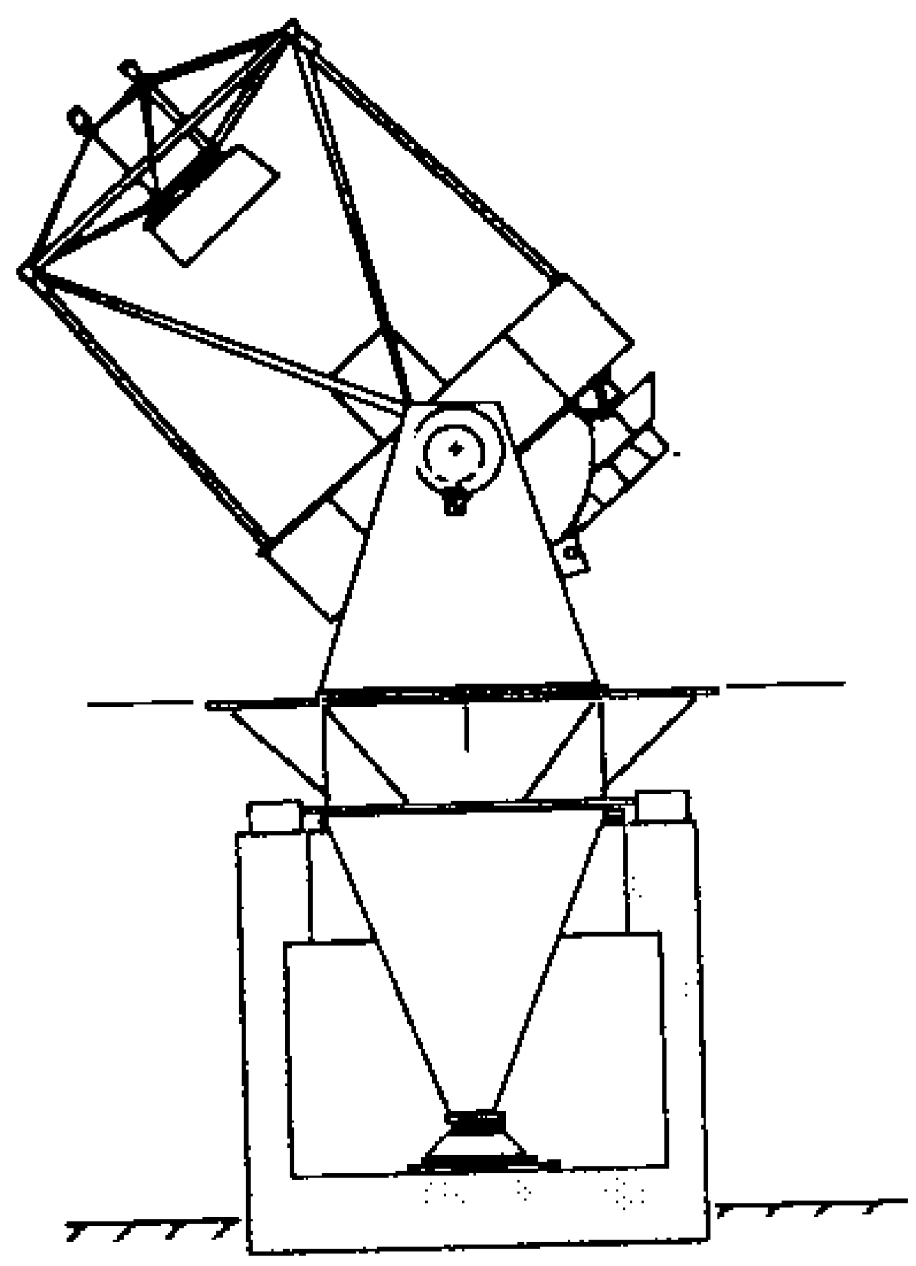
Wisconsin
Indiana
Yale
NOAO



3.5 Meter Telescope

Enclosure & Control Building Requirements for the WIYN 3.5 Meter Telescope

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Date

1. Design goals & Functional requirements

NOAO is joining with the University of Wisconsin, Indiana University and Yale University to build a new 3.5 m telescope on Kitt Peak (hereafter referred to as the WIYN Project or WIYN Observatory). Professional services of an architect/engineer (hereafter referred to as the Architect) are being sought for the design and engineering of an enclosure and attached control building to house both the telescope and associated activities.

