

AN OBSERVATORY

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AN UNDERGRADUATE THESIS IN ARCHITECTURE

A WRITTEN REPORT OF RESEARCH TOWARD THE
DESIGN OF AN ASTRONOMICAL OBSERVATORY.

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PROLOGUE

The knowledge we have of the heavens comes to us from the science of astronomy. Each new advance in equipment, technique, and facility is a step toward further knowledge, and an understanding of the universe, a realization of its inexpressible grandeur, its majesty and its unity.

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CONDITIONS CREATING A NEED • A

The Need

During the past decade, it has become evident that a keynote to the national welfare and survival is scientific research. A major facet of this scientific research deals in the realm of the universe, where man aspires to reveal to himself the secrets of his own existence and of the universal environment - to resolve factually that which has been solely or partially based upon scientific postulation. An important part of any scientific venture is the element of observation. Until man is capable of travelling at will through the cosmos to personally sample and observe, without the handicap of viewing through the earth's atmosphere, the observatory will remain the only extensive method of observing. A portion of this observing will be undertaken by orbiting telescope satellites in the near future, but these will be limited in size due to the problem of orbiting extremely heavy payloads.

The vastness of the universe requires a multiplicity of varied types of observational research. Mapping and spectrograph analysis of physical and chemical stellar behavior are but a few of the ambitions involved. These and other tasks can be pursued in an expedient manner by the establishment of new high quality observational equipment. This equipment should be located in an area which is most conducive to optimum telescopic viewing. The area of the United States where consistently good observing conditions are found is the Southwest. (1 : 7)

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PROPOSAL · B

The Proposal

I propose, in the interest of the nation and mankind, the establishment of an astronomical observatory; a further step toward a full understanding of the nature of the universe. I further propose that the observatory be located in the southwestern portion of the United States, in an area near Albuquerque, New Mexico.

Due to the highly specialized and complex nature of an observatory, the scope of this thesis will include the establishment of the observational and site-related facilities only. Not included is the headquarters of the observatory, to be located in Albuquerque. The headquarters of the observatory would be composed of the major administrative, research and maintenance elements. Subsequent reference to the observatory's headquarters will be purely speculative.

It is my intention that the organizational structure of this observatory basically coincide with that of the Kitt Peak National Observatory in Tucson, Arizona. The organizational structure of the Kitt Peak Observatory is composed of the National Science Foundation (NSF), the source of the initial and operational funds, and the Association of Universities for Research in Astronomy (AURA). AURA is under contract with the NSF for the building and administration of the observatory. (1 : 1-6) I assume that funds for the establishment and operation of the proposed observatory will be made available

through the National Science Foundation. I further assume that this observatory will be built and operated, under contract with NSF, by the University of New Mexico. The observatory's headquarters will be located on or adjacent to the campus of the University of New Mexico in Albuquerque. (See D., LOCAL CONDITIONS.)

INTRODUCTION - OBSERVATORIES - C

General

The first observatory in the United States was established at Yale University in 1830. (2 : 203) Since that time, approximately 100 observatories have been built in this country. Kitt Peak National Observatory, established in 1960 near Tucson, Arizona, is the most recent. The instrumentation of these observatories is of varying types and magnitudes. The 200" reflector telescope, at Mt. Palomar, California, is the largest in the world. The location and environmental conditions of the observatory determine, to a large extent, its success and value to the science of astronomy.

Optimum Location and Conditions of Operation

Geographical

The most astronomically important zone in the United States lies between 30° - 36° N. latitude. (1 : 7) From this zone, approximately 75% of the entire celestial sphere may be observed. Observatories located north of this area are limited in the number of stars which they may observe south of the celestial equator. (3 : 77) Atmospheric conditions further dictate the geographical requirements for the location of observatories. A belt, extending from W. Texas to the California coastline, best provides the clear atmospheric conditions required. (4 : 76) Within this belt, areas prone to earth tremors should be excluded because of the precision required during observation. For ease of administration and servicing,

it has been found most efficient and convenient to locate observatories close to cities. (3 : 79)

Topographical and Atmospheric

A semi-arid mountain peak or plateau, at an altitude between 5,000 and 9,000 ft. above sea level, is the most suitable location for an observatory site. Through the telescope, the density and turbulence of the atmosphere is the major deterrent in obtaining a sharp, clear stellar image. (2 : 168) Atmospheric turbulence causes frequent changes in light refraction. Most of this turbulence is excited by temperature aberrations, primarily associated with storm frontal systems and temperature extremes. (5 : 115) The area, then, should necessarily have no temperature extremes, few storms, and a fairly high altitude. At high altitudes, ground haze is eliminated and atmosphere becomes less dense and therefore, less able to distort light. (See Appendix A.) Although the earth's total atmosphere is hundreds of miles thick, 99% of its density is within the troposphere: sea level to seven miles altitude. Most atmospheric turbulence occurs in the troposphere. (5 : 116-117)

Altitudes above 9,000 ft. are not conducive to the high level of efficiency required of an observatory because of rarified atmosphere and low temperatures. (See Immediate Environment, below.) The capabilities of a human being begin to depreciate rapidly at 10,000 ft. Also, high winds often occurring at the higher elevations would continually threaten the stability of the

telescopic image. (See Appendix A.) The instrument, necessarily exposed to the weather by the narrow slit in the dome, would be susceptible to wind impact.

Atmospheric turbulence of a local nature can also disrupt telescopic observation. This turbulence often occurs in the form of eddy currents, which are a result of strong winds on rough terrain or a mountain peak. (5 : 288) Convection currents, currents of warm air rising to cooler air, are also a form of atmospheric turbulence. They occur in locales where certain elements, such as masses of exposed rock, bodies of water, asphalt roads, and roofs and chimneys of buildings, possess heat-retentive properties. These elements continue to radiate heat after the surrounding air has cooled. (5 : 98-99) At the new Kitt Peak Observatory, the buildings which house the telescopes are elevated on piers, which raise them above air turbulence at ground level. (1 : 10)

Immediate Environment

A rapid 5° temperature change, within close range of the telescope, may distort its lense to such a degree, that the instrument is inoperable for hours. Such a change could occur when the observing slot was opened. Because of this possibility, the telescope's dome is not heated and astronomers must often work at very low temperature levels. (6 : 11) This is one of the criteria for locating observatories in areas where low temperature extremes are not common. Domes should be well

insulated and painted with a reflective paint to prevent the heating of instruments by solar heat. (6 : 11-12)

Instruments

The fundamental instrument of research is the telescope and its prime purpose is stellar observation by means of photography. Stellar photography is accomplished by direct photography, spectroscopy, and photoelectric photometry. Direct photography can be by either an instantaneous or a time-exposed photograph. Time-exposed photographs build a detailed picture of a light source, though its intensity may be small, by the accumulation of its light over a period of time. Spectroscopy is the technique of separating the light from a stellar object into a spectrum by means of a prism or a diffraction grating. The resulting spectrum is recorded on a photographic plate which is termed a spectrogram. The spectrogram, by showing the peculiar arrangement of lines of a spectrum, portrays the chemical properties, temperature, direction and speed, relative to Earth, of a light source. Photoelectric photometry is the process of measuring and recording the brightness and color of celestial objects. All of the equipment used in stellar photography is auxiliary to the telescope. (1 : 15-16)

Direct telescopic viewing by man is a technique which has become practically obsolete. The photographic plate sees and records much more effectively than the human being. Also, photography provides a permanent record. (1 : 14)

All large telescopes must be mechanically rotated because of their great size and the need for high accuracy in tracking celestial objects. The telescope must be permitted to move in a vertical 90° arc and freely through a horizontal circle. The dome, usually used in covering the instrumentation, is rotated mechanically in coincidence with the horizontal movement of the telescope. A slot in the dome's surface permits observation through a vertical plane from the horizon to zenith. The slot is opened and closed by a shutter assembly and is equipped with wind screens. (4 : 256)

Problems relative to weight and strength mount as the size of the telescope increases. However, the requirement of precision remains the same. The 200" telescope at Mt. Palomar, weighing 530 tons, tracks its objective by the action of a one-twelfth horsepower motor. To insure stability, the framework supporting the telescope is usually separate from the framework of the building. (6 : 21)

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LOCAL CONDITIONS . D

General

My selection of an area near Albuquerque, New Mexico, for the location of the proposed observatory, is not entirely based upon the exceptional observational conditions found there. The following information reveals that the proximity of the site to Albuquerque makes readily available related technological fields of science, as well as excellent educational, cultural and living conditions.

Two possible sites are under consideration for the location of the observatory. Both of these sites are located in the Sandia Mountains. (See E., SITE CONDITIONS.)

Geographical

The Sandia Mountain Range, in north-central New Mexico, is a southern extension of the Rocky Mountains and is about eighteen miles in length, north to south. Geographically, the area lies within 35° and $35^{\circ} 30'$ N. lat., and $106^{\circ} 15'$ and 107° W. long. The Sandias roughly parallel the Rio Grande River at an approximate distance of twelve miles. The foothills of the range extend to points within the Albuquerque city limits. The highest point of the mountain range is Sandia Crest, 10,678 ft. above sea level and 5,364 ft. above the U.S. Weather Bureau Station in Albuquerque. From Sandia Crest, roughly 10,000 square miles of New Mexico can be clearly seen. (7 : 6) (See Figures 1 and 2)

Historical

The area was initially inhabited by indians. These indians were found residing in pueblo dwellings along the banks of the Rio Grande River by the first Spanish explorers. The Spanish explorers: De Guzman, De Niza, De Vaca and Coronado, visited the area during the period from 1528 - 1542. The city of Albuquerque, (now spelled Albuquerque), was established in 1706 by the Spanish governor of New Mexico, Cuervo y Valdez, in honor of the Viceroy of New Spain, the Duke of Albuquerque. Spain lost New Mexico to Mexico during the War of 1821, and New Mexico became a territory of the United States after the War of 1846. The territory was admitted to the Union in 1912. (8 : 151)

Climate

The following information is indicative of the climatological conditions for the general area. For the detailed climatological conditions of the mountainous area, where the site of the observatory is located, see E., SITE CONDITIONS, Climate.

