A N   A S T R O N O M I C A L   O B S E R V A T O R Y

near Beaufort-West.

Thesis for B.Arch.
Hans Paul Esslinger.
School of Architecture
U.C.T.   June 1963.

C O N T E N T S

The moon is gone
And the Pleiads set,
     Midnight is nigh:
Time passes on
And passes; yet
     Alone I lie.

Sappho.

I N T R O D U C T I O N.

"On the 5th of October, 1960 a convention was signed in the French Ministry of Foreign Affairs by the representatives of Belgium, France, Holland, Sweden, and Western Germany regarding the erection of an Observatory south of the Equator, to be known as the European Southern Observatory, equipped with instruments equivalent to the best in the northern hemisphere, and to be used jointly by the astronomers of these five countries. It will be yet another project in a series of Research Programmes launched by European countries and including nuclear and space research.

The final decision as to the selection of a site will be taken in October '63 by the Executive Committee, while construction work will commence in 1964. Completion of the scheme will take six to ten years."

From a report by Prof. O. Heckmann
Chairman E.S.O. Committee.

In this thesis I will attempt to find a solution for the architectural problems inherent in the design of an observatory, using the site, the instruments and the accommodation requirements of the E.S.O. as a basis.

Fig. 1 The Crab Nebula, remnant of an exploding star, glows like veined marble.

Chinese astronomers in 1054 recorded the appearance of a star so bright that it shone by day. It blazed for a few months, then disappeared, What the Chinese saw was nature's rarest and most awesome fireworks, a supernova Erupting with the brightness of a hundred million suns, the star ejected this cloud of gas, which ever since has been expanding 70 million miles a day. High-speed electrons, still gyrating violently after 900 years, illumine the nebula's interior. Racing electrons in the Crab's tentacles collide with nitrogen and hydrogen atoms, causing them to glow cherry red.

Invisible to the eye, these radiant colours were accurately presented with the use of newly developed film.

THE SELECTION OF A SITE

From the beginning the European Southern Observatory Committee concentrated on two countries in their search for a suitable site: Chile and South Africa. Australia was disregarded, being too far away from Europe. Small groups of students and astronomers were sent abroad to make an initial survey of climatic and seeing conditions. They roamed the country, camping, and gathering valuable information. In Chile a site with near-perfect conditions was discovered, but found to be too far off the beaten track, being 5 days on horseback from the nearest settlement!

In the Karroo two sites were subjected to elaborate investigatious, the one being near Seekoegat on the road from Prince Albert to Beaufort-West, the other at Klawervlei, 30 miles to the north of Beaufort-West in the Nuweveld Mountains. A most interesting visit to both sites revealed various factors in favour of Seekoegat and subsequently that site was selected as a basis for this thesis.

The site at Klawervlei, in fact three possible sites are up to 6300 feet above sea level and sixteen 'perfect' nights a year have been registered, compared to three on Mt. Palomar. Frequent mist in the mountains may, however, render many nights useless, and the access road, winding its way up the Nuweveld Mountains, is a limiting factor

Furthermore, to get the best possible conditions for each instrument, it has been suggested to split the observatory into three units, one on each site. This would lead to many problems and triplicate most services.

Seekoegat has no major disadvantage. It is one of those rare near-perfect sites, worthy of a large observatory.

All the sites under consideration are located in remote areas necessitating the seperation of the observational and analytical activities. Astronomers and their families cannot be expected to spend years in desert-like surroundings. Only instruments and accommodation essential for astronomical observations will be located on the site selected, the remainder, including the administrative office and large astro-physical laboratories, will be situated in the nearest city. On the desert site functions will again be seperated, the living-quarters, with the exception of the Directors' Residence and the Caretaker's flat, being approximately half-a-mile away from the observatory proper, so that lights at night will not interfere with observations.

This thesis will be limited to the design of the observatory.

Since Sir John Herschel's observations in the Cape two-hundred years ago South Africa contributed more to our knowledge of the Universe than any other country in the Southern Hemisphere But the results are negligible when compared with the information obtained by the giant American reflectors. Radcliffe Observatory at Pretoria has a large telescope by normal standards, but it does not suffice for a study of galaxies and nebulae, and the seeing-conditions are far from ideal, as are those at Bloemfontein's two observatories. The following incident may illustrate this: After elaborate investigations the astronomers at Radcliffe succeeded in making out fifty stars in the Magelanic cloud with their 74-inch reflector. One photo taken by a French astronomer at Seekoegat with the 20-inch Astrograph - to be used in the E.S.O. - revealed more than sixty stars.

The choice of a site for an Observatory is governed by one cardinal factor:

SEEING CONDITIONS

All other considerations are of secondary importance. Sir Christopher Wren, who designed the Royal Observatory at Greenwich, may have been the last architect to select a site for an observatory. Today this decision is taken by Astronomers and Meteorologists. The architect should, however, have a basic knowledge of the criteria involved, as these may greatly influence his design.

CLOUDS. A large number of cloudless nights evenly distributed throughout the year are desirable. Often observations are only possible during two or three nights, e.g. when a comet is visible low on the horizon, and a few rainy days would make them impossible.

Temperature and movement of the ATMOSPHERE. Our Atmosphere is not a homogeneous mass like optical glass, but a turbulent mixture of many layers of air at different temperatures with sharp lines of seperation between them. Clear, steady air masses that do not absor starlight and scatter it as would moving, turbulent air, are the firs necessity. Crackling, crystalclear air, made up of a throusand wavering layers of different densities cause the stars to twinkle and the images on the photographic plates to wobble around. This stratification is partly due to extreme changes in temperature betwee day and night, and partly caused by hot air rising at night. The latter cause can be eliminated as indicated later. While a telescope is in operation it is essential to have the same temperature inside and outside the dome to avoid air turbulence in front of the telescope tube, which can be overcome by air-conditioning the dome, a procedure adopted by every large observatory.

Even a gentle breeze, when disturbed by trees or buildings, can cause considerable turbulence. Therefore the domes should stand on an open plain, unobstructed by large buildings or high vegetation.

NATURE OF LAND AND SURFACE COVERING. Mountain edges or sudden rises in the ground cause rising currents of hot air. A small, flat piece of ground which rises gradually above the plains, is most suitable. It must be small enough to avoid storing too much heat and big anough to be out of the reach of updraughts. Rocky terrain without vegetation will store much heat during the day and keep the air above it turbulent for a long time after sunset.

ALTITUDE. At sea level the telescope receives light which passes through very thick layers of air. The higher the altitude the less light is lost and the danger of distortion diminished. From this it does, however, not follow that the highest mountain peaks offer ideal conditions. A loss of light can be compensated for by scientific methods: more sensitive plates and still larger mirrors, but the behaviour of the atmosphere remains beyond man's control and is the

THE LIGHTS OF A CITY less than 15 miles away will affect the photographic plates when long exposures near the Horizon are made. POLLUTED AIR as found near industrial centres can be a great hindrance. An observatory should preferably be more than 20 miles away from the nearest city.

To what extent does the site at Seekoegat satisfy the standards set above?

Tests conducted there during the last eighteen months have proven that the seeing conditions are as good as the best anywhere on our planet.

The Zwarteberge to the south form a massive barrier to clouds and moist winds from the sea. Only during summer do sudden thunderstorms occur.

The wind blows mainly due east or west and rarely straight into a dome during observations as these are made mainly on a north-south axis. The gentle rise of the koppie allows the wind to pass undisturbed. There is hence little turbulence in the air.

The koppie is covered with low shrubs and cacti amongst darkbrown stones. A hard, barren surface with little scope for duststorms but storing much heat during the day. This can be overcome by planting lawns around the domes.

When compared to Mazelspoort and other observatories the altitude of 3300 feet is rather low, but for reasons already explained this drawback is not too serious.

City lights and the polluted air of industrial centres will never interfere with the quiet seclusion of an observatory at Seekoegat. The out-skirts of Beaufort-West are fifty miles away and will remain so for the next hundred years.

T H E   S I T E

Fig. 2 That distant koppie is the site.

Both an interesting personality and a beautiful landscape rely for their appeal to a large extent on an element of surprise. There are arid regions atracting visitors from afar because man is always fascinated by thematic variations, whether the theme consists of lakes and forests or of weather-beaten rock outcrops. But in the Karroo monotony prevails. When approaching the site from the south the grandeur of the Zwarteberg Mountains suddenly fades away, leaving a landscape consisting of two components only: a horizontal plane and a line, the horizon. The visual impact of any object growing out of this geometric pattern will be intensely dramatized by the complete absence of competitive elements.

A splendid setting for an aristocratic building.

A C C E S S I B I L I T Y

Plans are being finalized for a tarmac road from Beaufort-West through Seekoegat and Meiringspoort to link up with the raod to the Cango Caves. An additional four miles of tarmac will link the E.S.O. to this road and the National Road from Cape Town to Johannesburg.

An air link between the observatory and the outside world would be in keeping with the spirit of the project and the obvious solution for the long distances concerned. Sites for an airport abound.

SOIL AND WEATHER CONDITIONS

At an average depth of 1'6" dark brown Sandstone occurs, the upper layers of which allow only low foundation loads, but at the same time have a low vibration transmission coefficient.

The following figures give the average rainfall and temperature for the last 25 years taken near the site.

	MONTHLY PRECIPITATION		TEMPERATURE (F.)	
	Max.	Med.	Max.	Min.
Oct.	1.5"	0.3	98	35
Nov.	2.8	0.6	103	40
Dec.	9.5	0.4	106	46
Jan.	3.2	0.4	108	47
Feb.	5.0	1.1	107	50
March	5.0	0.8	104	47
April	2.5	0.1	100	42
May	1.0	0.12	88	35
June	0.6	0.1	70	31
July	2.0	0.08	65	28
Aug.	2.5	0.02	76	30
Sept.	2.5	0.05	90	32

<u>Fig. 3</u> Looking south, towards the Zwarteberg Mountains.

Fig. 4 Yes, desert is rock-bound earth, prostrate to the sun.

H A B I T A B I L I T Y

An astronomer's work, his night-long vigils, and the extreme concentration required both when observing stars and when evaluating the data collected, necessiate a counterbalance in the form of sport, social contacts and opportunities to develop culturally. In this respect only limited provisions can be made on an isolated site. The students and astronomers at the present time conducting the research at Seekoegat and Klawervlei have to take leave for six days a month to visit a town or tour the country. Similar arrangements may be required at the E.S.O. Once the tarmac road is built Oudtshoorn and the Garden Route will be within easy reach, while Cape Town may prove to be a big attraction.

Fig. 5 The building housing the 20-inch Astrograph at Seekoevlei.

A S T R O N O M Y

Astronomy, which is without doubt the oldest of the sciences, has contributed more effectively than any other to the development of human thought. Although born of every day needs (the calendar, the time, navigation) and the fears of primitive man in the face of the terrifying phenomena of Nature - for which reason it has remained closely associated with the superstitions of the astrologers in the minds of the uneducated, even, alas, to the present day - Astronomy was nevertheless the first science to form the concept of natural physical law, which was demanded by the regularity of heavenly phenomena. It was also the first to develop, at a relatively early epoch, a discipline of accurate observation - to which the tablets of ancient Assyria and Chaldea, and the pyramids of Egypt bear witness.

At a much later date, it was the Copernican revolution in Astronomy that liberated man's mind from superstition, and gave birth to the authentic scientific attitude and the rational outlook of the present day.

Thanks to Astronomy, the enquiring spirit of man has finally discovere the true status of humanity in the Universe: a mere atom, but a thinking atom, situated on a microscopic planet, one of several revolving round a small and commonplace star, itself indistinguishable from a hundred thousand others, in the heart of a galaxy which in turn is lost among the millions that populate the tiny corner of space that we have been able to explore.

BRANCHES OF ASTRONOMY

PRACTICAL ASTRONOMY deals with the field of observation, design and use of the instruments, the methods of observing, the elimination of errors and the deduction of data employed in other branches of astronomy.

ASTROPHYSICS is that branch of astronomy concerned with the physical characteristics of celestial bodies, i.e. their luminosity and spectroscopic peculiarities, their temperature and radiation, the nature and condition of their atmosphere, their surface and both their qualitative and quantitative composition, and finally all the phenomena arising from these physical conditions. Though the youngest, this is the most active branch of astronomy and will probabl outgrow all the others combined.

ASTROMETRY deals with the geometrical relations of the celestial bodies, their positions, distances, dimensions and surface markings.

CELESTIAL MECHANICS is the astronomical application of the principles of mechanics which describe the motions of material bodies acted upon by external forces.

COSMOGONY studies the evolution and origin of the celestial bodies.

PHOTOMETRY deals with the intensity of light, particularly the brightness of stars and planets.

NAUTICAL ASTRONOMY includes as much of spherical and practical astronomy as the Navigator requires.

DESCRIPTIVE ASTRONOMY is merely the orderly statement of astronomical facts and principles.

The youngest branch of observational astronomy is SPACE RESEARCH, in which the new-found ability to make scientific observations from orbiting vehicles outside the earth's atmosphere is opening up completely new possibilities. Parts of the spectrum unobtainable to earth-bound astronomy, such as the far ultra-violet, can now be observed.

RADIO ASTRONOMY

Although this new branch of Astronomy is not within the scope of this thesis, I would like to mention it briefly.

After the war radar specialists found a curious application for their temporarily idle apparatus: eavesdropping on the universe. In 1931 a radio engineer heard in his home-made ultra-short-wave radio set a howling whistle which he suspected to come from an unknown source somewhere in the Milky Way. Since 1945 the big wire 'dishes' of the radar technicians were directed towards this radiation and the Milky Way was discovered to be a broadcaster of radio waves. These noises are the modern version of Pythagora's and Kepler's music of the spheres.

Radio astronomy has proven of enormous value to the large telescopes which can only make probes of the size of pinpricks into space. Using the extra-terrestial whistle tones as guides, the telescopes would be directed towards specific points in space, and a number of fascinating facts about the nebular universe were discovered. The collaboration between observatory and radio astronomy is increasing and has brought fruitful results.

It is reasonable to assume that once we have suitable observatories, radio telescopes will be required to guide them.

Fig. 6 The 250 ft. dia. Radio Telescope at Jodrell Bank, England.

<u>THE ASTRONOMER AND HIS ASSISTANTS.</u>

The functional pattern in an astronomical observatory is determined by the activities of the astronomer. The engineers, opticians, etc. merely assist him. Their work is confined to certain areas whereas the astronomer's interests include the laboratories and workshops, the offices and observation platforms, the library and the aluminizing room. As the astro-physical laboratories will be situated in Cape Town, the astronomer out at Seekoegat will concentrate mainly on observations. Those made with a large telescope are mainly of three kinds:

a. Photographs of the sky for the purpose of mapping or for delineating detail in clusters, gaseous nebulae, or galaxies.

b. Recording the spectum of a star by means of a Spectrograph attached to the telescope.

c. Measuring the brightness and colour of stars, either directly by photo-electric methods or by the analysis of photographs.

Let us accompany the astronomer on a night's duty.

A NIGHT WITH THE STARS

Extract from "Frontiers in Space".

