RESEARCH CORPORATION 2001 ANNUAL REPORT

RESEARCH CORPORATION

AND THE

LARGE BINOCULAR TELESCOPE

RESEARCH CORPORATION IS THE FULFILLMENT OF THE UNIQUE PHILANTHROPIC CONCEPT OF FREDERICK GARDNER COTTRELL, SCIENTIST, INVENTOR AND PHILANTHROPIST, WHO ESTABLISHED THE FOUNDATION IN NEW YORK IN 1912 WITH CHARLES DOOLITTLE WALCOTT, SECRETARY OF THE SMITHSONIAN INSTITUTION.

ONE OF THE FIRST PHILANTHROPIC FOUNDATIONS IN THE UNITED STATES, RESEARCH CORPORATION WAS CHARTERED "TO MAKE INVENTIONS AND PATENT RIGHTS MORE AVAILABLE AND EFFECTIVE IN THE USEFUL ARTS AND MANUFACTURES," AND TO DEVOTE NET EARNINGS OF THE CORPORATION TO PROVIDE "MEANS FOR SCIENTIFIC RESEARCH AND EXPERIMENTATION" AT SCHOLARLY INSTITUTIONS. RESEARCH CORPORATION HAS CONTINUED ITS PHILANTHROPIC MANDATE THROUGH ITS ENDOWMENTS FOLLOWING THE SEPARATION OF ITS TECHNOLOGY TRANSFER OPERATIONS TO RESEARCH CORPORATION TECHNOLOGIES.

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PRESIDENT'S MESSAGE

"All technology, that which we prize and that which troubles us, originates directly and inexorably from basic research."

The year 2001 marked the ninetieth year of operation for Research Corporation. A brief backward look reveals a history of bringing some of the great inventions of the twentieth century to public use, enabling us to put the fruits of research to work for the benefit of humanity. The foundation has played important roles in fields as diverse as pollution control and the environment (the electrostatic precipitator), medicine (nystatin, platinum anti-cancer drugs, PSA test, burn ointment), agriculture (hybrid corn, mushroom nutrient), nutrition (vitamin B_1, food enrichment, animal food supplement), and the computer sciences (the computer core memory). Toward the support of basic research in colleges and universities, the foundation has provided funding ranging from the early work of Robert Goddard on liquid fueled rockets to studies in virtually every modern aspect of chemistry and physics.

The foundation's charter defines one of its missions to be the support of "...scientific investigation, research and experimentation..." leaving it to the vision of its staff and directors how this could be best accomplished. Guidelines as to the division between basic and applied research were left to the discretion of the board, granting them the flexibility to meet challenges as they evolve in science and society. A consistent thread that runs through the foundation's grant activities has been to fund creative young people and provide them with the means of initiating a program of original research. The Cottrell College Science Awards, Research Innovation Awards, and the Cottrell Scholar program all target individuals in the early stages of their careers and have proven to be effective tools for launching thousands of individuals into meaningful roles in teaching and research.

Many of the challenges of the past, the quality of science education, inaugurating faculty research programs, and building vital science departments, remain as enduring concerns of the foundation. But the world abounds in problems — hunger, disease, pollution, global warming, drought, overpopulation, to name but a few. And lingering fundamental questions — the origin of the universe and its destination, the potential of our growing insights to the nature of biological processes — continue to highlight the need for good science and the application of the best of modern technology.

To quote from the foundation's 1978 annual report, "All technology, that which we prize and that which troubles us, originates directly and inexorably from basic research. If we value the fine things which technology has added to our lives, if we hope to solve the problems that other technologies presently impose upon on us, and if we hope for new technologies to solve problems that are as yet unsolved, there is no alternative. Basic research must be sustained at a vigorous level."

This, too, remains an enduring value of the foundation.

JOHN P. SCHAEFER
PRESIDENT
RESEARCH CORPORATION

IN MEMORIAM

This year saw the passing of two eminent and distiguished directors emeriti, Robert W. Morse of the Woods Hole Oceanographic Institute on January 19, and S. Dillon Ripley of the Smithsonian Institution on March 12.

ROBERT W. MORSE

A physicist with service in defense and science policy, and research interests in underwater acoustics, low temperature and solid-state physics, Robert Morse sat on on the Research Corporation board of directors from 1970 to 1988, and was a founding director of Research Corporation Technologies.

Born in Boston, Dr. Morse took his baccalaureate in math at Bowdoin College in 1943, served as an officer in the U.S. Navy during World War II, then received his doctorate in physics from Brown University in 1949. He then joined the Brown faculty in physics eventually becoming dean of the college. While at Brown, he was selected chairman of the National Academy of Sciences' Committee on Undersea Warfare, and as a member of the Academy's Project Nobska was instrumental in the creation of the Polaris submarine. In 1964 President Lyndon Johnson appointed Dr. Morse to be Assistant Secretary of the Navy for Research and Development. During his term he developed, with Admiral Hyman Rickover, the nuclear research submarine, the NR-1. He was presented the Navy's Distinguished Service Award in 1966 for his contributions to national defense.

Robert Morse was named president of Case University in 1966, then president of Case Western Reserve University after the merger with Western Reserve. Leaving Case in 1971, Dr. Morse joined the staff of the Woods Hole Oceanographic Institute (WHOI) as director of research. He served as associate director and dean of graduate studies from 1973 to 1979, and as director of marine policy and ocean management from 1979 to 1980. He returned for a short time to research as a senior scientist in the Ocean Engineering Department and retired from WHOI in 1983.

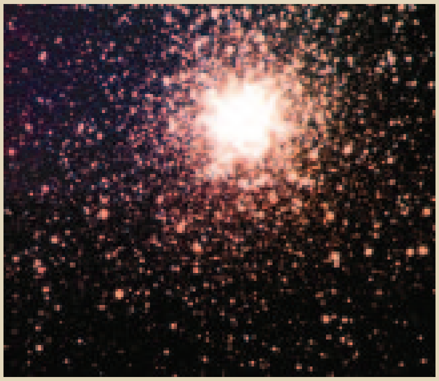
Robert Morse's contributions to WHOI were recognized in 1999 when the institute established an endowed chair in his honor. The new chair was endowed by the Frederick Gardner Cottrell Foundation of Research Corporation Technologies.

S. DILLON RIPLEY

Secretary of the Smithsonian Institution from 1964 to 1984, Dillon Ripley served on the board of Research Corporation from 1965 to 1977. He was the last Secretary of the Smithsonian to serve as a Research Corporation director, ending a tradition begun by Charles Doolittle Walcott, a Secretary of the Smithsonian who helped Frederick Gardner Cottrell to establish Research Corporation, and who served on the foundation's board from 1912 to 1927.

Dr. Ripley's biography reads like an adventure story. Born to wealth in New York City in 1913, he discovered nature — especially birds — on his family's Connecticut estate, and culture during childhood trips abroad. After graduating from Yale where he studied history in preparation for law, he decided he was more interested in ornithology and began zoological studies at Columbia University. Interrupting his degree work, he participated in museum expeditions to both New Guinea and Sumatra before returning to teach and earn a doctorate in zoology from Harvard in 1943.

He joined the Office of Strategic Services in 1942 and spent most of World War II coordinating U.S. and British intelligence efforts in Southeast Asia, an area of expertise from his early expeditions. After the war he joined the staff at Yale, became the first curator of ornithology at its Peabody Museum of Natural History in 1946, and served as the museum's director before his appointment as Secretary of the Smithsonian in 1964. Started, revamped or completed during his 20-year term were the Harvard-Smithsonian Center for Astrophysics, the American Art Museum, the National Portrait Gallery, the Renwick Gallery, the Hirschorn Museum and Sculpture Garden, the National Museum of African Art, the Arthur M. Sackler Gallery, the Anacostia Museum, the Cooper-Hewitt National Design Museum, and the Air and Space Museum. He also established the Smithsonian Magazine, the yearly Folklife Festival, ecological research centers in Florida and Maryland and increased annual Smithsonian visitorship from 10.8 million to over 30 million.



Globular cluster M15 taken with the new 6.5 meter mirror of the Multiple Mirror Telescope.

RESEARCH CORPORATION AND THE LARGE BINOCULAR TELESCOPE

At the time of its dedication the LBT will be the largest and most powerful telescope in the world, capable of imaging planets around distant stars and peering deeper into the universe than ever before.

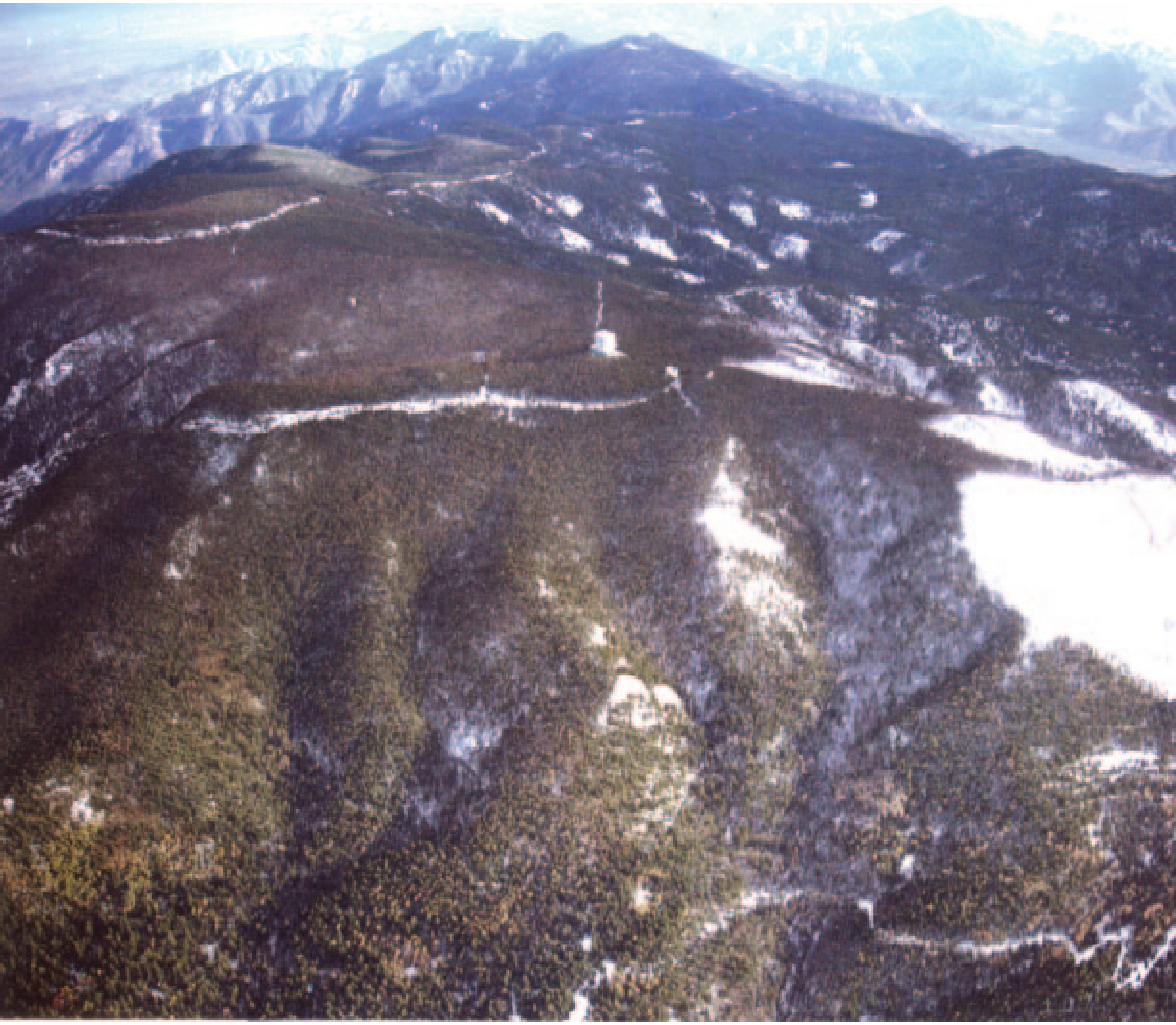
The opportunity to play an enabling role in a world-class project is what foundations hope to do but seldom achieve. Most applications for research grants deal with funding incremental advances in a particular field. While these advances are of vital importance to the advancement of science, they are rarely revolutionary. As it was conceived, the Large Binocular Telescope (LBT) pioneered a new route to the construction of a new generation of telescopes. The optics feature lightweight spin-cast mirrors with a large collecting area and a very fast focal ratio to achieve unprecedented resolution of distant objects. In 1992, when Research Corporation was approached by the founding partners in the project, the LBT, in the absence of additional funding, faced the prospect of being terminated. Fortunately, Research Corporation was in a position to intervene.

A concerted and well-financed effort of disparate groups opposed to the building of the telescope had the effect of causing a founding institution to withdraw. The foundation board was asked to consider underwriting the project while additional partners were identified. The foundation's board of directors agreed to do so based on its evaluation of the fundamental importance of the telescope to the future of astronomy. Based upon that commitment, a new partnership was created between institutions in Arizona and Italy, and Research Corporation and construction of the telescope was begun. We also began to search for additional partners and by 1997 had created an alliance with German institutions and Ohio State University, thereby securing the funding necessary to complete the full telescope.

In the intervening years construction of the telescope building on Mount Graham, Arizona, has been completed and the telescope mount is being installed as the two mirrors are being polished. Various groups of astronomers at the partner institutions in Europe and the United States are building instrumentation for the telescope. "First light" is anticipated in June of 2004. At the time of its dedication the LBT will be the largest and most powerful telescope in the world, capable of imaging planets around distant stars and peering deeper into the universe than ever before.

