Australian National University

Updated System Subsystem Requirements

Prepared For

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Document Identification

Document Revision Number	001
Document Issue Date	25/08/2017
Document Status	Draft

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Acronyms

ANU Australian National University.

BTO Beam Transfer Optics.

CAN Controller Area Network.

EC Electronics Cabinet.

EOS Electro-Optic Systems.

FLPM Fibre Laser Pump Module.

GSL Guide Star Laser.

LH Laser Head.

MSIR More Specific Information Required.

OCS Observatory Control System.

RFA Raman Fibre Amplifier.

1 Requirements and Constraints

While the 1.8m telescope and ~~Toptica GSL~~ system~~s~~ have already been designed and completely built, the EOS GSL and the ANU GSL have not. The requirements and constraints that these two lasers will add to our system interface are therefore yet to be finalised. Any numeric requirements for these two systems that may be subject to change, or have not been finalised, are displayed with appropriate error bounds.

1.1 Telescope Floor Layout

The telescope is split into four floors: the basement, entry, middle and observation floors. This is shown visually in Figure 5 in Appendix C. The basement is the lowest floor, and it is not used in this project. The entry floor is the floor with the main entrance. The entry floor is split into an outer stationary section and an inner rotating section. Above the entry floor is the middle floor. The top floor of the telescope is the observation floor. The observation floor is the major location for the laser-telescope interface.

1.2 Requirements Verification Matrix

The Requirements Verification Matrix, Table 1, shall provide a framework for verification of the system interface against the requirements, and that each requirement is quantitative.

The verification of each requirement shall be performed either by inspection (I), analysis / design (A), demonstration (D), testing (T) or a combination thereof.

At the time of project handover (19 May 2017) some requirements still require more information, or more specific values. These have been augmented with the comment 'More Specific Information Required (MSIR)' and an explanation of the extra information that is required, where possible. This comment was not added to any of the Australian National University (ANU) GSL requirements, as it is already well established that these are still largely unknown and subject to change.

Aside from the MSIR comment, other information included in the *Comment* section of the Matrix include a reference that indicates the source of the information for the particular requirement, the note 'Preference' to indicate that a particular requirement is not as strict as others, references to figures located in the Appendix are made when appropriate, and a note has been made if multiple sources provided differing information for a particular requirement.

[All comments marked as **U:** are those that are updates to existing requirements. This indicates that the information has been updated, the scope has changed, or some other form of new information was attained. All information that has been updated or removed has been struck out for this interim document. The finalised version will have this removed.]

Reference	Description	Verification				
		I	A	D	T	Comments
1.1.1	The telescope dictates that the System shall be fixed to the telescope via the following parts: COM-T1252-1-ANU, COM-T1252-2-ANU, COM-T1245-1-ANU, COM-T1245-2-ANU.	×				[1]
1.1.2	The telescope dictates that the System not obtrude more than 1000mm from the 1.8m telescope mounting position.	×				Measured 02/03/17
1.1.3	The telescope dictates that the System shall not extend more than 610mm above the 1.8m telescope's mounting plate on the left side.	×				Measured 02/03/17
1.1.4	The telescope dictates that the System shall not extend above the 1.8m telescope's mounting plate on the right side.	×				See Figures 6, 8, 10
1.1.5	The telescope dictates that the System shall not place more than 50MPA on any bolt into the telescope.		×			[2]
1.1.6	The telescope dome dictates that all systems components be able to pass through the entry level door or the observation shutters.	×				[3]. See Figure 4.
1.1.7	The telescope dome dictates that the observation shutters have dimensions of 1800mm by 2900mm for the purpose of passing components into the dome.	×				[3]
1.1.8	The telescope dictates that entry level door has dimensions of 2700mm by 2200mm.	×				[3]
1.1.9	The telescope dome dictates that the total mass of the System is constrained by the need for the Observer floor of the dome to remain level, which will depend on 16 Firestone Marsh Mellows Isolators (Product Code: W22-358-0187).		×			[4]. MSIR
1.1.10	The telescope dictates that the System shall [ideally] be mounted to the telescope using no more than the available holes as shown in Figure 6. [Additional may be drilled upon approval if required.]	×				[1] U: Holes may be drilled if they are requested.
1.1.11	The telescope dictates that peripheral electronics required on the observation floor shall be contained within a bench space of 2000 × 600 × 500mm (l × w × h) or an additional space of 2800 × 700 × 1200mm (l × w × h) .	×				Measured 21/04/17. See Figures 8,9a,9b.