"For the sake of being specific, consider an astronomer working at the 200" Hale telescope on Mt. Palomar. Assume also that he is a dark-of-the-moon observer, one interested for the time being in direct photography. This means that he will probably spend the night in the observer's cage at the Prime Focus. The night assistant, the engineer who is always present to assume responsibility for the general behaviour of the telescope, will spend the night at the control desk on the observing floor, far below.

The night assistant begins the night's work by opening the dome as early in the evening as possible, so that the mirror and the tube that holds it will have a chance to adjust themselves to the outside temperature before the work begins.

As night comes, the astronomer rides the prime focus elevator up to the mouth of the observer's cage, steps across a 10" gap, 75' above the floor of the observatory, and settles himself in the chair in the observer's cage. He has brought photographic plates with him, perhaps enough to last the night.

Settled, he uses the intercommunication system to tell the night assistant at the desk below - in terms of degrees, minutes and seconds of declination and right ascention - the locality of the spot in space where he wants to photograph. The night assistant sets his dials, pushes a button, and the great telescope swings to the proper aim. As it does so, the dome automatically turns to keep its slot in front of the telescope, and the canvas screen moves up or down in the slot as far as the telescopes position will allow.

Lights in the dome go out. The observer looks into the eyepiece, to make sure that the big mirror is reflecting the right part of the sky, and sets the cross-hairs of the eyepiece on a guiding star just outside the field he intends to photograph. He slides his photographic plate into place, and the exposure begins.

Until the exposure is finished, the observer keeps his eye on the guide star as the telescope sways inperceptably across the sky. From time to time he presses on a control panel - buttons controllin the same movements as the buttons on the main control desk - to keep the telescope aimed at its objective. These minor adjustments are necessitated by the changeable effects of the earth's atmosphere on the rays of light beamed on his photographic plate.

The work in hand, the seeing, and the other factors decide how long the observer remains in the cage. If he is devoting the night to a series of fairly short exposures, the chances are that at about midnight the lights in the dome will go on, and he will come down from the telescope for a cup of coffee and a sandwich and to warm up. Observing at the prime focus, particularly in winter, calls for heavy clothing. Recently electrically heated coats have been used with good results. The temperature in the dome is often below feeezing point, sometimes going as low as -12° centigrade.

Much depends upon the weather. Seeing may not become good enough to allow photography until one or two a.m. - perhaps not at all. Or there may be good seeing most of the night.

As soon as day breaks, the astronomer, possibly cold and cramped, rides down the elevator with his small collection of plates. Then, if his turn at the telescope is over, he returns to the offices to begin with a study of and laboratory evaluations of his plates. This is done with comparators that can measure the position of points on his photographic plates with an accuracy of a few hundred-thousands of an inch, and with microphotometers that determine the intensity of light that effected the emulsion on the plates. It may take the astronomer weeks or months to measure and interpret the photographs he has taken in one night's work."

Astronomers often feel as having a personal relationship with their instruments. They look upon them as something more than a means to an end; they could feel equal passion for technical problems and for the flights of pure science. A perfect example of this attitude was provided by the physicist Albert Michelson of the University of Chicago. He loved his instruments as if they were beautiful women, maintaining that they had human characters, and distinctly feminine ones at that. They react to flattery, persuation and threats. Handling them is as fascinating as a game of chess They come up with unforeseen manoeuvres, taking advantage of every mistake - like a woman!

The nature of his work, with its utmost concentration and precision behind the eyepiece and when analysing photos, demands pleasant surroundings well suited to their function. During his off-duty hours after intricate calculations, or during the tea break after strenuous hours in the cage of the telescope he should be allowed to relax in an environment that returns him to the other aspects of life and his human nature and delights him with the sight of green grass and rippling water.

Most astronomers prefer to develop all photographs themselves but often other duties predominate or a large number of prints are required from one negative. These are then done by the DARKROOM ASSISTANTS.

The movements of the 150-inch telescope and the Schmidt-camera are directed from a control-desk by the NIGHT-ASSISTANT, who has to be on duty whenever observations are made. He controls the movement of the domes and shutters, adjusts the air-conditioning systems and assists in the attachment of auxiliary instruments to the telescopes.

Visiting astronomers may bring along special instruments which have to be adapted to the particular telescope. This can only be done on the spot. Delicate adjustments are made by the INSTRUMENT MAKER who will also construct new attachments while the OPTICIAN grinds the necessary lenses and is responsible for the optical alignment.

The MAINTENANCE MECHANIC is in charge of the machine shop and has to ensure that all instruments are in a perfect working order. The electrical installations, the control gear for the telescopes and the electronic equipment including many of the measuring instruments are the responsibility of the ELECTRONICS ENGINEER. Tests in the laboratory are carried out by the laboratory assistant, according to the instructions of the astronomer.

The Director of the Observatory will have a PRIVATE SECRETARY who will also act as receptionist, while another SECRETARY is available to the astronomers and is in charge of the library.

A supervisor will be in charge of the kitchen and at the same time act as HOUSEKEEPER for the off-duty section. The CARETAKER is responsible for the remainder of the buildings and the garden.

Nine non-european boys will work under his supervision while one will assist the housekeeper.

THE TOOLS OF THE ASTRONOMER

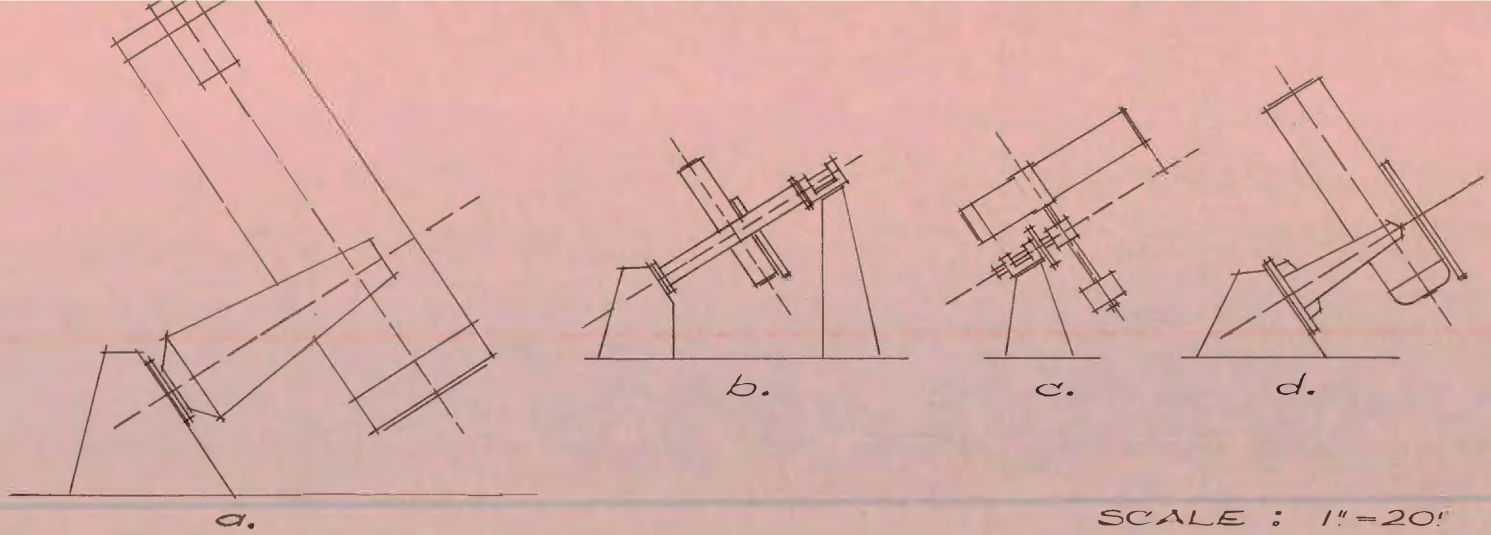
There is such a wide range of astronomical instruments that this survey can only include those, which will constitute the equipment of the European Southern Observatory.

THE TELESCOPE is the aristocrat amongst the tools of the astronomer. As a machine it ranks besides the largest of locomotives but as a precision instrument it must be the equal of the best microscope, with an accuracy that the finest watch could not hope to achieve.

There are two main types: the REFLECTOR and the REFRACTOR. The refractor corresponds to the popular conception of a telescope. Galileo, the first man to look at the moon, the planets and the stars with other than the naked eye, made and used such a telescope in 1609. It has certain disadvantages, limiting its size and the field of definition. The largest one built to date is the 40-inch refractor at Yerkes Observatory.

Every large telescope built since 1900 has been a reflector telescope In this type the parallel light rays from a star are focused into an image by a concave mirror mounted at the lower end of the tube. The first such telescope, made by Isaac Newton in 1668, had a thick metal mirror with a polished metal surface. Modern reflectors use a glass mirror with a thin coating of silver or evaporated aluminium on the front surface. Since no light rays pass through the glass, imperfections in the body of the mirror do not matter. While a lens can be supported only around its edges, a large mirror can be supported at many points on its unused back surface; this eliminates the problem of deformation of a large disk of glass under its own weight. The reflector may easily be made fast, i.e. with a focal length not more than five times the diameter of the principal mirror. This is of great advantage in photography. On the other hand lenses are much less vulnerable to temperature distortions than a mirror. The slightest distortion will impair the image of a star on the photographic plate. To minimize this effect "Pyrex" glass was used for the 200-inch Hale telescope on Mt. Palomar. The mirrors at the E.S.O. will be made of Quartz, which has a thermal stability twelve times greater than that of "Pyrex".

All large reflectors and refractors are mounted equatorially, i.e. rotating around an axis parallel to the axis of the earth. Comparing the various mounts, their advantages and disadvantages would inevitably lead to a long technical discussion. As the designs for the telescopes to be used at the E.S.O. have not been finalized, those mounts which were used on recently constructed telescopes of similar size will be adopted as a basis for this thesis.



The European Southern Observatory will be equiped with the following telescopes:

a. A 150-inch Reflector, second in size only to the 200-inch Hale telescope, but more powerful due to certain optical refinements and the superiority of its quartz mirror. The tube will be 14 feet in diameter and 48 feet long, supported by a fork mount as used for the 120-inch Lick reflector, (Fig. 23) with a Spectrograph attached to the coudé-focus.

b. A 20-inch Prism-Astrograph already in operation at Zeekoegat. This instrument is basically a double-barrel telescope, having one mirror to guide the instrument, another for photographic recordings. It is a prototype and has been specially disigned to suit conditions in the Karroo. It is 14 ft. long and supported by a yoke mount.

c. A 40-inch Reflector for spectrographic work with a high-dispersion spectrograph permanently fixed to the coudé-focus. The telescope is 20 ft. long and employs the German equatorial mount.

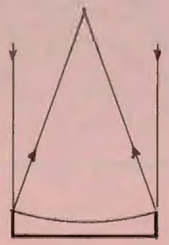
d. A 20-inch Reflector will be available to students and visitors. This instrument will be similar to the one shown in Fig.8 and does not require a dome, but could be kept in a store and only taken out when needed.

e. A 48-inch Schmidt-Camera, identical to the one at Mt. Palomar. A hybrid of reflecting and refracting telescope, the Schmidt combines the advantages of both. Briefly, it consists of a camera capable of sharp definition at focal ratios never before associated with a large field of vision. It contains but two optical parts, one a spherical mirror, the other a lens of negligible power.

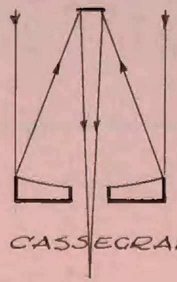
The apparent motion of the stars must be counteracted by means of a driving mechanism, usually referred to as the clock or drive, the rate of which must be continuously changed in order to correct, e.g. for differential refraction. This in the case of the 150-inch telescope and the Schmidt is accomplished by the use of a frequency-controlled synchronous motor drive governed by an electronic computer which allows for eight factors of variation. The two smaller telescopes have a less complicated drive only allowing for differential refraction. The 20-inch reflector obviously requires no automatic control gear.

The movements of the 150-inch and the Schmidt, the rotation of their domes, the opening and closing of the shutters and canvas louvres and various other items are controlled from a central desk on the observing floor where a night assistant will be attending. These desks are 6'x2'6"x 3' high. For the 40-inch and the astrograph only small switchboards are required.

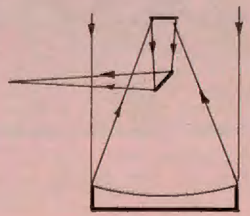
<u>FOCUS.</u> For different kinds of observations and research, different lens and mirror arrangements are used.



PRIME FOCUS



CASSEGRAIN



COUDÉ FOCUS

All four telescopes have a Cassegrain focus. When using this focus on the 150-inch, the observer sits in a "cage" behind the mirror, while on the other three instruments a movable hydraulic lift enables the observer to follow the movements of the telescopes. Only the 150-inch has a prime focus and this is accessible from a cage suspended in the centre of the tube. With the exception of the astrograph all have a coudé-focus which is taken down the forks and along the equatorial axis by means of a series of mirrors, and, in the case of the 150-inch and 40-inch, into a spectrograph room.

AUXILIARY EQUIPMENT

The starlight focused into an image by the telescope is the only connection between the astronomer and the distant part of the universe he is investigating. The tools he uses to unravel the information contained in that image are quite as important as the telescope. The human eye has long since been assigned a minor role, although for assessing fine detail on planets and in measuring the seperation of close double stars, it has never been surpassed.

THE PHOTOGRAPHIC PLATE can, during a long exposure, record objects quite invisible to the eye, as well as giving an impersonal record of many details. The degree of blackening is a measure for the intensity. By successive exposures with photographic plates, sensitized for blue, red, or infra-red light, combined with appropriate filters, the colour characteristics of the original source may be determined. Glass plates rather than films are used because of thei flatness and their great dimensional stability.

SPECROSCOPE AND SPECTROGRAPH

These two instruments have been the most powerful tools for increasing our knowledge about the physical condition of the stars and planets.

In 1825 the French philosopher Auguste Comte had no hesitation in citing the chemical composition of the stars as an absolutely indisputable example of knowledge that mankind would never possess.

advances in astronomy thanks to the development of spectroscopic analysis and the discovery of the fundamental laws of atomic and molecular radiation.

The Specroscope consists of one or more prisms dispersing the light to give a large spectrum. In astronomical work it is firmly bolted to the telescope, which collects a large amount of light from the object under observation. By replacing the eyepiece by a camera the Spectroscope becomes a Spectrograph.

When the Spectrograph is in operation for long exposures it is essential to keep the temperature the same in order to secure constant dispersion, and to do this the Spectrograph is enclosed in an outer case which is electrically heated and thermostatically controlled at a temperature which can be set beforehand. For working in the ultra-violet range a vacuum has to be created around the prisms.

The Spectrograph can be attached to the rear of the reflector behind the mirror i.e. at the Cassegrain focus in which case it is a light instrument approximately 5' long x 12" x 12" weighing 200 lb. When not in use it is kept in the instrument storeroom. The wide-dispersion Spectrograph at the coudé-focus of the 150-inch and the 40-inch are stationary instruments requiring a low constant temperature. They should preferably stand on the same base as the telescop

The sizes of these Spectrographs are:

150-inch telescope:	12'x8'x6' high
40-inch "	4'x4'x3' high

THE MICROMETER is used in visual work only at the focus of the glass of the objective to enable accurate measurements of small angles to be made. Each telescope requires a micrometer.

