separately. As an institute, we improved our Hubble productivity through many process improvements and system enhancements. However, there was no defined process for making new ideas visible to management, for allocating institute resources based on strategic priority, for focusing our search for external technologies to infuse in our systems, or for searching out external customers for capabilities we had developed. We created this new unit in the reorganization to provide that needed focus.

In 1999, we pursued new methods and improved processes in many areas including, for example, in the selection of the Hubble science program, our planning and scheduling services, the pipeline processes and our multi-mission archive. Our outreach efforts also exemplify the incentive to develop innovative programs. Our *Tour the Cosmos* series explored the impact of merging broadcast radio into Internet simulcasts, bringing together experts, the public and the visual impact of Hubble's view of the universe.

In the future, we will develop a clear definition of our goals for innovation and technology development. We will provide focus for our areas of endeavor and sponsor pilot projects to test the effectiveness of new ideas. We will cultivate external partnerships to stimulate and extend our capabilities and apply our experience to new missions.

ADMINISTRATION DIVISION

We provide business and administrative services to the Institute in the areas of finance, human resources, accounting, contracts, grant administration, procurement, facilities management, property administration, administrative support, and staff support services.

Our division was unchanged by the Institute reorganization with one exception: all administrative support staff were transferred into the Administration Division in an effort to provide consistent, high-quality support to all divisions and offices.

The Administration Division is organized into branches, groups, and offices according to our major functions and responsibilities. We strive for a strong customer service orientation, aware that we are involved directly or indirectly in almost every endeavor of the other organizational units of the Institute, as well as in the careers of Institute staff and the funded research of Hubble observers. We constantly seek new ways to improve our performance and increase customer satisfaction.

In 1999, based on an assessment of our training needs conducted by an independent consulting firm, we formulated a comprehensive Management Training Program, which will be implemented in 2000. Also on the horizon for the Administration Division are Institute-wide implementation of electronic time cards, purchasing credit cards, the new grants management system, increasing use of electronic information transfer through forms, and planning with The Johns Hopkins University to accommodate staff housing needs.

Finance Branch

We maintain all Institute financial records, prepare and monitor performance against indirect budgets, and produce management financial statements. We ensure that procurements of product and service are competitive, track property, and make travel arrangements for Institute staff and visitors.

In 1999, we passed audits of our financial statements and incurred cost. For the fourth year running, the government waived its review of our purchasing system, which demonstrates their confidence in our capabilities.

We consistently delivered internal cost reports within five working days of month end. We closed the fiscal year and delivered an accurate year-end financial statement to the auditors with similar dispatch. Typically, we turned accounts payable invoices into checks in fewer than five days.

Our Budgets group successfully transitioned the prime-contract budgeting work to the Program Management Office. We continue to budget and forecast all indirect costs associated with the Institute.

In 1999, we continued to work closely with various audit agencies, such as Defense Contractors Audit Agency and Klynveld Peat Marwick Goerdeler (KPMG). We submitted our forward pricing and a revised disclosure statement in a timely fashion. We passed all audits, including those for incurred costs, floor check, and cost-accounting standards.

With outstanding help from the Computer Information Systems Division, one-fourth of Institute employees currently use electronic time sheets. In 2000 we intend to implement this program Institute-wide.

In the procurement area, we are starting to see benefits from our conversion to the CostPoint system. This system provides improved management information, and soon will offer Institute staff the ability to create purchase requisitions from desktop computers. It also helped our procurement staff exceed our 5% cost savings goal.

Working with the Staff Support Services, we established furniture standards to improve and simplify the process for selecting and procuring staff furniture. In another process improvement, the procurement staff began using credit cards in appropriate situations, and we plan to offer this capability to Institute management in 2000.

Our Property Administration Office maintains database records of over 8,100 items of property with an original value of almost $29 million. The department supports the annual Government property audit, which was completed successfully in June 1999.

In 1999, our Travel Office processed a record number of trips, striving to provide our customers exceptional value in their travel spending. We experienced a considerable increase in arrangements for incoming visitors to various Institute events.

Grants and Contracts Branch

We provide all of the contract and grant administrative services for the Institute.

Our services include preparing grant budgets for proposals, interpreting and tracking compliance with the terms and conditions of grants and contracts, and in conjunction with the AURA corporate office, interpreting statutes and regulations. Our branch is divided into two offices, Grant Administration and Contracts and Sponsored Research.

Through our Grants Administration Office, we fund Hubble General Observers and Archival Researchers to conduct research based on Hubble observations. In the process, we facilitate the financial review of submitted budgets, and make funding recommendations to the Director for final approval. From inception, we have awarded $146M for 3529 grants, of which 577 grants worth $21.2M were awarded in 1999 alone. We also administer grant funds for the Initiative to Develop Education through Astronomy and Space Sciences program, for which we awarded $485K for 23 approved proposals in 1999.

In 1999, we participated in the design and testing of the new electronic web-based software system to manage the grants we administer. The Grants Administration Team for Organizational Re-engineering (GATOR) system is under development in collaboration with staff in Engineering and Software Services Division, using process-improvement funds. The primary goal of the system is to expedite the granting process. We released the new software system for initial testing both inside and outside the Institute. In addition, we gave presentations to selected grantee institutions to inform them of the outstanding features of the system and to gather their input. We expect to implement the system in the spring of 2000.

Through our Contracts and Sponsored Programs Office, we support Institute staff in preparing proposals, and in administering awarded grants and contracts. In 1999, we supported the preparation and submission of 127 new, continuation, or supplemental proposals for grant or contract funding. Of these, 107 proposals were for Hubble research funding. As of December 31, 1999, 222 grants and contracts (other than the Hubble Prime Contract) were in place, representing $18.8M in value. During the year, 95 new awards were received.

Human Resources Branch

We provide a wide range of personnel services to Institute staff and management, including recruitment and employment, relocation, wage and salary administration, benefits administration, development and maintenance of Equal Employment Opportunity/Affirmative Action plans, employee-management relations, and various forms of training, including the newly defined Management Training Program.

In 1999, our recruitment and employment activities resulted in 70 AURA hires, including 48 regular and 22 temporary employees. Additionally, 15 students were placed in student intern positions as part of an ongoing, affirmative action effort to provide training and develop future employment opportunities for women and minorities.

Institute-wide turnover decreased during the past year from 11.5% to 10.4%, comparing favorably with national statistics of 12.0%.

In 1999, we began an ambitious effort to develop the management skills of our employees. We began by offering courses on holding effective meetings and improving technical presentation skills. In a cooperative effort with management consultants and Institute management, we developed and presented a survey to Institute employees to gauge management training needs. This survey provided input to develop a management training curriculum for our employees, with implementation beginning in 2000. We sponsored a series of employee programs, including the annual Family Day, Bring Your Child to Work Day, United Way campaign, and Red Cross blood drives.

During 1999 we negotiated and purchased a new Human Resource Information System (PeopleSoft), which will provide us the ability to better manage employee information and provide extensive employment information to Institute management. We transitioned core capabilities to the new system from our old information system.

In 1999, our operations in human resources remained fully compliant with regulatory requirements, resulting in no Equal Employment Opportunity complaints filed during the year.

Facility Operations Group

We manage and maintain the Institute's facility operations, comprising the 120,000 square foot Muller Building and a 297-car parking facility. We also contribute auxiliary and logistical support services to our off-site leased office space at the Rotunda and The Johns Hopkins University's Bloomberg Building.

In 1999, in coordination with our landlord, the Johns Hopkins University, we continued our efforts to upgrade the Muller Building. We completed the front entrance project, which included new pavement, steps, and redesign of the roadway to improve deliveries and accessible parking. Also, we coordinated a major roofing maintenance program with Johns Hopkins, which will involve re-roofing the Muller Building and replacing the existing parapet-wall detail, which has been a constant source of leaks. We continue to work with Johns Hopkins to replace major mechanical equipment, such as a cooling tower and a chiller.

Also in 1999, we completed renovations and alterations to facilitate the expansion of the Office of Public Outreach. We provided design and construction services of the flight operations facility, which will accommodate the flight operations team when it moves to the Institute from Goddard Space Flight Center around October 2000. We renovated several rest rooms in the Muller Building to increase the number of accessible rest rooms.

To achieve more accurate and cost-effective operation, we automated the water treatment program for our heating, ventilation, and air conditioning equipment.

We maintained the Institute's Safety Program, which included efforts to reduce employee injuries due to the repetitive motions that are typical of our work environment. Also, we worked to remediate of indoor air quality problems. Our ongoing program also addresses fire safety, first-aid and cardiopulmonary resuscitation training, and compliance with the requirements of the Occupational Health and Safety Administration, the Americans with Disabilities Act, and the Environmental Protection Agency.

Staff Support Services Group

We provide a variety of services, including cafeteria, document reproduction, mail handling, telephone, security, housekeeping, and other logistical support.

In 1999, we renovated and refurbished the Cafeteria Conference Room and Central Copy Center, contracted new landscaping service for the grounds around the Muller building, and upgraded the parking facility access system software.

During the year, the mail room operation was incorporated into the Copy Center, and a new color copier was added. The Center produced 4.3 million impressions in total for the year.

MISSIONS DIRECTORATE

We plan, develop, and implement science and mission operations for all missions for which the Institute is responsible. We are currently responsible for the Hubble Space Telescope, the Next Generation Space Telescope, and the Multi-Mission Archive.

The Institute Deputy Director manages the Missions Directorate, which includes four Divisions designed to provide clear responsibility and accountability for managing our major missions. We draw supporting staff, services, and products from the expertise within the Missions Directorate and the Science Directorate.

The new Hubble Division is responsible for all science operations of the Hubble Space Telescope. This Division includes staff from our previous Science Support Division, the planning and scheduling staff from the Project to Re-Engineer Space Telescope Observing, and our former Servicing Mission Office. The Next Generation Space Telescope Division is responsible for designing and implementing the science and mission operations for the Next Generation Space Telescope. This is a new organization bringing together staff from numerous earlier Institute units. The new Archive, Catalogs, and Data Services Division provides pipeline processing and distribution of Hubble data, manages the data archives of Hubble and of other space and ground-based telescopes, and develops and maintains the Guide Star Catalog and Digitized Sky Survey. This Division includes staff from our previous Data Systems Division. The new Engineering and Software Services Division provides engineering and software development services to all programs at the Institute. The Division includes staff from our previous Science and Engineering Systems, Project to Re-Engineer Space Telescope Observing, and Science Support Divisions.

During the coming year, we will continue science operations for Hubble, support development of future Hubble instruments including the Advanced Camera for Surveys, Cosmic Origins Spectrograph, and Wide Field Camera 3, prepare for Hubble Servicing Mission 3B, and engage in science-definition and conceptual-design studies for the Next Generation Space Telescope. We will also begin to conduct flight operations for Hubble from a new control center located at the Institute.

Hubble Division

We implement the science program of the Hubble Space Telescope. We schedule the selected observing programs. We support the astronomical community with scientific and technical advice on current and planned observing programs, as well as on the use of archival data from current and legacy instruments. We prepare the community and the Institute for the most effective use of new instruments to be installed in future servicing missions.

The Hubble Division consists of three departments with inheritance from the previous organization. The Hubble Operations Department takes over the operational responsibilities for processing and scheduling the current Hubble observing program from the former PRESTO, and will include the Flight Operations Team when it is transferred to the Institute in 2000. The Science and Instrument Support Department includes all the instrument teams from the Science Support Division. The New Instruments and Servicing Department is identical to the former Servicing Mission Office.

The Hubble Division combines in one functional unit all the scientific and operational resources needed to implement the Hubble mission. This reflects a goal of the Institute reorganization, which is to identify clearly the unit responsible for each of our major missions.

Looking ahead, the Hubble Division will concentrate on completing the Cycle 7 and Cycle 8 observing programs, including the re-scheduling of observations delayed by the gyro failure and safemode entry. In March 2000, the Cycle 9 programs are due from the observers, with execution starting soon thereafter. We hope to reduce the turnaround time for Targets of Opportunity in Cycle 9 observations. We expect a major effort supporting the Cycle 10 Call for Proposals, which will offer observations with both the Near Infrared Camera and Multi-Object Spectrometer with the mechanical cooling system and the Advanced Camera for Surveys. Even though the Servicing Mission 3B will not occur until 2001, we will be involved in 2000 with testing the Advanced Camera for Surveys and the mechanical cooler, as well as with ground system training and verification prior to the mission.

Hubble Operations Department

We implement Hubble observations to provide observers with data of the highest possible quality.

Currently, we provide three major functions: observing program development, long-range planning, and short-term planning and scheduling. In 2000, we will add a fourth function, flight operations.

In observing program development, we work with the user to assure the accurate, optimal translation of their scientific requirements into the technical terms of the operating observatory. In long-range planning, we create the multi-year master schedule that reconciles observing requirements and operational constraints at a high level. In short-term planning and scheduling, we create the detailed command loads to execute each week of the Hubble science program.

Starting in September 2000, the Institute will host the Hubble Flight Operations Team. Our department will absorb the 12-16 flight controllers responsible for spacecraft and instrument housekeeping, monitoring and maintenance, and for the health and safety of the mission. Other departments will take in other members of the Flight Operations Team, such as computer operations staff and engineers.