Research Corporation will use its share of ownership in the LBT to make it and other telescope facilities available to astronomers at the University of Notre Dame, Ohio State University and other institutions. All of us who have been associated with this project look forward to the new discoveries and insights to the origin of the universe that will emerge.

BY JOHN P. SCHAEFER



Above and right, the LBT enclosure on Mount Graham, Arizona

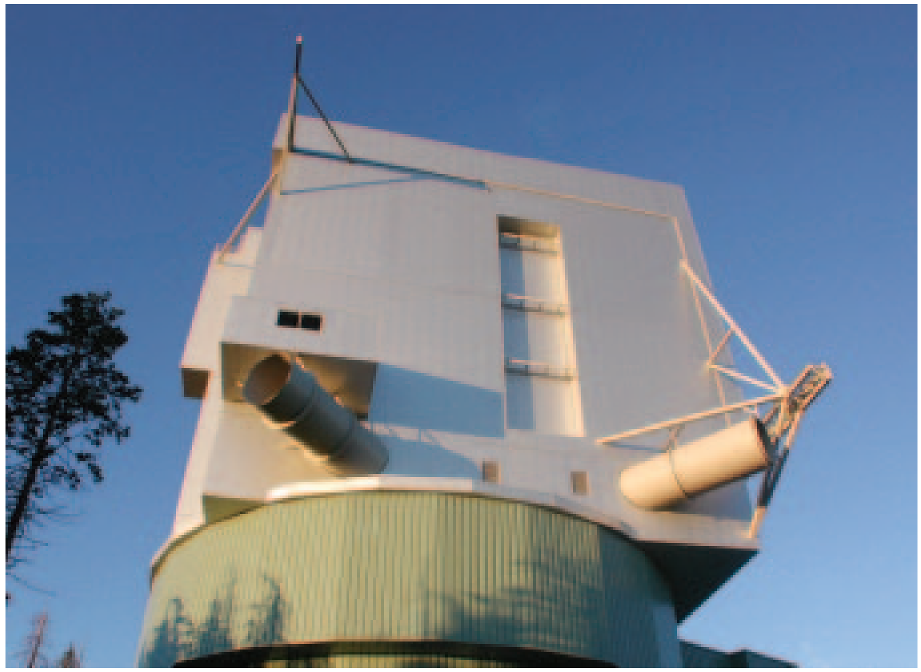
The Large Binocular Telescope

A BRIEF HISTORY OF INNOVATIONS

BY PETER A. STRITTMATTER

If I have been able to see further, it was only because I stood on the shoulders of giants.

—Isaac Newton



Over the past ten years, Research Corporation has played a key role in the creation of the Large Binocular Telescope (LBT), which is soon to be completed on Mount Graham near Safford, Arizona. The LBT will then be the most powerful single telescope in the world and because of its binocular configuration, will also be endowed with unique and exciting capabilities unmatched by any other facility anywhere. With the enclosure complete, the telescope parts made in Italy have arrived in Safford, and the first of two 8.4-meter primary mirrors is in its final stages of polishing at the University of Arizona's Mirror Lab. Thus the time is ripe for an update on this remarkable scientific and engineering marvel.

The LBT design is unlike any other telescope, with two 8.4-meter primary mirrors on a common mounting. It can be used either as individual telescopes with two separate instruments or at a combined focus. The LBT has the light-collecting area equivalent to a single 11.8-meter telescope, which allows it to study objects fainter than any other telescope, and, with the light from each primary mirror appropriately combined, it can achieve the image sharpness (angular resolution) of a 22.8-meter telescope, even on faint objects. It is this latter property (which enables astronomers to make images ten times sharper than the Hubble Space Telescope) that is most valuable and has made the project so attractive to the LBT partners. This unsurpassed image sharpness should

Schematic of the Large Binocular Telescope showing its mounting which is adjustible in both altitude and azimuth. Light is combined from the two 8.4-meter mirrors to give light-gathering power equivalent to a single 11.8-meter mirror. Its angular resolution corresponds to a 22.4-meter aperture.

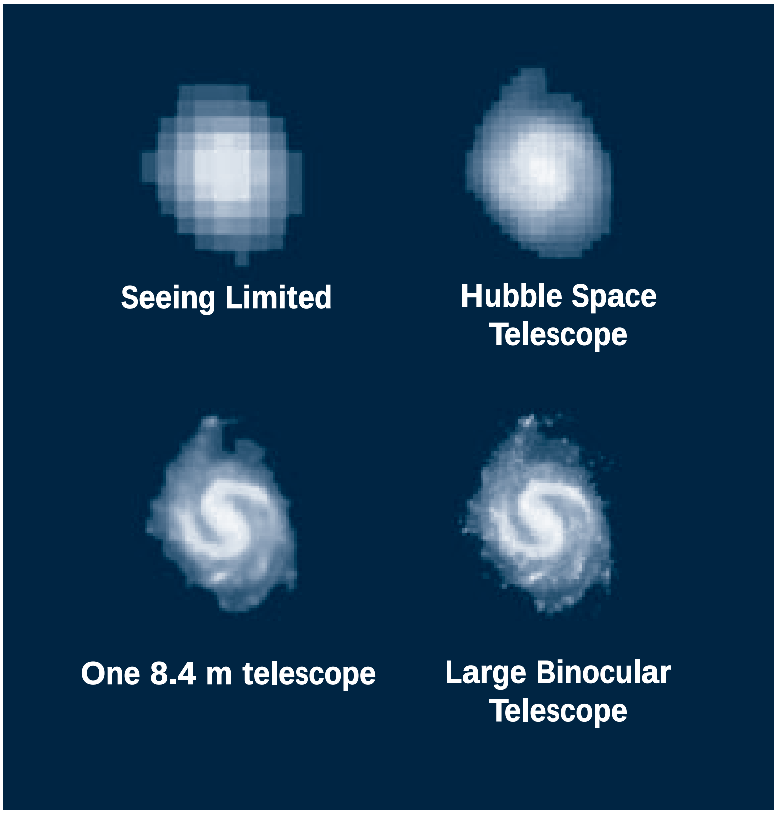
permit major advances in such disparate fields as the imaging of planets around nearby stars and the study of the formation of the most distant galaxies early in the history of the universe.

The LBT partners include Research Corporation, the Istituto Nazionale di Astrofisica (INAF) in Italy, the German LBT Beteiligungsgesellschaft (LBTB, a consortium of astronomical research institutions), Ohio State University, and the University of Arizona. The project is organized through the LBT Corporation, a not-for-profit corporation that is charged with constructing, owning, and operating the LBT. Each partner owns observing time rights on the LBT in proportion to its investment in the project and contributes operations funds in the same proportion. Research Corporation plans to make its observing time rights available to the astronomy programs at the University of Notre Dame and Ohio State University, and is negotiating similar agreements with the University of Minnesota and University of Virginia.

The LBT will see "first light" (with one primary mirror in operation) in mid-2004 and "second light" (both primaries in operation) in 2005. At the time of this writing, the enclosure on Mount Graham has been completed, has passed all its inspections and is ready for installation of the telescope. The telescope structure has been pre-assembled and tested at the Ansaldo-Camozzi Steel Works in Milan, has been shipped to Houston, Texas, by freighter, and overland to Safford, Arizona. The mechanical parts of the LBT are expected to be fully assembled on Mount Graham by September 2003. Meanwhile, both the 8.4-meter primary mirrors have been successfully spun-cast at the Steward Observatory Mirror Lab. The first of these mirrors, LBT-1, is now in the later stages of polishing. These mirrors are lightweight borosilicate honeycomb structures, giving excellent performance in regard to stiffness,

SECONDARY MIRRORS ENHANCE IMAGE SHARPNESS

The LBT incorporates several other unique features, most notably the adaptive secondary mirrors developed as a joint venture of the Italian and Arizona partners with the goal of correcting the atmospheric distortion of the light, without introducing any additional warm, reflective surfaces. This constraint is an especially important consideration for observations in the infrared, where objects at room temperature can be millions of times brighter than the astronomical objects being studied. Hence, the fewer warm surfaces needed to focus the light, the fainter the objects that can be studied. Each adaptive secondary mirror consists of a 91 cm diameter optical surface (or membrane) that is only 1.7 mm thick, controlled by 672 actuators, each capable of repositioning the membrane every millisecond to a precision of 20–30 nm. The information to do so is derived from either a natural star or a laser-guide star. Equipped with adaptive secondary mirrors, each LBT mirror will be capable of producing near diffraction-limited images. With this aperture, such images will be at least three times sharper than the Hubble Telescope operating at the same wavelength and are, in fact, as sharp as could ever be produced by an 8.4-meter telescope, even one in space.



Simulated images of a spiral galaxy (clockwise from upper left): as seen from the ground limited by atmospheric distortion, with the Hubble Space Telescope, with one 8.4-meter mirror using adaptive optics, and finally with the LBT using adaptive optics.

weight and thermal control (see accompanying article on the Mirror Lab, page 10).

When the light from the two mirrors is appropriately combined at a central focus, the result is an even sharper image in the direction joining the mirror centers. Because this direction rotates with respect to the object as the telescope tracks, a series of images taken at different times during the night can be used to reconstruct an image as sharp as that produced by a diffraction-limited 22.8-meter telescope. The simulations shown above illustrate the power of this technique, the essence of which has been tested successfully on the old Multiple Mirror Telescope.

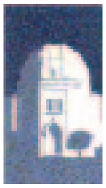
Another important feature of the LBT is the way it enables astronomers to change auxilliary instruments rapidly and thus exploit changes in atmospheric conditions. The LBT has a total of five pairs of focal stations where instruments such as cameras and spectrographs can be mounted. Each of these five pairs of focal stations can be accessed by redirecting the beam of light from the telescope with the appropriate mirrors. These secondary and tertiary mirrors are themselves mounted (unconventionally) on swing arm supports. The LBT will carry five instruments (in fact, five pairs of instruments) at any one time, and the time required to change from one to another is approximately fifteen minutes. This capability will permit much more efficient use of telescope time.

THE INSTRUMENTS OF THE LBT

Like the telescope, the instruments themselves are still in various stages of construction at the partner institutions. Perhaps farthest along at the time of writing is the Large Binocular Camera, a pair of prime focus optical cameras, optimized respectively for the blue and red spectral regions. They will provide LBT with an unexcelled combination of field size (area of the sky covered by one image) and collecting area (faintest object that can be detected) on any telescope over a broad range of wavelengths. The Italian team developing these cameras is led by Emanuelle Giallongo (Osservatorio Astronomico di Roma) and Roberto Ragazzoni (Osservatorio Astronomico di Padova). According to John Hill, the LBT project director (Steward Observatory), one of these cameras will almost certainly become the “first light” instrument in 2004.

A second instrument to analyze stellar spectra, the Multi-object

Continued on page 13



THE HERITAGE OF THE STEWARD Observatory Mirror Lab, like that of the LBT, is linked to the Multiple Mirror Telescope (MMT) and its six 1.8-meter diameter "egg-crate" mirrors (page 14). In 1970 the Corning Glass Works developed these mirrors for use in space, for they were lightweight, but still very rigid. They turned out to have a further advantage for ground-based applications: they had glass with properties of very low thermal inertia that readily adjusts to the local air temperature.

When the MMT went into operation in 1977, almost immediately, astronomers noticed that images were significantly sharper than on other Arizona telescopes. Furthermore, these sharp images were apparent within fifteen to twenty minutes after opening the dome, though images for each mirror had a slightly different response time. The initial blurring was due to thermal convection above each mirror caused by temperature differences between the mirror and the air above it. As the glass-to-air temperature difference decreases, the images become sharper. These changes occurred on the order of twenty minutes in contrast to time scales of several days for traditional solid mirrors then in use. This short time scale for the mirrors to reach thermal equilibrium was entirely due to their lightweight egg-crate structure. Since sharper images are extremely important to telescope performance, achieving a short thermal-response time became a high priority for mirror design.

Just as these thermal effects were recognized, astronomers around the world were considering building telescopes with mirrors of 7.5-meter aperture or larger; among them were Roger Angel and Nick Woolf at Steward Observatory. After hearing from glass-industry experts that it would be "impossible" to make such large "egg-crate" mirrors, Angel and his colleagues began experimenting with various fabrication techniques.

In 1980, Roger Angel, the Mirror Lab's founder and scientific director, was curious about the possibility of making large lightweight mirrors from Pyrex-like borosilicate glass and started to do some backyard experiments with such glass. He fused two Pyrex custard cups together in an improvised kiln. They blended seamlessly and this success led to larger kilns, a non-rotating oven, and then a rotating oven suitable for casting 1.8-meter mirrors. By 1985, with financial support from the U.S. Air Force, the National Science Foundation, and the University of Arizona, Angel had assembled a talented Mirror Lab team. A larger rotating furnace was built and a series of three 3.5-meter mirrors were successfully cast. However, the Mirror Lab team had their eyes set on a much bigger prize: spun-cast mirrors 8 meters in diameter.

Roger Angel, Mirror Lab founder and scientific director

By 1990 the Mirror Lab had to expand its quarters to accommodate two new mirror-polishing machines and an optical test tower. At this point they introduced a revolutionary polishing technique called "stress-lap polishing" that enables opticians to polish mirror surfaces with steep curves and correspondingly short focal lengths in relatively short times.

The ability to capture faint images depends on something called the focal ratio, i.e., the ratio of the focal length to the aperture, for the f/number. (For example, a fast camera has a lens with a focal ratio of f/1.2 or f/1.5.) The giant spun-cast mirrors have focal ratios of f/1.25 or f/1.14. With such short focal lengths, these telescopes fit in relatively small buildings. The spin- casting results in a mirror blank that very closely conforms to the parabolic shape required. Consequently, the cooling time and subsequent polishing time are significantly reduced. The spun-cast shape is already correct to about one millimeter when the mirror blank comes out of the oven.

