The Large Millimeter Telescope

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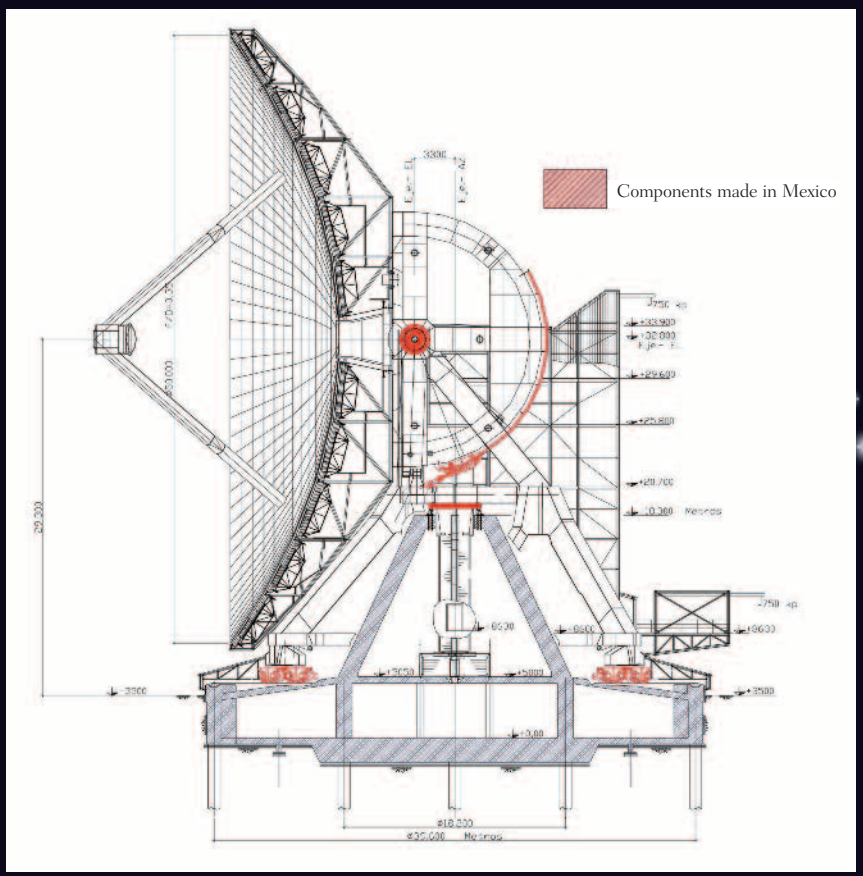

Courtesy of Alfonso Serrano

Diagram of the telescope.

People have been watching the skies since the great ancient cultures inhabited Mexico thousands of years ago. When the Spaniards arrived, these cultures had a more precise calendar than the Europeans. Today, a group of Mexican scientists has achieved world status in astronomy.

One of the most important prerequisites for bringing together a high-quality group of scientists is international collaboration; this makes for great demands in both learning and performance. Mexico has benefitted from the generosity of U.S. astronomers, who throughout the twentieth century contributed to the education, training and the development of infrastructure for astronomy in our country.

With this background, it is easy to understand why today, at the beginning of the twenty-first century, Mexico and the United States are involved in an unprecedented scientific adventure: the construction of an instrument that will revolutionize our understanding of the universe.

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The Large Millimeter Telescope
Origins and Scope

The idea of the large millimeter telescope (LMT), the most ambitious scientific project in the history of Mexico, was born in 1988 during a bilateral discussion in a Mexico City hotel. After a long process of national and international evaluation that concluded in November 1994, a binational project was approved, headed by Mexico's National Institute of Astrophysics, Optics and Electronics (INAOE) and the United States' University of Massachusetts.

