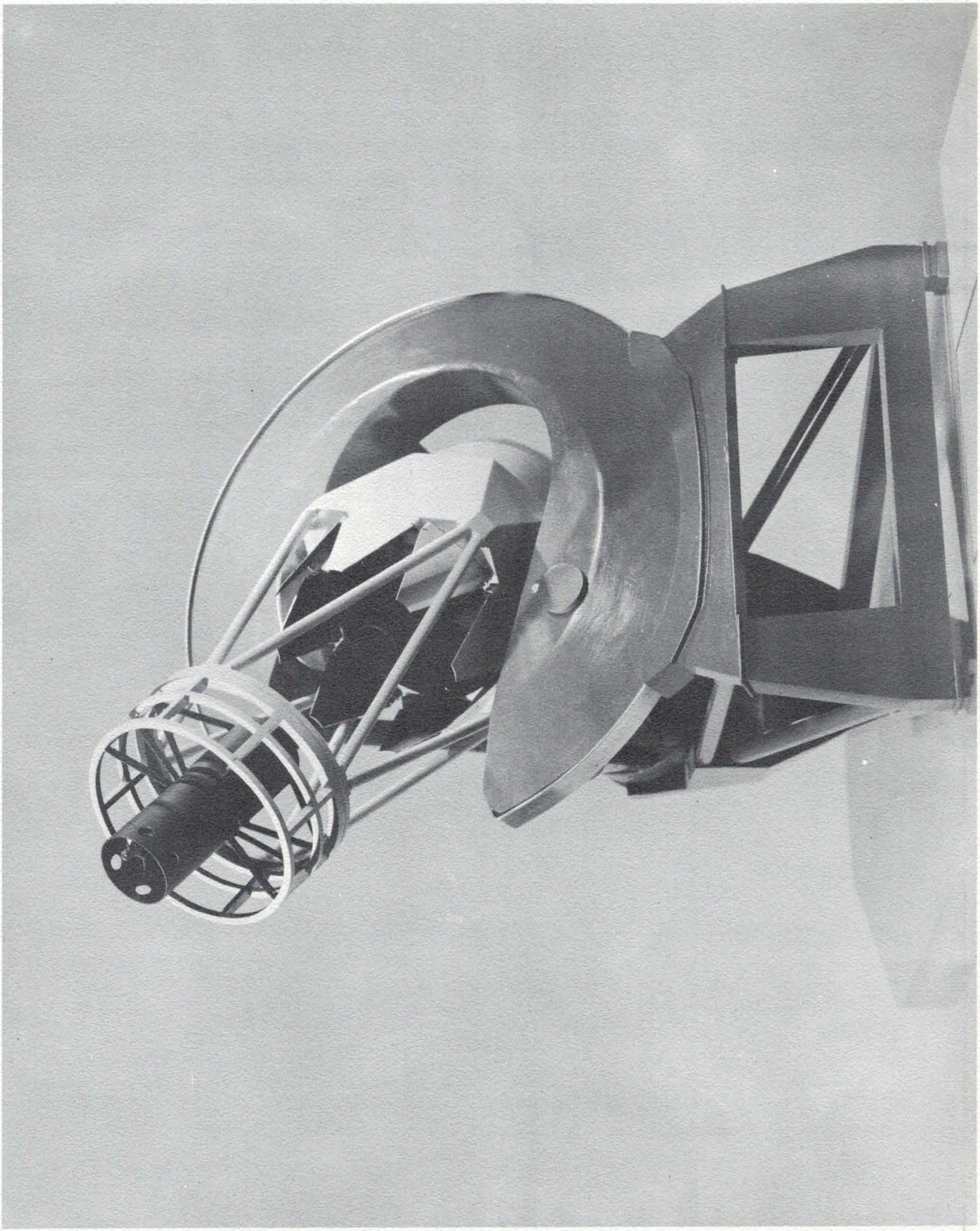
THE KITT PEAK 150-INCH TELESCOPE

D. L. CRAWFORD

STELLAR DIVISION
KITT PEAK NATIONAL OBSERVATORY

Tucson, Arizona



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*Contribution No. 000 from the Kitt Peak National Observatory.

**Operated by the Association of Universities for Research in Astronomy, Inc., under contract with the National Science Foundation.

I. INTRODUCTION

The recent report issued by the National Academy of Sciences entitled "Ground Based Astronomy, A Ten Year Program" (commonly called the Whitford Committee Report) paints vividly the pressing need for additional large optical telescopes.

In the first half of this century the United States held a dominant position in observational astronomy. This fact is due primarily to the large telescopes available to American astronomers, enabling active research astronomers to use these instruments and also stimulating exceptional graduate students to go into observational astronomy as a career.

Many of the break-throughs in modern optical astronomy were obtained with these large reflectors: the 200-inch Hale telescope at Mt. Palomar, the 120-inch at Lick Observatory, the 100- and 60-inch at Mt. Wilson, and the 82-inch at McDonald Observatory in western Texas. Outside the United States, two other large reflectors recently began their operation: the 102-inch reflector at the Crimean Astrophysical Observatory in Russia, and the 77-inch reflector at the Haute Provence Observatory near Marseilles in France. The 98-inch Isaac Newton telescope for the Royal Greenwich Observatory at Herstmonceux Castle in England is nearing completion.