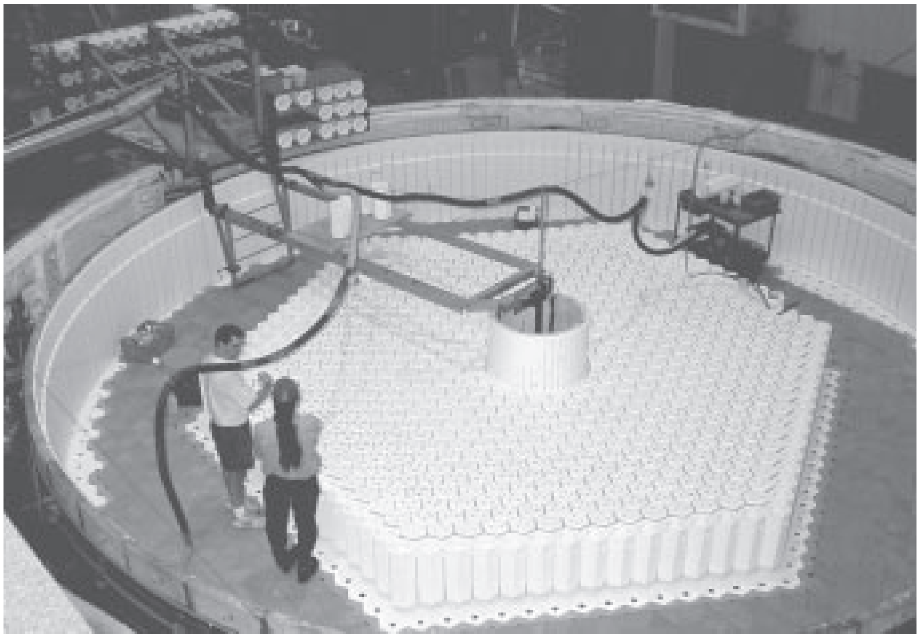
In 1991 the rotating oven was enlarged to cast 6.5-meter to 8.4-meter mirrors. The first 6.5-meter f/1.25 mirror was successfully spun-cast in April 1992 and is now in operation at the MMT Observatory. It replaces the six 1.8-m mirrors and has twice the light-collecting power (see page 14). Subsequently two more 6.5-meter mirrors were spun-cast, the first in 1994, and the second mirror in 1998. Both of these mirrors are now in place at the Las Campanas Observatory in the Chilean Andes.

Construction of the first mold for the casting of an 8.4-meter f/1.14 honeycomb blank was completed in the fall of 1996. Furnace modifications were then performed to accommodate

RIGHT:Assembly of the mold for LBT-1 where 20 tons of glass would be added to do the spin-casting.

BELOW: This rotating furnace has already spun-cast four 6.5-meter mirrors and two 8.4-meter mirrors. The casting of LBT-1 was completed in January 1997.

BELOW, RIGHT: A high-precision milling machine, called the Large Optical Generator, employs diamond-grinding tools to produce the approximate parabolic surface on each large mirror. Subsequently the mirrors are polished on the same machine using a stressed-lap polishing device. This tool dynamically changes shape as it moves from center to edge of each large mirror. The stressed-lap polishing technology was developed at the Mirror Lab and enables large areas of each mirror to be polished at once thus significantly reducing the time to complete the polishing.

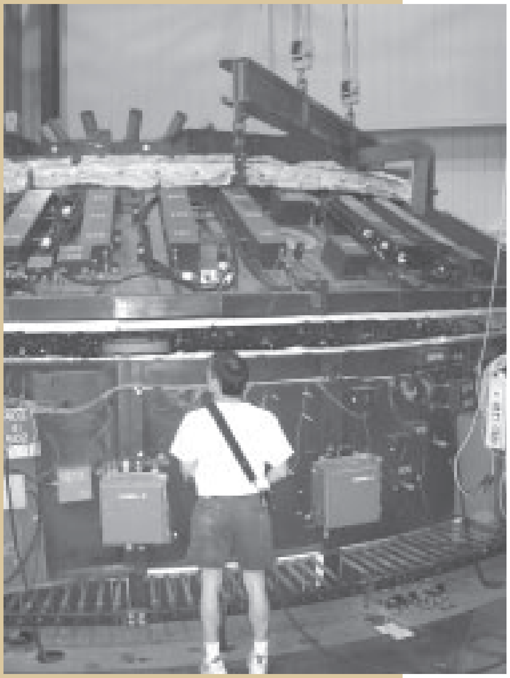


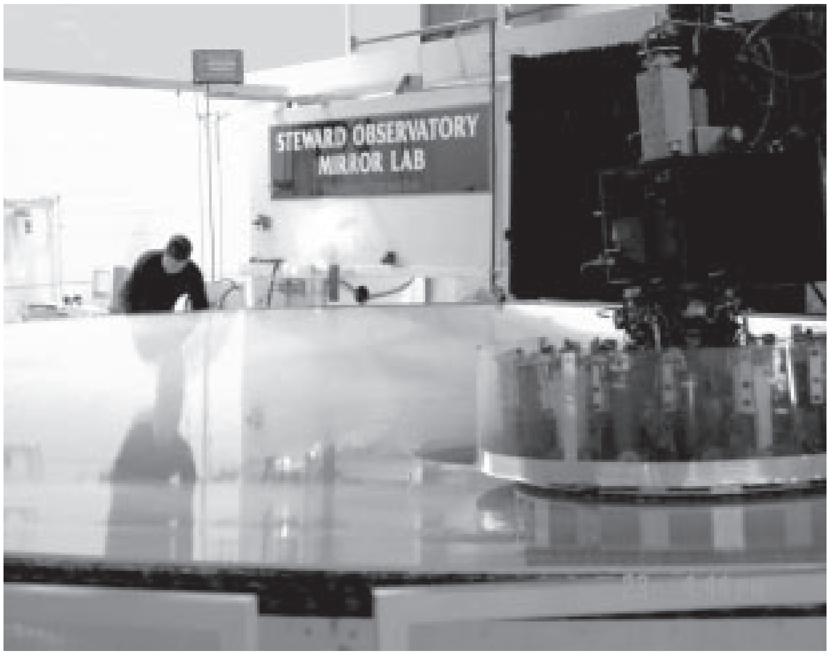
the geometry of the mold on the furnace hearth. The first of two 8.4-meter mirrors was cast in January 1997, for the Large Binocular Telescope Project. The second LBT mirror was cast in May 2000. First light is expected for LBT in 2004 and 2005, respectively, as the two giant mirrors each come into operation.

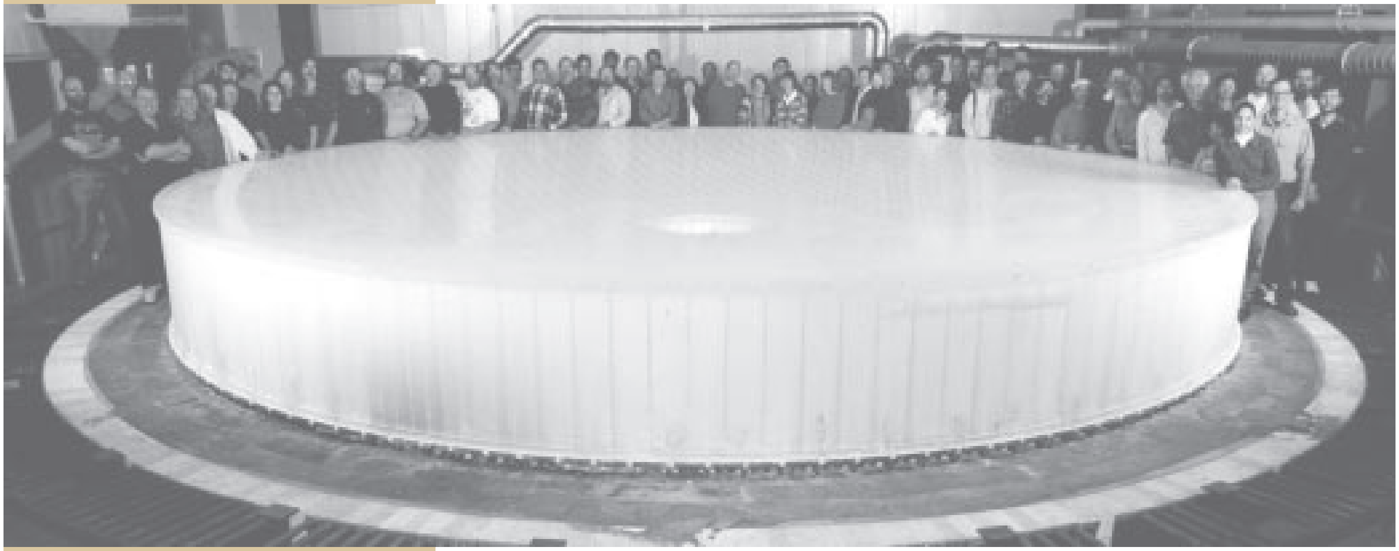
As part of the technology development process, the Mirror Lab has successfully produced twelve mirrors between 1.2 and 8.4 meters in diameter. Nine of the twelve mirrors are already operating in telescopes.

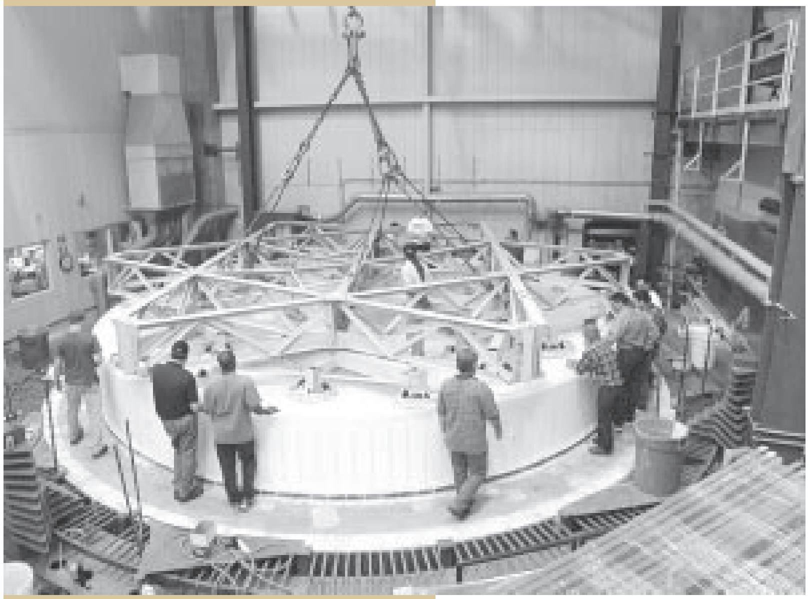
Now the Mirror Lab team of scientists and engineers is making giant, lightweight mirrors of unprecedented power for a new generation of optical and infrared telescopes.

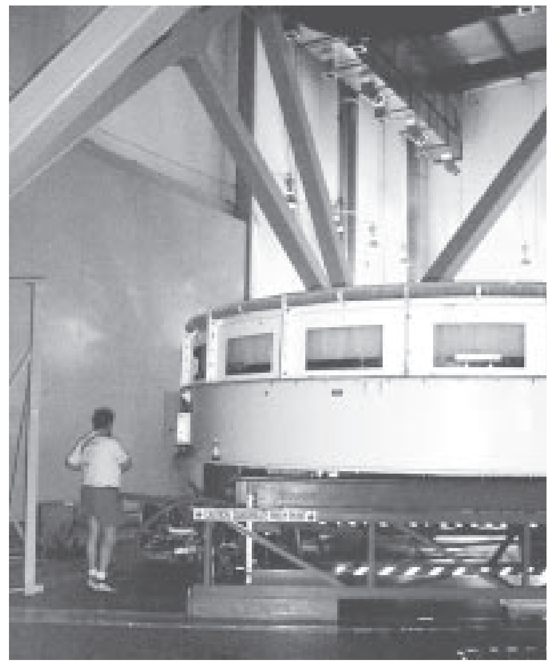
Ultra-lightweight thin mirrors are also being developed for two different applications. One is for space-based telescopes while the other is for second-











TOP: The Mirror Lab team and friends with LBT-1, the first mirror for the Large Binocular Telescope, spun-cast in 1997.

ABOVE, LEFT: After the mirrors have been spun-cast they are lifted with a special frame with 36 pads, each 60 cm in diameter, glued to the front surface of the mirror. A 45-ton crane lifts 88,000 pounds that includes the LBT mirror blank, the mold, and the lifting fixture.

ABOVE, RIGHT: The frame below the turntable is an air cart used to transport the mirror and its polishing cell between the polishing machine and the testing station.

ary mirrors in ground-based telescopes where the shape is actively controlled to correct them to the atmospheric turbulence they will experience. The first of these adaptive optics systems is currently undergoing tests on the new 6.5-meter telescope of the MMT Observatory. This 61-centimeter mirror has 336 actuators that affect the shape of the secondary mirror 550 times a second and thus will produce diffraction-limited images, which for a 6.5-meter mirror is equivalent to an image almost three times sharper than the Hubble Space Telescope.

A facility for polishing and testing the highly aspheric secondary mirrors required for these various large telescopes is now nearing completion. Stressed-lap polishing and testing with computer-generated holograms will allow the production of secondary mirrors up to 1.8 meters in diameter.

Steward Observatory's honeycomb mirrors are already becoming the next technological leap that will allow astronomers to press even farther into space, while keeping down the cost of doing big science.

A mirror cell and “bell jar” were coupled together in a test of their configuration when the 8.4-meter mirrors were aluminized at the Ansaldo-Camozzi Company in Milan, where most of the major mechanical parts for LBT were fabricated and machined.

