Troubled Times Ahead for Telescope-Makers

A proposed "new technology" telescope presents a classic choice between the old and new

FOR American astronomers, at least, the symbolism of the past few months has been both vivid and galling.

Four decades after the 5-meter Hale Telescope was completed on Palomar Mountain in 1948, the means are at hand for the construction of "new technology" telescopes having more than ten times that venerable instrument's light-gathering power, at considerably less than ten times the cost. On the summit of Hawaii's Mauna Kea construction is already under way for the \$87-million, 10-meter Keck Telescope, a privately funded joint project of the University of California and the California Institute of Technology. This past December, a consortium of eight European nations committed some \$240 million for an array of 8-meter telescopes in Chile. And sometime this spring, the government of Japan is expected to give its go-ahead for a \$100-million 8-meter telescope that will also be built on Mauna Kea.

In short, the 1980s have witnessed a renaissance in the art of telescope-making—which is precisely why U.S. astronomers are finding it so galling to contemplate the National Science Foundation (NSF). The foundation's national observatories have long taken the lead in providing access to advanced instrumentation for the community as a whole. And yet their hopes for a \$150-million National New Technology Telescope are fast fading into Gramm-Rudman limbo. Indeed, the funding picture is now so bleak for ground-based astronomy in general that the NSF sees little choice but to close some of its facilities, an option that U.S. optical astronomers have never had to face before. Several committees have now been formed to make recommendations.

"The U.S. community is paralyzed by the budget situation," says one astronomer who is closely involved in that review, and who asked not be be quoted by name. "We're losing any semblance of leadership in basic research. Europe is going ahead. Japan is going ahead. And we're sitting around trying to figure out which facilities to close!"

Of course, one can hear much the same cries of anguish in every other field of basic research, as the astronomers themselves are the first to admit. Nonetheless, the story of astronomy in general and the National New Technology Telescope (NNTT) in particular turns out to be more than just another exercise in academic poor-mouthing. Not only is the unremitting budgetary pressure forcing U.S. astronomers to reexamine their need for an NNTT, it is leading them to question their long dependence on federal funding for new facilities, and even the role of the national observatories themselves.

Historically, the idea for an NNTT first emerged about a decade ago, at a time when more or less independent proposals for new technology telescopes were also springing up at the University of California, the European Southern Observatory, and the universities of Arizona and Texas (page 29). So the first question to ask is why the NNTT seemed necessary at all.

For the Kitt Peak National Observatory, which quickly took the lead on the NNTT, the answer was simply that it had to fulfill its charter from the NSF. Although the United States does have a long tradition of privately funded observatories, with the Keck and the Palomar telescopes being prime examples, single institution instruments are primarily reserved for the astronomers who work at those institutions. That was why the federally funded national observatories were established in the first place, to give *every* U.S. astronomer access to top-quality instrumentation. And if that commitment was to have any meaning, went the argument, then the national observatories would have to stay on the forefront of astronomical technology.

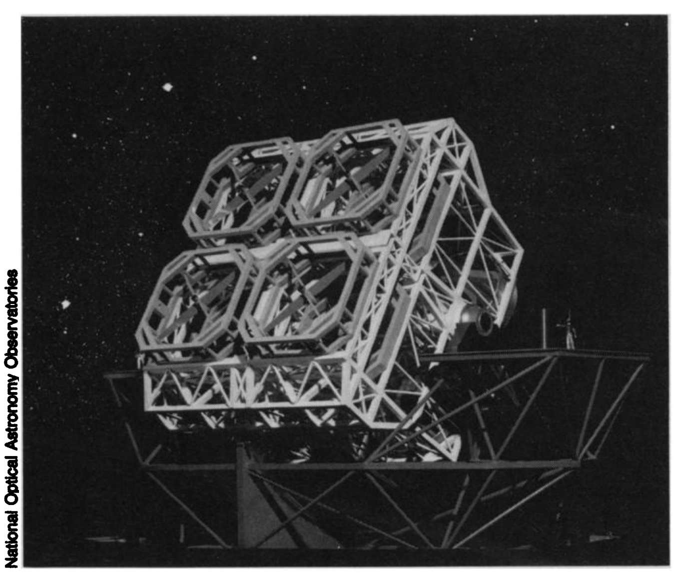
That argument carried considerable force at the time. The NNTT won the endorsement of the U.S. community at large in 1982, when the National Academy of Sciences' Astronomy Survey Committee named the instrument as one of its top priorities for the 1980s. Moreover, it has continued to receive strong support from the National Optical Astronomy Observatories (NOAO), an umbrella organization that was formed in 1983 to run NSF's optical facilities at Kitt Peak, Sacramento Peak in New Mexico, and Cerro Tololo in Chile.

