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The Isaac Newton Telescope

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(Chairman, Board of Management)

INTRODUCTION

While no one would wish to lay unnecessary stress on national achievements in astronomy, a science in which the whole of mankind can band together in an attempt to ascertain as much as possible about its remote environment, it is the business of those who have to plan the development of scientific endeavour in a particular country to take stock of its achievements as well as of its prospects. It was very natural for British scientists to take stock of the national position in astronomy, as well as in many other branches of science, at the end of the Second World War, and this they did. British astronomy is made illustrious by the great achievements of Isaac Newton, and for two hundred years after the appearance of the *Principia* the British continued to make advances in both practical and theoretical astronomy, with a success rivalled only by that of two or three other countries. In the present century, however, a change in the relative importance of British astronomy has undoubtedly taken place. In the first half of the century the British withdrew to some extent from observational astronomy and their most important astronomical achievements were theoretical. It is true that very recently they have been extremely active in a new branch of the subject, namely radio astronomy, but there can be no denying that in the optical field British (and indeed European) observational astronomy has suffered a relative decline.

This was of course due to the great advances made in America. Very large telescopes were expensive, in the scale in which scientific expenditure was assessed a generation ago: the money was forthcoming in America. Also, the climate of California is such as to afford a great deal of excellent observing weather. The British astronomers had made use of their ready access to South Africa by conducting much important work at the Cape of Good Hope, and had placed an important telescope in Pretoria (the Radcliffe 74-inch reflector—though this was not fully working till after the Second World War). Was it desirable to place a large telescope in Britain itself? Did the amount of clear weather justify such a venture? These were the questions posed by Professor H. H. Plaskett in his Presidential Address of 1946 (*M.N.*, **106**, 80). It was from his strongly affirmative answers to both questions that the whole project stemmed. Backed by the full support of a special meeting of Fellows at Burlington House (*Obs.*, **66**, 308, 1946), the Council of the Society took up the matter with vigour (*M.N.*, **107**, 11, 1947). Events thereafter moved with astonishing speed. Within six months the British Government had accepted the Society's main submission, supported as it was by the Royal Society and by powerful arguments from the then Astronomer Royal, Sir Harold Spencer Jones (D. H. Sadler, *Obs.*, **66**, 380, 1946). On 1946 July 15 the Chancellor of the Exchequer announced that he would ask the House of Commons to make financial provision for a 100-inch telescope to be erected in Great Britain for the use of all British astronomers.

This decision was taken sixteen years ago, but for various reasons there have been serious delays in implementing it. Many of these have been due to investigations, necessarily prolonged, of novel proposals concerning both the optical and the mechanical design; and to this extent they can hardly be deplored. Some have been outside the astronomers' control, as when a decision in 1958 to withdraw financial support temporarily delayed the project for rather more than a year. It is now expected that the telescope will be completed in 1966. It seems an appropriate time to give as much information as possible in the limits of a short article to the Fellows of the Royal Astronomical Society, by way of a reminder to Fellows who have played a part in the decision to build this telescope and in the working out of its design, and also to inform the many Fellows of the Society who have been elected since the original discussions were held. Those who care to compare what follows with the Council's second memorandum to the Royal Society (*M.N.*, **107**, 15, 1947) will note with what success the scheme there outlined has withstood fifteen years of detailed discussion. It can now be seen taking shape in essentially the form in which it was first proposed. British astronomers have reason to be grateful to Professor Plaskett as originator of the project and to his fellow-members of Council for their timely and effective support.

MANAGEMENT

The telescope will be managed by a special Board of which the Chairman is the Astronomer Royal *ex officio*. Four members of this Board are appointed by the Royal Society and four by the Royal Astronomical Society, each serving for four consecutive years. One half of the cost of the telescope is to be borne by the Admiralty and one half by the Treasury. The telescope will be erected at Herstmonceux in the grounds of the Royal Greenwich Observatory, which will be responsible for its maintenance. The instrument is intended for the use of all suitably qualified British astronomers, including the staff of the Royal Greenwich

Observatory, and the arrangements whereby time on the telescope is apportioned will be in the hands of the Board of Management.