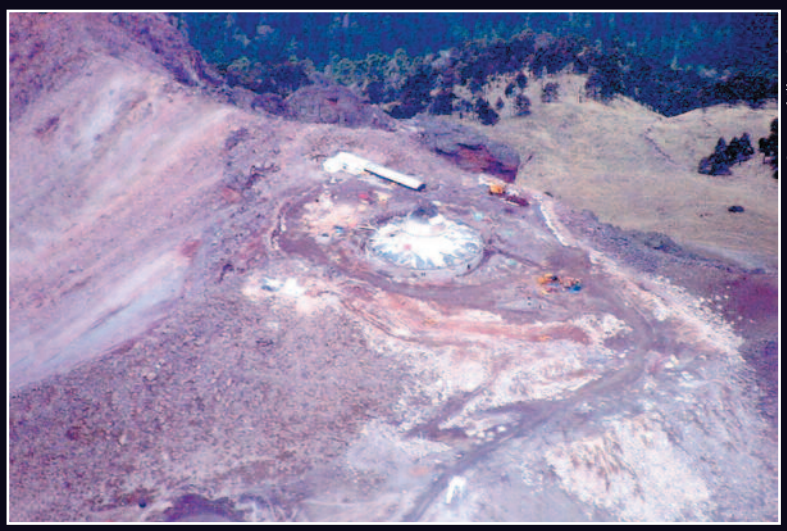
The design of the telescope, the largest of its kind in the world, began in 1995 with the author of this article as Mexico's principal researcher on the project. Today, construction is very advanced, in the stage of assembly at the site, the Tliltépetl, or "Cerro de la Negra" in Puebla, at an altitude of 4,600 meters. It will begin operations in 2003. The work that has gone into the project represents a considerable investment, half of which has come from the U.S., and has had important scientific, educational and technological consequences for Mexico and for our bilateral relations. It will be used by the world's best astronomers and will give Mexican astronomy a big push forward. Even before the telescope is in operation, it has already been the reason for visits by first-rate astronomers who see it as a developmental opportunity that exists in few institutions worldwide.

This telescope will be Mexico's first world-class scientific instrument. There is nothing in the world like it. Its manufacture has created a series of technological challenges that are being met for the first time in history. Across its 50-meter diameter (with nearly 2,000 square meters of reflecting surface), it must be perfect within a fraction of a millimeter, which means that innovative systems of control of an intelligent surface must be used. At the same time, its 2,000 tons of steel must move with the precision of a Swiss watch.

The description "millimeter" refers to the kind of light it can capture, the light in the color of millimeters located between infrared and

Courtesy of Alfonso Serrano

The finished cone.



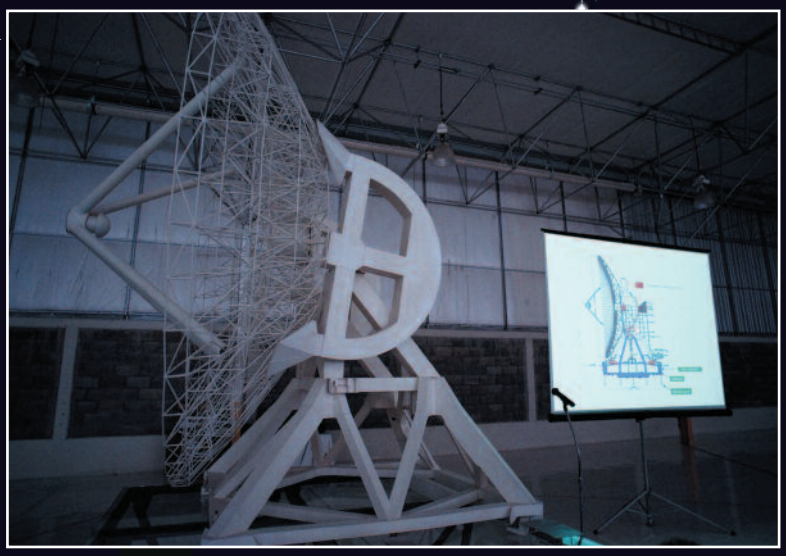
Courtesy of Alfonso Serrano

Aerial view of the construction site.

