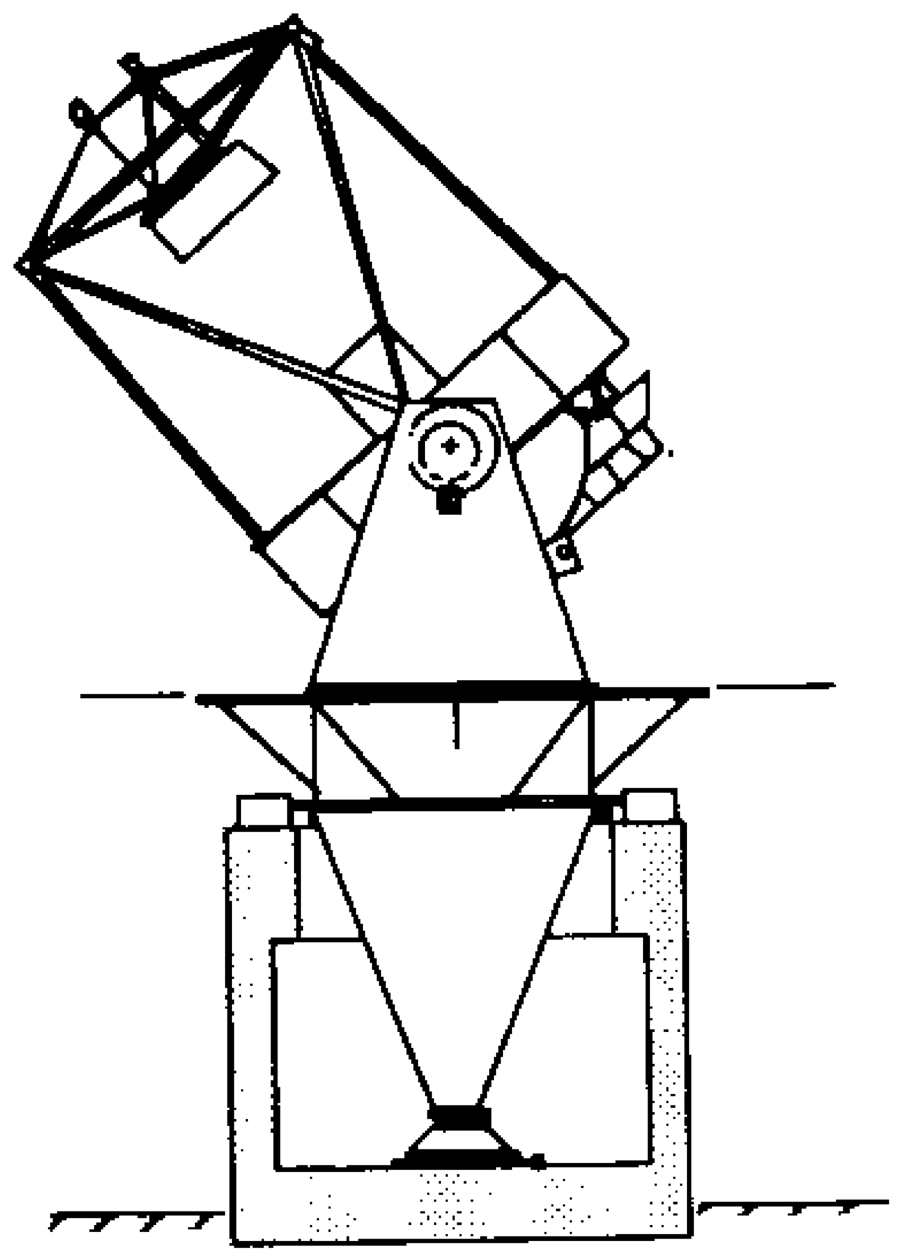
Wisconsin
Indiana
Yale
Noao



3.5 Meter Telescope

Instrument Adapter Subsystem Design Requirements for the WIYN 3.5 Meter Telescope

WODC 01-18-09

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Instrument Adapter Subsystem Design Requirements

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Instrument Adapter Subsystem Design Requirements

1. Purpose & Scope

This document defines the design requirements for the Instrument Adapter Subsystem (IAS).

2. General Description

The IAS provides many of the common functions (acquisition, guiding, etc.) required for observing by most instruments on the WIYN port. It provides the general control necessary for the Telescope Control System (TCS) to:

Acquire an observation field.
Acquire guide stars on the edge of the observation field.
Guide on these stars.
Derotate the image.
Focus the telescope.
Provide instrument calibration.
Measure wavefront aberrations.
Compensate for atmospheric dispersion.

The IAS consists of an instrument mounting box with calibration sources, IAS Motor Control electronics box (IASMC), and Instrument Adapter Computer with Image Processing (IACIP). The mounting box is shown schematically in figures 1, 2, and 3. The electrical block diagram is shown in figure 4.

The instrument mounting box mounts on the Nasmyth Instrument Rotator (NIR) and provides a rigid mounting surface for Science Instruments. The instrument mounting box contains the following components:

Two ICCD cameras on x-y stages for field acquisition, guiding, field derotation and focus.
Wavefront sensor for active optics.
Integrating sphere and associated optics for calibration sources.
Atmospheric dispersion compensator/corrector (ADC).
Dark slide. (Not shown.)

The ADC consists of a pair of doublet lens-prisms (lensms) that will be rotated relative to each other and relative to the parallactic angle to provide a variable amount of spectral dispersion to compensate for dispersion in the atmosphere. The prisms will have correction to extend the 15 arcminute usable field of the bare Ritchey-Chretien optics to 30 arcminutes. The ADC assembly will be mounted on a stage for insertion in the optical beam and will be removable for programs that don't require its capabilities.

