Technical Parameters of the

1.3-m Devasthal Optical Telescope Observatory

Contributors :

	Name	Affiliation	Date	Signature
Prepared by*	Brijesh Kumar Jay Shreekar	ARIES, India	23-10-2010	

*On behalf of the technical team for Installation and verification of 1.3m DOT

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Scope :

The purpose of this document is to provide as-built technical specifications of the 1.3-m Devasthal Optical Telescope at system, sub-system as well as component level as a single document in compact form. The 1.3m DOT observatory includes telescope, enclosure and instruments. A GPS receiver and a weather station is part of the observatory.

Reference Documents :

RD1 : Contract between ARIES and DFM for supply (i.e. manufacture, packaging and transportation) of a 1.3m astronomical optical telescope to be installed at Devasthal, India (Contarct No. ARIES-DOT-PN-003-C0 dated 15th March 2006, 6 pages)

RD2 : Revised contract between ARIES and DFM for supply, installation and verification of the 1.3m astronomical optical telescope (dated 15th April 2009)

RD3 : Final design drawings of telescope related to optical, mechanical and electrical dated 26th February 2010

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[A] TELESCOPE

No.	Parameter	Value / Description
1	System	F/2.3 F/4 Optical System Equatorial fork mount
2	Total weight	11500 pound
3	Height (above telescope floor)	Total height : 4671 mm Height of center section : 2451 mm
4	Telescope pier	Size : 2133.6 mm x 1524 mm Height above telescope floor : 124 mm The RCC pier has three 6-inch diameter conduit for telescope cables. Pedestal of the telescope is mounted on three bolts of the pier.
5	Additional note	This is the third f/4 (1.3m) system being installed by DFM. Previous two systems are at a private Observatory, Arizona, USA (1990) and at US Naval Observatory, USA (1995). The one at Arizona delivered sub-arcsec images.

[B] OPTICAL SYSTEM

No.	Parameter	Value / Description
1	Configuration	Ritchey-Chretien with Cassegrain focus
2	Pupil aperture	Annular Outer size : 1310.64 mm diameter Inner size : 657.86 mm diameter
3	Telescope focal length	5149.6 mm (~ F/4) Plate scale = 40.0545 arcsec / mm
4	Primary mirror (M1)	Hyperbolic R = 6045.2 mm Concave K = -1.6306 Location (X,Y,Z[n1])=(0.0,0.0,0.0) mm
5	Secondary mirror (M2)	Hyperbolic R = 6153.658 mm Convex K = -35.8429 Location (X,Y,Z) =(0.0,0.0,-1750.06) mm
6	Field Corrector	Clear aperture : 236.22 mm diameter Location (X,Y,Z) =(0.0,0.0,83.82) mm
6	Axial focal plane	Circular : 101.6 mm diameter (~ 67.83 arcmin) Location (X,Y,Z) =(0.0,0.0,438.15) mm Range of focus in Z = +80.67/-80.67 mm [Corresponding to travel range in M2 = +/-20.32 mm] Focus amplification = 3.97 (f/f1)^2 +1.
7	Operational wavelength	350 nm to 2500 nm
8	Science field of view	66 arcmin unvignetted field for axial port
9	Optical image quality	80% energy in less than 0.6 arcsec diameter; (for 14 arcmin field of view with elevation range 40 to 90 deg and for the wavelength range 350 nm to 2500 nm)

[n1] The X, Y and Z axes are defined with reference to the vertex of the M1. The X and Y axes are perpendicular to the optical axis and the minus (-)Z axis points towards the center of curvature of M1.

[C] PRIMARY MIRROR (M1)

No.	Parameter	Value / Description
1	Mirror substrate	Corning TSG Concave blank with flat bottom
2	Outer mechanical diameter	1318.26 mm
3	Central hole diameter	457.2 mm
4	Thickness at the edge	153.16 mm Diameter-to-thickness ratio = 8.6
5	Thickness at the central hole	123.19 mm
6	Useful optical surface diameter	558.8 mm to 1310.64 mm minimum
7	Radius of curvature of concave optical surface at vertex	6045.2 mm
8	Conic constant of concave optical surface	-1.6306
9	Polishing accuracy of the concave optical surface	22 nm RMS WFE and 158 nm PV WFE @ 633 nm on useful optical surface Strehl ratio = 0.952
10	Surface finish of the concave optical surface	Scratches and digs according to ISO 10110-7 80-60
11	Reflectivity of the concave surface	Aluminium with Silicon monoxide overcoat 88.4% mean between 400 - 700 nm
12	Weight of the mirror blank	374 kg
13	Chamfers	Outer diameter (flat and convex) : 6.35 mm x45 deg Inner diameter (flat and convex) : 6.35 mm x45 deg