The project goal is to build a thermally optimized enclosure that will allow the telescope to take advantage of the good seeing conditions found on Kitt Peak. In addition to providing environmental protection for the telescope, the new buildings will provide space for a control room, instrument labs, and a computer room.

The functional requirements for the two structures are that they:

- Permit the normal operation of the telescope including the ability to observe astronomical objects in all parts of the sky.
- Contain heated work space for the scientists.
- Provide equipment for periodic removal of the telescope mirrors for re-coating.
- Provide equipment for moving scientific equipment between the work areas and for mounting it on the telescope.
- Are easily maintained.
- Be a safe place to work.

It is now widely recognized that waste heat produced around the telescope is largely responsible for much of the image blur seen by older telescopes in traditional enclosures. This heat could come from conditioned spaces in the enclosure, electronic instruments, and mechanical equipment. In addition, the enclosure structure itself produces unwanted heat as it cools during the night. The strategies that shall be employed in the design of the WIYN observatory to deal with this problem are the following:

- Design the telescope enclosure with a low thermal mass and ventilate it well.
- Move heated spaces out of the enclosure into a well insulated control building.
- Insulate the enclosure to prevent heat build-up during the day. Insulate the control building to control heat loss at night.
- Reduce the power consumption of instruments around the telescope and actively cool them whenever possible.
- Trap waste heat and exhaust it away from the enclosure.
- Use surface coatings to control radiation losses and gains.

The enclosure concept design described in the following sections was developed by the WIYN project team to meet these design goals and functional requirements. The drawings that accompany this description show the general layout and space requirements. It shall be the Architect's responsibility to take this concept and develop the appropriate construction documents to achieve these design goals.

2. Site Information

The WIYN Project will be located at Kitt Peak on a developed site subleased from the National Science Foundation. The observatory is 55 miles from the downtown Tucson offices of NOAO on paved state highway. A number of other telescopes belonging to NOAO and various universities are also operated on the mountain. While the site is not subject to local zoning or building codes, all design shall be in conformance with nationally recognized codes (ie. UBC, UPC, OSHA, etc.).

A smaller, existing telescope and enclosure will be removed by NOAO to make way for the new observatory. Water, power, sewer and telephone service already exist at the site. The architect shall be responsible for determining whether these services are adequate for the WIYN observatory based on site information provided by NOAO. A plan for upgrading utility service to the site is not part of the basic Architect contact but may be covered by an extension if current service is inadequate. The architect shall have responsibility for designing all building utility connections to the Kitt Peak infrastructure.

The WIYN site is at 6836' elevation and is subject to high winds, snow, hail, heavy rainfall and lightning. The following specifications shall be incorporated into the design of the enclosure.

<u>Operating conditions</u>:

Shutters and ventilation windows	open
Peak wind gusts	60 mph
Temperature	5°F to 100°F
Humidity	98% non-condensing

<u>Survival conditions</u>:

Shutters and ventilation windows	closed
Peak wind gusts	120 mph
Snow load	24 inches
Earthquake	UBC Zone 2

Operating conditions shall apply when the enclosure shutters and windows are open and the dome is rotating to track the telescope. Survival conditions describe the worst case weather conditions at the site at which time the dome will be parked with the shutters and windows closed.

Due consideration shall also be given to the special construction conditions on Kitt Peak when designing the building. These may include:

- Minimal staging area around the enclosure.
- Remote site.
- Need to minimize the disruption of other mountain activities.
- Water conservation measures.
- No nighttime access or work.

3. Telescope enclosure

3.1 General description

The purpose of the telescope enclosure is to house the 3.5 m telescope and provide space for activities directly associated with the telescope operation. The building concept has three stories with the telescope imbedded in the center of the building and spanning the three floors. The rotating roof (hereafter referred to as "the dome") opens up to allow the telescope to view all parts of the sky.

The enclosure uses steel construction for the walls and supporting structure with the goal of keeping the building weight and thermal time constant low for good thermal performance.

3.2 Telescope Structure (not included in contract)

The 3.5 m telescope is shown in the section views of the enclosure. The telescope uses a two axis mount with the horizontal axis above the vertical axis of the fork assembly. This type of mounting is called an altitude-azimuth, or alt-az, mount with the altitude axis being the horizontal axis.