Observing Program Development. Phase 2 is the period following an observing program's approval by the Director during which the user interacts with the Institute to clarify his or her observations in operational terms. During Phase 2, we assign a Program Coordinator from our Observation Planning Team to each Hubble user, to serve as the user's primary contact. The Program Coordinator provides accurate and timely information to the user and keeps this initial segment of the pipeline of Hubble observations flowing.

Process improvements and automation have greatly decreased the level of effort required for Phase 2. Today, eight Program Coordinators are handling the workload that required eighteen in 1994.

The extended zero-gyro safemode that stopped observations in November and December 1999 has required rework and replanning of more than 500 orbits to establish new observing windows. While a number of the affected programs have been easily replanned, more than 300 orbits require rework due to user-specified observing constraints, such as timing or spacecraft orientation, or due to lack of suitable guide stars. We will give this rework priority in the early months of 2000.

Long-Range Planning. The Hubble long-range observing plan serves as the multi-year master schedule for all Hubble science and calibration observations. The long-range plan is used externally by the astronomical community and internally by observatory staff to order and prioritize workload. The Hubble observing plan must meet the goals of individual science and calibration programs as well as satisfy physical, scientific, and programmatic constraints and requirements.

The Institute's ability to address and reconcile 12 to 18 months worth of planned Hubble observations has proven extremely valuable. It is essential to minimize the impact of changes to the observatory, accommodate special observing campaigns, handle targets of opportunity, and plan servicing missions.

During 1999, we devoted a significant effort to catch up on observing programs that were delayed by the need in 1998 to accelerate observing with the Near Infrared Camera and Multi-Object Spectrometer when its cryogen was found to be rapidly depleting. The delayed observations primarily used the Wide Field and Planetary Camera 2 and the Space Telescope Imaging Spectrograph. Pre-Cycle 8 programs are now over 99% complete.

Short-Term Planning and Scheduling. Short-term scheduling has been likened to assembling a jigsaw puzzle with extra pieces thrown in. The 'pieces' are the approximately 200 orbits of candidate observations on the long range observing plan for a specific week: only 80-90 of the orbits can be scheduled. The short term scheduling process takes the individual candidate observations, prioritizes them according to time-criticality, and attempts to put them together in various sequences. We select the sequence that optimizes the use of the observatory in terms of on-target efficiency and number of programs accomplished.

In 1999, with the exception of two months lost to the extended zero-gyro safemode and the third servicing mission, Hubble observing efficiency has remained high, about 50%.

Looking ahead, the year 2000 focus in short-term planning and scheduling will be to decrease the time required for Hubble to respond to activated targets of opportunity. Today, two to five days are required to respond, depending on the readiness of the program and the timing of the activation. A structural impediment is that, currently, once a command load segment is uplinked to the Hubble, it can not be interrupted except by safing the vehicle. Therefore, we are investigating ways to intercept the Hubble command plan that would enable response to target of opportunity programs in less than 24 hours.

Science and Instrument Support Department

We enable Hubble observers to use the science instruments with maximum effectiveness by providing scientific and technical advice in developing observing programs and interpreting data, and by calibrating and characterizing the science instruments.

Before the reorganization, we were included in the Science Support Division.

Most of our staff are in groups that correspond to the Hubble science instruments: one for the optical camera, Wide Field and Planetary Camera 2 (WFPC2); one for the near-infrared camera, Near Infrared Camera and Multi-Object Spectrometer (NICMOS); one for the spectrographs, Space Telescope Imaging Spectrograph (STIS), Goddard High Resolution Spectrograph (GHRS), and Faint Object Spectrograph (FOS); one for general observatory support, including the ESA-built Faint Object Camera (FOC), and the Fine Guidance Sensors (FGSs); and one for the Advanced Camera for Surveys (ACS), which will be installed in Hubble in mid-2001. Our Data Analyst Group supports all the instrument groups in their calibration and user support activities. Data analysts also help Institute astronomers in their personal research, as well as support various Institute-wide projects, such as the Hubble Heritage Project and the Hubble Deep Field.

We support Hubble users during all phases of their observing programs. For difficult programs, or when requested by the observer, we assign a 'contact' scientist to the program. These contacts are proactively responsible for aiding the principal investigator teams in strategies for carrying out their programs, and for answering questions about the execution of the program or how best to analyze the data. For programs without contact scientists, and for general questions from the astronomical community, the help desk is available, quickly answering all manner of questions about past, present, and future instruments, or about data analysis software and techniques, proposal preparation, or documentation. With help-desk-support software, we track incoming questions accurately and efficiently; practically all queries are answered within two working days, most within a few hours. Supplementing the contact scientists and help desk, data analysts are available to provide hands-on data-reduction and analysis support to local, visiting, and remote observers.

One of our primary activities in 1999 was preparing for, executing, and then analyzing the results from the orbital verification tests following the servicing mission in December. From an instrument standpoint, our main goal was to safeguard the instruments during and following the servicing mission, to determine whether any of the instrument characteristics changed, and to commission the new Fine Guidance Sensor 2R (Replacement), which replaced Fine Guidance Sensor 2. The servicing mission was a complete success.

We formed a cross-instrument tiger team in 1999 to address degradation of the charge transfer efficiency in Charge-Coupled Device (CCD) detectors. This problem has been identified in the Wide Field and Planetary Camera 2 and the Space Telescope Imaging Spectrograph. The effect—which is increasing with time and is probably due to radiation damage —causes sources located at the top of the CCD to appear fainter than those at the bottom, due to loss of charge as it is transferred down the columns of the array during readout. For the Wide Field and Planetary Camera 2, the loss can be as much as 50% for the worst case of a faint source on a faint background. (However, for images with high count levels and significant background, the effect remains roughly constant at the launch-era value of 4%.) The problem will likely be more serious for the future Advanced Camera for Surveys and the Wide Field Camera 3, both of which have longer columns, 2048 pixels as compared with 800 pixels in the Wide Field and Planetary Camera 2. Our tiger team on charge transfer efficiency monitors the changing situation closely, and acts as a forum between the various instrument groups and for the community. Also, we have developed and published a formula for correcting the effect as a function of position, background level, target brightness, and time.

A primary activity for the coming year will be the development of plans for the next servicing mission, currently scheduled for launch in June 2001. During this mission the Advanced Camera for Surveys will be launched along with the NICMOS Cryocooler System, which will revitalize our infrared capability.

WFPC2 Group. *We are responsible for the optimal utilization of the Wide Field and Planetary Camera 2.*

The Wide Field and Planetary Camera 2 continued to operate flawlessly throughout 1999. The long-term photometric stability for bright stars appears to be excellent, with fluctuations of two percent or less in most filters between 1994 and 1999. Both the number of hot pixels and the low-level dark current show modest increases due to radiation damage but have no significant impact on science observations.

Following servicing mission 3A, we carefully monitored the camera's UV throughput to look for contamination due to sunlight-induced polymerization of organic contamination on optical surfaces. We found the throughput remained within acceptable ranges, and science observations were resumed. Additionally, we found that none of the other important characteristics of the camera—dark counts, hot pixels, and charge transfer efficiency—were affected by the servicing mission.

In 1999, we completed a study of the field dependence of the photometric aperture corrections in Wide Field and Planetary Camera 2. We found that the correction increases with distance from the center of the field, due to better optical quality at the center, which means concentration of light in a smaller region. As expected, the effect is most pronounced for the smallest apertures, with the correction for a one-pixel aperture varying by up to 10% from the center to the edge of the detector.

Our most significant challenge for the coming year will be to maintain a high level of calibration accuracy in the presence of effects such as degraded charge transfer efficiency.

NICMOS Group. *We are responsible for the optimal utilization of the Near Infrared Camera and Multi-Object Spectrometer.*

The Near Infrared Camera and Multi-Object Spectrometer has had a short, but productive life to date. Due to the anticipated cryogen exhaustion, and the subsequent dewar warm-up, the last observation was executed on January 7, 1999. Shortly afterward, the instrument was placed in a safe configuration, where it will remain until installation of the new mechanical cooling system during the next servicing mission.

During warm-up, we monitored the instrument to learn what to expect when the detectors resume operating at the higher temperatures of the new cooling system. Based on our findings, we expect the instrument to regain essentially all its basic science capabilities.

We found one anomaly during the warm-up. We observed an unexpected increase in dark current at temperatures around 75°K. Together with the instrument team at the University of Arizona, we have explored the hypothesis that we were observing trapped charge being released at a critical temperature threshold. Unfortunately, no increase in dark current was observed during the laboratory test, and hence the cause of the dark current anomaly remains unknown.

In 1999, we developed and distributed two new products to support users of the Near Infrared Camera and Multi-Object Spectrometer. We released the new NICMOS Data Handbook, which is a guide to understanding, reducing, and analyzing data from this instrument. The handbook includes extensive discussions of calibration software, data anomalies with suggested solutions, and useful information about photometric calibration, pixel scales and geometric distortion, point-spread-function subtraction, and coronagraphic, polarimetric, and grism data analysis.
(http://www.stsci.edu/instruments/nicmos/nicmos_doc.html)

Second, we delivered the first release of a software tool package designed to correct for various anomalies commonly encountered in NICMOS data.
(http://www.stsci.edu/instruments/nicmos/NICMOS_tools/nicmos_tools.html)

Our challenge for the year 2000 will be to develop plans for bringing the Near Infrared Camera and Multi-Object Spectrometer safely back to operational status following the installation of the mechanical cryocooler during the next servicing mission. We look forward to the resumption of science observations in the infrared and the recharacterization of the instrument in mid-2001.

Spectrographs Group. *We are responsible for the optimal utilization of the current spectrograph—Space Telescope Imaging Spectrograph—and for supporting archival analysis of data from the earlier Faint Object Spectrograph and Goddard High Resolution Spectrograph.*

Nearly all calibration reference files for the Space Telescope Imaging Spectrograph are now based on in-orbit data, and the data calibration pipeline provides reliable and robust processing of all data from this instrument. Its performance has been excellent: good basic stability, including focus, flux repeatability, acquisition accuracy, flat fields, internal geometry, and mechanism reliability. After a period of lower usage while the science program of the Near Infrared Camera and Multi-Object Spectrometer was expedited, the percentage of observations with the Space Telescope Imaging Spectrograph increased to roughly 50% in 1999.

Using two different techniques, we measured the charge transfer efficiency in the CCD detectors of the Space Telescope Imaging Spectrograph. We found consistent results, indicating a charge transfer efficiency loss after 2.5 years in orbit of 10% to 15% for a very faint star located at the chip center. The measured degradation rate, then, is about 5% per year. We also found that a minimal sky background exposure, of only a few electrons per pixel, can alleviate the loss of charge transfer efficiency by a factor of two.

During the orbital-verification phase following the servicing mission, we found no operational aspects of the Space Telescope Imaging Spectrograph had been affected. The instrument has resumed normal science observations. We will continue to study the one anomaly encountered, a slight elevation in CCD read noise, which has only a minor impact on science.

For the 12-day bright-earth-avoidance period following Servicing Mission 3A, the Spectrographs Group, in collaboration with other Institute scientists, planned a science program using the STIS CCD to take advantage of time that otherwise would not have been used. In a total of 45 visits, deep images were obtained of the regions surrounding several radio galaxies, nearby irregular galaxies, and two interacting galaxies. We also obtained a slitless spectrum of objects in the NICMOS region of the Hubble Deep Field North. All data from this program are publicly available in the archive.

In the coming year, we look forward to implementing a method to correct for scattered light, which is a major problem for observations using the highest spectral resolution. We also anticipate that much of our effort in the year 2000 will be devoted to preparing for the next servicing mission, as the new cooling systems to be installed will have an important impact on STIS operations.

Observatory Support Group. *We monitor the focus of the telescope, support the use of the Fine Guidance Sensors as astrometry science instruments, and provide support for Faint Object Camera observations.*

In 1999, we formed a group to work on an issue that arose with the focus of the Hubble telescope. Whereas historically the focus had changed slowly and continuously due to the telescope structure desorbing water, two discontinuous slips occurred last year of about 3 microns each—roughly the level at which observers start noticing an effect on their data. Our focus group is responsible for closely monitoring the focus, and addressing cross-instrument needs and approaches. Following the last servicing mission, we conducted intensive focus tests and made rapid and accurate changes to the Hubble focus before restarting science observations.

During the second servicing mission, in the spring of 1997, the Fine Guidance Sensor 1 was replaced with the refurbished Fine Guidance Sensor 1R. Monitoring data from Fine Guidance Sensor 1R, we find that it has stabilized and indeed performs better than Fine Guidance Sensor 3, which had served as the science astrometer since launch. Fine Guidance Sensor 1R has resolved binary systems with separations as small as 7 milliseconds of arc, which is a dramatic improvement over Fine Guidance Sensor 3's resolution of about 20 milliseconds of arc. Because its fringe stability is also dramatically better, we designated the Fine Guidance Sensor 1R as the Hubble astrometric science instrument for Cycles 8 and 9.

