The New Technology Telescopes

Astronomers are giving high priority to a new generation of instruments built on a Brobdingnagian scale

Looking beyond the grim budget realities of the moment, American astronomers are planning a series of ground-based optical telescopes that will dwarf anything now in existence. Known generically as New Technology Telescopes (NTT's), these instruments will be a radical departure from the optical tradition that culminated a generation ago in the 5-meter instrument on Mount Palomar in California. Three independent but closely coordinated projects are under way: the University of Texas is planning an NTT with a primary mirror 7.6 meters across; the University of California is planning one 10 meters across; and Kitt Peak National Observatory, together with the universities of Arizona, Texas, and California, is evaluating designs for a national NTT effectively 15 meters across—a light-collecting area twice that of the 20 largest telescopes in the world put together.

The NTT concept has broad support within the astronomical community both here and abroad, as evidenced by the hundreds of astronomers who recently gathered in Tucson, Arizona, to review the very rapid progress in the field.* The NTT is among the highest priorities listed in a soon-to-be-published National Academy of Sciences report† on the needs of astronomy in the 1980's. Kitt Peak director Geoffrey Burbidge considers the preliminary design effort so important that he continues to fund it in the face of severe budget cuts and pressure to spend the money on more immediate needs. "I'm an optimist," he declares. "I think things will turn around, though I don't know when. I know that this is the best way to go."

The new technology has grown out of a decade-long effort to achieve higher telescope performance at reasonable cost. The phrase takes in everything from new coatings for the mirrors to new designs for the domes. But two concepts stand out.

First and most important is active optics. A telescope's reflecting surfaces have to remain accurate to a fraction of a micrometer, regardless of temperature changes or the shifting stresses as the instrument scans across the sky. In virtually every large telescope to date this has been achieved by making the mirror thick and rigid. But there is a limit, and the 5-meter telescope on Mt. Palomar probably comes close to it. Scaling the mirror up to 10 or 15 meters would be prohibitively expensive in materials cost alone, if it were even possible.

With the advent of modern electronics, however, astronomers have begun to explore a different approach. Make the mirror light, thin, and, most especially, cheap. In fact, make it in many separate pieces. Then put those pieces on movable mounts, hook in position sensors, and put the whole thing under the control of a computer. A mirror that would otherwise sag hopelessly can thus maintain its figure "actively." If the system is quick enough, in fact, it might even be able to undo some damage done to the image by the atmosphere: the rapidly changing distortions due to turbulence might be compensated by equally rapid adjustments of the mirror.

Computers have also made possible a second important element in the new technology, the altitude-azimuth mounting. For generations, professional astronomers and serious amateurs have used the equatorial mount, which allows the telescope to track a star with a simple, steady rotation around a north-south axis. This altazimuth mount is a less elegant affair resembling the coin-operated binoculars at a scenic overlook: to follow a star the telescope must swing up or down around a horizontal axis (altitude) while simultaneously pivoting around a vertical axis (azimuth). But modern computers can handle the simultaneous motions easily. The payoff is that an altazimuth mount is compact, cheap, and strong enough to hold a much larger telescope.

Both these concepts (and many others) have already been demonstrated in the Multiple Mirror Telescope (MMT), which began operation in 1980 atop Mount Hopkins in southern Arizona. Managed jointly by the Smithsonian Astrophysical Observatory and the University of Arizona, it consists of six 1.8-meter mirrors mounted on a common frame, with secondary mirrors directing the light to a common focus. Its alt-azimuth mounting has worked quite well, as have the active optics—although an early effort to coordinate the six mirrors with lasers had to be abandoned, in part because the light proved irresistible to certain Arizona moths. The mirrors are now aligned by a computer that monitors a guide star in the field of view and makes sure that the star always has one image instead of six. The ultimate goal is not only to get the beams focused to a point but to get them focused with the light in phase. The MMT would then attain an angular resolution approaching that of a single 7-meter mirror. Several experiments earlier this year have achieved just that, and more experiments are planned.

