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REPORT ON CONSTRUCTION OF THE CANADA-FRANCE-HAWAII TELESCOPE†

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Abstract

The general features of the Canada-France-Hawaii Telescope, its dome and site are described and a report is given of the progress made on the project up to the end of 1976. Construction of the dome on Mauna Kea has been completed and manufacture of the telescope is well advanced. If the current schedule is maintained, first observations with the 3.6-metre telescope will be made towards the end of 1978 or early in 1979.

Introduction. In May, 1973, the Canadian Government announced that it had approved participation by Canada with France in the construction of a large optical telescope on the summit of Mauna Kea in Hawaii. Now, some three and a half years later, construction of the 3.6-metre Canada-France-Hawaii Telescope is well advanced and Canadian astronomers are looking forward with excitement to the night in late 1978, or early 1979, when they will make their first observations with one of the finest and largest telescopes in the world.

The new facility is being constructed under the terms of a "Tripartite Agreement" signed in the spring of 1974 by the National Research Council of Canada, the Centre National de la Recherche Scientifique of France and the University of Hawaii. To manage the construction, and later the operation of the observatory, the three agencies decided to create a non-profit corporation, named the Canada-France-Hawaii Telescope Corporation. Established under the laws of the State of Hawaii, the Corporation is administered by a Board of Directors composed of four members appointed by NRC, four by CNRS and two by the University of Hawaii. Technical advice is provided by a Scientific Advisory Council whose members are astronomers appointed in a similar manner. The detailed design of the facility, supervision of construction and management of contracts are the responsibility of a Project Office directed by a French astronomer, Dr. Roger Cayrel, and a Canadian astronomer, Dr. Graham Odgers.

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France and Canada are contributing equally to the cost of the observatory itself, i.e. the telescope, dome and ancilliary equipment. In as equal a fashion as possible, maximum use is being made of French and Canadian industry in its design and construction. The University of Hawaii is providing the site for the telescope and providing services at the summit of Mauna Kea and will construct a dormitory and office building at a mid-level location. Users of the telescope will also have access to the computer and other facilities located at the Institute of Astronomy in Honolulu. For its contribution, the University of Hawaii will receive 15 percent of the available observing time on the telescope; Canada and France will each be entitled to 42.5 percent.

The Site. As is well known, the advantages of a large, well-constructed telescope can only be realized if it is located on the best possible site. It is for this reason that France and Canada entered into an agreement with the University of Hawaii to place the telescope at the University's Mauna Kea Observatory. The University of Hawaii has operated an 88-inch and two 24-inch telescopes there for several years and experience with these instruments has demonstrated that the site is undoubtedly an excellent one (Morrison and Jefferies 1972). Although Canadian and, particularly, French astronomers will have to travel long distances to use their telescope, the rewards, in terms of the quality of the data which they will take home with them, will make the trip worthwhile.

As can be seen in figure 1, Mauna Kea is located at latitude 20° N, on the big island of Hawaii, approximately 300 km from Honolulu, the state capital. From the port city of Hilo, the largest community on the island, the summit can be reached by road in about 90 minutes. Mauna Kea and its sister mountain, Mauna Loa, are both gigantic volcanic cones rising to a height of more than 4200 metres above the Pacific Ocean. However, unlike Mauna Loa, which is one of the most active volcanoes in the world, Mauna Kea has been extinct for tens of thousands of years. Its summit, which consists of a group of small cinder cones is desolate and devoid of vegetation of any kind. Because it was built by molten lava the mountain has extremely gentle slopes. When viewed from sea level its breadth creates the illusion that it is not very high. At the summit though, the reduced supply of oxygen makes one conscious of the altitude. Some persons, at least at first, experience considerable discomfort or are lethargic. To astronomers, however, the difficulties are more than offset by the excellence of the observing conditions. In any event, the loss of efficiency of the astronomer can, to a great extent, be overcome by the use of pre-programmed digital computers to control the functions of the telescope.