During Servicing Mission 3A, Fine Guidance Sensor 2R was installed in place of Fine Guidance Sensor 2, which had degraded mechanically. We supported the planning and preparations for the commissioning or recommissioning of all the Fine Guidance Sensors following Servicing Mission 3A, which included designing the tests, selecting suitable targets, and generating detailed observing scripts.

We collaborated with scientists throughout the community to develop an astrometric science program during the bright-earth-avoidance period following Servicing Mission 3A, to make use of observing time that would otherwise have gone unused. Out of 200 potential targets, 62 were actually observed. Early analysis of the data from this program indicates that the pointing stability of Hubble with the new gyros is nominal, and the excellent astrometric performance of Fine Guidance Sensor 1R is unchanged.

Looking ahead, our primary activity for the coming year will be to calibrate fully the new Fine Guidance Sensor 2R and to monitor the stability of all three of the Fine Guidance Sensors.

ACS Group. *We will be responsible for the optimal utilization of the Advanced Camera for Surveys.*

During 1999, we continued prelaunch preparations for science operations with the Advanced Camera for Surveys.

Much of the infrastructure to support the first call for proposals was put in place with the installation of new web pages, an exposure time calculator, and the development of the ACS Instrument Handbook. (http://www.stsci.edu/cgi-bin/acs)

In 1999, we worked closely with both the ACS Science Team and Institute engineers and programmers to develop the necessary onboard instructions for commanding the Advanced Camera for Surveys. We tested many of these commanding instructions directly on the instrument while it was undergoing thermal vacuum tests at the Goddard Space Flight Center.

We conducted an end-to-end test of the ground system, which started with real observing proposals run on an ACS simulator, followed by processing data through the ACS pipeline, and ended when the simulated data was loaded into the Hubble archive. The basic ACS ground system is ready.

We supported ground calibration activities at both Ball Aerospace in Boulder, Colorado, and the Goddard Space Flight Center. These opportunities provided us a preview of the operational capabilities of the instrument and allowed us to start addressing calibration issues well in advance of launch. Two known issues are the expected difficulty obtaining high quality flat fields and the geometric distortion calibration for the wide field channel. Accurate characterization and correction of geometric distortion will be critical for many ACS science programs, such as mapping the distribution of mass in galaxy clusters using weak gravitational lensing.

Looking ahead, we will focus on commanding for special activities related to the servicing mission, and on developing specialized data-analysis software to address the calibration challenges posed by the Advanced Camera for Surveys.

New Instruments and Servicing Department

We facilitate the use of new science instruments by participating in their development, capturing and transferring information about instrument operation and calibration to the Institute, and coordinating the recommissioning of all the instruments following a servicing mission.

In the previous organization, the Servicing Mission Office conducted or coordinated the Institute's activities related to servicing missions and bringing new instruments on-line.

The highlight of 1999 was the successful servicing mission—Hubble's third—culminating in the safe return of the seven astronauts to Earth after making much-needed repairs to the telescope. After numerous delays, the shuttle Discovery lifted off on December 19 to rendezvous with Hubble. Following acquisition of the telescope, the crew worked three long days in spacesuits to replace Hubble's six gyroscopes, upgrade the flight computer, and replace one of the Fine Guidance Sensors. Other essential repairs and improvements were also made. Our Servicing Mission Observatory Verification program began at the moment of Hubble's release from Discovery on December 25 and proceeded according to plan. The spacecraft recommenced operations smoothly under the control of its new computer, using the new gyroscopes. All science instruments were successfully re-commissioned. The great care and caution taken to avoid contaminating any mirror surfaces were rewarded by no observable decline in efficiency. Immediately following release of two images from Early Release Observations, Hubble resumed the Cycle 8 General Observer science program, which had been interrupted on November 13, 1999, by the loss of the fourth gyroscope and safing of the telescope.

We worked closely in 1999 with the teams developing new instrumentation for the fourth and fifth servicing missions. On the fourth, in June 2001, the Advanced Camera for Surveys (ACS) will replace the Faint Object Camera. Also, two cooling systems will be introduced in Hubble's aft-shroud instrument compartment. One cooling system will enhance the performance of the Advanced Camera for Surveys and the existing Space Telescope Imaging Spectrograph by lowering the temperatures of their detectors. The other cooling system is for the Near Infrared Camera and Multi-Object Spectrometer, which has not been operational since its solid-nitrogen coolant ran out in 1998.

In our role leading the ground-system software development to accommodate the Advanced Camera for Surveys, we completed testing the baseline systems and awaited the calibration reference files due from instrument testing in thermal vacuum. The final thermal vacuum tests and ground calibration of the Advanced Camera for Surveys were delayed about a year due to problems discovered with the optical bench, which we helped troubleshoot. We used this delay to innovate ways to optimize the scientific return of the Advanced Camera for Surveys. For example, as we expect radiation damage to ACS's Charge-Coupled Device (CCD) detectors after launch, we supported incorporating post-flash calibration units, and we developed tests to monitor radiation damage.

On the fifth servicing mission planned for 2003, astronauts will install two new scientific instruments, the Cosmic Origins Spectrograph and Wide Field Camera 3. In 1999, we reviewed and documented the operations of both instruments with the development teams. Based on these reviews, we laid out our anticipated development schedules, with activities starting this year. We hope to minimize new operational software for the 2003 instruments by reusing as much already-written software as possible.

For the Wide Field Camera 3, we completed the hiring of the science group and began a range of development work in partnership with Goddard. We organized a workshop during the summer of 1999 to obtain suggestions from the community regarding filter selection. We supported testing of the prototype CCD and infrared detectors, collaborating with colleagues at the Detector Characterization Laboratory at the Goddard Space Flight Center. We developed an exposure calculator tool to facilitate work on the Design Reference Mission for Wide Field Camera 3. Working jointly with members of the Science Oversight Committee, we prepared a Science White Paper elaborating the scientific goals for the instrument. We provided support in the overall management of the Wide Field Camera 3 team, including organizing and hosting the Science Oversight Committee meetings and leading the development of the instrument specification document.

Looking ahead, we have begun planning for the next mission in June 2001. We expect this mission to be more complex than any previous one, demanding even more careful planning and more detail in the verification phase. Over the next year, we will plan the start of the first observing cycle with the Advanced Camera for Surveys, and commence the ground systems developments for the Cosmic Origins Spectrograph and the Wide Field Camera 3.

Archive, Catalogs, and Data Services Division

We process Hubble data in the pipeline, distribute Hubble data products to the community, and operate the Institute archives. We maintain and upgrade the Guide Star Catalog and Digitized Sky Survey.

Before the reorganization, we were part of the Data Systems Division. We are now grouped in the Missions Directorate to maximize the capability for multi-mission science operations and archiving.

Our selection as NASA's optical and ultraviolet science archive center extends our role beyond Hubble to include a wide range of missions. This extension has strengthened our connection to other archive centers. We continue to play a leadership role in defining and developing new concepts for data mining, enhanced scientific products for archival research, and higher-order research based on questions posed in scientific terms.

Observation Processing and User Support

We are responsible for pipeline processing of all Hubble data, including procedural evaluation of observation quality. We also provide offset-slew and real-time target acquisition support for Hubble observers.

In 1999, we typically delivered a new science observation to the archive for access by users within 26 hours after it was made. This is a 25% improvement over the 1998 average delay of 35 hours. The total number of observations processed in 1999 (47,362) was down by 50 percent from 1998 due to the completion of the NICMOS mission and to the gyro failure in early November. Nevertheless, this number was more than double the number in any year prior to the 1997 Servicing Mission.

We have been streamlining to reduce costs. In 1999, we eliminated weekend staffing by increasing automation. We have made significant progress in computer system consolidation by porting most of our operations tools to platform-independent software, which enables us to use Unix boxes and PCs instead of VAXs to manage pipeline data processing. We have transitioned to the Vision 2000 Control Center System as the source of engineering data for instrument monitoring, astrometric science observations, and pointing jitter analysis.

Looking ahead, we will begin support plans for receiving data from Advanced Camera for Surveys and the Near Infrared Camera and Multi-Object Spectrometer following the fourth servicing mission planned for mid-2001. We also anticipate completing the consolidation of our computer systems and further refining and streamlining our operations.

Archive Branch

We operate the Institute's archive systems, striving to improve data delivery to users, facilitating search and retrieval, and ensuring the scientific integrity and accuracy of the data archive.

The Hubble data archive is the largest and most heavily used collection of pointed observations in astronomy today. Its increasing data volume and usage enables new approaches to astronomical research and assures the archive's key role in the second decade of Hubble operations. Indeed, the Hubble archive has clearly demonstrated the fundamental utility of astronomical archives to the broader community and has inspired new initiatives now being taken in many ground-based facilities to provide on-line access to their datasets.

The technological barriers to accessing and processing large quantities of data are rapidly vanishing. We are taking advantage of these technological opportunities by demonstrating the utility of open access to high quality science data. Today, the Hubble archive fosters two exciting kinds of exploration. First, the archive is used intensively for scientific research and discovery. Second, the archive is in the vanguard of worldwide efforts to improve the art and science of archival research itself. This dual role resonates with NASA's original decision to include the entire astronomical community in the Hubble project.

In 1999, the Hubble Archive ingested 1.2 Terabytes of data, which raised the total data volume over 7 Terabytes. We distributed nearly 5 Terabytes of data to observers and archival researchers, which brought the total volume of Hubble data distributed since launch to 18.5 Terabytes. (http://archive.stsci.edu/)

Our Hubble Archive Re-engineering Project team continued to make improvements to the archive's on-line functionality and assure its utility for the lifetime of Hubble, while lowering costs. One measure of our team's achievements is the current on-line availability of 89% of all science data, which is almost four times the on-line science capacity planned before the initiative.

The re-engineering team implemented on-the-fly calibration for Hubble data from two instruments, the Wide Field and Planetary Camera 2 and the Space Telescope Imaging Spectrograph. When completed, this important archive enhancement will permit the removal of all calibrated science data from our storage systems, reducing operational costs. It will also improve data quality, benefiting users directly, by assuring the best possible calibration at the time of data retrieval.

Our Multi-Mission Archive grew and offered new user services. We completed the transfer of all International Ultraviolet Explorer science data to CD-ROMs, which allows us to provide more rapid and reliable access to this still-valuable astronomical resource. Data sets from ASTRO-Ultraviolet Imaging Telescope, ASTRO-Hopkins Ultraviolet Telescope, and Copernicus were placed on-line for the first time. Perhaps most importantly, we began to ingest science and engineering data from the Far Ultraviolet Spectroscopic Explorer satellite, which was launched in June 1999.
(http://archive.stsci.edu/mast.html)

We provided several new archive utilities in 1999, including a beta release of a second-generation version of the archive user interface. Starview II is Java-based, which means it will be simpler to maintain and also more capable, enabling useful features that the current Starview cannot support. We also expanded catalog cross-correlation tools, improved science abstract search tools, and developed a more coherent web-site design.

We eliminated production of paper products for Hubble data. These summaries were labor-intensive and costly to print and distribute. We have replaced the hard-copy product with a more accessible, electronic version delivered over the Internet. The new approach enables electronic searches for keywords.

Looking ahead to the year 2000, we will implement Starview II and extend on-the-fly calibration to data from the Near Infrared Camera and Multi-Object Spectrometer. Also, we will undertake the most significant remaining improvement in the archive infrastructure, which is complete migration to magneto-optical storage media. The 1999 choice to transition to this storage technology was based on cost effectiveness. Magneto-optical media and storage jukeboxes are five times less costly per unit data volume than our existing Sony optical platters. Furthermore, magneto-optical systems are in wide use, conform to an industry-wide format standard, and offer superb reliability.

Catalogs and Surveys Branch

We produce and distribute all-sky digital images and deep object catalogs to support observatory operations worldwide and to provide a research and educational resource to the community.

We obtain our images and catalogs by digitizing, processing, and analyzing the photographic sky survey plates from the Palomar and Anglo-Australian Schmidt telescopes. These data products provide accurate target coordinates, guide stars, and finding charts used in telescope operations. Also, they are used for many scientific purposes, such as the optical identification of sources detected at other wavelengths.

We are completing the scanning and archiving of the second-epoch surveys, which will cover the sky in three passbands. In the blue J-bandpass and the red F-bandpass, virtually all plates have been digitized, and we are now scanning the near-infrared bandpass plates. We make these products available to the community via a number of web servers around the world.
(http://www-gsss.stsci.edu/dss/dss.html)

We are constructing the second-generation Guide Star Catalog from the digitized images. The Guide Star Catalog II will have all-sky coverage and contain colors and proper motions for ten billion stars down to at least 18th magnitude.

By the end of 1999, we processed over 80% of the available plate material. In addition to supporting Hubble operations, this catalog will be used operationally by the Gemini, Very Large Telescope, and Galileo observatories. We released a preliminary version of Guide Star Catalog II, offering a subset of the sky. As fields become available, the Institute uses them to provide automated bright object protection for Hubble.

A special achievement of the development program for Guide Star Catalog II was the successful development and deployment of a modern object-oriented database combined with a hierarchical storage management system. We use this powerful configuration to manage and calibrate the huge catalog in an efficient and effective manner.

We reached a collaborative agreement with the Sloan Digital Sky Survey to inter-compare our pipeline products with theirs, which will provide quality assurance and characterize the differences between the datasets.

