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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.
- Guide and derotate the image.
- Focus the telescope.
- Provide spectral calibration.
- Measure wavefront aberrations.
- Compensate for atmospheric diffraction.

The IAS consists of the interface box, Guide Control Computer (GCC), and remotely located calibration sources.

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

- Two moveable cameras on x-y stages for field acquisition, guiding, field derotation and focus.
- Wavefront sensing camera for active optics.
- Integrating sphere and associated optics for calibration sources.
- Atmospheric dispersion compensator (ADC).
- Dark slide.

These systems are shown schematically in figure TBD.

The ADC consists of a pair of doublet prisms that will be rotated relative to each other to provde 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-Chrétien optics to 30 arcminutes. The ADC assembly will be mounted on a stage for insertion in the optical beam and be removable for programs that don't require its capabilities.

A set of emission line sources will be provided for wavelength calibration of science instruments (spectrometers, etc.). An integrating sphere and associated optics will relay the calibration light to the focal plane.

High intensity calibration sources will be mounted below the observing floor where waste heat can be collected and vented away from the observatory. Fiber optic cables will transmit light to the integrating sphere in the interface box. Low brightness calibration sources will be mounted in the IAS interface box next to the integrating sphere.

The wavefront sensor will be used to measure the quality of the image

delivered by the telescope optics. The information derived from the sensor will be used by the telescope active optics system to adjust the figure of the primary mirror and collimation of the secondary. The sensor will consist of a probe and integrating camera mounted on a translation stage below the ADC. The stage mechanism will allow the probe to be positioned at any point along a radius from the center of the field out to the edge. Rotating the NIR will allow the complete focal surface to be examined. Light going to the science instrument will be interrupted during a wavefront measurements near the center of the field. For normal observing, a single measurement will be taken before the start of an observation. A typical integration time long enough to average out atmospheric seeing would be 30 seconds.

The wavefront sensor image will be sent to the primary mirror controller for the actual reduction.

Because the telescope is alt-az, guiding will involve tracking corrections applied to both the mount axes and the instrument rotator. Two probes with imaging detectors will provide the signals necessary for detecting pointing and field rotation errors. Each probe will be mounted on an x-y stage and cover approximately half of the usable field. Either probe may be moved to the center of the field to view the on-axis image for field acquisition. The probes will be moved to the edge of the field for guiding to leave the center of the beam going to the science instrument unobstructed. One probe will contain optics for measuring focus and provide autofocus capability for the telescope.

The GCC will contain:

- Motion controllers for stages and filter wheels.
- Camera gain controls.
- Frame grabbers and image processing for acquisition/guide.
- Video display drivers for the acquisition/guide images.
- Interfaces to the control system and the primary mirror controller.

3. Interfaces

3.1 Nasmyth Instrument Rotator (NIR) Interface

The WIYN port NIR has a bolt pattern defined in drawing TBD for mounting the IAS or other scientific instrumentation, see figure TBD. Cable connections and heat exhaust hoses for the IAS interface box are mounted on the telescope fork tine near the NIR. Cables and hoses are draped to the interface box allowing for rotation.

3.2 Optical Interface

The optical configuration is defined in *System Definition and Configuration*, WODC 01-01, and is given here for reference. Refer to figure TBD.

Back focal distance	5" (127 +/-.6 mm) nominal
Plate scale:	9.36 arcseconds/mm
Minimum IAS clear aperture	24.5cm diameter about optical axis

With ADC:	
Corrected Field of View	30 arcminutes.
Field curvature:	Infinite (plano).
Nomimal wavelength range:	
Without ADC:	
Corrected fied of view:	15 arcminutes.
Field curvature:	2.11m.

3.3 Science Instrument Interface

Science instruments will be mounted on the IAS. Except for mounting pins nothing will extend beyond the mounting surface. Flexible heat exhaust hose and conductors will drape from connectors on the fork tines to the SI allowing for rotation. The SI will place its focal plane at the BFD defined in section 3.2. The SI will conform to the following maximum weights and moments.

Max instrument weight	600 kg
Max cantilever moment from IAS surface	2500 N-m TBD
Max SI envelope, depth is defined by the moment	2.0m x2.0m
Max total combined imbalance about axis	150 N-m

3.4 Control System Interface

The GCC communicates with the control system over the observatory LAN. The LAN is Ethernet using TCP/IP with remote procedure calls (RPCs). For complete control system interface specifications to the IAS, refer to WODC TBD. Figure TBD schematically illustrates the functional blocks of the IAS and how they may interface to the control system.