The baseline conceptual design for the NNTT was announced in 1984, after an extensive series of design studies. It was to be a multimirror arrangement with four mirrors, each 8 meters in diameter, mounted on a single support structure. By focusing the light from all four mirrors into a single image, it would thus achieve the light-gathering power of a single mirror 16 meters in diameter. Each of these mirrors, in turn, was to be cast in a single piece, most likely using the "spin casting" technology being pioneered by the University of Arizona's Roger Angel (page 29).

And therein lies the problem. For some time now NOAO has been funding Angel and his colleagues at roughly \$1 million per year, a rate that has so far allowed them to complete an 8-meter turntable and to cast several small prototype mirrors. And yet to keep them on an optimum schedule as they work their way up through a series of larger and larger mirrors—the first 8-meter casting

A model of the NNTT

A surrogate and a catalyst for a much larger question: what is the role of the national observatories?


National Optical Astronomy Observatories

could come as early as 1991 or 1992—NOAO needs to boost their funding to some $3 million per year. This is $3 million that it does not have: NOAO's budget has been declining steadily in real terms for 5 years straight.

At NOAO headquarters in Tucson, director Sidney Wolff outlines the situation as it now stands. "If you calculate what it would cost us to do exactly what we are doing today, with 4% inflation," she says, "you get $25.7 million. But the President's 1989 budget is only $24.4 million. So we've got a $1.3-million problem already. Now you add in the fact that some new projects need expansion." In addition to the NNTT effort, for example, there is a project to study the oscillations of the sun—GONG—that needs to ramp up from $1 million to $2.5 million next year to start buying hardware.

In short, says Wolff, it comes down to a classic dilemma: "What is the proper balance between new facilities and old facilities?"

Back in NSF's Mathematical and Physical Sciences Directorate, meanwhile, director Richard Nicholson tells much the same story about the astronomy program as a whole. The astronomy division's $90-million budget request for fiscal year 1989 represents an increase of 4.7% over 1988, he says, or just a little more than inflation. But nobody really believes that Congress is going to approve that much. Since 1984, every requested increase in the astronomy budget has been penciled out by Capitol Hill committees trying to deal with the deficit. Funding has stayed essentially flat in the face of an aggregate inflation of 15%. And Nicholson, like everyone else in the astronomy program, wonders how much longer this can go on. And after a point, he says, "you just can't keep spreading the money around more and more thinly."

Indeed. So what are the options for the NNTT—and for astronomy in general?

■ **Scale back the NNTT to something less ambitious.** In a sense this has already happened. The decision came this past August during a retreat by the board of the Association of Universities for Research in Astronomy (AURA), the 20-university consortium that operates the NOAO under contract to the NSF: as a preliminary step toward the NNTT, said the board, AURA will submit a proposal by the end of 1988 to build two single-mirror 8-meter telescopes. One would be in the Northern Hemisphere, presumably on Mauna Kea, and the other would be in the Southern Hemisphere, presumably in Chile.

Building the two 8-meter instruments would cost an estimated $100 million, which represents a considerable savings over the estimated $150 million for the full-scale,

Bigness: Why and How

The momentum behind the NNTT and the other large telescopes stems basically from two motivations, which can loosely be described as supply and demand.

On the demand side is the science itself, and the astronomers' never-ending quest for more photons. Until quite recently, of course, that hunger for photons has mostly been fed by steady improvements in detector technology. That, plus the difficulty and expense of making very large optical surfaces with the available technology, meant that the flagship telescopes built in the post-Palomar era were typically no more than 3 to 4 meters in diameter.

By the late 1970s, however, the pendulum had begun to swing back. The community was putting more and more emphasis on such cosmological questions as the timing of galaxy formation and the origin of large-scale structure in the universe. Moreover, it was clear that the only way to find out what the universe had been like in the aftermath of the Big Bang was to look for the faintest and most distant galaxies and quasars possible. And the only way to do that, given that the new charge-coupled device detectors were already close to detecting individual photons, was to collect more light with bigger mirrors. As an added incentive, astronomers quickly realized that larger ground-based instruments would provide a nice complement to the Hubble Space Telescope. The atmosphere might keep those instruments from ever reaching the 0.1-arc-second resolution of Space Telescope, but their size—Space Telescope's mirror will only be 1.4 meters across—would give them a huge advantage in sheer light-gathering power.