We developed and successfully integrated software that enables access to the Guide Star Catalog II by both the Expert Assistant tool and the SKYCAT interface at the European Southern Observatory. These are graphical user interfaces used for observation planning, catalogs, and visualizing images. (http://www.stsci.edu/apsb/doc/SEA/home.html) (http://archive.eso.org/skycat/)

In 1999, we completed a study to compare current galactic models with recent observations and to extend those models to the near-infrared wavelengths at which the Next Generation Space Telescope will operate. Such theoretical near-infrared stellar distributions provide estimates of guide-star availability and positional accuracy. Those results will be used to set performance requirements for the Next Generation Space Telescope guidance system.

Next Generation Space Telescope Division

We collaborate with the Goddard Space Flight Center to develop the scientific, technical, and operational vision of the Next Generation Space Telescope (NGST). We are responsible for developing the NGST Science and Operations Center, with which we will operate the telescope and implement its science program.

After the reorganization, we are a unit of the Missions Directorate. In creating the NGST Division, we drew scientists, managers and engineers from the Science and Engineering Systems Division, the Science Support Division, and the Director's Office.

We share a great challenge, which is to construct and operate Hubble's successor at a fraction of Hubble's cost. We also share an unprecedented opportunity: to use state-of-the-art technology to achieve Hubble-like performance at infrared wavelengths, with which to observe the birth of the first stars and galaxies. The Next Generation Space Telescope is a joint endeavor of three international partners: NASA, the European Space Agency, and the Canadian Space Agency.

We are members of the NASA project team for the Next Generation Space Telescope. This badgeless partnership has been the foundation of our successful relationship with NASA on this complex, fast moving program. Our staff play essential roles, providing leadership in optical design and technology development, science operations, and instrument design.

During 1999, we undertook numerous scientific and technical studies to better understand and define the NGST observatory and mission. We refined and expanded the capabilities of the NGST Mission Simulator, with which we evaluated the time required to complete the Design Reference Mission. We participated in studies of the candidate instruments for NGST and joined efforts with the NASA project office to conceptualize the instrument complement and the management of its development. We conducted an extensive study to improve our understanding of the operational characteristics of NGST and to explore critical design and operations issues.

We provided comprehensive information on our mission to the Panel on Ultraviolet, Optical, and Infrared Astronomy from Space, which is part of the Astronomy and Astrophysics Survey Committee of the National Research Council. The Panel is setting priorities in the NASA program of which the Next Generation Space Telescope is part. We prepared, and the Office of Public Outreach produced, a booklet describing the scientific goals, technical issues, and fiscal hurdles we face. We and the NASA NGST Project Scientist briefed the Panel in person. (http://ngst.gsfc.nasa.gov/public/unconfigured/doc_344_3/nas.survey.pdf)

We worked with the NGST Ad Hoc Science Working Group to set priorities for the science program and scientific capabilities of the Next Generation Space Telescope. These priorities were based in part on a set of science observations ranked by the Ad Hoc Science Working Group, called the Design Reference Mission. (http://www.ngst.stsci.edu/drm/index.html)

The priorities were also informed by the results of some twenty-one instrument studies commissioned by the NGST project. (http://www.ngst.stsci.edu/aswg/instruments/index.html)

We facilitated the deliberations on NGST science capabilities with a variety of activities, including a workshop on the state-of-the-art in infrared detectors, which drew experts from all over the world. (http://www.ngst.stsci.edu/conferences/detector_conf99/detector_conf.html)

On the basis of these science and instrument studies, the Ad Hoc Science Working Group recommended to the NASA NGST Project Scientist and the international partners a core set of science capabilities for the Next Generation Space Telescope: a wide-field, near-infrared imager (1-5 microns); a multi-object, moderate resolution, near-infrared spectrometer; and a general purpose, mid-infrared imager and spectrometer (5-28 microns). (http://ngst.gsfc.nasa.gov/public/configured/doc_632_5/ASWG_Rec.pdf).

We worked throughout 1999 with the Office of Public Outreach to produce and coordinate special sessions and sponsored events at the AAS to publicize the recommendations of the Ad Hoc Science Working Group and the progress of NGST technology development.

In 2000, the NGST Project will complete the early definition phase and prepare for the selection of a design and the prime aerospace contractor. To support these culminating telescope studies, we will add depth and detail to the science and operations concept and issue an Operations Concept Document midway through the year. With our assistance and the advice of the Ad Hoc Science Working Group, NASA will develop a plan for the development of the science instrument payload and the procurement of U.S. instruments. In the meantime, we continue to work with NASA in designing a program that both breaks the Hubble cost paradigm and pushes back the boundaries of the observed Universe.

Engineering and Software Services Division

We are responsible for all software development and all engineering support at the Institute.

We are organized in four departments: Science User Systems, Planning and Scheduling Systems, Ground Systems, and Mission and Flight Engineering. Our division was formed by combining the former Science and Engineering Systems division with the software teams of the former Project to Re-engineer Space Telescope Observing and the former Science Support Division.

Our division consists of scientists, engineers, and software professionals dedicated to developing quality software and delivering expert engineering with the sole aim of enhancing science return to the astronomical community. By combining all the Institute's software and engineering teams within one division, we intend to secure efficiencies and economies through commonality and sharing.

In 1999, we completed a number of important initiatives in support of Hubble, all of them coming to fruition just before the new millennium.

In the fall of 1999, the Hubble lost another of the gyroscopes used to point the telescope, sending the observatory into a special safe mode and sending our engineering and commanding teams into a prolonged period of alert. After a long tense wait, the shuttle flew in December to refurbish the observatory. We provided engineering and management support for the servicing mission, working around the clock and through the holiday season as the astronauts repaired the Hubble observatory.

We finished two data-pipeline initiatives. First, we implemented pipeline components to handle the large-format images that the Advanced Camera for Surveys will produce after it is installed during the next servicing mission. Second, we introduced on-the-fly calibration for the pipeline and archive systems. On-the-fly calibration means that science data is calibrated each time it is retrieved from the archive. Our understanding of Hubble data is constantly improving, as is our ability to calibrate it. On-the-fly calibration allows observers and archival researchers to obtain the best-calibrated data any time they retrieve data from the Hubble archive.

We also produced a suite of Internet-based tools to aid the international effort to plan the science and operation of the Next Generation Space Telescope. Finally, we successfully assured the Y2K readiness of all our software.

In 2000 we will deploy several new software systems to benefit Hubble observers directly. These systems will include a grants management system and new interfaces for the archives, proposal preparation tools, and data-reduction software. We will also complete the on-the-fly calibration system for the Near Infrared Camera and Multi-Object Spectrometer and prepare to deploy it for the Advanced Camera for Surveys.

We plan to improve the Hubble scheduling systems, which will further reduce the time needed to produce a short-term calendar. This and other improvements to our core software systems will provide more efficient Hubble operations in the observatory's second decade.

We will continue to provide responsive engineering support for Hubble, including for the development of the new instruments, Advanced Camera for Surveys, Cosmic Origins Spectrograph, and the Wide Field Camera 3. We will also be involved with the development of the new cooling systems.

We will be extensively involved in preparations for the next servicing mission, currently planned for June 2001. We will make ready and test the ground system software to support the capabilities of the new instruments and develop the Servicing Mission Orbital Verification activities for the new hardware and software systems to be deployed.

Our laboratory will support the Institute's scientific staff in instrument development and detector testing.

In 2000, we expect growing involvement in developing systems for the Next Generation Space Telescope.

Science User Systems Department

We develop and support the software used by scientists to prepare their Hubble programs for execution and to analyze their data after the observations.

Our department includes two groups, the Science Software Group, which was formerly part of the Science Programs Division, and the Astronomer's Proposal Software Team, which is a new group. In the future we will incorporate other development projects for software used directly by scientists, including, for example, the new Starview II interface to the Hubble Data Archive and the new grants management system (GATOR).

With all the science- and user-software systems gathered into one department, we have the opportunity to develop a more consistent external interface for our observing community.

Science Software Group

We develop the calibration and data analysis software used by the instrument groups, the pipeline data processing team, Hubble archive users, and Hubble observers.

Previously, we were part of the Science Support Division.

In 1999, we completed and tested the first version of the Advanced Camera for Surveys calibration package, which will be used to routinely calibrate all the data from that instrument, after it is installed in 2003. The Advanced Camera for Surveys will produce much more data than previous instruments, which presents challenges both for storage at the Institute and for transmission over the Internet to observers. For this reason, we developed a new compressed-image format, which allows images from the Advanced Camera for Surveys to be compressed by up to a factor of ten while still allowing easy data access by analysis tools.

We created a new set of tools for analyzing data from the Near Infrared Camera and Multi-Object Spectrometer. These tools compensate for many of the quirks of that instrument's data. This development increases the scientific value of both archival data and the new data to be acquired after the next servicing mission. We are now in the process of incorporating some of these new capabilities into the calibration pipeline for the Near Infrared Camera and Multi-Object Spectrometer.

We completed the first version of a new data-analysis command language called Pyraf. The Pyraf system is based on the freely available, widely used Python scripting language. It allows access to all our existing data-analysis tasks, including scripts written in the former command language, which was much less open and extensible than Pyraf. Pyraf is currently being tested and will be released to the public later in 2000. Our long-term goal is to create a data-analysis environment that is more powerful and more productive for both astronomers and programmers.

Astronomer's Proposal Support Team

We develop the software used by astronomers to plan their Hubble observations and describe them for execution by the spacecraft.

We are a new group consisting of staff from three former divisions: Science and Engineering Support, Project to Re-engineer Space Telescope Observing, and Science Support.

Our current proposal-preparation software is called Remote Proposal Submission 2 (RPS2). This software aids astronomers in preparing their programs by ensuring that the correct syntax is used, checking for legal instrument configurations, and determining that the program is feasible and can be scheduled. In 1999, we improved this software to provide better diagnostics and advice to users, who can now submit observing programs with no processing errors. Also, we integrated the new Guide Star System II into the proposal-preparation software, which means that astronomers can determine when their targets have no guide stars available and modify their programs if necessary. This feature will be used by observers in their February 2000 proposal preparation.

In 1999, we began work on the Astronomer Proposal Tools project, which will produce a new generation of tools for use in proposal preparation for Hubble and other observatories. This project is based partly on the prototype Java tools developed by the Scientist's Expert Assistant project. Astronomer Proposal Tools will provide a more modern interface to our existing tools, in addition to new capabilities to make proposal preparation easier and more interactive.

Planning and Scheduling Systems Department

We have responsibility for developing and maintaining the planning and scheduling software products used at the Institute and other observatories.

Our department consists of three development teams and a testing team. The Institute reorganization placed all engineering talent related to planning and scheduling systems within our department. For our customers, this consolidation guarantees that we will continue to provide a high standard of support while taking full advantage of the skills within our software groups.

In 1999, we supported various ground system software components for the Far Ultraviolet Spectroscopic Explorer and for the Next Generation Space Telescope Mission Simulator.

Looking ahead, we will continue to support software development for our current missions while pursuing new opportunities to provide cost-effective planning and scheduling products to other missions.

Planning Development Team

We develop and enhance front-end planning and scheduling software.

Previously, we were known as the Science Scheduling team and were part of the Project to Re-Engineer Space Telescope Observing.

A goal within our group is to improve the state of the art of observatory planning operations by applying our planning solutions to multiple observatories and presenting our innovations to the community.

In 1999, we delivered planning and scheduling systems for the European Southern Observatory's Very Large Telescope and the Far Ultraviolet Survey Explorer. We began work on planning and scheduling systems for the Space Infrared Telescope Facility, Subaru, and Chandra observatories. For Hubble, we delivered redesigned software to translate user-entered observing plans into the information needed by the planning and scheduling systems.

Spacecraft Scheduling and Commanding Team

We provide software, operational analysis, and documentation support for the Hubble ground system.

Previously, we were known as the Payload Operations Control Center Application Software Systems team and were part of the Project to Re-Engineer Space Telescope Observing.

Our main focus remains the application-software system that ingests the weekly Hubble science plan and produces the command loads for transmission to the spacecraft. The process entails expanding the science plan to include pointing control, antenna and recorder management, and relay-satellite communications. We also provide planning and scheduling support for the Hubble Vision 2000 project.

In 1999, we transferred our application software to run on the ALPHA operating system, which involved streamlining the software to simplifying processes and enhance maintainability. As a result, the software can now process a week's science plan in less than one hour.

We supported the December 1999 Hubble servicing mission, responding to multiple operational issues and helping to keep the observatory running smoothly for science.

Scheduling Development Team

We provide the short-term scheduling system for Hubble and other missions.

In the previous organization, we were known as the Planning and Scheduling team and were part of the former Science and Engineering Systems Division.

We now support a diversity of missions and projects including Hubble, the Far Ultraviolet Spectroscopic Explorer, the Next Generation Space Telescope, and the Institute's grants management system.