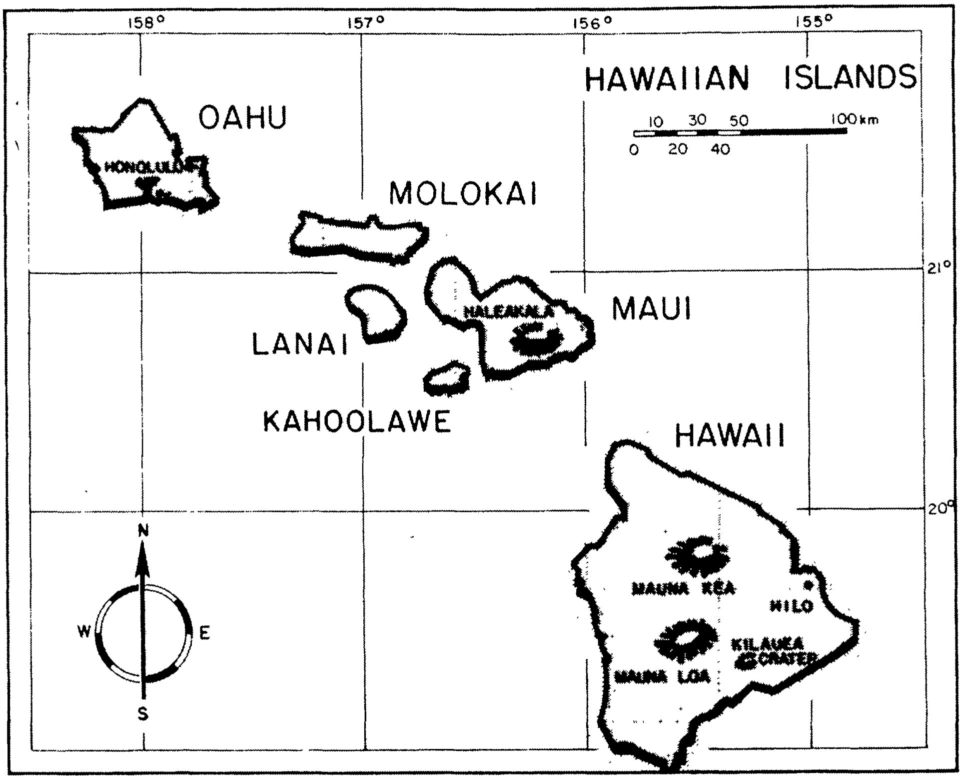

FIG. 1—A map of the Hawaiian Islands showing the location of Mauna Kea.

On most nights Mauna Kea rises well above the clouds which normally shroud its lower slopes. Although cumulus clouds often cap its peak during the day, rapid cooling of the barren terrain at sunset usually causes the inversion layer to fall and the clouds to disappear. As a result, more than 60 percent of nights are free of clouds and on these nights fluctuations in the transparency of the atmosphere are small – conditions ideal for photometric observing. An additional 10 to 12 percent of nights are useable for spectroscopic observations, which do not require such stable conditions.

For many astronomical observations the critical characteristic of a site is the quality of the "seeing". For a large telescope, this is the amount by which inhomogeneities in the atmosphere blur the image of a star. Records compiled by the University indicate that, on Mauna Kea, the "seeing" is typically one second of arc and frequently less. This compares favourably with the sites of other large telescopes, such as the ones in Chile.

Partly because of the altitude, but also because of the low density of population on the island, the sky as viewed from Mauna Kea is very dark. Since clouds normally obscure the settlement at sea level, light pollution is not expected to be a problem for the foreseeable future.