PHOTOMETERS. There are two main groups of photometers. The first type measures the intensity of the object at the telescope, while the second measures the intensity of the photographs taken earlier at the telescope (in the laboratory at leisure). It enables the astronomer to determine by how much two sources of light - a star and an artificial source - differ. The latter type, two of which will be available to astronomers in the measuring room, can only be used in complete darkness, and thus require seperate cubicles

For measuring the brightness and colour of stars the PHOTO-ELECTRIC CELL is increasingly used. It provides yet another form of photometer, which can be used both at the telescope and in the laboratory. The current is so weak, however, that sensitive electronic equipment must be used to amplify it. The results are usually recorded automatically on a paper chart.

In the ELECTRONIC IMAGE TUBE the more efficient photo-electric cathode is substituted for the photographic plate. This complex

Fig. 7 An Iris photometer.

device, similar in principle to a television camera, is still in the developmental stage. It seems destined to replace the photographic plate for the difficult tasks, and, once its potentialities are realized, it will increase the power of all large telescopes. One of these instruments will be built for the 150-inch and alterations and improvements will be done in the E.S.O. workshops.

THE DENSITOMETER. When the astronomer desires to measure the brightness of stars recorded photographically, he must have a scale of photographic blackening or density to interpret his measures The Densitometer is used to impress such a scale into every plate before it is used. It is a light instrument, standing in the main darkroom.

THE BLINK MICROSCOPE is used to compare two photographs of the same region of the sky to detect changes which may have taken place between the two exposures. Two of these instruments, 2'x1'x1' high, will be used in the measuring room.

OBJECTIVE PRISM. A spectrograph can only collect light from one star. It is, however, often desired to study the spectra of a number of stars in an area of the sky. This can be done by using the objective prism, which consists of a large piece of optically worked glass, prismatic in section but circular in plan, placed in front of the object glass at the focus.

THE STELLAR INTERFEROMETER is used to seperate the disks of two stars very close together and has enabled astronomers to determine the angular diameter of the largest stars. Only the 150-inch will be equipped with a 20 ft. wide Interferometer, which, when in use, is attached to the upper end of the tube.

ASTROLABE. An instrument used for determining the altitude of celestial bodies from which time and latitude are deducible. With a history of 2000 years it may claim to be the oldest scientific instrument. The latest versions bear no resemblance to the traditional brass circle and are highly sensitive optical instruments. The one to be used at the E.S.O. is 3'x3'x2' high with an angle of vision of 45^{o} above the horizon.

THE ELECTRONIC COMPUTER. The theoretical work carried out in offices and computing laboratories seeks to access or interpret observations and to correlate such information by forming new theories susceptible to further observational tests. Some astronomers devote their whole career to such work. This aspect of astronomy largely relies on electronic computers. Hardly any measurement made at the telescope is of any use until it has passed through a process of calculations and correction more or less prolonged. The continual variations in the adjustments of the telescope, the refraction of the air, and the daily and yearly changes in the position of the celestial equator have all to be included in the calculations, which are done by intricate electronic computers. The E.S.O. requires only a small computer about 2'x1'6"x3' high, controlled by one of the secretaries.

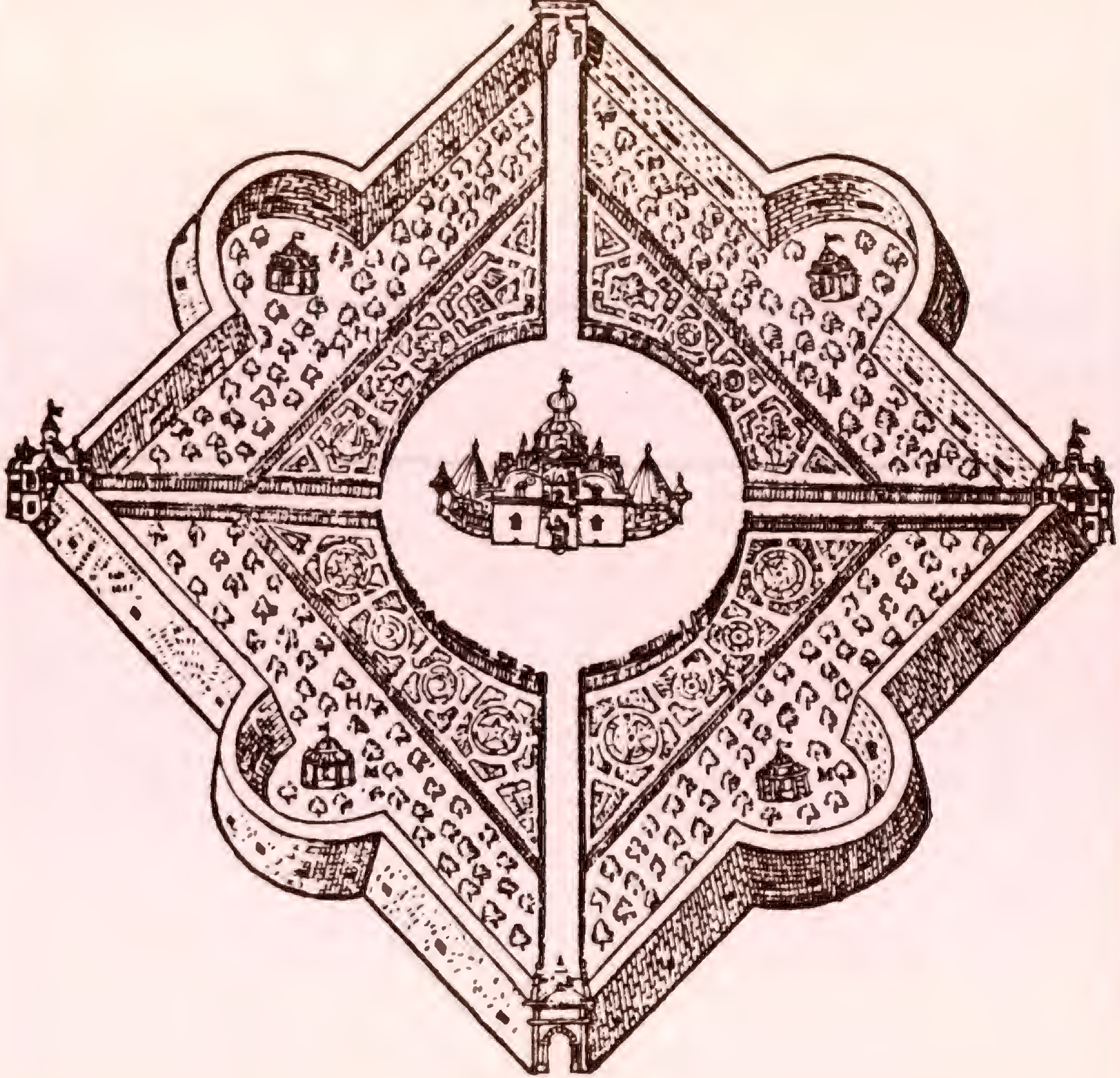
Fig. 8 A transportable 20-inch reflector.

P R E C E D E N T

The erection of special buildings for astronomical research has a long tradition. It is said by Diodorus that the great temple of Belus at Babylon was built for astronomical purposes. Chinese records indicate, that during the same period (2300 B.C.) the gnomon was first used for measuring the altitude of the sun. There is no evidence of the existence of an observatory of Greek or Alexandrine origin until about 300 B.C. when one was built at Alexandria, but we have limited records as to its shape and the instruments used. In the 12th century a splendid observatory was built at Maragha in north west Persia, basically still a temple, but adapted to the needs of observing stellar bodies. Others followed in western Asia and in central Europe, but the first one that may be considered a prototype of modern national observatories was that of Tycho Brahe on the islan of Hveen, off the south-west coast of Sweden, and appropriately named Uraniborg, i.e. "Castle of the Heavens". This building was of some magnificence (Fig. 9) and large enough to house Tycho and several young men, who lived with him as students or observers. It had a ring wall around it, with the corners directed to the cardinal points and observations were made with simple instruments, which operated through holes in the wall.

The discovery of the principle of the magnifying glass enabled Galile to build the first telescope in 1610. Within a couple of years most theoretical speculations on which the Astronomy of his time was

Fig. 9 Tycho Brahe's Uraniborg.



Uraniborg and Grounds

based, had to give way to observed facts. A similar situation developed with the building of the 100-inch and 200-inch telescopes. Again the theories - by Einstein, Eddington and others - were far advanced of factual knowledge, but this time they were confirmed by the observations, at least in principle.

Galileo never had a fixed place which could be called an "observatory because his marvellous telescope of such modest dimensions could be directed towards the sky from any place whatsoever, from a window or a garden, perhaps with the help of some crude tripod, but without the need of a special locality or particular accessories. Several decad had to pass, before the first genuine astronomical observatory was founded and built on the roof of the University of Leyden in 1632. All the larger stationary instruments were exposed to the weather throughout the year.

In 1675 work was begun on the Royal Observatory at Greenwich, designe by Sir Christopher Wren (Fig. 14). The site he selected was well suited for the purpose and it was only centuries later that the Obser vatory had to be moved, due to the sprawling suburbs and the polluted air from industries, resulting in bad sky conditions.

In most of the European countries, mainly in Italy observatories were multiplying and continuously perfecting their instruments in order to achieve greater precision in the determination of the positions of the celestial bodies. Sir David Gill, Director of the Cape observatory, when writing its history, mentions a book on the construction of the Pulkovo observatory in Russia:

"There is inspiration to be found in nearly every page of it, for its author has the true genius and spirit of the practical astronomer - the love of refined and precise methods of observation and the inventive mechanical and engineering capacity - these qualities in him being stimulated to the highest degree by the unique opportunity offered by Emperor Nicholas I of Russia, viz., the command to design and erect, almost regardless of cost, the most perfect and complete observatory that Struve could device."

As the instruments became more complex and sensitive they required some means of protection against the weather. Revolving domes were developed and gave observatories a distince appearance. At first they were placed onto rooms of various shapes (Fig. 15) but as their size increased structural considerations pointed to cylindrical substructures. Little thought was given to the relationship between these circular shapes and adjoining rectangular buildings (Fig. 22).

Dacquerre invented the photographic process which radically changed the astronomers methods. Previously telescopes required little auxiliary equipment, but with the introduction of spectrographic analysis and astrophysics, laboratories and workshops became necessar
In the search for better sky conditions, for calmness and transparenc
of the atmosphere, observatories moved away from cities, mostly onto high mountains and self-sufficient settlements evolved (Mt. Wilson, Bergedorf) Outposts of Science!

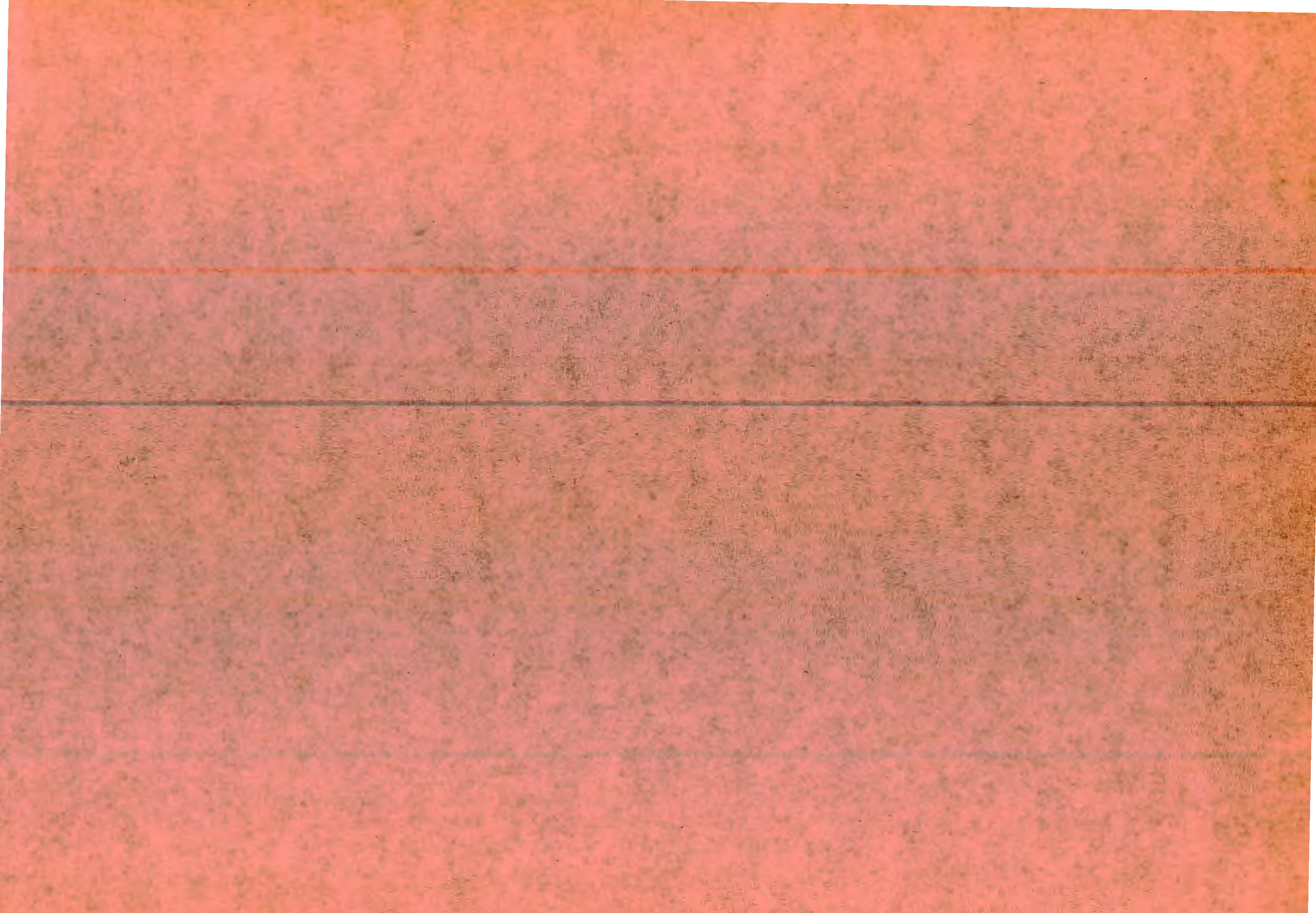


Fig. 10 An Inka Observatory at Chichen Itzá

"Greeks of the new World" built this Astronomical Observatory at Chichen Itzá in Mexico. Spaniards named the Maya structure "El Caracol" from the resemblence of its interior spiral stairway to the whorl of a snail shell. Astronomers took observations through the windows near the top, along definite "lines of sight". Note the striking resemblance of this building to the typical contemporary domes.

J A I   S I N G H ' S   O B S E R V A T O R Y

in Rajput, India.

<u>Fig. 11</u> Jai Singh's Observatory.
A quadrangle with dials.

