Science Requirements and Technical Specifications at Conceptual Design

Site characteristics				
Observatory latitude	19.9 degrees			
Accessible Sky	30,000 square degrees (airmass < 1.55 i.e., δ > -30 degrees)			
Median image quality	0.37 arcsec (free atmosphere, zenith, 500 nm)			
Av. length of night adjusted for weather	8 hours			
Observing efficiency (on-sky, on-target)	80%			
Expected on-target observing hours	2336 hours / year			
Expected on-target fiber-hours	10,119,552 fiber-hours / year (total): 7,589,664 (LR & MR) / 2,529,888 (HR)			
Telescope architecture				
Structure, focus	Altitude-azimuth, Prime			
M1 aperture / Science field of view	80.8 m^2 / 1.5 square degrees			
Spectrograph system	6 x LMR spectrographs (4 channels / spectrograph), all identical, each channel seperately switchable to provide LR and MR modes			
Fiber positioning system				
Multiplexing	4,332 (total): 3,249 (LR & MR) / 1,083 (HR)			
Fiber size	1 arcsec (LR & MR) / 0.75 arcsec (HR)			
Positioner patrol radius	90.3 arcsecs			
Positioner accuracy	0.06 arcsec rms			
Positioner closest approach	Two fibers can approach with 7 arcsecs of each other (three fibers can be placed within 9.9 arcsec diameter circle)			
Repositioning time	< 120 seconds			
Typical allocation efficiency	> 80 % (assuming source density approximately matched to fiber density)			
Low resolution (LR) spectroscopy				
Wavelength range	360 ≦ λ ≦ 560 nm	540 ≦ λ ≦ 740 nm	715 ≦ λ ≦ 985 nm	960 ≦ λ ≦ 1320 nm
Spectral resolution *(center of band)*	2,550	3,650	3,600	3,600
Sensitivity requirement *(pt. source, 1hr, zenith, median seeing, monochromatic magnitude)*	m = 24.0 SNR/res. elem. = 2, λ > 400 nm SNR/res. elem. = 1, λ ≦ 400 nm	m = 24.0 SNR/resolution element = 2	m = 24.0 SNR/resolution element = 2	m = 24.0 SNR/resolution element = 2
Moderate resolution (MR) spectroscopy				
Wavelength range	391 ≦ λ ≦ 510 nm	576 ≦ λ ≦ 700 nm	737 ≦ λ ≦ 900 nm	1457 ≦ λ ≦ 1780 nm
Spectral resolution *(center of band)*	4,400	6,200	6,100	6,000
Sensitivity requirement *(pt. source, 1hr, zenith, median seeing, monochromatic magnitude)*	m = 23.5 SNR/res. elem. = 2, λ > 400 nm SNR/res. elem. = 1, λ ≦ 400 nm	m = 23.5 SNR/resolution element = 2	m = 23.5 SNR/resolution element = 2	m = 24.0 SNR/resolution element = 2
High resolution (HR) spectroscopy				
Wavelength range	360 ≦ λ ≦ 440 nm	420 ≦ λ ≦ 520 nm	500 ≦ λ ≦ 900 nm	
Wavelength band	λ / 30	λ / 30	λ / 15	
Spectral resolution *(center of band)*	40,000	40,000	20,000	
Sensitivity requirement *(pt. source, 1hr, zenith, median seeing, monochromatic magnitude)*	m = 20.0 SNR/resolution element = 10, λ > 400 nm SNR/resolution element = 5, λ ≦ 400 nm	m = 20.0 SNR/resolution element = 10	m = 20.0 SNR/resolution element = 10	
Science calibration				
Sky subtraction accuracy	0.5% requirement (0.1% goal)			
Velocity precision	100 m/s (HR, SNR/resolution element = 30)			
Relative spectrophotometric accuracy	3% (LR, SNR/resolution element = 30)			