The climate of Albuquerque and vicinity can be described as "Arid Continental". The average annual rainfall is 8.28 inches, almost one-half of which falls during the period from July to September. Prolonged rainy spells are practically unknown. Most of the precipitation falls in the form of brief, and sometimes severe, thunderstorms. Temperatures are characteristic of high altitude, dry climates. Extreme temperatures are rare.

Normally there is less than one day a year when the temperature reaches 100°F or drops to 0°F. The average annual temperature is 55.7°F. The highest temperature recorded is 104°F and the lowest recorded is -16°F. The air is dry with an average annual relative humidity of 43%. An attractive feature of the climate is the large number of clear days. On an average, sunshine occurs during more than three-fourths of the hours from sunrise to sunset on each day of the year. The average wind velocity throughout the year is 8.9 miles per hour. The prevailing wind is from the southeast. (9 : 1)

Population

The population of the area is mainly concentrated in Albuquerque and its immediate vicinity. According to the 1960 U.S. Census, Albuquerque was the thirteenth fastest growing city in the United States during the period from 1950 - 1960. The population of the central city in 1960 was 201,189, an increase of 107.8% over the 1950 population. The population of the area outside of the central city in 1960 was 61,010, an increase of 24.9% over the 1950 population.

Economy

Primarily, the extensive growth of the population and economy of the Albuquerque area can be attributed to the research, development and testing phases of the nation's defense and space endeavors. These programs are engaged in by both the Federal Government and private industry. The two

major private corporations involved in these defense and space efforts are Sandia Corporation and ACF Industries, Inc. Together they employ over 10,000 persons, who earn \$95,000,000 annually.

(7 : 3)

Education

The University of New Mexico is located in Albuquerque. The university, performing ^{l.c.}key nuclear and space research under several Federal grants, is becoming a leading center for the training of technicians and scientific personnel. In the period 1961 - 1962, 8,086 students were enrolled at the university. (10 : 329)

The university provides its students and the citizens of Albuquerque with a diversified cultural program in the fine arts. This, together with the fine civic program, presents excellent cultural opportunities. (7 : 5)

Transportation

The Albuquerque area is served by ample means of transportation. The Albuquerque Airport, one of the nation's ten busiest, accommodates TWA, Continental and Frontier air lines. TWA and Continental offer transcontinental jet service. Albuquerque is on the main line of the Atchison, Topeka and Santa Fe Railway. The city is also served by nine truck lines and two transcontinental bus lines. Two major National highways intersect in Albuquerque: U.S. 66 and the Pan American Highway, U.S. 85. An intra-city

freeway system is under construction.

Portions of the above information were provided by the
Industrial Development Dept., Greater Albuquerque Chamber of
Commerce.

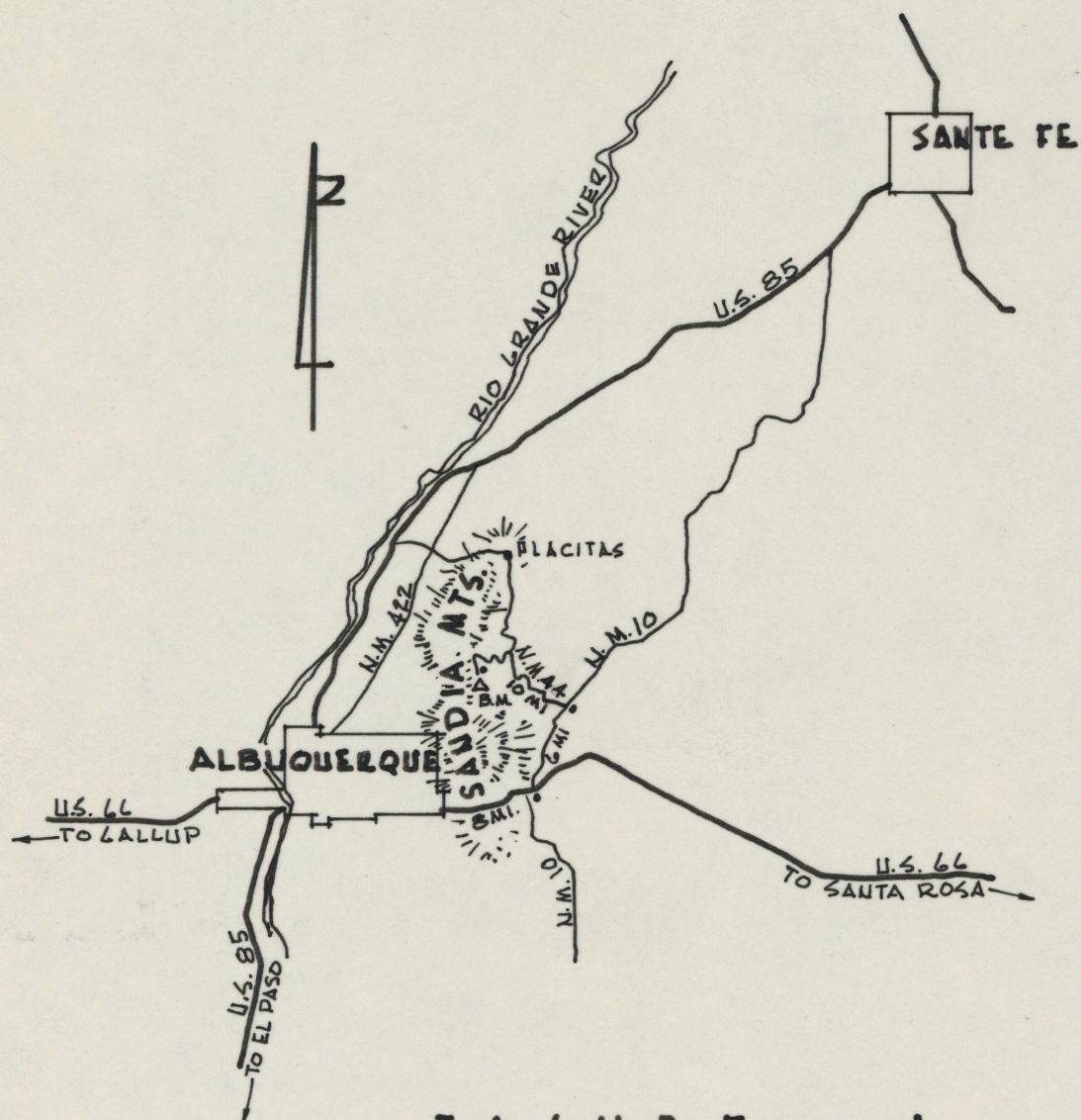


FIGURE 1

SCALE: 1" = 12 MILES

SITE CONDITIONS • E

General

The two sites under consideration for the location of the observatory are in the Sandia Mountains. Each is within a radius of 2.5 miles of U.S. Geodetic Survey Bench Mark (USGSBM) Sandia, elevation 10,678 ft. (See Figure 2.) The bench mark is geographically located at $35^{\circ} 13'$ N. lat. and $106^{\circ} 27'$ W. long. The entire area lies within Cibola National Forest. The immediate vicinity of USGSBM Sandia is known as Sandia Crest. It is a point of scenic interest because of the clear and magnificent view it provides of the New Mexican country-side. In recent years, the four Albuquerque television stations have located their transmission towers and equipment in an area just northwest of the Sandia bench mark.

Sandia Crest is serviced by paved road from Albuquerque, a distance totaling twenty-six miles. Along State Road 44, most of which is within the Cibola National Forest, the Forest Service has developed numerous public camping and recreational sites. (See Figures 1 and 2.)

Following is a description of conditions generally relative to both sites. Any deviation from these conditions will be noted in the description of each site.

Geology

The Sandia Mountain land mass is basically Pre-Cambrian, of granite and schist composition. The granite and schist

formation is exposed on the steep, rugged west slope of the range. The eastern slope of the Sandias is very gentle. This slope is plated by 300 - 700 ft. of carboniferous limestone of the Pennsylvanian period. The depth of soil covering the limestone plated east slope is varying, but minimal. (11 : 15) (See Figure 3.)

Land Ownership

Both sites are a portion of Cibola National Forest, owned by the Forest Service, U.S. Dept. of Agriculture.

Land Acquisition and Conditions of Use

Acquisition: Either site would be acquired for use from the Forest Service, U.S. Dept. of Agriculture, by means of a Special Use Permit. Under the provisions of the permit, a maximum of eighty acres is available for an indefinite period of occupancy. Separate Special Use Permits are issued for different types of land use such as: building site, road site, power line site, or water line site.

Conditions of Use: The following is a summary of the required conditions of land use specified by the Special Use Permit:

1. The forest supervisor must approve, in advance, all development plans or alteration of improvements for this area. He must also approve any revision of such plans.
2. Removal of trees, shrubs or plants, and planting

of the same, must be approved by the forest officer in charge.

3. The permittee must maintain the improvements and premises to standards of repair, orderliness, sanitation and safety acceptable to the forest officer in charge.

4. The permittee, in exercising the privileges granted by this permit, must comply with all Federal, State, County and municipal laws, ordinances, or regulations which are applicable to the area or operations covered by this permit.

5. The permittee must take all reasonable precautions to prevent and suppress forest fires.

6. The permittee is responsible for any damage to National Forest property other than that caused by normal use.

7. The permit may be terminated upon breach of any of the above conditions or at the discretion of the regional forester or the Chief of the Forest Service.

The above information was obtained in an interview with Mr. Earl Welton, Recreation and Lands Staff, Regional Office, Gallatin National Forest.

Climate

Tabulated on the following pages is the mean annual and monthly climatological data for Sandia Crest. The information was provided by the U.S. Weather Bureau and was recorded at their Sandia Crest Sub-station.

	<u>Jan</u>	<u>Feb</u>	<u>Mar</u>	<u>Apr</u>	<u>May</u>	<u>Jun</u>	<u>Jul</u>	<u>Aug</u>	<u>Sep</u>	<u>Oct</u>	<u>Nov</u>	<u>Dec</u>	<u>Annual</u>
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TEMPERATURE (°F)

Mean	20.9	21.4	25.2	33.9	43.7	55.0	57.0	55.1	51.5	40.8	29.3	24.0	38.1
Max.	47	46	56	59	70	76	80	74	71	62	52	50	-
Min.	-8	-24	-4	-2	16	29	37	37	29	11	-6	-5	

PRECIPITATION (in.)

