II. SOAR Top-Level Telescope & Facility Requirements

1 Configuraton

The basic design of the SOAR telescope is Ritchey-Chretien at f/16 on an alt-azimuth mount. The principal foci will be at the two Nasmyth locations, requiring three reflections. Both foci will have an instrument rotator and acquisition/guider (A/G) unit. Two different instrument adapter modules will be provided: one will accept the space/mass envelope of a single Gemini instrument, the other will have provisions for mounting up to three less massive instruments in a co-rotating cluster. The telescope will be bilaterally symmetric up to the two instrument rotator flanges, so at some future time the two modules could be mixed or matched to mount e.g. either two Gemini instruments or two co-rotating clusters with up to six smaller instruments.

Switching between foci will be accomplished by rotating the tertiary mirror (M3) to index positions, to feed the beam to the desired Nasmyth focus. The 3-instrument cluster will allow rapid switching between each instrument via a fold mirror (M4) while sharing wavefront sensing, guide, and acquisition functions.

The telescope enclosure will co-track the telescope in azimuth during observations. It will be designed to take best advantage of the expected excellent site and to contribute minimal "dome seeing" consistent with the allowance in the error budget. The enclosure will also shelter the telescope from dust and inclement weather. The telescope facility building will house the equipment needed to operate and maintain the telescope, a control room, and instrument storage and preparation areas.

In the following, [G] means project goal.

2 Other elements

2.1 Provision for Bent Cassegrain Foci [G]

Provision will be made for 2 bent-Cass. foci located on the elevation structure. Provisions include a clear light path to the foci at f/16, provisions for indexing M3 to feed the telescope beam to the foci, and provisions for mounting instrument rotators at the foci. Rotators, guiders, etc will not be provided.

Bent. Cass. payload: 300 kg

2.2 Provision for coaxial laser launch telescope

The enclosure will be sized and the telescope top end will be designed in such a way that a small coxaxial laser launch telescope may be implemented in the future. Such implementation may require modification of the top end.

Maximum launch laser tele. length: 0.5 m

Mass (estimated): 100 kg

3 Safety

All parts of the telescope and facility will be designed to promote safety to personnel and to equipment and to conform to all safety policies currently in effect at CTIO.

4 Environmental

The telescope will meet all performance specifications throughout the following range of environmental conditions:

4.1 Normal operations

Under the following conditions, telescope+enclosure are required to produce at most $0\farcs18$ FWHM image degradation.

Temperature: -1 to 20 $^\circ$C
dT/dt <1.5 $^\circ$C/hr [value for 80% of time 8pm-6am, Pachon 88-92]
Relative Humidity: 0 to 95% non condensing
Steady wind <10 m/s [80% of operating time]
Peak gusts <15 m/s

4.2 Marginal operating conditions

In addition, the telescope will continue to operate outside the above conditions, albeit with degraded performance.

4.3 Non-operating survival conditions

Dome closed >20 m/s steady (dust control)
Temperature -25 $^\circ$C to 25 $^\circ$C
Occasional exposure to condensing conditions wind gusts to 67 m/s (150 mph)
Lightning strikes rain, hail [how big, golfballs?], snow [how much load?], earthquake to 0.34 g & 3 mm amplitude

5 Image budget

5.1 Core d50 encircled energy

The image size budget sets the goals for the telescope in the absence of atmospheric effects and instrument degradation, and pre-allocates limits to the sources of image degradation to guide the design of the telescope and enclosure.

Image sizes are specified in arcseconds FWHM. Depending on the shape of the point spread function, these units may or may not be easily converted to a measure of enclosed energy. Assuming a Gaussian profile, an image $1''$ FWHM has a $1\farcs1$ rms diameter (63% enclosed energy) and concentrates 80% of its energy in $1\farcs52$.

The required image size budget for the SOAR Telescope, averaged over a 15′-diameter field is 0.″18 FWHM contribution from the telescope and enclosure, including the effect of aperture and azimuthally averaged spider diffraction. The diffraction is evaluated at a wavelength of one micron. The field is flattened and corrected with a 2-3 element refractive corrector whose residual optical aberrations throughout the waveband 340 to 1000 nm are included as a term in the 0.″18 budget. This goal is chosen to degrade the best quartile seeing FWHM of the site by no more than 40%.

The contribution to image size from seeing is not included in this table, but grows as (cos z)$^{-3/5}$ where *z* is the zenith distance. The total image budgets for the telescope and enclosure are allowed to increase from the zenith according to the same relation to keep the same relative contributions.