And finally, the astronomers were also quick to realize that bigger telescopes would provide higher resolution images at infrared wavelengths. (Space Telescope will not carry any infrared instruments, at least initially.) It turns out that infrared photons are much better than visible-light photons at penetrating interstellar gas and dust, which are ubiquitous in our galaxy. The bigger telescopes would thus be powerful tools for studying our galaxy's dusty star-forming regions, not to mention the shrouded "engine" at its center that is thought to be a 1-million-solar-mass black hole.

On the supply side, meanwhile, the growing scientific interest in large new instruments was leading designers to explore a variety of "new technologies" that would make the behemoths possible, not to mention affordable. These technologies included such innovations as advanced mirror-polishing techniques; multiple-mirror arrangements that combined the light-gathering power of several mirrors; and the use of compact, computer-controlled "altitude-azimuth" mountings that made a telescope resemble nothing so much as a stubby gun turret. In fact, the latter two technologies were demonstrated as early as 1979 with the successful completion of the Multiple Mirror Telescope, a joint project of the Smithsonian Institution and the University of Arizona.

Most crucially, however, the new technologies also included at least three different approaches to the creation of precision optical surfaces 8 meters or more in diameter. One was the "thin-meniscus" approach taken by the European Southern Observatory (page 31). Another was the "segmented" mirror concept, which was being pursued by a multicampus group of researchers at the University of California. The Californians' idea was to form their optical surface as a mosaic of hexagonal segments, each about 1 meter across; an elaborate system of computer-controlled supports would then keep the segments aligned to within a tenth of a micrometer. Their idea is now coming to fruition as the 10-meter Keck Telescope atop Hawaii's Mauna Kea.

The third new approach, which will be used in the NNTT if it is ever built, is the "honeycomb" design pioneered by University of Arizona astronomer Roger Angel. Basically a much lighter and thinner version of the Palomar mirror—it even uses the same kind of glass, a borosilicate material similar to Pyrex—the honeycomb is cast by spinning the mold. The surface of the molten glass then forms a paraboloid, which is exactly the mathematical surface that a mirror needs to focus light. Once the glass is cool and the curve frozen in, all that remains is the final polishing. Admittedly, this final step is a long and painstaking one. Angel has designed a new, computer-controlled polishing lathe for that very purpose. Nonetheless, spin-casting completely eliminates the wasteful and time-consuming process of grinding out the basic curve from a slab of flat glass. ■ **M.M.W.**

four-barreled NNTT itself. However, as AURA president Goetz K. Oertel has stressed repeatedly, money was not the primary motivation. The board members, like many others in the astronomical community, were much more worried about technical and managerial issues, he says. A four-shooter seemed like too ambitious a first step, especially when NOAO is out of practice—the national observatories have not built a large optical telescope since the early 1970s—and especially when no one has yet demonstrated that an 8-meter mirror of the required accuracy can be made. Without some kind of intermediate step, says Oertel, the AURA board members judged it unlikely that the NSF either could or would commit to the full NNTT.

Of course, opting for the two 8-meter instruments is risky. The full-scale NNTT will certainly be pushed back well into the next century, and may never get built at all. On the other hand, the proposal does have considerable appeal in its own right. Each of the two smaller instruments would still have more than twice the light-gathering power of the Palomar telescope. The fact that they would each be in opposite hemispheres means that one or the other of them would be able to see anything in the sky. And if everything stayed on schedule, the first one could be operational as early as 1995.

However, that just brings us back to the budget crunch in 1988: where is the development money going to come from that will keep the program on schedule? Thus the next option:

■ **Raise the NSF astronomy budget.** Although this option may sound a bit like writing to Santa Claus, it came tantalizingly close to reality last year when NSF director Erich Bloch got the Reagan Administration to agree to a 5-year doubling of the NSF budget overall. The plan had strong support on Capitol Hill and would have benefited basic research handsomely. But it collapsed last fall when Congress virtually eliminated the first installment of NSF's increase as part of its emergency budget pact with Reagan. Basic research budgets now look to be flat or slightly falling for the foreseeable future.