Telescope Optical Architecture:	Description	Comment
Optical Design Characteristics	Wide-field prime-focus segmented-mirror telescope	Requires wide field corrector (WFC) and atmospheric dispersion corrector (ADC)
- M1 effective collecting diameter	10 m	Accounted for telescope central obscuration
- Field of view, optical	Circular FoV with diameter of 1.52 degrees	584 mm in size, average plate scale of 106.7 um/arcsec
- Field of view, science	Hexagonal FoV with 1.5 square degrees area	Size of inscribing hexagon within the optical FoV
- Final focal ratio at prime focus	f/1.926	Distance between M1 vertex to PF vertex is 19.1 m
- Focal surface radius of curvature	11.33 m	Convex toward M1
Primary Mirror Configuration	60 hexagonal segments	With 10 unique segment types and no central segment
- M1 aperture diameter	11.25 m	Diameter of circumscribing circle
- M1 focal length	18.845 m	
- M1 conic constant	-1.11	
- Segment size	1.44 m, measured from corner-to-corner	With 2 mm gap and 0.5 mm edge bevel
Wide Field Corrector Configuration	Five lens design with integrated atmospheric dispersion correction	With one aspheric surface per lens element
- WFC lens diameters	1300 mm (L1), 900 mm (L2), 800 mm (L3), 784 mm (L4), 690 mm (L5)	Clear aperture
- WFC lens materials	Fused silica: L1, L2&L4; Ohara PBM2Y: L3&L5	
- ADC design	Atmospheric dispersion correction provided by lateral shifting L2 lens	Image motion due to differential refraction also reduced by half across the field

Observatory Building and Enclosure Architecture:	Description	Comment
Overall height	42.3 m	Observatory building and enclosure
Observatory building exterior diameter	28.8 m	Diameter of concrete foundation at ground level
Enclosure style	Calotte with integrated ventilation modules on rotating base	Contain independently rotating base and cap, and fixed shutter plug attached to rotating base
Enclosure spherical diameter	36.8 m	Exterior dimension
Enclosure aperture opening	12.5 m	Oversized to allow dome tracking by intermittent motion
Height of spherical center of enclosure	24.0 m	Height from ground level

Telescope Mount Architecture:	Description	Comment
Mount configuration	Altitude-azimuth mount	Independent azimuth and elevation structures
Mount structure overall length	24.7 m	
Range of motion, observing	Azimuth: +/-270°; zenith: 1° to 60°	
Range of motion, servicing	Azimuth: +/-270°; zenith: 0° to 90°	
Instrument rotator range, total	+/-270°	Rotator derotates focal surface to maintain targets to fiber inputs alignment during observation as part of telescope tracking and guiding
Active optics correction		
- M1 control system, segment figuring	Moment actuators on segment support whiffletree provide warping adjustment to maintain segment figure	Phasing and alignment camera provides feedback
- M1 control system, global shape	180 actuators, three per segment, provide piston and tip/tilt corrections to maintain M1 global shape	300 edge sensors provide M1 segment global shape real-time feedback during observation; initial phasing provided by the phasing and alignment camera
- Prime focus hexapod system range of motion	+/-10 mm defocus correction and +/- 10 mm decenter correction	Hexapod moves WFC to maintain optical alignment w.r.t. M1 during observation
Motion Characteristics		
Maximum reconfiguration time	2 minutes	Between any two points within the observing range of motion and including unwrapping of cable wraps
Pointing accuracy	2.0 arcsec RMS	Based on pointing model correction
Tracking accuracy	+/- 0.25 arcsec RMS over 15 minutes	Based on pointing model correction
Guiding accuracy	+/-0.055 arcsec RMS	Include acquisition and guide cameras real-time feedback

Positioner System Architecture:	Description	Comment
Sphinx fiber positioners with metrology camera	Positioner carries a single fiber through its tilting spine and patrols a circular area by pivoting around its base	Metrology camera provides positional feedback during configuration where the fibers are back-lit from the spectrograph for camera viewing.
Number of Fiber Positioners	4332 total	Two sets of positioners are deployed to select targets for low/moderate resolution (LMR) spectrographs and high resolution (HR) spectrographs. Both sets provide full-field coverage simultaneously.
- LMR fibers	3249	
- HR fibers	1083	
System configuration time	75 sec combined in three stages	Coarse motion, fine motion and final measurement
System positional error	6.3 um RMS/0.042 arcsec RMS	
Positioner pitch	7.77 mm	Center separation between two positioners
Radius of patrol area	9.64 mm/90.35 arcsec	1.24 x pitch
Tilt-induced defocus at max. patrol area	93 um/0.87 arcsec	Based on 250 mm spine length
% of field coverage by 1 or more fibers	99.99% (LMR)/100.00% (HR)	
% of field coverage by 2 or more fibers	99.83% (LMR)/58.06% (HR)	
% of field coverage by 3 or more fibers	97.07% (LMR)/4.47% (HR)	
Min. separation between centers of two fibers	0.75 mm/7.03 arcsec	Closest approach between two fibres
Min. circle between three fibers	1.06 mm/9.93 arcsec	Diameter of circumscribing circle between three fibers
Robustness against positioner collision	No damage	Collision avoidance control software minimizes occurrences