[D] SECONDARY MIRROR (M2)

No.	Parameter	Value / Description
1	Mirror substrate	Corning TSG
2	Outer mechanical diameter	609.6 mm
3	Central hole diameter	72.44 ± 0.25 mm
4	Thickness of the blank	88.9 mm
5	Useful optical surface diameter	236 mm to 584 mm minimum
6	Radius of curvature of convex optical surface at vertex	6153.658 mm
7	Conic Constant of convex optical surface	-35.8429
8	Polishing accuracy of the convex optical surface	28 nm RMS WFE and 220 nm PV @ 633 nm Strehl Ratio = 0.926
9	Surface finish of the convex optical surface	Scratches and digs according to ISO 10110-7 60-40
10	Reflectivity of the convex surface	Enhanced Aluminium with Silicon monoxide ; 92% at 400 nm, 95.5% at 450 nm; 96.3% at 500 nm; 96% at 550 nm; 95.5% at 600 nm; 94.5% at 650 nm; 92.2% at 700 nm
11	Weight of the secondary	37 kg

[E] CORRECTOR LENS

A single element corrector is part of the system.

No.	Parameter	Value
1.	Material	Fused Silica (Quartz)
2	Thickness	6.6548 mm
3	Size	236.22 mm diameter clear aperture; 241.3 mm mechanical diameter
4	Location	(X,Y,Z) = (0,0,83.82)
5	Figure	4^{th} order Schmidt, ½ correction on each side
6	Coating	anti-reflective layers with reflection between 0.3 to 0.7%
7	Transmission	99.3-99.7 %; a mean of 99.5%

[F] MECHANICAL SYSTEM

No.	Parameter	Value / Description
1	Mounting	Equatorial fork mount
2	Pointing accuracy	< 10 arcsec RMS for any point in the sky for zenith angle 0 to 60 degree < 15 arcsec RMS for zenith distance down to 70 degree
3	Tracking accuracy	< 0.5 arcsec for less than 10 min without auto-guider for zenith angle 0 to 40 degree
4	Telescope motions	Max. slew speed : 3 deg s^{-1} Guide speed (default) : 100 arcsec s^{-1} Set speed (default) : 5 arcsec s^{-1} Smallest motor step : 0.1 arcsec s^{-1} Celestial objects having speeds from 0.001 arcsec/s to 3 deg/s are possible to track by setting RA and DEC rates.
5	Re-targeting time	Less than 10 s for 2 deg move
6	Rotation freedom	Final Software limit -1 : 72 deg zenith distance Approaching software limit : 70 deg zenith distance Hardware limit : 80 deg zenith distance in DEC and RA (except 72 deg in South) DEC Limits : -40 deg to +90 deg HA hardware limit : +/- 11.5 hr HA software limit : +/- 11.3 hr
7	Covers	4 motorized doors for primary mirror, based on limit switches and operated from TCS. Opening/closing time : 1-minute
8	Five axis focus housing	Five-axes motion of secondary mirror is provided with a resolution of 2 micron in Z, 25 micron in X and Y translation and 2 arc sec in tilt. It is remotely controlled from TCS.
9	Capacity to take imbalances	4 kg.m in dec; 8 kg.m in ra
10	Natural frequency of the overall system	All the materials used in mechanical system cross section and overall system when coupled with optical system should have a natural frequency more than ~ 5 Hz .