Whether Bloch's budget-doubling plan can ever be revived is anyone's guess. Even if it were, however, there is another imponderable: NSF's own institutional priorities. There is certainly no evidence to show that Bloch is actively hostile to basic research—although more than one astronomer has been heard to mutter that charge in private. Nonetheless, as a former director of corporate research at IBM, he has markedly increased the foundation's emphasis on science education, and on such areas of "applied" science as computers and engineering. Moreover, this shift in emphasis has undoubtedly been a factor in the gradually tightening budgets for astronomy and the other basic research disciplines.

Whether Bloch's sense of NSF's priorities will survive his own tenure as director is, once again, anyone's guess. Certainly he has had his share of critics. On the other hand, as he himself said in a recent speech to the American Physical Society, "If science and engineering research and education are the foundation of much of our economy, we cannot expect to be insulated and shielded from the daily discussion and action that make up the political process. Science research is not an entitlement. . . . " By emphasizing education and economic competitiveness, in other words, Bloch's NSF is responding to powerful political currents. And the pressure to do that is not going to go away anytime soon.

"A significant part of the community is looking at the big telescopes and asking. 'What do you get for your money?' "

■ **Begin to shut down older facilities.** Barring some kind of fiscal miracle, the choice seems inevitable: if U.S. astronomers ever expect to get anything new, they are going to have to give up something old. Indeed, the NSF has recently asked University of Illinois physicist Donald Langenberg, a former deputy director of the foundation, to chair a committee to review its commitments in radio astronomy. AURA and NOAO, meanwhile, have undertaken their own review of the optical observatories.

Of course, one could argue that this is only fair. The physicists, for example, are quick to point to the accelerators that *they* have had to close. But fair or not, the choices will not be easy. The obvious candidates for mothballing are the NOAO's smaller telescopes, which typically have diameters in the range of 1 to 2 meters. And yet these are still the instruments of choice for wide-angle surveys, for new instrument development, or for graduate students doing their thesis work. Closing them would force their users to compete for time on the NOAO's larger telescopes, which are oversubscribed by a factor of 4 already.

Furthermore, it is not clear that closing down individual telescopes would really save very much. The big money at any observatory goes to roads, staff, housing, and utilities, the fixed costs of keeping the facility open as a whole. And that means in turn that the only way for NOAO to achieve any significant savings is to shut down a whole mountain.

The question is which mountain? Kitt Peak is home to such flagship instruments as the 4-meter Mayall Telescope, and Cerro Tololo is the only U.S. national observatory in the Southern Hemisphere. That leaves the solar observatory at Sacramento Peak in New Mexico. And indeed, in 1985 NOAO did try to close Sacramento Peak—whereupon the astronomers who regularly used it went screaming to their congressmen and got a mandate to keep it open.

■ **Give up on the NNTT entirely.** Most astronomers still pay lip service to the NNTT, in one version or another. But the knives are coming out.

"There's a significant part of the astronomical community looking at the big telescopes and asking, 'What do you get for the money?' " says University of Minnesota astronomer Roberta Humphreys, one of the most vocal critics of NSF's approach to astronomy. In particular, she says, NSF's obsession with newness and bigness has led to an acute shortage of U.S. telescopes in the 3- to 4-meter range, which would be more than adequate for most astronomical purposes. "The United States has only built two since 1970," says Humphreys, those being the Kitt Peak and Cerro Tololo 4-meter instruments. "Since then the Europeans have taken the lead with good telescopes in good, dark sites" such as Mauna Kea, Chile, and the Canary Islands.

As for large telescopes, she says, the Keck is already under construction. The European 4-by-8 has already been funded. The Japanese 8-meter will very soon be funded. And Arizona's Roger Angel is well on his way to becoming an industry unto himself. His approach looks so promising that the five-university "ARC" consortium plans to use one of his 3.5-meter mirrors in a new telescope on Sacramento Peak; the Multiple-Mirror Telescope will eventually have its optics replaced with a 6.5-meter mirror; and Arizona has entered into two new university consortia to use Angel's 8-meter mirrors for telescopes in Arizona and in Chile.

"I'm not opposed to large telescopes," says Humphreys, "but how many do you need?"

How many indeed? If all these telescopes do get built—admittedly a big if—then the NNTT would be superfluous at best. So why should the NNTT be such a priority?

Ultimately, of course, this is not so much a question about an individual piece of hardware as it is a question about values and political choice. The NNTT in particular can be seen as both a surrogate and a catalyst for a much larger question: what is the role of the national observatories?