Because atmospheric water vapour is concentrated in the lower levels,

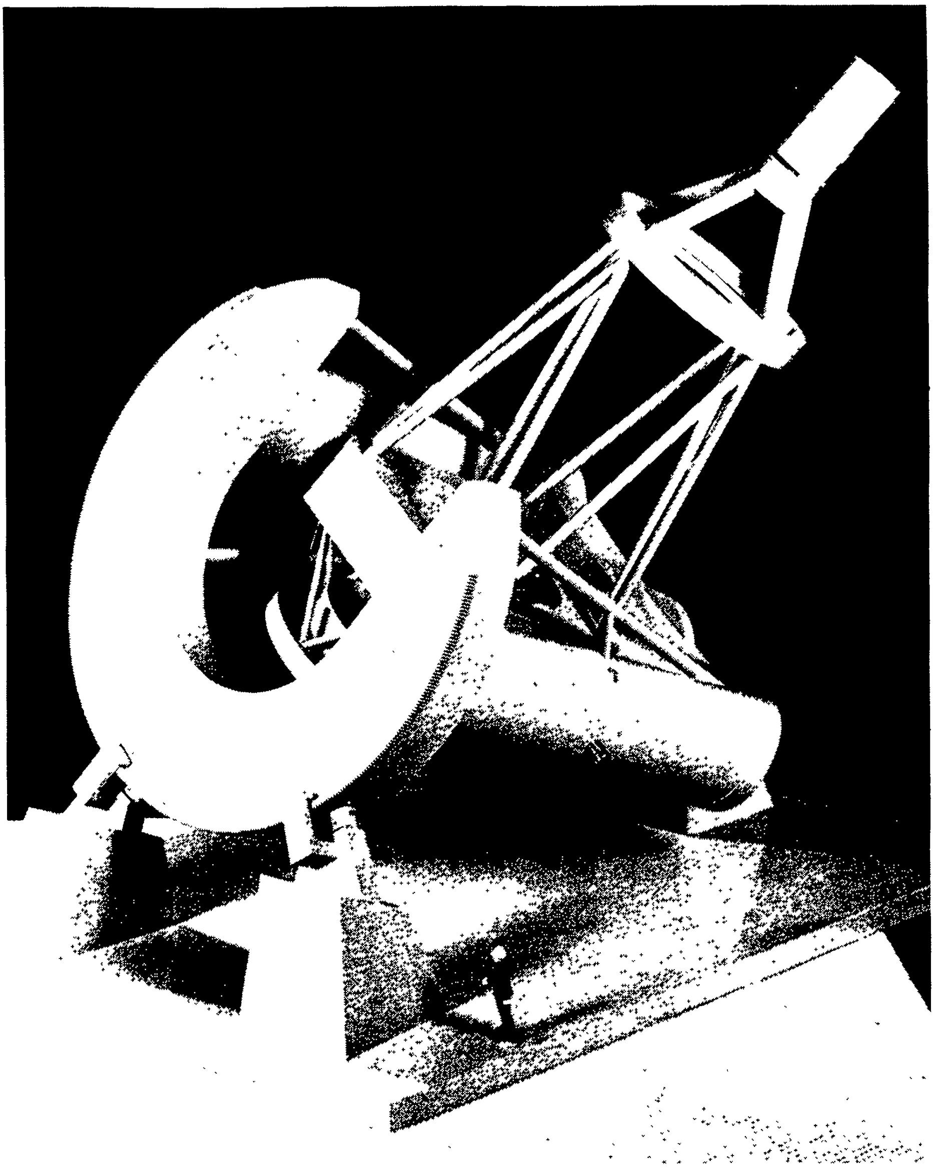

FIG. 2—Photo of a scale model of the Canada-France-Hawaii Telescope with the prime-focus observing cage installed.

the air above a high mountain is normally very dry. Measurements indicate that on clear nights the precipitable water vapour in a vertical column of air above the summit of Mauna Kea is less than a millimetre, whereas at sea level the amount is typically 10 millimetres. Since water vapour is the main source of infrared absorption in the atmosphere, the site is an excellent one for infrared observations. To take advantage of this feature of the site, the C-F-H Telescope will be equipped to make observations in the infrared, as well as the optical, region of the spectrum.

FIG. 3—The mechanical parts of the telescope being assembled at La Rochelle, August 1976. The structure was later enclosed by an inflatable building.

The Telescope Mounting. The mechanical design of the C-F-H Telescope (figure 2) is similar to the familiar Hale Telescope (the 200-inch telescope on Mt. Palomar) but there are three important differences. The first is that the portion of the telescope tube which carries the secondary optics can be removed and replaced with another. This makes it possible to provide, in a single telescope, a variety of optical configurations. Initially, there will be three interchangeable upper ends: one will carry the prime-focus observing cage and coudé secondary mirrors, a second will carry the secondary mirror for the f/8 Cassegrain system, and the third, which will be used for infrared observing, will carry an oscillating secondary mirror.

Another difference is that the telescope is driven in hour angle through a large gear (10 metres in diameter) fixed to the horseshoe, instead of through a gear located near the south support. The third difference is that the declination and hour-angle axes do not intersect. The declination axis has been raised above the hour-angle axis by an amount sufficient to balance the mounting, making it unnecessary to place heavy weights in the ends of the horseshoe.