A set of emission line and continuum sources will be provided for wavelength calibration of science instruments (spectrometers, etc.). An integrating sphere with multiple ports and associated optics will relay the calibration light to the focal plane. A motorized and encoded filter holder will reside at the output of the integrating sphere that can be inserted into the beam to control intensity and wavelength. A mirror will be inserted into the beam to direct calibration light onto the focal plane.

The wavefront sensor will be used to measure the quality of the image delivered by the telescope optics. The wavefront phase map information derived from the senor will be used by the telescope active optics system to adjust the figure of the primary mirror and collimate the secondary. The sensor will consist of a probe and integrating camera mounted below the ADC. A mirror mounted on the calibration mirror slide will moved into the beam directing star light to the wavefront camera. Light going to the science instrument will be interrupted during a wavefront measurement. For normal observing, a single measurement will be taken before the start of an observation.

The raw wavefront sensor image will be sent to the Primary Mirror Computer (PMC) for the phase map calculation and adjustment of the primary mirror supports.

Guiding will involve tracking corrections applied to both mount axes and the instrument rotator. Two probes with ICCD cameras will provide the star images necessary for detecting pointing and field rotation errors. The probes will be mounted on x-y stages that cover approximately half of the useable field. Either stage may be moved to the center of the field to view the on-axis image for field acquisition. For guiding the probes will be positioned in the annulus around the edge of the field , leaving the center of the beam unobscured for science instrument observations. One stage will contain optics for measuring focus.

The IASMC will contain:

- Motion controls for both X-Y stages.
- Filter wheel controls.
- Focus adjustment controls.
- Slide position controls.
- Calibration component controls.
- Camera gain controls.

The IACIP will contain:

- Instrument Adapter Computer.
- Video Multiplexer for multiple inputs.
- Frame grabbers, frame buffers, image processors for image acquisition and statistics.
- Video output multiplexer and drivers for the video display.
- Interfaces to the control system and the Primary Mirror Computer.

3. Interfaces

3.1 Nasmyth Instrument Rotator (NIR)

The WIYN port NIR has a bolt pattern defined in figure 5 for mounting the Instrument mounting box. Cable connections coming from the telescope will be connected directly to the instrument mounting box. Cables are draped to the instrument mounting box through a cable chain and allow ± 180 degree rotation of the rotator. No part of the instrument mounting box will protrude across the plane of its mounting surface except for alignment pins.

3.2 Telescope Optical Design

The telescope optical configuration is defined in *Science & Technical Requirements*,WODC 00-01 and is repeated here for reference.

Back focal distance:	127 +/-0.6 mm, nominal.
Plate Scale:	9.36 arcseconds/mm.
Minimum IAS clear aperture:	245mm dia. about optical axis.

With ADC:	
Corrected Field of View:	30 arcminutes.
Field Curvature:	Infinite (plano).
Linear field:	192mm.
Nominal wavelength range:	0.35-1.1 microns.
Without ADC:	
Uncorrected Field of View:	15 arcminutes.
Field Curvature:	2.11m.
Linear field:	96mm.

3.3 Science Instrument Mechanical Interface

Science instruments will be mounted on the instrument mounting box. Bolt circle is shown in figure 6. Except for alignment pins, no part of either box shall extend across the plane of its mounting surface. Utility cables will drape across the NIR bearing to the fork tine. The science instrument focal plane will be placed at the back focal distance defined in section 3.2. Science Instrument specifications:

Maximum instrument weight:	600 kg.
Maximum cantilever moment from IAS surface:	2500 N-m.
Maximum science instrument envelope:	2.0m Dia. x 2.0m L.
Maximum imbalance about optical axis:	30 N-m.

3.4 IAS Control

The motion control electronics box mounted on the instrument mounting box will communicate with the IACIP by an RS485 link, receiving commands for the motion controllers, sending guide probe positions and status. Video from the Acquisition/Guide and Guide/Focus cameras will be RS170 and will be fed directly to the image processor input multiplexer.

The IACIP will calculate the centroids of star positions on the guide probes and send the probe and star centroid position information to the TCS. The TCS takes the position data and calculates tracking corrections for the azimuth, elevation, and NIR servo systems.

Two images of a star are formed on the guide/focus camera. The two images are used to calculate the best focus position which is sent to the TCS to control the telescope secondary.

The TCS provides commands and receives data from the IACIP necessary to control telescope guiding and tracking over the observatory ethernet LAN. The protocol used for commands and transmission of engineering data will be TCP/IP. For complete control system interface specifications to the IAS, refer to WODC 01-20.

3.5 Primary Mirror Computer

Raw images from the wavefront camera are acquired by the IACIP and transferred to the PMC by a TBD method. Wavefront phase maps and error matrices are calculated by the PMC using techniques outlined in the following papers: "*Guide-Alignment Figure Sensor*", F. Forbes and N. Roddier, presented at the AAS Meeting, January 1991 and more recently, "*Wavefront Curvature Tests of the KPNO 2.1-m Telescope*", Fred F. Forbes, Nicolas Roddier, and Ron Probst. Images will be sent on demand to the engineering data system for archiving and display.

4. IAS Mechanical

4.1 Configuration

Refer to figure 7 which schematically shows the IAS mounted on the telescope with the cable drape.

4.2 Size and Weight

Instrument mounting box specifications:

Maximum IAS weight:	400 kg.
Maximum cantilever moment from NIR surface:	500 N-m.
Maximum imbalance about the optical axis:	120 N-m including cables.
Maximum IAS envelope:	1.5m Dia. x.381m L.