Double Spectrometer, was designed and constructed at Ohio State University. Patrick Osmer, chairman of the astronomy department, leads this project. The instruments will be located at the “straight through” foci, immediately behind the primary mirrors, and will provide the LBT with powerful optical spectroscopic capability, especially for faint objects. The first of the instrument pair should also be ready for “first light.”

A third instrument is a near-infrared imager and spectrometer, being built as a contribution by the German team based in Heidelberg and led by Immo Appenzeller (director, Landessternwarte, Universitäts-Heidelberg). This instrument pair will be installed at one of the three bent foci. It is designed to work at wavelengths of 1.0 to 2.4 microns in both the seeing-limited mode (limited by atmospheric distortion) and in the diffraction-limited mode (sharpest image achievable) exploiting the adaptive secondary mirrors and distortion-correcting actuators. Together with guider and acquisition instruments, the diffraction-limited components are being constructed at the Astrophysikalische Institut Potsdam (near Berlin).

The above set of instruments represents the basic equipment that will be available for first light (single-mirror operation). In each case a second instrument will be implemented at second light. Once both primary mirrors are in place, the potential capability of the LBT increases dramatically. A major effort is now underway in Europe and in the U.S. to provide the appropriate beam combiners and analyzers to exploit this capability.

At the University of Arizona, Philip Hinz is principal investigator on a NASA contract to build a beam combiner to operate at over infrared wavelengths of 1.5 to 20 microns. The project, designated the LBT Interferometer, is part of NASA’s Navigator Program. Its scientific goal is to capture images of Jupiter-size planets orbiting nearby stars and to measure the brightness of the zodiacal emission (dust particles) orbiting and illuminated by the same stars. The latter effort is in preparation for future efforts to image earth-like planets and to search for spectroscopic evidence of biological activity on them — suggestions first made by Roger Angel and Neville Woolf of Steward Observatory more than twenty years ago. To detect very faint planetary or zodiacal light in the immediate vicinity of an adjacent bright star seemed impossibly difficult until only a few years ago. The LBT, with its two primary mirrors and adaptive secondary mirrors, is tailor-made for the purpose. Hinz is designing a “nulling interferometer” to

The original Multiple-Mirror Telescope (MMT) on Mount Hopkins, Arizona, seen as it was in December 1981. Six mirrors, each 1.8-meters in diameter, operated on a common mounting with the light-gathering power of a single 4.5-meter telescope.

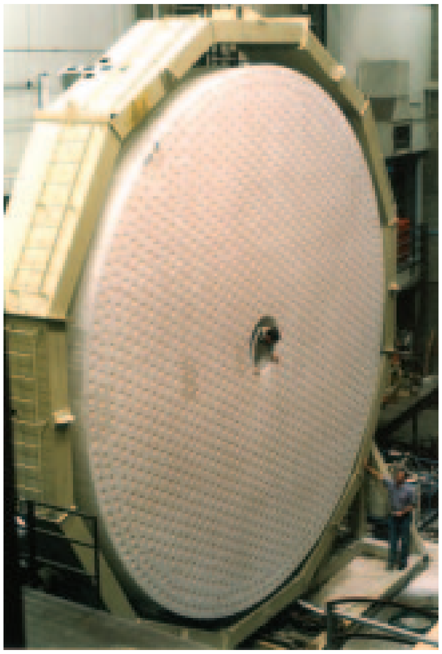
attach to the beam combiner. The light from a star collected by each of the two mirrors is combined precisely out of phase so that the star essentially disappears, while the light from the planet or zodiacal disk is combined in phase and thus appears brighter than from a single mirror. This dramatic result, called nulling, was originally suggested in 1977 by the radio astronomer, Ronald Bracewell (Stanford University) and was first demonstrated in an astronomical context at optical wavelengths with the Multiple Mirror Telescope (MMT) by Hinz and his collaborators.

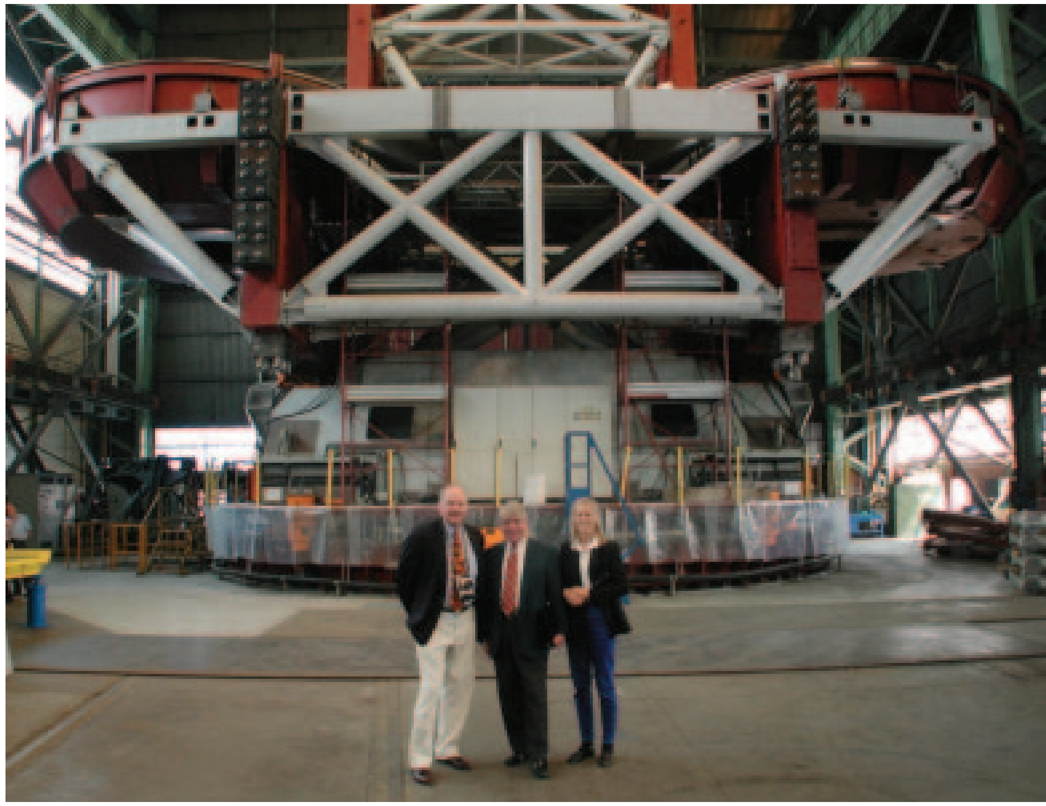
Our European partners are developing a second beam-combiner for optical and near-infrared wavelengths. One of the scientific goals is to achieve sufficient angular resolution, for example, of faint, very distant galaxies in a small patch of sky called the Hubble Deep Field, to provide data on the evolution of galaxies in the early universe. This beam-combiner works on the same principles as the LBT Interferometer but faces more difficulty in coping with the effects of atmospheric turbulence that are more severe at shorter wavelengths. The adaptive secondary mirrors will give good performance over a small field of view in the near infrared but will require additional deformable mirrors at shorter wavelengths and for wider fields. Roberto Ragazzoni and Tom Herbst (Max Planck Institut für Astronomie, Heidelberg) are leading this project.

While several other instruments are currently under consideration, it is clear that the above complement of instruments will provide unique and powerful observational capabilities to the partner institutions. The LBT project has brought together a multinational group of talented people to develop a telescope concept that is unlike any other. How did this synergism all come about?

ORIGINS OF LBT TECHNOLOGY

The heritage of the LBT goes back to the six-mirror MMT, a concept originally proposed in 1972 by Aden Meinel (then at Steward Observatory) for a large space telescope which was adapted by Frank Low (Steward Observatory and Infrared Labs), Ray Weymann (Observatories of the Carnegie Institution of Washington) and others as a ground-based telescope. By using six 1.8-meter mirrors on a common mount, the MMT provided a collecting area equal to a 4.5-meter telescope and the angular resolution of a 6.9-meter telescope. The MMT primary mirrors, with focal ratios of f/2.7, were well within the state-of-the-art at the time, yet the geometry allowed the entire telescope to be housed in a building with a volume not significantly greater than a single conventional 1.8-meter telescope. The net result was a telescope of extraordinarily low cost for its collecting area, which proved enormously productive during its twenty-year lifetime. Part of the success of the MMT came from unexpected sources. First was the excellent imaging capability (i.e., improved dome seeing) produced by its lightweight, egg-crate mirrors (see companion article on the Mirror Lab, page 10). Unlike solid mirrors of the same size, these mirrors were able to come to equilibrium with the air temperature very quickly. Second, due to the superb telescope structure





Honeycomb mirror blank after spin-casting with LBT director John Hill at lower right and engineer Warren Davidson in mirror center.

Above right, the Large Binocular Telescope fully assembled at Ansaldo-Camozzi Company in Milan with (l. to r.) John Schaefer, author Peter Strittmatter, and Lucy Ziurys in the foreground (June 30, 2001).

designed by Meinel and Weymann, it was possible to operate the six mirrors together with an effective (interferometric) aperture of 6.9 meters. The features of the MMT led directly to the 8.4-meter honeycomb borosilicate mirrors spun cast for the LBT whose effective aperture is 22.4 meters. The volume effect led to the development of optical fabrication techniques that would permit fast (f/1.1) primary mirrors. However, there were many steps in between.

The basic LBT concept arose as a result of proposals made by various groups in the early 1980s for a 15-meter National New Technology Telescope (NNTT). After extensive evaluation, the National Organization of Astronomical Observatories (NOAO) selected a "four-shooter" MMT design proposed by Roger Angel and Nick Woolf and based on four 7.5-meter honeycomb mirrors, which was deemed to be the most cost-effective approach for NNTT. Unfortunately, the Association of Universities for Research in Astronomy (AURA) board of directors decided that the NNTT was too ambitious, and settled instead for a single infrared-optimized 8-meter telescope, a project which then evolved into Gemini, an international collaboration to build two such telescopes, one in each hemisphere. Meanwhile at Steward Observatory, Angel, Woolf, and engineer Warren Davison realized that, with a sacrifice of a factor of two in light-gathering power, most of the unique capabilities of the four-shooter could be retained in a still more cost-effective and structurally more robust design. This "two-shooter" or binocular design, with its big C-ring elevation bearings now known as the "Davison mount," ultimately became the LBT.*

* Adaptive secondary mirrors were not contemplated initially but were added in the mid-1990s.

Shutters open wide on LBT enclosure (June 2001), on Mount Graham, Arizona, elevation: 3,192 meters. The enclosure is 51 meters high. The upper part of the enclosure can be fully rotated and weighs about 1400 tons.

PARTNERSHIP MAKES LBT POSSIBLE

The remaining question was, of course, funding. While the LBT design was being developed, Eugene Capriotti (then astronomy department chairman at Ohio State University) submitted a proposal to then president Edward Jennings of Ohio State to participate in an 8-meter telescope. After discussions with University of Arizona president Henry Koffler, it was agreed that the two universities should explore building either a single 8-meter telescope or, if two additional partners could be found, the "two-shooter" or Columbus telescope as the LBT was then known. At roughly the same time, a group of Italian astronomers, including Franco Pacini (director, Osservatorio Astrofisico di Arcetri), Giancarlo Setti (department of astronomy, Universita di Bologna) and Piero Salinari (Osservatorio Astrofisico di Arcetri) visited Mount Graham as a potential site for an Italian national 3.5-meter telescope project. After further analysis, Italy decided to join the feasibility study for the "two-shooter" and was followed shortly thereafter by the University of Chicago. During the years from 1986 to 1988, the four partners completed feasibility studies, which included the scientific case, a detailed design, a cost analysis and funding sources. This study provided the basis for a unanimous decision to proceed and to establish a not-for-profit corporation for the purpose. However, at the last minute, the University of Chicago found itself unable to make the necessary financial commitments. Nonetheless, the three remaining partners signed an agreement to proceed with the construction of a "one-barreled two-shooter," confident that they could construct a working telescope and attract a fourth partner to complete the entire project.

Unfortunately, in 1991 Ohio State University was forced to withdraw, also for financial reasons. Without three partners there were insufficient funds to build a single

Inside the LBT enclosure as construction proceeded in 2001. The enclosure is designed to allow maximum airflow so as to normalize inside and outside temperatures at night. Floor to ceiling height is about 30 meters.

working 8-meter telescope and the project was at an impasse. However, discussions were held with Research Corporation president John Schaefer, who recognized the great potential of the project. He raised the possibility that Research Corporation might be able to underwrite the funding required to complete a bare-bones working telescope. This amount was approximately one-eighth of the total project cost and the concept was presented to the Research Corporation board of directors, who agreed, in 1992, to underwrite the project. A year later, Research Corporation changed its role as underwriter and joined what then became the LBT Corporation as a one-eighth partner, an interest it has maintained ever since.

After some delay caused by opponents of the LBT, in 1996 the foundations were poured for the telescope enclosure on Mount Graham, near Safford, Arizona. At the same time, discussions were proceeding with a group of German astronomical institutes toward their participation in the project at the twenty-five percent level, the same as Arizona and Italy. Concurrently, Ohio State University decided to rejoin the project at the one-eighth level. The German consortium (the LBTB) and Ohio State University became partners in the LBT Corporation in 1998. With that, funding for the telescope project was finally assured.

ABOUT THE AUTHOR

Peter Strittmatter is the director of the Steward Observatory at the University of Arizona. Born and raised in England, in 1958 he entered the University of Cambridge where he studied mathematics as an undergraduate. He continued his studies in Cambridge as a graduate student in applied mathematics, working under the guidance of Dr. Leon Mestel on problems in theoretical astrophysics. While he was still a graduate student, he had the opportunity to work at Princeton University, at the High Altitude Observatory in Colorado and at the University of California, San Diego. Returning to Cambridge in 1966 as a Research Fellow at Peterhouse, he was a founding staff member of Fred Hoyle's newly established Institute for Theoretical Astronomy.