The cell which holds the primary mirror is a critical part of the telescope. It must cradle the heavy mirror in such a way that, regardless of the position of the telescope, gravitational forces do not distort its reflecting surface. In the mirror support system adopted for the C-F-H Telescope the back surface of the mirror rests on a number of pads. A pneumatic bellows system automatically adjusts the pressure exerted by each of these pads as a function of the zenith angle of the telescope.

The various parts of the telescope were manufactured in a number of locations and then shipped to La Rochelle on the west coast of France, where assembly began early in 1976 (figure 3). By the end of the year the telescope structure was essentially complete and ready for testing.

Meanwhile, the drive and control system of the telescope was being designed and manufactured in Montreal. As in all modern, large telescopes the motions of the telescope will be under the control of a digital computer. Among other advantages, the use of a computer allows observing procedures to be established in advance and permits corrections to be applied automatically for such factors as refraction, aberration, precession, nutation and flexure of the telescope. Over the winter of 1976–77 the control system will be integrated with the telescope at La Rochelle and rigid shop tests of the mechanical and electrical systems will be carried out. If these tests go according to plan, the telescope will be dismantled and shipped to Hawaii during the summer of 1977.

The Optics. The design parameters for the various optical configurations of the telescope are given in Table I. The figure of the primary mirror is paraboloidal and that of the Cassegrain secondary is hyperboloidal. This ''classical'' system was chosen because it permits observations to be made at both the prime and Cassegrain foci without employing correctors which inevitably introduce absorption and scattered light. Since, in the classical system, the field without coma is small, corrector lenses will, however, have to be inserted for observations requiring a wide field of view. When used in the coudé mode, a series of mirrors will direct the light vertically downwards into one of two coudé rooms situated underneath the telescope where large spectrographs or other massive equipment can be located.

The figuring and polishing of both the primary mirror and the f/8 Cassegrain secondary mirror have been entrusted to the Dominion Astrophysical Observatory. The blanks for both these mirrors are of CER-VIT material, a crystallized glass possessing an extremely small coefficient of thermal expansion. Work has not yet started on the secondary, although the polishing tools for it have been manufactured and the large mirrors needed for testing have been completed. Finishing of the primary mirror (figure 4) is, however, well advanced, the surface now being within a half-wave of the final figure. Frequent optical tests are being made as the polishing progresses. During these tests the mirror rests on the pneumatically-controlled

TABLE I

Optical Design Parameters of the
Canada-France-Hawaii Telescope

Primary Mirror—	
Material	CER-VIT
Outside diameter	3.66 m
Useable diameter	3.58 m
Figure	paraboloidal
Focal length	13.50 m ± 5 cm
Prime Focus—	
Focal Ratio	f/3.8
Useable Field	2′.5 without corrector ~1° with 3-lens corrector
Cassegrain Focus (visible and ultraviolet)—	
Focal Ratio	f/8
Useable Field	10′ without corrector 20′ with 2-lens corrector
Cassegrain Focus (infrared)—	
Focal Ratio	f/35
Wobbling Mirror	±5″ amplitude (max.)
Coudé Focus—	
Focal Ratios	f/160 (first focus) f/20 (second focus)
Useable Field	~20″ without field lens 2′.5 with field lens

support pads so that the mirror is tested under the same conditions as when it is installed in the telescope. The polishing is painstaking work, and, when completed, will have taken almost three years. No difficulty is anticipated in meeting the stringent specifications and delivery of the finished mirror is expected to be on schedule.