Reference	Description	Verification				
		I	A	D	T	Comments
1.1.12	~~The telescope dictates that peripheral electronics on the entry floor shall not occupy more than 3±3m^2 of floor space.~~	×				Measured 31/03/17. See Figure 12. U: Origin of value unclear. Remeasure.
1.1.13	~~The telescope dictates that peripheral electronics on the entry floor shall not exceed 2500mm in height.~~	×				Measured 31/03/17 U: Origin of value unclear. Remeasure.
1.1.14	~~The telescope dictates that peripheral electronics on the middle floor shall not occupy more than 2 ± 1 m^2 of floor space.~~	×				Measured 31/03/17. See Figure 11.U: Origin of value unclear. Remeasure.
1.1.15	~~The telescope dictates that peripheral electronics on the middle floor shall not exceed 1900mm in height.~~	×				Measured 31/03/17 U: Origin of value unclear. Remeasure.
1.1.16	The telescope dictates that equipment used on the middle floor must pass through a [1140]~~1400~~mm × [520]~~600~~mm access hatch.	×				~~[3]. See Figure 7.~~ U: Measurements indicate CAD model is inaccurate. See figures **Upload**
1.1.17	The telescope dictates that all equipment be mounted on the rotating part of the telescope.	×				[1]
1.1.18	The telescope dictates that the Beam Transfer Optics (BTO) of 325 × 250 × 155 mm(l × w × h) fit between the laser beams and the central elevation axis port.	×				[1]
1.2.1	The telescope dictates that three phase power outlets can be installed if three phase power is required.	×				[5]

Reference	Description	Verification				
		I	A	D	T	Comments
1.2.2	~~The telescope dictates that the System must not draw more than 60 ± 20A of electricity, including equipment already installed.~~		×			EOS Staff have indicated power consumption of existing telescope components is 'low' [5]. MSIR: how low? U: EOS Staff have indicated that the power available is 'greater than previously thought' MSIR what is actual value?
1.2.3	The telescope dictates that the System shall require no more than 6 standard electrical plugs (240 V, 10A) on the top floor of the telescope.	×				Measured 24/03/17
1.2.4	The telescope dictates that the System shall require no more than 3 standard electrical plugs on the second floor of the telescope.	×				Measured 24/03/17
1.2.5	The telescope dictates that the System shall require no more than [8]~~6~~ standard electrical plugs on the first floor of the telescope.	×				~~Measured 24/03/17~~ Measured 18/08/2017
1.3.1	The telescope dictates that incoming laser beams be 2.8mm in width at the $1/e^2$ intensity point of the Gaussian beam.		×			[6]
1.3.2	The telescope requires any free laser beams conform to AS/NZS 2211.1:2004.		×			[6]
1.3.3	The telescope requires any free laser beams conform to ANSI Z136.1-2014 *Safe Use of Laser for Indoors* and Z136.6-2015 *Safe Use of Laser for Outdoors*.		×			[7]
1.4.1	The telescope dictates that a Controller Area Network (CAN) bus should be used for communication via the EOS Observatory Control System (OCS) whenever and wherever possible.	×				[5]

Reference	Description	Verification				
		I	A	D	T	Comments
1.4.2	The telescope dictates that if 1.4.1 can not be complied with, communication be performed using Ethernet infrastructure.	×				[5] Preference.
1.4.3	The telescope dictates that System communication between the dome and the wider system occurs via Ethernet infrastructure.	×				[5]
1.4.4	The telescope dictates that the fibre communication network in the dome cannot be used for the logical interface of the laser control system.	×				[5]
1.4.5	The telescope dictates that 4 Ethernet connections to the EOS OCS are available within the telescope.	×				[5]
1.4.6	The telescope dictates sub-components be controlled by the EOS OCS.	×				[5]
1.4.7	The telescope dictates that automated and remotely accessible laser control systems using the EOS OCS are used wherever possible.	×				[5] Preference.
1.4.8	The telescope dictates sub-components have access to accurate weather data from the dome, external meteorology station and metal truss sensors via the EOS OCS.		×			[5]
1.5.1	The telescope dictates that the System shall account for temperatures up to 28±2°C.				×	[8] U: Reference material doesn't account for highest possible temperatures. Need clarification.
1.5.2	The telescope dictates that the temperature and humidity shall never drop below the dew point.	×				[5]
1.5.3	The telescope dictates that the System shall account for a maximum vibrational input of as specified by the power spectral density specified in figure 3.				×	[8]
1.5.4	The telescope dome dictates that the System shall exist within a dirty and dusty environment.	×				[8]. MSIR: how dirty?