In 1999, we delivered over forty software releases, which ranged from major system enhancements to minor bug fixes in the Hubble scheduling system. We provided critical systems-engineering support for the Wide Field Camera 3 instrument development and the grants management system. We delivered several operational systems needed for the launch of the Far Ultraviolet Spectroscopic Explorer in June 1999 and continue to provide operational support for that mission. We provided a suite of Internet-based tools to aid the international effort to develop the design reference mission for the Next Generation Space Telescope.

Ground Systems Department

We are responsible for the Institute's science ground system, including archives, post-observation data processing, and a supporting infrastructure of databases and software systems.

Our department comprises the Archive Team, Data Processing Team, Systems Infrastructure Team, and Database Developer Team.

The Institute's ground system operates over interconnected servers, simultaneously running multiple, complex, interrelated tasks. We place increasing emphasis on developing our applications to be open and flexible, which will allow the software to be used for non-Hubble or non-Institute applications, such as the Far Ultraviolet Explorer mission.

Looking ahead to 2000, we will finish preparing for the next Servicing Mission in June 2001, when astronauts will install the Advanced Camera for Surveys and the mechanical cooling system for the Near-Infrared Camera and Multi-Object Spectrometer. We will deploy the new grants management system and new versions of the on-the-fly calibration system. We will replace the existing optical storage media systems used for archiving with magneto-optical media systems.

Archive Team

We develop, deploy, and upgrade the systems and interfaces used for archival scientific research.

Previously, we were a team within the Science and Engineering Systems Division.

In 1999, we supported the implementation of on-the-fly calibration for Hubble data from two instruments, the Space Telescope Imaging Spectrograph and the Wide Field and Planetary Camera 2. This innovation saves storage volume because it obviates the need to archive calibrated data. On-the-fly calibration also benefits the observer by assuring that data are delivered with the most up-to-date calibration algorithms and reference files at the time of the data request. It also rebuilds the science data headers. (http://archive.stsci.edu/mast.html)

Data Processing Team

We are responsible for the routine data processing and calibration pipelines.

Previously, we were in the Science and Engineering Systems Division.

In 1999, we supported the completion of the first phases of the on-the-fly calibration system.

We also made progress in migrating our software systems to the Unix platform, which has allowed them to be used for other missions, notably for the Far Ultraviolet Spectroscopic Explorer and the Space Infrared Telescope Facility missions.

Systems Infrastructure Team

We investigate, test, and deploy new technologies, products, and tools used on the science ground system components. We develop and maintain the application-programming interfaces used to access databases, and support the system for tracking problem reports and work requests on the science ground systems. We are developing the new grants management system.

We were known as the Tools and Technology team and were part of the Science and Engineering Systems Division.

In 1999, our major focus was developing the new interactive system for managing grants. The Cycle 9 Principal Investigators will use this new user interface to submit, monitor, and report on their Hubble grant proposals and funding awards. We also helped develop the user interfaces to the new Hubble telemetry archive.

Database Developer Team

We manage and support the proposal and planning databases for Hubble.

The team was previously known as the Database and Systems Administration team and was part of the Project to Re-Engineer the Space Telescope Observing.

We provide database support and produce the database reports used during the Phase 1 and Phase 2 portions of the Hubble proposal cycle. In 1999, we also produced database reports from the CostPoint financial systems for the Administration Division.

In 1999, we developed new tools to notify Principal Investigators and Contact Scientists when a significant change was made to their planned Hubble observing programs.

Mission and Flight Engineering Department

We are responsible for the health and safety of the Hubble instruments and spacecraft.

Before the reorganization, our Engineering Team and our Command Maintenance and Development Group were parts of the Science and Engineering Systems Division. Our Systems Engineering Team is a new group formed of individuals who had been dispersed throughout the prior organization.

We have in-depth engineering knowledge of the Hubble flight hardware and flight software, which we combine with a synoptic understanding of the operational needs of the Hubble mission. On this basis, we provide systems-engineering services to projects at the Institute and at Goddard Space Flight Center.

Engineering Team

We maintain engineering knowledge of the Hubble instruments and spacecraft hardware.

We respond to problems that threaten Hubble observations, and work with the operations staff to resolve them. We monitor the health and performance of the various payload elements. We track and report on the status of limited-life devices. In advance of servicing missions to Hubble, we work with NASA personnel to define the operational requirements of new hardware and provide 24-hour support during the servicing mission itself.

We led the group that developed the monitoring program for Near Infrared Camera and Multi-Object Spectrometer as its cryogen was exhausted early in 1999. We helped investigate the anomalously high detector dark current during the warm-up. We also played an active role in the contamination analysis for the mechanical cooler to be installed on this instrument in the next servicing mission, in June 2001.

In response to a failure of the third of six gyros, we led the effort to define the payload configuration if a fourth gyro should fail. When the fourth gyro did indeed fail, we worked with NASA personnel to define the procedures for commencing the servicing mission in zero gyro mode.

In 1999, we led the effort to characterize the charge transfer efficiency of the CCD detectors being developed for the Advanced Camera for Surveys. In the process, we defined requirements for later measuring charge transfer efficiency on orbit.

Command Maintenance and Development Group

We are responsible for the systems and procedures that develop command loads for Hubble science operations.

We implement, test, document, and maintain all instructions and database elements for commanding science operations. We also define and document the software requirements for the software system that provides a transformation interface between proposals and spacecraft commanding.

We provide various forms of support to Hubble operations. We review non-standard proposals, such as those for the orbital verification program that follows a servicing mission. We analyze spacecraft anomalies and define recovery activities.

In 1999, we supported preparations for the December servicing mission by reviewing all orbital verification proposals, designing special implementations for non-standard requests, creating and testing special instructions, and upgrading the instructions for the new flight computer. During the servicing mission, we reviewed all flight calendars, providing inputs for the calendar delivery notices involving special handling requests, and analyzing a multi-bit error in the Near Infrared Camera and Multi-Object Spectrometer.

During the past year, we also supported analysis and recovery efforts for instrument anomalies. For example, these anomalies included detector rate violations and timetag-mode problems in the Space Telescope Imaging Spectrograph. Also, we began supporting the ground-system implementation for the Cosmic Origins Spectrograph and Wide Field Camera 3 and continued our work on the commanding for the future cooling systems for the Hubble's aft shroud and Near Infrared Camera and Multi-Object Spectrometer.

Systems Engineering Team

We define the requirements and design of many of the Institute's software systems.

In 1999, we worked with the development teams to define the science requirements for the Advanced Camera for Surveys, Cosmic Origins Spectrograph, and Wide Field Camera 3. Our goal is to assure that these new instruments can be operated cost effectively within the framework of the Institute's software systems.

We led the effort to define the system requirements and develop the design for on-the-fly calibration. We followed and supported implementation of this new system through testing.

We contributed to the system requirements for processing science and engineering telemetry in the new control center software, which was developed at the Goddard Space Flight Center. Also, we participated in the Hubble Systems Management Board and the Guide Star Working Group.

We participated in the definition of the system requirements and design development for the grants management system and for the implementation of scheduling and archiving for the Far Ultraviolet Spectroscopic Explorer.

We participated in working groups to define the requirements for the operations and flight software for the Next Generation Space Telescope.

SCIENCE DIRECTORATE

We promote scientific research at the Institute, conduct critical science processes, and facilitate the communication of Hubble discoveries within the scientific community as well as to public audiences. We provide scientific expertise to mission-critical groups in the Institute to carry out their functions.

The Associate Director for Science leads the Science Directorate from within the Director's Office. The Science Directorate comprises the Science Division, the Science Policies Office, the Office of Public Outreach, and the Library. Formerly, the Research Programs Office played the role of the new Science Division, fostering the intellectual life of the Institute; it also supervised the Library, which is now a separate unit. The Science Program Selection Office is now part of the Science Policies Office, which also has the role of interfacing with committees that advise or oversee the Institute. The Office of Public Outreach is changed only in reporting to the Associate Director for Science instead of the Director.

A primary responsibility of the Associate Director for Science is assuring a vigorous research environment at the Institute. This scientific vitality is not only an expectation of the Institute staff, who have chosen careers that combine community service with opportunities for personal research. It is also the expectation of NASA and the astronomical community, which are committed to and confirmed in the notion that the science operations of Hubble are best conducted by front-rank scientists.

The Associate Director for Science oversees the Office of Public Outreach to ensure its scientific integrity.

The Associate Director for Science appoints and oversees the Science Recruitment Committee, which does the staff work involved in hiring scientists, and the Science Personnel Committee, which does the same with respect to promotion and tenure of scientists already at the Institute.

A major reason for creating the Science Directorate was to improve the interplay and potential synergism of the separate and distinct functional and research duties of the Institute scientific staff. The Associate Director for Science will undertake the appropriate deployment of scientific expertise to divisions with operational and development responsibility for Hubble and the Next Generation Space Telescope. The Science Division will conduct the formal matrixing procedure for assigning scientists to functional tasks.

The Associate Director for Science is responsible for the effectiveness of the Institute's external science functions, such as peer reviews.

During the coming year, the Science Directorate will foster several initiatives by scientific staff members to submit proposals for large research projects on space observatories. We will take special steps to promote the professional development of junior members of the scientific staff. Also, we will collaborate with NASA Headquarters in starting new education initiatives in the Office of Public Outreach targeted at public schools.

Science Division

We foster and enhance the Institute as a research environment for all our scientific staff. We participate in the functional assignment of scientists to assure a balance of career development and institutional requirements.

In the previous organization, the Research Programs Office performed the subset of our tasks that service the Institute's research environment, such as arranging talks and running visitor or fellowship programs. We have not inherited the Library, which has been reorganized as a separate unit within the Science Directorate. Our other responsibilities, as the 'home' of scientists from which they are assigned to functional positions, are new creations of the reorganization, which introduces the formalism of matrix management to the Institute for the first time.

In 1999, the Research Programs Office organized the annual selection process for the Hubble Fellows. We convened an outside panel to review applications, and ten new fellows were appointed. In the summer, the cycle was started again with the announcement of the year 2000 opportunity to apply to the Hubble Fellowship Program.

The selection of the 1999 Institute Fellow was carried out with the help of an internal advisory panel, and James Rhoads joined us in the Fall as our third Fellow. The announcement of the competition for the 2000 Institute Fellowship was issued about the same time.

A high point of the science life in the Institute in 1999 was the May Symposium, *The Largest Explosions Since the Big Bang*, which we organized. The symposium focused on Supernovae and the enigmatic Gamma Ray Bursters. More than one hundred participants attended, and the proceedings are being published by Cambridge University Press.

The Visitor Program is an important stimulus to the scientific life of the Institute. In 1999, we hosted two sabbatical visitors and more than one hundred short-term visitors. On any average day one can find six visitors at the Institute.

We organized several series of talks for the scientific staff featuring prominent researchers from the astronomy and physics communities. These series included the regular Weekly Colloquium series, the monthly Popular Talks series presented by Institute researchers for all Institute staff, and the bi-weekly meetings of the five topical Journal Clubs.

Young researchers constitute an important component of the Institute's research productivity. In 1999, we provided the administrative support for approximately twenty-five Postdoctoral Fellows and twelve Graduate Students. This year, many of the Postdoctoral Fellows and Graduate Students moved from the Bloomberg building back into the Muller building, reversing an unpopular trend brought about by a severe shortage of space. In 1999, we assisted with the Summer Student Program, which introduced twenty enthusiastic undergraduates to an eight-week session doing research at the Institute.

The Director's Discretionary Research Fund is a vital source of support for those research programs of Institute staff that cannot otherwise be funded from external grants. For example, the Fund provides startup funds for young staff members, travel to ground-based observatories and scientific meetings, and salaries for postdoctoral fellows, data analysts, and graduate students working on staff research projects. We administer the Fund, calling for proposals twice each year and conducting a review with the help of an internal panel appointed by the Director. Presently, we administer more than ninety active Fund accounts, including several multi-year programs intended to strengthen the research infrastructure of the Institute.

In the coming year, we will develop and implement the policies and procedures for making the matrix assignments of scientists to functional positions. In parallel, we will coordinate the renewal, promotion, and tenure processes for the scientific staff. With respect to the Institute as a research environment, we will pursue initiatives, such as instituting interest groups in major topical areas of astronomy to coordinate scientific activities and opportunities.

Science Policies Division

We are the Institute point of contact with oversight committees. We conduct the selection process for the Hubble science program and establish science metrics to evaluate its success.

Our Division encompasses tasks previously assigned to the Director's Office and the Science Programs Selection Office.

Our advisory committees counsel us on optimizing our services to the community. We have three standing advisory committees with terms of reference outside the Institute, and two that are creations of the Director, one of which is currently dormant. The Space Telescope Institute Council, our primary management oversight committee, is selected by and reports to the AURA Board of Directors. The Institute Visiting Committee, which evaluates the productivity, working conditions, and morale of the staff, is selected by the Space Telescope Institute Council and reports to NASA through AURA. The Space Telescope Users Committee is selected by and reports to both the Institute Director and the NASA Project Scientist on matters related to the utility of the telescope and the quality of Institute services. The Telescope Allocation Committee is appointed by the Director to evaluate observing proposals and recommend an allocation of Hubble orbits to selected programs. Finally, the currently-inactive Space Telescope Advisory Council is available to the Director for advice on any subject related to the Hubble science program.