4.3 Structural Requirements

The instrument mounting box will be designed for minimum deflection and hysteresis.

5. Acquisition/Guide Requirements

[G]

Guide stars will be chosen at the edge of the field, leaving the central 15 arcseconds unvignetted. Each guide probe will be able to access half of the 30 arcminute field.

The probability of finding at least 1 guide star of a given visual magnitude for three different galactic latitudes is shown in figure 8. The camera system performance is summarized as:

Minimum detectable magnitude:	21st magnitude stars in 10 sec w/ dark sky.
Minimum guide magnitude:	16th magnitude stars.
Field of view:	1.5 arcminute.
Sensitivity:	Centroid to 10% seeing disk at mv=16 & 1 Hz.
Dimensional stability:	0.1 arcsecond RMS.

5.1 Acquisition Probe

The pick-off element for the acquisition/guide camera will be a flat mirror 38 mm by 54 mm mounted on a 45 degree inclined plane, suspended and protruding into the field of view to project the image of a "guide" star onto the intensified camera.

5.2 Acquisition/Guide Cameras

The acquisition and guide cameras will be uncooled ICCDs. The cameras must have maximum sensitivity, seeing about 21st magnitude. A suitable camera has been developed at KPNO, however, other cameras are under consideration. These cameras will have standard RS170 output.

5.3 Camera Filter Mechanism

The planned acquisition/guide and guide/focus cameras will have light intensifier tubes that can be permanently damaged by exposure to excessive light. A filter slide or filter wheel shall be provided for color filters and neutral density filters to attenuate the light from bright stars used for guiding. The filter holder will contain 6 filter positions:

Position 1:	open.
Position 2:	red.
Position 3:	blue.
Position 4:	ND2.
Position 5:	ND4.
Position 6:	unassigned.

Filters shall be a standard size TBD, mounted in a filter slide or filter wheel in order of increasing density. It will take a maximum of 10 seconds to change filters.

5.4 Camera Focus

[G]

Curvature of the image plane and the difficulty in making all filters and configurations parfocal will require focus adjustment of the acquisition/guide camera. The camera focus will be remotely adjusted by moving the camera mount with a small step motor. This motion will not be encoded, however, position will be available in steps from last position.

Total travel:	6 mm.
Minimum position accuracy:	63 micron.

5.5 X-Y Stage

The acquisition/guide camera will require an X-Y stage to access the guide field. Both X and Y axes will be motorized and encoded to ensure the following motions. The stage and probe will be completely removeable from the 30 arcminute field.

Minimum position accuracy in X and Y:	10 micron or .1 arcseconds.
Repeatability:	5 micron.
Encoder resolution:	2.5 micron.
Maximum travel time to traverse the field:	10 seconds.
Minimum field coverage:	half of the 30 arcminute field of view.
Position stability:	5 micron [G].

6. Guide/Focus Requirements

The guide/focus system will provide error signals for the calculation of tracking corrections and focus information to the secondary mirror.

6.1 Probe Assembly

The goal of the focus probe is to detect focus changes in accordance with the *Science & Technical Requirements*, WODC 00-01. Two designs are currently under consideration.

6.2 Camera

Guide/focus camera requirements are the same as described in section 5.2.

6.3 Filter

Filter requirements for the guide/focus camera are the same as described in section 5.3.

6.4 Focus Stage

Focus stage requirements for the guide/focus camera are the same as described in section 5.4.

6.5 X-Y Stage

X-Y stage requirements for the guide/focus camera are the same as described in section 5.5.

7. Wavefront Sensing

The wavefront sensor provides information describing deformations in the wavefront caused by seeing effects and optical imperfections. By using an integrating camera and integrating for ≥30 seconds, seeing effects are minimized leaving contributions due to the optical system. Phase and force maps are generated from the wavefront information and used to adjust the optical system collimation and figure.

7.1 Wavefront Probe Assembly

The goal of the wavefront probe is to detect wavefront changes in accordance with the *Science & Technical Requirements*,WODC 00-01. Two designs are currently under consideration. One uses the wavefront curvature sensing techniques outlined in, "*Adaptive optics using curvature sensing*", F. Forbes and N. Roddier,NOAO and, "*Wavefront Curvature Tests of the KPNO 2.1-m Telescope*", Fred F. Forbes, Nicolas Roddier, and Ron Probst.

The second design uses the Shack-Hartman techniques as referenced in TBD.

7.2 Shutter

The shutter will be electrically operated and controlled by the IAS. The shutter will have:

Minimum exposure:	<0.1 seconds.
Maximum exposure:	Continuous.
Maximum power to hold open:	2.5 watts.

7.3 Camera

The wavefront camera will be:

- Commercially available.
- Thermo-electric cooled.
- Integrating, bare CCD.
- Have control electronics with digital output.

Must interface to the IACIP.

The integrating camera currently in use at KPNO for wavefront curvature sensing is a Photometrics Star 1 camera system with the following specifications:

CCD pixels size:	23 x 23 microns.
CCD Format:	384 x 576, full-frame CCD.
Camera head weight:	2.5 pounds.
Camera head size:	11.4 cm Dia. x 9.84 cm L.
Power dissipated:	TBD watts.
Shutter response:	minimum 0.04 secs.

7.4 Camera Control Electronics

The camera control electronics will be located TBD. The IACIP will communicate with the camera controller via a standard TBD interface providing remote control of all functions. Camera controller will be able to control the camera integration times and shutter exposure times, digitize the slow scan CCD video, store and transmit the output video.