The Dome and Building. The design of the structure to support and house the telescope is shown in figure 5. At the centre is a concrete cylindrical pillar, 17 metres in diameter, which supports the telescope and contains three rooms – two coudé rooms on the upper levels and a room for aluminizing mirrors on the lower level. Surrounding the pillar and vibrationally isolated from it is an annular building which supports the rotating dome and the observing floor. This building has four levels below the observing floor, providing ample space for the telescope control system, a data acquisition computer, dark rooms, an electronics laboratory, a

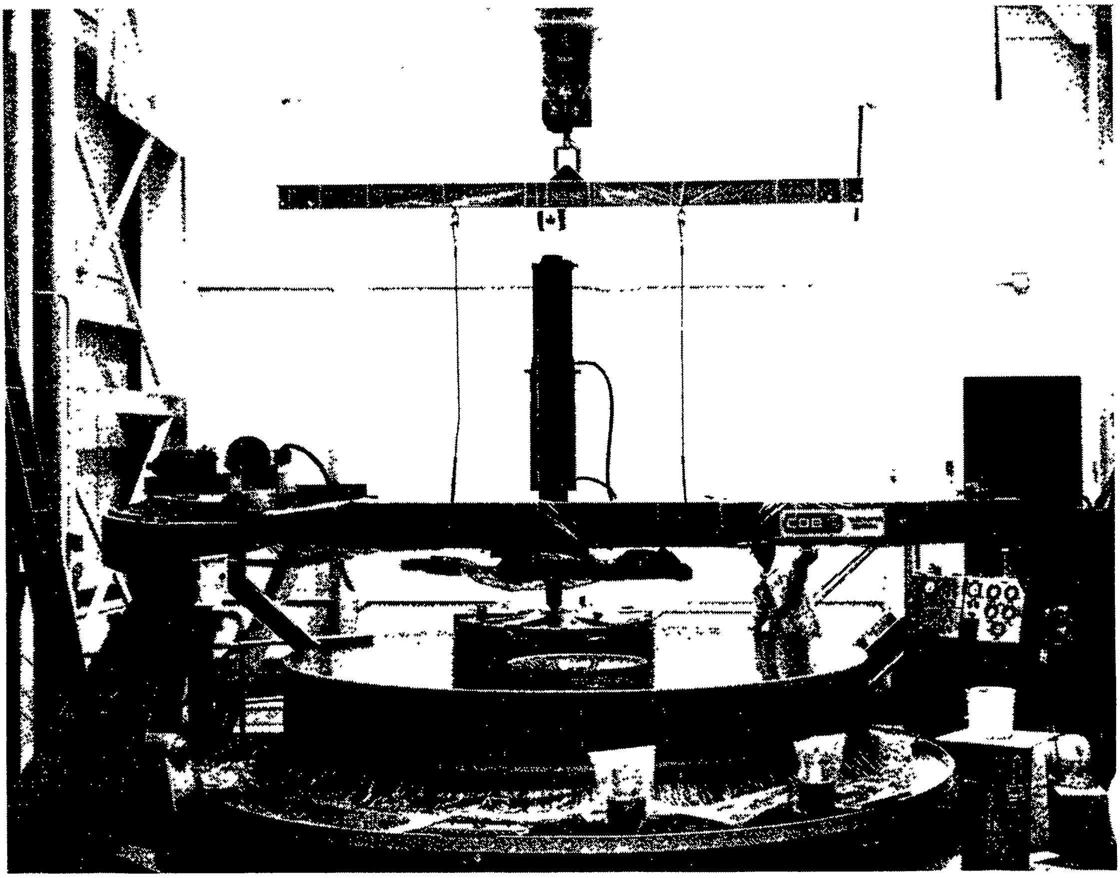

FIG. 4—The 3.6-metre mirror blank being polished at the Dominion Astrophysical Observatory.

machine shop and other service areas. The dome itself is 32 metres in diameter and slightly more than a hemisphere. To reduce turbulence, the shutter is of the up-and-over type. Careful consideration has been given to the thermal properties of the structure and the dissipation of heat generated within the building. Cooling pipes imbedded in the observing floor will enable the temperature within the dome to be adjusted during the day to the expected temperature of the outside air at nightfall.