The Space Telescope Institute Council met in February, June, and October 1999. The Institute has an excellent relationship with this committee, which has been supportive of a number of initiatives, including our plans for the 1999 reorganization of the Institute. The Space Telescope Institute Council also endorsed the Institute's activities related to detailed planning for the NGST's mission and science operations.

We received the support of the Space Telescope Institute Council for our plans to streamline and improve the proposal selection process, which included fewer panels, fewer scientific categories, increased focus on large programs, incentives for medium programs, and allocating observing time coordinated with the Chandra X-ray observatory.

In 1999, the Director brought two tenure cases to the Space Telescope Institute Council, which were endorsed and subsequently approved by the AURA Board of Directors.

The Space Telescope Users Committee met twice, in June and November 1999. We have achieved a renewed spirit of cooperation with this committee, which has been helpful in prioritizing the Institute's development activities. It helped evaluate and refine the requirements for the Science Expert Assistant package. The committee endorsed the Institute's role in developing Wide Field Camera 3, the plan to outsource selected instrument calibrations to the community, and the streamlining of the Institute's user support functions to make them more cost effective.

The Institute Visiting Committee met in April 1999 to review the Institute's progress toward its annual goals and objectives and to survey the perspectives and issues of the Institute's staff. They noted the significant positive change in the future prospects of the Institute because of the extension of Hubble operations until 2010 and the directive by NASA designating the Institute as the Science and Operations Center for the Next Generation Space Telescope. They commented positively on the importance of a first-rate staff research program to the health of the Institute and to the science leadership role that we should exercise.

The Institute Visiting Committee gave strong support to our outreach and education activities, which have played a major role in making Hubble's scientific achievement known to a large fraction of the population. Finally, the committee was impressed by our success in maintaining a very high observing efficiency with Hubble while coping effectively with a number of hardware problems.

In 1999, we carried out a number of activities to evaluate the scientific impact of Hubble's observing program. Working with the Hubble Second Decade Committee, we analyzed a subset of the past observing programs, researched the number of publications resulting from the observations, and measured their impacts in terms of citations in the literature. This analysis provided a statistical basis to the statement that large observing programs have been generally more productive than small programs when normalized by the amount of time allocated to each. This statement led to the recommendation that a larger fraction of Hubble observing time be allocated to large programs, which was achieved in the selection of Cycle 9 proposals. (http://sso.stsci.edu/second_decade/treasury/)

Looking ahead, we have begun developing a set of science metrics to identify the most scientifically effective Hubble observing programs and evaluate their impact on astronomy. We will use the results to guide our strategic planning and program selection process. We will continue to provide leadership and oversight of opportunities to improve Hubble's scientific efficiency, such as Treasury programs, the use of parallel time, and the Director's Discretionary time.

Science Program Selection Office

We conduct the selection process for the Hubble science program.

Our roles in selecting the Hubble science program include issuing an annual Call for Proposals to the astronomical community, organizing the proposal review, handling proposals for Director's Discretionary observing time, and formulating relevant policies. Our goal is to select the most important Hubble observations—those with deep and lasting impact on the field of astronomy—while maintaining absolute fairness and equity of opportunity to every proposer.

In 1999, we made significant changes to the proposal review process. The process used for the nine previous review cycles was showing signs of strain due to the doubling of submitted proposals since Cycle 1. It involved too many people (at high cost) and relied on a Time Allocation Committee too large for in-depth scientific discussions. Furthermore, we needed a way to equalize the chances for larger proposals, so that scientific excellence, not 'cheapness,' would be the primary criterion for success of a proposal. We were also concerned about conflicts of interest, which were exacerbated by the increasingly narrow focus of single-topic review panels. Finally, we wanted a better way to set priorities among science subdisciplines—one that stressed Hubble's unique capabilities.

There were five key changes in the proposal review process for Cycle 9. Extensive feedback from the Cycle 9 panels and Telescope Allocation Committee indicates the changes were very successful, and we plan to use the new process (with minor changes) in Cycle 10.

First, we greatly increased the number of large observing programs, as recommended by external advisory committees. The redefined role of the Time Allocation Committee was to review proposals of 100 orbits or larger, for which we made 1,000 orbits available. We encouraged medium-sized proposals (15-99 orbits) by orbit subsidies in the review process. To encourage more submissions, these new opportunities were well advertised in the Call for Proposals, the Institute Newsletter, and elsewhere. As a result, more than fifteen times as many large proposals were submitted as in Cycle 8, constituting one-quarter of proposed orbits rather than a few percent. The Time Allocation Committee recommended a total of six large programs, for about one-quarter of the total allocated orbits. Meanwhile, requests for medium-sized allocations doubled, constituting about 60% of the requested orbits and a similar percentage of the selected orbits. Thus the acceptance rate was largely independent of proposal size.

Second, we charged each review panel with allocating orbits to all proposals asking for fewer than 100 orbits. This broadened scientific focus improved the science balance within the panels. In preparation for this change, proposers were urged to explain the importance of their program to astronomy as a whole. As a result, all proposals were evaluated via in-depth discussions by experts, rather than the gray-area proposals being discussed by the larger, more diverse Time Allocation Committee. The Cycle 9 panels were highly supportive of this change. Even though some panelists admitted pre-meeting apprehensions about the breadth of expertise required, by the end they embraced the new process. Because we had redundant panels for each broad area, there were effectively two independent determinations of science priorities per cycle. In a few cases, mirror panels came up with quite different mixes of science, making the new process arguably more robust against the vagaries of peer review.

Third, by creating two panels for each broad science area (except the Solar System panel, for which there were too few proposals), we minimized the impact of conflicts of interest while still allowing experienced Hubble users to participate in the review. Mirror panels meant that a panelist's proposals could be reviewed by the other panel. The result was the same proposal acceptance rates for PIs who served as reviewers as for those outside the process. There were also dramatically fewer instances of panelists having to recuse themselves because of conflicts of interest, leading to a more consistent review involving a larger fraction of panel expertise.

Fourth, we enabled exciting new science opportunities. We increased the number of fast Target-of-Opportunity proposals allowed and reduced the minimum activation time proposers could request (with actual implementation to be driven by the proposed science). We instituted the first joint multi-wavelength opportunity, for the Chandra X-ray Observatory and Hubble, awarding up to 400 kiloseconds of Chandra time and giving the Chandra project 100 orbits of Hubble time for their next review. Several of the top-rated Cycle 9 proposals involved fast activation of Targets of Opportunity and Chandra-coordinated science, attesting to the importance of these opportunities.

Fifth, we reduced the burden on the astronomical community. We halved the number of panels and thus panelists and cost. We implemented a triage process to keep the burden on individual reviewers manageable. We took this step after conducting tests on the review databases from previous cycles and verifying that triage accurately identified the bottom one-third of proposals.

Our new Hubble review process has been successful, and we plan to continue it in future cycles. Because they now have the same chance of success as other proposals, we expect the number of large proposals to increase. With two more instruments available in Cycle 10—the Advanced Camera for Surveys and the re-cooled Near Infrared Camera and Multi-Object Spectrometer—we also expect the overall number of proposals to increase.

In this golden age of astronomy, when Hubble consistently provides the top science news stories year after year, our efforts will ensure the continued vitality of the Hubble science program and the continued satisfaction of the astronomical community with Hubble's science program selection process.

The Library

We provide access to the astronomical literature for Institute astronomers, visiting scientists, and Hubble users worldwide. Also, we provide a variety of information-related services to the whole Institute staff and outside users on a time-available basis.

The Library is now a unit in the Science Directorate. Before the recent reorganization, the Library was in the Research Programs Office. Currently, our staff consists of the Institute Librarian and two support persons.

We acquire, maintain, and provide easy access to a breadth and depth of astronomical publications in both print and electronic forms. Beyond those traditional library services—updated to the Internet era—we also help Institute staff with special expertise on Internet resources, copyright issues, citation analyses, information management—and even grammar and spelling! To assure that the Institute Library remains in the vanguard, we introduce advanced techniques and technologies as they mature, and maintain good communications with other research libraries around the world.

We compile the Hubble Bibliography of all papers making original use of Hubble data, including papers written both by observers and archival researchers. We identify these 'original use' papers by searching all incoming journals and conference proceedings for papers that use Hubble data directly without citing prior usage of that data. The Hubble Bibliography is included in the publications database searchable at http://NTweb.stsci.edu/STEPsheet/. One routine data byproduct of the Hubble Bibliography is a list of newly published Hubble papers, which we distribute fortnightly over the Internet. At the end of 1999, the Hubble bibliography held 2600 entries, 378 of which were papers published during 1999.

At the end of 1999, the Library's physical inventory included over 12,300 monograph and journal volumes, 269 CD-ROMs, 174 reels of microfilm, and 6100 microfiche. During 1999, Library-mediated access to electronic journals increased by about 20%. Electronic journals are an important trend for the future, even though the need for traditional paper products has not yet declined. We spent a considerable effort negotiating access and cost issues with publishers.

In 1999, we did a study of citation rates of Institute scientific staff, and we provided citation analyses of Hubble papers in support of the Second Decade Study. The two 'behind-the-scenes' projects were moving the Hubble Bibliography and preprint information from a flat ASCII file to a database and moving our bibliographic database (i.e., the electronic 'card catalog') from a VMS-dependent product to a fully web-based one, which runs under Windows NT. (http://stlibrary1.stsci.edu/uhtbin/cgisirsi.exe/STSI/0/49)

Office of Public Outreach

We develop and deliver astronomy-related educational products and services to classroom students, the public, and the astronomical community. We support and enable individual scientists in developing valid educational contributions based on their research. Our goal is to bring the excitement—and to demonstrate the relevance—of scientific discovery and technological advances to the public.

In the reorganization, we have relocated to the Science Directorate. Our scope remains broad and unchanged, including formal and informal science education, public outreach, news products, the Origins Education Forum, grants for education initiatives, and outreach to the astronomical community for the Next Generation Space Telescope.

Our development strategy is to engage scientists and engineers actively in our programs, harnessing and directing their knowledge and enthusiasm towards useful educational outcomes. Our method is to act as catalyst by teaming the scientists and engineers with educators, students, and members of the general public to create educational resources for wide distribution.

Our delivery strategy is adaptive, involving both direct and indirect channels. We distribute electronic products directly to users over the Internet. We display exhibits in public spaces. We prepare news products that are picked up and amplified by the mass media.

Our science community support strategy is to provide resources and proven methodologies to researchers wishing to pursue initiatives that showcase their research in educationally valid products or services. Our three community support programs are the Origins Education Forum, our education grants programs, and science community outreach for the Next Generation Space Telescope.

In 1999, we continued our established programs in curriculum support and crafting news. We strove to complete the design of our traveling exhibition on Hubble, which is a collaboration with the Smithsonian Institution. We completed a series of four experiments using simulcast technologies to assess inventive ways to deliver science to the public. (http://www-sisn.jpl.nasa.gov/ISSUE49/Christian.html, and http://outreachoffice.stsci.edu/technology-experiments/index.shtml)

Looking ahead to 2000, we will showcase our new web-site, called *HubbleSite*, which is intended to be the premier general source of information on Hubble. We anticipate the summer opening of our traveling Hubble exhibit. In the arena of informal science education, we plan to provide multimedia vignettes on the discoveries achieved with Hubble.

K–12 Curriculum Program

We develop educational materials that address national education standards and are directly relevant to K-12 curricula.

The heart of our effort is a 5-week summer workshop involving K-12 teachers, graphic artists, writers, web developers, education evaluators, and Institute scientists and technology experts. The workshop participants collaborate in developing on-line, interactive modules based on Hubble that are designed to harness students' fascination with space to improve their math, science, and technical skills. After review and testing, we distribute these materials nationally. We also demonstrate the materials at professional meetings of both teachers and astronomers, such as the National Science Teachers Association, the National Council of Teachers of Mathematics, the Association of Science-Technology Centers, and the American Astronomical Society. (http://amazing-space.stsci.edu/)

In 1999, we released two on-line interactive activities, *Galaxies Galore*, a K-5 process-skills lesson and *The Truth about Black Holes*, an eighth to twelfth grade research and writing lesson.

Looking ahead, we will release several new curriculum products in 2000. *Comets* is a K-5 lesson that enables students to create and identify comets. A *Blast from the Past* is a middle-school module that students use to investigate mysterious gamma-ray bursts. We will also start the development of other, similar resources, including *Aiming the Hubble Space Telescope*, *Math Behind Escape Velocity*, and a unit based on the Hubble Deep Field, which is intended to develop students' understanding of statistical significance. Looking further ahead, we will explore other Hubble topics with good educational potential, such as planetary nebulae, stellar evolution, and the cosmological distance measurement.

Informal Science Education Program

We bring the excitement of scientific discovery and technological accomplishment to a wide audience through science museums, planetariums, libraries, and the Internet.

The public's natural curiosity about space, astronomy, and technology creates a valuable opportunity to disseminate Hubble results. Science museums regularly feature Hubble images and consult with us. By frequent request, we advise science museums and planetariums on making the most effective use of Hubble materials in their exhibits and productions. In 1999, for example, we helped the Maryland Science Center mount a permanent exhibition devoted to Hubble.