In 1971, Dr. Strittmatter joined the faculty of Steward Observatory and has been its director since 1975. Under his leadership, the Steward Observatory staff and astronomical facilities have grown significantly with the commissioning of the Multiple Mirror Telescope (Mt. Hopkins), and the Heinrich Hertz Telescope (Mt. Graham). He also contributed to the establishment of the Steward Observatory Mirror Lab and to the creation of the international consortium that is constructing the LBT on Mt. Graham.

Peter Strittmatter's astronomical interests include stellar structure and evolution, star formation, quasars and active galactic nuclei.

Above right: The Crab Nebula, an expanding remnant of a supernova that exploded in June 1054 A.D. (This image was acquired by Jay Gallagher and Eric Wilcots, WIYN Telescope, Kitt Peak.)

PRIVATE FOUNDATIONS PLAY A MAJOR ROLE IN ASTRONOMY

As the LBT approaches completion, other universities are participating through arrangements with Research Corporation, among them Notre Dame and probably Minnesota and Virginia. Their participation will strengthen the impact of LBT on U.S. astronomy as a whole. But perhaps, most importantly, Research Corporation has continued the remarkable tradition of private foundation support for innovation in telescope design that for more than a century has kept the U.S. at the forefront of astronomical research. That tradition, of course, includes the Carnegie Institute and Rockefeller Foundation's support for the developments of the Mount Wilson (1902) and Palomar Observatories (1928), respectively, under the direction of George Ellery Hale and George Ritchey. Today the Keck Foundation's support of the segmented-mirror approach, pioneered by Jerry Nelson (University of California, Santa Cruz) and his colleagues, has resulted in the two 10-meter Keck telescopes in Hawaii. Similarly, the funding for the Hobby-Eberly Telescope at the University of Texas and the Magellan telescopes in Chile was made possible by private donors, including Landon Clay and the William and Flora Hewlett Foundation.

Without such private support, U.S. and international astronomy would be far poorer, not only in telescope power but, more importantly, in innovation. Individuals and private foundations are able to take risks that are anathema to government agencies, so that new approaches and the development of new technology for major facilities are heavily dependent on such philanthropy and are likely to remain so in the foreseeable future.

PROGRAM REVIEW

AWARDS APPROVED

FINANCIAL STATEMENTS

OFFICERS AND DIRECTORS

Predominantly undergraduate institutions have come to realize that scientific research is essential to the fabric of their academic programs.

2001 PROGRAM REVIEW

Research Corporation marked the thirtieth anniversary of the Cottrell College Science Award program in 2001. In 1971 then vice president Sam C. Smith wrote that the program was inaugurated "at predominately undergraduate institutions as a means of reasserting the importance of research as a vital component of their academic programs." After thirty years of experience and consideration of our study *Academic Excellence:A Study of the Role of Research in the Physical Sciences at Undergraduate Institutions*, a comprehensive project funded and undertaken by five private foundations, we are led to conclude that Smith's rationale is still valid and remains intact today.

In the inaugural year of the program, Research Corporation considered forty-seven proposals from faculty at private liberal arts colleges and funded twenty-three in the amount of $251,478. From its inception the program grew rapidly and immediately. In 1972, 207 applications, a four-fold increase, led to approval of ninety-seven awards and $1,098,500 in faculty support. Public institutions were invited to participate in 1986. Today the number of proposals submitted by faculty from private and public institutions is about equal. Over the last fifteen years the Cottrell College Science Award Program has been our largest, with awards totaling between $2 to $3 million per year throughout the decade of the nineties. (In 2001, sixty-seven faculty received $2,278,422 in funding.) Over the lifetime of the program, the foundation has invested a total of more than $46,000,000 in individual faculty scholars at predominantly undergraduate institutions both public and private.

What has been the return on investment? While we need to see more of this, over the lifetime of the program many faculty who received funding have, along with students, added significantly to the body of scientific knowledge through peer-reviewed publication in respected journals. Large numbers of students involved in research with their faculty mentors have gone on to graduate work in science, helping to fill an important national need. While we need a greater commitment, by and large, predominantly undergraduate institutions have come to realize that scientific research is essential to the fabric of their academic programs. They realize that the scientific recognition which accrues to faculty scholars as a result of their research also accrues to their students and institutions themselves. They have come to realize the value of research to all of their students as eloquently stated in 1970 by past Research Corporation president James S. Coles, who said that students "once they have been exposed to the wonders of intellectual curiosity, of the tantalizing quest for logical answers, and the joy of independent discovery, will take with them to postgraduate life something that will serve them well in whatever becomes their life work."

RAYMOND KELLMAN
SENIOR ASSOCIATE

AWARD SUMMARY

One hundred forty-three awards were approved in 2001 in support of faculty research, research-enhanced teaching, and special projects in science. For the programs listed below, they totaled $6,115,551 after allowing for discretionary awards, recisions and refunds.

COTTRELL COLLEGE SCIENCE AWARDS

Marking this program's thirtieth anniversary in 2001, the Cottrell College Science Awards committed $2,278,422 in support of faculty research in chemistry, physics and astronomy at undergraduate institutions. The program, which encourages student research involvement, awarded 67 projects out of 237 applications giving it a funding rate of about 28 percent. The average award in 2001 was $34,995, a 2.9% increase over last year.

COTTRELL SCHOLAR AWARDS

The Cottrell Scholar Awards which recognize excellence in research and teaching, funded 17 faculty projects, out of 103 applications, in chemistry, physics, and astronomy at Ph.D.-granting institutions. Open to faculty in the third year of their first tenure-track positions, these awards are made in the amount of $75,000 each and can be used at the discretion of the Scholar.

RESEARCH INNOVATION AWARDS

Open to faculty at Ph.D.-granting institutions, this five-year-old program encourages innovation by scientists early in their academic careers. Of 242 applications received this year — the most since the start of the program in 1997 — 46 were recommended for awards which totaled $1,610,000.

RESEARCH OPPORTUNITY AWARDS

Research Opportunity Awards support midcareer faculty of demonstrated productivity seeking to explore new experimental research at Ph.D.-granting institutions. In 2001, nineteen candidates were nominated by their department chairs and nine proposals were funded for a total of $425,955.

SPECIAL OPPORTUNITIES IN SCIENCE AWARDS

A program of invited awards, Special Opportunities in Science Awards (formerly General Foundation Awards) provide support for projects that advance scientific research or that impact the infrastructure of science, but that fall outside other program guidelines. Approved in 2001 were two awards totaling $376,174.

PARTNERS IN SCIENCE SUPPLEMENTAL AWARDS

The Partners In Science Program, which was discontinued in 1999, paired high-school science teachers with a university mentor for two summers of research. The Supplemental Awards allowed teachers to bring the benefits of their research back to their high-school classrooms. Eleven final awards were funded in 2001 for a total of $33,000.

AWARDS APPROVED

COTTRELL COLLEGE SCIENCE AWARDS

AMHERST COLLEGE

David S. Hall: Tunable interactions in a ^{87}Rb Bose-Einstein condensate—$39,786

BARNARD COLLEGE

Linda Helen Doerrer: Perfluorinated salts for development as electrolytes, weakly-coordinating counterions and redox active, pH senstive metal complexes—$34,000

BARRY UNIVERSITY

Irina A. Struganova: Kinetics of optical characteristics of J-aggregates in the process of their formation and growth—$35,240

BOISE STATE UNIVERSITY

Henry A. Charlier: Mechanistic studies of the peroxisomal multifunctional proteins I and II—$38,840

Susan E. Shadle: Investigations of the interactions between anthracyclines and calsequestrin: Implications for anthracycline cardiotoxicity—$36,192

BOWDOIN COLLEGE

Eric S. Peterson: Protein folding dynamics: Characterization of intermediates with sol-gel trapping and time-resolved Raman and T-jump spectroscopy—$45,000

BRIDGEWATER STATE COLLEGE

Edward J. Brush: Synthesis and evaluation of novel glutathione conjugates targeting glutathione-dependent anti-cancer enzymes—$28,420

BROCK UNIVERSITY

Jeffrey K. Atkinson: Studies of the structure, function and ligand binding abilities of tocopherol transfer proteins—$32,500

Stuart M. Rothstein: Towards generating the complete structure distribution of a protein: Exploiting novel and established pattern recognition techniques—$24,877

CALIFORNIA POLYTECHNIC STATE UNIVERSITY, SAN LUIS OBISPO

John P. Sharpe: Stochastic resonance and pattern formation in two-dimensional optical systems—$31,267

CALIFORNIA STATE UNIVERSITY, FRESNO

Raymond Edward Hall: Investigation of possible physics beyond the standard model through studies of top quark properties with the D0 detector—$34,183

CALIFORNIA STATE UNIVERSITY, LONG BEACH

Lijuan Li: Metal-metal interaction between binuclear dinitrosyliron complexes with bisphosphine linkers—$34,238

CALIFORNIA STATE UNIVERSITY, LOS ANGELES

Frank A. Gomez: On-column enzymatic degradation and kinetics of plasmids using capillary electrophoresis—$39,220

CALIFORNIA STATE UNIVERSITY, SACRAMENTO

Randy L. Phelps: A survey to detect Herbig-Haro objects in the Rosette Molecular Cloud—$25,144

CENTRAL WASHINGTON UNIVERSITY

Anthony L. Diaz: Fundamental studies of vacuum ultraviolet damage processes in luminescent materials—$36,763

COE COLLEGE

Scott J. Stoudt: Synthesis, structure, and reactivity of hypervalent tin compounds bearing triarylmethyl “propeller” ligands—$29,100

COLBY COLLEGE

Rebecca R. Conry: New biomimetic Ni, Mo, and W complexes with derivatives of the biphenyl-2-2'-dithiolate ligand—$39,282

COLGATE UNIVERSITY

Joseph C. Amato: Vortex dynamics in superconducting thin films with artificially-implanted pinning centers—$40,576

COLLEGE OF THE HOLY CROSS

Timothy Roach: Atomic wave diffraction from magnetically patterned surfaces—$34,382

DAVIDSON COLLEGE

Mario J. Belloni: Using supersymmetric quantum mechanics to construct and investigate new exactly solvable PT-symmetric periodic potentials—$26,682

DEPAUL UNIVERSITY

Ross A. Hyman: Investigation of a gradiant search method for orbital-dependent functionals in current density-functional theory—$35,718

Richard F. Niedziela: Measuring complex refractive indices directly from organic aerosol infrared extinction spectra—$26,483

EAST CAROLINA UNIVERSITY

William E. Allen: Fluorescent mimics of phosphotyrosine as probes for intracellular signal transmission—$38,494

Yu Yang: Reversed-phase separation using high-temperature water as the mobile phase—$39,418

George Fox University

Michael A. Everest: Interfacial chemical kinetics studied *in situ* with evanescent-wave cavity ring-down spectroscopy—$35,500

Hamline University

Ty J. Prosa: Correlating structure with electron transport in conducting polymer systems—$37,966

Andrew R. Rundquist: Generation, detection, and optimization of coherent lattice vibrations in quartz using Impulsive Stimulated Raman Scattering—$38,180

Hendrix College

Randall A. Kopper: Biochemical characterization and the effect of digestion on the allergenic properties of a major peanut protein—$35,038

Hofstra University

Oleg A. Starykh: Effect of geometric frustration and disorder on weakly coupled spin chains—$27,384

Hope College

Brent P. Krueger: Protein-protein interactions studied through 1-d and 2-d fluorescence lifetime spectroscopy and molecular dynamics calculations—$45,200

Illinois State University

Rainer Grobe: Transmission of laser pulses in atomic and molecular vapors—$34,818

James Madison University

Barbara A. Reisner: The role of solvent effects and hydrogen-bonding in the synthesis of open framework transition metal phosphates—$37,890

Knox College

Diana M. Cermak: Stereoselective synthesis of amino phosphonic acids via reduction of imino phosphonates—$43,210

Lewis and Clark College

Louis Kuo: Aqueous investigation of molybdocene hydride organometallic complexes—$34,806

Middlebury College

Richard C. Bunt: Probing the electronic origins of chiral ligand asymmetry in palladium-catalyzed allylic-alkylation reactions—$33,381

Occidental College

Mingming Wu: Path instabilities of air bubbles rising in fluids—$28,184

Rutgers University, Camden

Paul Maslen: Ab-initio prediction of thermochemical properties to chemical accuracy—$28,000

Saint Cloud State University

Emory F. Bunn: Statistical characterization of foregrounds for microwave background observations—$33,720

Saint Joseph's University

Brian S. Hammes: Utilization of proton-coupled electron transfer as a means for controlling dioxygen activation—$38,830

Saint Lawrence University

Catherine L. Jahncke: Size effects of barium titanate nano-crystals investigated by near-field scanning optical microscopy—$33,106

San Francisco State University

Zhigang Chen: Modulation instability and pattern dynamics of incoherent light—$36,218

Bruce A. Manning: Molecular and electronic structure elucidation of arsenic and selenium complexes on iron and manganese oxide surfaces—$37,948

Santa Clara University

John Birmingham: Neuromodulation of the code used by a stretch sensor in a crustacean motor control network—$41,118

Scripps College

Adam S. Landsberg: A study of correlations and synchronization effects in systems of interacting automata—$22,480

Southwest Missouri State University

Suchismita Guha: Raman spectroscopy of organic and hybrid optoeletronic devices under operation—$19,000

Robert A. Mayanovic: Structure studies of rare earth and first-row transition metal ions in aqueous solutions at sub- and supercritical conditions—$34,066

Swarthmore College

David H. Cohen: Neon photoionization experiments on the Z-machine: Creating an x-ray nebula in the laboratory—$38,146