There are a number of other large telescope projects just beginning, enough so that an International Astronomical Union (IAU) symposium (No. 27) will be held in April, 1965, in the southwestern United States, to discuss large telescope design. There will be 10 different groups attending who are actively interested in large telescopes. A number of these groups are already funded for their projects, and others are developing their initial proposals. The ones most active at present are: the Kitt Peak 150-inch project, the European Southern Observatory (ESO) and its 140-inch reflector in Chile, the recently announced Queen Elizabeth II Observatory with a telescope of 150-inch aperture for Canada, and the Russian 6-meter (236 inches) reflector now under design. The Russians are also planning to build two more 102-inch reflectors. The Carnegie Southern Observatory (CARSO) project is conducting a site survey in Chile and in Australia for a proposed 200-inch telescope in the southern hemisphere.

Many of the astrophysical problems of great current interest can only be attacked by large telescopes. One exciting example is the study of quasi-stellar radio sources. These are faint stellar-like objects that have, however, such large red shifts that they are most probably extremely distant objects that radiate energy at an enormous rate, 10 to 100 times greater than that from entire normal galaxies. Intensive theoretical work is currently being done to try to explain the nature of these objects, but much more observational work is necessary to identify additional sources and to study their energy distribution in detail. Ordinary radio galaxies, especially those involving exploding nuclear events, are also in crying need of much observational work. Spectral energy distribution, polarization data, radial velocities, and many more optical identifications are very necessary.

Another problem is the collection of enough data on red shifts of faint galaxies to aid in unraveling the structure and cosmology of our universe. Studies of individual galaxies themselves are lagging badly due to the lack of rotation curves and mass determinations. Likewise, the study of individual stars in galaxies is moving at an extremely slow rate due to the lack of large telescopes.

In the field of Milky Way astronomy, much data are still needed on faint stars, especially on those in clusters, for studies of stellar evolution and galactic structure. Spectral types, multi-color photometry, radial velocities, polarization data, etc., are all needed. The study of the interstellar medium requires large scale and large light-gathering power. Work in the field of determination of chemical compositions, and of theories of creation of chemical elements, requires large reflectors equipped with coudé spectrographs.

Likewise, the increased interest in recent years in solar system astronomy - the study of planets, their atsmospheres, and the interplanetary medium - both by space astronomical techniques and from the ground, means that existing large telescopes cannot meet the demand for observing time. Even though millions of dollars are being spend for in-space techniques needed to explore the planets, a sad deficiency in solar system physics research still exists. Currently, very little time with large telescopes can be spent on planetary work because of committments to other programs. Spectroscopic studies with high spectral and spatial resolution can only be done with large reflectors. Deep space probes are few and extremely expensive, and the timing of their flights is necessarily so infrequent that there is no valid reason for using space probes for any job that can be accomplished on the ground. They should be used where no present-day ground-based technique works. A large telescope-spectrograph combination can help to establish the physical and chemical composition of planets, and hence to provide data on the thermal and kinetic structures of their atmospheres.

It is not practicable to reduce below a certain minimum the number of nights on a telescope devoted to any given problem, because then no effective advance is really possible. This condition, of course, results because astronomical sources are so faint that, even with large telescopes, many nights must be devoted to collecting enough data to solve the problem. On any given instrument, therefore, only a very limited number of such problems can be handled at any one time. The existing large telescopes are already running at or beyond this maximum utilization, and thus few astronomers outside the major observatories are able to work on problems at the astronomical frontier. Hence, qualified astronomers not at these big observatories are just out of luck.

Kitt Peak National Observatory was founded in an effort to ease this type of problem, and it is succeeding fairly well at present for the smaller instruments. It makes available, with good sky conditions, modern high-quality small (16-inch) and intermediate-sized (36-inch) telescopes to observers from locations without either the good weather or the instrumentation or both.

(The larger size 84-inch telescope came into full-scale operation in September, 1964.) Kitt Peak is the only place where many of these observers are able to get observing time, since the other large observatories are already fully committed to their resident staffs.

As the Whitford Committee Report indicates, nearly every phase of observational astronomy is hampered today because the rate of growth of new facilities has not kept up with the need for fundamental data. "We are living on the legacy of the past, using instruments handed down from the era of private financing." Since there are just not enough of these powerful instruments in existence, the Whitford Committee Report recommends that three large optical telescopes be built, one of which would be the 150-inch telescope for Kitt Peak National Observatory.

II. HISTORY

At the March, 1961 meeting of the AURA Board of Directors, a resolution initiated by the late Dr. R. M. McMath was passed that the Observatory staff should begin a program of design and location studies for a 150-inch stellar telescope. The Board agreed on the urgent need for more large telescopes, and on a program for studying the physics of seeing for optimum location studies of large telescopes. It also emphasized that this 150-inch telescope was in no way to be associated with the so called "X-inch" telescope.

The decision to have the size be 150 inches in diameter resulted primarily from a balancing of several criteria. The telescope must be large enough to attack adequately the problems at the frontier of astronomical research. It must also be large enough for operation of an efficient prime focus cage, but one that would not block out too much of the incident light. It must not be so large that a lot of new experimental engineering would have to be done in the design of the telescope, i.e. it must either be a copy of the 120-inch or the 200-inch brought up to date, or an interpolation somewhere between these two designs. It must also be built at a cost consistent with funds likely to be available from the National Science Foundation, and it must be ready in a reasonable time in order that attacks on the threshold astronomical problems could begin as soon as possible. In June, 1961, Dr. N. U. Mayall, Observatory Director, appointed a 150-inch Telescope Advisory Committee to advise the staff on large-telescope problems. This committee first met on September 23, 1961, and it agreed that a general purpose large telescope should be constructed on Kitt Peak as soon as possible. At that time rough specifications were listed and general design philosophy was discussed.