Reference	Description	Verification				
		I	A	D	T	Comments
2.1.1	The EOS GSL dictates that the Laser Head (LH) be mounted on 3 carbon fibre breadboards.	×				[9]
2.1.2	The EOS GSL dictates that the System include 3 breadboards with dimensions of 1800 × 800 × 100 mm (l×w×h).	×				[9]
2.1.3	The EOS GSL dictates that the System include 3 breadboards with a minimum space of 250 mm between them.	×				[9]
2.1.4	The EOS GSL dictates that the gravitational orientation of the System does not change after the EOS GSL is mounted and calibrated.	×				[9]
2.1.5	The EOS GSL dictates that the 3 EOS GSL breadboards be aligned such that all through holes are concentric.				×	[9]
2.1.6	The EOS GSL dictates that the System include 3 EOS GSL breadboards each with optical components weighing 150 ± 50kg.				×	[9]
2.1.7	The EOS GSL dictates that $1/3 \pm 1/6$ of the central EOS GSL breadboard will be free space (ie free volume).	×				[9]
2.1.8	The EOS GSL dictates that the System include an auxiliary Electronics Cabinet (EC) with dimensions of 500 × 500 × 1750 mm (l×w×h). [This cabinet will be within 2m of the system.]	×				[9], **Citation**
2.1.9	The EOS GSL dictates at least 10 power cables must enter the EOS breadboards collectively.	×				[9]
2.1.10	The EOS GSL dictates that 10 ± 2 cooler pipes must enter the EOS GSL breadboards collectively.	×				[9]
2.1.11	The EOS GSL requires that coolers be attached to the System at a distance constrained only by the size of the telescope dome, and the vibrational impact on the lasers.	×				[9]

Reference	Description	Verification				
		I	A	D	T	Comments
2.1.12	The EOS GSL requires that a TermoTek P307-14176 420W ??? cooler with dimensions of 653 × 483 × 267 mm (l×w×h) be connected to the System.	×				[9, 10]
2.1.13	The EOS GSL requires that a ThermScientific Accel 250~~V~~[W] LC cooler with dimensions of 487 × 232 × 620 mm (l×w×h) be connected to the System.	×				[9, 11]
2.1.14	The EOS GSL requires that a ThermScientific Accel 250~~V~~[W] LC cooler with mass of 30kg be connected to the System.	×				[9, 11]
2.1.15	The EOS GSL requires that a TermoTek P307-14176 420W ??? cooler with mass of 40kg be connected to the System.	×				[9, 10]
2.1.16	The EOS GSL requires that the System accounts for the currently unknown vibration from the coolers.	×				[9]. MSIR
2.1.17	The EOS GSL dictates that a deionised water and OptiShield Plus solution be used as a coolant.		×			[9]
2.1.18	The EOS GSL dictates that any coolant additives be 100% soluble in de-ionized water.		×			[9]
2.1.19	The EOS GSL requires that the Thermo-Scientific cooler is re-filled with ≤2.8L of water as necessary.		×			[11]. MSIR: how often?
2.1.20	The EOS GSL requires that the TermoTek cooler is re-filled with ≤2L of water as necessary.		×			[10] MSIR: how often?
2.2.1	The EOS GSL requires 2.4kW of power via a standard single phase (230V / 10A) power socket.			×		[9]
2.2.2	The EOS GSL requires that at most 2 cooling units be connected to the System.	×				[9]
2.2.3	The EOS GSL requires 2 ± 1 standard power plugs for the EC.	×				[9]
2.2.4	The EOS GSL requires 2kW (at 230V/50Hz) via a single phase power socket for the ThermScientific Accel 250V LC cooler.	×				[9]

