

An Update on the Chinese Space Station Telescope Project

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Milestones

- Science case: 2009, suggestion of a telescope for astronomy onboard the Chinese space station (CSS); 2010, preliminary science goals and mission proposal; concept of a wide-field multiband imaging & slitless spectroscopy survey was well received by China Manned Space Agency.
- Telescope: 2011, feasibility review; 2012, CSS applications selection; 2013, down-selection of design, budget review & approval; 2014, man-tended free flyer concept (Optical Module); 2015-, preliminary design & technology dev; 2021, qualification for flight; 2023/2024, launch.
- Instruments: 2015, Survey Cam (led by NAOC & IOE) & THz Receiver approved; 2019, new instruments approved; to be launched with the telescope.

NAOC is organizing the proposal effort for the science center, science ground segment, and science preparation.

Optical Module for Astronomy

A 2m space telescope in the same orbit as the China Manned Space Station, serviceable while docking with the station. **Instruments:** Survey Camera (SC), Terahertz Receiver (THz),

Multichannel Imager (MCI), Integral Field Spectrograph (IFS), Cool-Planet Imaging Coronagraph (CPIC).

Mission: wide-area multiband imaging & slitless spectroscopic survey (7yr); other key programs & GO programs (2+yr).



OM/CSST (~2024)









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Telescope Specs

Aperture	≮2m
Focal length	28m
Field of view	≮1.7 □° (≮1.1 □° for survey)
Wavelength	0.255-1μm, 0.9-1.7μm, 0.41-0.51GHz
Image quality	optics: R _{EE80} ≯0.13", full system R _{EE80} ≯0.15" e _{avg} ≤0.05, e _{max} ≤0.15 (λ=0.6328μm, within ≮1.1□°)
Throughput	<0.65 (NUV-Vis-NIR average, optics only)
Pointing accuracy	LOS: ≽5" (w/ guide star), 10" (w/o GS) Roll: ≽10" (w/o GS)
Stability (≮300s)	LOS: ≽0.05" (3σ, w/ GS), ≽9" (w/o GS) Roll: ≽1.5" (w/o GS)
Jitter	≽0.01" (3σ)
Slew	1°/50s, 20°/100s, 45°/150s; max 0.35°/s

Docking & servicing





System Design



Precision Control with Fast Slew

	HST	Euclid	JWST	CSST	
Orbit	600km LEO	L2	L2	400km LEO	
M. I.(kg·m²)	82600	3100	90000	135000	
Mass (Kg)	10880	2160	6330	15500	
Abs pointing (″、3σ)	a few " (?)	30	19.5	LOS 5 Roll 10	
Stability (″、3σ)	LOS 0.009/1.5h Roll a few " (?)	LOS 0.075/700s Roll ~3/700s	spacecraft: LOS 0.65 Roll 2.4	spacecraft: LOS 0.85/300s Roll 1.5/300s	
			final: LOS 0.021	final: LOS 0.05	
Slew	90°/1080s	0.8°/290s	90°/3390s	1°/50s, 45°/150s	
FGS (″、3σ)	0.003 (rel)	0.6(abs) 0.03 (rel)	0.01 (rel)	0.2 (abs) 0.01 (rel)	

CSS Optical Survey

- 17500□° imaging : 255-1000nm, ≥6 filters, avg ≥25.5^m (5σ, point source, AB mag);
- 17500□° slitless spect: 255-1000nm, R≥200, ≥22-23^m;
- 400□° deep imaging & spect: at least 1^m deeper.



Imaging & Slitless Spectrum Survey |b|>=20deg Ultral Deep Survey Imaging & Slitless Spectrum Survey 15=<|b|<20 deg

Ecliptic Coord. Deep fields will be finalized later; sim results for demo only.

Science

Cosmology: dark energy, dark matter, gravity, large-scale structure, neutrinos, primordial non-Gaussianity...

AGNs: high-z AGNs, clustering, dual AGNs, variability, UV excess, host galaxies...

Galaxies: formation & evolution, mergers, high-zs, dwarfs, LSBs, near field, halos properties... Milky Way: structure, satellites, dust, extinction... Stellar science: formation, dwarfs, metal poor... Solar system (high inclination): TNO NEA... Astrometry: reference frame, star clusters... 8

Camera Specs

	Physical area	≥262435mm ²				
Main focal plane	Light sensitive area	≥80% of physical area				
	Flatness	≤60µm (PV)				
Wavelength coverage	Imaging	0.255-1.0μm, ≥6 bands Ref: NUV (0.255-0.32μm), u(0.32-0.40μm), g(0.40-0.55μm), r(0.55-0.69μm), i(0.69-0.82μm), z(0.82-1.0μm)				
	Spectroscopy	0.255-1.0μm, ≥3 bands				
	NIR	0.9-1.7μm, 2 bands				
Imaging	Readout noise	≤5e⁻/pix				
	Readout time	≤40s				
	Dark current	≤0.02e ⁻ /pix/s @ working temperature				
	Digitization	16bit				
	Dynamical range	≥84dB				
	Full well capacity	min ≥70 ke⁻, avg ≥90ke⁻				

Camera Specs

Throughput	Imaging	NUV: ≥0.26; u: ≥0.32; g: ≥0.58; r: ≥0.63; i: ≥0.62; z: ≥0.25			
	Spectroscopy	255-400nm: ≥0.24; 400-600nm: ≥0.44; 600-900nm: ≥0.43; 900-1000nm: ≥0.25			
Spectral resolution		R≥200			
Image quality (R _{EE80} , given the optics)	Imaging	NUV: ≤0.135″; u: ≤0.135″; g: ≤0.135″; r: ≤0.135″; i: ≤0.145″; z: ≤0.165″			
	Spectroscopy	average: ≤0.3"; max: ≤0.4"			
Mission reliability	In-orbit time	≥10 years			
	Observing time	≥6.5 years			
	Reliability w/ service (CL 0.7)	≥0.9746			
	MTBF	≥4 years			

Camera Design



Focal Plane Arrangement



- Filters & gratings mounted in front of each detector
- Imaging in central region w/ better image quality
- use optical model to position filters and gratings and determine detector separation, clear aperture for filters, etc.



Filters & Limiting Mags



	t _{exp}	NUV*	u	g	r	i	Z	у*
17500 □°	2×150s	25.4	25.4	26.2	25.9	25.8	25.2	24.5
400 □°	8×250s	26.7	26.7	27.4	27.1	26.9	26.4	25.7

*NUV & y: 4×150s

w/ ~ 0.2^{m} margin from design $_{13}$

Gratings & Limiting Mags



Broadband limiting mag w/ ~0.2^m margin

Gratings





Design: peak efficiency of 1st order spectrum ~75%



Actual test results are around 60%. Zeroth order image contains ~5-10% energy.

Camera Technology Demonstration



Cryo test model



Shutter (1.3M+ ops tested)





Mock focal plane, flatness: 31µm (PV)



cryocooler



Detectors tested



SiC mounting plate for detectors



Summary

- The Optical Module/CSST project overall has completed the first phase work (detailed design, interface definition, tech dev & demo) except for the 3 newly approved instruments (MCI, IFS, CPIC).
- Qualification model (only the telescope & instruments): delivery by the end of 2021
- Flight model: delivery in 2023
- For the survey camera, the detector is the critical path, and we will have to implement both CCD and CMOS design on the qualification model to leave enough time for decision before the flight model start production.