The committee and observatory staff also discussed astronomical problems for which a large telescope is needed (some of these problems have been mentioned above), and the auxiliary instrumentation necessary for these programs. In particular, it was considered that a large field is needed at the prime focus for survey work, and that the field corrector-lens systems should transmit ultraviolet light. It was noted that "limit" photography would be done at the Cassegrain focus, and that the f-ratio there should be about f/9, since the limiting magnitude obtained on photographic plates is primarily a function of focal length. Dr. I. S. Bowen, former Director of the Mt. Wilson and Palomar Observatories, discussed this point in his Russell Lecture of June, 1964. However, if the f-ratio is too large, such as the conventional f/15, then exposure times become prohibitively long. The f-ratio of the primary, on the other hand, should be as small as feasible, probably limited by the art of designing "fast" prime focus corrector systems, and by the capability of the optical shop to make the relatively short focal length primary mirror. The fast f-ratio not only enables "high speed" photography to be done at the prime focus, but it also means that the Cassegrain secondary mirror will not have to be too large a fraction of the size of the primary mirror. A coudé focus should be included so that the telescope may be used in bright moonlit skies. Types of mountings, domes, shutters, control systems, etc. were discussed in a general way at this meeting, and many of the ideas were later incorporated into the design mentioned below.

Members of the Advisory Committee at the present time are: Drs. H. W. Babcock and I. S. Bowen, Mt. Wilson and Palomar Observatories, W. A. Hiltner, Yerkes Observatory, A. B. Meinel, Steward Observatory, O. Mohler, University of Michigan, B. Strömgren, Institute for Advanced Study, A. E. Whitford, Lick Observatory, and Mr. Bruce Rule, California Institute of Technology.

By early 1962, preliminary cost estimates were obtained and many of the staff and committee suggestions from the September, 1961 meeting were spelled out in greater detail. It was felt that the telescope project would cost approximately ten million dollars with fused quartz mirros, and that the project would take a minimum of six years to complete. At its April 15, 1963 annual meeting, the AURA Board of Directors approved fused quartz as the material for the optical blanks of the 150-inch telescope. They also approved the firm of Skidmore, Owings & Merrill, Chicago, Illinois, as the architects for the initial design studies of the telescope dome and building, because of their outstanding design of the McMath Solar telescope. At the June 29, 1963 meeting, the Board approved a proposal from the Westinghouse Electric Corporation, Sunnyvale, California, to undertake the preliminary design of the telescope mounting, and the author was appointed Project Manager, responsible to the Observatory Director.

A second meeting of the Advisory Committee was held

September 14, 1963. The status of the project and of the designs were reviewed, and the design criteria were approved as given in Table I.

TABLE I

GENERAL TELESCOPE SPECIFICATIONS

1. Large field at prime focus ($3/4^{\circ}$ to 1°), ratio about f/2.8. Field correctors should transmit ultraviolet light.
2. A Ritchey-Chrétien (coma-free) optical system for the Cassegrain focus, and a horizontal coudé spectrograph.
3. The primary mirror blank should be made of fused quartz, as well as all secondaries.
4. Extensive care to be given to local seeing effects, including the possibility of placing the telescope about 150 feet above the ground.
5. As versatile a telescope as possible without compromising efficiency, and at reasonable cost; quick interchangeability of secondary mirrors.
6. No extensive new engineering studies (for example, alt-azimuth type mounting).

A third meeting of the Advisory Committee was held October 12, 1964. Figure 1 shows the group in attendance at this meeting. The status of negotiations concerning the purchase of the primary mirror blank, and the preliminary designs of Skidmore, Owings & Merrill and of Westinghouse, were summarized for the committee members. These items are discussed in more detail below.

III. OPTICS

One of the main features about this new telescope was suggested at the very beginning by the AURA Board, with subsequent full concurrence by the Advisory Committee and by the Kitt Peak staff, namely, to have the mirror blanks made of fused quartz. At the time of this suggestion, the Corning Glass Works was the only firm making fused silica mirror blanks of some size. They had produced an excellent 61-inch mirror for the United States Naval Observatory astrometric reflector at Flagstaff, Arizona. The process used by Corning has been described by K. Strand (Sky and Telescope, Vol. XXVII, p. 204, April, 1964), and it involves the production of fused silica in a furnace from gases at high temperature; the result is a high-quality mirror blank of pure silica. A 150-inch mirror blank, however, would have to be made from a mosaic of several blanks of approximately 60 inches in diameter, and in several layers to obtain the necessary thickness.

