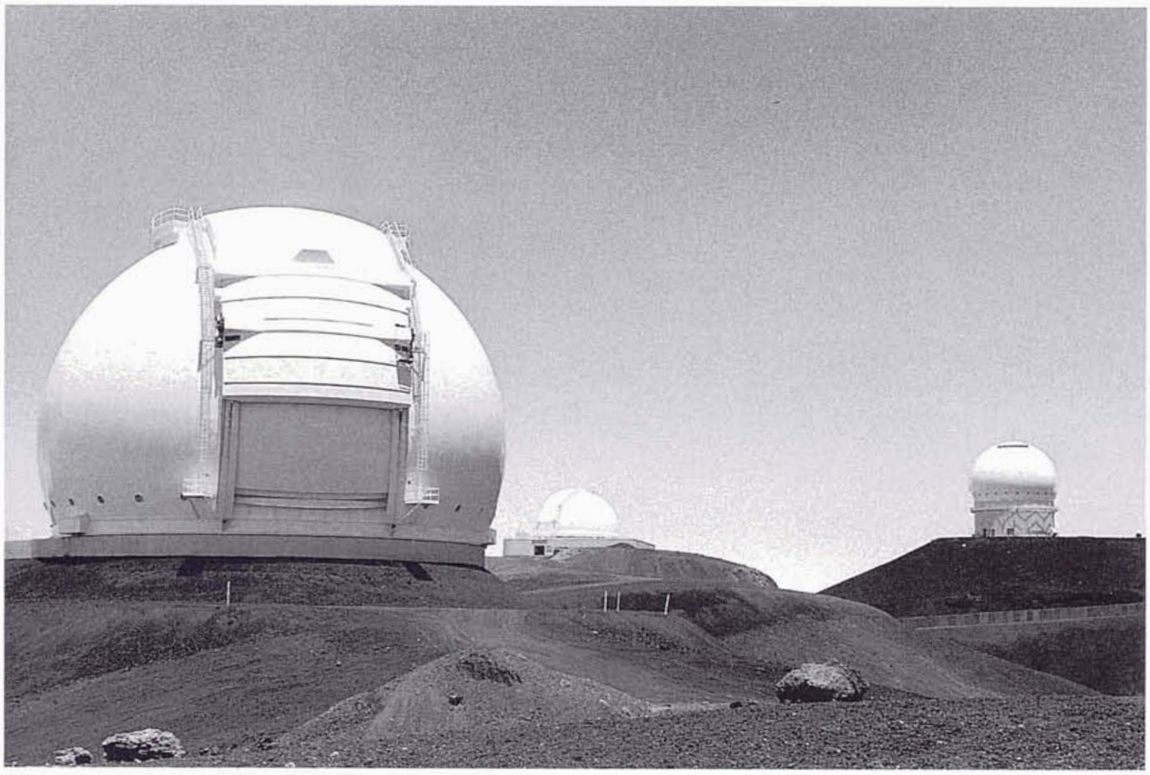
# CATALAN TECHNOLOGY IN THE KECK TELESCOPE



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THANKS TO ITS HIGH POWER OF RESOLUTION, THE NEW KECK TELESCOPE WILL MAKE IT POSSIBLE TO OBSERVE OBJECTS FARTHER AWAY IN TIME AND FIND OUT MORE ABOUT THE FORMATION OF STARS AND GALAXIES. SEVERAL CATALAN RESEARCHERS WERE ON THE TEAM RESPONSIBLE FOR DESIGNING ITS CONTROL SYSTEM AND THE CONSTRUCTION OF ITS COMPLEX MOBILE STRUCTURE CARRIES THE NAME OF A FIRM IN OUR COUNTRY.