Mean	2.03	1.42	2.53	1.33	1.23	0.75	2.89	3.07	1.22	2.56	1.11	2.19	22.33
Max.	3.15	2.43	6.52	3.21	2.51	1.60	6.23	6.18	4.56	4.79	3.64	5.38	

GREATEST PRECIP. OBS'D IN 24 HOURS (in.)

	1.20	0.90	2.10	1.30	0.80	1.10	2.25	1.20	1.40	1.57	1.00	2.35	
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SNOWFALL (in.)

Mean	22.1	17.3	22.9	10.5	2.70	0	0	0	0	8.50	8.30	24.2	116.5
Max.	40.5	32.0	67.9	34.5	5.50	0	0	0	0	24.0	27.6	53.0	

RELATIVE HUMIDITY (%)

Mean	51.8	47.8	41.0	32.3	27.5	29.8	41.8	50.0	47.3	36.3	57.3	58.3	43.4
Max.	67.0	65.0	55.0	48.0	40.0	44.0	60.0	67.0	67.0	49.0	71.0	72.0	
Min.	35.0	31.0	29.0	20.0	17.0	18.0	24.0	34.0	30.0	25.0	42.0	45.0	

	<u>Jan</u>	<u>Feb</u>	<u>Mar</u>	<u>Apr</u>	<u>May</u>	<u>Jun</u>	<u>Jul</u>	<u>Aug</u>	<u>Sep</u>	<u>Oct</u>	<u>Nov</u>	<u>Dec</u>	<u>Annual</u>
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WIND VELOCITY (mph)

Mean	19	17	23	17	14	18	10	11	15	17	16	18	16.25
Fastest Mile	57	68	<u>82</u>	52	50	57	27	40	40	57	68	69	

DEGREE DAYS

Mean	1381	1266	1221	951	647	283	244	286	392	756	1086	1213	9726
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ATMOSPHERIC CLEARNESS

Clear Days	13	11	12	12	14	18	13	13	18	18	16	14	172
Part Cldy Days	8	8	10	9	11	9	14	14	8	8	8	8	115
Cldy Days	10	9	9	9	6	3	4	4	4	5	6	9	78
Thunderstorms	0	0	1	2	4	5	12	12	4	3	1	0	44
Possible Sunshine (%)	70	72	73	79	75	84	76	76	82	79	78	70	77
*Mean Sky Cover	4.9	4.9	5.0	4.8	4.3	3.3	4.4	4.3	3.2	3.5	3.7	4.5	4.2

*The sky cover scale is based on a 0 - 10 rating, in tenths, as follows:
~~0~~ clear, 0 - 3; 4 - 7, partly cloudy; 8 - 10, cloudy.

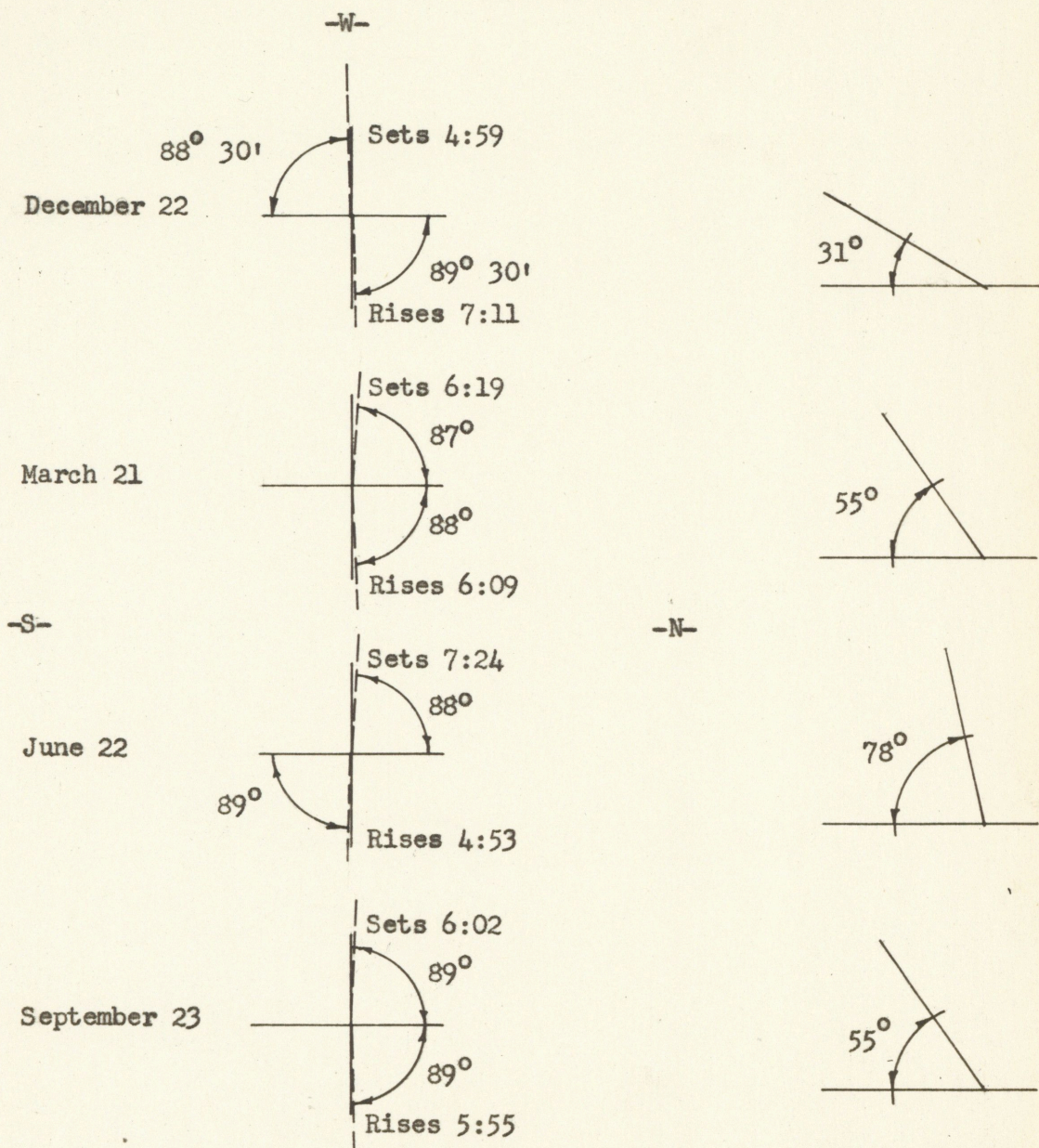
Note: Readings underlined, as 67.9, indicate the record maximum or minimum.

Freeze Data

Last Day in Spring		* No. Days		* First Day in Fall		* No. Days		* Frost-	
Month	Day	* Fm. Jan 1*		Month	Day	* Fm. Jan 1*		Free days	
Mean	May	29	149	Oct	6	279	130		
Max.	Jun	2	153	Sep	22	265	112		

Prevailing Wind - S.W.

SUN ANGLES



Sun Angles at Noon

Sunrise and Sunset

Site No. 1

Orientation

Corner A of Site No. 1, el. 10,600 ft., is 750 ft. S 43° E of USGSEM Sandia, el. 10,678 ft. (See Figures 2 and 4)

Topography

Site No. 1 encompasses an area of approximately seventy-seven acres. The site slopes from its highest elevation, 10,645 ft., at an average of about 10°. The maximum slope is 14° and the minimum is 7° 30'. The entire S.W. boundary of the site is a segment of the main ridge of the Sandia range. The lowest point of the site is Corner B, el. 10,315 ft.

Vegetation

The site is 30% - 40% forested. This foresting is not dense and is composed of aspen and fir trees. Grass covers the lower slope of the site, and sparsely covers the upper slope.

Climate

Because of the proximity of Site No. 1 to Sandia Crest, the location of the U.S. Weather Bureau Sub-station, there is no appreciable deviation of climatological conditions between the two areas.

Adjacent Environment

The above description of Site No. 1 is typical of the

adjacent environment. The entire area is a part of Cibola National Forest. The area adjacent to the S.W. site boundary drops to the S.W. at a slope of about 45° . This area is characterized by rock outcroppings and sparse vegetation.

Special features of the environment include:

1. USGSBM Sandia, 750 ft. N.W. of the site.
2. Television transmission towers and facilities, 3,000 ft. N.W. of the site.
3. State Road 44, 850 ft. N.W. of site.

Views

The view from the S.W. site boundary is unobstructed with the exception of that to the N.W. On a line N 38° W, the Sandia Crest land mass represents an obstruction of about $4^{\circ} 30'$ above the horizon.

Services

A power and telephone line serves the nearby television transmission facilities. The line terminal is 3,000 ft. N.W. of Corner A. The New Mexico State Highway Commission maintains State Road 44 year around. No other utility or service is now available. Water is currently carried to the television facilities by truck. The nearest natural source of water (spring water) is located at a point two miles to the N.E. The spring is over 1,000 ft. below the site.

Accessibility to the Site

An unimproved dirt road serves the site from State Road 44.

Site Advantages and Disadvantages

The following statements are based on the suitability of the site relative to the requirements of an observatory. (See C. INTRODUCTION - OBSERVATORIES.)

Advantages: In my opinion, Site No. 1 meets the requirements listed in C. INTRODUCTION - OBSERVATORIES, with the exception of the disadvantages listed below.

Disadvantages: The following conditions are either in disagreement with optimal observatory conditions or are those contrary to general utilitarian use.

1. The elevation is over 10,000 ft.
2. High winds are common to the area.
3. Localized eddy turbulence would be occurring in the area just above the rocky, 45° slope to the S.W.
4. Water is not available within a reasonable distance.
5. State Road 44, from the area of Capulin Peak to Sandia Crest, is hazardous because of the numerous sharp curves and steep grade. This is especially true in winter.