A ground-breaking ceremony took place on Mauna Kea on 2 July 1974. Pouring of concrete for the central pillar and the foundations of the peripheral building was completed before autumn and the structure was left to cure over the winter. In the spring of 1975 erection of the framework of the circular building began (figure 6). The external cladding enclosing the building was installed before winter (figure 7). (Although the air temperature on Mauna Kea is near the freezing point both winter and summer, higher winds in winter make outside work difficult and uncomfortable.) The work of finishing the interior – installation of plumbing and electrical

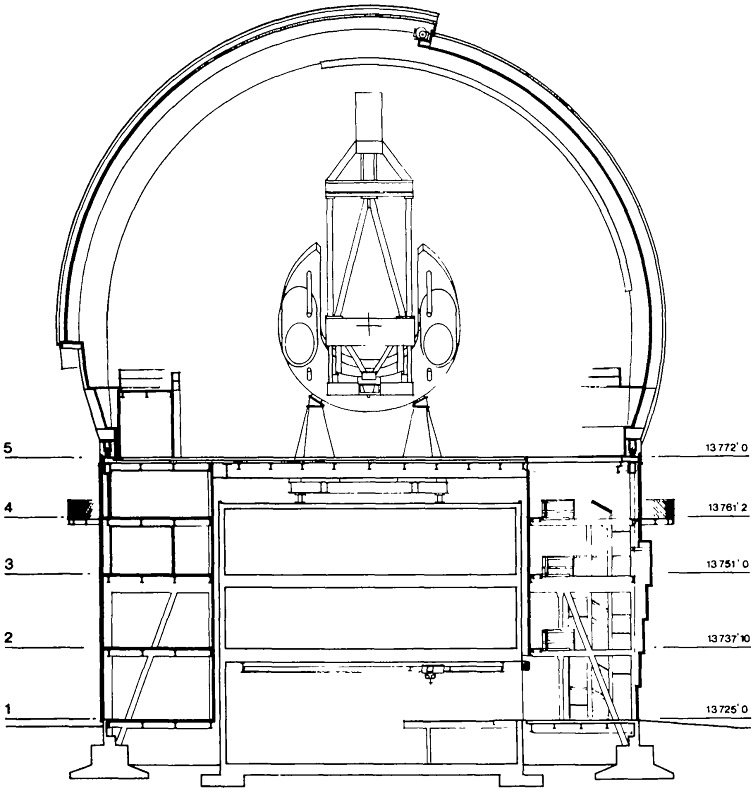

FIG. 5—Elevation drawing of the dome for the C-F-H Telescope.

fixtures, construction of laboratories, etc. – began in September 1975 and continued throughout 1976.

The rotatable steel dome, including the shutter and wind screen, was constructed on the Canadian west coast, shipped to the site and installed during the latter part of 1976 (figure 8). By the end of the year, despite the difficulties associated with construction at such a high altitude, the dome and building were complete and ready to accept the telescope.

The telescope will be reassembled within the dome and the primary mirror installed during the winter of 1977–78. After months of testing, observations at the prime focus should be possible before the end of 1978 and at the other foci early in 1979.

Instrumentation. The task of specifying the instrumentation for the telescope – cameras, detectors, photometers, spectrographs etc. – is the responsibility of the Scientific Advisory Council. Contracts for some instruments have already been let and others will be let soon. Since the instruments must employ the most advanced techniques, they will, in general, be designed and constructed by astronomical research groups possessing the