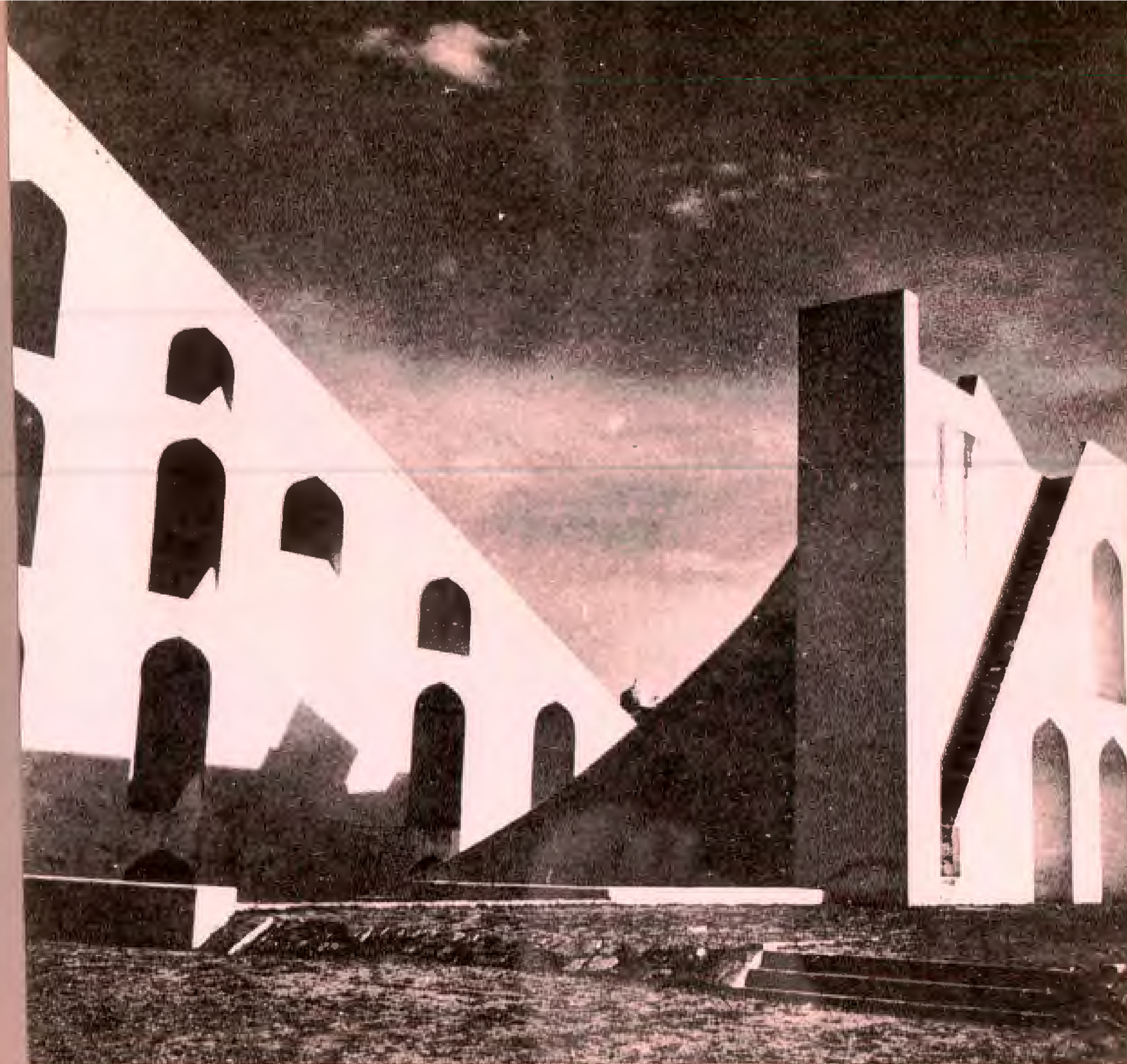
Fig. 11

It is a vast quadrangle filled with curious instruments in masonry invented and designed by the Maharaja himself; great twists and curves in grey and white marble set in red sandstone or pale yellow-washed plaster. "Strange things", as Kipling describes them, "of stone and mortar, of which people hardly know the names and but very little of the uses." Their effectiveness, however, has been proven by competent astronomers.

Fig. 12

The great Yantra Samrat, or Prince of Dials, rising a hundred feet up into the blue sky. One need not understand the instruments; their shapes alone are extraordinarily stimulating, like abstract sculptures. Here is a good illustration of how beautiful abstract form can be, when made on a suitable scale and in a proper setting. The hours go by and the shadows creep over the face of the dials, measuring, for those who know how to read it, the time of eternity.

Fig. 12 The Yantra Samrat.



THE EINSTEIN TOWER IN POTSDAM, GERMANY

Designed by Eric Mendelsohn and built in 1920-21 it is a combination of a solar observatory and an astrophysical laboratory. Mendelsohn himself, thirty years later, could not fully explain the design of the tower. It was a product of "the mystique around Einstein's universe". A plastic and homogeneous structure growing out of the site with an urge to see around it in all directions.

Fig. 13 The Einstein Tower, Potsdam.

T H E   R O Y A L   O B S E R V A T O R Y

at Herstmonceux, Sussex.

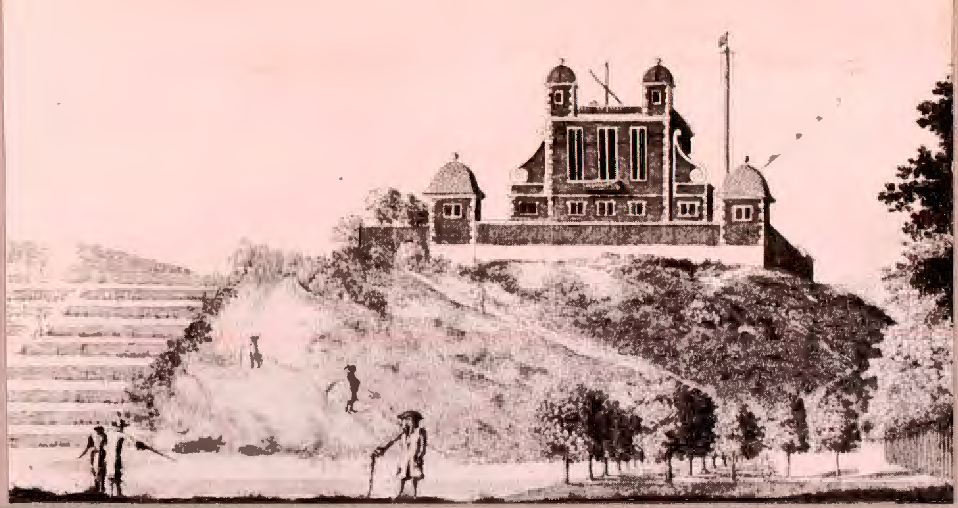
After the war the Royal Observatory moved from Greenwich to Herstmonceux to avoid the increased interference of observations caused by street lighting and atmospheric pollution.

In the existing castle are offices, library, conference room, staff canteen and a residence for the Astronomer Royal, while several new buildings were erected, including Meridian and Equatorial groups, the Time and Nautical Almanac Building and a works pound with boiler house and garages etc. The Equatorial Group consists of six domes, set on high ground east of the castle. The general design of the domes is similar, but diameter and floor areas vary. Deep foundations are carried down independent of the buildings. The construction up to floor level is of reinforced concrete design with brick facings and a cavity between. The dome drums are of light steel faced externally with copper on boarding and internally with removable vertical board panelling. The revolving domes are framed up with steel tube horizontals and channel ribs to which wood grounds are fixed to take a sandwich covering of hardboard with glass fibre insulation and copper covering.

On the plan the domes are related to each other and to the adjacent buildings by means of a grid of pathways, low walls and lawns; a solution limited to two dimensions. When viewed from a distance the domes tend to float around. The method of linking the two domed structures to the central building is not convincing. Circles, cylinders and domes prefer independence, appear unhappy when attached to other structures; unless they are the focal point, i.e. the centre of a series of shapes surrounding them.

The domes were covered with copper "to blend in with the landscape", which they don't. White or silver would have been more expressive of the real function of the building and better from a thermal control point of view. The proportions and character of the domes and their substructure: what a degeneration when compared with the shapes of Jai Singh's observatory!

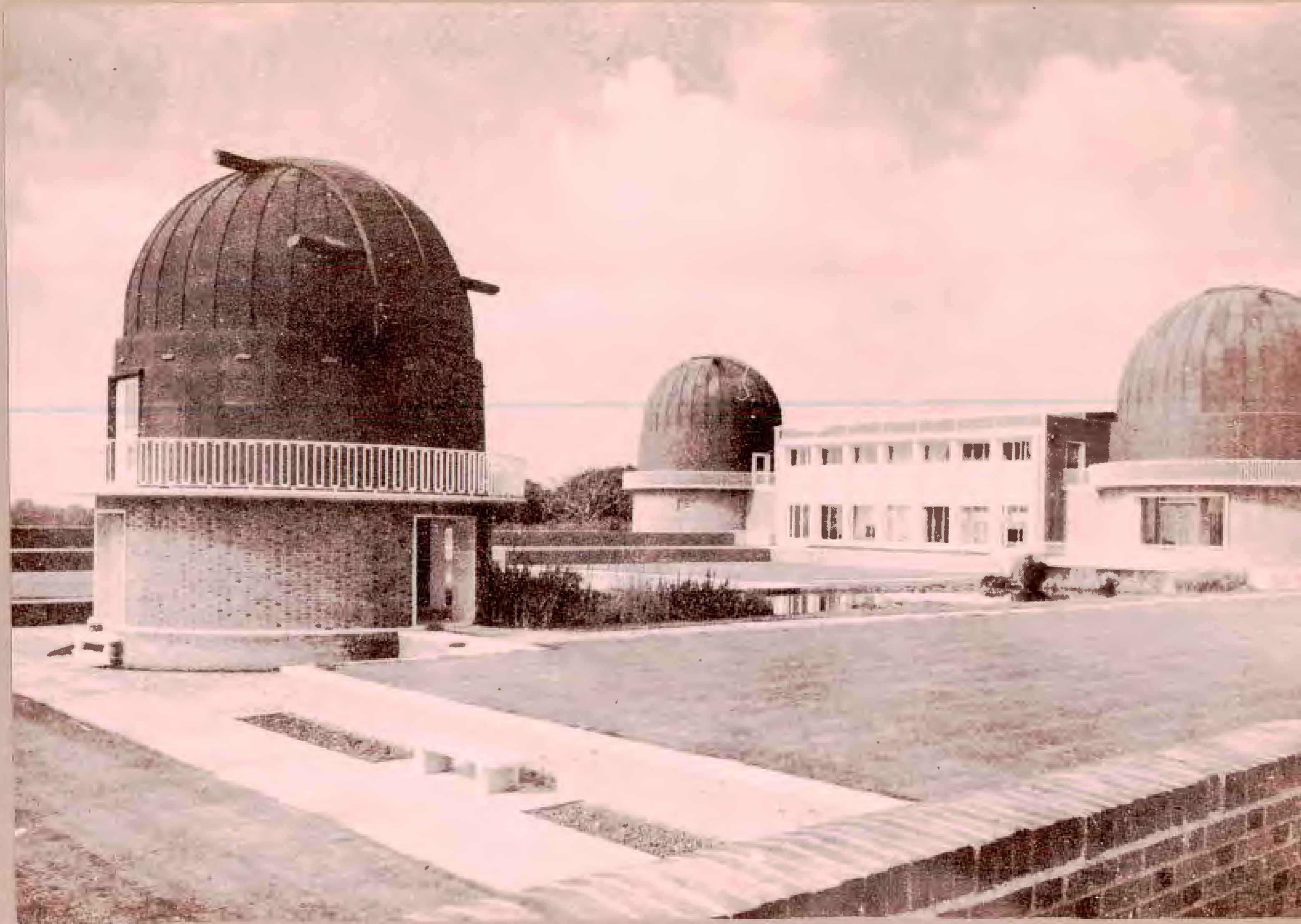
Fig. 14 Sir Christopher Wren's design for the Royal Observatory at Greenwich.




PROSPECTUS SEPTENTRIONALIS.

Fig. 15 A 28-inch visual refractor at Greenwich.

Fig. 16 Architecture at Herstmonceux.



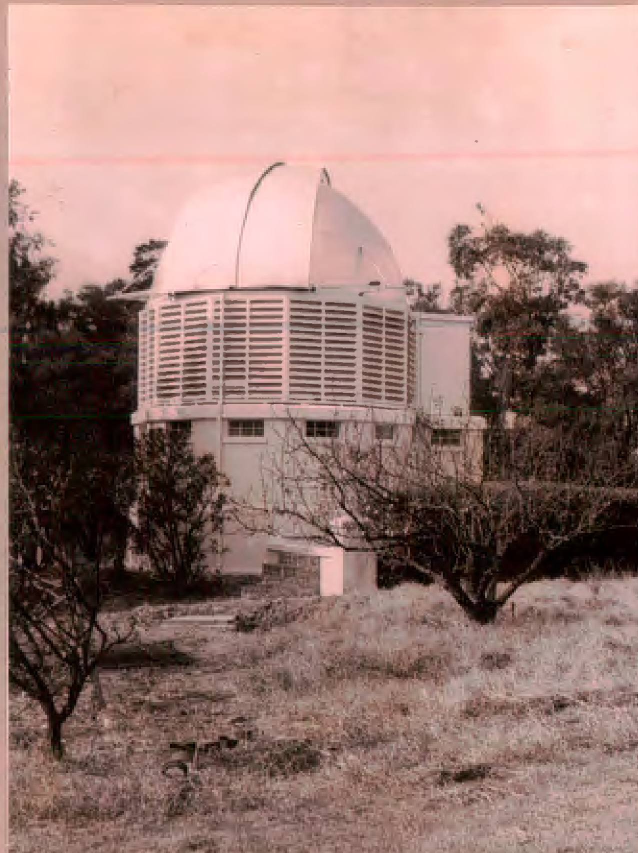
In 1820 the Lord Commissioners of the Admirality resolved to establis an observatory at the Cape of Good Hope for the improvement of practical astronomy. Fourteen years later Sir John Herschel established at the Cape a temporary observatory which was historically important. During four years he completed a survey of the southern heavens, extending the work his father had done many years earlier in the northern sky.

The Schmidt-camera on Mr. Palomar has just completed its "sky survey" of the northern hemisphere. The European Southern Observatory will complete our picture of the universe (i.e. that part within the reach of our present instruments), by mapping the southern sky.

The Cape Observatory has a reversible transit of modern design and an equatorial twin telescope with a 24-inch photographic lens and 18-inc visual lens, known as the Victoria telescope for photographic and spectroscopic work. A 40-inch reflector will be installed within a couple of years.

Nothing can be gained from a closer study of our local Observatory and its architectural merits. It was the prey of a slow development hampered by a constant lack of funds and suffered through the absence of a master plan. What an environment for an institution that did such excellent research work!

Fig. 17 The Royal Observatory, Cape Town.



The L A M O N T - H U S S E Y O B S E R V A T O R Y at Bloemfontein is a branch of the University of Michigan and contains a 27-inch refractor telescope, the largest in the Southern Hemisphere.