Minimum required integration time:	0.05 seconds.
Power dissipated:	150 watts.

8. Atmospheric Dispersion Compensator/Corrector

8.1 Optical Design

The ADC optical design has been described in *System Definition and Configuration*, WODC 01-01, figure 3.

8.2 Mounting and Control Requirements

The two paired ADC lensms will be mounted so that they can rotate independently without restriction in both directions. Each lensm will be rotated by a step motor and encoded by counting steps from an index position. Specifications:

Repeatability	TBD arcminute
Maximum time to position:	10 seconds.
Step resolution:	1000 steps / revolution.
Index position	TBD

8.3 ADC Slide Stage

The ADC assembly will be mounted on a slide so that it can be removed from the telescope optical beam. This motion will be manual with limit switches at the ends of travel.

9. Calibration Source

Various spectral line and continuum calibration sources will be available to illuminate the calibration integrating sphere. The individual sources will be TBD. (Suggested sources are bright and dim continuum, Thorium-Argon, Helium-Argon-Neon, and Mercury-Cadmium.) These sources will provide wavelength calibration for science instruments mounted on the IAS.

The calibration sources will be mounted such that any combination of sources can illuminate the integrating sphere. Light from the calibration sources may be piped to the integrating sphere from a remote location by optical fiber or mounted on the instrument mounting box if enough light is not available. A sliding stage moving a calibration mirror and condensing lens in and out of the beam, will direct the integrating sphere calibration light to the center of the instrument focal plane illuminating a small field uniformly, diameter of 5 acrminutes. The light will pass through a filter wheel that is motorized and encoded and capable of holding TBD filters. The sliding stage will be motorized with limit switches at the ends of travel and designed for minimum flexure.

10. Image Processor

The IAS computer and image processor, IACIP, will be responsible for control of the IAS camera positions, calibration lamps, ADC rotation, filter positions, camera focus positions, gathering star centroid position information, image acquisition and task processing. This information will be sent to the TCS for secondary control, telescope guiding control, and rotator control.

A summary of minimum requirements follow:

- Multiplexed input, able to receive inputs from 4 analog cameras and 1 digital wavefront camera.
- Real time digitizer to at least 8 bits.
- Coadding capability with word depth sufficient to maintain accuracy.
- Leaky memory algorithm.
- Centroid on objects in a subframe.
- Frame subtraction for sky background subtraction.
- Set leak rate and other parameters.
- Output LUT (lookup table) for scaling video.
- 8 bit video output, 7 bit video plus 1 bit for overlay graphics.
- Wavefront camera controller.

11. Thermal Requirements

Heat escaping into the dome from the IAS will be minimized to less than 30 watts by channeling waste heat into the fork tine and venting it with other waste heat away from the building.

12. Electrical

Power, control and data signals from the control computer and power supply will be provided through cables and connectors that connect directly to the instrument mounting box. This cabling will be routed across the WIYN NIR drape to the fork, down inside the telescope structure, through the Azimuth maypole, to the IACIP and power supplies at location A or B (refer to WODC 03-03 for telescope cabling). Power used by the instrument mounting box will be minimized and supply voltages will be standard supply voltages listed below.

± 15 volts	TBD amps
± 5 volts	TBD amps
+24 volts	TBD amps

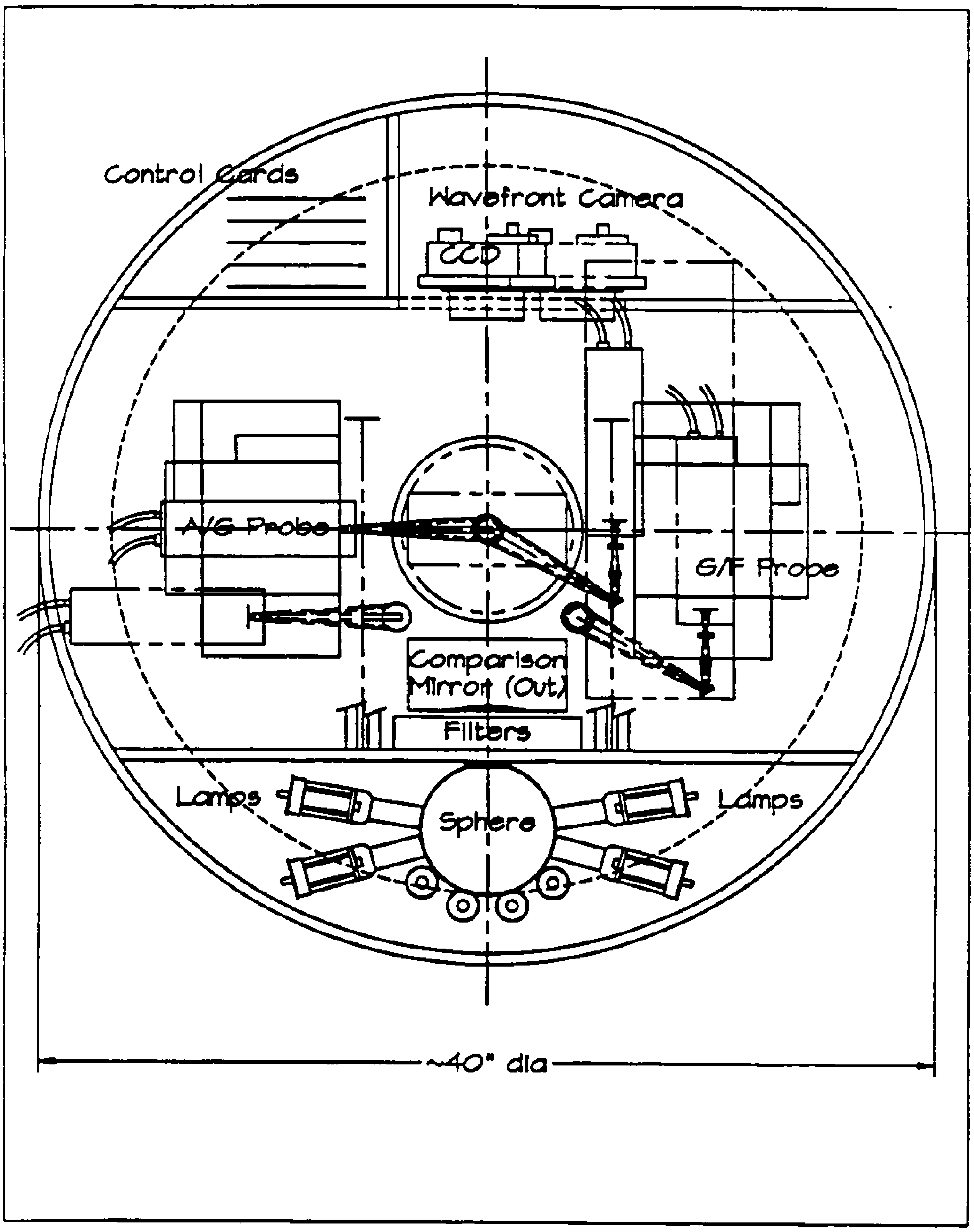
All other supply voltages needed will be derived from the standard supplied voltages, if feasible.