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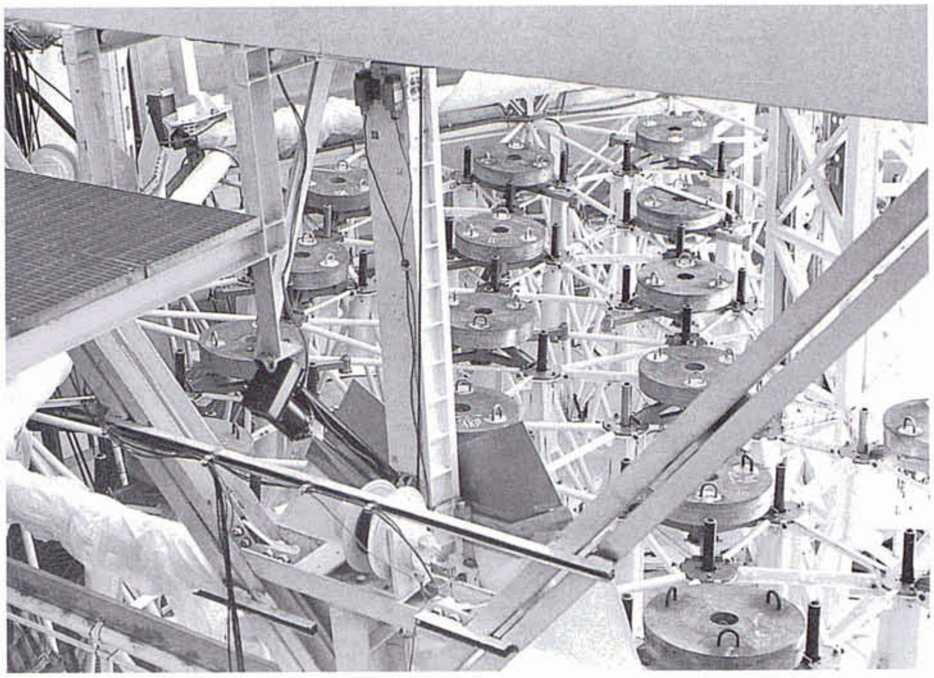

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The observation of astronomical phenomena is one of the oldest-established scientific activities. In fact, we know of work carried out since the remotest times and in all cultures. At the beginning of the seventeenth century, Galileo built a primitive instrument which, with an aperture of three centimetres, was able to spectacularly increase the number of objects that could be detected. Progress in observations has been enormous, starting with the early discoveries of planets and their satellites in our solar system, to the quasars, pulsars, gravitational lenses, colliding galaxies and clouds of dark matter it has been possible to observe through the use of telescopes operating in different parts of the spectrum, from X-rays to optical, infra-red and ultraviolet spectra. But these improvements in our knowledge of the universe still leave a series of basic questions unanswered, chiefly those that refer to the formation of stars, galaxies and other astronomical phenomena. The new instruments have made it possible to find new answers and to confirm or reject theories, thanks to the use of advanced technology systems. This success set off a whole series of improvements in these instruments, which gave way to the design of bigger and bigger and more and more powerful optical telescopes.

At each step, all the available technological resources have been stretched to the limit of their possibilities.

Developments in the design of traditional optical telescopes reached its peak with the construction, halfway through this century, of the Hale telescope on Mount Palomar in California. Its principal characteristic is that the primary reflector is monolithic; it measures five metres in diameter, is seventy centimetres thick and weighs twenty tons. As the telescope has to be directed at different points in space and has to compensate for the Earth's rotation so as to be able to accurately observe "fixed" points in space, the reflector's supporting structure is very heavy and rigid. The weight of the mobile part (reflector, tube, support, rotational and tube inclination system) reaches 500 tons.

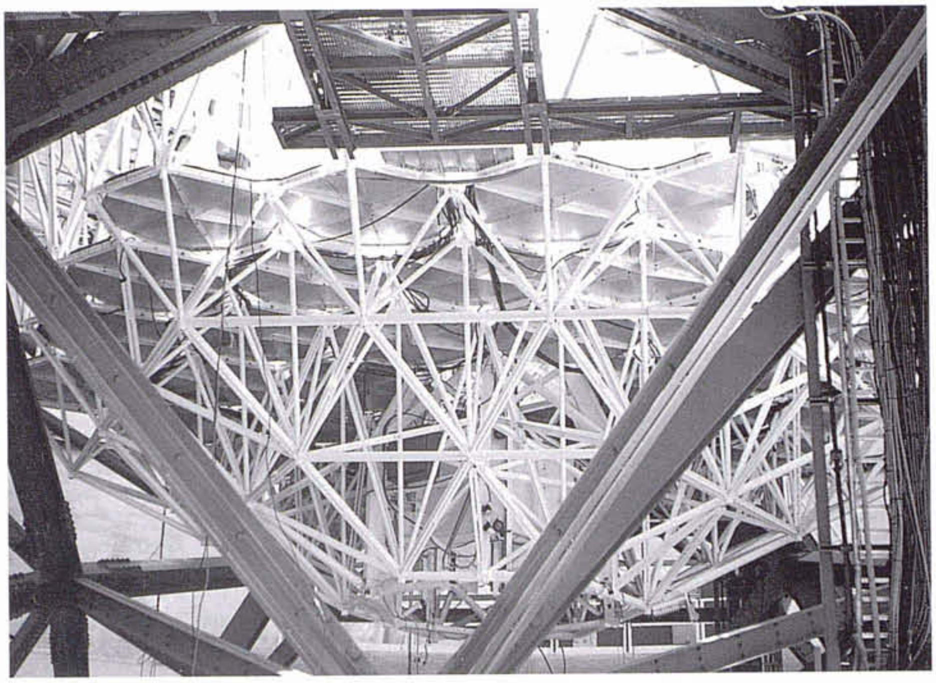
After this telescope it became clear that to build larger and more powerful telescopes a new design would have to be found that would allow us to overcome the previous technological barrier, since doubling the diameter of the reflector following the same structure would multiply the weight of the mobile part by eight. This, then, is how the new generation of telescopes came about, the aim of which is to have mirrors that are larger but not so heavy. The W.M. Keck telescope is a perfect example of these new instruments.