The major optics of the telescope are mounted in the central tube structure called the Optical Support Structure (OSS). It is supported from the ends of the fork tines by bearings in the OSS. The altitude axis passes through the centers of the bearings. The OSS is free to rotate about the altitude axis through an angle of 90° from the zenith-pointing to horizon-pointing. The fork assembly rotates about the vertical azimuth axis through a maximum range of 540°. The combination of these two motions allow the telescope to view all parts of the sky above the horizon. The arc described by the upper end of the telescope as the OSS rotates about the altitude axis has a radius of about 18' and sets the minimum inside diameter of the enclosure (plus some allowance for safety, ladders, hoists, etc.). The total rotating weight of the telescope is approximately 90,000 lbs. The two axes are encoded and motor driven for remote operation.

The WIYN telescope will be a high performance telescope by traditional standards. The telescope is being designed with maximum slew rates of 5°/second for both axes. The lowest locked-rotor resonant frequencies are specified to be 7 hz minimum. This level of performance will have an impact on the design of the telescope mounting and and the maximum rotation rates of the dome.

Scientific instruments are mounted on the outboard sides of the forks at the level of the altitude axis. A mirror in the center of the OSS directs the beam out through the hollow axles. Instruments will weigh up to about 2,000 lbs. and sizes will vary. The instrument handling equipment provided as part of the enclosure design shall accommodate instruments with footprints of up to 5' x 5'. Larger instruments will be moved with the mirror handling equipment.

The telescope controls and cabling are not included in this contract except that cable ways shall be provided as described in section 5.1.

3.3 Dome

The concept for the WIYN enclosure was adapted from the enclosure design for the proposed Magellan 8 m telescope. The goal is to provide a lightweight, thermally optimized structure using space frame techniques. The shape approximates the traditional hemispherical dome using flat panels for ease of fabrication and low cost.

The dome is projected to have an internal frame of square structural tubing or I-beams to support the skin and shutters. Additional girts and bracing shall be added as necessary. The skin may be fabricated from commercially available insulated panels with a maximum U-value of 0.05. The estimated rotating weight of the dome is 70,000 lbs.

A pair of laterally parting shutters open up during observing to provide a 14' wide slot for viewing. Each shutter will be made up of three joined panels and roll on tracks at their top and bottom ends. The shutters shall be designed for operating wind conditions in the open configuration and survival conditions while closed. The maximum time to open/close shall not exceed 30 seconds.

The dome will rotate on trucks rolling on a circular track. The decision as to whether the trucks will be attached to the dome and the track attached to the stationary building or the other way around will be made during the design development phase. Electric motors and gearboxes shall be provided at two or more places as required to drive the dome.

The shutter opening shall track with the telescope while observing and when the telescope is moved to a new object. The rotation rate may vary from zero to 4°/second with a projected maximum acceleration of 0.75°/second/second. Under operating conditions, the rotation mechanism shall be designed to drive the dome against any additional loads which may be imposed by the wind. Fail-safe brakes shall be incorporated in the design to prevent any and all uncontrolled dome rotation. In addition, safety clips shall be required to prevent the dome from lifting off the rails as a result of strong winds or earthquakes.

The architect shall be responsible for the design of the dome rotation mechanism which shall include but not be limited to the trucks, safety hold-downs, drives, encoder mounts, power and control signal contactors. The architect shall coordinate the selection of drive motors and encoders with the NOAO project control system engineer. The architect shall also be responsible for the design of the shutter mechanism including but not limited to trucks, rails, operating mechanism, hold-downs and brakes.

Seven large remotely operated motorized windows shall be incorporated into the vertical side walls of the dome to provide openings for air to flush the telescope chamber. The actual size and type of window shall be determined in the design development by what is commercially available. Roll-up windows and bi-folding doors have been considered during the conceptual design.

The dome design shall incorporate easily serviceable seals in the following areas to prevent the infiltration of rain and snow:

- Baffle seal at the interface of the stationary building and the dome.
- Baffle and P-seals between the shutter panels.
- Sliding seals around the shutter panels.
- As required for the windows.

Any and all water which may enter the dome in the closed shutters condition shall be caught and directed away from the telescope.

A permanent platform shall be provided for standing and working on the upper shutter track and drive. The platform shall be reached by an enclosed ladder suspended from the inside of the dome. A hatch in the roof will provide access to the top of the shutters. (Details not shown on concept drawings).