[G] PRIMARY MIRROR SUPPORT SYSTEM

No.	Parameter	Value
1	M1 cell	The M1 cell is a welded mild steel structure bolted to the center-section that supports the M1 mirror through the radial and axial support systems. M1 cell weight : 1600 pounds
2	Axial supports	The mirror is axially supported by 36 counterweight lever actuators that float the mirror. Each actuator location is a machined surface of stainless steel of 20 mm diameter. 6, 12 and 18 actuators are placed along three radii.
2	Axial definers	Three axial definers are implemented at 120 deg close to the outer edge of the mirror and they consist of a bracket assembly. A dial indicator is placed near the axial definers as input for the mechanical alignment of the mirror. These definers are thermally compensated.
3	Axial set-up supports	Three axial set-up supports are provided at 120 deg at a radius 500 mm (?) and they consist of a small Al (derill) pad of 40 mm (?) diameter on the mirror rear side. These set-up supports are used during initial loading of the mirror. A dial indicator is placed near the set-up supports as input for the mechanical alignment of the mirror.
4	Radial supports	The mirror is supported on a-static levers connected at mid thickness on the outer rim of the mirror blank. The connection between lever and mirror is made by dedicated Al rods with steel rod end with counterweights (3 pounds each ?). The levers act in a “push-pull” configuration. There are 16 radial supports.
5	Radial definers	Four radial definers are implemented at 90 deg on the outer rim of the mirror in tangential direction. The definers include a Nylon 66 cylindrical pad. These definers are thermally compensated (steel = 6 micro-inch/inch/deg F; Nylon66 = 25 micro-inch/inch/deg F; Corning TSG ~ 0 mico-inch/inch/deg F). Two dial indicators are provided on the North and West.
6	M1 earthquake guards	The M1 cell has four inner axial restrainers (made up of Nylon) which are used to secure the safety of M1 in case of earthquakes and horizontal pointing.
7	M1 baffle	The M1 baffle is a hollow cylinder made up of Aluminum and has a thickness of 2 mm (?). The baffle is painted with a flat black paint with thickness more than 2 mircometer (?). Inner Diameter = 419.354 mm Total length = 1129.03 mm Weight = 12 pound Location = Z=-965.2 mm (?) to +125 mm (?)

[H] SECONDARY MIRROR SUPPORT SYSTEM

The M2 mirror is supported by a back plate, which is connected to 5 axis focus housing.

No.	Parameter	Value
1	M2 baffle	The M2 baffle is a welded structure and is defined as a cylindrical tube. The baffle is made of Aluminum The baffle is painted with flat black paint with thickness more 2 mircometer. Inner Diameter = 657.86 mm Total length = 295.66 mm Weight = 6 pound Location = Z=-??? mm to ??? mm mm
2	M2 unit	The M2 unit consists of the M2 mirror, the M2 baffles, the axial plate and radial mount, the M2 five axis housing, the interface structure with spider. The total weight of the M2 unit is 150 kg. M2 unit is defined axially with four invar rods to the M1 cell and supported radially by the connection to the top ring.
3	M2 unit spider	The M2 unit spiders link the M2 unit to the top tube (steel) ring of the telescope. The spiders are four in number and it is made of standard steel with 3 mm (?) arm thickness and 420 mm (?) arm height..

[I] FIVE AXES FOCUS HOUSING

The five axes focus housing is a five degrees-of -freedom positioning system for the secondary mirror. It controls the translation (Tx, Ty, Tz) and rotation (Rx, Ry) of M2.

No.	Parameter	Focus (Tz)	Centering (Tx, Ty)	Tip/Tilt (Rx,Ry)
1	Travel range	± 20 mm	± 1.27 mm	± 5 arcmin
2	Absolute accuracy	2 micron	25 micron	2 arcsec
3	Repeat ability	2 micron	25 micron	2 arcsec
4	Time response	< 2s / 25 micron	< 1 s / 10 micron	< 1 s /10 arcsec
5	Speed	0.3 mm/s	0.02 mm/s	0.04 arcmin/s
6	M2 housing enclosure	A cylinder-shaped box; Diameter : 12 inches; Height : 440 mm (?)		
7	Thermal dissipation	About 0.6 W (optical encoder in it) a few milli amps		
8	M2 focus housing weight	80 pounds		

[J] INSTRUMENT INTERFACE UNIT

The telescope has one axial port (Cassegrain focus) for instruments.

No.	Parameter	Value
1	Instrument envelope	Cylindrical cum conical space of 1 m height below the M1 cell. A constant cylindrical diameter of 152 cm from cell to 20 cm and a decreasing conical diameter from 152 cm to 70 m corresponding to the distance below the cell from 20 cm to 1 m.
2	Mounting screws	Four sets of 12 tapped holes (size-3/8-24) on the back of the mirror cell are provided for mounting instruments. The diameters of bolt circle are 19, 20, 24 and 36 inches.
3	Location of axial port Cassegrain focus	242.1 mm behind the cell (with filter) 240.2 mm behind the cell (without filter)
4	Maximum weight of the instrument	200 kg Counterweights are provided to balance the telescope

[K] TELESCOPE CONTROL SYSTEM (TCS)

The TCS is a software system that forms the interface between the telescope's hardware and the user.