Site No. 2

Orientation

Corner A of Site No. 2, el. 8,800 ft., is 2.36 miles E 15° N of USGSBM Sandia, el. 10,678ft. (See Figures 2 and 5)

Topography

Site No. 2, an area of approximately eighty acres, encompasses most of the land mass known as Capulin Peak. Capulin Peak, elevation 8,929 ft. is a minor peak of the Sandia Mountains. The site rises gently from the north, east, and west boundaries to Capulin summit at an average slope of about 7°. The minimum slope, on the west side, is approximately 4° 30'. South of the summit, the maximum slope is about 19°.

A source of spring water, near Corner A of the site, is known as Capulin Springs. The springs flow perennially but are not considered important to the watershed of the Rio Grande River Basin. All spring water in the Sandias is either absorbed by the land or evaporated before it reaches any free flowing stream of the watershed. Vegetation in the Sandia Mountains is solely dependent upon moisture from rainfall and melting snow. (12 : 19)

Vegetation

The site is about 30% forested. The foresting is not dense and is composed of spruce, fir, and aspen trees. Grass covers the ground over most of the site.

Climate

A major deviation in average wind velocity occurs between Site No. 2 and the sub-station at Sandia Crest, because of the protective nature of the land mass to the S.W. of the site. The difference in altitude also has an effect on the average wind velocity. Although no climatological equipment is located at Capulin Peak, climatologists estimate the average wind velocity to be about twelve miles per hour, for the site, from the S.W. The U.S. Weather Bureau estimates that in mountainous areas the temperature rises about 3.3°F for every 1,000 ft. decrease in elevation. Based on this average, the temperatures at Capulin Peak would be approximately 6°F higher than those averages recorded at Sandia Crest. (5 : 107)

Although a small difference of the other climatological conditions may exist between the site and the sub-station, they will be considered the same in the preliminary analysis.

Adjacent Environment

The adjacent environment is a part of Cibola National Forest and typical of the site in description.

Special features of the environment include:

1. State Road 44, 600 ft. S. of the site.

Views

The view from the line N 35° W, clockwise to the line S 3° E, an arc of 212°, is unobstructed. From S 3° E to N 35° W,

an arc of 148° , clockwise, the view is obstructed in varying degrees. Following is a listing of representative maximum obstructions plotted from Capulin Peak summit. (See Figure 2.)

Line A, N $5\frac{1}{4}^{\circ}$ W, $3^{\circ} 30'$	obstruction above horizon.		
Line B, W 23° N, $5^{\circ} 55'$	"	"	"
Line C, W 04° S, $7^{\circ} 37'$	"	"	"
Line D, W 15° S, $8^{\circ} 02'$	"	"	"
Line E, S 22° W, $4^{\circ} 20'$	"	"	"

Services

The power and telephone line serving Sandia Crest passes through the site. State Road 44, adjacent to the site, is maintained year around by the New Mexico State Highway Commission. No other utility or service is currently available.

Accessibility to the Site

An unimproved dirt road serves the lower W. side of the site, from State Road 44.

Site Advantages and Disadvantages

The following statements are based on the suitability of the site relative to the requirements of an observatory. (See C. INTRODUCTION - OBSERVATORIES.)

Advantages: In my opinion, Site No. 2 meets the requirements listed in C. INTRODUCTION - OBSERVATORIES, with the exception of the disadvantages ^{stated} ~~listed~~ below, and possesses

the following additional advantages:

1. Water is available on the site.
2. Travel by road from the site to Albuquerque, year around, would be a safe and easy task.
3. A power and telephone line passes through the site.

Disadvantages: The following condition is in disagreement with optimal observatory conditions.

1. The expanse of vertical obstruction limits the field of vision to varying degrees through an arc of 148° .

Site Selection

Site No. 2 will be the location of the proposed observatory. This site was selected for the following reasons:

1. It meets the requirements listed in C. INTRODUCTION - OBSERVATORIES. Site No. 2 is located at a more astronomically ideal elevation than is Site No. 1.
2. Water is available on the site.
3. An electric power and telephone line passes through the site.
4. State Road 44 is closer to the site than it is to Site No. 1.
5. There are no hazardous sections of State Road 44 between the site and Albuquerque.
6. The contours of Site No. 2 are more desirable for the location and utility of roads and buildings than those of Site No. 1.

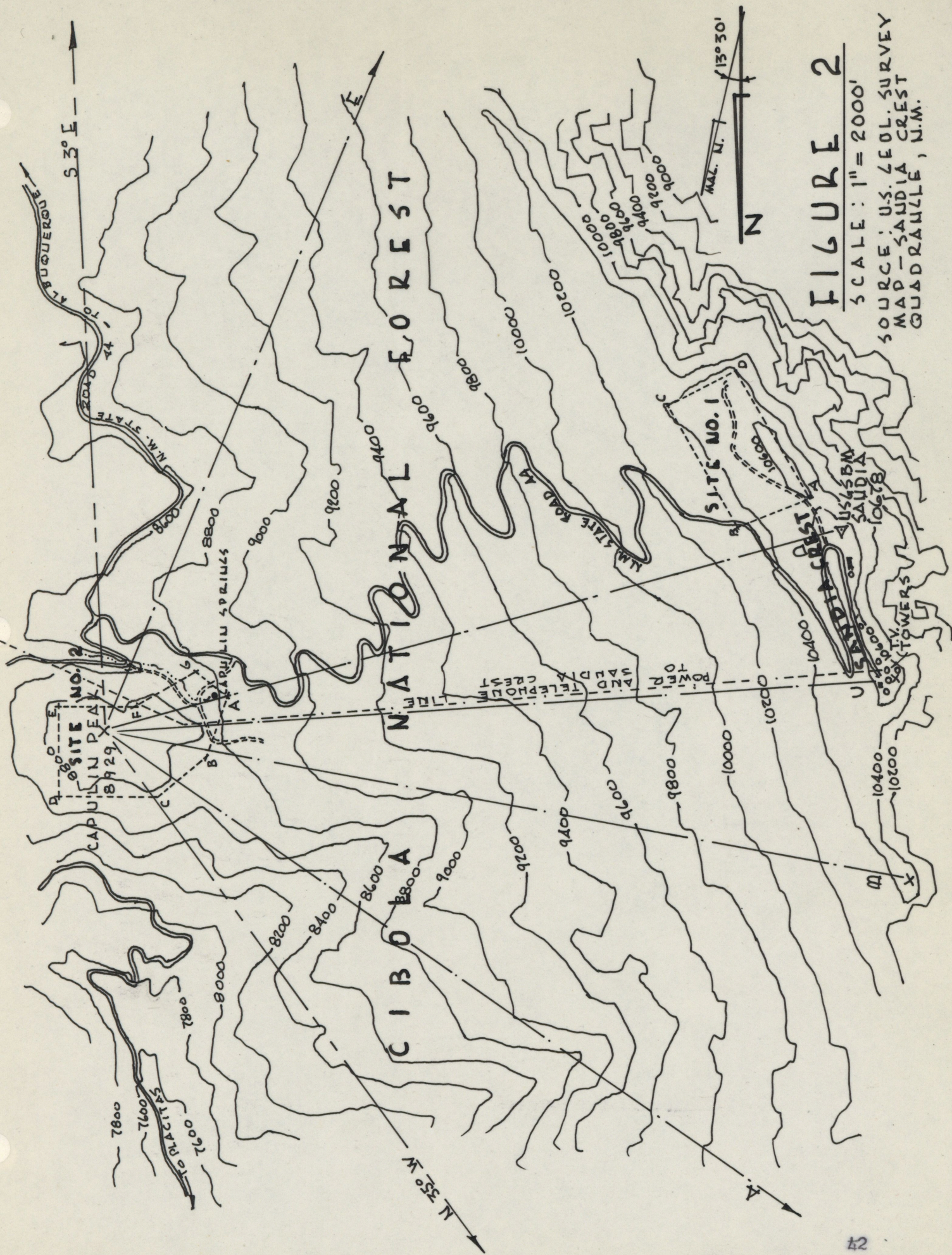
Preliminary investigation revealed a major disadvantage in Site No. 2. Its surrounding terrain creates certain viewing obstructions. (See Site No. 2, above.) The average obstruction, through the 148° arc, is approximately 5° . The maximum high point of obstruction is $8^{\circ} 2'$ from the horizon.

In my opinion, this disadvantage in observation may reasonably be overlooked. Observation in such proximity to the horizon is seldom successful, even when the view is not obstructed by land masses. The closer an observation, descending from zenith,

comes to the horizon the more the thickness of the atmosphere increases. When viewing an object outside the earth's atmosphere, at zenith, the astronomer must view through an atmosphere hundreds of miles thick. The closer the observation, descending from zenith, comes to the horizon, the thicker is the atmosphere relative to the observer. The atmospheric extinction would be twenty times as great at the horizon as it is at zenith. Atmospheric extinction is the sum total of all absorbtion, scattering, and distortion of stellar light as it passes through the thickness of atmosphere. (4 : 173-179)

At an angle of 8° above the horizon, the amount of atmospheric extinction would greatly limit the chances for successful telescopic observation. Spectroscopic experiments in the ultraviolet or infrared zones would also be extremely limited at this angle. Atmospheric ozone is highly absorbant of ultraviolet rays, and would be especially so at such great density. The moisture, which is damaging to infrared observation, usually present in this amount of atmospheric extinction, would render infrared observation ineffective. (5 : 119)
(See Appendix A.)

Research has shown that the 8° 02' obstruction in telescopic viewing is a negligible disadvantage in Site No. 2. Therefore, I feel that the site I have chosen approximates most of the ideal conditions for the location of an astronomical observatory.



FILE 2

SCALE: 1" = 2000'

SOURCE: U.S. GEOL. SURVEY
MAP - SANDIA CREST
QUADRANGLE, N.M.