A fixed hoist attached to the inside of the dome shall be provided for servicing the primary mirror during removal for re-coating. The dome and hoist shall be designed to safely lift the the mirror and rotate it into position above the hatch in the observing floor for lowering to the ground floor.

3.4 Pier

The architect shall be responsible for designing a mounting base (hereafter referred to as "the pier") for the telescope. The mechanical connection of the telescope to the pier shall be designed by others and the NOAO telescope engineer shall provide the architect with assembly and shop drawings showing how the connection is to be made and the details of any fixtures, plates, etc. which must be incorporated in the pier design. The telescope engineer shall also provide the architect with telescope engineering design criteria necessary for analyzing the pier and laying out the enclosure.

There shall be no rigid connections between the pier and the enclosure that would transmit building vibrations to the telescope other than the connection provided through the mountain itself. The pier shall be anchored to the bedrock of the mountain if a suitable layer of rock exists below the site. If not, the pier shall be designed with sufficient mass to stabilize the telescope. The Architect shall analyze the pier to determine that its stiffness will not compromise the dynamic performance of the telescope.

All signal and power cabling and coolant lines on and off the telescope will pass through the bearing at the base of the fork assembly. The architect's design for the pier shall incorporate conduits necessary for routing cables into the base of the telescope. The number and size of cables and other specifications such as shielding, accessibility, etc. shall be determined by the NOAO project engineer.

3.5 Stationary Section

The lower, stationary, portion of the enclosure surrounds the telescope and pier and provides a base for the dome. The two upper floors shall be supported entirely by the outer walls of the stationary building. (The floors in the enclosure do not rotate with the telescope.) The exterior walls of the stationary building shall be insulated at a minimum to the same U-value as the dome.

The top floor of the building, the observing floor, will provide access to the telescope OSS and instrument area. It shall be reached by an enclosed stairway from the intermediate level. A door at the bottom of the stairway shall prevent air exchange with the lower levels. The area above the floor, the telescope chamber, will be exposed to the outside environment when the shutters are open and is unconditioned. The observing floor shall be insulated and have a low thermal mass and conductivity.

Scientific instruments will be rolled to the telescope across the observing floor and raised into position using a lift platform designed and provided for that purpose. The lift platform shall be level with the floor when fully lowered to allow instruments to be rolled on and off. It shall extend up as required to position the instrument at the level of the altitude axis. The safety of people riding on the lift shall be considered in the design.

The telescope mirrors will also be periodically moved onto the observing floor as described in a section 3.6.

The seam between the telescope and enclosure where the telescope penetrates the observing floor shall be provided with a non-contacting, rotating air seal or baffle whose purpose is to prevent warm air from rising into the telescope chamber from below. The NOAO telescope designer shall be responsible for designing this seal and the architect shall incorporate it into the building design.

The intermediate floor, the mezzanine, is to be used for instrument storage and for working on the telescope azimuth drive.

The ground floor shall have space for equipment storage and a well insulated, conditioned, spectrograph room. Except for the spectrograph room, the two lower floors shall be maintained close to the outside temperature at night by drawing outside air through the enclosure base.

The spectrograph room shall be designed to be light tight with baffles where the instrument cables pass through the walls. The temperature in the room shall be regulated to +/- 2°F. A ventilating system with light tight vents, filters and a fan shall be provided for air exchange with the outside. Exhaust air shall be vented away from the enclosure. The doors into the room shall seal against light leaks and dust.

Instruments and equipment shall be moved between the three levels in an elevator to be provided as part of the enclosure design. The elevator is not intended to carry people. The capacity of the elevator shall be not less than 4000 lbs. with minimum inside dimensions of 5.5' W. x 6' D. x 7' H.. The minimum door size shall be 5.5' W x 7' H. The hole through the observing floor where the elevator penetrates shall automatically seal against air leaks when the elevator is not in use.

A 16' wide door at ground level will provide access for moving equipment in and out of the enclosure.

3.6 Mirror handing

The telescope mirrors are removed approximately once a year for re-coating. The architect shall be responsible for designing the necessary hoists and hatches as required to move the mirrors from the observing floor to the ground floor. It shall be the architect's responsibility to determine that adequate clearances exist within the enclosure for these operations.