Antonio Nava/AVE

Lower part of the plate.

Antonio Nava/AVE



Model of the telescope.

Antonio Nava/AVE

Lower part of the alidade.

Antonio Nava/AVE

Carbon-fiber factory prototype of the mirrors.

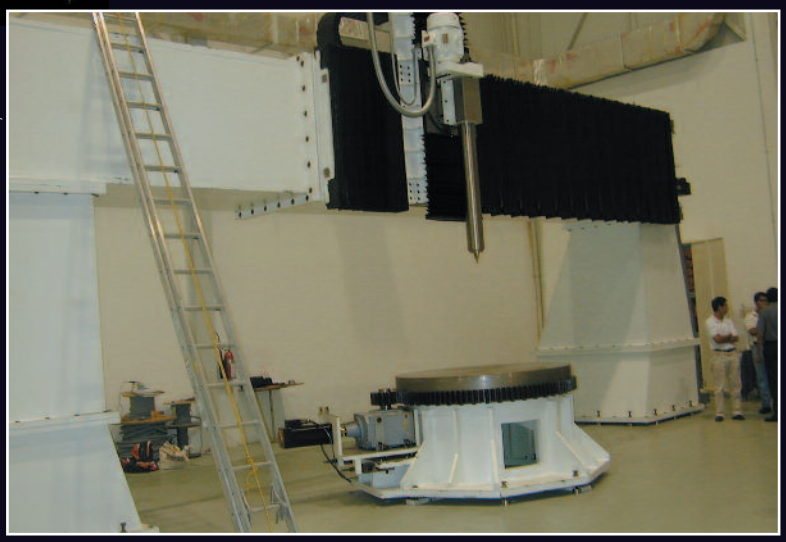
microwave colors, all of them invisible to the human eye; this, of course, will open up a new window to the universe. In this color of light, we will be able to observe the rotation of all the molecules as well as the objects that have changed color due to the expansion of the universe. Thanks to this, we will be able to study asteroids, comets, planets, molecular clouds and their chemistry, the regions of star formation and the spiral arms of the galaxies. But, above all, we will be able to observe that first age of the universe, just after the big bang, when the first stars and galaxies were formed.

Impact on Education and Technology

Two doctorate programs of excellence have been developed because of the LMT project: one in astrophysics and the other in electronics, today among the country's most important. More than 100 students, both from Mexico and abroad, have already gotten their degrees in these areas. Today we also have a group of specialists in high frequency communications that did not exist when the project began.

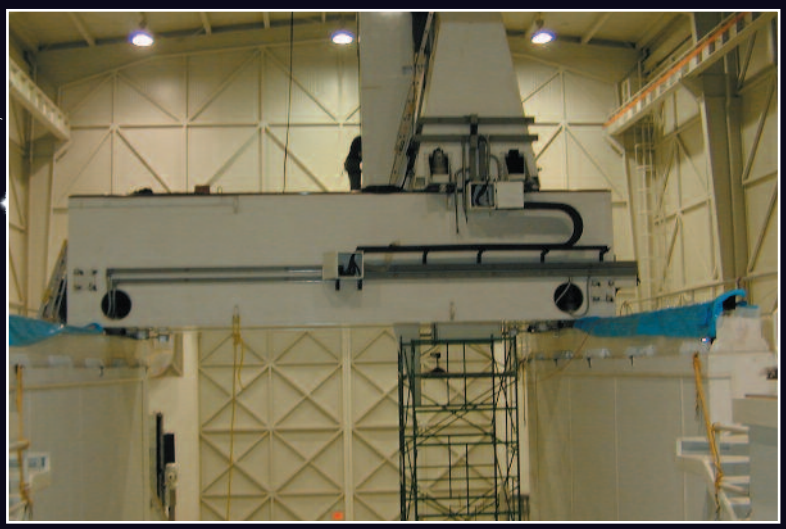
A binational team has also been formed with the participation of a large number of national public higher education and research and technological development institutions. Among the Mexican institutions are the National Autonomous University of Mexico, the University of Guadalajara, the Autonomous University of Puebla, the Technological Institute of Puebla, the Center for Scientific Research and Higher Education of Ensenada, the Center for Research and Higher Education in Social Anthropology, the Mexican Corporation for Research in Materials, the Center for Research in Advanced Studies, the Center for Advanced Technology, the Center for Optics Research, the National Metrology Center, the Institute of Ecology and the Center for Scientific Research of Yucatan. Among the international collaborative projects is the work to develop advanced two-dimensional detectors with Caltech and the measurement designs