A building at peace with itself and the surrounding landscape.

Fig. 18   The Lamont-Hussey Observatory, Bloemfontein.

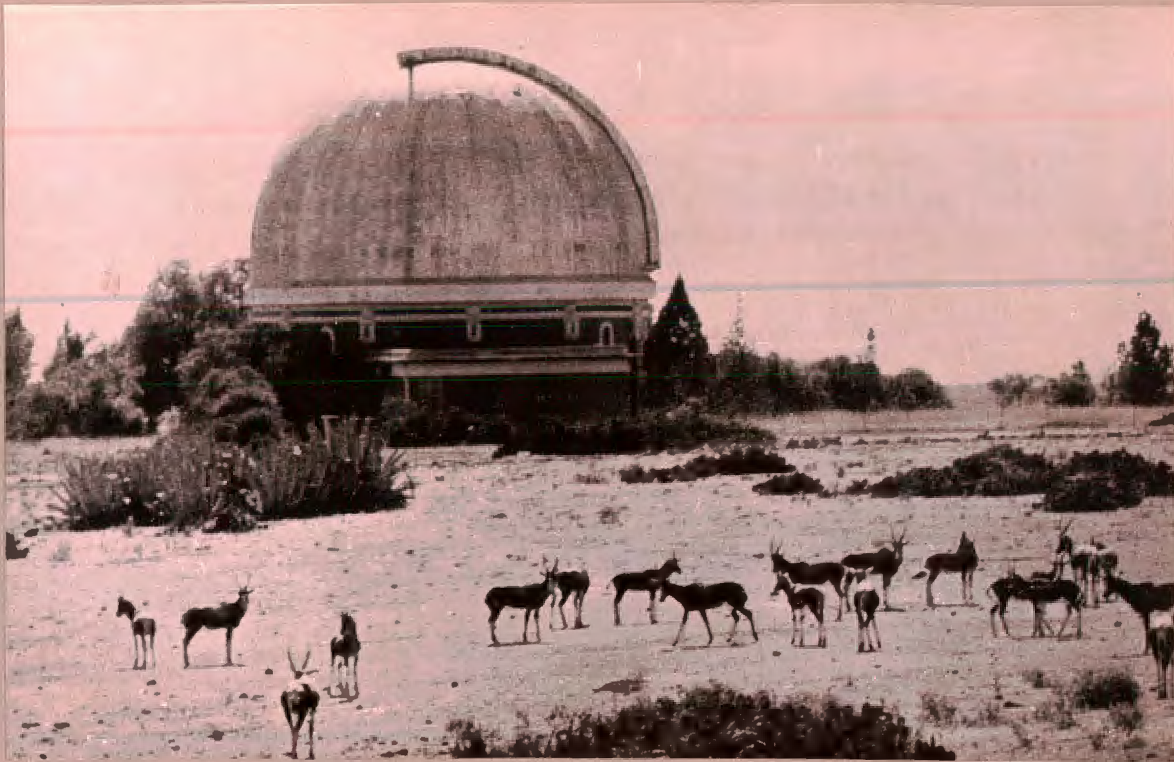


Fig. 19 A Japanese Observatory.

T H E   L I C K   O B S E R V A T O R Y

California.

Mount Hamilton rises 4,200 feet above sea level. The crest of the mountain is a naroow ridge extending in an easterly direction from the main building of the Observatory, which stands on the west peak. Along the ridge the 120" reflector and several smaller telescopes, various service buildings and homes of Observatory personnel are loca

The present Observatory community numbers about 100 persons. Spring a few hundred feet below the summit provide an adequate water supply, while a post office, an elementary school, and a branch of the county library serve the residents.

The Observatory's primary function is research into the nature of the universe, and its staff of faculty-level astronomers engages into whatever lines of investigation appear to be the most fruitful utilization of the telescopes. No formal courses are taught at Mount Hamilton, but advanced graduate students gain observatory experience and undertake research under the direction of the staff. Visiting astronomers also use the equipment to investigate special problems. An estimated 35,000 people visit the Observatory annuall

Fig. 20 The Lick Observatory.

Fig. 21 The recently completed dome housing the 120-inch reflector. The 'after-thought' on the right encloses the spectrograph, which basically is part of the telescope.

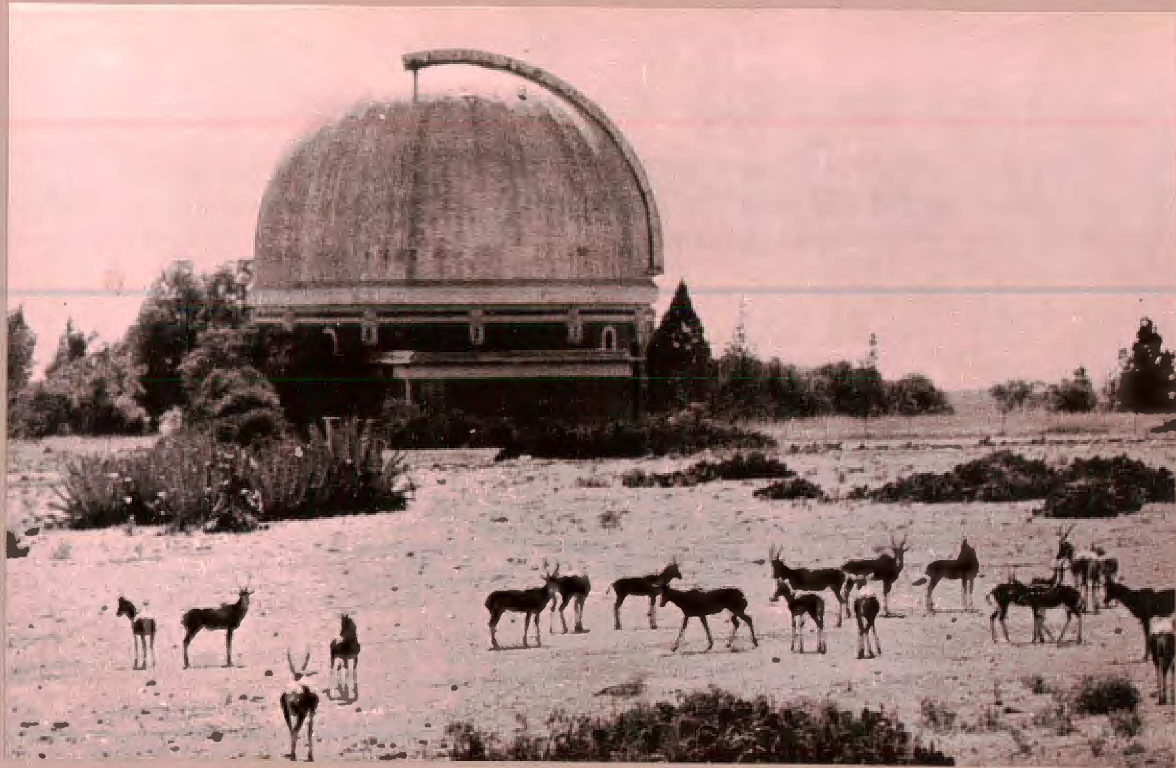


Fig. 19 A Japanese Observatory.

THE LICK OBSERVATORY

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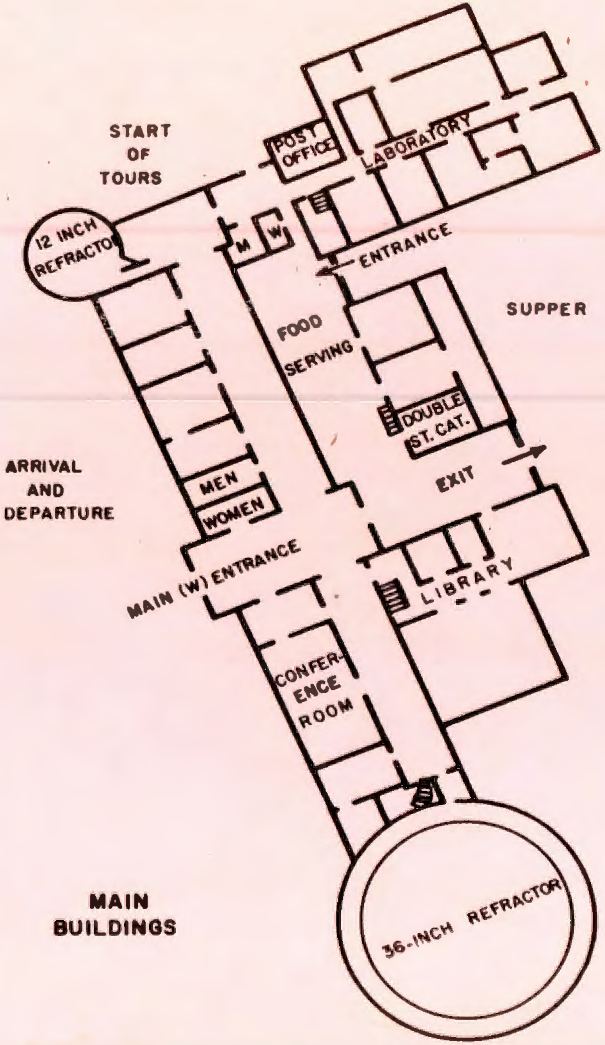
Fig. 20 The Lick Observatory.

Fig. 21 The recently completed dome housing the 120-inch reflector. The 'after-thought' on the right encloses the spectrograph, which basically is part of the telescope.

Fig. 22 No architect is responsible for this - I hope!



MAIN BUILDINGS

Fig. 23 The 120-inch reflector.

P A L O M A R   O B S E R V A T O R Y

This observatory is located at an elevation of 5,600 feet on Mt. Palomar which is about 100 miles from Mount Wilson. The dome and building for the great telescope were erected in 1938 while the telescope itself was only installed ten years later. This instrumen named the Hale telescope, is used in two forms: primary focus with focal length of 55 feet; and condé combination, equivalent focal leng 500 feet. In addition the observatory operates a 48-inch telescope of the Schmidt type, utilizing a 72-inch concave spherical reflector while smaller instruments include an 18-inch Schmidt telescope and a 20-inch reflector.

We shall study this observatory in some detail, as the problems it attempted to answer bear a resemblance to the problems inherent in th European Southern Observatory. At the same time its architecture is typical for most observatories, perhaps - I hope - the culmination of a style that never was.

<u>Points of similarity between Palomar and E.S.O.</u>

Palomar is located on a remote site and has to supply its own electri ty and water.
The observatory proper is seperated from the living quarters.
Huge domes are the dominating features.
An attempt was made to express certain values and convictions through the idiom of Architecture.

The dome, dwarfed by the mountain ranges that surround it, appears small although it is 137 feet in diameter and 135 feet high - i.e. about the size of the Pantheon in Rome. (Fig.26)

The most inportant requirement in the design was good insulation. For this reason there is a 4-foot gap between the concrete walls whi form the base of the building. The interior wall is filled with aluminium foil insulation. For the same reason a 4-foot gap is lef between the inner and outer walls of the steel dome. The inner fac of the dome is made of aluminium panels built in the shape of boxes and filled with crumpled aluminium foil. As the warm air rises through the double walls of the building and the double layers of th dome, cool air enters below through vent holes which, because of the size, lend such a wrong scale to the building. The outside of the dome is composed of steel plates, 3/8" thick, butt welded and moulde to form a strong but smooth hemispherical dome. The supporting str ture is designed somewhat like an aeroplane wing. From two box-girder arches at each side of the slit, thin built-up beams radiate to support the skin-plates of steel. The rotating part of the 1,000-ton dome is mounted on tracks. It rotates on thirty-two four wheeled trucks which have to move so smoothly that no vibration is transmitted to the telescope. It is driven by two four-horsepower motors.

Within the dome, with its foundations entirely seperate, the telescope base is built on the foundation of decomposed granite of which Palomar is made - built, as it were, on a cushion that protects it from jar and vibration.

The observatory building is an amazing place, containing everything the astronomer might need for his comfort as well as for his work. The ground floor contains offices, dark rooms, air-conditioning equipment, a library, and a lunch room where he can prepare his midnight lunch in a well designed kitchenette and eat it in warm comfor on the coldest winter night.

The first floor is used for public rest rooms, electric panel boards time-standard equipment, and the oil-pumping equipment for the telescope oil-pad bearings.

The second floor contains the instrument itself and the glassed-in room from which visitors may view the telescope. To carry the astronomer from the ground floor to the observing floor there is a passen lift, while a freight lift handles instruments. High above the observation floor a 60-ton crane travels between the shutter arches to lift or move necessary equipment. On the side of the shutter is the lift or observing platform (Fig.27) which climbs the side of th dome to carry the observer to his eyrie in the telescope tube.

ANALYSIS

When approaching the building one is overpowered by its sheer size, although the building itself rather lacks scale. It is a pure geometrical shape, but an intravert one, anxiously protecting its contents. The dome is beautiful, with a smooth silver surface, and functional, except for the huge arches covering the slot which can cause considerable turbulence and somewhat detract$ from the otherwise light and airy appearance of the dome.

Nothing indicates that the whole building is a light steel structure nor is there an appreciable difference between the texture of the welded steel dome and the plaster-on-lath treatment of the walls.

Once you have passed through the enormous entrance a new world surrounds you. These are the first impressions of a visitor:
"The foyer inside the main entrance is obviously Porter's handiwork, with its New England simplicity. There is a small rotunda here, very plain and fine, with elliptical arches, supporting a miniature dome above. Hidden red and green lights behind the cornice give th place a soft illumination which prepares one for the quiet of the great spaces beyond."

It is hard to believe, that this tomblike structure enables man to encompass the vastness of the universe.

This windowless, fully air-conditioned, streamlined structure reminds one of a space-ship. An environment completely detached from this world and independent of nature's moods, a setting for the Astronomer, travelling millions of light-years into the Universe, spending many a night amongst distant stars and galaxis.

Palomar exists because of the 200" telescope, this masterpiece of modern technology. It does not acknowledge the fact, that, in the last analysis, the mind which encompasses the universe is more marvellous that the universe which encompasses the mind.

Fig. 24 The main dome on Mt. Palomar.

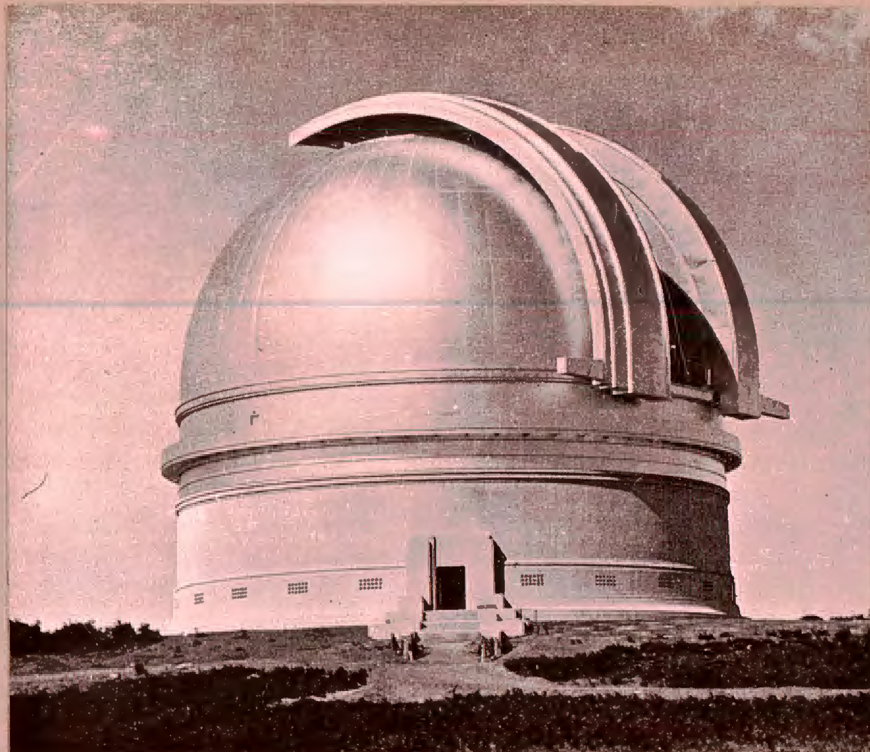


Fig. 25 The dedication ceremony.