Consider Humphreys' list of big telescope projects. One of the most striking things about it is that all of the American instruments are being planned by university consortia; moreover, none of those consortia are going to seek federal money. They maintain that the telescopes will be funded by private individuals and foundations if they are funded at all. (The one exception is the construction money for the ARC telescope, which will be partially supplied by NSF.)

Humphreys herself is part of that movement. Instead of just waiting for the NSF to build her some new conventional telescopes, she has spearheaded yet another consortium, an 11-university group known as the Alliance for the Construction of Telescopes. Their goal is to build a cluster of three or four 3.5-meter instruments on a site somewhere in the American Southwest. And they, too, plan to seek private funding. As Humphreys says with classic understatement, "Most people are rather skeptical of NSF's abilities to start new projects."

In short, the American astronomical community is getting so fed up with federal funding cutbacks and the chronic shortage of observing time that people are beginning to take matters into their own hands. And perhaps this is a good thing. After all, self-reliance is usually considered a virtue.

But then, where does this surge of independence leave the national observatories? Are they supposed to just give up on projects like the NNTT and settle down into being quiet backwaters, places where those few researchers who do not work at consortium universities can make a few routine observations? Or are they still supposed to try, somehow, to stay at the cutting edge of technology in spite of the tightening budgets? What is the worth of that ineffable something called "leadership"?

The NSF and AURA committees will surely be grappling with those questions in the coming months. And the answers, not surprisingly, are far from clear. For all the vagaries of the federal budget, for example, NOAO's funding may still be more reliable than these much-vaunted "private donations." With the exception of the Californians, who got $70 million from the Keck Foundation, who else has demonstrated that those donations will ever materialize? For that matter, what private donor is going to risk several million dollars on a mirror technology—Angel's—that has not even been demonstrated yet? And who is going to pay for that demonstration if not NOAO?

As Wolff says almost plaintively, "There's still something to be said for a ***national*** facility." ■ **M. MITCHELL WALDROP**

A European Behemoth

The Very Large Telescope, as it is known, is the fruit of some 10 years of design effort by the European Southern Observatory (ESO), an eight-nation* consortium that has been operating a Southern Hemisphere observatory at La Silla, Chile, since the 1960s. The $240-million project was given its official go-ahead by the ESO council in Garching bei Muenchen, West Germany, on 8 December 1987.

The telescope itself will most likely be located at Cerro Paranal, a peak lying several hundred kilometers north of La Silla in one of the driest parts of Chile's Atacama desert. It will consist of four individual telescopes spaced evenly along a distance of 104 meters. Each of these telescopes in turn will have a primary mirror 8 meters across, 60% larger than the 5-meter Hale Telescope atop Palomar Mountain. (See model below.)

Aside from its sheer size, the ESO proposal is notable for its "thin-meniscus" approach to mirror design. As the name suggests, each mirror will be only a few centimeters thick to save on weight and materials cost. In effect, it will be an 8-meter-wide membrane of glass. To keep its optical surface accurate to a fraction of a micrometer, meanwhile, a set of piston-like supports on the backside will push and pull at the membrane under the control of a computer, always applying just enough force to balance the distorting effects of gravity as the telescope tracks the stars. The thin-meniscus technology has already been demonstrated in ESO's 3.5-meter New Technology Telescope, which is scheduled for completion at La Silla this year.

Another notable feature of the design is the use of inflatable domes made of fabric, instead of the conventional telescope buildings made of steel and concrete. The inflatable structures will fold down to leave the telescopes completely open to the night air during observations, thereby eliminating the troublesome thermal effects associated with fixed buildings.

Still a third notable feature of the design—in fact, the most obvious thing about it—is the fourfold duplication of the telescopes. For many observations the instruments will be pointed independently, as four separate 8-meter telescopes. For other observations, all the telescopes will be pointed at the same object, and their light combined to produce a fourfold increase in collecting area. The facility will then become the equivalent of a single 16-meter telescope.

And in a third mode, finally, ESO astronomers will point all four telescopes at the same object and attempt to combine their light in phase. This will be difficult and ambitious in the extreme. But if it works, the facility could achieve angular resolutions on the order of milliarc seconds, sufficient to see fine details in the turmoil of matter around newborn stars, or to study the dynamics of galactic nuclei. ■

M.M.W.

* Belgium, Denmark, France, West Germany, Italy, the Netherlands, Sweden, and Switzerland.


European Southern Observatory