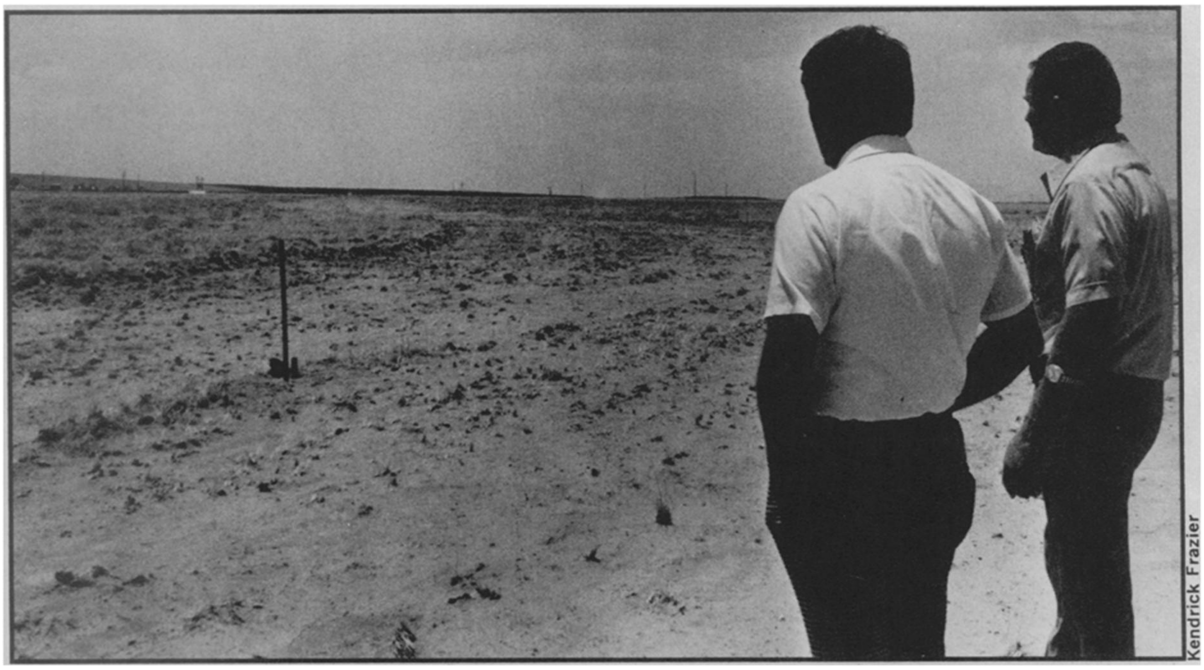
FUTURE WORLD CENTER OF RADIO ASTRONOMY

With 27 85-foot antennas spread out over miles in a Y-shaped array, the VLA will revolutionize radio astronomy

by Kendrick Frazier



Kendrick Frazier

From grama grass to advanced observatory: Egler and Wells look over path for southwest arm of array.

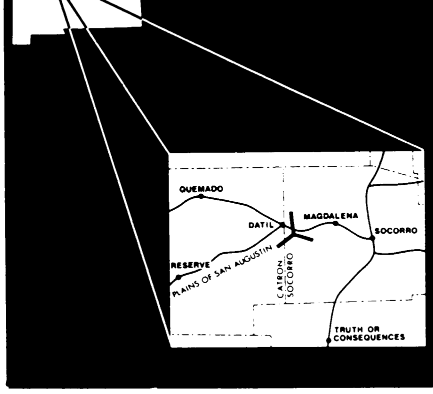
The high, dry plains of western New Mexico, rugged, lonely, silent, betray no hint of their future role as the world center of astronomy's search for the radio sounds of the universe.

A visitor driving on U.S. Highway 60, 20 miles west of the old cattle-drive and mining town of Magdalena, N.M. —an area of broadly rolling semiarid terrain marked only by an occasional windmill and ranch house—turns south onto state road 78 to confront a sign that warns: "Next food and gas 63 miles." Two miles farther one turns west along an old abandoned road, stops to open a barbed-wire cattle gate and soon pulls up at a white trailer set on the sandy soil a few dozen yards from a waiting armada of giant, yellow earth-moving equipment.

It was the morning of June 24, the day before construction began on the largest and most sophisticated system of radio telescopes ever to be erected on earth.

Here, at the eastern end of the broad, 7,000-foot-high Plains of San Augustin, a former Pleistocene lake bed, will be built the world's foremost center for radio astronomical observations of the universe—a mobile network of 27 huge dish-shaped antennas, each 85 feet wide, arranged in the shape of a "Y" across a 26-mile-diameter area. All the antennas will be linked by double-line railway microwave waveguides and central computer.