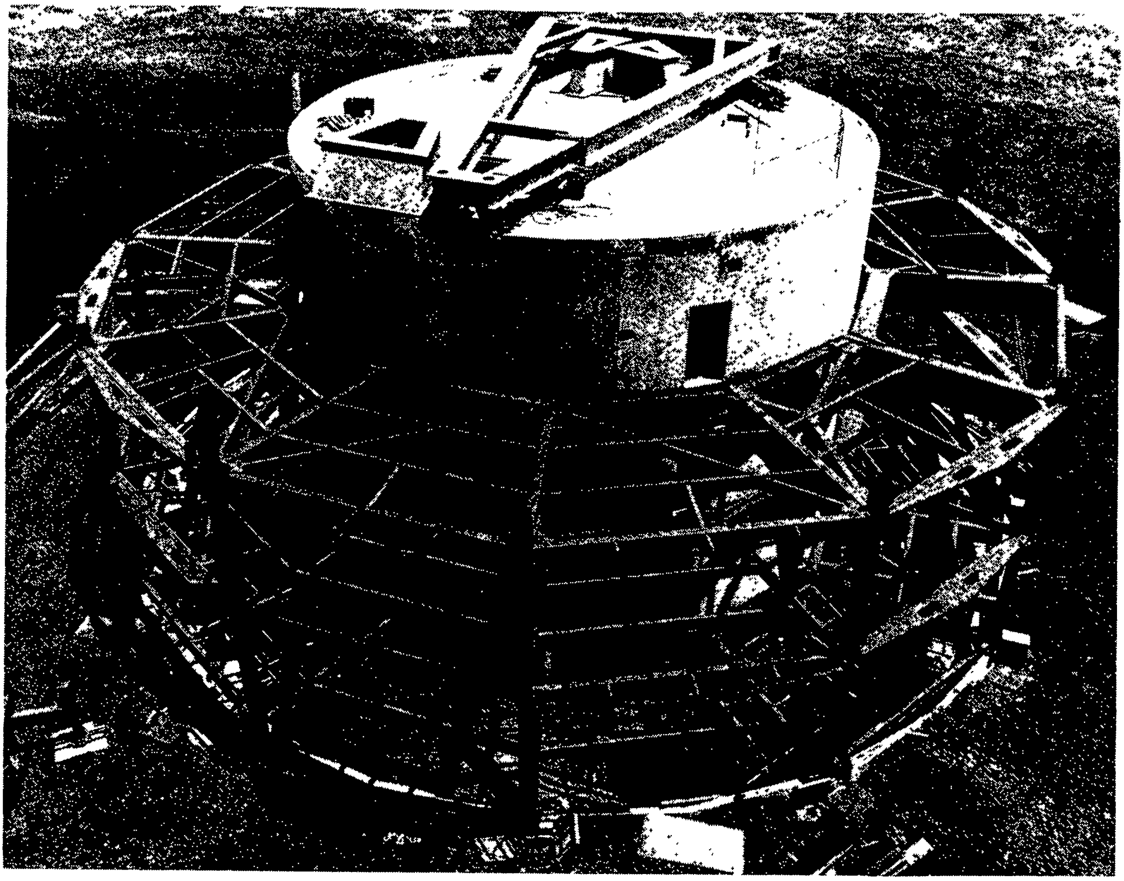

FIG. 6—A view of construction on the site during the summer of 1975.

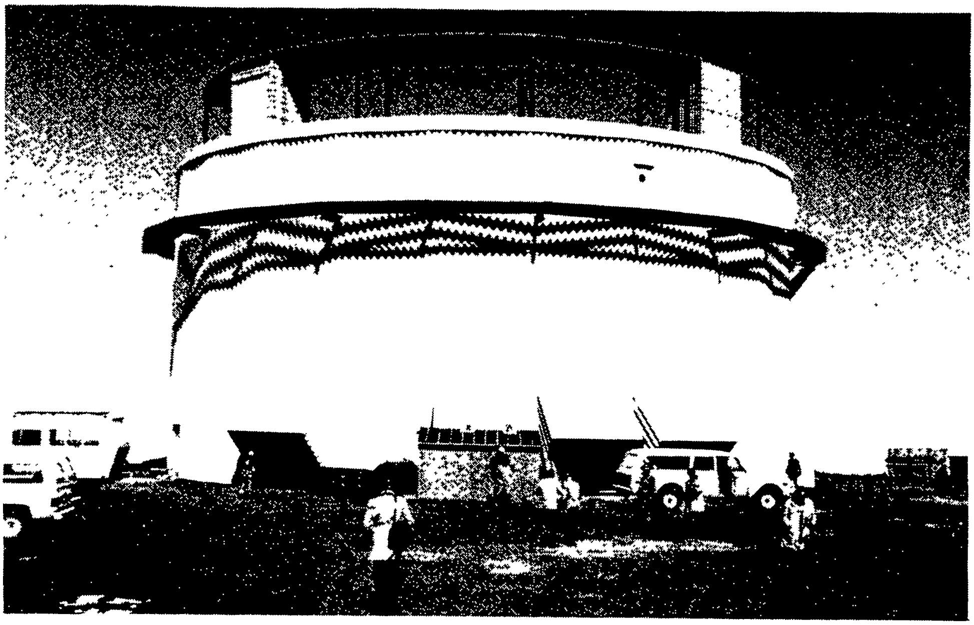

FIG. 7—The Telescope building as it appeared in October 1975. Although the exterior was nearly finished, work has just begun on the interior.