In an effort to stimulate competition in the making of large mirror blanks, and to help justify a contract involving the spending of large public funds, the Kitt Peak staff, led by Mr. J. M. Miller, Associate Director, Administrative Division, sought to interest other firms in the production of large mirror blanks. Two other firms appeared actively interested. One was a partnership of Heraeus in Hanau, Germany, and Amersil in Hillsdale, New Jersey, who proposed a large mirror blank made of opaque industrial-type quartz with a thin layer of optical quartz fused onto the top. This type of blank appears to have several advantages: no bubbles at all in the final optical surface and an inherently rather inexpensive grade of quartz as the major volume. Unfortunately, at the present time this process appears to be unduly expensive. The other concern was the General Electric Company, Lamp Glass Department, near Cleveland, Ohio. Their process consists of taking a large number of quartz ingots about 6 inches in diameter and 24 inches high and fusing them together to make up the large mirror. In their lamp business, they have made thousands of these ingots per year from almost pure natural quartz.

Sample mirror blanks from all three concerns have been extensively tested in the Observatory's optical shop, and a detailed report of these tests will be published soon. They indicate that all three types of blanks would yield excellent mirrors for astronomical purposes, with the Heraeus-Amersil example considered somewhat superior because of its complete freedom from bubbles in the optical surface.

All of the quartz blanks were, of course, much less sensitive to thermal effects than existing blanks of Pyrex, and they were also easier to work in the optical shop. The physical properties of fused quartz are such that a mirror made from it should have only 1/10 the sensitivity to temperature changes as one made from Pyrex. When introduced in the 1930's, Pyrex was, of course, a great improvement over the types of glass previously used for mirrors.

On the basis of the results of these tests, and on cost and delivery quotations, a contract was signed with the General Electric Company on December 31, 1964, for the delivery of a 150-inch mirror blank. This blank is expected to be delivered in Tucson on or before June 1, 1966. The cost will be approximately one million dollars.

The General Electric Company, Schenectady, New York, was the concern that first tried to produce a 200-inch diameter fused quartz mirror blank for the Hale telescope on Palomar. Under the leadership of Dr. Elihu Thompson, this group produced a number of small and intermediate-size quartz blanks in the early 1930's. Unfortunately, it proved too expensive at that time to produce a 200-inch blank, and subsequently the Corning Glass Works produced a successful 200-inch mirror blank of Pyrex. However, two of the mirrors (63- and 48-inches diameter) that resulted from the General Electric work, are now in use as preliminary mirrors in the McMath Solar Telescope at Kitt Peak.

The optical grinding, polishing, figuring, and testing of the 150-inch mirror blank will be done in the Observatory's optical shop at Tucson. The special grinding machine, and the necessary expansion of the optical shop, are now being designed, and construction is planned to be finished in time to receive the large mirror blank. Provision will be made for both vertical and horizontal shop tests of the 150-inch mirror. The optical work will be done by the opticians who produced the 84-inch mirror for Kitt Peak, and the 60-inch mirror for the Cerro Tololo Inter-American Observatory near La Serena, Chile. The chief opticians are Don Loomis and Norman Cole, while overall charge of the optical work and of the Observatory optical shop is in the hands of Dr. A. K. Pierce, Associate Director, Solar Division. Final testing of the mirror will be done in the telescope on stars, as one of the last steps to be taken before the telescope will be in operation.

The optical design of the mirror surface, and of the prime focus corrector system to achieve the specified large field, is being done by Dr. D. H. Schulte, the Observatory's optical designer. Most of this work has been done on the Observatory's Control Data Corporation 160-A digital computer. A number of consultants have worked with Dr. Schulte on these designs; in particular, Dr. A. B. Meinel, University of Arizona, and Dr. C. G. Wynne, Imperial College, University of London. Close association also has been maintained between Dr. Schulte and the European Southern Observatory optical designers, especially Dr. H. Köhler, F.A. Carl Zeiss, Oberkochem, Germany, and Dr. A. Barrane, Marseilles Observatory, France. The improvement possible over previous large telescope optical systems is well illustrated in the two accompanying diagrams (Figures 2 and 3). These "spot diagrams" are produced directly at the computer by an on-line XY digital plotter.

One of the most important items to achieve success with any large-telescope optical system is the primary mirror-support system. Although work has begun on the design of this system, no definite conclusions are yet available. Two general types of systems are being investigated. One is similar to the mechanical lever systems of the Kitt Peak 84-inch telescope. The second is the air-bag support system of the United States Naval Observatory's 61-inch astrometric reflector, and of the 98-inch Isaac Newton telescope. A combination of these systems will also be investigated.

IV. MOUNTING

The present concept for the 150-inch mounting was developed by Mr. W. W. Baustian, Chief Engineer of the Observatory. A model of the mounting is shown on the cover. His design is a modification of the types of mounting investigated originally for the 200-inch telescope project. In many ways, it is similar to the 200-inch telescope mounting itself, although the "horseshoe" yoke is now located at the declination axis; that is, the tube swings free between the tines of the yoke, rather than between the struts running from the yoke to the south bearing. The yoke or horseshoe will be approximately 41 feet in diameter, and this size is adequate to contain the tube and still have sufficient structural strength to hold deflections within tolerable limits. It is also small enough that it can be made on existing vertical milling machines at several fabrication plants in the United States. The yoke also acts as the north journal of the polar axis of the telescope, as in the 200-inch design.