The 3.5 m diameter primary mirror of the telescope will be attached to the bottom of the OSS in a cell that separates from the telescope for mirror removal. The estimated weight of the mirror, cart and cell is 18,000 lbs. The mirror alone and its lifting band will weigh approximately 6,000 lbs.. The mirror removal procedure will be as follows:

> A cart (not included in this contract) will roll the mirror and cell out from under the OSS on temporary rails installed on top of the observing floor. The floor shall be designed to carry the live load of the mirror and cell with special attachment points for the rails.
>
> Once out from under the telescope, the mirror will be lifted out of the cell by a hoist fixed to the dome and the dome will be rotated to position the mirror over a hatch in the observing floor. The hatch will

be opened and the mirror lowered onto a truck at the ground level. From there it will be shipped to a nearby building (NIC) for aluminization.

This reverse procedure will be followed to re-install the mirror.

The 1.2 m secondary mirror is mounted at the top of the telescope in its own cell. The combined weight of the secondary and cell is estimated to be 650 lbs. A small jib crane attached to the dome shall be provided to remove the secondary when the telescope is pointed at the horizon. Once out of the telescope, the secondary may be taken to the ground level in the equipment elevator described in section 3.5.

4. Control building

4.1 General description

Conditioned areas for an instrument lab, computer room, and telescope control room shall be provided in a control building attached to the telescope enclosure. The two buildings shall be located at the same level with doorways and passageways wide enough to allow instruments and equipment to be rolled from the enclosure into the instrument lab. Space shall also be provided for a lavatory, storage room, and mechanical equipment room. The space requirements and suggested layout are shown on the conceptual drawing.

Waste heat produced by the control building shall not be released in the vicinity of the telescope or enclosure. The steps that shall be taken to prevent this are the following:

- The building walls and roof shall be insulated.
- Potential air leaks shall be sealed.
- Waste heat from air conditioning and cooling equipment shall be collected and vented away from the enclosure.
- A thermal buffer shall be established between the control building and enclosure.

4.2 Special requirements

The Architect shall incorporate the following special requirements into the design of the control building:

- Cleanliness requirements for the instrument lab, computer room and control room shall be the same as for a clean office environment.
- Anti-static floor coverings shall be provided in the instrument areas.
- Dark shades are required for all windows.

4.3 Mechanical room

The mechanical room will contain the following equipment:

- A water chiller unit (NIC) for the primary mirror thermal control system. This unit will produce approximately 8 KW of waste heat.
- One or more uninterruptible power supplies (UPS, NIC) with a total estimated capacity of 10 KVA.
- Electrical panels, heating and air conditioning equipment as required by the Architect's design.

Effective sound isolation shall be provided between the mechanical room and the control room.

5. Miscellaneous equipment

The following mechanical equipment shall be included in the Architect's design for the WIYN observatory:

5.1 Cable ways

In his design, the Architect shall provide cable ways for signal cables between the various control locations in the observatory. Figure 1 shows schematically the areas that need to be connected. The WIYN project engineer shall determine the number and size of cables to be accommodated and other specifications such as shielding and cable accessibility. Air baffles shall be provided where cables pass from a conditioned to an unconditioned area.

Power cables shall be run in separately from the signal cables in conduit. There shall also be a separate tray for the primary mirror coolant lines.

5.2 Heating and air conditioning

The areas of the observatory that shall be conditioned include the work areas in the control building and the spectrograph room in the enclosure. Separate cooling is required for the computer room.

The air in the spectrograph room shall be conditioned to maintain the temperature in the room as specified in section 3.5. Heat sources in the room will total approximately 1 kw.

5.3 Ventilation Systems

Systems for extracting waste heat from the enclosure and control building shall be provided as part of the Architect's design. The affected areas and proposed conceptual designs are described in this section and shown in Figure 2. It shall be the Architect's responsibility to develop these ideas or suggest alternatives for achieving the desired level of thermal control.

5.3.1 Telescope structure

The interior cavities of the telescope mount are open to allow air to be drawn through the structure for improved thermal performance. Make-up air for the system enters through the upper truss of the OSS. The required air flow is about 5000 cfm at 1" SP. Holes in the conical base of the fork assembly allow the air to exit inside the pier. An air seal between the telescope and top of the pier will confine the air in the pier.

The enclosure design shall include an exhaust fan connected to the pier with a flexible duct to pull air through the telescope and out the pier. The exhaust air shall be ducted outside the building where it would then be released away from the enclosure.