13. Environmental

The Instrument Adapter Subsystem including all its parts will meet specifications under the following operating conditions:

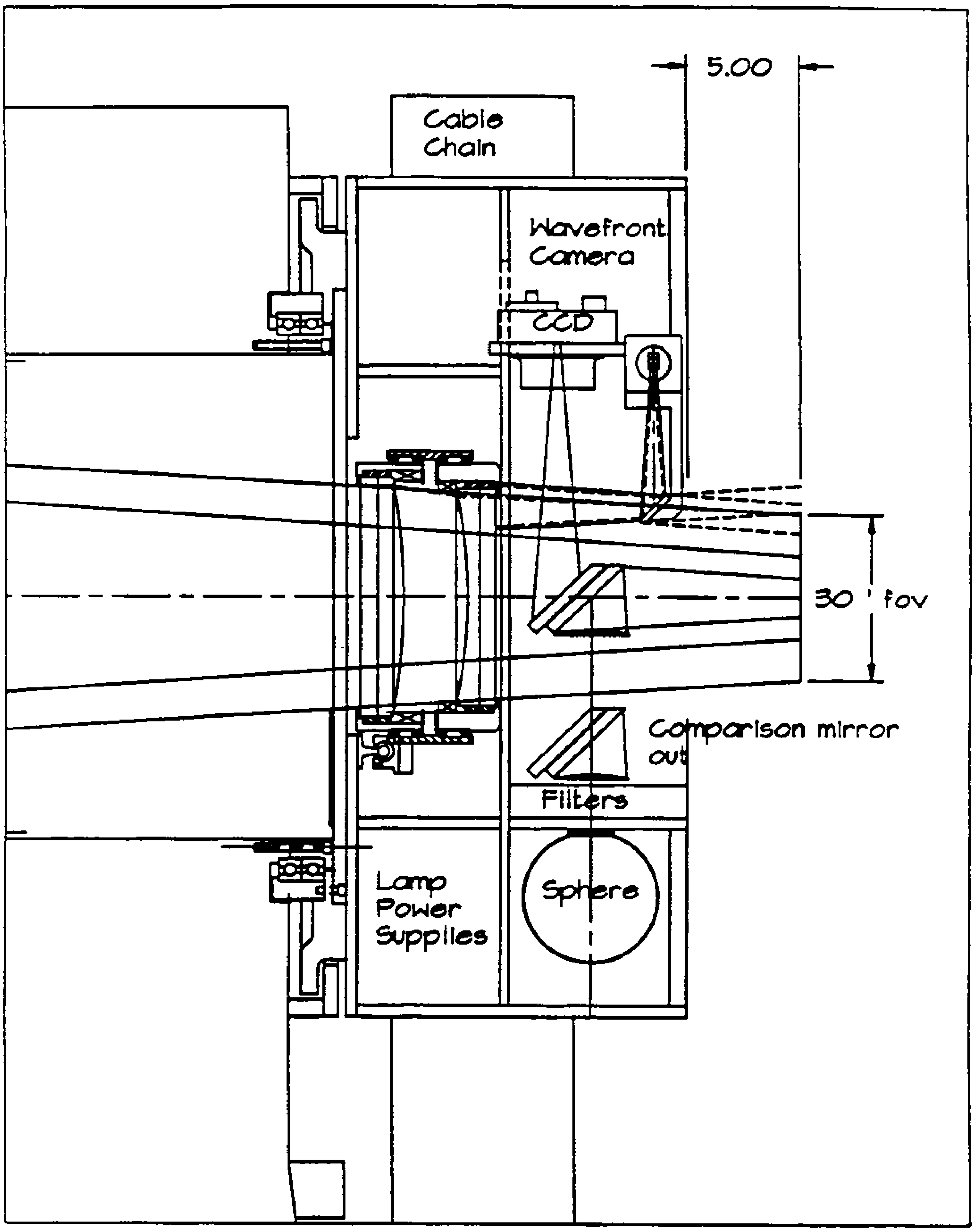
Ambient temperature	0 to 80 degrees F
Humidity	98% non-condensing
Altitude	6838 ft

The IACIP will operate in an enclosed chassis expected to be located on the second floor of the enclosure where the temperature will be higher than ambient. The IASMC will be mounted in the mounting box on the telescope where the temperature of the electronics is expected to be higher than ambient.