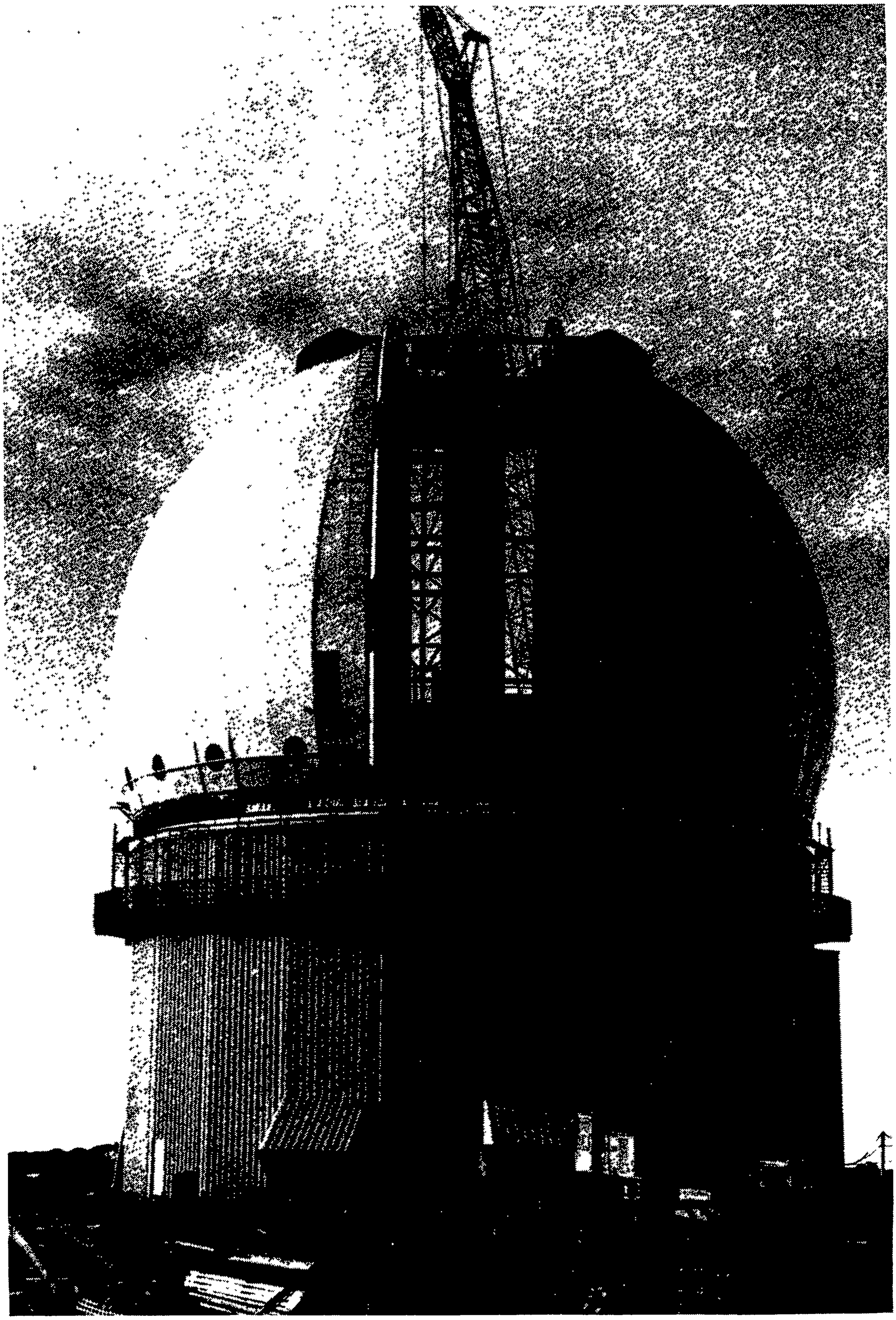

FIG. 8—Erection of the rotating dome, October 1976.

necessary expertise. Fundamental instruments, such as cameras, photometers and spectrographs for both the prime and Cassegrain focii, are expected to be available upon commissioning of the telescope and more sophisticated instruments and coudé equipment should follow soon after. In any event, the production of up-to-date instrumentation will be a continuing activity throughout the life of the telescope.

REFERENCE

Morrison, D. and Jefferies, J. T. 1972, *Sky and Telescope,* **44**, 361.