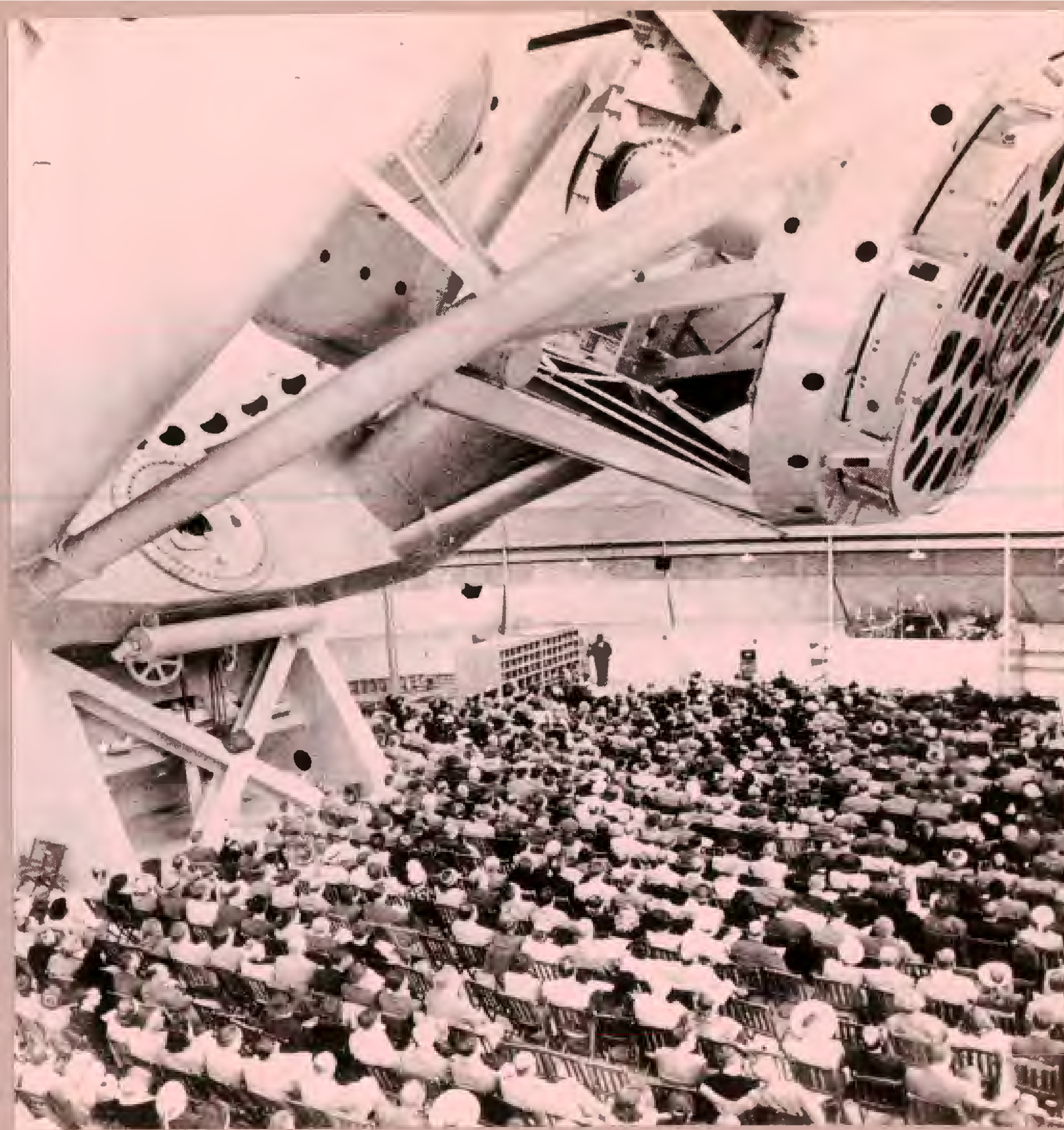


Fig. 25 One ounce of aluminium and photographic emulsion constitute the essential optical surfaces of the 200-inch Hale telescope. To permit these surfaces to function properly, however, some 18 tons of glass and about 500 tons of steel are required.

Fig. 26   This dome is equivalent in size to the one covering the 200-inch telescope.

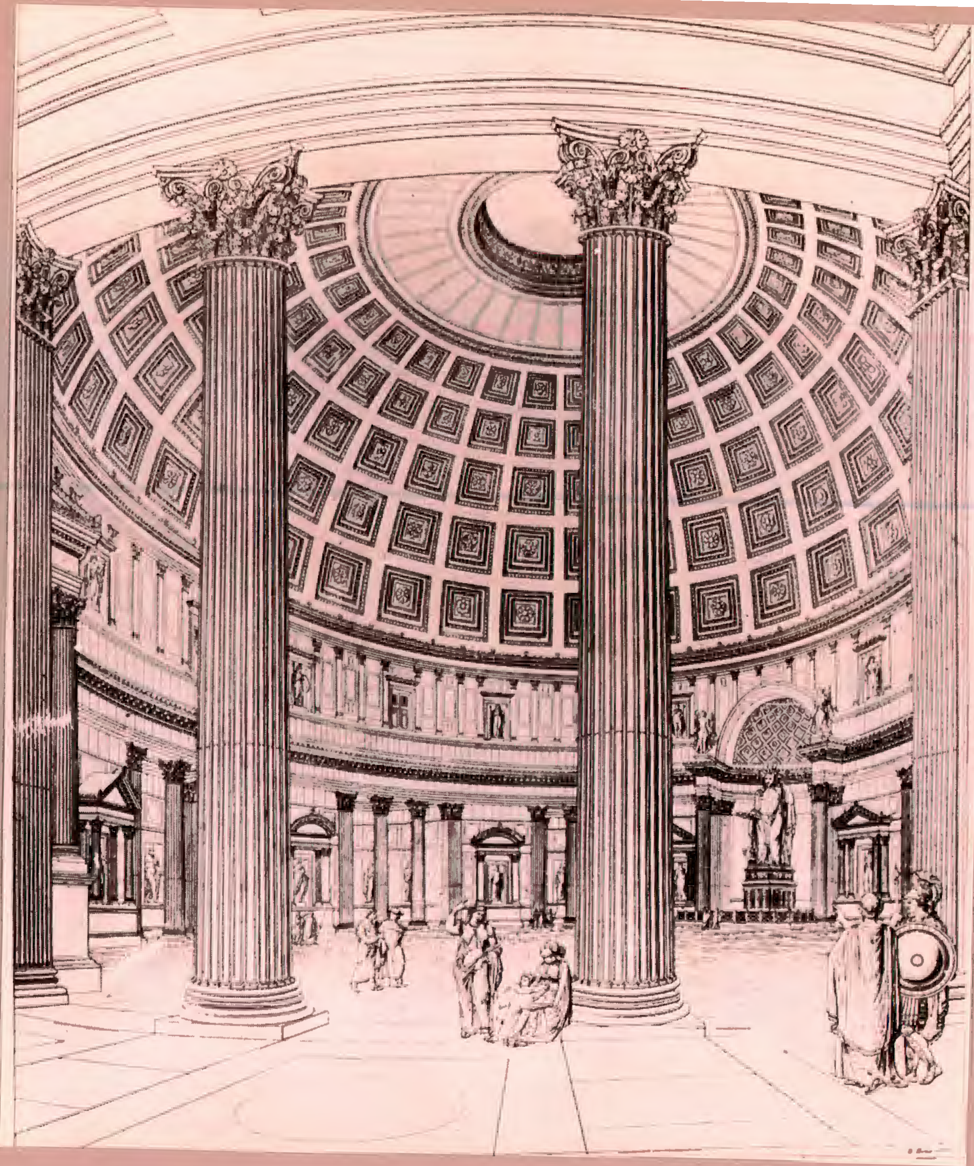


Fig. 27 The lift travelling up the slot in the dome.

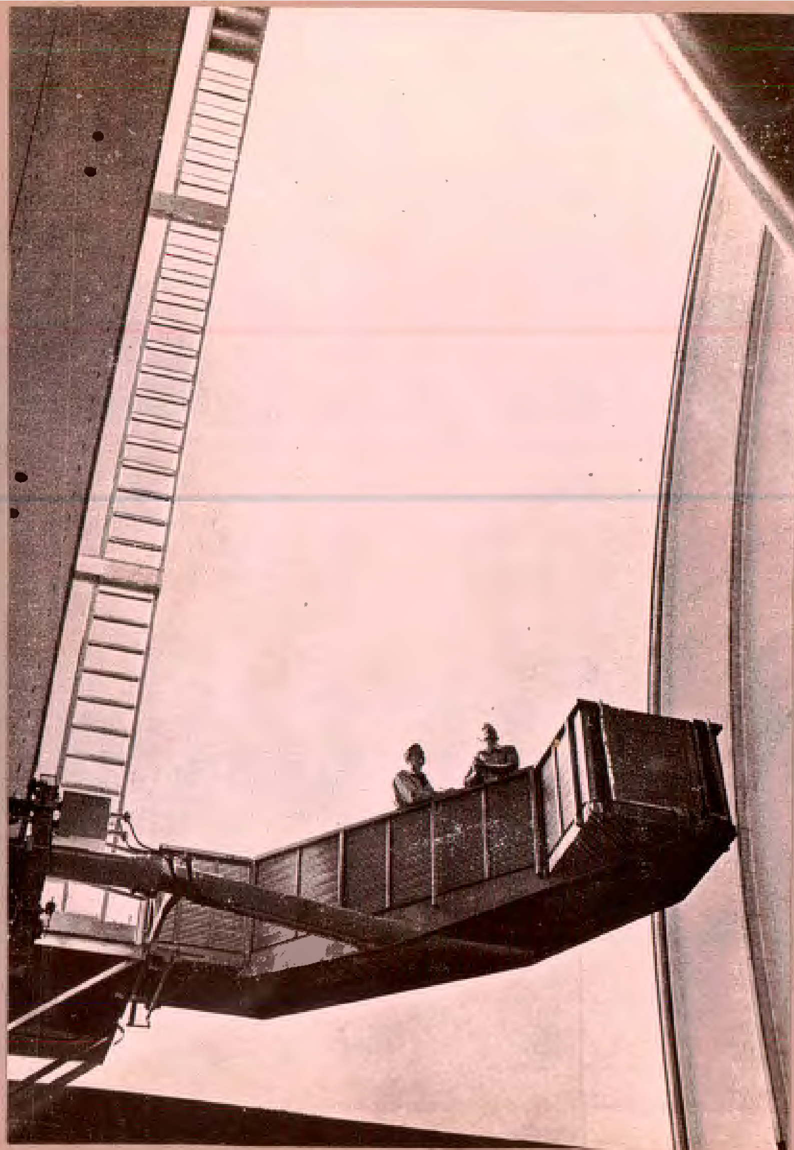


Fig. 28 At the controls of the Schmidt camera. Note the control desk in the background.

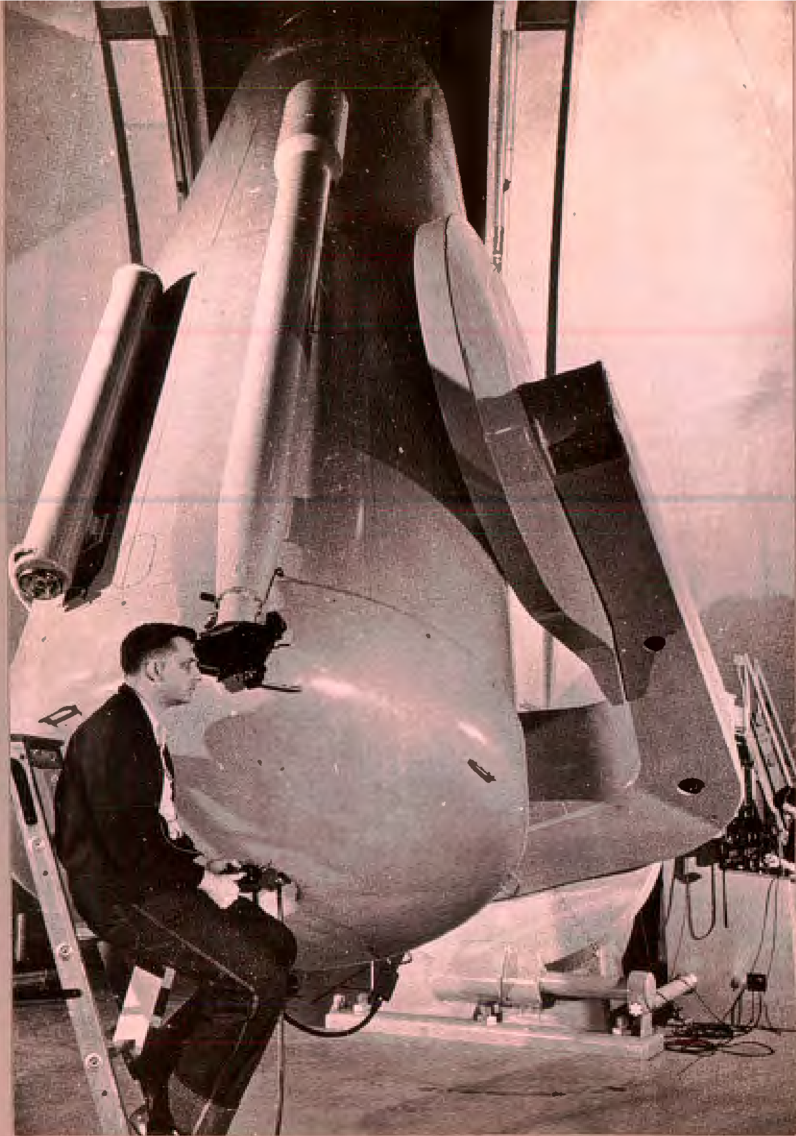
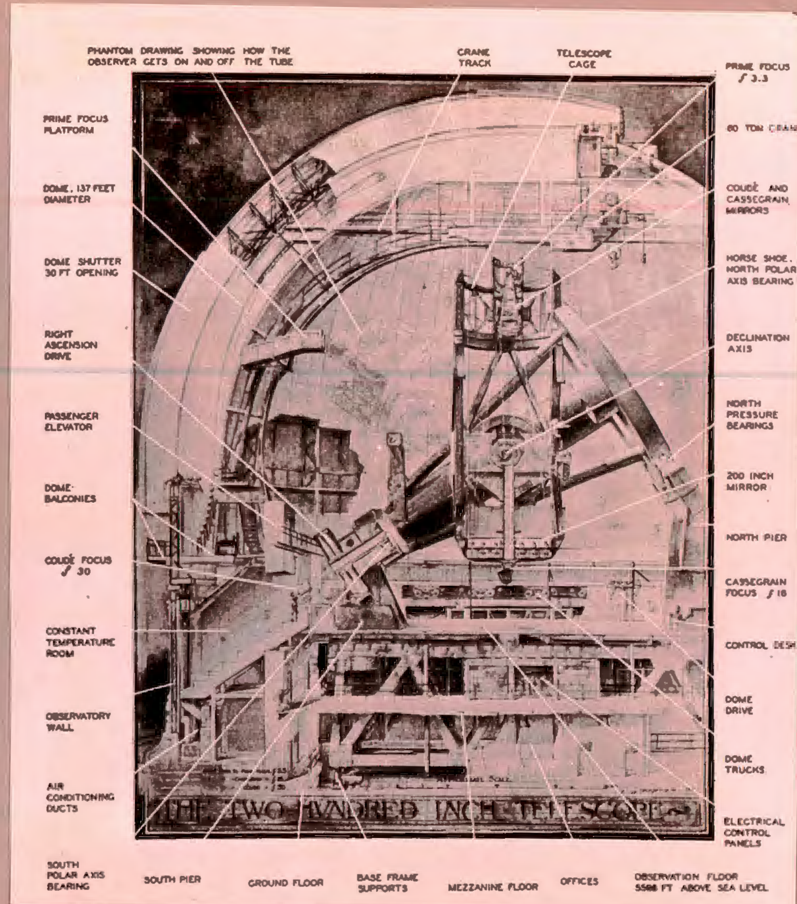


Fig. 29 The 200-inch telescope and its dome shown in section.