Sweet Briar College

Scott David Hyman: A galactic center variable and transient radio source monitoring program—$19,342

Trinity University

Bert D. Chandler: PAMAM dendrimers as nanoreactors for size, composition, and morphological control over supported metal particles—$40,250

Union College

Jonathan M. Marr: Examination of the spectral turnover in gigahertz-peaked spectrum sources: Synchrotron self-absorption vs. free-free absorption—$20,236

United States Naval Academy

James J. Butler: Nonlinear optics in capillaries and capillary arrays—$40,316

Virginia F. Smith: Investigating oxidative repair from a protein folding perspective: Substrate recognition by peptide methionine sulfoxide reductase—$30,950

University of Akron

Robert R. Mallik: Vibrational spectroscopy of ultra-thin films of cadmium-telluride, and cadmium-selenide—$29,000

University of Minnesota-Duluth

Alec Habig: Neutrino oscillation studies at the University of Minnesota, Duluth—$37,548

University of Minnesota-Morris

Timothy James Soderberg: Identification and characterization of enzymes in the non-oxidative pentose phosphate pathway in Archaea—$36,772

University of North Carolina at Charlotte

Daniel Rabinovich: Sulfur-donor ligands in supramolecular chemistry—$29,161

University of North Florida

Lev Gasparov: Raman and infrared studies of the layered and transition metal chalcogenides—$39,000

University of Richmond

Mirela Simona Fetea: Signature splitting/inversion in odd and odd-odd near-drip line nuclei in 130 mass region—$38,881

University of Tulsa

Gil Belofsky: Natural products chemistry and the neurosciences — plants with receptor binding activity from the Nature Conservancy's Tallgrass Prairie Preserve—$31,724

University of Wisconsin-Eau Claire

Michael J. Carney: Neutral group 6 olefin polymerization catalysts—$32,000

University of Wisconsin-La Crosse

Todd Michael Weaver: Light atom induced nucleophilic activation of free water during enzymatic olefin production—$35,761

Western Washington University

Steven R. Emory: Viral template-directed assembly of metal nanoparticles for ultrasensitive surface-enhanced Raman spectroscopy—$37,299

Wheaton College

Daniel L. Burden: Interrogating rapid single DNA/protein interactions using confocal microscopy combined with single-molecule optical manipulation—$41,000

Peter K. Walhout: Rotational and translational diffusion of dye molecules in polyelectrolyte multilayer assemblies—$33,000

Wofford College

Caleb A. Arrington: Sensitization reactions of C_4 unsaturated hydrocarbons isolated in a rare gas matrix—$38,088

Wright State University

Daniel M. Ketcha: Synthesis of polyalkylated indole marine natural products—$35,640

Youngstown State University

Peter Norris: Synthesis of C-glycoside glycomimetics using dithiane chemistry—$39,678

RESEARCH INNOVATION AWARDS

Arizona State University

Dmitry V. Matyushov: Anisotropic polarization and control of electron transfer rates—$35,000

Brigham Young University

Matthew R. Linford: A new method of simultaneously functionalizing and patterning silicon and other materials—$35,000

California Institute of Technology

Brian M. Stoltz: New directions in asymmetric catalysis—$35,000

Colorado School of Mines

C. Jeff Harlan: Oxidative addition to d^0 metal complexes—$35,000

Cornell University

Brian R. Crane: Evolving new redox proteins to establish the role of structure in biological electron transfer—$35,000

Dartmouth College

Amy C. Anderson: Structural biology reveals a path for the development of new, biologically active peptides—$35,000

Robert R. Caldwell: Testing the gravitational physics of vacuum energy—$35,000

Duke University

Stephen L. Craig: Exploring the novel physics of noncovalent polymers: Physical organic chemistry of materials—$35,000

Georgetown University

Paola Barbara: Liquid, solid and superconducting mercury/carbon-nanotube junctions—$35,000

David Andrew Egolf: Nonlinear dynamical analysis of fluctuations and jamming in granular media—$35,000

Georgia Institute of Technology

Donald F. Doyle: Engineering protein receptors and enzymes through genetic selection—$35,000

Northern Illinois University

Oliver Hofstetter: Stereoselective interaction of antibodies with stereoisomers that are chiral by virtue of isotopic substitution—$35,000

Ohio State University, Columbus

Heather C. Allen: HCI adsorption on ice surfaces: Molecular versus ionic—$35,000

Pennsylvania State University

Ari Mizel: Ground state quantum computer using array of Josephson junctions—$35,000

Purdue University

Garth J. Simpson: Vibrational spectroscopy by surface second harmonic generation—$35,000

Rensselaer Polytechnic Institute

Gyorgy Korniss: Non-equilibrium surface growth concepts in scalable parallel discrete-event simulations—$35,000

Rice University

Thomas C. Killian: Laser cooling and trapping an ultracold neutral plasma—$35,000

Douglas Natelson: Molecular- and atomic-scale three terminal electronic devices—$35,000

Rutgers University-New Brunswick

David S. Talaga: Single molecule conformational trajectories reconstructed from multidimentional fluorescence using hidden Markov models—$35,000

Stanford University

Hari C. Manoharan: Information transport and nanoscale encoding using coherent quantum states—$35,000

Texas A & M University

Stephen A. Miller: Activation of carbon dioxide: Polyester formation via coordination polymerization of carbon dioxide and olefins—$35,000

Texas Tech University

Lionel W. Poirier: Using symmetrized orthogonal wavelets to customize quantum dynamics calculations of atomic nuclei in molecules—$35,000

University of California, Los Angeles

Yung-Ya Lin: Chaotic magnetic resonance spectroscopy and imaging—$35,000

University of California, San Diego

Douglas E. Smith: Biophysical studies of viral DNA packaging using single molecule microscopy—$35,000

University of Chicago

Juan I. Collar: A new approach to neutrino and WIMP detection using low-cost telecom-grade electrooptic and fiber-optic components—$35,000

Rustem F. Ismagilov: Electron transfer systems with high internal reorganization energy as model molecular machines—$35,000

University of Colorado at Boulder

Jason Glenn: An innovative technique for measuring the redshifts of submillimeter galaxies in the early universe—$35,000

University of Guelph

France-Isabelle Auzanneau: Discovery and characterization of tumor associated carbohydrate epitopes: Application to vaccine design—$35,000

Carl E. Svensson: Isospin symmetry breaking in superallowed Fermi beta decays—$35,000

University of Illinois at Urbana-Champaign

Taekjip Ha: Combined force and fluorescence study of DNA helicase unwinding activity at the single molecule level—$35,000

University of Iowa

Leonard R. MacGillivray: The solid state as a medium for conducting molecular synthesis by design: Principles and application—$35,000

University of Maryland

Wolfgang Losert: Adaptive control of crystal microstructures using variable laser patterns—$35,000

University of Massachusetts, Amherst

Igor A. Kaltashov: Investigation of multi-protein dynamics in the transferrin cycle: Use of mass spectrometry to model endocytosis—$35,000

University of Nevada, Reno

David M. Leitner: Theory of energy flow in biological molecules and its influence on chemical reaction kinetics—$35,000

University of North Carolina at Chapel Hill

Jeffrey S. Johnson: Tandem dynamic kinetic resolution—$35,000

University of Rochester

Todd D. Krauss: Coherent vibrational dynamics of carbon nanotubes applied to nanometer-scale ultrasonic microscopy—$35,000

University of Toronto

Gregory D. Scholes: Correlating optical response and dynamics to structure of complex organic assemblies—$35,000

University of Virginia

Charles A. Sackett: A magnetic waveguide system for Bose-Einstein condensates—$35,000

University of Washington

Daniel R. Gamelin: On the unique physical properties of doped semiconductor quantum dots and related nanoparticulate materials—$35,000

Sarah L. Keller: Investigating domain formation in lipid monolayers and bilayers using a novel hybrid system—$35,000

University of Wisconsin

Silvia Cavagnero: A novel approach to elucidate cotranslational protein folding pathways at the amino acid-specific level—$35,000

University of Wisconsin-Milwaukee

Daniel F. Agterberg: Theory of d-wave superconductivity in cubic materials—$35,000

University of Wyoming

David T. Anderson: Infrared laser initiated hydrogen abstraction reactions in a quantum solid—$35,000

Wake Forest University

Martin Guthold: A novel method to identify, isolate, amplify and analyze individual molecules with desirable binding properties—$35,000

Washington University

Thomas P. Vaid: Isostructural doping of organic molecular semiconductors—$35,000

Yale University

Victor S. Batista: Coherent control of ultrafast photo-transduction dynamics—$35,000

COTTRELL SCHOLAR AWARDS

Arizona State University

Ian R. Gould: Oxidative processes in duplex DNA—$75,000

Boston University

Ulrich Heintz: Search for the origin of mass and a b-quark trigger for the D0 experiment—$75,000

California Institute of Technology

David W. C. MacMillan: Enantioselective organocatalysis: A new and broadly useful strategy for asymmetric synthesis using organic catalysts—$75,000

Case Western Reserve University

J. Christopher Mihos: Using intracluster light to probe the evolution of galaxy clusters—$75,000

Clemson University

Dennis W. Smith, Jr.: Synthesis and fabrication of novel fluoropolymers for photonic applications—$75,000

Columbia University

Dalibor Sames: C-H bond activation in complex chemical assembly—$75,000

Dartmouth College

Brian Chaboyer: Stellar ages and cosmology—$75,000

Louisiana State University

David Allan Spivak: Controlling the molecular architecture of functionalized organic materials using novel fluoro-organic mesophases—$75,000

Southern Illinois University at Carbondale

Shaowei Chen: Nanoscale electron transfer: An electrochemical perspective—$75,000

State University of New York
at Stony Brook

Carlos L. Simmerling: Using large clusters of personal computers to improve simulations in the condensed phase and increase enthusiasm in the physical chemistry curriculum—$75,000

University of Maryland

Lyle D. Isaacs: Hydrophobic self-assembly: Integrated teaching and research initiatives—$75,000

University of Montreal

Normand Mousseau: Ab-initio activation-relaxation technique study of self-diffusion mechanisms in GaAs and GaN, and an outreach scientific program for Southeastern Ohio—$75,000

University of Rochester

Kevin S. McFarland: Precision studies of the top quark and muon telescopes for high school classrooms—$75,000

University of South Florida

David A. Rabson: Geometric effects and tunneling in layered magnetic structures—$75,000

University of Toronto

Andrei K. Yudin: New generation of versatile asymmetric catalysts derived from polyfluorobinaphthol ligands—$75,000

University of Wisconsin-Milwaukee

Paul F. Lyman: Experimental tests of a direct method for surface x-ray crystallography—$75,000

University of Wyoming

Jeffery L. Yarger: Understanding structural transitions within tetrahedral network glasses and liquids—$75,000

RESEARCH OPPORTUNITY AWARDS

BOSTON COLLEGE

William H. Armstrong: Can chloride play a redox co-catalytic role in water oxidation?—$50,000

DUKE UNIVERSITY

Steven W. Baldwin: Choline analogs in the detection and treatment of cancer—$50,000

FLORIDA STATE UNIVERSITY

David H. Van Winkle: Advances in ultrafast imaging applied to time-resolved polarized optical microscopy—$50,000

NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY

Tanja Pietraß: NMR investigations in heterogeneous catalysis—$36,750

OHIO UNIVERSITY

Peter de B. Harrington: Data compression, modeling, and pattern recognition of static time-of-flight secondary ion mass spectrometry (Tof-SIMS) images—$49,063

PENNSYLVANIA STATE UNIVERSITY

Roy F. Willis: Charge and spin conduction in single carbon nanotube devices—$42,142

UNIVERSITY OF IOWA

Johna Leddy: Magnetic effects on carbon monoxide oxidation—$48,000

UNIVERSITY OF OKLAHOMA

John E. Furneaux: Vibrational spectroscopy of polymer electrolyte systems—$50,000

UNIVERSITY OF OREGON

Thomas R. Dyke: Femtosecond pulse pair experiments for nonlinear wavepacket interferometry—$50,000

SPECIAL OPPORTUNITIES IN SCIENCE AWARDS

AMERICAN PHYSICAL SOCIETY

Alan Chodos: Research Corporation prize to a faculty member for research in an undergraduate institution—$58,000

EARTHTALK, INC.

Ryan Britton: Earth and Sky Radio Series, "Tonight's Sky"—$318,174

PARTNERS IN SCIENCE SUPPLEMENTAL AWARDS

ALOHA HIGH SCHOOL, ALOHA, ORE.

Kathleen Mary Sprague: Increasing scientific literacy through the use of biotechnology *(Sponsor: The M. J. Murdock Charitable Trust)*—$3,000

Tim Swihart: The use of computer-interface probes with inquiry-based projects in the high school science classroom *(Sponsor: The M. J. Murdock Charitable Trust)*—$3,000

BOTHELL HIGH SCHOOL, BOTHELL, WASH.

Linda M. Hill: From DNA to protein: Transferring concepts and skills learned through experiments with DNA electrophoresis to protein profiling in the high school lab *(Sponsor: The M. J. Murdock Charitable Trust)*—$3,000

CHENEY HIGH SCHOOL, CHENEY, WASH.

Thomas B. Stralser: An ecological research program: Using the Slavin property as a field station *(Sponsor: The M. J. Murdock Charitable Trust)*—$3,000

COLTON HIGH SCHOOL, COLTON, ORE.

David Allan Bruner: Project STATIS (Statistical Techniques In Science) *(Sponsor: The M. J. Murdock Charitable Trust)*—$3,000

GRESHAM HIGH SCHOOL, GRESHAM, ORE.

Stephen Scannell: Sidewalk astronomy for high school science students and the community *(Sponsor: The M. J. Murdock Charitable Trust)*—$3,000

OLYMPIA HIGH SCHOOL, OLYMPIA, WASH.