Because of the need to reduce the weight of the mobile structure, the step was taken of dividing up the ten metre diameter reflector into a reticle or mosaic, made up of thirty-six hexagonal segments each two metres in diameter and seven and a half centimetres thick.

The choice of these characteristics was made in the hope of reaching a compromise between ease of manipulation, construction, the complexity of the supports and the cost of the segments, which improve as their diameter diminishes, and the complexity of the control, which increases with the number of reflectors. These segments have to make up a parabolic surface turning on the telescope's axis and with a very high degree of precision.

The reflector's supporting structure was constructed with a network of rigid bars, using computer-assisted design (CAD) systems, in such a way as to minimize the weight of the system and maximise resistance to deformation. The result of this design is a reflector weighing 15 tons, while the total weight of the mobile section is 270 tons.

The job of building this structure was given to the Catalan firm Schwartz-Hautmont, in Vilaseca-Salou, who have considerable experience in the construction of metallic structures for such applications as, amongst others, large-



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scale transmitters. This firm, using an automated system of assisted manufacturing design, produced all the pieces for the structure, tested them and checked their operativity. Then they were sent to Hawaii, to the observatory on the top of a 4,200 metre extinct volcano.

However, the challenge is not only in the structure. The dynamic control system and the position of the segments have to ensure that errors are negligible if the observed images are to be of sufficient quality. Since mechanical deformations can reach one millimetre and the tolerances of the optical surface must be less than fifty nanometres, there had to be an automatic system of sensors that would at all times measure the position and inclination of each of the mirrors, a control algorism to interpret the sensor readings and determine how the segments ought to be positioned and activators to move the segments into the desired position. This system of control uses the measurements from the 168 position sensors installed in the segments and sends instructions to 108 motors, which move each of the 36 segments individually.

The computer support for the dynamic control system is made up of a multicomputer consisting of twelve high-speed processors working in parallel, nine of which carry out the preliminary treatment of the signals from the sensors and condition the instructions to the activators, while the other three carry out the work of computing the control algorisms, communicating with the telescope operator, supervision and co-ordination of the control work.

The job of designing this control system was given to the University of California's Lawrence Berkeley Laboratory, where a team of engineers and technicians developed the computer system and the control programmes. Two Catalan scientists were involved in this work, Dr Jordi Llacer, a physicist at the Lawrence Berkeley Laboratory, and Dr Josep M. Fuertes, an engineer at the Universitat Politècnica de Catalunya taking part in the Gaspar de Portola programme for scientific co-operation between Catalan universities and the University of California. The contributions these scientists have made to the telescope have been, amongst other things, in the studies of the dynamic behaviour of the active control system of the telescope segments and in the evaluation of results as regards the design specifications.

The observatory's official inauguration took place before the end of 1991, when its first light was presented, although only nine of the thirty-six segments needed to complete the reflector were in place. With this arrangement, though, the collector surface was already the same as that of the Hale telescope. It is foreseen that the remaining segments will be fitted during the course of this year and it will then be possible to make an experimental evaluation of the results of these new designs and technologies. The results obtained so far have been such that the construction of a twin telescope has been financed, to be installed on the same volcano of Muna Kea, in Hawaii, less than 200 metres away. Furthermore, a European consortium has started the work of designing a fifteen metre telescope based on a similar segmentation of the primary reflector.

The telescope will be used with scientific objectives relating chiefly to current cosmogonic theories. Its high power of resolution will make it possible to observe objects that are farther removed in time, find out more about the formation of stars and galaxies, analyse the activity in the centre of our Milky Way and observe very faint objects. The results obtained from these observations will foreseeably motivate increasing improvements in our own world, and at the same time will serve to consolidate the technological advances developed in the design and construction of this instrument. ■