At Mount Wilson Observatory there is an arrangement for placing the 100-inch telescope in the hands of Guest Investigators from time to time. This arrangement has been so successful that it should be carefully studied by the Board of Management when the time comes to make specific plans for the use of the Isaac Newton Telescope. Astronomers who wish to use the 100-inch telescope must make applications to the Director of the Mount Wilson Observatory who discusses proposals with an Observatory Board. This Board allots time on the great telescope to astronomers of proved ability in amounts dependent on the Board's assessment of the scientific worth of the particular programme. On the mountain itself, the Observatory's maintenance staff have powers to restrain observers from taking actions which are laid down as likely to cause damage to the instrument.

DESIGN

The optical and mechanical designs have been throughout in the hands of sub-committees of the Board of Management; final decisions are of course taken by the Board itself. Much technical discussion took place in earlier years on a duplex optical layout in which the main mirror was to be spherical, with (on the one hand) a large correcting plate converting it into a Schmidt camera or (on the other) a Gregorian secondary mirror feeding light into a coudé spectrograph. Formidable difficulties were however foreseen in providing and in suitably mounting the corrector plate. Doubts on this score were reinforced by some feeling that such a design would not in any case result in the most generally useful instrument, and in 1956 a less unconventional design was adopted by the Board. The telescope will be a quasi-parabolic reflector of 98 inches diameter, and will have a prime focus at $f/3$, a Cassegrain focus at $f/15$ and a coudé focus at $f/32$. It is accordingly a versatile instrument which can be put to a great variety of uses.

Problems of flexure beset the designers of any large telescope. The Mechanical Design sub-committee has investigated many novel proposals for the mounting and has fully discussed how modern techniques and modern materials might be used in constructing it. A system in which the strength members were to be hydraulically stiffened was considered but has not been adopted. Though the optical design calls for extremely close tolerances in some respects, notably in aligning the mirrors, proved methods of mounting can provide the necessary rigidity; and where flexure cannot be prevented it is often possible to match the deflection of one part of the structure with that of another so as to nullify its effect.

The telescope is being manufactured by Sir Howard Grubb, Parsons and Co. at Newcastle-upon-Tyne, who are responsible for details of the design.

Plates 1 and 2, showing different views of a model constructed by the contractors, give some idea of the general arrangement of the telescope and its housing. Some technical data are reproduced on p.257 in tabular form, whilst Figure 1 is a simplified general arrangement drawing showing the instrument in its dome.

BUILDING

The cylindrical building housing the telescope will be surmounted by a conventional double-skinned hemispherical dome 61 ft. in diameter. Provision is made to draw night air downwards through the shutter opening when observing is in progress. The arches of the dome are stout enough to carry a 27-ton crane to be used during erection; a smaller crane enables the mirror to be lowered to the ground floor for re-coating in an aluminizing tank.

The coudé spectrograph room is contained between the instrument pier and the building wall, which departs from the general cylindrical form on the south side to allow this. There is ample room at the coudé focus for all foreseeable requirements, and work-rooms, darkrooms and stores have been provided on a generous scale.

Most observatories are under some pressure from the public, who want, not unnaturally, to see the telescopes. In the case of a big telescope provided out of public funds there is perhaps a special obligation to satisfy this desire, so far as it is possible to do so without prejudicing the operation of the instrument. The observing floor of the Isaac Newton Telescope is big enough to devote a substantial area on the east side to a visitors' enclosure, completely partitioned off behind glass so as to allow a good view without physical access. The enclosure is reached by an independent stairway from a separate visitors' entrance that will be open to the public during daylight hours.

MIRROR

The mirror blank was presented to the Board, through the late Sir Harold Spencer Jones, by the Trustees of the McGregor Fund. It is a pyrex blank cast by Messrs. Corning when they were making the blank for the 200-inch telescope. As is the case with this latter, there are a number of striae in the interior of the blank: in the opinion of Grubb Parsons these striae are not of importance, and in fact the firm's opinion is that the blank is a very good one. It has already been ground without untoward incident to the heavy curvature needed for a focal ratio of *f*/3, and the firm