Dawn Woodnutt: Using technology based investigations in chemistry to learn about the world around us *(Sponsor: The M. J. Murdock Charitable Trust)*—$3,000

OREGON CITY HIGH SCHOOL, OREGON CITY, ORE.

George Cashdollar: Hand-held data collection using calculator-based laboratory explorations in field biology *(Sponsor: The M. J. Murdock Charitable Trust)*—$3,000

SAINT LABRE INDIAN SCHOOL, ASHLAND, MONT.

Thomas Jon Andres: A systematic study and descriptions of Triassic Scleractinian corals of the luning formation of Mina, Nevada *(Sponsor: The M. J. Murdock Charitable Trust)*—$3,000

SALEM ACADEMY HIGH SCHOOL, SALEM, ORE.

Margery S. Barkman: Integrated laboratory experience in biotechnology for beginning and upper level biology *(Sponsor: The M. J. Murdock Charitable Trust)*—$3,000

THE BUSH SCHOOL, SEATTLE, WASH.

Peggy O'Neill Skinner: Malaria in the classroom: A multidisciplinary approach *(Sponsor: The M. J. Murdock Charitable Trust)*—$3,000

INDEPENDENT AUDITOR'S REPORT

Board of Directors
Research Corporation
Tucson, Arizona

We have audited the accompanying statements of financial position of Research Corporation (the "Foundation") as of December 31, 2001 and 2000, and the related statements of activity and changes in net assets and of cash flows for the years then ended. These financial statements are the responsibility of the Foundation's management. Our responsibility is to express an opinion on these financial statements based on our audits.

We conducted our audits in accordance with auditing standards generally accepted in the United States of America. Those standards require that we plan and perform the audit to obtain reasonable assurance about whether the financial statements are free of material misstatement. An audit includes examining, on a test basis, evidence supporting the amounts and disclosures in the financial statements. An audit also includes assessing the accounting principles used and significant estimates made by management, as well as evaluating the overall financial statement presentation. We believe that our audits provide a reasonable basis for our opinion.

In our opinion, such financial statements present fairly, in all material respects, the financial position of the Foundation at December 31, 2001 and 2000, and the results of its operations and its cash flows for the years then ended in conformity with accounting principles generally accepted in the United States of America.

Deloitte and Touche, LLP
Phoenix, Arizona
March 29, 2002

STATEMENTS OF FINANCIAL POSITION

December 31, 2001 and 2000	2001	2000
ASSETS		
INVESTMENTS:		
Marketable securities – At market (Note 2)	**$ 86,598,708**	$ 105,537,683
Program-related investment in Research Corporation Technologies, Inc. (Note 3)	**25,000,000**	25,000,000
Science and technology investments (Notes 4 and 8)	**10,696,190**	9,517,190
Other investments (Note 5)	**20,073,378**	13,202,601
Total investments	**142,368,276**	153,257,474
Cash and cash equivalents	**119,041**	392,429
Accrued dividends and interest receivable	**391,049**	100,217
Property and equipment – net (Note 6)	**58,755**	70,475
Prepaid pension cost (Note 8)	**4,769,757**	4,173,756
Other assets	**22,218**	571,743
TOTAL	**$ 147,729,096**	$ 158,566,094
LIABILITIES AND NET ASSETS		
LIABILITIES:		
Grants payable	**$ 4,538,056**	$ 4,673,110
Line of credit (Note 7)	**4,144,821**	4,500,000
Other (Notes 8 and 11)	**1,362,787**	1,417,151
Total liabilities	**10,045,664**	10,590,261
COMMITMENTS AND CONTINGENCIES (Notes 9 and 10)		
NET ASSETS	**137,683,432**	147,975,833
TOTAL	**$ 147,729,096**	$ 158,566,094

See notes to financial statements.

STATEMENTS OF ACTIVITY AND CHANGES IN NET ASSETS

Years ended December 31, 2001 and 2000	**2001**	2000
REVENUE:		
Unrestricted revenues and gains:		
Interest and dividends from marketable securities	**$ 1,786,997**	$ 2,096,884
Interest income from program-related investment (Note 3)	**1,750,000**	1,750,000
Other interest income	**327,863**	6,177
Pension income (Note 8)	**596,001**	676,490
Total unrestricted revenues and gains	**4,460,861**	4,529,551
Contributions released from restrictions	**167,000**	198,053
Total revenue	**4,627,861**	4,727,604
EXPENSES (Note 11):		
Grants approved	**6,027,016**	6,405,684
Science advancement	**1,080,129**	1,173,193
Information and communications	**99,910**	141,435
General and administrative expenses (Note 8)	**1,892,007**	1,804,225
Interest and other expense	**537,325**	1,155,784
Total expenses	**9,636,387**	10,680,321
DECREASE IN NET ASSETS BEFORE NET LOSS ON INVESTMENTS	**(5,008,526)**	(5,952,717)
NET LOSS ON INVESTMENTS (Notes 2, 4 and 5)	**(5,283,875)**	(12,228,484)
DECREASE IN NET ASSETS	**(10,292,401)**	(18,181,201)
NET ASSETS, BEGINNING OF YEAR	**147,975,833**	166,157,034
NET ASSETS, END OF YEAR	**$ 137,683,432**	$ 147,975,833

See notes to financial statements.

STATEMENTS OF CASH FLOWS

Years ended December 31, 2001 and 2000	2001	2000
CASH FLOWS FROM OPERATING ACTIVITIES:		
Interest and dividends received	**$ 1,778,950**	$ 2,106,036
Interest received from program-related investment	**1,750,000**	1,750,000
Contributions received	**167,000**	198,053
Other income	**100,792**	200,250
Grants paid	**(6,101,506)**	(6,067,278)
Cash paid to suppliers and employees	**(3,395,311)**	(2,401,372)
Cash paid for taxes	**(16,906)**	(160,914)
Contributions paid	**(60,564)**	(51,697)
Interest paid	**(309,158)**	(230,120)
Net cash used in operating activities	**(6,086,703)**	(4,657,042)
CASH FLOWS FROM INVESTING ACTIVITIES:		
Purchase of marketable securities	**(13,783,400)**	(16,400,000)
Proceeds from sale of marketable securities	**26,210,767**	27,350,000
Purchase of science and technology investments	**(2,699,000)**	(4,054,853)
Purchase of other investments	**(4,150,000)**	(4,626,956)
Repayments on note receivable	**600,000**	150,000
Purchases of property and equipment	**(10,123)**	
Proceeds from sale of property and equipment	**250**	320
Net cash provided by investing activities	**6,168,494**	2,418,511
CASH FLOWS FROM FINANCING ACTIVITIES:		
Borrowings on line of credit	**13,780,690**	15,156,312
Repayments on line of credit	**(14,135,869)**	(12,681,359)
Net cash (used in) provided by financing activities	**(355,179)**	2,474,953
NET (DECREASE) INCREASE IN CASH AND CASH EQUIVALENTS	**(273,388)**	236,422
CASH AND CASH EQUIVALENTS, BEGINNING OF YEAR	**392,429**	156,007
CASH AND CASH EQUIVALENTS, END OF YEAR	**$ 119,041**	$ 392,429
RECONCILIATION OF DECREASE IN NET ASSETS TO NET CASH USED IN OPERATING ACTIVITIES:		
Decrease in net assets	**$ (10,292,401)**	$ (18,181,201)
Adjustments to reconcile decrease in net assets to net cash used in operating activities:		
Net realized gains on sales of marketable securities	**(1,587,881)**	(21,405,245)
Unrealized net depreciation of marketable securities	**8,099,489**	33,633,729
Unrealized net (appreciation) depreciation of science and technology investments	**1,320,000**	641,559
Unrealized appreciation of other investments	**(2,547,733)**	
Depreciation and amortization	**21,844**	10,764
(Increase) decrease in accrued dividends and interest receivable	**(290,832)**	9,152
Increase in prepaid pension costs	**(596,001)**	(676,490)
Decrease in other assets	**549,525**	198,836
(Decrease) increase in grants payable	**(135,054)**	338,406
(Decrease) increase in other liabilities	**(54,584)**	773,448
Other	**(573,075)**	
NET CASH USED IN OPERATING ACTIVITIES	**$ (6,086,703)**	$ (4,657,042)

See notes to financial statements.

NOTES TO FINANCIAL STATEMENTS

Years ended December 31, 2001 and 2000

1. SUMMARY OF SIGNIFICANT ACCOUNTING POLICIES

Research Corporation (the "Foundation") prepares its financial statements in accordance with accounting principles generally accepted in the United States of America. The following are the significant accounting policies followed by the Foundation:

a. *Nature of Business* – The Foundation is a New York not-for-profit corporation dedicated to the advancement of science.

b. *Basis of Accounting* – The financial statements are prepared on the accrual basis of accounting and are prepared in accordance with standards set forth in the Statement of Financial Accounting Standards ("SFAS") No. 117, *Financial Statements of Not-for-Profit Organizations*, and the American Institute of Certified Public Accountants' *Audit and Accounting Guide for Audits of Not-for-Profit Organizations*.

c. *Securities Valuation* – The Foundation carries its investments in marketable securities at fair market value (see Note 2). Realized gains and losses are computed based on the difference between the net proceeds received and cost at time of acquisition using the average cost method as of January 1, 2001. Prior to the current fiscal year, the Foundation used the first-in, first-out method as the cost basis for the marketable securities. The change in accounting method during the current year did not have a material impact on prior year financial statements. Therefore, no prior year adjustment to the financial statements was deemed necessary. Unrealized net appreciation or depreciation of investments in marketable securities represents the change in the difference between acquisition cost and current market value at the beginning of the year versus the end of the year.

d. *Other investments* consisting of unconsolidated limited partnership interests are recorded at fair value in accordance with SFAS No. 124, *Accounting for Certain Investments Held by Not-for-Profit Organizations*. Investments without a readily determinable fair value are recorded at cost. The cost of investments sold is determined using the specific identification method. Other than temporary impairments are recognized in the period in which they occur and are included in net loss on investments.

e. *Revenue and Expenses* – Interest income is recorded as earned; dividends are accrued as of the ex-dividend date. Grant expense is recorded at the time the awards are approved by the Board of Directors.

f. *Contributions* – Restrictions on contributions received are generally satisfied in the year the contributions are received. The Foundation reports contributions as restricted support if they are received with donor stipulations that restrict the use of donated assets. When a donor purpose restriction is accomplished, temporarily restricted net assets are recognized as unrestricted net assets and reported as contributions released from restrictions in the statement of activity and net assets.

g. *Property and equipment* are stated at cost. Depreciation is calculated using the straight-line method over estimated useful lives as follows:

Tenant improvements	5 years
Furniture, fixtures and equipment	5–10 years

Maintenance and repairs are charged to operations as incurred. Major renewals and betterments are capitalized.

h. *Income Taxes* – The Foundation qualifies as a tax-exempt private operating foundation under Internal Revenue Code Section 4940(d).

i. *Statements of Cash Flows* – For purposes of reporting cash flows, cash and cash equivalents include cash on hand, demand deposits, savings accounts and highly-liquid debt instruments purchased with an original maturity of three months or less which are not carried in the Foundation's portfolio of marketable securities.

j. *New Accounting Pronouncement* – In June 1998, the Financial Accounting Standards Board issued SFAS No. 133, *Accounting for Derivative Financial Instruments and Hedging Activities*. SFAS No. 133, as amended, was adopted by the Foundation as of January 1, 2001, which requires that the Foundation record all derivatives as assets or liabilities, measured at fair value, with the change in fair value recognized in earnings or in comprehensive income, depending on the use of the derivative and whether it qualifies for hedge accounting. The Foundation noted that the adoption did not have a material effect on its financial statements.

k. *Use of Estimates* – The preparation of financial statements in conformity with accounting principles generally accepted in the United States of America requires management to make estimates and assumptions that affect the reported amounts of assets and liabilities and disclosure of contingent assets and liabilities at the date of the financial statements and the reported amounts of revenues and expenses during the reporting periods. Actual results could differ from those estimates. The Foundation utilizes various investment instruments. Investment securities, in general, are exposed to various risks, such as interest rate, credit, and overall market volatility. Due to the level of risk associated with certain investment securities, it is reasonably possible that changes in the values of investment securities will occur in the near term and that such changes could materially affect the amounts reported in the statements of financial position.

2. MARKETABLE SECURITIES

Marketable securities at December 31 consist of the following:

	2001		**2000**	
	Market Value	**Cost**	**Market Value**	**Cost**
Capital Guardian Trust Mutual Funds:				
Emerging Markets Growth Fund	**$ 4,107,035**	**$ 5,557,494**	$ 4,318,153	$ 5,557,494
U.S. Value Equity Fund	**15,568,231**	**14,642,186**	16,785,000	15,128,221
Global Equity Fund	**63,047,926**	**54,730,703**	80,188,902	64,752,715
American High Income Fund	**3,875,516**	**4,708,058**	4,245,628	5,039,497
Total	**$ 86,598,708**	**$ 79,638,441**	$ 105,537,683	$ 90,477,927

The objectives of the mutual funds, according to each fund's prospectus, are as follows:

a. *Emerging Markets Growth Fund* seeks to obtain long-term growth of capital through investment in equity securities of businesses located in developing countries.

b. *U.S. Value Equity Fund* seeks to outperform the Russell 1000 Value Index over a full market cycle, with a similar level of risk, by investing primarily in U.S. large CAP stocks with value characteristics.

c. *Global Equity Fund* seeks to achieve capital growth and future income through investments in a portfolio of securities of U.S. issuers, American depository receipts for securities of foreign issuers and securities whose principal markets are outside of the United States.

d. *American High Income Fund* seeks to achieve monthly income through investments primarily in bonds and also U.S. and foreign securities.