It is the long-dreamed-of, if prosaically named, Very Large Array (VLA) radio telescope.



Drawings: NSF

Site is 50 miles west of Socorro, N.M.

"I believe this instrument is going to revolutionize radio astronomy," says David S. Heeschen, director of the National Radio Astronomy Observatory.

Heeschen has been involved with the VLA since 1961. That's when the first discussions began that led to the concept of the VLA. "I'm very pleased that it is now finally funded and under construction." The VLA will be administratively part of NRAO, whose major radio facilities now are at Green Bank, W. Va.

"This antenna system . . . will be by far the largest and most advanced radioastronomical instrument ever constructed," reported the Astronomy Survey Committee of the National Academy of Sciences in 1972. "Such a giant step in capability will certainly produce major discoveries and surprises that cannot be predicted."

The committee regarded the construction of the VLA the single most-important program to be carried out in astronomy in the United States in the next decade.

The basic idea behind the VLA is that

the signals from an array of radio telescope antennas spread out over miles can be combined electronically to produce as detailed a picture of the object as a single antenna as large as the entire array. Thus the VLA will produce the equivalent of a radio ear roughly 26 miles in diameter.

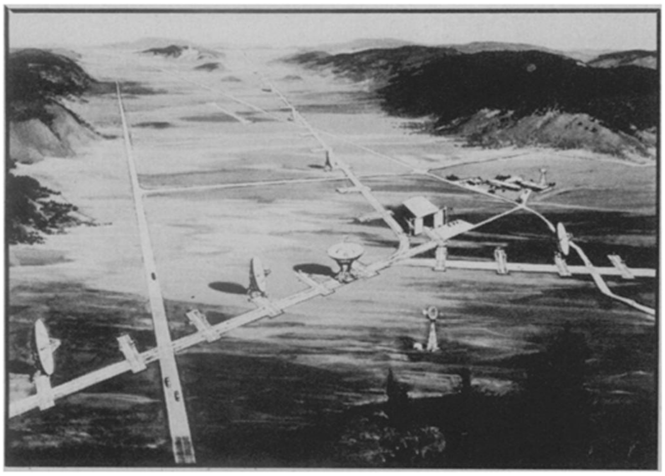
The rotation of the earth will cause the Y system to rotate relative to the sky, allowing a complete radio "scan" to be made of a celestial object in 8 to 12 hours observing time. The VLA should be able to take radio pictures of astronomical objects comparable in sharpness to the optical pictures taken by the 200-inch telescope on Mt. Palomar.

"The sensitivity and resolution are going to be unmatched anywhere," says Heeschen. The jump in sensitivity will allow the VLA to observe the universe to great depth, and the jump in resolution will allow it to see objects with unprecedented clarity.

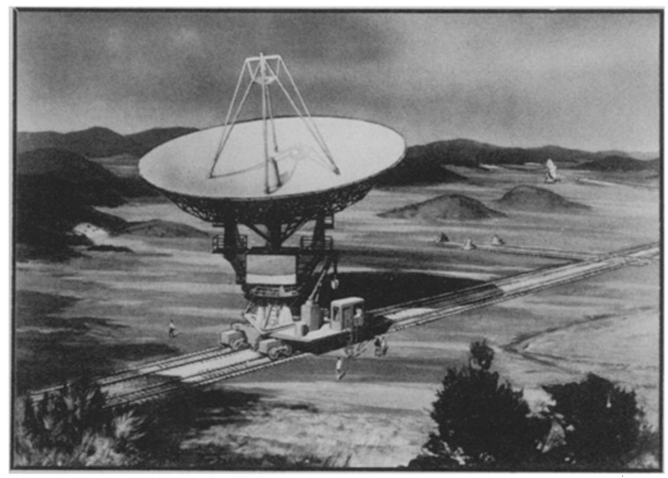
"Such an instrument," as the NAS survey committee put it, "can break through existing observational barriers on a broad front and reveal important new lines of inquiry." The array should be able to make detailed pictures of radio galaxies and quasars, both violently explosive objects of great interest to astronomers. The array's narrow beam and large collecting area will enable it to distinguish large numbers of point sources from one another, a capability needed in cosmology to help decide among different models for the origin of the universe. The VLA should provide the first information on the continuous radio emission of many normal stars, a type of observation now possible only with our own star. The array should give the first clear picture of the nucleus of our galaxy, where violent events have strongly influenced galactic evolution. It should also produce pictures of the gas clouds of our galaxy in such detail that the processes of heating, cooling and collisions taking place within them should be discernible.