PHILLIPS BOOK STORE - BOZEMAN, MONTANA

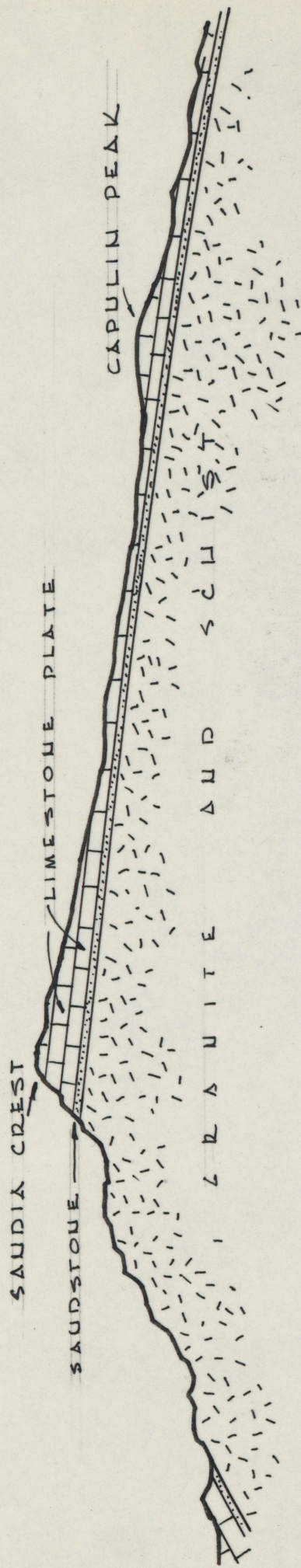
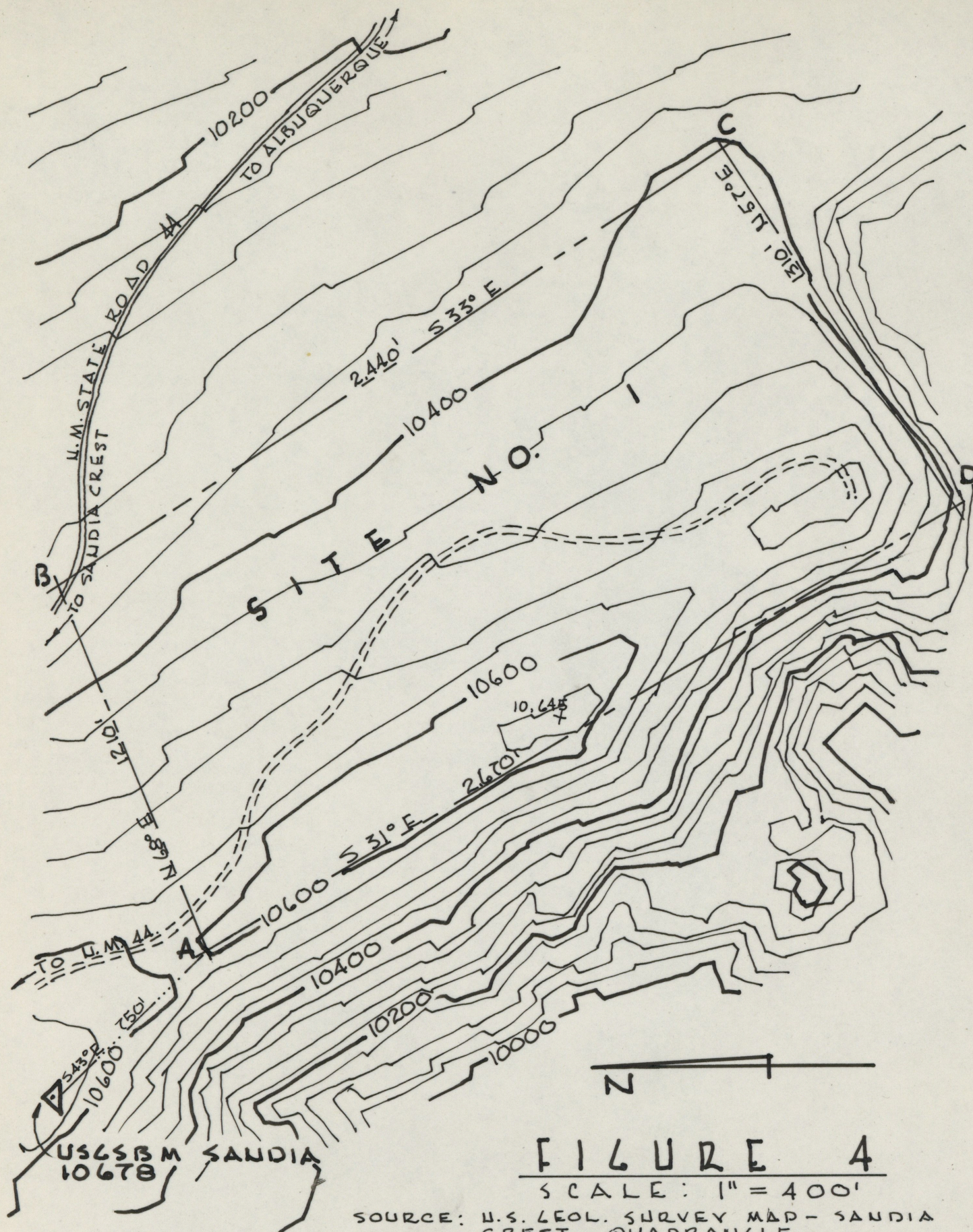


FIGURE 3
SANDIA CREST AND CAPULIN PEAK
LOOKING NORTH.

SOURCE: U.S.G.S. BUL. NO. 613 - 1916.



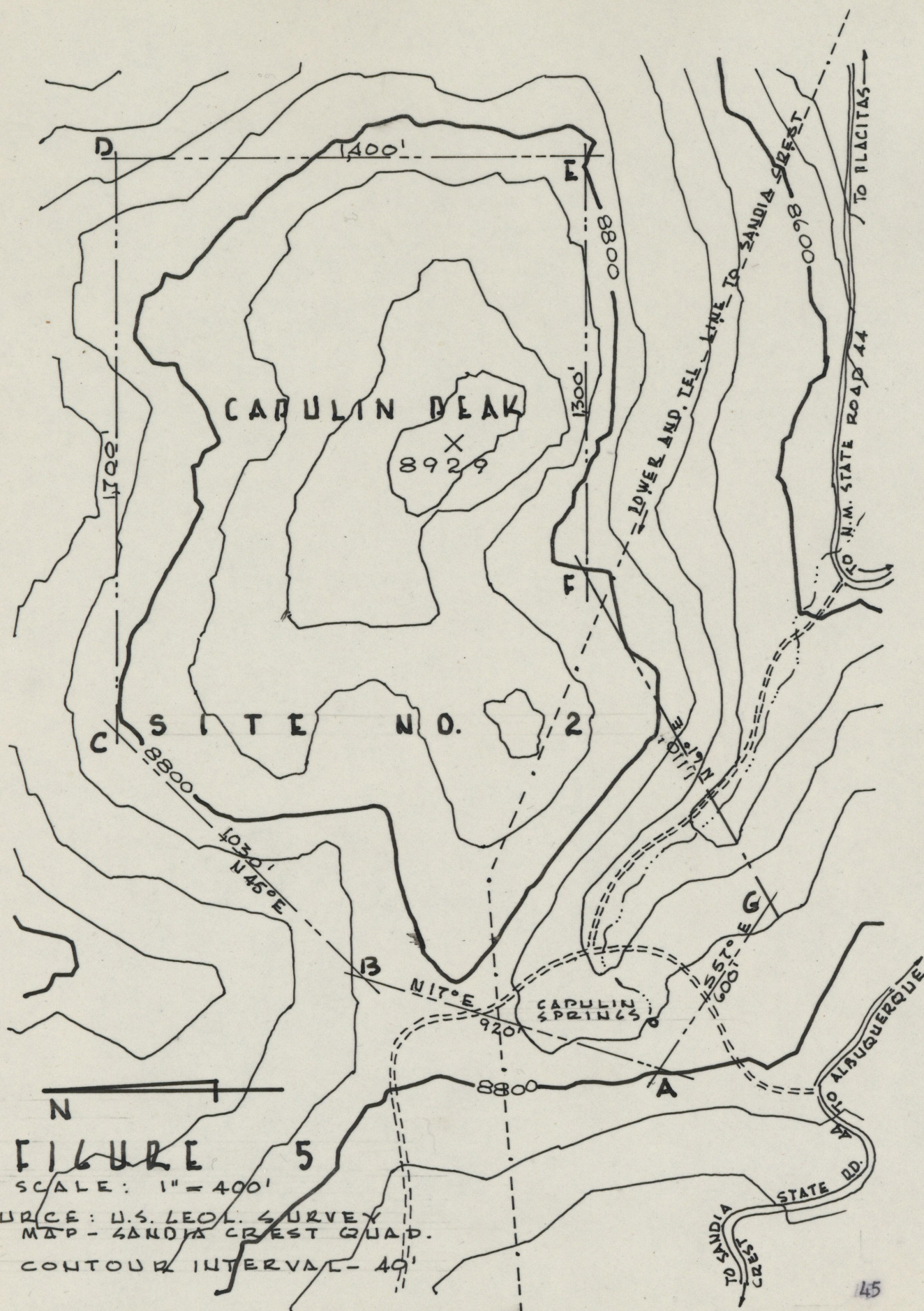


FIGURE 5

SCALE: 1" = 400'

SOURCE: U.S. GEOL. SURVEY
MAP - SANDIA CREST QUAD.

CONTOUR INTERVAL - 40'

PROGRAM • I

General

The primary function of this observatory is to provide visiting and staff astronomers with instrumental facilities for astronomical research. The provision of space for the housing and expedient operation of the astronomical instrumentation is of utmost importance in the design of the observatory. The designer must spatially organize and structurally plan the building elements, relative to the observing instruments, in such a manner as to insure their maximum operational efficiency. The final and most time consuming portion of astronomical research will be carried on at the observatory's administrative and research headquarters in Albuquerque. Details of the headquarters are beyond the scope of this thesis. However, space must be provided for immediate processing of observed data and its partial evaluation and storage at the observatory site. The data would then be filed at the observatory for reference or taken to Albuquerque for research or storage.