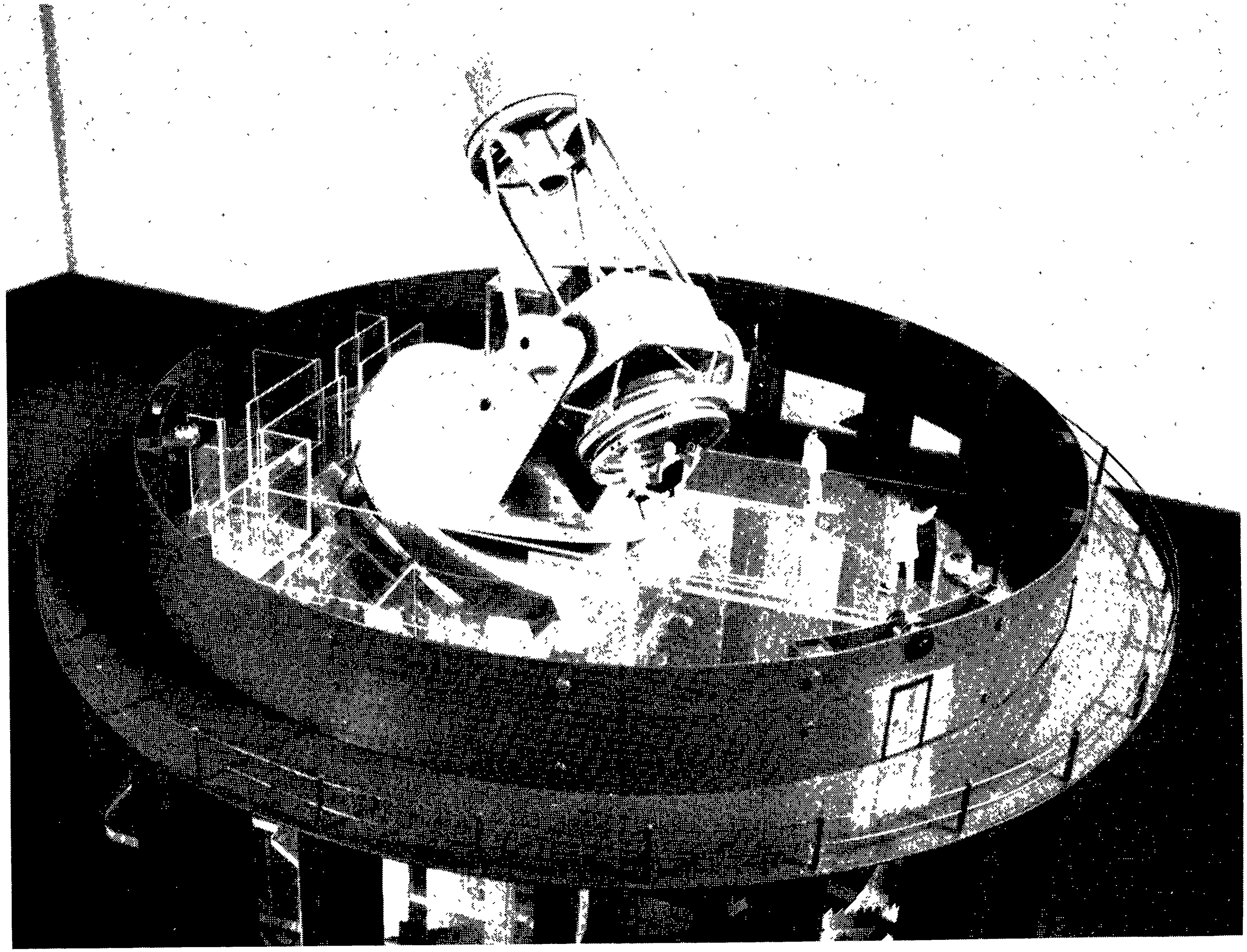

PLATE I

[facing p. 252

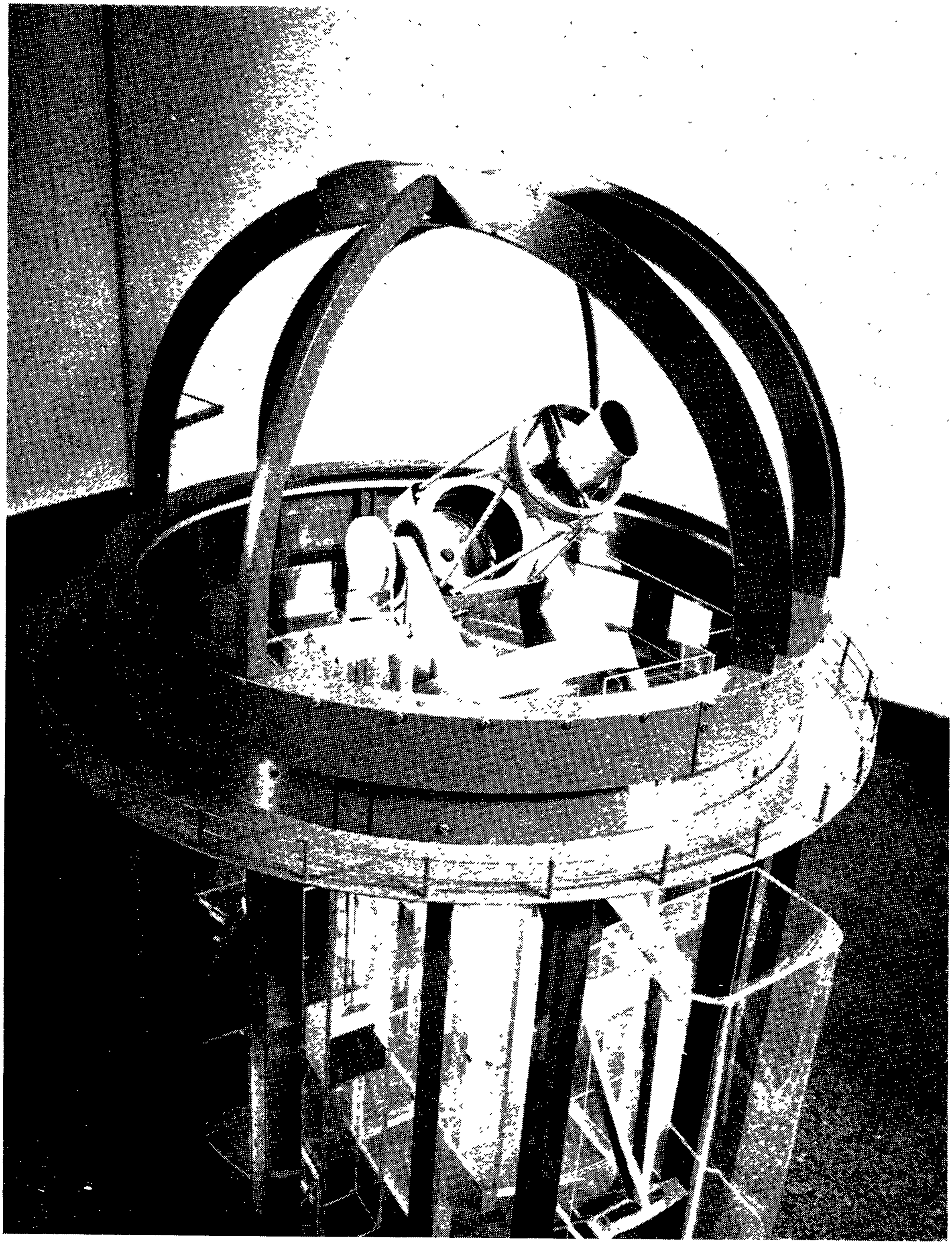

PLATE 2

has undertaken to figure it. The design combines small departures of the main mirror from a paraboloid with compensating departures of the secondary mirror from a hyperboloid so as to remove coma at the Cassegrain focus. A special tower has been built so that the mirror can be tested with its axis pointing vertically upward.

As some apprehensions have been expressed about this blank on account of the striae, whose importance or unimportance can only be assessed by those familiar with the grinding and polishing of great telescope mirrors, it is well to stress Grubb Parsons' good opinion of it: and well, perhaps, to remark that although fifteen years ago it would have been a difficult matter to obtain so large a blank, it would now be quite possible and not expensive in relation to the total cost of the project to get another blank, should there appear to be any good reason to do so.

LOCATION AT HERSTMONCEUX

Herstmonceux was selected on the evidence of meteorological data as the new location of the Royal Observatory on its removal from Greenwich. The choice of this site has been justified by the amount of night observing actually carried out by the Royal Greenwich Observatory in the last three years (i.e. the three years since systematic observation began at Herstmonceux).

On the average of these years, one quarter of the nights prove to be such that observation can be conducted throughout the night, and another quarter are suitable for observation during part of the night. Forty-six per cent of the nights during which observations were scheduled were overcast to such an extent that no observation was possible at all.