The TCS receives error signal information from the IAS describing deviations from expected positions and rates of change. The IAS calculates this information from centroids of star positions on its guide probe and derotation probe. The TCS takes the error data and calculates pointing information for the azimuth and elevation drive servo systems. The IAS also receives the out-of-focus image and an in focus image from the derotation probe. These images are used to calculate the best focus position and generate error signals to control the piston of the secondary.

3.5 Primary Mirror Controller

The Primary Mirror Computer calculates errors in the wavefront images from the wavefront sensor using techniques described in section 7. The IAS transfers these images to the PMC in the TBD format over the observatory LAN.

4. Mechanical

4.1 Configuration

The IAS interface box will be mounted on the WIYN port NIR via a bolt pattern defined in figure TBD. SIs will be mounted on the IAS interface box via a bolt pattern defined in figure TBD. Mounting pins will be provided to

register the proper bolt locations between the IAS interface box and the NIR, and the SI and IAS interface box mounting surfaces. Stainless steel inserts will be used in all threaded mounting holes on the IAS interface box.

4.2 Size and Weight

The NIR will perform to specifications outlined in WODC 00-01 and WODC 01-15 which are expanded here for clarification and convenience. The IAS interface box will conform to the following maximum weights and moments.

Max IAS weight	400 kg
Max cantilever moment from NIR surface	500 N-m
Max imbalance about rotational axis	TBD
Max IAS envelope	1.5m x 1.5m x .381m

4.3 Structure Requirements

The following apply for all load conditions and refer to the IAS/SI mounting surface relative to the elevation axis:

Concentricity	<.0762mm (.003")
Non-perpendicularity	<20 arcseconds
Repeatability	<.1 arcsecond
Maximum deflection	.0127mm

5. Guide/Acquisition

Guide stars will generally be chosen at the edge of the field, leaving the central 15 arcseconds unvignetted. Under certain circumstances it may be acceptable to have the guide probe within the central field.

The probability of finding at least 1 guide star of magnitude mv or brighter to guide off of in three different orientations with respect to the galactic plane is shown in figure TBD. Figures TBD and TBD show the positional uncertainty in arcseconds verses integration time for several different magnitudes. The difference between the figures is in the sky background.

5.1 Pick-Off Probe

The pick-off element for the guide/acquisition camera will be a flat mirror about 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 Camera

The guide/acquisition and the derotation/autofocus cameras will be CCDs with fiber optic coupled light intensifier tubes able to detect faint stars. The light intensified cameras will use neutral density filters to reduce light while viewing bright stars. The two intensified cameras are mounted on a focus stage which is mounted on an X-Y translating stage.

The acquisition/guide camera will have:

Intensified CCD with a fiber optic coupled, light intensifier tube.
RS 170 output at standard frame rates.
Detect, at a minimum, 21st magnitude stars.
Guide, at a minimum, off of 16th magnitude stars.
Greater than 1 arcminute field of view.
Guide at .1 arcsecond.
Resolution to .05 arcseconds.
Centroiding to .05 arcseconds.
Dimensional stability to .1 arcsecond.
CCD pixel size should be approximately 10 to 20 microns.
Minimum number of pixels is 500 x 500.
Camera weight shall not exceed TBD pounds.
Camera size shall not exceed 3h x 4w x 6d inches.
Power dissipation shall not exceed TBD watts.
Gain controls to adjust signal intensities.

5.3 Filter Wheel

The guide/acquisition and guide/autofocus 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 neutral density filters to attenuate the light from bright stars used for guiding. The filter holder will contain 4 positions:

Position 1	open
Position 2	ND3
Position 3	ND6
Position 4	closed

Filters shall be a standard size, mounted in a filter slide or filter wheel in the following order; open, less dense, more dense, and closed. It will take a minimum of TBD seconds to change filters.

5.4 Focus Stage

Curvature of the image plane in the narrow field configuration will require independent focus adjustment of the guide camera when moving it to a new radial position in the field and to adjust for slight changes in the focal plane position. The focus will be adjusted independently of the X-Y motion by moving the camera with a stage. The stage will be motorized and encoded to ensure the following motions.

Total travel	TBD 6 mm
Minimum position accuracy	TBD 5 micron
Minimum repeatability	TBD 10 micron

5.5 X-Y Stage

The guide/acquisition camera will require an X-Y stage to access guide field. The X-Y stage must be rigid between the guide probes and the SI mounting surface. The stages will be completely removeable from the optical beam. The stages will be motorized and encoded to ensure the following motions.