A pair of radial oilpads are located at the north end of the polar axis, and pairs of radial and axial-thrust oilpads are located at the south end of this axis. Concentricity and smoothness of surface are all-important in these large journals, since the mounting has to move precisely in these bearings with a minimum of friction. The declination bearings, one on each side of the tube where it connects to the yoke, will be of roller-bearing or ball-bearing design. Each declination bearing will have a clear central hole of about 28 inches diameter, through which the coudé light beam can pass. The coudé system will include 5 mirrors at all times, as shown in Figure 4. Therefore, the center section of the tube need not be weakened by a slot in it to pass the light beam, as is necessary in three-mirror systems. The greater strength of the solid center section can then be used to reduce torsional deflections. A folded Cassegrain system will be included; it will use the Cassegrain secondary and the first coudé flat mirror to bring the light to a focus in one arm of the yoke, as in the 200-inch telescope.

The Westinghouse contract included deflection studies of the tube and yoke systems, and all computed deflections are well within the specifications, which are: Relative motion of the secondary mirror optical axis from the primary mirror axis to be less than 0.040 inches, and maximum field rotation at the prime focus less than 0.002 inch in a 5-inch radius. The contract also included the determination of the optimum location of the struts and the south bearing.

In a large telescope, the top end of the telescope tube must hold an observer's "cage" for prime focus work, and also the Cassegrain and coudé secondary mirrors. The 150-inch telescope tube will have two separate upper sections. One will include the prime focus cage and a coudé secondary mirror. For the direct photography, the observer will ride in the cage similar to those in the 200-inch at Palomar and the 120-inch at Lick Observatory. Large-field photographic work will be of utmost importance at the prime focus. Probably several different corrector systems will be available.

When cloud conditions or the moon prevent prime focus photography, it will be possible to swing a coudé secondary mirror quickly into operating position under the prime focus cage. A separate upper tube section will be available, with the Cassegrain mirror and another coudé secondary, both mounted in a flip assembly similar to that in the 84-inch stellar telescope. Nearly all photoelectric photometry, spectroscopy, and "limit" photography will be done at the Cassegrain focus, where the observer will ride in a cage behind the primary mirror for this type of work. The inclusion of another coudé secondary again provides for rapid change to the coudé focus when bright moonlight and cloud conditions prevail. The possibility of adding other secondary mirrors is being investigated as well.

The telescope tube and yoke assemblies are supported on a basebrame, as shown in the photograph. When the primary mirror is taken out for aluminizing, it will be lowered onto a mirror handling carriage, which is raised into position on an elevator built into the telescope support pier. The carriage is lowered to the working floor, and then moved to the north between the two legs of the baseframe to the working area. The oilpads for the yoke and for the south bearing will be attached to the baseframe, together with the piping system for the oil. The baseframe is mounted on a south pivot support, and on two adjustable north supports, for the critical alignment of the polar axis.

One of the major items in the mounting design is the drive and control system. Both the right ascension and declination axes will have high-precision drives. Each drive will have several speeds: slewing for rapid motion from one object to another, and several fine motions for accurate centering and guiding on the celestial objects. There will be automatic drives, also, to compensate accurately for the earth's rotation and for the apparent motions of planetary objects and the moon. The final design of the main sidereal drive is still open. Probably two large gears will be used, one for the slewing and the other for the fine motions. Readout of the telescope position will be through encoders and synchros attached to the axes. There will be one main control console and a sub-station at each observing position. There is a possibility that a small digital computer will be included as part of the control system. Much effort is being made to keep the control system versatile and adaptable, but still simple and trouble-free.

V. DOME AND BUILDING

The preliminary dome and building layouts have been made by Skidmore, Owings & Merrill in consultation with the Observatory staff. Figure 5 shows an artist's rendition of their design. This preliminary design was based on locating the declination axis 150 feet above the ground. It is possible that in the final design a somewhat lower height will be used. The rotating dome itself will be similar to the domes for the 120- and 200-inch telescopes. It will be a double-shell arrangement with air venting in the space between the shells. The aim is to carry off excess heat that is absorbed in the daytime by the outer shell. The basic requirement is that the air temperature inside the dome remains throughout the day within a few degrees of nighttime temperature.

Various schemes of venting, insulation, and painting are now being investigated, including the use of titanium dioxide type paint. The entire structure of the McMath Solar Telescope was covered with such paint, and it has proved to be very effective in preventing the sun from overheating the structure, and very recently the 84-inch telescope dome was similarly painted. The shutter will be an up-and-over type, similar to those for the 120-inch at Lick and the 84-inch at Kitt Peak. Several crane hoists will be included as part of the dome equipment; they will be used for installation of the mounting and for instrument handling. An observing platform or "bridge" will travel up the shutter opening, to provide access to the prime focus cage. This bridge will also be used for auxiliary instrumentation operation and storage.

The fixed base structure for the dome will also be of double-shell construction, and the same criteria for thermal control will be used. The large concrete pier support for the telescope mounting will be located in the center of the base structure, and be isolated from all vibrations in the rest of the building.

At the observing floor level there will be several well-insulated rooms containing the coudé spectrograph, coudé experimental laboratory, photographic dark rooms, an observers' lounge, and necessary mechanical equipment. At the ground floor there will be several offices and laboratories. Provision will be made for a visitors' gallery so that the public may view the telescope in the daytime. Separate elevators will carry staff members and visitors from the ground floor to the observing level. Aluminizing of the telescope mirrors will be done at the observing floor level.