Maintenance facilities must be located at the observatory site to render minor service to observational equipment, mechanical systems, and the observatory complex in general. Major maintenance problems occurring at the site will be resolved by the engineering or maintenance staffs to be headquartered in Albuquerque.

Most of the housing facilities will be of a limited and simple nature. At most observatories, astronomers are allotted

from three to six nights per month for pursuit of their individual research programs. Since observing is done at night, accommodations for the astronomers must be provided with features conducive to daytime rest. (6 : 25-26) The remainder of the astronomers' time will be spent working and residing in Albuquerque, where the major laboratories and libraries of the observatory are to be located.

A small amount of housing of a more permanent nature will be located at the observatory site to accommodate persons having essential maintenance or supervisory positions. Accommodations for the families of these employees might also be incorporated in the housing facilities.

Dining facilities must be provided at the site to serve members of the staff and interim staff. These facilities will be operational throughout the day and night to coincide with the activities of site personnel, carried on at different intervals throughout the 24-hour period.

Office space will be included at the site to accommodate a minor administrative facility. This facility will concern itself with day-to-day site administration rather than the broader scope of administration carried on by the Albuquerque headquarters. Functions of the administrative facility at the site will include:

1. Serving as the communication medium between the observatory and the headquarters in Albuquerque.

2. Immediate supervision of employees and their responsibilities at the site.

3. Immediate supervision of all activities carried on at the site including maintenance and the activities of all visitors.

An area for research will be provided at the site for astronomers to evaluate information that they have obtained. A small library should be included in the research area to provide pertinent data collected at this and other observatories. The library will be an abridgment of the observatory's library in Albuquerque and therefore not intended to satisfy any complex and long range research needs. (1 : 9)

Certain areas of the site will be available for public access. Guided tours, lectures and displays within these areas will serve to acquaint the public with the instruments, activities, and goals of contemporary astronomy. Similar services are offered to the public at most major observatories in this country and are very popularly received. The Mount Wilson and Palomar Observatories together attract over 250,000 visitors yearly. The public will be admitted to glass inclosed galleries within the observation areas for viewing the telescopes and related equipment. In addition to the visitors' galleries, a small museum containing photographic and diagramatic displays will be provided. (1 : 9),(3 : 12)

An assembly area will be included at the site to accommodate

groups of visitors, students, or members of the profession in the event of special lectures, meetings and motion picture showings.

Specific

On the basis of the fundamental functions and requirements discussed in General, above, the following program is set forth. Also considered in the development of this program is information detailed by astronomers and engineers in various publications and in questionnaires prepared in the interest of this thesis.

This program should be considered a flexible guide which is not final in nature. Unforeseen circumstances may arise, requiring addition, expansion, reduction or deletion of a certain part or parts of the whole.

The General Flow Diagram (Figure 6) describes the relationship of the major areas. Relationship of spaces within a typical observation area, and its related spaces, is shown in Figure 7.

Assumptions

1. Total Observatory Staff

<u>Title</u>	<u>No. Persons</u>
Director	1
Astronomers (one is Assoc. Director)	6
Technicians	
Instrument and Optical	6
Computers	4
Other	4
Maintenance	2
Site Superintendent	1
Assistant Site Superintendent	1
Clerical	3
Buildings and Grounds	2
Services	4
Total Staff	34

2. Permanent Staff at the Site

Site Superintendent	1
Assistant Site Superintendent	1
Clerical	1
Buildings and Grounds	2
Services	4
Total On-Site Staff (Perm.)	9

3. Persons Required for Operation of Telescopes at Any
One Time

<u>60" Reflector</u>	<u>No. of Persons</u>	
Astronomers	2	
Night Assistant (Technician)	1	
Total	3	3
 <u>36" Schmidt</u>		
Astronomer	1	
Night Assistant (Technician)	1	
Total	2	2
 <u>Maintenance</u>	1	1
Total Persons Required		6

4. Total Persons at the Site at Any One Time

Permanent Staff	9
Astronomers (Rotating: 1 week/month)	3
Night Assistants (Technicians)	
(Rotating: 1 week/month)	2
Maintenance (Semi-permanent)	2
Possible Visitors (Additional)	3
Possible Staff (Additional)	3
Total Possible at Site	22

5. Basic Observational Equipment (60" Reflector)(6 : 17)

1. Purpose of detailed stellar analysis.

2. Field of ^{1/4}vision restricted to small areas of space at one time.

3. Equipped for direct photography, spectroscopy, and photometry.

4. Mirror diameter is 60".

5. Approximate weight is 23 tons.

6. Basic Observational Equipment (36" Schmidt)(6 : 22)

1. Purpose of mapping and locating points of interest to be investigated by the 60" Reflector.

2. Field of ^{1/4}vision is wide-angle.

3. Equipped for direct photography only.

4. Length is about 18 ft.

SPACE A - REFLECTOR TELESCOPE AREA

Functions

1. House 60" Reflector Telescope and provide for its:
 - a. Stability.
 - b. Operational mobility.
 - c. Operational utility.
 - d. Safety.
2. Inclusion of equipment and facilities necessary for telescopes expedient operation.
3. Provision for public viewing of the telescope by means of a visitors' gallery.

Specific Areas or Equipment

1. Dome:
 - a. Rotational assembly and drive.
 - b. Slot opening assembly and drive.
 - c. Wind shutter assembly and drive.
 - d. Control console for the above.
2. 60" Reflector Telescope:
 - a. Telescope assembly.
 - b. Mounting assembly.
 - c. Drive system.
 - d. Auxilliary equipment (spectroscope, etc.).
 - e. Control console for the above.
3. Support Equipment:
 - a. Observation platform with vertical movement.

4. Other:

- a. Glass enclosed visitors' gallery.
- b. Misc. storage.

Special Requirements

- 1. Sufficient insulation in exterior walls to reduce solar heating.
- 2. Exterior painted with titanium oxide to reflect solar heat. (See Appendix A.)
- 3. Efficient control of visitors to eliminate any possibility of damage to equipment.
- 4. Location of SPACE A in an area on the site where heat or light from other buildings will ^{not} destroy the observing conditions. (See Appendix A.)

Capacity

Staff	-	3
Visitors	-	20 - 25

Floor Area

2,000 Sq. Ft.

Special Consideration

- 1. SPACE A should be raised above grade far enough to avoid air turbulence occurring at ground level. This turbulence would be detrimental to good observing conditions. (1 : 11)

SPACE A1 - OBSERVATIONAL SUPPORT

Functions

1. Provide Dark Rooms for immediate development of photographic plates. (See Appendix A.)
2. Provide photographic plate storage.
3. Provide office space for astronomers utilizing the telescope.

Specific Areas

<u>Space</u>	<u>Sq. Ft.</u>	<u>Capacity</u>
2-Dark Rooms at 40 sq. ft.	80	2
Workspace and Chem. Storage	100	2
Refrig. Photo. Plate Storage	50	
2-Offices at 80 sq. ft.	160	2
Rest Room	50	

Total Floor Area

525 Sq. Ft.

SPACE B - SCHMIDT TELESCOPE AREA

Functions

1. House 36" Schmidt Telescope and provide for its:
 - a. Stability.
 - b. Operational mobility.
 - c. Operational utility.
 - d. Safety.
2. Inclusion of equipment and facilities necessary for telescopes' expedient operation.

Specific Areas or Equipment

1. Dome:
 - a. Rotational assembly and drive.
 - b. Slot opening assembly and drive.
 - c. Wind shutter assembly and drive.
 - d. Control console for the above.
2. 36" Schmidt Telescope:
 - a. Telescope assembly.
 - b. Mounting assembly.
 - c. Drive system.
 - d. Auxilliary photographic equipment.
 - e. Control console for the above.
3. Other:
 - a. Misc. storage.

Special Requirements

1. Sufficient insulation in exterior walls to reduce

solar heating.

2. Exterior painted with titanium oxide to reflect solar heat. (See Appendix A.)

3. Location of SPACE B in an area on the site where heat or light from other buildings will not destroy the observing conditions. (See Appendix A.)

Capacity

Staff	-	2
Visitors	-	0

Floor Area

1300 Sq. Ft.

Special Consideration

1. SPACE B should be raised above grade far enough to avoid air turbulence occurring at ground level. This turbulence would be detrimental to good observing conditions. (1 : 11)

SPACE B1 - OBSERVATIONAL SUPPORT

Functions

1. Provide Dark Room for immediate development of photographic plates. (See Appendix A.)
2. Provide photographic plate storage.
3. Provide office space for astronomers utilizing the telescope.

Specific Areas

<u>Space</u>	<u>Sq. Ft.</u>	<u>Capacity</u>
Dark Room at 40 sq. ft.	40	1
Workspace and Chem. Storage	50	1
Refrig. Photo. Plate Storage	50	
Office	80	1
Rest Room	50	

Total Floor Area

325 Sq. Ft.

SPACE C - RESEARCH

Functions

1. To assist astronomers in briefly evaluating their current research data.

Specific Areas

<u>Space</u>	<u>Sq. Ft.</u>	<u>Capacity</u>
Computing Area	175	2 - 3
Lab. Area	200	3 - 4
Library (Stack and Reading)	400	4 - 6
2-Rest Rooms at 75 sq. ft.	150	

Total Floor Area

1000 Sq. Ft.

Special Requirements

1. SPACE C should be located in close relational vicinity of SPACES A, A1, B, B1, and D.

SPACE D - ADMINISTRATION

Functions

1. The housing of site administrative facility.
2. Provision of small staff conference area.
3. Provision of reception area.

Specific Areas

<u>Space</u>	<u>Sq. Ft.</u>	<u>Capacity</u>
Office - Site Superintendent	175	1
Office - Asst. Site Superintendent	125	1
Office - Clerical	100	1
Conference/Reception Area	200	15
2-Rest Rooms at 50 sq. ft.	100	

Total Floor Area

750 Sq. Ft.

SPACE E - MAINTENANCE

Functions

1. Provision of minor maintenance facility for instruments.
2. Provide space for fire protection equipment.
(See Appendix A.)
3. Provide vehicle storage.
4. Provision of buildings and grounds facility.
5. Provision of mechanical facility - heating, etc.