Minimum position accuracy in X and Y	10 micron(.0004") or .1 arcsecs
Repeatability	5 micron
Encoder resolution	2.5 micron
Minimum travel from the optical center	130 mm
Minimum travel time from one edge of the field to the other	10 seconds
Minimum field coverage	225 mm x 130 mm (half of the 30 arcminute

field of view)
Stability in X and Y TBD5 micron[G]
Stability as it is rotated TBD5 micron[G]

6. Guide/Focus

The guide/focus system will provide guide information to be used in derotating the instrument image and focus information used in focusing the telescope. This technique has been used by TBD as referenced in TBD. Total star power will be calculated which is a novel approach to sky seeing monitoring.

6.1 Pick-Off Probe

The pick-off probe consists of beamsplitter and mirror arrangement shown in figure TBD. Star light enters the beamsplitter from the top, reflecting approximately 50% of the light onto the intensifier tube via path d1. The transmitted star light is reflected by a mirrored surface onto the intensifier tube via path d2 which is a little longer optical path than that of the d1. The camera is focused on the d1 image and thus the d2 image is out-of-focus. The images are taken and reduced as described in the paper referred to above. The guide computer determines the guide and focus errors which are sent to the TCS.

6.2 Camera

The requirements for the guide/focus camera are the same as described in section 5.2.

6.3 Filter Wheel

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

6.4 Focus Stage

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

6.5 X-Y Stage

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

7. The Wavefront Sensor

The wavefront camera image will be transferred to the Primary Mirror Computer (PMC) for processing following the 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, as yet unpublished.. The PMC will reduce the image for mirror figure and collimation errors and control the active optics system. The image can be distributed about the observatory, archived, examined, or displayed by the IRAF reduction computer.

7.1 Pick-Off Probe

The pick-off probe consists of two beamsplitters and four prisms arranged as shown in figure TBD. Surfaces A and B are 100% mirrored while surfaces C and D are 50% mirrored. Star light enters the first beamsplitter from the top, reflecting approximately 50% of the light into another prism with mirrored sides which bend the light through a long optical path d1 and back to the CCD. The transmitted star light is reflected by a mirrored surface onto the CCD via path d2 which is a shorter optical path than that of the d1. The camera is focused such that the d1 image and the d2 image are equally out-of-focus on both sides of focus. The image is sent to the PMC for processing, as mentioned above.

The pick-off probe is extended with the camera by the translating stage into the field to acquire a star bright enough to provide images with integrating times typically >30 seconds.

The PMC receives wavefront images from the IAS wavefront sensor and calculates the collimation error and primary mirror wavefront correction coefficients. The collimation errors are used to control the tip/tilt of the secondary. The wavefront correction coefficients are used to drive force actuators on the back of the primary mirror to control its figure. These are done following the 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, as yet unpublished.

The wavefront camera image will be stored on disk in FITs format and accessible by the Primary Mirror Computer (PMC) for processing. Correction forces are calculated in the PMC which determine motion required for the primary mirror necessary to correct for any detected distortion. Collimation information is also calculated and sent to the TCS to control secondary motion. The image can be distributed about the observatory.

7.2 Shutter

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

- Minimum open time of .04 seconds.
- Maximum open time of 5 minutes.
- Shutter mechanism must remain below TBD degrees while in operation.

7.3 Camera

An integrating camera is used to eliminate seeing effects and obtain sufficient signal to noise in the out-of-focus images. The camera used for wavefront sensing will be a cooled CCD camera with the following capabilities:

- Minimum integration time will be 1/25 seconds.
- Maximum integration time will be 5 minutes.
- Detect and use, at a minimum, 9th magnitude stars.
- CCD pixel size should be approximately 10 to 20 microns.
- Minimum number of pixels is 500 x 380.
- Resolution to .05 arcseconds.
- Detector dimensional stability to .1 arcsecond.
* Camera weight shall not exceed TBD pounds.
* Camera size shall not exceed 3h x 4w x 6d inches.
* Power dissipated shall not exceed TBD watts.
* Photometric accuracy will be better than 1% per pixel.

7.4 Camera Control Electronics

Camera control electronics will be able to control the camera integration times and shutter open times.

Integration time will be .04 to 300 seconds.
Shutter exposure will be 1/40 th second to 300 seconds.
* Power dissipated shall not exceed TBD watts.
* Communication with the control system will be via the GCC.
* Cabling for power and signals will snake through the fork tine.
* Located in the TBD. under the observing floor below the skirt.

7.5 X Stage

The wavefront camera will require a translating stage to access a star at the optical axis or at an intermediate radial position. The stage must be rigid between the wavefront sensor and the SI mounting surface. The stage will be completely removeable from the optical beam. The stage will use a step motor and encoding will be done by counting steps from an index sensor position to ensure the following motions.