PHANTOM DRAWING SHOWING HOW THE OBSERVER GETS ON AND OFF THE TUBE
CRANE TRACK
TELESCOPE CAGE
PRIME FOCUS ƒ 3.3
PRIME FOCUS PLATFORM
60 TON CRANE
DOME, 137 FEET DIAMETER
COUDÉ AND CASSEGRAIN MIRRORS
DOME SHUTTER 30 FT OPENING
HORSE SHOE, NORTH POLAR AXIS BEARING
RIGHT ASCENSION DRIVE
DECLINATION AXIS
PASSENGER ELEVATOR
NORTH PRESSURE BEARINGS
DOME BALCONIES
200 INCH MIRROR
NORTH PIER
COUDÉ FOCUS ƒ 30
CASSEGRAIN FOCUS ƒ 16
CONSTANT TEMPERATURE ROOM
CONTROL DESK
OBSERVATORY WALL
DOME DRIVE
DOME TRUCKS
AIR CONDITIONING DUCTS
ELECTRICAL CONTROL PANELS
THE TWO HVNDRED INCH TELESCOPE
SOUTH POLAR AXIS BEARING
SOUTH PIER
GROUND FLOOR
BASE FRAME SUPPORTS
MEZZANINE FLOOR
OFFICES
OBSERVATION FLOOR 5598 FT ABOVE SEA LEVEL

T H E   A C C O M M O D A T I O N

T H E D O M E S

form the nucleus of every observatory, both functionally and visually. They are basically enclosures protecting the telescopes, with special openings permitting their use at night. Domes usually consist of light steel structures covered on the outside with thin sheet iron or aluminium and internally with sandwich panels, which, together with the cavity between the two skins, provide a high degree of insulation against the heat of the sun; a cardinal consideration in the design of domes. In day-time the slot is covered by two shutters, while during observations canvas louvres cover all of it, except the portion in front of the telescope tube. These louvres are automatically adjusted to the declination of the telescope while the shutters are operated from the control desk. A series of heavy trolleys running on steel tracks allow the dome to rotate. The drive is synchronized with the clockwork of the telescope, so that the slot of the dome is always opposite the tube.

The domes are kept tightly closed all day. An air-conditioning system maintains the interior at the temperature anticipated for the next night. As this involves the cooling of half-a-million cubic feet of air the importance of insulation is evident.

The 150-inch telescope requires a 30-ton crane travelling between the shutter arches to lift or move equipment, and a lift climbing the side of the dome to carry the observer to the cage in the telescope tube. (Fig. 27) The smaller domes will have 4-ton cranes only.

On the observing floor will be the control desk and a movable light hydraulic lift used by the observer when working on the Cassegrain focus. Usually a large, stationary hydraulic lift is provided to lower the mirror to the level of the aluminizing room and to transport other equipment. The two larger domes will have glazed-in galleries from which the public can view the telescopes.

The domes of the 150-inch and the 40-inch each require a <u>COUDÉ - SPECTROGRAPH ROOM</u>. In this room a beam of light from the most distant of nebulae will arrive along the coudé focus after reflection from five different mirrors. With the aid of an 'image slicer' it will be delivered into a high-dispersion spectrograph and focussed onto a highly sensitive plate as a spectrum. So delicate is this operation, that room and instrument must be kept at perfectly constant temperature and without the smallest vibration. Electronics has just entered this field and new types of spectrographs are being devised and tested. Adequate space should be provided, allowing latitude for future additions. A support for small spectrographs will be part of the independant telescope support, while a tired room (Fig. 29) will be provided for high-dispersion apparatus.

Near each telescope should be a <u>ROOM FOR STORING INSTRUMENTS</u> (e.g. Cassegrain spectrographs) with a refrigerator for the photographic plates. A seven cubic feet domestic unit with modified shelves would be adequate. This room would also be used as a darkroom for loading plate holders.

The special bearings of the 150-inch require high-pressure oil-pumping equipment located in a seperate room, while each telescope has a room containing the electronic control gear and switchboards. Large built-in cupboards for the cleaner's requirements will be provided, supplemented by store-rooms for stepladders, crates for the instruments etc.

Each dome should be supplied with efficient fire-fighting equipment, as water hoses cannot be relied upon due to the low pressure. On all domes lightning protection is of cardinal importance.

The <u>ALUMINIZING ROOM</u>. Approximately every eighteen months the mirro have to be recoated. This process consists in principle by covering a number of coils of tungsten wire with pure aluminium, suspending these above the mirror in the tank, creating a high vacuum and then boiling the aluminium off in a shower upon the disk, by passing an electric current through the coils. Astronomers are always extremel nervous when this operation takes place, as the mirror has to be unscrewed from the telescope, lowered through a hole in the main observing floor and conveyed on a special trolley to the aluminizing tank where the new reflective surface is to be applied. The utmost precuation must be taken as the slightest jerk may damage the delicat piece of glass. This applies mainly to the 150-inch mirror which can weigh as much as 20,000 pounds. The handling of the smaller mirrors present no real problem. Therefore this room should be near the largest reflector. The equipment consists of the following

one tank	14 ft. dia.	3 ft. high	
" "	5 ft. dia.	2 ft. high	
" "	4'3" dia.	2 ft. high	

a vacuum pump driven by an electric motor;
a 10-ton overhead crane.

To reduce handling, the bottom halves of the tanks double up as trolleys onto which the mirrors are lowered from the telescopes. A temporary cover protects the mirrors against dust and undue changes of temperature. In the aluminizing room the crane lifts the upper half onto the trolley, an air-tight seal is formed and the vacuum pump is connected and switched on.

The ASTROLABE is used for observations at an angle of 45° right around the horizon. The room, which has to be air-conditioned, must have an opening in the roof permitting these observations and have a concrete pedestal in the centre of the room, 3 feet high and 2 feet square, taken down to a deep, independent foundation.

Complete thermal control and protection against vibration is essential in the room containing the QUARTZ CHRONOMETERS. These timekeepers are a recent development and so accurate that any irregularities in the rotation of the earth (2 or 3 seconds a year) can be detected - provided the temperature in the room remains constant.

These chronometers should be near the measuring rooms and control slave clocks in the domes.

When the spectrum is obtained it requires interpretation; the lines in the spectrum, for example, may correspond in position exactly with the lines produced by the vapour of iron, but some may be abnormally strong and others hardly visible. It is then the task of the astrophysist to discover what this difference means. His laboratory is equipped with dynamos, electric arcs, furnaces, pressure pumps and vacuum pumps. As most work of this nature will be done in Cape Town a small LABORATORY at Seekoegat will suffice, equipped with two laboratory benches, each with a laboratory sink and a two-point gas outle connected to liquid gas containers; a fume cupboard; a small furnac two large tables for pumps and electrical equipment; and a basin wit a hot and cold water supply.

The MEASURING ROOM is equipped with tables for two Blink Microscopes and an Iris Photometer, at each of which the results are recorded automatically. Two darkroom cubicles contain Photometers while another two cubicles contain Spectroscopes. Four large tables will be required for preparing sky-maps, sorting photos etc. Excellent daylight is essential.

The COMPUTER should stand in a seperate room close to the measuring room.

THE DARK ROOMS

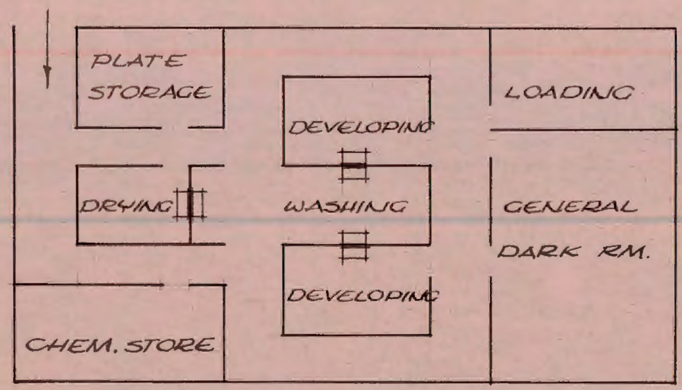
Although in routine observation programmes the processing of the photographic plates can be done miles away, a dark room close at hand is advisable for the loading of plate-holders, the testing and standardization of plates and other operations. This need not be right next to the telescope, as with long exposures and plates changed only each hour or so, a short walk to the dark room will be a welcome change for the astronomer, especially if he has been guidi in a cramped position. In the case of short exposures where plates are changed perhaps every five minutes, he will probably take along a good supply.

For processing the photographs a large main dark room is planned in conjunction with several smaller one, all of which have to be near the laboratories and cubicles where the instruments are. These rooms must be designed especially for astronomical photography. The main dark room will include the following:

- About 20 cub. ft. of refrigerated plate storage;
- a thermostat sink;
- a copying camera;
- two enlargers;
- facilities for processing large quantities of prints
- provision for handling large numbers of plates.

These dark rooms should all be completely air-conditioned and kept at a constant temperature. They require no day-light.

The drawing below shows the arrangement of a main dark room used by more than one person, as recommended by the Eastman Kodak Company.



STORAGE for photographic plates should consist of a large store closely related to the library and kept at a constant, low temperature. It will contain the plates of current programmes as well as those of visiting astronomers. The filing is done by the secretary in charge of the library.

T H E W O R K S H O P S

Continually new auxiliary equipment is being developed for the variou types of research. These have to be built in the observatory to facilitate testing. Visiting astronomers bring along their own atta ments, but often have to modify them according to the construction o a particular telescope. This will be done in the INSTRUMENT SHOP. Lenses and mirrors will be ground in the OPTICAL SHOP. For testing the alignment of apparatus an unobstructed space five foot wide and sixty foot long is required. The instrument shop will be equipped with workbenches, a small lathe, drills, welding units and all tools essential for precision metal work. Machines for handling larger units will stand in the MACHINE SHOP and enable the mechanics to dea with any maintenance problem. A well equipped ELECTRONICS DEPARTMENT is essential as virtually all instruments' efficiency depend on faultless electric circuits. Both the electronics engineer and the chief maintenance mechanic will have their own office.

THE AIR-CONDITIONING PLANT

The following units require 1). Air-conditioning and cooling
2). Constant low temperatures.

a. All domes
Aluminizing room
Measuring room
Computer room
Dark rooms
Laboratory
Optical shop
Astrolabe room

b. Quartz-chronometer room
Spectrograph rooms.

Due consideration should be given to the possibility of air-conditioning the administrative offices, the common room and the Restaurant. Small units might also be installed in the living room and bedrooms of the Director's residence and the caretaker's flat.

T H E   A D M I N I S T R A T I V E   O F F I C E S

A generous FOYER related in some way to the largest of the domes will welcome the visitor and install in him the atmosphere of a large observatory. The reception desk will be closely related to the offi of the director's secretary.

The E.S.O. will be the scene of frequent meetings and conferences attended by astronomers and students from all over the country. Thes will be held in the BOARD ROOM, also used for staff meetings, and, should this prove too small, in the LECTURE THEATRE accommodating eighty people. The latter will also be used for public lectures and film shows that are to be part of the conducted tours to stimulate public interest.

Eight OFFICES, each spacious enough for two people to work in comfort will be used by the resident and visiting astronomers. The director will occupy a generous office near the entrance.

THE LIBRARY. Apart from books on astronomy it will contain the publications of every other observatory, which are obtained by exchange, as well as the journals of the astronomical and kindred societies; and a few technical journals by subscription. In addition a wide selection of books on other topics will be available. Every member of the staff has access to the library and no control system is necessary. The astronomers' secretary will do the cataloguing and filing and will be in attendance during fixed hours. A READING AREA opening out onto a quiet court will be an asset.

THE OFF-DUTY SECTION

During tea breaks the staff will gather in the RESTAURANT served by a KITCHEN where snacks and light meals are prepared. Quite a numbe will spend their lunch-time there too, while others will go down to the living quarters during the lunch break, which usually lasts 1½ hours.

Shortly after midnight the observer and his night-assistant will lea the telescope and come down to the Restaurant. He or one of his colleagues will prepare a few cups of coffee and some sandwiches in the KITCHENETTE, while the others play a game of chess, smoke a pipe or just relax and discuss the latest topic.

The COMMON ROOM will be used during lunch hours and at night by astr nomers waiting for clouds to clear away. It is the social centre of the observatory and should be related to the Restaurant as well a a carefully planned courtyard.

CHANGING ROOMS for the staff will be provided somewhere near the Restaurant.

Gents:	2	W.C.'s
	1	Urinal
	2	Showers
	3	Basins
	Lockers for 40 people	
Ladies:	2	W.C.'s
	1	Shower
	2	Basins
	Lockers for 10 people.	

Clouds may obscure parts of the sky and make observations impossible Astronomers and their night-assistants then have to wait for conditions to clear up, a time usually spent in the Common Room, but some will prefer to sleep for a couple of hours, which they can do in bedrooms available to them.

These ameneties are open to all members of staff and an authority from Greenwich may find himself sitting next to the assistant electrician. This will cause no tensions, as all have the same main interest and because each member of the staff is a highly skilled specialist.