Control Cards
Wavefront Camera
CCD
A/G Probe
G/F Probe
Comparison
Mirror (Out)
Filters
Lamps
Sphere
Lamps
~40" dia

FIGURE 1.



5.00
Cable Chain
Wavefront Camera
CCD
30 ' fov
Comparison mirror out
Filters
Lamp Power Supplies
Sphere

FIGURE 2.

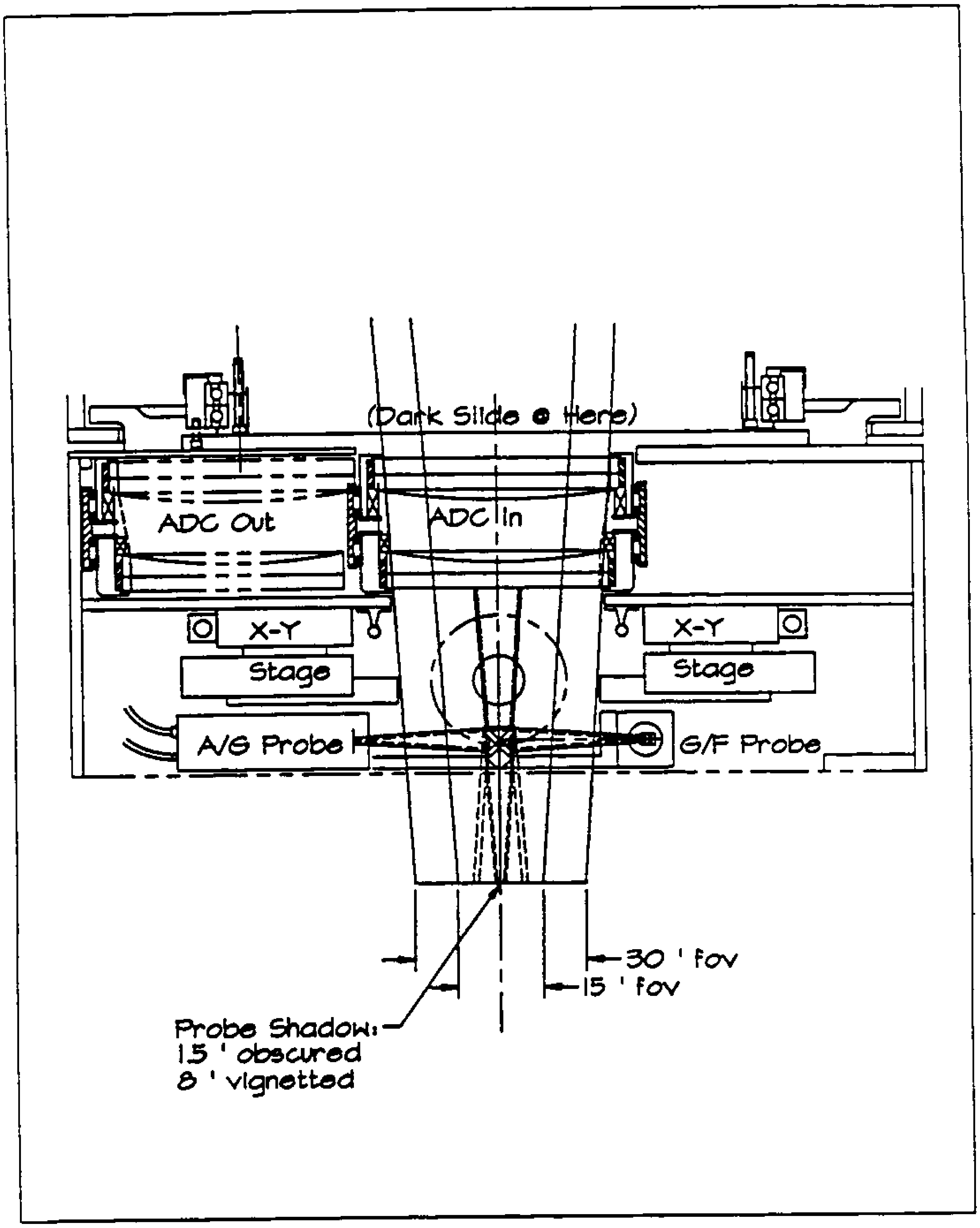
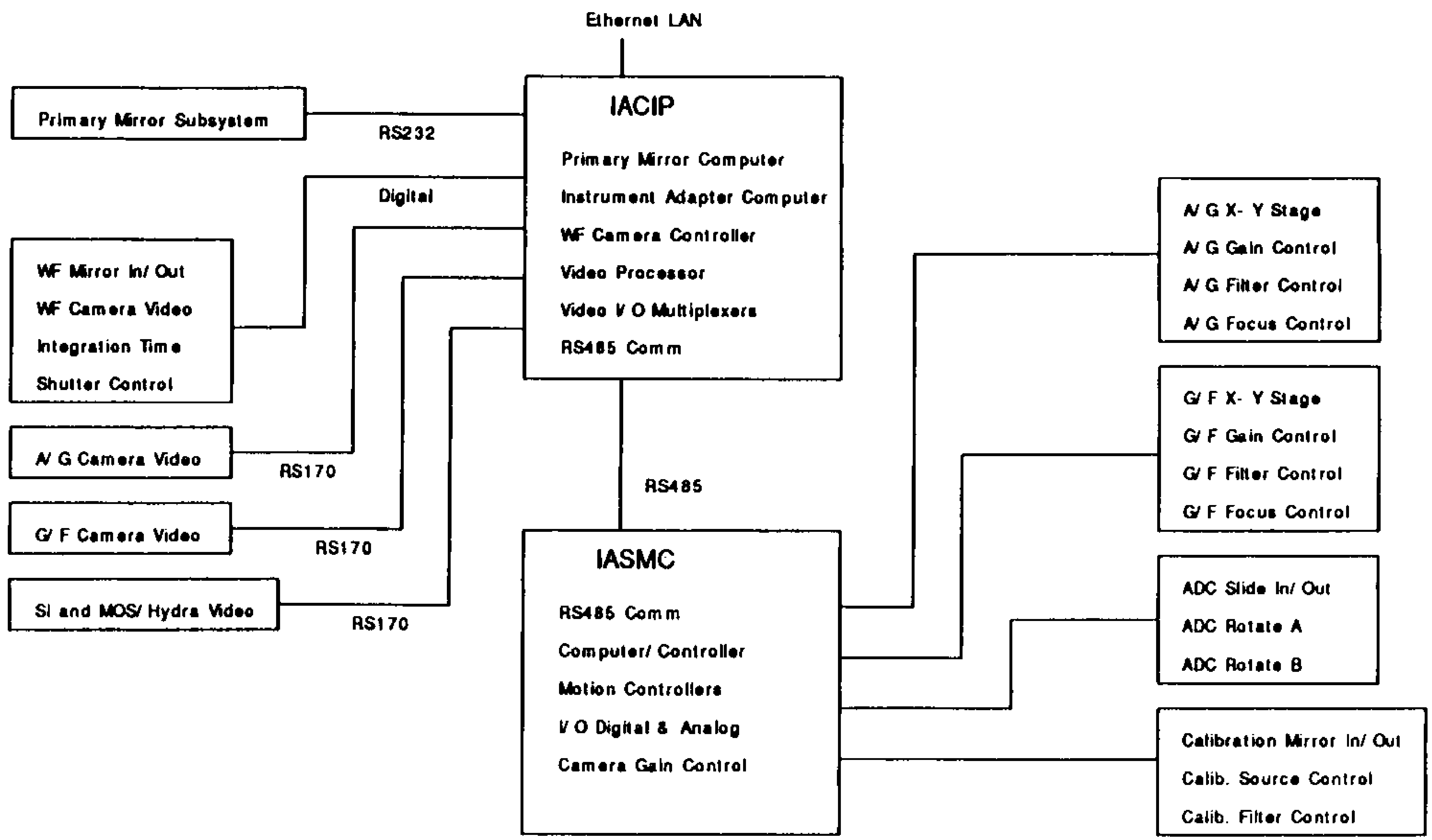
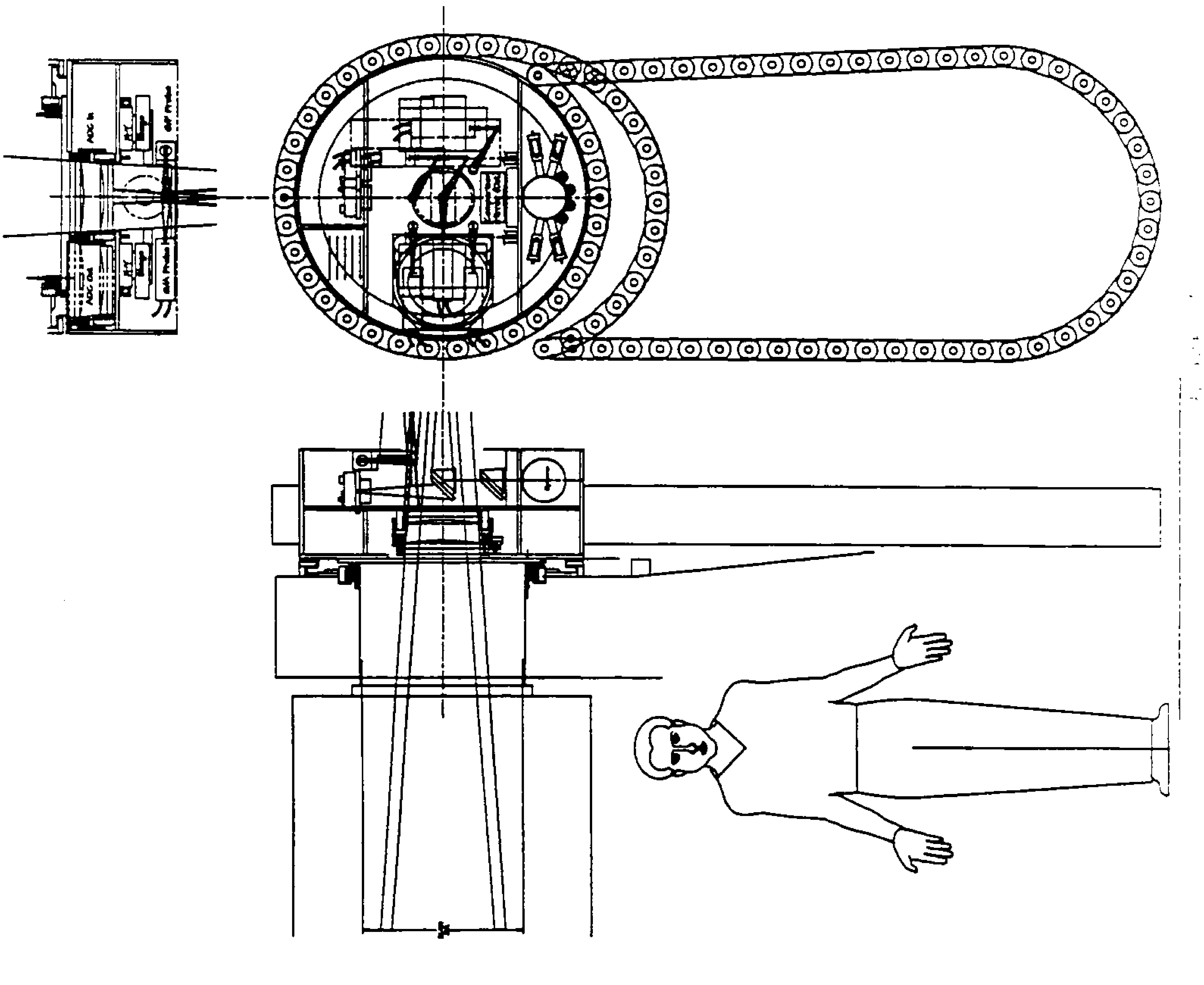