One major undecided item is the exact location of the telescope on Kitt Peak. Three specific sites are being studied by the physics of seeing techniques developed by Dr. Roger Lynds. The decision on the site is expected to be made during the Spring of 1965, at which time most of the other undecided questions also should be resolved, such as the exact height of the dome.

Many of the Observatory's support staff will be involved in this project over the coming years; in particular, an expansion of the present Engineering Department is essential. Although most of the detailed design, and almost all of the construction, will be handled through contracts with industry, design review and contract monitoring must be taken care of by the Kitt Peak staff.

VI. USE OF THE TELESCOPE

The current policy on observing time at Kitt Peak, as set by the AURA Board of Directors, is as follows:

"The Kitt Peak National Observatory was established to provide American astronomers and qualified graduate students with modern telescopic and instrumental equipment for astronomical research. The Board of Directors of AURA (Association of Universities for Research in Astronomy, Inc.) has set the policy that about 60 per cent of the observing time on Kitt Peak shall be made available to visiting astronomers and graduate students.

"It is AURA policy that observing time requests be granted on the basis of scientific merit of the proposed program. In most cases, the Observatory staff reviews proposals and makes recommendations regarding assignments; occasionally, the advice of outside referees may be sought. Visiting astronomers are expected to do their own observing on Kitt Peak, although they may bring a qualified assistant if their program requires it.

"Subject to existing Federal regulations, qualified foreign astronomers may use the Observatory's facilities. In cases of U. S. and foreign programs judged to be of equal merit, however, preference will be given to astronomers resident in the U. S., because of the national character of the Observatory.

"To the extent that funds are available, the Observatory's graduate student program pays for travel and subsistence expenses of qualified, advanced-degree U. S. students."

Policy for allocation of observing time with the 150-inch telescope probably will be the same. There is no arbitrary limit to the time assigned for a given program. Scientific merit is the overriding criterion, subject only the the observer being qualified, and the problem requiring the use of the 150-inch telescope and its instrumentation.

150-INCH PHOTOS

Figure 1. Members of 150-inch Advisory Committee, National Science Foundation, Kitt Peak National Observatory (KPNO) and Consultants in attendance at the Advisory Committee Meeting held October 12, 1964. Reading from left to right:

B. H. Rule, Advisory Committee; J. Miller, KPNO; W. W. Baustian, KPNO; D. J. Ludden, KPNO; Dr. H. W. Babcock, Advisory Committee; Dr. H. A. Abt, KPNO; Dr. L. F. Gardner, National Science Foundation; Dr. I. S. Bowen, Advisory Committee; L. A. Cowell, KPNO; Dr. F. K. Edmondson, AURA, President; Dr. N. U. Mayall, KPNO; Dr. A. K. Pierce, KPNO; D. Trumbo, KPNO; J. Case, Consulting Engineer; Dr. A. A. Hoag, U. S. Naval Observatory (now KPNO); Dr. G. F. W. Mulders, National Science Foundation; D. Phillips (front), Westinghouse Electric Corporation; Dr. A. B. Meinel, Advisory Committee; W. E. Dunlap, Skidmore, Owings & Merrill; Dr. C. R. Lynds, KPNO; Dr. A. E. Whitford, Advisory Committee; Dr. D. Schulte, KPNO; Dr. D. L. Crawford, KPNO; Dr. W. A. Hiltner, Advisory Committee.

Figure 2. Spot diagrams showing the predicted shapes of star images for an existing prime focus corrector. This one was designed by F. E. Ross in 1944 for the 200-inch Hale reflector, and typifies the "Ross Corrector" now in use on several large telescopes. The three patterns contained within each vertical column show the effect of a slight change from "best focus", with each column representing a particular field angle (0, 5 and 10 minutes of arc radius in this case). The circle drawn at left center defines the scale; it is one second of arc in diameter. To its right is drawn schematically the amount of coma that the corrector removes at that field angle. The size of this pattern, if drawn, would increase proportionally to field angle.

Figure 3. Spot diagrams similar to Figure 2 for a proposed prime focus corrector for the 150-inch telescope. This design uses three thin aspheric plates to correct simultaneously spherical aberration, coma and astigmatism. This approach was proposed by A. B. Meinel in 1953, and the actual design pictured was produced by D. H. Schulte in 1963. The amount of coma to be removed is noticeably larger for the f/2.8 150-inch than for the f/3.3 200-inch, since it increases inversely as the square of the f-ratio.

Figure 4. Optical system of the 150-inch telescope. The diagrams show the mirrors, focal ratios and the scales. In the coudé system all mirrors are on fixed mountings except No. 5, which will have a tracking drive.

Figure 5. Artist's rendition of the preliminary dome and building designed by Skidmore, Owings & Merrill for the 150-inch telescope. This design is for a maximum telescope center height of 150 feet above the ground.

f/3.3 - f/4.7 (FER no. MNT-Doublet plus meniscus):

Present negative-power corrector for 200-in.