To an observer making an expedition to a far country it is of course of the greatest importance to get as near a hundred per cent of fine nights as he can: but to a man who resides next to a telescope, or lives so near that frequent journeys are not extremely expensive, one hundred per cent clear weather is not vital. An hour's successful exposure can make many days or even months of reduction time. Indeed there is even a danger of astronomers in too good a climate becoming slaves to their telescopes without time to reduce their observations or even time to think.

The seeing at Herstmonceux is satisfactory for spectroscopy and for direct photography. Stellar images with a diameter of 2″ are common on the slit of the spectrograph attached to the 36-inch Yapp telescope, and images as large as 4″ or as small as 1″ are rare. Double-star seeing is specialized and a night may be good for double-star work and poor for spectroscopy, or vice versa: the Annual Reports of the Astronomer Royal to the Board of Visitors of the Royal Greenwich Observatory show that a substantial number of measures of pairs with separations less than 0″.5 are made each year. The distribution of fine night observing weather at Herstmonceux is uniform, a favourable circumstance; the short summer nights are systematically better than the winter nights so that the number of useful hours per month varies little through the year.

OBSERVATIONAL PROGRAMMES

The intention throughout has been to provide a telescope for the use of all British observational astronomers, whatever their interests. The optical design strikes a balance between the well-tried but unadventurous combination of paraboloid and hyperboloid common amongst the big telescopes of the world and several attractive but revolutionary systems considered by the Board of Management in the early stages of discussion. It is possible to say now that the telescope *will* be suitable for many programmes of work at one or other of the three foci available, and that it *may* be suitable for others, desirable or even urgent but at present impossible to carry out on any existing telescope.

The telescope will be a splendid one for coudé spectroscopy, especially the study of metal abundance, a lively topic at the moment, and aerodynamical phenomena in stellar atmospheres. Stellar spectroscopy can certainly be prosecuted in the English climate. The I.N.T. will be well suited for the determination of radial velocity, either at the coudé focus or at the Cassegrain focus. Systematic knowledge of radial velocity ceases at the sixth magnitude, as can be seen merely by looking at the *Bright Star Catalogue*. While one might think of more exciting things to do than merely to collect all the radial velocities of *all* the stars of the seventh magnitude, one may remark that knowledge of the gravitational field of our own Galaxy is still fragmentary, and the study of radial velocities of selected faint stars offers one means of adding to knowledge of this field. At Herstmonceux, work is already in progress on modern grating spectrographs at Cassegrain and coudé foci of existing reflectors, and a reserve of design and operational experience will be available when the time comes to construct spectrographs for the I.N.T.

Apart from spectroscopy, it is intended to try whether astrometry can be carried out at the Cassegrain focus, in particular the measurement of stellar parallax: and it is hoped that the prime focus, and perhaps the Cassegrain focus, will be of interest to radio astronomers, through the detailed examination of fields containing sources of radio emission.

The instrument may be expected to be a very useful one for photographic photometry, and for photographic proper motions. Much work of this character has already been carried out recently at the Royal Greenwich Observatory in these fields, employing for the most part material brought in from elsewhere. Naturally, proper-motion work with a new telescope demands a lapse of time (a quarter of a century at least) before it can be completed. No attempt has however been made to lay down specific programmes for the Isaac Newton Telescope: it would be foolish indeed to attempt to forecast the topics which will be of the greatest interest to astronomers in the 1970's and 1980's. A versatile instrument will be available to British astronomers of the future: we can do no more than our best to see that its versatility will not be overtaxed by their ingenuity.

A very good reason for holding back on a choice of programme is the prospect that when the I.N.T. is commissioned, image converters will be freely available for use: and if this proves to be the case, very much fainter objects can be studied than is at present possible under given circumstances (e.g. in the case of spectra, with a given dispersion), even with the 200-inch telescope on Mount Palomar. Ample room has been left at the coudé focus so that future users, who will be encouraged to try out new ideas for observational work, are not cramped.

CONCLUSION

It is much easier to put up a telescope than to make intelligent use of it. The I.N.T. has been secured by one generation of astronomers, and will be used by another, who must be trained in advance to use it. They must be big-telescope men not only in their ability to manipulate the telescope and to design and use auxiliary equipment, but, more important, in their ability to think about the problems in astronomy on which observations made with great telescopes can throw light.