T H E   P U B L I C ' S   S H A R E

The fascinating mysteries and realities of the universe with its stars, asteroids and planets, as well as the noblest instrument of modern science, the giant telescope, are so awe inspiring, that not only the professional but also the layman should have a right to share this experience. With the Observatory being so close to the Cango-caves and accessible on tarmac roads, the combined attrac tion of these two may result in ever increasing numbers of tourists visiting the observatory.

A 20-inch reflector will be installed for them through which they can view the stars and planets in the early evening. Tours will be conducted under the guidance of a member of the staff, and include lectures, slide and film shows in the LECTURE ROOM and provide the opportunity of seeing the telescopes from glazed-in galleries. A comfortable restroom will serve those who arrive too early for a conducted tour. Post cards will be for sale at the enquiries counter, but no refreshments will be avaiable, as the shop at Seekoegat is only a few miles away. While everything should be done to make these visits an unforgettable experience, the circulation of the public should in no way interfere with the work of any member of the staff.

The GENTS' CLOAKROOM will include:

2 W.C.'s
1 Urinal
2 Basins

The POWDER ROOM will include:

2 W.C.'s
2 Basins

S E R V I C E S

A fully automatic telephone system is essential, including connections between the various observing positions on the telescope and the control desk. Trunk calls will be handled by the secretary.

Only male Africans will be employed as cleaners and garden boys. At the observatory a resting room is available to them including:

1 W.C.
1 Urinal
2 Basins
1 Shower
Lockers for 12 men.

Their living quarters are near those of the European staff.

The proposed scheme will have its own POWER PLANT consisting of Diesel-powered units standing on huge blocks of concrete which in turn are supported in pits on springs at the four corners, to suppress all vibration. Although the plant will be at least half a mile from the domes, the mirror system might respond even to the Diesel engines will be controlled by a Telechron master-clock system, so that the current will be generated at a frequency withi one percent of sixty cycles at all times, to form a steady basis for the driving machinery for the telescope as well as furnish timed current for electric clocks all over the settlement.

The WATER SUPPLY will depend upon boreholes supplying large reserv in the valley near the residential quarters from where it will be pumped to the pressure tank at the Observatory.

COURTYARDS: Conditions in the Karroo suggest an intravert scheme, where fully enclosed working spaces are related to partly enclosed courtyards, exhibiting a balanced play of water, lush vegetation, paths and open spaces.

P L A N N I N G

From all available sources not one example could be found of an Observatory designed as a homogeneous whole in an contemporary archi tectural idiom. Most consist of domes and numerous buildings hap-hazardly scattered amongst trees and lawns, often using the remnants of past centuries to house laboratories and workshops.

An attempt will be made to correlate the various functions and acti ties within a unified group of integral spaces.

Observations mainly occur along the meridian where the telescopes should command an unobstructed view down the horizon. Usually no observations are made at an angle of less than 10 degrees, due to distortions in stratified air. The angle of vision required deter-mines the distances between the domes and thus becomes a governing factor in the planning and positioning of the various domes.

The following angles of vision have to be allowed for:

150-inch telescope	- 5 degrees
48-inch Schmidt	- 10 degrees
40-inch telescope	- 15 degrees
20-inch astrograph	- 15 degrees

15 Degrees is adequate for the smaller instruments, as only excepti observations will be made at a lower angle, and these are all handl by the 150-inch reflector.

The laboratories and workshops will not be forced in underneath one of the domes - as so often is the case - but form a core related to all the domes with careful considerations given to the possibilities of daylight and natural ventilation. Many of the rooms, especially those housing the instruments, require air-conditioning. The consequence of this is often that all rooms are air-conditioned and day light is ignored (e.g. Mt. Palomar). But the astronomer and his staff remain human beings dependant for their well-being on the rythms of nature.

The magnificent view towards the Zwarteberge will be fully utilized, especially in the design of the off-duty section.

To eliminate the danger of rising air around the domes at night virtually all observatories employ large expanses of lawn. The resu justify its use even in the Karroo. The astrograph at Seekoegat stands on lawn 80 feet x 100 feet and the astronomer there regards t as one of the reasons for the instruments' success. An adequate supply of water is guaranteed so that approximately 150 feet of lawn around the largest dome and 100 feet around the smaller ones will be incorporated in this scheme. This lawn as an element of design wil present interesting architectural problems.

C I R C U L A T I O N

There are three distinct arterial systems of circulation in an observatory.

a. STAFF CIRCULATION. The activities of the astro seperated into the following groups:

1. Observing and photographing at the telescope.
2. Developing the photos.
3. Analysing, measuring and correlating the results.
4. Office work.
5. Devising new apparatus.
6. Off-duty.

Each activity will occupy him for a long period of time, but the sequence has to be studied carefully, as it will govern the general pattern of circulation. The movements of the rest of the staff ar[e] limited to certain areas - with the exception of the maintenance engineer and the cleaners.

b. <u>INSTRUMENT CIRCULATION</u>. This involves the handling and conveyance of mirrors and delicate instruments and should preferably b[e] limited to one level. Allowance must be made for the size of some of the telescope attachments, the largest of which are the 12'6" di[a] mirror and the 20' long interferometer of the main telescope. The passages linking the domes should furnish a certain amount of prote[c]tion against the weather, but do not have to be fully enclosed. The mirrors and all instruments will be transported under air-tight plastic covers. As these instruments will not be moved frequently this circulation can coincide with that of the staff.

c. <u>PUBLIC CIRCULATION</u>. Astronomers usually abhor visitors ---- because of the naïve questions they ask and their eagerness to learn, to understand every instrument, process and method of work. No specialist whose work requires the utmost concentration likes to be interrupted. Therefore public circulation will be limited to certain parts of the observatory and completely seperated from the activities of the staff. Large numbers of tourists are expected.

S T R U C T U R A L   A N D   T E C H N I C A L

C O N S I D E R A T I O N S.

To support a rotating dome weighing some 600 tons presents many problems; e.g. considerable wind forces have to be absorbed in such a way that no vibration can occur. The supports and foundations of the dome have to be distinctly seperated from those of the telescope which will be taken down into the solid rock with no direct contact between the supports and the surrounding substance for the first ten feet, so as to eliminate all tremours transmitted through the upper strata.

Although the design of the rotating dome is an engineering problem and can not be dealt with in any detail in this thesis a knowledge of the various possibilities is essential. In the Analysis of Precedent the construction of the dome at Palomar has been described. This is a rather conventional structure of considerable weight. A lighter and more elegant type of construction is desirable, as it would simplify the problem of transporting these elements to the site at the same time decreasing the stresses in the sub-structure.

The dome nestling over the inner well at the top of the Rotunda Building, the hub of Ford Motor Company's Dearborn office, spans 93 feet and weighs 8½ tons compared to 160 tons of a conventional steel dome of equivalent size. It is a geodesic dome, and all units were factory cut and drilled to a tolerance of 0.005 inch and assembled on the site. (The weight given does not include the covering material). Tempting as this type of construction may be to the architect, it must be remembered that when pierced by a slot a geodesic structure looses its inherent strength, the distribution of forces changes and considerable stresses occur along the edges of the slot.

Another possibility that should be investigated is the structural system used for the Dome of Discovery, built for the South Bank Exhibition as part of the 1957 Festival of Britain (Fig.30). This system is based on a series of concentric circles. Within this scheme the ribbed arches were laid across in three directions. Thi created an overall pattern of triangular sections, making it possibl to fabricate segments of arches, joists and purlins in standardized curvatures and dimensions. Aluminium was used throughout.

The need for good insulation and lightness suggests aluminium as the appropriate material for the domes because of its high reflection coefficient and low weight.

For the structure supporting the domes as well as for enclosing most of the other instruments - all of them highly sensitive to vibration - concrete seems to be the appropriate material, especiall when used in large corss-sections and bold shapes to form a steady support.

The time available does not permit a penetrating study into the mechanics of the instruments, but this being a thesis dealing with the architectural aspects of an observatory, this information would be irrelevant. All instruments are entities, each standing on a support or table seperated from all other units and requiring no services other than electrical conduits and the air-conditioning plant.

__Fig. 30__ The aluminium construction for the dome of discovery.

Relatively late in history man assumed a role of opposition to nature, endeavouring to shape a more favourable environment. The Spanish philosopher José Ortega Y Gasset expressed this rather well:

.... Till then only one space existed, that of the open country, with all the consequences that this involves for the existence of man The man of the fields is still a sort of vegetable. His existence, all that he feels, thinks, wishes for, preserves the listless drowsiness in which the plant lives. The great civilisations of Asia and Africa were, from this point of view, huge anthropomorphic vegetation But the Greco-Roman decides to seperate himself from the fields, from Nature, from the geo-botanic cosmos. How is this possible? Ho can man withdraw himself from the fields? Where will he go, since the earth is one huge, unbounded field? Quite simple; he will mark off a portion of this field by means of walls, which set up an enclosed finite space over against amorphous, limitless space. ...... The square, thanks to the walls which enclose it, is a portion of the country-side which turns its back on the rest, eliminates the rest, and sets up in opposition to it. This lesser rebellious field, which secedes from the limitless one, and keeps to itself, is a space 'sui generis', of the most novel kind, in which man frees himself from the community of the plant and animal, leaves them outside, and creates an enclosure apart which is purely human, a civil space.

from a C.I.A.M. Symposium.

Homo sapiens, a temperature-sensitive organism, always abhorred desert life and turned to it only when no other alternative remained. To him it was the land of the dead - he remained the oppressed. The Arabs in their villages never quite freed themselves; their houses are of hesitant shape, moulded by the desert wind. Only a great civilization rooted in fertile regions, the Egyptians, had the inertia to make definite statement, to achieve harmony through contrast: the pyramids.

The technology of our age enabled man to invade the land of the dead --- in pursuit of solitude and in pursuit of knowledge. Desert homes provide isolation and complete comfort to those who can afford it. Outposts of science ignore the inclination of human nature and disappear under arctic ice or in lonely desert regions. New demands suggest new idioms. The desert is more than a neutral background - it is a challenge.

"Desert character seems to cry out for a space-loving architecture of its own. The straight line and flat plane must come here - of all places - but they should become the dotted line, the broad, low, extended plane, textured, because in all this astounding desert there is not one hard, undotted line to be seen.

Yes, desert is rock-bound earth, prostrate to the sun. All life there above the crystal is tenacious sun life. All life there dies a sun death. Evidence is everywhere, sometimes ghastly.

It is gratifying as we look around us to see how well we fit into this strange, stern, well-armed, creeping cover of abstract land and its peculiar growth, almost as abstract.

A desert building should be nobly simple in outline as the region itself is sculptured: should have learned from the cactus many secrets of straight line patterns for its forms, playing with the light and softening the building into its proper place among the organic desert creations - the manmade building heightening the beauty of the desert and the desert more beautiful because of the building.

Anyone may see that the desert abhors sun defiances as nature abhors a vacuum. This universal sun- acceptance by way of pattern is a condition of survival and is everywhere evident. That means integra ornament in everything. Sun acceptance in buildings means dotted outlines and wall-surfaces that will eagerly take the light and play with it, break it up and render it harmless or drink it in until sunlight blends the building into place with the creation around it."

Frank Lloyd Wright.

L I S T   O F   A C C O M M O D A T I O N

150-inch REFLECTOR

Dome	110	ft.	diameter
Spectrograph room	600	square	feet
Instrument and plate storage	200	"	"
Oil pumping equipment	80	"	"
Electronic control gear	150	"	"
General store	150	"	"
Visitors' gallery	300	"	"

48-inch SCHMIDT CAMERA

Dome	55	ft.	diameter
Instrument and plate storage	150	square	feet
Electronic control gear	120	"	"
General store	100	"	"
Visitors' gallery	300	"	"

20-inch ASTROGRAPH

Dome	40	ft.	diameter
Instrument and plate storage	100	square	feet
General store	100	"	"

40-inch REFLECTOR

Dome	40	ft.	diameter
Spectrograph room	200	square	feet
Instrument and plate storage	100	"	"
General store	100	"	"

ASTROLABE

Room with sliding roof	200 square feet

20-inch TRANSPORTABLE REFLECTOR FOR PUBLIC

Store room	100 square feet

ALUMINIZING ROOM 800 square feet

AIR-CONDITIONING PLANT 1000 square feet

PHOTOGRAPHIC DEPARTMENT

Main Dark room	1000	square	feet
6 Small dark rooms	450	"	"
Plate storage	150	"	"

ANALYSIS

Measuring room	600	square	feet
Quartz-chronometer	150	"	"
Computer room	150	"	"
General laboratory	250	"	"
Chemical store	80	"	"

ADMINISTRATION

Foyer			
Reception and Secretary	150	square	feet
Secretary	150	"	"
Director	250	"	"
8 Offices	1200	"	"
Board room	600	"	"
2 Cloak rooms	200	"	"

LIBRARY

Library and reading area	1500	square	feet
Stackroom for books	300	"	"
Stackroom for photographic plates	200	"	"

OFF-DUTY

Common room	700	square	feet
Restaurant	300	"	"
Kitchen	150	"	"
Kitchenette	80	"	"
Pantry	50	"	"
2 Cloakrooms	300	"	"
4 Bedrooms	500	"	"
Cleaner's store	80	"	"
General store	150	"	"

PUBLIC

Restroom	500 square feet
Lecture room	800 " "
2 Cloakrooms	300 " "

WORKSHOPS

Instrument shop	600 square feet
Optical workshop	300 " "
Machine shop	800 " "
Store room	600 " "
Electrical workshop	300 " "
Electrician's office	100 " "
Mechanic's office	100 " "
Cleaner's store	80 " "
Loading and packing	

SWITCH ROOM	100 square feet
GARDEN TOOLS	100 " "
COVERED PARKING FOR 15 CARS	
CHANGE ROOM AND CLOAKS FOR AFRICANS	400 square feet

PRESSURE WATER TANK for 1000 cub. ft.

DIRECTOR'S RESIDENCE

Entrance	
Living	300 square feet
Dining	160 " "
Study	120 " "
Kitchen	150 " "
Pantry	50 " "
Boxroom	50 " "
Laundry	80 " "
Master Bedroom	200 " "
2 Bedrooms	300 " "
Guest room	150 " "
Bathroom	80 " "
Cloakroom	30 " "

CARETAKER'S FLAT

Entrance	
Living/Dining	350 square feet
Kitchen	120 " "
Pantry	50 " "
Boxroom	50 " "
Bath	80 " "
3 Bedrooms	400 " "

PARKING for 30 visitors' cars

Stairs, ramps, lifts and terraces as required.

THE PEOPLE CONCERNED

1	Director of the Observatory with family
16	Astronomers - visiting and permanent
2	Secretaries
1	Electronics engineer and 1 assistant
1	Maintenance mechanic and 1 assistant
1	Optician
8	Astronomers' night assistants
1	Instrument maker and 1 assistant
2	Darkroom assistants
1	Laboratory assistant
1	Housekeeper
1	Caretaker and family
12	Native boys

DRAWINGS PROPOSED

1. 16th-inch Site layout
2. 16th or 8th scale drawings fully explaining the scheme
3. Perspective studies
4. A model of the scheme
5. Half-inch details
6. Colour study
7. A special study on Thermal Control

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