In planetary astronomy, the VLA should be able to distinguish detail in the radio emission of all the planets except Pluto, enabling their temperatures to be established for various latitudes, times of day and seasons. And it should provide information on the atmospheres and surfaces of the planets.

If the flow of funds from Congress to the National Science Foundation for the $76-million project continues no slower than expected, the system should be in limited operation in 1976 and in full operation in 1981. (Only half the desired first-year start-up money was appropriated last year, but this year's requested funds seem to be encountering no obstacle.)



The Y-design concept, a 13-mile arm extending to horizon.



Transporters will move 214-ton dishes on double railroad.

Associated Universites Inc., the consortium of nine universities that operates NRAO, will build and operate the VLA, under contract from NSF.

For the site, astronomers needed a high-altitude, broad, flat, low-radio-noise valley of some 3,500 acres that offered protective mountains and a low water-vapor content in the atmosphere. (Water vapor causes phase fluctuations in incoming radio signals.) The site west of Magdalena chosen for the VLA satisfies all those requirements.

One can stand above a small, round metal surveyor's marker designating the exact center of the array's Y and look out over a scene that is typically western in expanse and color. Everywhere are clumps of yellow-brown grama grass, parched in the summer sun. Well off into the distance, 12 to 20 miles in all directions, a series of low-lying mountains surround the area, rising 2,000 to 3,000 feet above the plains. And above it all is the deep blue New Mexico sky, flecked with a few clouds of fair-weather cumulus.

The area receives an average of 12 inches of precipitation a year, easily enough to avoid considering it a desert. But as construction got underway in late June, no significant rainfall had fallen since October, and site engineer Forrest Wells and construction engineer Emory Egler were looking forward to some relief during the "rainy season," the afternoon thundershowers of July and August.

As the earthmoving machinery waited to move into action, the only sign that something big was in the works was a broad, rough roadway, scraped out of the loose soil. It extended from near the center marker of the array far to the southwest, clear over a low hill on the horizon. This is the path of the southwest arm of the telescope array, and it's the one on which construction is being done this year. The southwest and southeast arms of the Y will extend 13 miles each and the northern arm, 11.8 miles.

During the next six months, the first three miles of railroad embankment will be built, the first one mile of double railway trackage laid and six antenna foundations and their links to the railroad tracks constructed.

Later this year a 100-foot-high antenna assembly building will be erected alongside the southwest arm. "That'll sure change the skyline here," notes Egler. Soon thereafter, the first of the 27 85-foot-diameter parabolic antennas to be used by the VLA will begin emerging from the building, like some mechanical Brobdingnagian giant, moving slowly along its own railway spur to connect with the main southwest arm. The assembly building will remain as a permanent maintenance facility for the antennas after the entire array is in operation.

By mid-1976, a mile-long section with an antenna at each end should be completed and tested, and astronomers can begin operational use of that part of the system. Actually, testing of the first two antennas is to begin by the summer of 1975. "And if you know astronomers," says Claud M. Kellett, project officer for the VLA at the National Science Foundation, "you know they'll

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find a way to get some useful scientific observations out of the tests."

The enormous weight of the antennas (214 tons each) and their diesel-electric transporters (70 tons) will be distributed across two sets of standard railroad tracks, separated by an 18-foot distance between their centerlines. If it is an irony that the antennas of the most sophisticated radio astronomy observatory in the world will be moved about on railroad tracks, it is further irony that the tracks, and the ties on which they will rest, will be not new, but used. The prices of new timber ties and railway-track steel have skyrocketed in the past year or two. So VLA officials have been scrambling to obtain what they need from no-longer-used railroads on military bases and other government facilities.

The sprawling array will cross ranch property boundaries, one county line and U.S. Highway 60. A standard railroad crossing will be built where the northern arm goes across the highway. When the antennas are moved into various configurations along the array, they'll occasionally have to cross the highway, creeping along at rates of 5 miles per hour. "There's a clear view for 10 miles in either direction so there shouldn't be any problem," says Wells. "But," adds Egler, "I sure bet we see some surprised motorists."

The antennas will make their observations not from the main tracks, but from permanent observing stations, 100 feet off to the side, connected by spurs perpendicular to the main railway. This will leave the main tracks free to carry personnel and maintenance equipment and alleviate the need for access roads. There will be 72 of these observing stations, giving astronomers great flexibility in positioning the 27 antennas. Each station will have three foundations, one for each leg of the antenna. The foundations are meant to prevent overturning of the antennas and to support them in a precisely fixed position.