Specific Areas

<u>Space</u>	<u>Sq. Ft.</u>	<u>Capacity</u>
Instrument and Optical Maint.	1000	4 - 5
Vehicle Storage (4 vehicles)	800	
Buildings and Grounds Area	200	2
Fire Protection Equip. Area	200	
Mechanical (heat, aux. power, etc.)	750	

Total Floor Area

3000 Sq. Ft.

Special Requirements

1. Locate SPACE E at a distant enough location from observational facilities to insure that heat convection from Mech. Area will not disrupt observational conditions. (See Appendix A.)

SPACE F - HOUSING

Functions

1. Provision of permanent and temporary housing facilities for permanent site staff, rotating staff and visitors. (See Appendix A.)

Specific Areas

<u>Space</u>	<u>Sq. Ft.</u>	<u>Capacity</u>
Type 1 (Single Residence)		
1-Site Supt. - 3 B.R.	1500	4 - 6
1-Asst. Site Supt. - 2 B.R.	1000	2 - 4
Type 2 (Apartments - Permanent Staff)		
2-Maint. - 2 B.R., at 500 sq. ft.	1000	2 - 4
2-Bldg. and Grounds - 2 B.R., at 400 sq. ft.	800	2 - 4
Type 3 (Dormitory - rooms)		
9-Rooms, temp. staff, at 80 sq. ft.	720	9
3-Rooms, visitors, at 100 sq. ft.	300	3
Restrooms w/showers, Lounge Area and Circulation	780	

Total Floor Area

6500 Sq. Ft.

Special Requirements

1. Type 3 Housing should be located in an area, and built in a manner, conducive to daytime sleep.

SPACE G - DINING

Functions

1. To provide day and night dining (cafeteria) facilities for all personnel on site requiring its use.

Specific Areas

<u>Space</u>	<u>Sq. Ft.</u>	<u>Capacity</u>
Dining Area - capacity of 25 x 15 sq. ft. per person	375	25
Kitchen, Serving Area and Storage	200	2
2-Rest Rooms at 50 sq. ft.	100	

Total Floor Area

750 Sq. Ft.

Special Requirements

1. SPACE G should be located in proximity of all operational facilities - a centralized location.

SPACE H - ASSEMBLY

Functions

1. To provide a meeting area for classes, special lectures and motion picture showings.
2. Area to function as a meeting area for both the staff and visitors.

Specific Areas

<u>Space</u>	<u>Sq. Ft.</u>	<u>Capacity</u>
Hall - 50 person cap. x 8 sq. ft.		
per person	400	50
Storage and Circulation	100	
2-Rest Rooms at 150 sq. ft.	300	

Total Floor Area

800 Sq. Ft.

Special Requirements

1. Provide projection area and speaker's platform.
2. Locate SPACE H in proximity to both public and operations areas.

SPACE I - MUSEUM

Functions

1. Provide facilities for photographic, diagramatic, small instrument, or model displays.

Specific Areas

<u>Space Area</u>	<u>Sq. Ft.</u>	<u>Capacity</u>
Exhibit Area	1000	20 - 25
Circulation and Storage	200	
2-Rest Rooms at 100 sq. ft.	200	

Total Floor Area

1500 Sq. Ft.

Special Requirements

1. Exhibit Area must have abundant blank wall space for posting exhibits.
2. SPACE I must be located in an area of the site which will not cause interference with technical operations.
3. SPACE I should be located in proximity of Assembly and Administrative areas.

SUMMARY - TOTAL ESTIMATED FLOOR AREAS

<u>Area</u>	<u>Sq. Ft.</u>
SPACE A	2,000
SPACE A1	525
SPACE B	1,300
SPACE B1	325
SPACE C	1,000
SPACE D	750
SPACE E	3,000
SPACE F	
Type 1	2,600
Type 2	2,000
Type 3	1,900
SPACE G	750
SPACE H	800
SPACE I	1,500
TOTAL ESTIMATED FLOOR AREA	18,450 Sq. Ft.

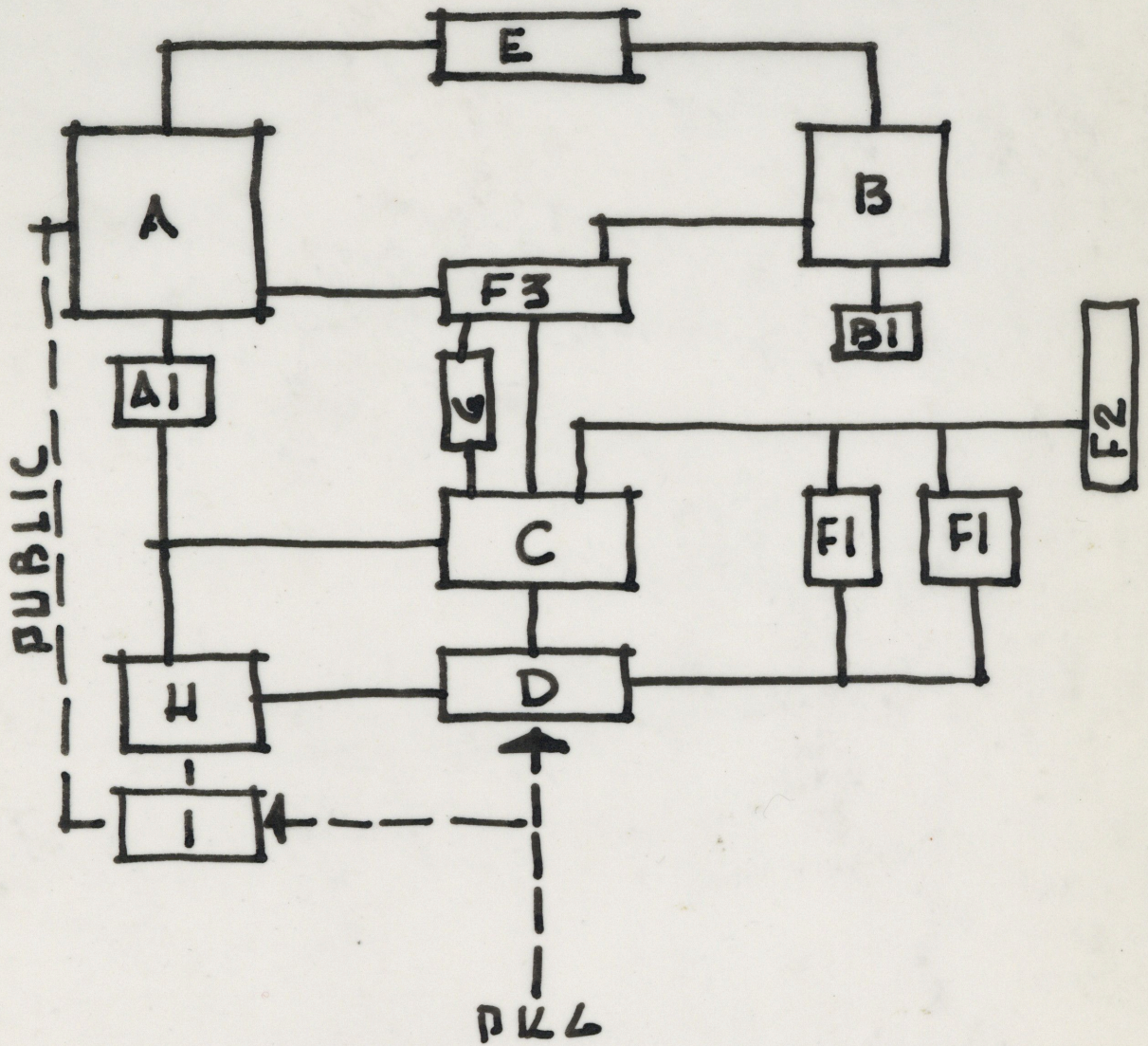


FIGURE 6

AESTHETIC CONSIDERATIONS • 6

Considerations

The observatory is the popular symbol of the science of astronomy. Within astronomy it is "the tool of observation", a necessary constituent of orderly scientific process. The placement of large precision instruments necessarily dictates many of the aspects of its design. These instruments, which are of massive proportion, require operational mobility and rigidly controlled operational conditions.

The needs of the human being who will work and live at the observatory must also be considered. Not only the functional needs of these people must be satisfied, but also their basic aesthetic needs. The designer must also extend his consideration to the layman who will visit the site and to those living in the surrounding area. Nearby communities will look upon the observatory as a point of civic pride.

The aesthetic intention of this design is necessarily very ambitious. Ours is the "Space Age" and the observatory deals with man's investigation of space. It is my hope that this aspiration be expressed in the design of the complex.

An environment should be created which is conducive to the order and precision which are prerequisite to scientific investigation. Further, the design should reflect the dignity of the learned men who will work in the observatory, and the dignity of science, itself.

The serenity of the be^autiful, forested Sandia Mountains and the clear blue of the New Mexican sky presents a challenge to the designer. The observatory should complement rather than disrupt this quiet beauty.

The employment of the abundant indigenous materials, such as stone and timber, offers further opportunity to complement the locale.

My foremost intention in this design shall be to establish a coherent interrelationship between the observatory's technical instrumentation, the lofty aspirations of the science of astronomy, and the observatory's Sandia Mountain locale.

ECONOMICS • H

Costs

The following cost data was obtained from the Marshall Valuation Service, Calculator Method, (except where noted), on the basis of square foot cost. The costs are averages of final costs and include architect's fee and contractor's overhead and profit.