Minimum position accuracy	1mm(.04") or 10 arcsecs
Repeatability	.1mm
Encoder resolution	.05mm
Minimum travel from the optical center	130 mm
Minimum travel time from one edge of the field to the other	10 seconds[G]
Stability in X and Y	TBD 5 micron[G]
Stability as it is rotated	TBD 5 micron[G]

Stars used for wavefront sensing will generally be on the optical axis, however, it is possible to access stars any where in the field by moving the stage and rotating the NIR.

8. Atmospheric Dispersion Compensator/Corrector

The WIYN port instrument adapter will have a combined atmospheric dispersion compensator and field corrector (ADC/C), shown in figure TBD, that can be inserted or removed from the optical path. The ADC/C corrects for atmospheric dispersion by adjusting the rotation of the two paired elements while flattening the 30 arcminute field of view.

8.1 Optical Design

The ADC/C optical design has been described in *System Definition and Configuration*, WODC 01-01, and discussed in section 3.2 of this document.

8.2 Mounting and Control Requirements

The two paired ADC/C elements, shown in figure TBD, will be mounted so that they can rotate freely without restriction in both directions. The ADC/Cs will be driven by a step motor with encoding done by counting steps from an index position.

Minimum rotation accuracy	5.4 arcminutes
Repeatability	1 arcminute
Step resolution	TBD 200 steps/R 20x
Index position	TBD

8.3 Rotary Stages

The rotating stages will have an absolute encoder or incremental encoder with an index, to define its angular position. The ADC/C maybe stepper motor driven or AC or DC servo motor driven at TBD speed.

speed	TBD
angular resolution	TBD

8.4 Slide/Swing Stages

The ADC/C will be mounted so that it can be removed from the telescope optical beam by swinging or sliding out of the way.

9. Calibration Source

Various spectral line and continuum calibration sources will be available to insert into the IAS calibration integrating sphere.

- bright and dim continuum
- Thorium-Argon
- Helium-Argon-Neon
- Mercury-Cadmium
- etalon

These sources will provide wavelength and field calibration for SIs mounted on the IAS.

The calibration sources will be mounted such that any one source can illuminate an integrating sphere by rotating into place or being manually inserted into place. The light from the sources may be piped to the integrating sphere by optical fiber so that the sources could be remote to the IAS interface box if enough light is available. The output from the integrating sphere will be directed to the center of the instrument focal plane, by a translating stage and mirror, to illuminate a small field uniformly (TBD mm x TBD mm). The mounting will allow for the multiple sources mentioned above.

10. Controller

The IAS controller will control the IAS functions through the following commands, telemetry, and services.

10.1 Commands

measure pointing error/generate pointing map
start/stop autofocus
start/stop autoguide
initialize probe/camera(3)
set probe position(3) position on star
adjust probe position/Manual(3) tweak
set camera guide(n)
select calibration source(n)

calibration source in/out(n)
calibration source on/off(n)
initialize ADC
set ADC
adjust ADC
store camera image(3)
display camera image(3)
open camera shutter(3)
close camera shutter(3)
camera intensifier gain(n)
camera filters(3) neutral density filters + ...
camera focus(3)
remember guide position(n) and filter, focus, gain settings
return to guide position(n) and filter, focus, gain settings

10.2 Telemetry

calibration source on/off
calibration source status(which one? in place? burned out?...)
autoguiding on/off
current pointing errors
autofocus parameters
autofocus on/off
autocollimation on/off
probe status(3)
probe position(3)
camera gain(n)
ADC position(n)
ADC status
selected camera
model parameters(TBD)
camera filter position(n)
camera shutter in/out(n)

10.3 Services

acquire images of guide field(3)
target selection
guide star selection
image manipulation
graphics overlay control
troubleshooting procedures
camera control(3)
stage control(3)
gain control(3)
integration control(n)
filter control(3)
shutter control(3)

11. Image Processor

The IAS image processor will calculate centroids and image intensities of

images collected by the guide cameras to determine locations the best focus condition and send this information to the TCS for secondary control, guiding, and rotator control.

The image handler, i.e. frame collector, must be able to manipulate the image, save the image, provide the image for distribution about the observatory, and provide statistical information on the image, i.e. collimation information and wavefront errors for primary mirror figure control, i.e. centroiding information and position errors from previous frames.

12. Thermal Requirements

Power dissipation into the dome will be limited to 200 watts maximum from all sources. Heat generated in the IAS and SIs will be channeled into the fork tine and vented with other waste heat away from the building. External electronics generating waste heat not vented into the tine, will be limited to less than 10 watts dissipation into the dome environment.

13. Electrical

Power will be provided to the IAS interface box through cables that terminate at the fork tine in a connector. Control signal and date signal cables from the control computers will also terminate at this patch panel. Cabling from the fork tine to the IAS interface box will drape across allowing freedom for the NIR to rotate. Power used by the IAS interface 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.

14. Environmental

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

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