5.3.2 Enclosure base

Air will be drawn through the enclosure base to force the inside temperature to follow the air temperature in the telescope chamber. The air pressure in the base will be maintained slightly below the pressure in the telescope chamber to insure a downward flow of air and prevent warm air from escaping upward into the telescope chamber.

Make-up air will enter at the mezzanine level through vents in the observing floor. The number of vents and their locations shall be designed to eliminate warm air pockets under the observing floor. The required air flow is about 6000 cfm at 1/8" SP.

5.3.3 Control building

A system shall be provided for collecting and venting waste heat from the control building. Sources of heat will include:

- Chillers for the primary mirror thermal controls.
- Building air conditioning.
- Uninterruptible power supplies.
- Instrumentation and computers.
- Lighting.

In the conceptual design for the control building, waste heat is collected in the mechanical room by locating heat producing equipment and A/C compressors in that room. The air in the room is vented out through the wall into a duct that carries it well away from the telescope enclosure.

5.4 Electrical power

The Architect shall be responsible for designing the electrical system at the observatory including the service location and size of panels and conduits. The required number and type of circuits shall be determined from the building loads plus the additional equipment specified for installation in the project.

Two grades of electrical service shall be provided at the observatory. The mountain power is commercial electrical power backed up by Kitt Peak emergency generators (NIC). UPS power will be provided at the WIYN site by one or more uninterruptible power supplies fed by mountain power. Both types of service shall be made available in the instrument areas of the control building and enclosure. The NOAO project engineer shall designate those areas that will require UPS power. The two types of service shall be distinguished by color coded outlets. All areas of the enclosure and control building shall receive mountain power including, for example, inside the telescope pier.

5.5 Plumbing

The control building shall have a lavatory and sink with hot and cold water. A utility sink shall be provided in the unconditioned area leading into the enclosure.

5.6 Lighting

Three levels of lighting are defined although not all areas will require all three:

- Low level safety lights to light passage ways.
- Intermediate level lighting with intensity controls for "dark-adapted" work.
- High intensity lighting for reading and instrument work.

The NOAO project engineer shall specify the lighting requirements for the different areas.

5.7 Lightning protection

A building structure lightning protection system shall be required.

Fast acting lightening and surge protection shall be provided on the mountain power coming into the observatory.

6. Key design areas

In the judgment of the project staff, these are the key design areas that will determine the overall success of the project. Special emphasis shall be given to these areas in the Architect selection evaluation and during the enclosure design.

6.1 Dome rotation and shutter mechanisms

It has been NOAO's experience that most of the mechanical problems in a telescope enclosure are associated with the rotation and shutter mechanisms. The lightweight design and fast rotation rates expected for the WIYN dome make it imperative that these mechanisms work well, reliably and safely.

6.2 Telescope Pier

Wind shake of the telescope structure will be a major factor tending to blur the image. A stiff mount is being designed to get the telescope resonant frequencies above those typically excited by wind turbulence. A soft pier for the telescope would effectively defeat this purpose.

6.3 Thermal design

A successful thermal design will depend not only on controlling heat produced in the enclosure but on understanding the way the enclosure interacts with its exterior environment. Water tunnel tests have been conducted to study flow around a variety of enclosure shapes before settling on the current design. Other areas to consider are the effects of the surrounding ground cover and parking lots. The Architect shall be expected to consult with the NOAO project engineers to gain an understanding of the issues involved before proceeding with the observatory design.

6.4 Mirror and instrument handling

The optics of the telescope represent the major investment in project time and cost and must be protected from damage during handling. The structured geometry of the WIYN primary mirror makes it more susceptible to damage than a conventional solid mirror. Safe lifting equipment and procedures for maneuvering the mirror out of the telescope are mandatory.

Scientific instruments are also large and delicate pieces of equipment that rival other parts of the telescope in cost. The same attention to design for instrument handling shall be required as for the telescope optics.

6.5 Safety

Working around any piece of moving equipment such as a telescope or dome involves certain hazards that must be dealt with in the design of the work place. When that work must be performed at night in a dark environment and/or on elevated platforms, the hazards are increased. Measures to insure the safety of workers shall be required as part of the enclosure design and the final design shall be required to pass a safety review conducted by the Architect and NOAO.