We continued to collaborate with the Smithsonian Institution in developing a traveling exhibition, *Hubble Space Telescope: New Views of the Universe*. The exhibition will exist in two forms, a large and a small version. The larger version will open at the Adler Planetarium in Chicago in June 2000, and the smaller will debut in Saginaw, Michigan, in August 2000.

In 1999, the traveling exhibition team presented the final script and design to its advisory committee and to the exhibition's sponsors, Lockheed Martin and NASA. The plans earned high praise from both reviews. A contractor is now fabricating the exhibits.

We reached an agreement with the International Planetarium Society to distribute 35-mm slides of Hubble images on a non-profit, fee-recovery basis. Planetariums can subscribe to this low-cost service to receive timely mailings of 35-mm slides.

Also in 1999, we began work on a series of PC-based multimedia presentations, collectively called *Deep Cosmos*, using software donated by Scala, Inc. Combining images, digital movie and animation files, text and music, these presentations are designed to loop continuously in a darkened exhibition alcove or planetarium lobby. The *Deep Cosmos* programs will emphasize the beauty and wonder of Hubble imagery, while placing the images in spatial and conceptual contexts. We will draw the content primarily from Hubble news releases and from material stored in our news archive. The Scala presentation software allows a superior, 'broadband' look, which is easily distinguished from the bandwidth-limited multimedia experiences available to most home Internet users. We demonstrated *Deep Cosmos* prototypes to museum and planetarium professionals, drawing significant interest. We will start distributing *Deep Cosmos* programs in 2000.

Public Information and Outreach Program

We provide Hubble information directly to the public.

The Internet is developing into a prime source of information for most citizens. The general public and the news media use our sites to get first-hand information about Hubble and its discoveries. We maintain over 14 web servers, which host a variety of sites tailored to different audiences. In 1999, our web-sites received over 231 million hits during 10.5 million user sessions.

During the last quarter of 1999 we began development on *HubbleSite*, a new web-site specifically designed to appeal to the general public. *HubbleSite* was designed to be easily navigated, readily understood by the lay reader, and visually on the cutting edge. It offers background information about the telescope's systems, its discoveries, and the people who use it. It hosts a stunning gallery of Hubble images, as well as a section for Hubble-based educational games and activities. *HubbleSite* is scheduled to premier in the first quarter of 2000.

In May 1999 our *Tour the Cosmos* series produced its fourth web program, *Spinning Stardust into Stars*. *Tour the Cosmos* merges *The Marc Steiner Show*, which is a live, National Public Radio program, with on-line multimedia elements at http://hubble.stsci.edu/steiner/. The web-site provides visitors with multimedia materials that offer a deeper understanding of the featured topic, which in the most recent case was Hubble imagery of circumstellar disks where planets may be forming. In 1999, the *Tour the Cosmos* web-site attracted over 3.8 million hits in 307,000 user sessions. In 2000, we will document our experiences with *Tour the Cosmos* and disseminate the report for the benefit of others. We will consider opportunities to continue *Tour the Cosmos* in collaboration with outside partners.

Another component of our public information program is responding to public inquiries via e-mail, post, and telephone. These requests are usually for hard-copy materials such as photos, slides, and pamphlets. In 1999, we responded to over 5,300 e-mail and 1,200 postal requests. We maintain a set of Hubble lithograph photos and standard e-mail answers, with which we respond to most requests. We envision continuing this service well into the future.

The News Program

We develop press releases, photo releases, and Space Science Updates to disseminate Hubble discoveries via print, electronic, and broadcast media.

Over the years, we have crafted an effective process for producing press events and press information packages for empowering the mass media channels to disseminate Hubble news. This valuable service is available at various levels to all Hubble observers to assist them in publicizing their research.

In 1999, we conducted three major press conferences about new Hubble findings, which were on circumstellar disks, the Hubble constant, and galactic bulges. At the two meetings of the American Astronomical Society, we issued press releases in support of posters and papers presented by Institute staff.

On average, we issued over three press or photo releases per month in 1999. The press release archive is available over the Internet at http://oposite.stsci.edu/pubinfo/pr.html. Electronic versions of these releases were distributed to over 500 news organizations.

In 1999, the Hubble Heritage program released fifteen compelling images from the Hubble archive, available at http://heritage.stsci.edu/.

Our annual science writers' workshop was held in conjunction with the Institute's 1999 May symposium, which was on the topic of gamma-ray bursts. One outcome of the workshop was a feature article in the New York Times.

The News Program supported the December 1999 Hubble servicing mission by disseminating early release observations shortly following the conclusion of the mission.

Overall in 1999, Hubble news activities yielded approximately 400 science articles in major U.S. newspapers, some 600 broadcast media reports, and about 300 magazine articles.

Looking ahead, we plan to popularize the 10th anniversary of Hubble's launch by conducting a science writers' workshop at the Institute and by distributing a press package and video summarizing Hubble's key accomplishments.

Origins Education Forum Program

We operate a forum to coordinate the education and public outreach efforts of all of the NASA missions within the Origins Theme.

NASA's Origins Theme includes such missions as SIRTF, SOFIA, NGST, Keck, FUSE, Hubble, and the Astrobiology Institute. Our Origins Education Forum serves as a central jump station for public information about these missions and their scientific results. (http://origins.stsci.edu)

Through the Origins Education Forum, we foster collaborations between missions, and we match up scientists and educators for collaborative projects. We make effective use of NASA education funding by avoiding duplication of effort and by identifying areas particularly in need of education and public outreach materials. Our special expertise in evaluating educational products and processes has allowed us to establish a well-developed set of methodologies and models. We offer our evaluation service to member missions of the Origins Forum and share our evaluation expertise with other institutions.

In 1999, we started development of the Space Science Resource Catalog, which will provide educators with an easily searched, user-friendly on-line catalog of NASA's space science resources. Our development program is connected with other educational cataloging efforts. During 1999 we researched relevant key words, investigated database and interface design options, and developed an end-to-end prototype. In early 2000 we will test the user interface at science and mathematics teacher conferences, and we will release the initial version of the Space Science Resource Catalog in late summer.

Education Grant Programs

We empower individual scientists to conduct their own education and public outreach programs.

We manage the Initiative to Develop Education through Astronomy and Space Science (IDEAS) program for NASA, which provides funding and other support for scientists, who collaborate with educators to produce educational resources and services. In 1999, we allocated approximately $500,000 to twenty programs variously intended to reach students, teachers, museums, libraries, and the general public. (http://ideas.stsci.edu/)

We also manage an education-grants program for Hubble telescope observers. In response to the 1999 Cycle 9 Call for Proposals, approximately 10% of the proposals also sought education-related funding from this program. We will announce the results of this competition in early 2000.

We will offer both funding opportunities again in the fall of 2000.

Next Generation Space Telescope Science Community Outreach

We provide the community with information about the Next Generation Space Telescope.

In 1999, we coordinated special sessions and sponsored events at the January and June American Astronomical Society meetings, where the progress made in detector and mirror technology was highlighted.

COMPUTING AND INFORMATION SERVICES DIVISION

We install and support all Institute computing and networking facilities and maintain the Institute's information systems infrastructure. We also lead a number of interdivisional committees and working groups in planning for future computing and information systems needs.

The new Computing and Information Services Division is based on the former organization's Computing and Network Services Branch of the Data Systems Division. We added specialists in applications software and information services, who were scattered in several units of the previous organization. By consolidating computer support and information services into a single division, we provide a stronger platform for managing and disseminating information, which is a prime service for our user communities and our own staff. The Institute's Chief Information Officer, a new position, heads the Division and reports to the Director. This new high visibility position—and the realignment of this division—will ensure the efficiency and effectiveness of planning and implementation in all technical and management aspects of information services and computer support.

A major accomplishment in 1999 was the early implementation of the Institute's annual computer augmentation plan. This plan, which is produced by the Institute's interdivisional Computer Planning Committee, identifies the top priorities for computer hardware and software purchases for a three year period. The timely completion of the 1999 plan, and the quick review and approval by the Hubble Project at Goddard, meant that we could purchase $850,000 worth of equipment with FY'99 instead of FY'00 funds, which are proving much tighter. All purchase orders were prepared, placed with vendors, and all equipment was delivered by the end of the 1999 fiscal year.

In 1998, we embarked on an effort to reduce the number of computer system platforms in use and supported at the Institute. Some diversity of platforms—combinations of hardware architecture and operating system—is desirable to avoid dependency on any one vendor, but too much variety imposes a burden on system administration and software support. In 1999, we made significant progress by phasing out VAX/VMS systems in the science VMS cluster and the ground systems development and operations environments. Over half of the Institute's 84 VAXes operating at the beginning of 1999 were removed from service, and the remaining VAXes are scheduled for retirement this year.

The decommissioning of the science VMS cluster required migrating the Library's on-line system to a Windows NT platform. We also helped a number of users to convert from VMSmail to Netscape or another platform-independent mail reader. Other consolidation activities included removing Novell as a network communications system for administrative PCs.

Also starting in 1998, the Institute began work on facilitating document exchange between different computer platforms. Here, a major challenge was to provide Unix system users access to standard Windows-based office productivity tools, such as Word, Excel, and Powerpoint. The Citrix MetaFrame software was selected in 1998 to solve this problem, and a small deployment of the package with a host application server was completed then. In 1999, we added a second application server and augmented the software suite to include Microsoft Project, Visio, and electronic timecards. We now have over 150 regular users of Citrix MetaFrame, as we continue to expand support for this environment.

In 1999, we devoted significant effort to ensure that all of our computing systems and software were Y2K compliant. The certification of the Hubble ground system was achieved early in the year. By December, we had applied the final patches on PC/Windows and Sun/Unix systems, which had been delayed by the flurry of Y2K patches released by vendors in the last months of the year.

We recognized in 1999 that the Institute's main web-site, http://www.stsci.edu, was operating with a design over three years old—ancient by cyberspace standards—and had serious deficiencies in providing easy access to the information. To correct these shortcomings and reinvigorate this important window into the Institute, we began a major redesign of the web-site. A tiger team reviewed the prior findings of the Documentation Working Group, and pursued improvements in both the appearance and functionality of the web-site. In the process, the tiger team is revamping the very manner in which the Institute manages web information, to ensure it is current, correct, and easy to locate. The continuing redesign effort is a collaboration between the Computing and Information Services Division and the Strategic Communications Office.

Looking ahead, our year 2000 efforts will focus on developing a new infrastructure for information and document management, and using this infrastructure to support both internal and external communications, primarily via the Internet. We will convene an interdivisional working group to assist in identifying, testing, and implementing appropriate new technologies for information management, presentation, and dissemination. We will continue to work closely with the Strategic Communications Office to assure that a clear message of Institute goals, services, and accomplishments emerges. We will expand the horizon to long-term strategic planning through a new interdivisional working group and through collaboration with the Office of Technology and Innovation. Two priority technology evaluations for 2000 are options for improving the Institute's management of e-mail and options for the Linux operating system to become a cost-effective environment for desk-top scientific and technical computing.

STRATEGIC COMMUNICATIONS OFFICE

We help provide a coherent, authoritative Institute voice to the outside world through print and electronic channels. We assess and strive to improve internal communications at the Institute.

We were the Special Studies Office before the reorganization. We have new responsibilities to publish the Institute Newsletter and to improve the Institute's web-site.

The Institute reorganization provided a special opportunity to improve the effectiveness of managing and communicating information as end-to-end processes. Most jobs at the Institute are now information-based or -oriented, and handling information has become critical to institutional as well as personal success. Our explicit objective is to improve channels of communication and to use them adroitly for strategic purposes. Our implicit goal is to raise the level of expression at the Institute and to promote clarity of thought to facilitate the resolution of issues and the coordination of efforts.

Effective information management means excellence in both content and presentation, as well as excellent skills, tools, support infrastructure, and delivery systems. We work with the Chief Information Officer to assure the necessary assets, for both strategic communications as well as for performing daily work and managing scientific, technical, and programmatic information.

In 1999, we produced the Institute's 1998 Annual Report for the first time. The Annual Report included a Views column from the Director, top News at the Institute in the preceding year, and Reviews of accomplishments from each organizational unit. (http://sso.stsci.edu/annual_report/)

From April to August, 1999, our exhibit of Hubble imagery, *A Universe of Change*, hung at the National Academy of Sciences, in Washington, DC. It portrayed Hubble's view of evolutionary—sometimes cataclysmic—astrophysical events in objects ranging from planets to stars to galaxies.