5.2 Scattered light requirement

5.2.1 Optics surface smoothness

Optical finish will be specified to ≤ 1.5nm rms surface roughness, attained by spot surface interferometric measurements [and perhaps atomic force microscopy?] Optical vendors will sample surface wavefront errors using a CCD with at least 1K^2 pixels, then derive the azimuthally averaged 2d power spectrum to demonstrate that there are no spatial frequencies with power in excess of wavefront errors produced by the best quartile atmosphere.

5.2.2 Baffles

The telescope will be provided with comprehensive baffles and light-absorbing material to eliminate light paths from the focal plane to the night sky or inside of the dome. These will be designed to provide optimal scattered light rejection with minimum obscuration.

Obscuration: <4% [G] A goal is to employ diaphragm-like baffles in the M3 chimney and elsewhere, which could reduce scattered light when the full telescope field is not in use.

6 Telescope Requirements

6.1 Axis range of motion

Azimuth travel: $\pm 270^\circ$

Elevation travel, observing: 0.4° < z < 75° (i.e. within 15° of horizon)

Elevation travel, hard stops: -2 and 90°

6.2 Zenith exclusion zone

0.8° diameter max. Program interruption at transit: 3.2 minutes max

6.3 Slewing

Maximum slew rate: 1.5°/sec.

Slew ramp: 1 deg/sec^2

Time for track to track: 100 sec. max, <360° azimuth rotation.

6.4 Pointing accuracy

Blind, all sky <2$''$ rms

Offsets < 1°: <0$''$.2 rms

Offsets within 15$'$ guider fov: <0$''$.1 rms

Blind pointing accuracy in general requires ≈10 minutes overhead at the start of each night. Blind pointing performance shall be met at all instrument ports.

6.5 Track rates

Maximum track rate: 0.5°/sec

Track ramp: 0.1°/sec^2 max.

Settling time between slew and track: 30 sec max.

6.6 Tracking accuracy

Open loop (blind): <0$''$.1 rms image jitter (after the drift is removed)

Open loop drift: <0$''$.1/min

Closed Loop (Guided): <0$''$.1 rms image motion for 1 hour

7 Specification of foci

Focal ratio: f/16

Plate scale: 3$''$.22/mm

Nominal field of view: 15$'$ unvignetted, 19$'$ unvignetted but with intrusion by peripheral wavefront sensor.

Linear field: 0.279 m diameter (for 15$'$ diameter)

Field radius of curvature: 1.0 meter (natural RC.) Central 7$'$ can be used with 1.924 m curvature compatible with Gemini but will not be diffraction limited over this full field.

Distance to exit pupil: TBD

8 Nasmyth Instrument Rotators

Provided on both Nasmyth foci

Weight capacity: 2800 kg with CG 2000 mm from flange

Rotation range: 360°

Rotation rate: -5°/sec. to +5°/sec

Ramp rate: -1°/sec^2 to +1°/sec^2

Accuracy (open loop): <0$''$.02 at edge of 15$'$-diameter field on sky

Maximum inbalance: TBD

9 Instrument Interface Modules

Two units are required; one for each Nasmyth port. One will support a single large Gemini instrument and two lighter (100 kg limit) instruments or calibration units, the other will support three instruments that sum to 2000 kg. Both guiders will perform the functions of target aquisition and closed loop guiding, wavefront sensing for active optics control, and active collimation. General requirements for either unit:

Weight: 800 kg

9.1 Capabilities

9.1.1 Beam switching

Both units will allow the beam to be switched between instruments.

9.1.2 Wavefront sensor

Faint limit: m_V = 16, 20 [G]

Integration time: 30-60 seconds.

Program interruption for on-axis correction: <4 minutes including active correction after taking & processing 3$\times$30 sec integrations.

Update frequency: >30 minutes for on-axis correction but can operate continuously in a differential (peripheral) mode when offset from the field center.

9.1.3 Acquisition & guiding

Number: one probe.

Sensor types: TEC backside illuminated O(1K^2) CCD, IR sensitivity TBD

Field of view: $\simeq 80 \times 80\,''$ at f/16

Sensitivity: centroid to 10% of seeing disk at m_V=18 @ 1 Hz.

Update rate: 0.1 Hz. to 1 Hz.

Wavelength selection: TBD, provision for filtered photometric calibration [G]

9.1.4 Calibration

9.2 SOAR Nasmyth instrument cluster

Distance from Instrument Mounting Flange: 200 $\pm$0.6 mm nominal

Single Instrument weight: 700 kg max each instrument

Moment load: CG at 1 m from flange

Maximum inbalance: TBD

Instrument envelope: a rhomboid $\simeq$1.5 m L $\times 0$.6 m D. Volume includes instrument electronics boxes.