6.6 Maintenance and operations

The long-term success of the observatory will depend in part on how easy it is to operate and maintain. Members of the NOAO operations staff shall be part of the design review process and their suggestions shall be given due consideration.

The Architect shall provide a manual detailing preventive/periodic maintenance requirements and procedures for NOAO staff usage.

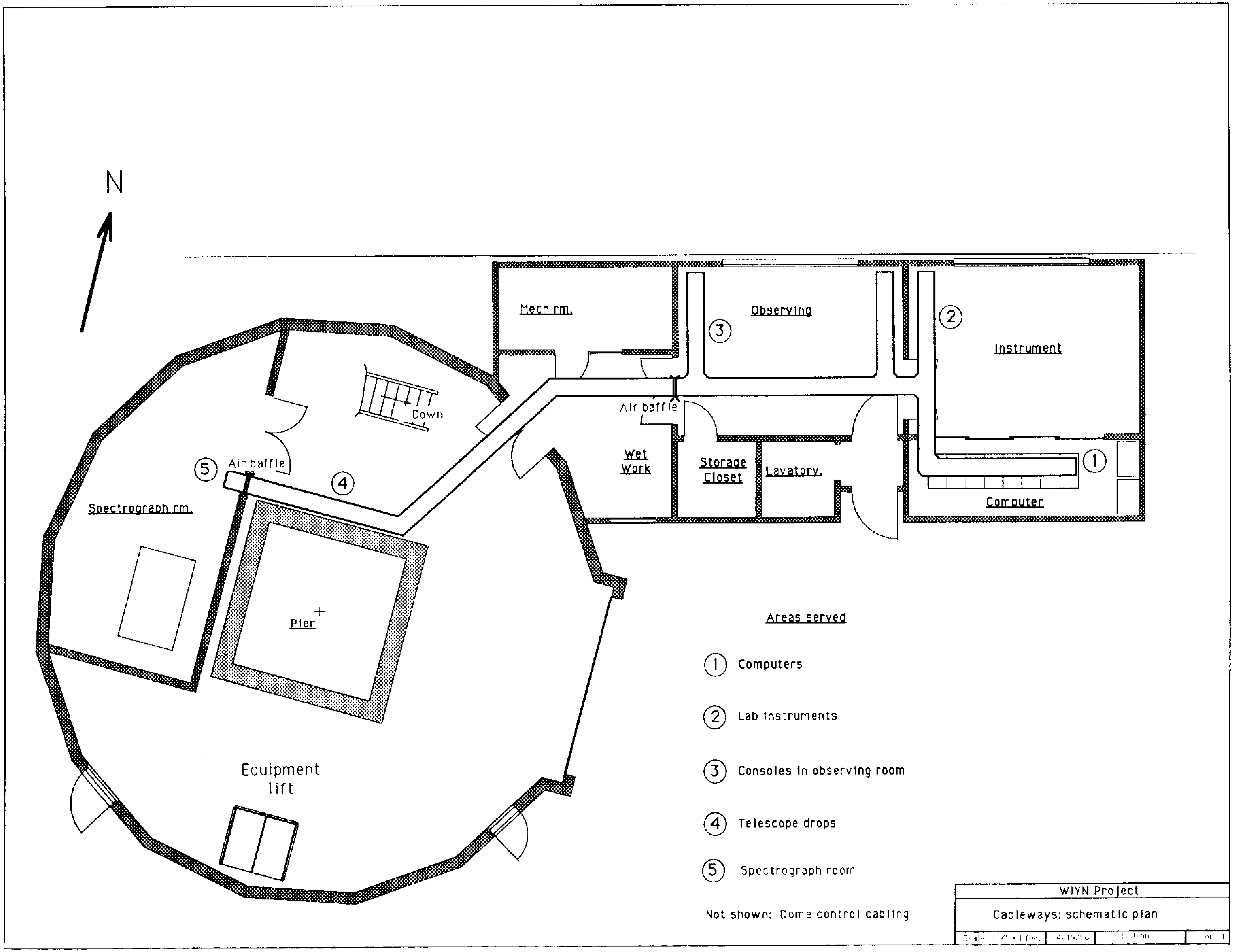
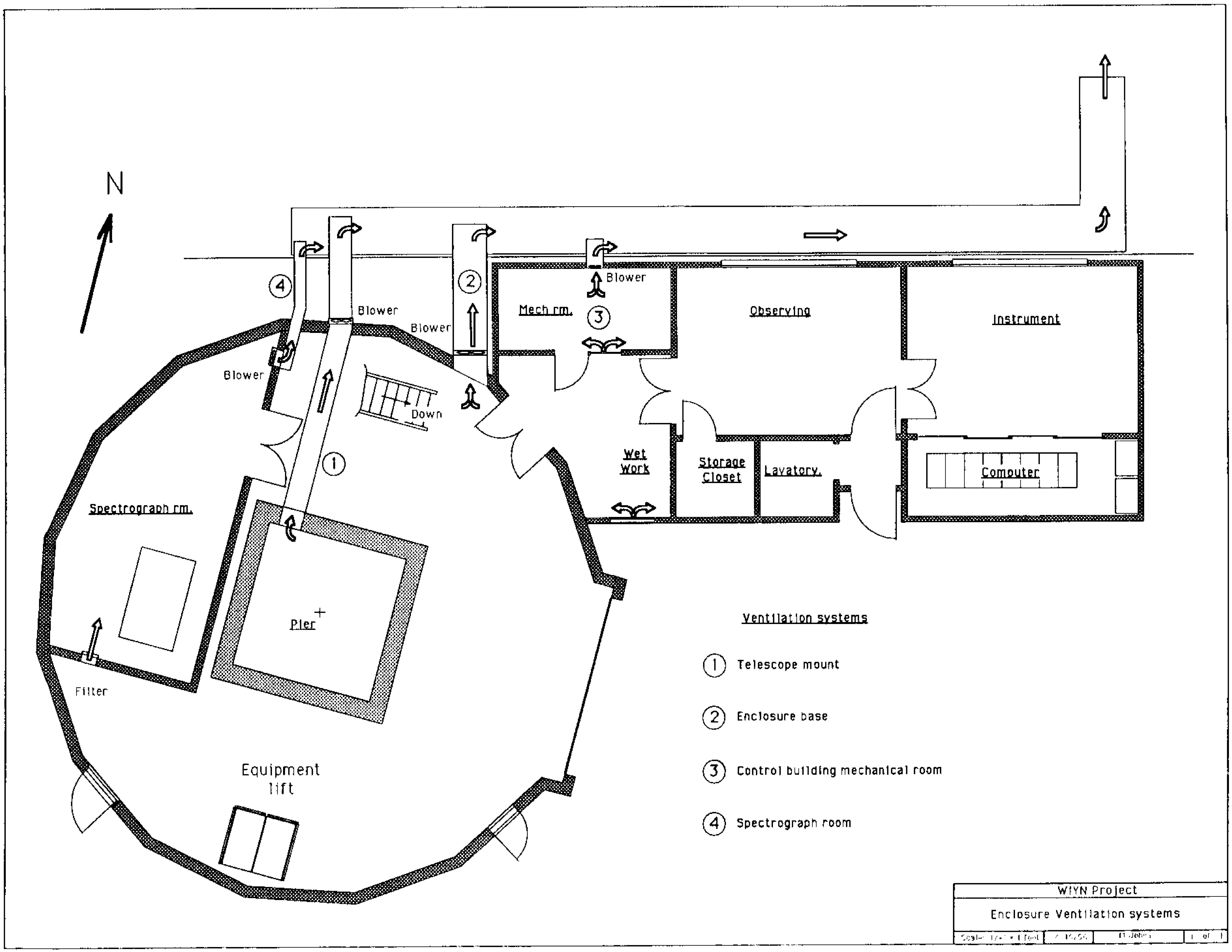

N
Mech rm.
Observing
Instrument
Air baffle
Down
Wet
Work
Storage
Closet
Lavatory.
Computer
Spectrograph rm.
Pier
Equipment
lift
Areas served
1 Computers
2 Lab instruments
3 Consoles in observing room
4 Telescope drops
5 Spectrograph room
Not shown: Dome control cabling
WIYN Project
Cableways: schematic plan

FIGURE 1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Blower
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Mech rm.
Observing
Instrument
Wet Work
Storage Closet
Lavatory.
Computer
Down
Spectrograph rm.
Pier
Filter
Equipment lift
Ventilation systems
1 Telescope mount
2 Enclosure base
3 Control building mechanical room
4 Spectrograph room
WIYN Project
Enclosure Ventilation systems

FIGURE 2