Leading the Second Decade Committee in formulating its final report, we developed and published electronically key recommendations on the Hubble Treasury Program, which would solicit, evaluate, and conduct major Hubble observing programs, and on the exciting future of the Hubble Archive. (http://sso.stsci.edu/second_decade/)

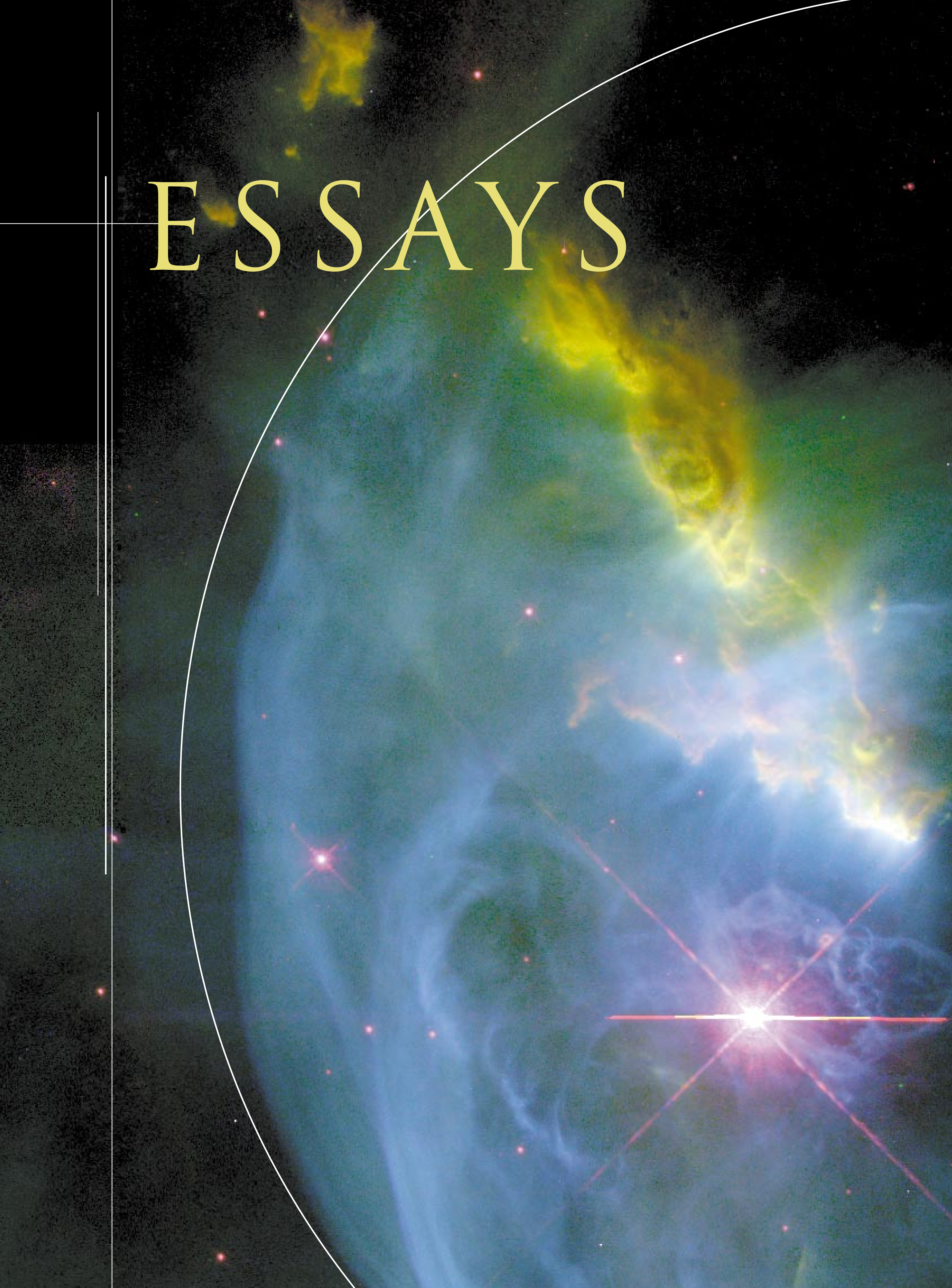
Working with the Chief Information Officer and the Computing and Information Services Division, we began a redesign and upgrading of the Institute's web-site.

We receive and respond to outside requests to use Institute-based intellectual property. We work with the Administration Division and the AURA corporate office to develop and state AURA/Institute policies on intellectual property.

In 1999, we published four issues of the Institute Newsletter, in January, June, September, and December. The print runs were 4,000 copies. (http://www.stsci.edu/ftp/stsci/newsletters/newsletters.html)

The Institute Newsletter continues to evolve in its mission as a prime channel of communication from the Institute to our community. Looking ahead, we plan to introduce appropriate use four-color printing, particularly to showcase Hubble science accomplishments. We will continue to provide important information on Institute services to the community and preparations for the Next Generation Space Telescope. In a special issue to appear in summer 2000, we will commemorate a full ten years of Hubble in orbit.

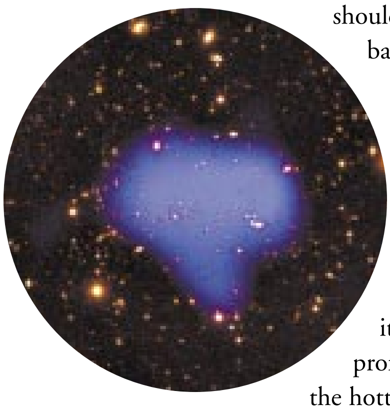
ESSAYS



CLUSTERS AND COSMOLOGY | MEGAN DONAHUE AND MARK VOIT

Seven decades ago, Edwin Hubble discovered that the Universe is expanding; its galaxies are gradually drifting apart, and the farther apart two galaxies are, the faster they tend to recede from one another. Astronomers have been pondering the Universe's fate ever since. Will it go on expanding forever, or will gravity ultimately halt the motions of galaxies, pulling everything back together in a Big Crunch? One way to address this question is to study the formation and evolution of the largest structures in the Universe, the clusters of galaxies.

This cosmic battle—eternal expansion versus eventual collapse—has been replayed in miniature on many different scales throughout the Universe. Galaxies are places where gravity defeated expansion long ago. A galaxy's stars and gas, bound together by gravitational forces, no longer expand with the rest of the Universe, but rather orbit around a common center of mass. Within clusters of galaxies, gravity has achieved victory more recently. The hundreds to thousands of galaxies that make up a cluster continue to attract new members by gravitationally halting the flight of galaxies on the outskirts of the cluster and pulling them back toward the core. If the Universe is destined to fall back together in a fiery crunch, then we expect this pattern of gravitationally driven structure formation to continue repeating itself on increasingly larger scales. The biggest objects in the Universe should grow even bigger with time as gravity wins ever greater battles over the flight of the galaxies.

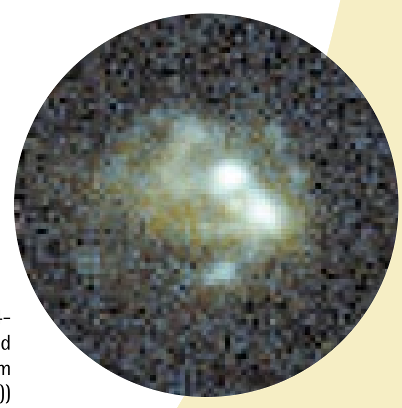


MS 1054-0321, a cluster of galaxies seven billion light years away and one of the hottest, most massive clusters known. Almost all the yellow objects are galaxies belonging to the cluster; X-ray observations of the hundred-million degree gas between the galaxies are shown in blue.

X-ray telescopes offer a way to test whether the largest objects in the Universe are still rapidly growing, presaging a Big Crunch in the distant future, or whether the growth of structure is abating, indicating that gravity will ultimately lose the battle to collapse the Universe. Powerful gravitational forces acting within a galaxy cluster strongly compress the gas between the cluster's galaxies, heating it to tens of millions of degrees and causing it to radiate profuse amounts of X rays. The more massive such a cluster is, the hotter its gas, so we can weigh a cluster of galaxies by taking its temperature with an X-ray telescope. If a Big Crunch were in the offing, we would expect the masses and temperatures of the largest clusters to be dramatically growing with time.

To test this possibility, we recently surveyed a sample of distant clusters of galaxies with ASCA, a Japanese-American X-ray satellite, and the Hubble Space Telescope. Some of these clusters are as distant as seven billion light-years, meaning that we are seeing them as they were when the Universe was only half its current age. Our observations show that, by and large, these distant clusters were nearly as hot seven billion years ago as they are today. We also find that these clusters contain numerous colliding galaxies. The construction rate of the Universe appears to have tailed off since then, implying that our ultimate fate is eternal expansion.

Because the strength of gravity on large scales is directly related to the amount of matter the Universe contains, our observations also reflect how much matter is out there. Comparing the observations with our models of just how quickly clusters should be drawing in new matter indicates that the Universe contains only thirty percent of the matter needed to halt the expansion. Completely independent approaches to this ultimate question, analyzing both distant supernovae and the microwave echo of the Big Bang, are simultaneously converging to similar answers, which reinforces our confidence that we now know how the Universe will end.



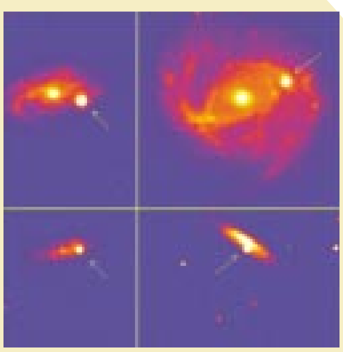
A colliding pair of galaxies in the cluster MS 1054-0321as seen with the Hubble's Wide Field and Planetary Camera 2. (Photo courtesy P. VanDokkum and M. Franx (Univ. of Groningen/Leiden))

'PEEKABOO' COSMOLOGY | ADAM G. RIESS

At the turn of the millennium, new observations and analyses are providing answers to some of the most profound and ageless questions. What is the extent of the Universe? How old is it? What is its shape? What is its ultimate fate? The answers to these questions have come from philosophers and religious leaders, but in the realm of experimental science, answers are now coming from exploding stars, the gentle tug of gravity, and the glow of the big bang. Observations of these astrophysical phenomena by Hubble and other telescopes are providing meaningful constraints on the two elusive cosmological parameters: Ω_M and Ω_Λ. These parameters measure the energy density of the Universe in gravitating matter and more exotic vacuum energy (i.e., a cosmological constant), respectively. In normalized units, a sum of one for all energy densities is the exact amount required to flatten the fabric of space-time. Observations of the explosive deaths of distant stars, as well as other astrophysical phenomena, have recently made a startling case for a positive cosmological constant. The likely implications of a positive cosmological constant is eternal, accelerating expansion of the Universe.

The difficulty in modern observational cosmology is that we do not know of a single controlled experiment that would reveal the individual values of the cosmological parameters. Rather, cosmologists must coax Nature into revealing the values of the parameters from combinations of ongoing astrophysical activity. Although observations of each phenomenon only yield constraints on a superposition of the cosmological parameters, by combining such observations one can determine the specific values of the individual parameters. This has led to the birth of 'Peekaboo' cosmology, in which cosmologists overlay independent constraints until only a narrow 'window' remains through which to glimpse answers to the universal questions.

A narrow window favoring a positive cosmological constant has recently been provided by observations of distant exploding white dwarf stars, called type Ia supernovae (SNe Ia). By observing the apparent brightness of distant SNe Ia, the High-Z Supernova Team and the Supernova Cosmology Project found SNe Ia to be surprisingly dim for their redshifts, implying that a positive cosmological constant has been acting to accelerate the post-Big Bang expansion. Yet because gravitating matter and a positive cosmological constant pull and push the universal expansion in opposite ways, the observations of SNe Ia alone still allow for many mixtures of the matter and vacuum energy.



Nearby Type Ia Supernovae. These cosmic explosions are tools used to determine the expansion rate and energy densities of the Universe. Clockwise from top left, SN 1995al, SN 1995E, SN 1995ac, and SN 1995ak.

Another approach is to quantify the degree to which mass in the local parts of the Universe tugs on nearby galaxies. Although the majority of the apparent motion of galaxies results from the expansion of the Universe, some amount of excess or 'peculiar' velocity results from the gravitational pull of nearby mass concentrations. Such measurements favor a mass density far below unity. Other measurements based on the mass, light, X-ray emission and numbers of clusters of galaxies provide constraints on the mass density of the Universe with typical values of 20% to 30% the amount needed to flatten space.

The parameter space favored by the combination of these results and the supernova results is seductively close to the theoretical preference for a geometrically flat Universe.

Any individual measurement can be vulnerable to biases; the advantage of combining the results of different experiments is that rarely are any two experiments afflicted by the same bias.

By pushing the observations of supernovae to greater distances it should be possible to conclusively confirm or refute the initial cosmological indications: a younger, smaller Universe is denser and contains less vacuum energy, undergoing greater deceleration from gravity. Therefore, the apparent brightness of supernovae will decrease more slowly with distance than would likely occur from the influence of the aforementioned systematic effects. With the Next Generation Space Telescope it should be possible to detect and measure distances to supernovae at redshifts of five or six. Even the existence of supernovae at such an early age in the development of the Universe may yield important clues about the history of chemical enrichment.

Finally, measurements of tiny ripples in the relic radiation from the hot Big Bang, the cosmic microwave background, are beginning to point towards a Universe which is geometrically flat. Recent results from the BOOMERANG experiment support the previously described indications that the geometry of the Universe is flat. More importantly, the cosmic microwave background data show that the cosmological conclusions appear to be robust against biases in any one of the three types of constraints.

Although some cosmologists have voiced concern that the recent cosmological forecasts imply that we live at a special time, i.e., shortly after the transition from a decelerating to an accelerating Universe, can there be any time more special than when we first begin to learn the answers to the universal questions?

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