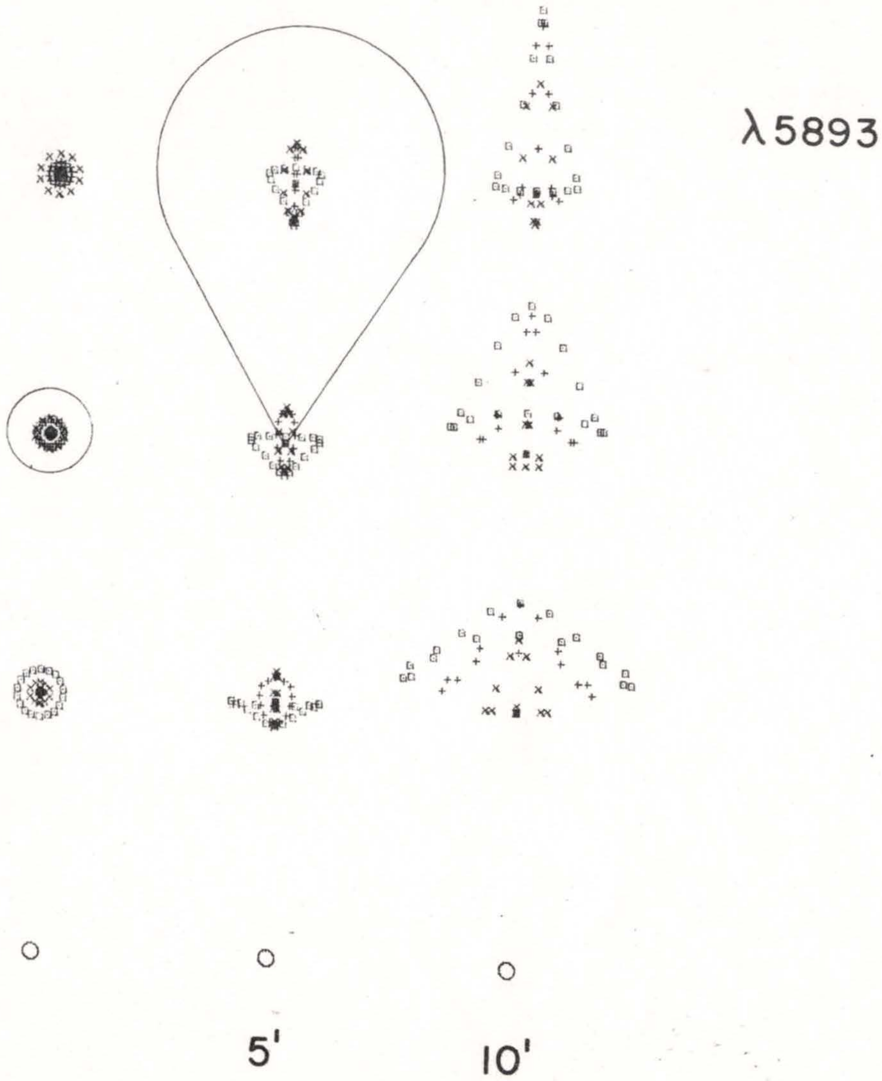

Figure 2

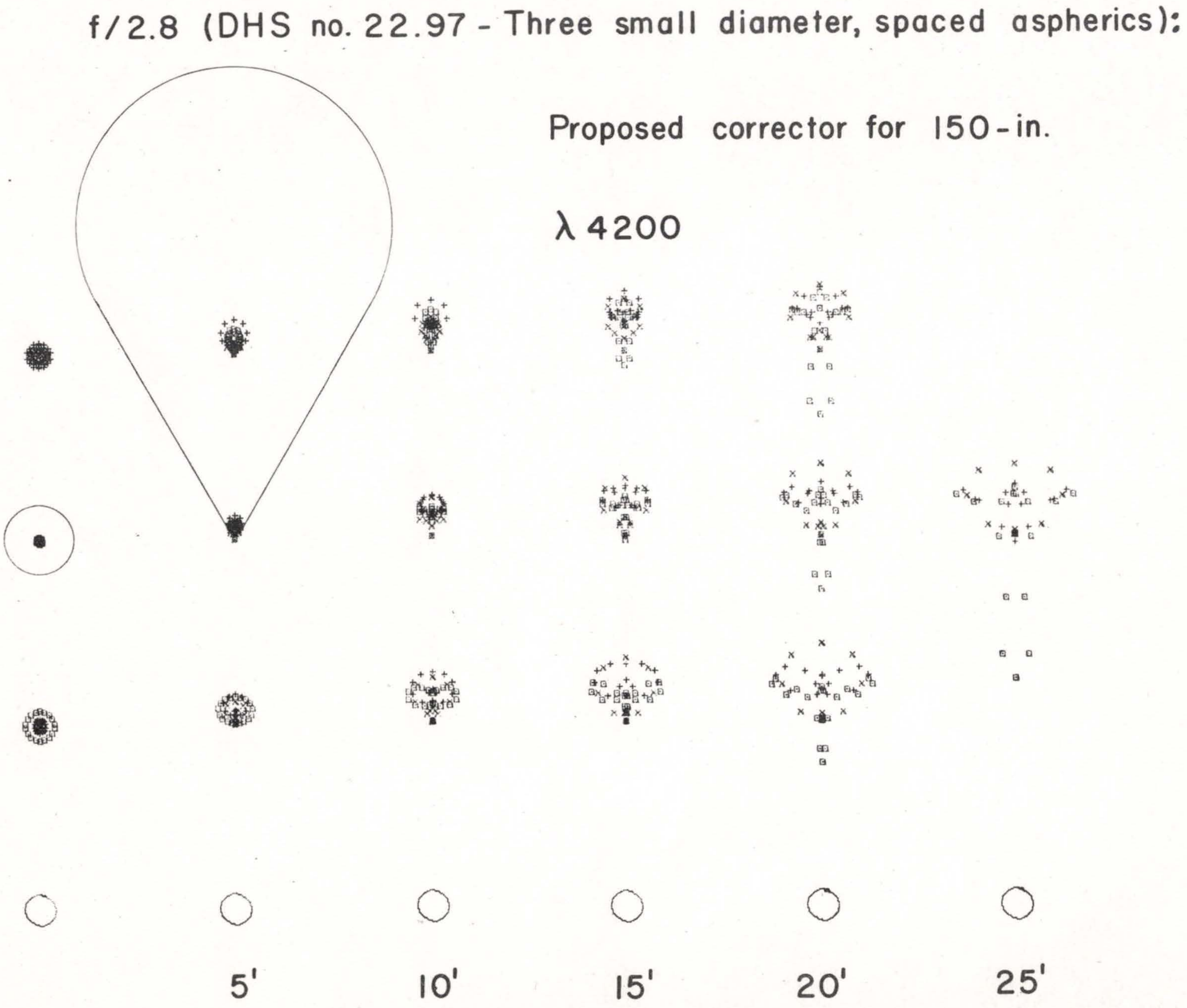
f/2.8 (DHS no. 22.97 - Three small diameter, spaced aspherics):
Proposed corrector for 150-in.
λ 4200
5'
10'
15'
20'
25'