There are two basic reasons for wanting a very large telescope. One is just astronomers' endless quest for more light, particularly for doing high-resolution spectroscopy of very faint objects such as distant galaxies and quasars. The spectroscope parcels the available light into narrow wavelength bands, and unless there is a very big mirror feeding it lots of photons, the signal tends to get lost in the noise. A 15-meter NTT could take spectra up to 100 times faster than existing instruments.

The other reason is that an NTT located on a high, dry mountaintop could make diffraction-limited images in the infrared. At these wavelengths, from 0.8 to 20 micrometers, radiation penetrates the clouds of interstellar gas and dust that obscure so much of the galaxy. With an NTT astronomers could study star-forming regions and the galactic center in unprecedented detail.

In fact, although it was not originally planned that way, the NTT's will nicely complement the National Aeronautics and Space Administration's Space Telescope, due for launch in 1985. Orbiting above the turbulence and background light of the atmosphere, Space Telescope will have unsurpassed resolution and sensitivity. But its aperture will only be 2.4 meters, modest even by current standards. Its spectral resolution will thus be far less than that of the proposed NTT's,

*International Conference on Advanced Technology Optical Telescopes, Tucson, Arizona, 11 to 13 March 1982.
†See page 282, this issue.

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and it will not operate at all in the infrared. On the other hand, without the space telescope the ground-based instruments could miss out on some potentially interesting objects. With time exposures they will be able to pick out faint sources even through the murk of the atmosphere. But without the information from Space Telescope the ground-based operators might never know where to point. "The NTT without Space Telescope would not be as productive—and vice versa," notes Lawrence D. Barr, manager of the Kitt Peak NTT design project.

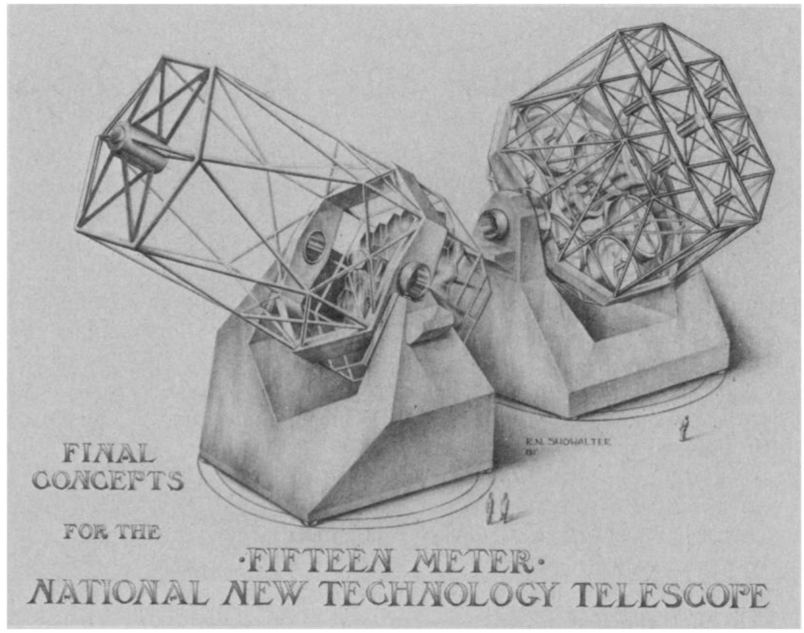
Kitt Peak began studying concepts for a 25-meter national NTT as early as 1975, says Barr. In 1980, this was cut back to 15 meters as a more practical size, and two concepts were chosen for detailed study. The first is a larger version of the MMT; it would achieve an equivalent diameter of 15 meters with an array of six (or perhaps four) individual mirrors, each 6 meters across. The other concept calls for a segmented primary mirror, a 15-meter-diameter mosaic of some 90 hexagonal mirrors, each 2 meters across.