(Dark Slide @ Here)
ADC Out
ADC In
X-Y
Stage
X-Y
Stage
A/G Probe
G/F Probe
30 ' fov
15 ' fov
Probe Shadow:
1.5 ' obscured
8 ' vignetted

FIGURE 3.



IAS Block Diagram

FIGURE 4.



Probability of finding a guide star mv or brighter.

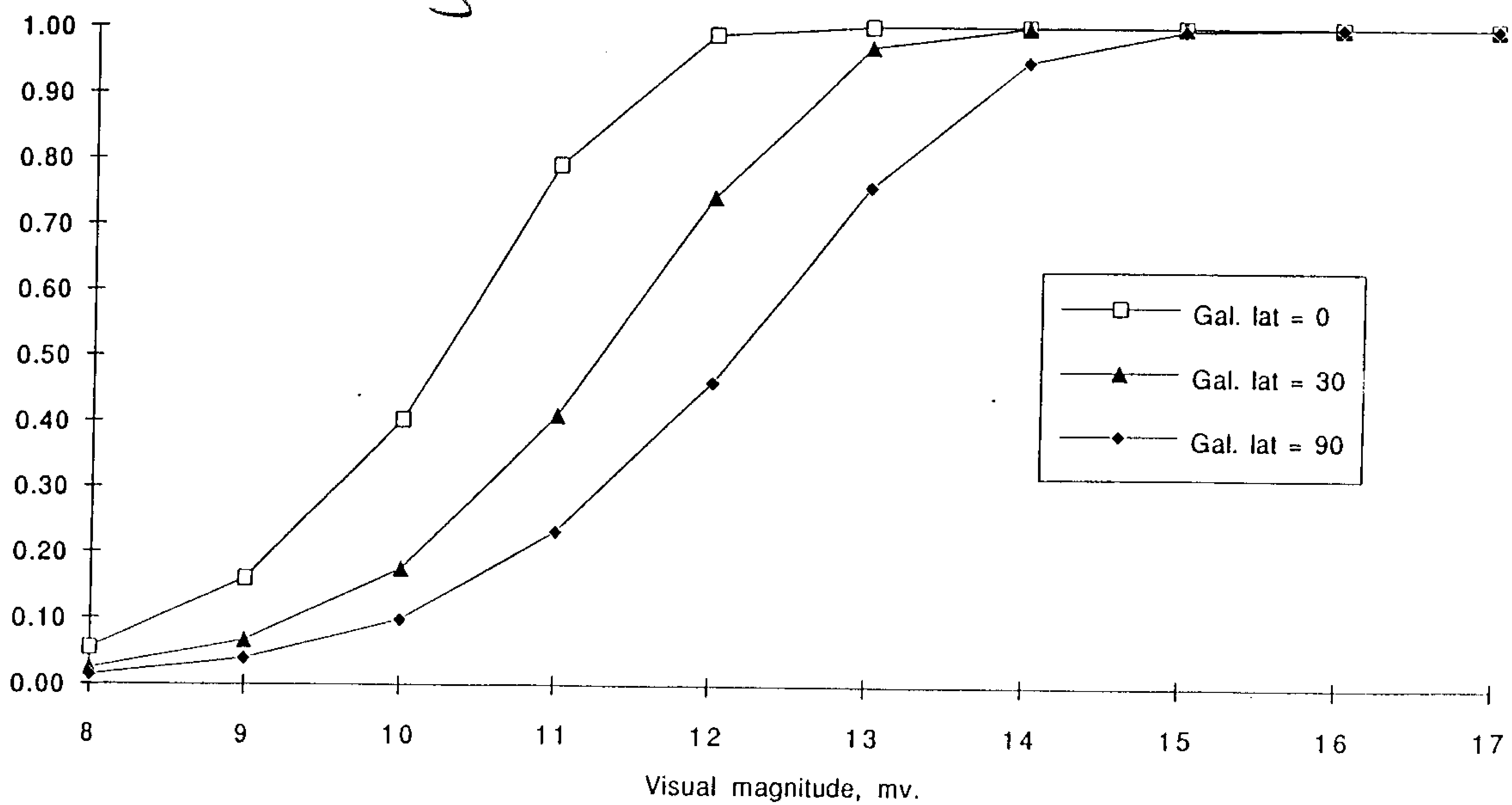


FIGURE 8.