9.3 Gemini compatible Nasmyth module

Distance from Instrument Mounting Flange: 300 mm $\pm$0.6 mm nominal
Instrument weight: 2300 kg max
Moment load: CG 1 m from flange
Maximum inbalance: TBD
Instrument envelope: $\simeq$3 m L $\times$2.0 m D as established for GNIRS + its electronics boxes. This is a subset of the Gemini instrument volume.

9.4 Bent Cassegrain port

Mounting surface: TBD
Back focus distance: TBD
Instrument weight: TBD
Cantilever: 500 mm from flange
Instrument envelope: TBD

10 Instrument utilities

Requirements for power, data LAN, gasses, vacuum, waste heat extraction, and cabling at the various instrument locations.

10.1 At the Gemini-compatible Nasmyth module

10.1.1 Gases & coolant

Helium for cryocoolers: TBD liters/minute at a pressure of TBD. Return line at TBD pressure. Purity 99.999%. 100 psi clean compressed air
Coolant: TBD liters/min at TBD pressure. Return line at TBD pressure

10.1.2 Power

Dirty power: 220V/3Ph, 50 Hz, TBD Amps
Clean power: 110VAC, 50 Hz, 20 Amps
Max instrument power dissipation: TBD

10.1.3 Signal lines

Video LAN: TBD, US HDTV compatible
Data LAN: TBD Control LAN: 100+ MB/sec fibernet
Time LAN: TBD, GPS receiver
Synchro Bus: TBD
Event Bus: TBD
Interlock System: TBD

10.2 At the 3-instrument module

A goal is to provide all of the Gemini utilities as well as dry N_2. The required gasses and coolant are:

10.2.1 Gasses and coolant

Dry filtered N2: 10 cfh at 5 psi. Coolant (piping only): 2 lines, 0.38" ID
Connection to a waste heat scavenge will be provided.

10.2.2 Power

Dirty power: 220V/3Ph, 50 Hz, TBD Amps
Uninterruptible clean power: 110VAC, 50 Hz, 20 Amps
Max instrument power dissipation: TBD

10.2.3 Signal lines (from computer room)

Control: optical fiber, TBD number
Data: Optical fiber, number TBD.
Coaxial cable, number TBD.
Video acq./guide/wavefront: Serial, TBD number
Camera gain: Four twisted pairs

11 Focus monitoring & control

A TBD means of sensing & correcting focus errors that are induced by the telescope and enclosure. May best be done w/ peripheral wavefront sensor (TBD).

12 Tertiary rotator

Description: Rotates M3 about the M1 optical axis to direct the telescope beam to one of two Nasmyth ports or two auxiliary bent Cass. ports.
Number of positions: 4
Time to beam switch: <1 minute for 180° switch.
Repeatability: <$0\farcs5$ on sky after motion <$0\farcs1$ [G]
The required telescope blind pointing accuracy may not be attained on the first exposure after M3 rotation. The offsets derived from this exposure will be used to update pointing so that subsequent exposures will meet the pointing spec.

13 M1 cover

Seal primary mirror against dust when closed. Protect against blunt impacts of < 20 kg-m/s. Present minimal cross section for wind shake when open. Allow good air circulation over the primary mirror.

14 Great white spot

Description: A screen and illuminating lamps covering the full aperture of the telescope for routine recalibration of the instrumental response over the full field of view. Two banks of flat field lamps will be provided: a high intensity set for quick exposures and a continuum set with color balance filters.

15 Servicing & Maintenance [G]

15.1 Typical time for routine periodic operations

Remove or install M1: <7 hrs
Remove or install M2: <3 hrs
Remove or install M3: <3 hrs
Mount & cable instrument: <2 hrs
Collimate telescope: <7 hrs

15.2 Time to perform servicing and maintenance operations

Service/replace dome truck or drive: <2 days
Replace shutter drive: <2 days
Replace telescope encoder & electronics: <1 day
Replace telescope drive & amplifier: <1 day

15.3 Optics cleaning

Provisions will be made for regular CO_2 or other cleaning of M1 and smaller optics. Manual cleaning is a baseline requirement with automated cleaning as a project goal. A goal is to clean as often as required to ensure that dust scattering does not limit telescope photometric performance. Dust accumulation *will* set the IR emissivity of the telescope.
Time to clean telescope optics: 30 mins