Our predecessors were right to put the Radcliffe telescope in Pretoria, to tackle the very rich material in the Southern hemisphere. It is a great pity that there was not then enough money available to put up two large telescopes, one in England and one in South Africa, because as long as there is no major telescope in England there is nothing immediate to tempt a young British physicist to take up optical astronomy, and there is no means of training him—short of sending him to California or Pretoria, where he finds himself unprepared to use a really large instrument and, too often, unaccustomed to thinking about the right problems. However, we have to accept the fact that there is no telescope larger than 36-inch diameter in Britain, and in fact a large number of British astronomers of all ages have gone out to work at Pretoria and at Mount Wilson of recent

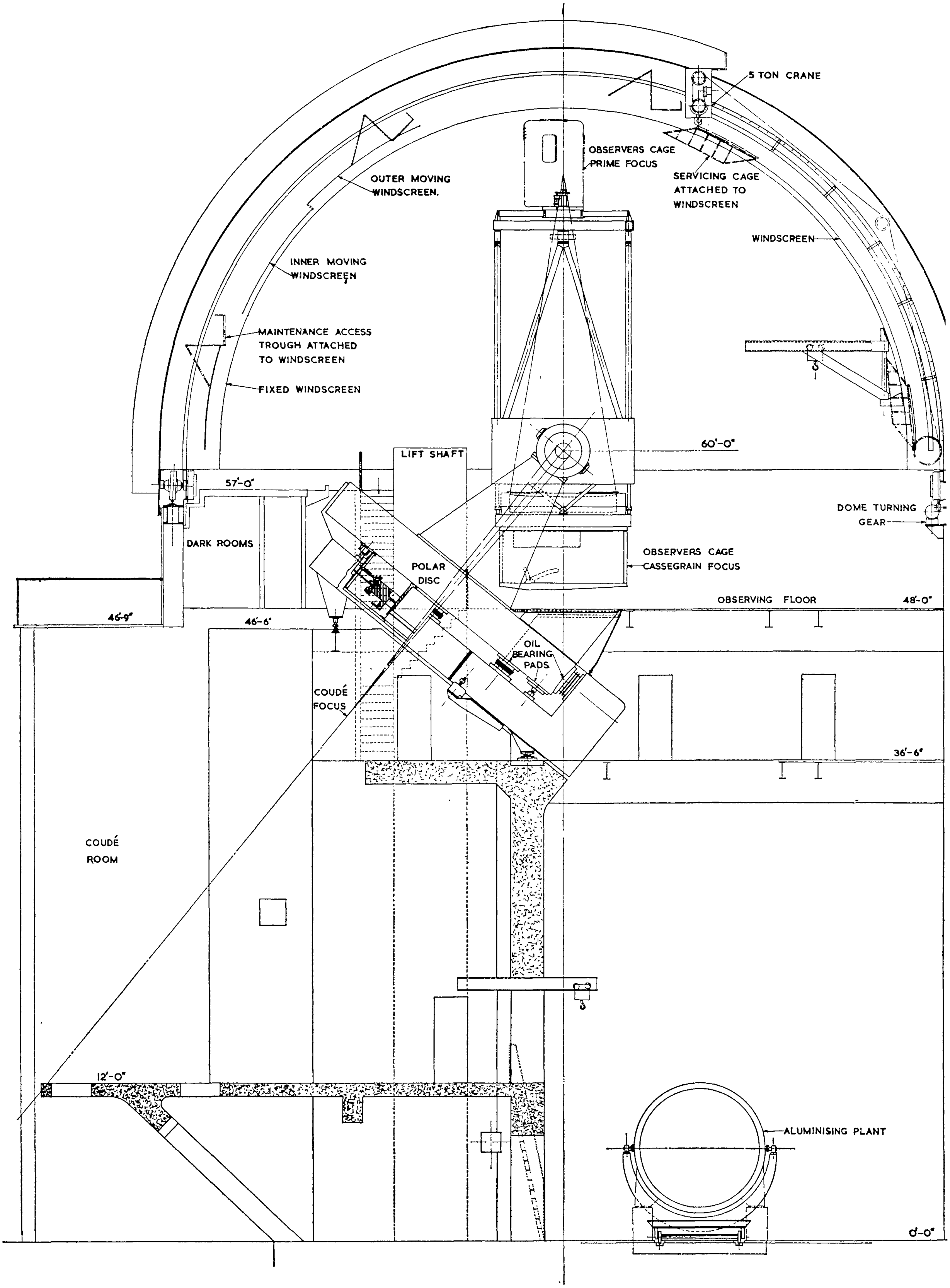

Fig. 1. The Isaac Newton Telescope
(*for details see facing page*)