Annual investment activity for the year ended December 31 consists of the following, at market value:

	2001	**2000**
Opening balance	**$ 105,537,683**	$ 129,156,020
Purchases	**13,783,400**	16,400,000
Sales	**(26,210,767)**	(27,350,000)
Net depreciation	**(6,511,608)**	(12,668,337)
Ending balance	**$ 86,598,708**	$ 105,537,683

Proceeds from sale of marketable securities in 2001 and 2000 were used to fund purchases of other investments and science and technology investments.

Net loss on investments in marketable securities consists of the following for the years ended December 31:

	2001	2000
Net realized gains on sales of marketable securities	**$ 1,587,881**	$ 21,205,247
Unrealized net depreciation of marketable securities	**(8,099,489)**	(33,873,584)
Net loss on marketable securities	**$ (6,511,608)**	$ (12,668,337)

3. PROGRAM-RELATED INVESTMENT IN RESEARCH CORPORATION TECHNOLOGIES, INC.

On March 2, 1987, as amended on March 25, 1994, in accordance with Section 1605(c) of the Tax Reform Act of 1986, the Foundation and Research Corporation Technologies, Inc. ("RCT"), a nonprofit corporation subject to regular corporate income tax laws, entered into agreements through which RCT assumed responsibility for the Technology Transfer Program (the "Program"), which the Foundation had operated for many years. In addition to the transfer of the Program, the Foundation transferred $35,000,000 in cash and securities in exchange for a $35,000,000 fully subordinated unsecured note from RCT (the "Note") due February 28, 2017.

RCT has prepaid $10,000,000 of the Note and the remaining $25,000,000 principal amount of the amended Note is due on February 28, 2017, subject to acceleration at the option of the Foundation after December 31, 2012 provided RCT's retained earnings exceed $100,000,000. Basic interest at the rate of 7 percent per annum on the outstanding principal amount is due semiannually.

To qualify as a program-related investment under Section 4944(c) of the Tax Reform Act of 1986, the terms of the loan were required to be less than prevailing terms. In addition, this investment is a vehicle for the Foundation to continue one of its charter purposes. As there are no comparable alternative program-related investments available to the Foundation, the Foundation believes it is not practicable to estimate the fair value of this investment.

Interest income on the Note for each of the years ended December 31, 2001 and 2000 was $1,750,000.

4. SCIENCE AND TECHNOLOGY INVESTMENTS

The Foundation has invested in and made advances to various entities that engage in the advancement of science and technology. Such investments are not readily marketable and are carried at cost. At December 31, such investments consist of the following:

	2001	2000
Large Binocular Telescope Project (Note 9)	**$ 5,666,190**	$ 4,917,190
Seaphire International Inc.	**5,030,000**	4,300,000
Magellan University		300,000
Total science and technology investments	**$ 10,696,190**	$ 9,517,190

Increases in science and technology investments in 2001 relate to additional investments in the Large Binocular Telescope project of $949,000 and in Seaphire International Inc. of $1,750,000. In addition, unrealized depreciation of $1,020,000 and $300,000 was recorded on Seaphire International Inc. and Magellan University, respectively, as included in net loss on investments.

5. OTHER INVESTMENTS

Other investments at December 31 consist of the following, at estimated fair value:

	2001	2000
Limited partnership interest (AG Super Fund LP)	**$ 7,153,109**	$ 6,527,616
Limited partnership interest (AG Realty Fund IV LP and AG Realty Fund V LP)	**6,227,405**	3,398,029
Limited partnership interest (AG Capital Recovery Fund)	**6,492,864**	3,276,956
Total other investments	**$ 19,873,378**	$ 13,202,601

Increases in other investments in 2001 relate to additional investments in AG Realty Fund IV LP of $1,400,000, in AG Realty Fund V LP of $1,000,000 and in AG Capital Recovery Fund of $1,750,000. In addition, unrealized appreciation of $625,493, $1,492,864 and $429,376 was recorded in AG Super Fund LP, AG Capital Recovery Fund and the AG Realty Funds, respectively, as included in net loss on investments.

The objective of AG Super Fund LP is to achieve capital appreciation through specialized investment strategies, including investing in merger arbitrage, distressed debt, special situations and convertible hedging.

The objective of the AG Realty Funds IV and V LP is to invest in real estate assets, including options and mortgage loans.

The objective of the AG Capital Recovery Fund is to invest in distressed entities to allow them a chance to reorganize as viable entities.

6. PROPERTY AND EQUIPMENT

Property and equipment at December 31 consist of the following:

	2001	2000
Tenant improvements	**$ 358,289**	$ 358,289
Furniture, fixtures and equipment	**315,786**	305,662
Total property and equipment	**674,075**	663,951
Less accumulated depreciation	**615,320**	593,476
Property and equipment – net	**$ 58,755**	$ 70,475

7. LINE OF CREDIT

The Foundation has a $6,000,000 revolving line of credit which is due July 3, 2002 and bears interest at the prime rate (4.75 percent at December 31, 2001) or LIBOR plus 1.50 percent (3.945 percent at December 31, 2001), at the Foundation’s option. At December 31, 2001 and 2000, borrowings of $4,144,821 and $4,500,000, respectively, were outstanding under the line of credit. The Foundation recognized interest expense of $302,987 and $251,557 for the years ended December 31, 2001 and 2000, respectively. In March 2002, the Foundation increased its revolving line of credit to $10,000,000, which is due May 30, 2003, and bears similar terms and interest rates.

8. PENSION PLAN AND POSTRETIREMENT BENEFITS

Pension Plan – The Foundation has a noncontributory defined benefit pension plan (the "Plan") covering substantially all of its employees. The benefits provided by the Plan are generally based on years of service and employees' salary history. It is the Foundation's policy to fund pension cost accrued; however, at December 31, 2001 and 2000, the Plan is in an overfunded status and no contributions are required.

The components of the net periodic pension income for the years ended December 31 are as follows:

	2001	**2000**
Service cost – benefits earned during the period	**$ (172,491)**	$ (153,456)
Interest cost on projected benefit obligations	**(195,182)**	(193,673)
Expected return on Plan assets	**759,376**	789,637
Net amortization and deferral	**237,467**	300,583
Net periodic pension income	**629,170**	743,091
Postretirement benefits transfer	**(33,169)**	(66,601)
Total pension income	**$ 596,001**	$ 676,490

Assumptions used in the accounting for the Plan for the years ended December 31 are:

	2001	**2000**
Discount rate	**7.25%**	7.75%
Rate of increase in compensation levels	**5.25%**	5.75%
Expected long-term rate of return on assets	**7.50%**	7.50%

The measurement date for the Plan is December 31. The following sets forth the Plan's funded status at December 31:

	2001	**2000**
Accumulated benefit obligation	**$ (2,360,209)**	$ (2,099,947)
Projected benefit obligation	**$ (2,796,056)**	$ (2,474,482)
Plan assets at fair value, primarily invested in stocks and bonds	**9,793,545**	10,205,963
Funded status	**6,997,489**	7,731,481
Unrecognized transition net asset	**(340,769)**	(454,359)
Unrecognized net gain	**(1,959,595)**	(3,187,272)
Unrecognized prior service cost	**72,632**	83,906
Prepaid pension cost	**$ 4,769,757**	$ 4,173,756

During 2001 and 2000, $33,169 and $66,601, respectively, were transferred out of the Plan to provide for payment of postretirement medical benefits. These transfers were made in accordance with the Omnibus Budget and Reconciliation Act and were treated as negative contributions. In addition, during each of the years 2001 and 2000, total benefits paid were $282,488 and $459,754, respectively. There were no other participant or employer contributions in 2001 or 2000.

During 2001, the Foundation decided to terminate the pension plan. The Foundation intends to provide a new plan with similar benefits to participants upon termination of the existing plan.

Although no estimate has been made of the benefit obligation using liquidation type assumptions at December 31, 2001, the Plan is overfunded.

Postretirement Plan – In addition to providing pension benefits, the Foundation provides certain health care benefits to retired employees and their spouses. Substantially all of the Foundation's employees may become eligible for these benefits if they reach normal retirement age while working for the Foundation.

The components of net periodic postretirement benefit cost at December 31 are as follows:

	2001	**2000**
Service cost – benefits earned during the period	**$ 34,430**	$ 29,799
Interest cost on accumulated postretirement benefit obligation	**73,700**	85,468
Net amortization and other	**33,689**	21,656
Net periodic postretirement benefit cost	**$ 141,819**	$ 136,923

During 2001 and 2000, benefits paid were $89,025 and $60,574, respectively. Other than the transfer from the pension plan, there were no participant or employer contributions.

A reconciliation of the accumulated postretirement benefit obligation to the liability recognized in the statements of financial position in other liabilities is as follows at December 31:

	2001	**2000**
Accumulated benefit obligation	**$ 1,028,025**	$ 976,702
Unrecognized net gain subsequent to transition	**715,532**	789,873
Unrecognized transition obligation	**(1,061,369)**	(1,137,181)
Accrued postretirement benefit liability	**$ 682,188**	$ 629,394

The actuarial calculation assumes a health care inflation assumption of 10 percent in 2001, decreasing uniformly to 4.25 percent by 2008 and remaining level thereafter. The assumed discount rate is 7.75 percent.

The Foundation's postretirement medical plans are not funded.

9. COMMITMENT

The Foundation has an agreement to commit up to $7,500,000 in construction costs plus 12.5 percent of the operating expenses for each year to the Large Binocular Telescope Project (the "Project"), which was organized to construct a telescope. In return for the commitment, the Foundation receives observing time for use or sale to other astronomy research institutions. As of December 31, 2001 and 2000, approximately $8,281,000 and $7,532,000, respectively, had been funded to the Project under the construction costs commitment by the Foundation and are recorded in science and technology investments. In addition, the Foundation had contributed cumulative amounts of approximately $889,000 and $814,000 to cover operating expenses as of December 31, 2001 and 2000, respectively.

In 1999, the Foundation sold one quarter of its viewing rights to a research institution in exchange for $400,000 cash and a note receivable of $1,062,669 (net of unamortized discount of $137,331 based on an imputed interest rate of 8.5 percent). At December 31, 2000, $552,996 was outstanding on the note, net of unamortized discount of $47,004 and is included in other assets in the statements of financial position. The note receivable was paid in full in 2001.

In addition, the Foundation granted viewing rights for additional nights to a research institution. Grant expense of $2,615,167 was recognized in 1999 in relation to these transfers of viewing rights to research institutions.

The Foundation is in negotiations to sell the remaining viewing rights.

10. LITIGATION

The Foundation is subject to claims arising out of the conduct of its business. Management believes these matters are without merit and intends to contest them vigorously. These claims, when finally concluded, in the opinion of management based on information it presently possesses, will not have a material adverse effect on the Foundation's financial position, results of operations or cash flows.

11. RELATED-PARTY TRANSACTIONS

The Foundation and RCT have certain agreements under which:

a. The Foundation has an office facilities lease agreement with RCT that expires July 31, 2003. Lease expense paid to RCT under this agreement for the years ended December 31, 2001 and 2000 was approximately $201,000 and $192,500, respectively.

b. The Foundation pays a management service fee to RCT for making available professional and other services to the Foundation to the extent that such services are reasonably required by the Foundation. The fee for such services is negotiated yearly and is approved in the budget by the Foundation's Board of Directors. The management service fee for the years ended December 31, 2001 and 2000 was approximately $112,400 and $107,000, respectively. Effective January 1, 2002, the management service agreement was terminated.

c. At December 31, 2001 and 2000, the Foundation had amounts payable to RCT of approximately $286,000 and $156,000, respectively, relating to expenses paid by RCT on behalf of the Foundation.

OFFICERS AND DIRECTORS

JANUARY 1, 2001 – DECEMBER 31, 2001

OFFICERS

JOHN P. SCHAEFER
President and Chief Executive Officer

MICHAEL P. DOYLE
Vice President and Secretary

SUZANNE D. JAFFE
Treasurer

SHERRI R. BENEDICT
Assistant Secretary to the Foundation

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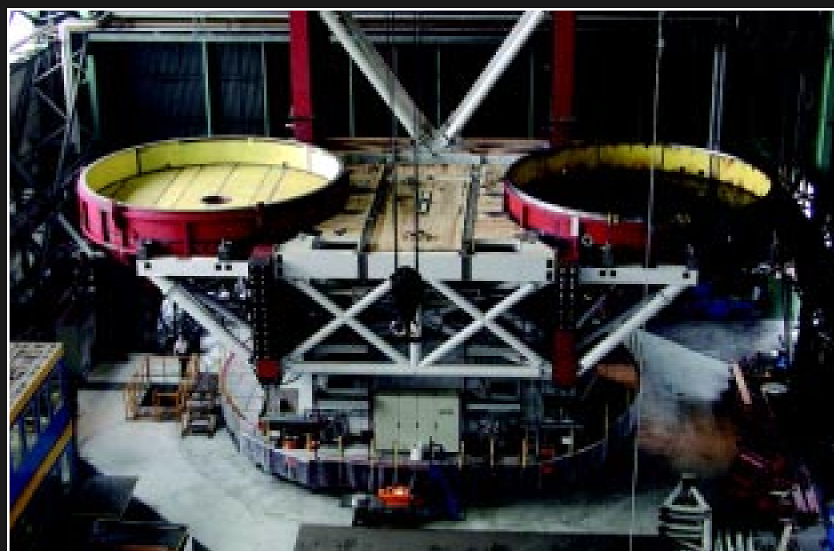

“The Large Binocular Telescope: A brief history of innovation”
“The Steward Observatory Mirror Lab”
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Page 20: Section of the Rosette Nebula - Peter Challis, Center for Astrophysics, MMT Minicam
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