The TCS consists of weather station, mount control system, and PC. The weather station shall measure dew point, air temperature, air humidity, air pressure, wind speed and wind direction at the telescope level and it will send the information to the TCS PC through a RS 232 serial link. The TCS controls the motion of RA, DEC, M2 five axes housing, M1 mirror doors and the roll-off roof.

The TCS provides access to both the operational and engineering control of the telescope hardware and it also interfaces with the 5-axes M2 mirror housing, guiding unit system and the imaging instrument if any. It is installed on a dedicated industrial PC with in-built GPS card and with communication ports (TCP/IP, EXCOM, and MNCP) to communicate with the observatory control system. The TCS is written in Turbo-pascal and it runs on the WINDOWS (XP) platform.

[L] IMAGE QUALITY OF THE TELESCOPE

The E80 will fall within 0.6 arcsec (equivalent FWHM PSF of 0.45 arcsec) for stellar images up to field of view of 1 degree. The stellar images with 1 arcsec FWHM were recorded on 23rd Oct 2010.

[M] ENVIRONMENTAL CONDITIONS FOR THE INTEGRATED TELESCOPE SYSTEM OPERATION

The entire hardware and software is designed and realized for successful operation of the telescope on continuous basis under the following environmental conditions that are likely to be encountered during diurnal and seasonal variations at the Devasthal site.

(M1) Normal Operating Conditions:

No.	Parameter	Value
1	Temperature	– 5 to 25 ^{0}C
2	Relative Humidity	20 to 90%
3	Wind	< 3 m s^{-1}
4	Peak Wind	< 4 m s^{-1}
5	Variation in temperature	~ 2 ^{0}C between 8 pm to 4 am in the night Note : 5 deg C variation shall need more frequent calibrations of the telescope during the night.

(M2) Marginal operating conditions:

No.	Parameter	Value
1	Temperature	– 5 to 30 ^{0}C
2	Relative Humidity	20 to 95%
3	Steady wind	< 8 m s^{-1}
4	Peak gusts	< 10 m s^{-1}

(M3) Non-operating survival conditions:

No.	Parameter	Value
1	Temperature	–10 to 40 ^{0}C
2	Relative Humidity	20 to 100% (without condensation on telescope)
3	Steady Wind	~ 20 m s^{-1}
4	Peak Gusts	~ 30 m s^{-1}
5	Seismic zone V	3.6 m s^{-2} (average acceleration)

[N] TELESCOPE ENCLOSURE

The telescope enclosure is a roll-off roof structure which moves on rail. The roof has two motorized shutters to give passage to the telescope while opening. An electric hoist of 2-ton capacity is mounted on the roof structure. Telescope need to be parked before closing the roll-of roof.

No.	Parameter	Value
1	Roof Structure	Height : 7450 mm Width : 8000 mm Length : 8000 mm Weight : 3000 kg
2	Rolling Shutters (North and south)	Height : 3000 m Width : 2750 mm Cast : double wall Al strips
3	Opening/Closing time	Roof : 2 min shutters : 30-s each
4	Electric hoist	3 HP motor hoist 2 ton capacity 10 m lift Hoisting speed : 5-7 m/min
5	Floor hatch	1.75 m x 2 m towards north side of the floor

[O] POWER CONSUMPTION BUDGET FOR THE 1.3m TELESCOPE OBSERVATORY

	Non UPS Load	
No.	**Equipment**	**Load (kVA)**
1	Roll-off roof and shutters drive	6
2	Electric hoist (2 ton capacity)	3
3	Lighting (CFL and tubelight)	10
4	Power points	13
5	UPS	18
	Total Non UPS Load	**50**
	UPS Load **(A 15-KVA 3-phase UPS is used for telescope and computers; 1 hour back-up at peak load.)**	
2	Telescope	1 [500 W (typical 350 W)]
2	Computers	5
3	Emergency light	1
4	EPBAX	1
5	Future estimate	5
	Total UPS Load	13