Fiber Transmission System Architecture:	Description	Comment
Fiber material	High numerical aperture (NA=0.26-0.28) Polymicro FPB fiber with pure silica core	Target light can be injected directly at fiber input without reformatting optics; reformatting optics is expected at spectrograph slit block
Fiber length	50 m (HR fiber), 35 m (LMR fiber)	Extra length incorporated for telescope mount motion
Fiber diameter	0.8 arcsec (HR fiber), 1.0" (LMR fiber)	Fiber diameter changed to 0.75 arcsec in the HR spectrograph design
Fiber Cable Configuration		
- Number of connectors	0	Fusion splicing requires to integrate fiber with positioner
- Number of cables	57	Cables are identical
- Number of tubes per cable	4	Three tubes for LMR fibers and one tube for HR fibers
- Number of fibers per tube	19	
- Provision for broken fibers	Loop boxes provide access to spare fibers for splicing	Each cable contains two loop boxes

Optical Coating Choices	Description	Comment
M1 segment	Blue-enhanced protected silver coating from ZeCoat	20% more reflective in the "blue" than the Gemini protected silver coating
WFC optics	Anti-reflection (AR) coating with MgF_2 and Sol-Gel overcoat	Sol-Gel applied by spin-coat process
Spectrograph slit block	Dielectric AR coating and index matching coupling gel	

LMR Spectrograph Architecture	Description	Comment
Multiplexing configuration	Six units for 542 spectra each	
Location	Telescope instrument platforms	Fiber fed, gravity invariant, exposed to observing environment
Spectrograph operating temperature	-80° C	Cooled to reduced thermal background for H-band
Spectral channels	Blue, Green, Red and NIR	Coverage provided in four spectral channels, three optical and one NIR
Low Resolution Mode	*Spectral Resolution*	*Spectral Coverage*
- Visible-band (blue) channel	R min = 2022, R average = 2584	Wavelength range: 360 - 560 nm
- Visible-band (green) channel	R min = 3086, R average = 3657	Wavelength range: 540 - 740 nm
- Visible-band (red) channel	R min = 3030, R average = 3602	Wavelength range: 715- 985 nm
- YJ-band channel	R min = 3048, R average = 3619	Wavelength range: 960 - 1320 nm
Moderate Resolution Mode	*Spectral Resolution*	*Spectral Coverage*
- Visible-band (blue) channel	R min = 3788, R average = 5524	Wavelength range: 391 - 510 nm
- Visible-band (green) channel	R min = 5647, R average = 6255	Wavelength range: 576 - 700 nm
- Visible-band (red) channel	R min = 5459, R average = 6063	Wavelength range: 737- 900 nm
- H-band channel	R min = 5437, R average = 6039	Wavelength range: 1457 - 1780 nm
Four-Arm Optical Design		
- Collimator	Off-axis f/2.083 Schmidt collimator, beam aperture 175 mm	
- Dispersers	Resolution change by switching between VPH grating (LR) and VPH grating + prism (MR)	Max. line density 2275 l/mm, and size of 200 mm
- Cameras	Five element transmissive camera with strong aspheric surfaces	f/1.2 camera, max. clear aperture 216 mm
- Detectors	Visible channels: E2V CCD 231 series, 4K x 4K, 15 um pixel, NIR channel: Teledyne Hawaii 4RG15	AR coating optimized for each optical spectral channel

HR Spectrograph Architecture	Description	Comment
Multiplexing configuration	Two units for 542 spectra each	
Location	Observatory building Coude room	Fiber fed, gravity invariant, protected from observing environment
Spectral channels	Blue, Green and Red	Three separate spectral windows with narrower working windows
High Resolution Mode	*Spectral Resolution*	*Spectral Coverage*
- Blue channel	R=40K	Wavelength range: 360 - 440 nm
- Green channel	R=40K	Wavelength range: 420 - 520 nm
- Red channel	R=20K	Wavelength range: 500 - 900 nm
- Working window width	Blue: λc/30@ λc=408.55 nm, Green: λc/30@λc=481 nm, Red: λc/15@λc=650.5 nm	λc is the central wavelength, working windows are reconfigurable by replacing dispersers
Three-Arm Optical Design		
- Collimator	Off-axis f/2.05 Houghton collimator, beam aperture 300 mm	
- Dispersers	Grism (grating + prisms)	Max. line density 5800 l/mm, and length of 650 mm
- Cameras	Five element transmissive camera with three aspheric surfaces	Max. clear aperture 500 mm, focal length 474 mm
- Detectors	E2V CCD 231-C6, 6K x 6K, 15 um pixel	AR coating optimized for each spectral channel