Isaac Newton Telescope

Mounting: Fork type, with $11\frac{1}{2}$ ft fabricated tines carrying trunnion bearings.

Polar axis: Disk 22 ft diameter and 3 ft thick, supported on pressurized oil-pad bearings.

Tube: A-frames projecting downwards from the central cube carry the air-conditioned mirror cell, in which the axial load of the mirror is taken by an air-bag. Similar A-frames projecting upwards carry a tubular upper section with deflection matched to that of the mirror cell. Interchangeable units carry the prime focus camera, the Cassegrain mirror and the coudé mirror with their focusing motions.

Motions: Slewing motions in R.A. and Dec. accelerating to 90°/min.
Setting motions in R.A. and Dec. $\frac{3}{4}'$/sec.
Guiding motions in R.A. and Dec. 2″/sec.
R.A. trailing speed for spectroscopy variable between $\pm 0{\cdot}2$ per cent and ± 10 per cent sidereal rate, Dec. trailing between 2″ and 100″/min.

Prime focus: $f/3{\cdot}03$, scale 1 mm. = $27''{\cdot}5$. Coma reaches 1″ at 48″ off axis. Central image enlarged $1''{\cdot}1$ by spherical aberration. Aspheric Ross-type correcting lens to minimize coma and spherical aberration over a field $3\frac{1}{4}$ in. square.
Simple plateholder, knife-edge focusing. Provision for later installation of double-slide plateholder with automatic photoelectric guidance, or of prime-focus spectrograph.

Cassegrain focus: $f/15$, scale 1 mm = $5''{\cdot}5$. 21 in. quartz secondary. Radial coma zero; lateral misalignment of secondary mirror by 0·8 mm gives $0''{\cdot}43$ coma over all the field. Double-slide plateholder 8 in. square; provision for later addition of servo control. Alternatively a Cassegrain spectrograph can be fitted behind the main mirror by turning the light through a right angle. Observer sits in a carriage hung below the mirror cell and guides on an off-axis image. Tubular baffle and a 31 in. stop near the secondary mirror eliminate sky fog at the plate.

Coudé focus: $f/32$, scale 1 mm = $2''{\cdot}7$. 21 in. quartz secondary figured to produce a stigmatic image on axis. Three plane quartz mirrors to direct the coudé beam to a focus below the polar disk. Spectrograph room 25 ft long to allow a 12 in. collimator. Spectrograph cameras mounted on optical bench inclined at polar angle.

years. Our collective experience of using great telescopes is now by no means negligible.

Since the time on the 100-inch telescope which Mount Wilson generously puts at the disposal of guest investigators is necessarily limited, all those who have gone to Mount Wilson to do spectroscopy could have done much more in England with the I.N.T. had it been completed. Time for guest investigators at Pretoria is precious, and it should ideally be reserved for those who are thoroughly familiar with the technique they wish to exploit; for people, that is to say, who are anxious to deal with the Southern hemisphere because they have successfully tackled similar work in the North and feel the need to push South.

The completion of the I.N.T. will make journeys to Mount Wilson unnecessary except for the very real benefits of working alongside American colleagues. It will also make journeys to the South more productive, because the observers will be better trained: but the I.N.T. is not to be thought of as a mere training instrument. Galactic problems must be tackled in *both* hemispheres and abundance problems can be tackled in either.

The Isaac Newton Telescope will in fact give the British astronomers of the future a chance to get right inside the problems of contemporary observational astronomy.

For years the writer has had support for the I.N. project and also technical advice on a variety of points from Dr I. S. Bowen, the director of the Mount Wilson and Mount Palomar Observatories, and from Dr C. D. Shane, former director of the Lick Observatory. To these and many other American astronomers the thanks of the writer, and of the British observers of the future, are due.