Figure 3

Figure 4

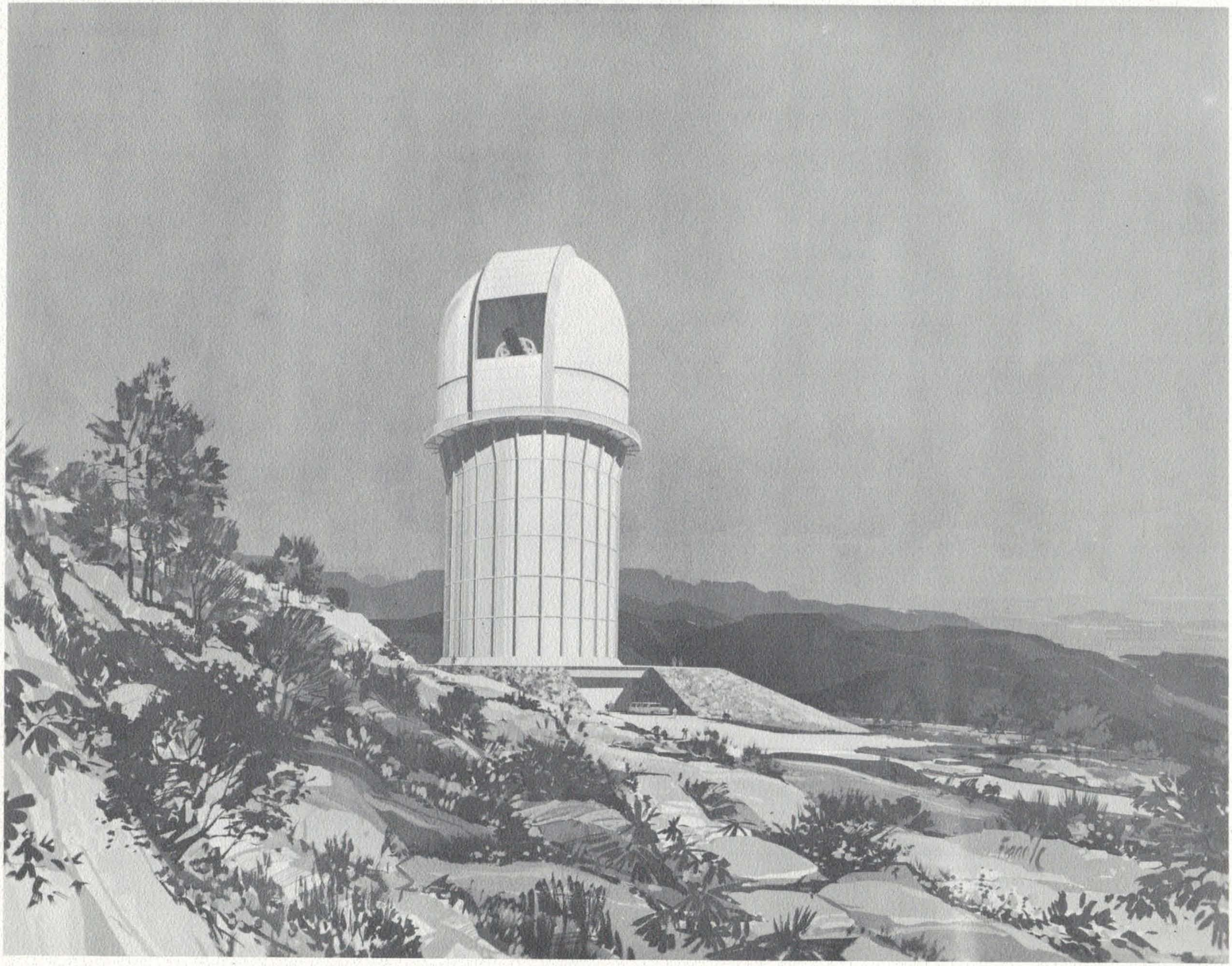

Figure 5