<u>SPACE</u>	<u>SQ. FT.</u>	<u>COST/SQ. FT.</u>	<u>COST</u>
A	2,000	\$100 (See App. A)	\$200,000
Al	525	25	13,125
B	1,300	100 (See App. A)	130,000
Bl	325	25	8,125
C	1,000	21	21,000
D	750	12.5	9,375
E	3,000	9	27,000
F			
- Type 1	2,600	13	34,800
- Type 2	2,000	12.5	25,000
- Type 3	1,900	10	19,000
G	750	14	10,500
H	800	14	11,200
I	<u>1,500</u>	13	<u>19,500</u>
<u>TOTAL AREA 18,450 Sq. Ft.</u>		<u>TOTAL EST. COST</u>	<u>\$528,625</u>

$$\text{AVERAGE COST/SQ. FT.} = \$528,625/18,450 = \underline{\underline{\$28.50/\text{sq. ft.}}}$$

COST OF 60" REFLECTOR TELESCOPE (See App. B)	\$500,000
COST OF 36" SCHMIDT TELESCOPE (See App. B)	250,000
COST OF LAND	0 ¹
SITE IMPROVEMENT COST	- ²
TOTAL	<u>\$750,000</u>
TOTAL ESTIMATED BUILDING COST	<u>528,625</u>
INITIAL TOTAL ESTIMATED COST OF OBSERVATORY	<u>\$1,278,625</u>

1. Mr. Earl Welton, Recreation and Lands Staff, Regional Office, Gallatin National Forest, informed me that there would be no fee for the use of this land. The fee exemption applies to any Federal, State, or non-profit (scientific) organization utilizing the land under the provisions of the Special Use Permit.

2. The cost of site improvement will be unknown until the preliminary design phase.

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APPENDIX • J

APPENDIX A

Contents

1. Sample Questionnaire - sent to 13 observatories.
2. Letter from Dr. Menzel, Director, Harvard College Observatory.

Note

1. Of the 13 questionnaires originally mailed to observatories, only a few have been returned to me. None of those returned were completed in a conclusive or satisfactory manner. Therefore, they are not significant for purposes of this thesis. It is my hope that I will receive letters or completed questionnaires, in the near future, that are of the same quality as Dr. Menzel's letter. The Director of Lick Observatory recently informed me that "^{we}they~~are~~ are working on the information that ^{you}~~I~~ requested". Any additional information that I receive will be inclosed in addendum if it is pertinent.

C O P Y

HARVARD COLLEGE OBSERVATORY

Cambridge 38, Massachusetts

February 27, 1963

Mr. Eugene K. Baker
520 South Willson
Bozeman, Montana

Dear Mr. Baker:

I am sorry to have delayed so long in reply to your letter of January 27, but I have been in South America and there was no one available to reply to your questionnaire. I am very much interested in your project and wish that I could be of more help. I've built several observatories, but unfortunately these plans are no longer available. Of course you are probably referring to a general observatory and not a specific type of observatory, such as the one that I built in New Mexico, at Sacramento Peak, where solar observations are made. At any rate, I am trying to reply responsively to your question. Your request is somewhat ambiguous. I am not sure whether you are asking for suggestions about a purely hypothetical observatory or something related to our own observatory. In Cambridge we have a very unusual situation, involving an association of Harvard and Smithsonian Astrophysical Observatories, with approximately 500 people in all on the combined staffs. We have a large teaching institution. We have several subordinate observatories located at different places in the world. And the structure is so complex that I would find it almost impossible to describe it to you. Moreover I would think that it would not be too useful.

An observatory such as you suggest might preferably be similar to the one at Kitt Peak, although perhaps somewhat smaller, since Kitt Peak is a truly national observatory. Hence, I shall reply to the questions in your questionnaire in terms of this hypothetical observatory with a hypothetical director. In this sense, I find it extremely difficult to answer a good many of your questions, which seem more related to knowing the structure of our observatory here. However, one usually has an observatory on a mountain top, connected with some observatory on the campus of some nearby university, or even at some distant university. It is generally important to keep on the mountain top only the observing members of the staff, and even these may be rotated. Lick Observatory, Mount Hamilton, California, is an exception to the rule. Astronomers both live there and work there and they maintain a full working staff. Sacramento Peak Observatory in

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New Mexico is also an exception, but this is because of the extremely remote conditions and the fact that Sacramento Peak is a very desirable place to live. Most mountain tops are not, on the whole. Usually the organizational structure will consist of a director resident in the university or research institution rather than on the mountain. He will have his own structure consisting perhaps of half a dozen persons of professorial rank located on the university headquarters. A dozen astronomers would be a large group. You can figure about five technicians per astronomer, with a few additional secretaries and staff members, not including the janitorial help. This will give you some sort of an idea as to what a large observatory would be. Few observatories in the United States are any larger than this. Most of them would be smaller. The observatory members would visit the mountain top on occasion, you would have to have a few residences for caretakers and maintenance personnel. You would have to have dormitories. The dormitories probably would be of double variety, one for nighttime observers and one for daytime (solar) observers. Some means must be provided for furnishing the astronomers with meals. Perhaps they cook their own. Some do. I would assume that no astronomer would reside permanently at the site. That there might be 12 or 15, or perhaps 20 maintenance personnel and technicians, three or four clerical, and six or eight persons to provide general services. Do not forget to allow one or two for garbage disposal, fire protection, and so on. Be sure that you have a good water supply and plenty of water pressure. You must make allowance for visiting astronomers from other institutions. These will be slightly more elaborate dormitories, perhaps small apartments available. Some observatories open their facilities to the public. Others do not open them at all. Some have a partial opening, such as having a glassed-in balcony, where the visitors can view the telescope and, on occasion, even see the astronomer at his work. But this is not usual. Of course you must have parking facilities for the cars. A large observatory will probably have a museum, exhibit room, snack bar, public toilets, and so on. I would judge that an observatory of this size would have to have on the order of \$350,000 a year to operate. This does not include the funds for the basic researches of the people who are the supporting observing personnel in the neighboring university.

There are various reasons for scattering the telescopes over the ground. Each building is a potential source of smoke or heat waves and atmospheric disturbances. A heated roof can be a definite hazard to good definitions of the sky. Also, one telescope building could partially obscure the view from another. This is why they tend to scatter them over the observatory grounds. Also there is the question of lights. Heating, cooking, living conditions in general are often detrimental to seeing conditions.

Most commonly, the altitude of an observatory is generally chosen to be high enough over the ground haze and, in particular, to provide good drainage of the cold air from the mountain peak. The idea is to get as stable an atmosphere as possible over the peak. If

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one goes too high, then extra disturbances come in, definitely tied in with the mountain peaks themselves. At very high altitudes the skies are often cloudy. Also at high altitudes, as I myself have found, having built the two highest altitude observatories in the United States, one at Climax, Colorado at 11,500 feet and the other at Sacramento Peak, New Mexico, it is difficult to support the personnel in these higher altitudes. About 10,000 feet the efficiency of a human being d/windles rapidly. The water supply is different for any location and is more or less unique. Where you cannot get the water from the ground, where springs are few, one has to build a catch basin and op/erate on that. You actually may even have to plan for carrying the water at certain times of the year.

For a good observatory, one wants to have no major seasonal cloudiness. For example, a region that is cloudy all w/sinter is poorer than one where the cloudiness has some distribution. You want the relative humidity to be low because some experiments, especially the far infrared, depend on having low humidity for their success. The average precip/itation will vary and the wind velocity, especially at night, should be under 30 miles an hour, preferably under 20. These are not things which are representative of all observatories. I've had to close up at Lick Observatory, for example, when the wind occasionally reached the speed of 50 miles an hour or higher. Occasional storms are useful, not only because they clear the atmosphere, but they also provide the necessary water supply. The telescopes themselves are generally open to the air. We do not try to change the temperature in the building, except to control its heating in the daytime, so that the temperature will be approximately that of the ambient temperature outside. I am not able to give you costs of telescope housings. Would suggest that you write to Kitt Peak National Observatory, making your request there. They have the latest information.

Most telescopes do not employ any air-cleansing system. It would be impossible to do it for most kinds of telescopes. In the case of the coronagraph, however, which requires an extremely clean atmosphere, we do sometimes circulate cleaned air inside the telescope. Your questions about what temperature telescopes function at optimum is meaningless. You might better have paraphrased it as to what indoor temperatures do astronomers function at optimum? Remember that the indoor temperature must be kept equal to the outdoor temperature for most cases, because otherwise the rising or falling air currents would destroy the seeing.

Various methods are used to control the warm air turbulence. Most important of all is painting of the dome with titanium oxide paint, because titanium oxide radiates rapidly and reflects a good deal. This means that it does not get hot, as does aluminum paint.

The kinds of support buildings will depend a great deal upon the kind of operation and the size of the operation at

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the observatory. I think I've described the most of them. Of course you may need maintenance for trucks, storage of fire-control equipment, and similar things. Also, of course, you need specialized darkrooms and storage spaces, including refrigerated spots for plates.

Electric heating is generally the best, though it may be too costly. It is almost necessity for the solar installations, which depend so much on lack of any smoke. Of course there should be electric auxiliary generators available.

The most ideal observational conditions occur in the southwestern part of the United States.

From experience in building on mountain tops, I would say that most laboratory buildings would cost something of the order of \$30 per square foot, and that a dome, say 50 feet in diameter, would cost a couple of hundred thousand dollars. But I'm not really very certain of the cost of domes.

I trust that these off-hand remarks will be of some help to you. I wish you good luck in your work.

Cordially yours,

(signed)
Donald H. Menzel
Director

DHM:gq

APPENDIX B

Contents

1. Letter from J. W. Fecker Division, American Optical Company.

Note

1. This letter was in reply to my question: "Could you possibly supply me with installation, operation, and cost information for a 36" Schmidt and a 60" Reflector?"
2. According to any recent publication, concerned with astronomy and observatories, J.W. Fecker Division seems to be the major supplier and installer of large telescopes in this country.

C O P Y

J. W. FECKER DIVISION

American Optical
Company

4709 Baum Blvd., Pittsburgh 13, Pennsylvania

6 March 1963

Mr. Eugene K. Baker, Jr.
520 S. Willson
Bozeman, Montana

Dear Mr. Baker:

We have none of the specific information you request readily available, and the cost for us to assemble all this information from our various files would be prohibitive.

We suggest you read Kuiper's "Telescope" and Kings, "The History of the Telescope".

As to the costs of the instruments you mention, they would be in the ball park of from \$250,000 to \$500,000.

Very truly yours,

J. W. FECKER DIVISION
AMERICAN OPTICAL COMPANY

(Signed)
M. G. Schwartzmiller
Sales Department

MGS:rb

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