Courtesy of Alfonso Serrano



Polisher for building molds.

Courtesy of Alfonso Serrano



Machine for measuring coordinates.

Courtesy of Alfonso Serrano

Rails made in Vatech, Morelia.

studied by some national laboratories in the United States.

This project has required the most advanced techniques and the participation of companies able to manage and develop cutting-edge technology. During the process of the telescope's design and construction, we have benefited from the advisory and consulting services of experienced engineers and scientists from different institutions throughout the world, including the National Aeronautics and Space Administration (NASA).

More than a hundred contracts for design, technical services supplies, manufacture and civil engineering have been bid for and signed: two German, three U.S., one Dutch and several Mexican companies have participated, with 82 percent of the investment in pesos. This will promote Mexican industry, helping it to compete internationally. Infrastructure that had not previously existed in Mexico has already been created for measuring coordinates and polishing of surfaces, which will have significant applications in the auto industry.

This project has led to the creation of the country's most important microwave laboratory where prototypes for high-frequency microwave circuits can be designed, characterized and built. These waves are used to transmit high volumes of information at high speeds. The current market for communication equipment for this kind of microwaves is close to U.S.$12 billion a year. In this lab, human resources unique in Mexico are being forged, working for science and industry.

A strategic binational alliance among companies has led to the establishment of Mexico's first carbon-fiber components manufacturing industry, creating jobs at the same time.

The new capabilities of the National Institute of Astrophysics, Optics and Electronics (INAOE) have prompted its linking up with the private, public and social sectors, resulting in the creation of electronic water meters, computerized stoplights, security systems, pointing systems, hearing aids, satellite receivers for education and high-frequency radios, among other projects.

Courtesy of Alfonso Serrano

Digital illustration of the telescope.

The institutional development that this project has involved has set the basis for Motorola company creating two research and development centers in Puebla —one in microelectronics and the other in software development— thanks to the human resources trained by INAOE.

Brilliant Binational Collaboration

This project is an example of the fact that in the complex interaction between Mexico and the United States, not everything is a problem: areas of opportunity exist in which the bilateral relationship can be not only mutually beneficial, but can also give both countries a competitive advantage vis-à-vis the rest of the world.

Thirteen years after the first discussions about the telescope, we can say with great pride we have overcome the tremendous obstacles that we met on the way. The first of them, on the Mexican side, was the need to absorb the meaning of setting ourselves the goal of an ambitious, world-class project and meeting the capabilities and performance requirements that this implies. We have also had to learn to work binationally, not an easy task taking into consideration the great cultural differences between our two countries: we had to develop mutual trust and learn to make joint decisions. We had to learn to manage a far-reaching project, with six different funding sources, each with its own rules and limitations. Also, to make the most important decisions, we have had to learn to get advice from the people with the most experience and ability in the world. An entire generation of Mexican engineers has been educated together with this project and in conjunction with outstanding international companies. Mexico's own companies have had to meet quality requirements that they had not previously been used to. We scientists have had to learn to work with engineers, and the engineers with scientists; research centers have had to learn to work with private companies, and the companies with the centers.

The large millimeter telescope is a project that has very effectively combined basic and applied science, specialized training and technological impact. Even though its most important effects will be felt in the future, it is already a matter of pride for Mexican science and engineering and a brilliant example of binational collaboration.