Every antenna could be moved to a new position within 48 hours, according to Wells. Since only one antenna will be moved at a time, observations can proceed without interruption.

But it will be seven more years before all the construction and testing is completed and astronomers are making full operational use of all antennas at once. The construction is not all that difficult, but the funding is being spread out over a number of years so that the chunks of money required from any given budget year are smaller. Loyal engineers, Wells and Egler fully understand the budgetary realities, but they can't disguise a certain wistfulness about the length of time required. Says Egler: "If we had all the money at once, we could finish this up in two years." □

. . . Seeing *(from p. 133)*

If there are 25 elements in the corrector, there is less than a millisecond to adjust each one since the turbulence changes about every 20 milliseconds. Yet Muller and Buffington think it can be done.

Itek's RTAC is in essence a rubber mirror. The basic element is a piezoelectric crystal. When a voltage is applied to a piezoelectric crystal, it can be made to expand or contract. The crystal has independent electrical connections for each two seconds of arc across its surface. Thus each element of that diameter can be individually squeezed or expanded. The surface of the piezoelectric crystal is covered with a thin layer of aluminized glass to do the actual reflecting.

The deformable RTAC mirror deforms according to instructions given by a shearing interferometer that makes an instantaneous map of the wavefront as it enters the telescope. RTAC is a reimaging device that can be mounted on an existing telescope and will work on the light reflected by it.

A laboratory model of RTAC now exists and has done well in tests on artificially degraded images. Within the year Hardy and collaborators hope to try it out on actual stars. It is expected to be useful for objects as faint as 10th to 12th magnitude.

These are only a few of the projects intended to help astronomers with their seeing difficulties. Success would remove a serious age-old frustration. Astronomers' feeling about it is exemplified in the tone of Stachnik's voice when he says of RTAC: "They show an image of a star distorted. They flip a switch, and the image shrinks to a little dot." □

. . . Infrared *(from p. 135)*

advantage is that radio receivers are more sensitive to amplitude and frequency differences than infrared ones at present. Heterodyne techniques have also been tried in infrared interferometers. Testing with artificial light sources indicates that one can get interference fringes this way. The actual spacing between the two telescopes that would be set up in a working model is still a matter of controversy.

Given the techniques now available, what do you see? Starting near home, infrared can be used to study the atmospheres of the planets. Take Mars for example. Infrared confirms that carbon dioxide is there. Infrared can be used to study the temperature of the Martian atmosphere as a function of height above the surface and pressure. This is one way to measure variations in the height of the surface.

The same can be done for other planets. Work on the pressure and temperature of gases on Jupiter has only recently been done. Among other things it found a lot of ammonia there.

By knowing the detailed structure and activity of other atmospheres planetary scientists can come to understand the earth's better. The atmosphere of Venus is 100 times as heavy as the earth's; that of Mars one hundredth as heavy. Scientists cannot experiment on the earth's atmosphere by, say, heating it up 50 degrees and seeing what happens, but by observing the atmospheres of other planets they can see some of what the possible effects of changes in our own might be.

Further out in the galaxy the beginning and the end of a star's life provide circumstances where infrared observation is especially valuable. Dust clouds appear to be the places where stars are born. "One can see through them in the infrared," says Rank. "It's impossible to see through them in the visible." The temperature of the dust is characteristically anything from 150 to 300 or 400 degrees K.

In the clouds one sees relatively warm objects that are totally invisible optically. These are presumably the spots where dust and gas are condensing into stars. The infrared observers want to study the time scale of star formation and the mechanisms by which it occurs.

Toward the end of its life a star may puff off a cloud of gas which forms a dusty, gassy halo around the star. How the dust gets formed presents astronomers with a chicken-or-egg problem, says Rank. Dust particles don't like to form unless there are other dust particles around, but somehow the process has to get started.

Once the dust forms, infrared astronomy can study its chemical composition. One finds calcium carbonate, silicates (sand), ordinary minerals. The dust is similar to rocks on earth. "It's interesting to know that that's the way it is," says Rank.

To further universalize chemistry—to prove that the far reaches of the universe are made of stuff much like that in our corner of it—one can study the chemistry of distant galaxies. Infrared will prove a useful medium in this endeavor.

Finally there are the now famous—and strange—infrared sources in the centers of galaxies. One question to settle, says Rank, is whether the sources are really in the centers or whether it just looks that way. Of course the big question is: What are they?

And who knows what new species of infrared-emitting object may be discovered next week. The universe, seen and unseen, is full of many more kinds of things than Horatio's philosophy ever dreamed of, and one has to watch closely to keep up with the astronomers as they discover them. □