Meanwhile, the University of California started planning its 10-meter NTT in 1977 pooling the efforts of astronomers from the Berkeley, Santa Cruz, Los Angeles, and San Diego campuses. They have recently settled on a segmented mirror design with 36 2-meter segments.

The University of Texas project began in 1979. Since the Texans' idea was to build the instrument without federal money, they decided on a 7.6-meter mirror for psychological reasons: 7.6 meters translates to exactly 300 inches, "the magic number for fund raising," as one Texan puts it.

That same year the University of Arizona began to consider a larger MMT. And in 1980 the rising pace of activity in NTT's led Kitt Peak and the three universities to form a consortium to coordinate their efforts. "We've divided the common technical tasks into chunks that each of us can work on," says Barr.

The Californians, for example, are concentrating on a critical technology of the segmented mirror concept: how to control segment positions inside the telescope. No small part of the problem is the development of actuators that can move the segments rapidly and reliably over displacements of a fraction of a micrometer. Meanwhile, California and Kitt Peak are both working a second critical technology: how to make off-axis parabola mirror segments. The mosaic mirror as a whole will have the shape of a paraboloid, but this means that each of the individual hexagonal segments will have a slightly different shape. None will be symmetric about its own center. Grinding and polishing these skewed surfaces to the requisite submicrometer tolerance promises to be a formidable task. However, a mathematical theory developed and tested on a small scale at Berkeley suggests that such segments can be made rather easily if each mirror blank is first put under a bit of carefully calculated stress. Just polish in a spherical surface, which is straightforward, and when the stress is released the mirror will relax into the required off-axis shape. Kitt Peak is currently getting ready to test this concept on a full-scale 2-meter mirror segment.



Kitt Peak National Observatory

On the left is the segmented mirror; on the right, the multiple mirror

A critical technology for the multiple mirror concept is the production of the mirrors themselves: each of the six primaries of a 15-meter equivalent NTT would be bigger than the Palomar mirror, and a way has to be found to keep their cost down. The ultra-low thermal expansion materials used in most modern telescopes would be prohibitively expensive. At the University of Arizona, however, J. Roger P. Angel and his colleagues are reviving an older and much cheaper material: Pyrex. Its thermal expansion is relatively high, but with new casting methods they believe they can make very thin mirrors backed by an integral, thin-walled glass honeycomb; the result would be a very light, stiff mirror that reaches thermal equilibrium with its surroundings very quickly. (The Palomar mirror is also a Pyrex honeycomb, but its 10-centimeter walls are ten times the thickness of Angel's.) The Arizona team plans to make a 1.8-meter mirror soon and install it for testing in the MMT.

The conference on NTT's held last month in Tucson was the second of its kind—the first was in 1980—and it was basically an interim progress report, says Barr. "A lot of the technical problems have begun to look solvable," he told *Science* afterward, adding that the decision-making process for the Kitt Peak NTT is already in motion. "By the end of the calendar year you should be able to see a consensus for one concept or another pretty plainly." The final choice will be made officially in 1983.

There are other questions still to be settled, of course. Each of the projects will have to choose a site, for example. For political and financial reasons, the Texas telescope will be built in Texas. California has settled on Mauna Kea, Hawaii, largely because of its excellence as an infrared site (*Science*, 27 November 1981, p. 1010). Kitt Peak is looking at both Mauna Kea and Mount Graham, a remote peak in Arizona.

Most important, however, there is the matter of money. Texas and California hope to proceed without federal funds. Kitt Peak cannot. The national NTT could cost as much as $100 million. Without some change in Washington's attitude toward new research projects, this one seems doomed from the start. And yet, listening to the astronomers gathered last month in Tucson, one felt a certain inevitability about it. As Barr said, "it is hard to think of a time when there has been so much activity as now, when the time has been so ripe for a revolution in telescope design."

—M. MITCHELL WALDROP