Reference	Description	Verification				
		I	A	D	T	Comments
2.2.5	The EOS GSL requires 1.5kW (at 230V/50Hz) via a single phase power socket for the TermoTek P307-14176 420W cooler.	×				[9]
2.2.6	The EOS GSL dictates that the current coolant have a conductivity <1500 μS/cm for OptiShield concentrations < 2.5%.		×			[9]
2.3.1	The EOS GSL dictates that a final beam size between 10 μm and 5mm is required.		×			[9]
2.4.1	The EOS GSL requires that one Ethernet cable be connected for engineering and maintenance.	×				[9]
2.4.2	The EOS GSL requires that Ethernet communication with the EOS GSL be conducted using SSH command line protocol.		×			[9]
2.4.3	The EOS GSL requires that CAN bus protocol be used for control.	×				Not currently implemented [9]
2.4.4	The EOS GSL requires connection to the EOS OCS for control and monitoring.				×	[9]
2.5.1	The EOS GSL requires no special ambient temperature conditions.			×		[9]
2.5.2	The EOS GSL dictates that one of the 3 EOS GSL breadboard shall contain several beam dumps which will produce heat.	×				[9]. MSIR: how much heat?
2.5.3	The EOS GSL dictates that the central board will contain a peltiair box which will produce 15 ± 5 W of excess heat.	×				[9]
2.5.4	The EOS GSL requires that it is not exposed to vibration an order of magnitude greater than the power spectral density shown in figure 2.				×	[9]
2.5.5	The EOS GSL requires air quality to 10 000 class clean room standards.		×			[9]
2.5.6	The EOS GSL requires that the area in which the System is located has an anti-static floor.	×				[9]
2.5.7	The EOS GSL requires that the area in which the System is located has a non-conductive floor.	×				[9]

Reference	Description	Verification				
		I	A	D	T	Comments
2.5.8	The EOS GSL requires humidity below 50%.				×	[9]
2.5.9	The EOS GSL requires that the 1050nm laser assembly be kept at a temperature of 20±1°C.	×				[9]
2.5.10	The EOS GSL requires that the amplifier components of the 1342nm laser assembly be kept at a temperature of 17±1°C.	×				[9]
3.1.1	~~The Toptica GSL dictates that the System shall account for a LH with dimensions 900 × 700 × 400 mm (l × w × h) .~~	×				[12] (difference with [13])
3.1.2	~~The Toptica GSL dictates that the System shall account for an external EC of 900 × 900 × 1730 mm (l × w × h) .~~	×				[12]
3.1.3	~~The Toptica GSL dictates the maximum distance between EC and LH is defined by the length of the pump fibre.~~	×				[13]
3.1.4	~~The Toptica GSL dictates that the total length of the pump fibre from Raman Fibre Amplifier (RFA) to Fibre Laser Pump Module (FLPM) shall be as short as possible; a total length below~~ [redacted] ~~is highly recommended.~~	×				[13]
3.1.5	~~The Toptica GSL dictates that the System shall account for a LH with a weight of no less than 90kg.~~	×				[12]
3.1.6	~~The Toptica GSL dictates that the System shall account for a 600kg EC.~~		×			[12]
3.1.7	~~The Toptica GSL dictates that a splice can be included on the optical cable near the LH if more than 27m of separation is required between the LH and EC.~~	×				[13]
3.1.8	~~The Toptica GSL dictates that the LH must not undergo an angular velocity greater than~~ [redacted] ~~°/s in the azimuth orientation.~~				×	[13]
3.1.9	~~The Toptica GSL dictates that the LH must not undergo an angular velocity greater than~~ [redacted] ~~°/s in the altitude orientation.~~				×	[13]

Reference	Description	Verification				
		I	A	D	T	Comments
3.1.10	~~The Toptica GSL dictates that the LH must not undergo an angular acceleration greater than~~ [redacted] ~~$^{\circ}/s^2$ in the azimuth orientation.~~				×	[13]
3.1.11	~~The Toptica GSL dictates that the LH must not undergo an angular acceleration greater than~~ [redacted] ~~$^{\circ}/s^2$ in the altitude orientation.~~				×	[13]
3.1.12	~~The Toptica GSL dictates that coolant used to cool the LH and EC must contain particles with diameters no larger than~~ [redacted] ~~μm.~~	×				[13]
3.1.13	~~The Toptica GSL dictates that coolant used must have a flow rate between~~ [redacted] ~~and~~ [redacted] ~~L/min to the LH.~~	×				[13]
3.1.14	~~The Toptica GSL dictates that coolant used must have a maximum flow rate of 5litres/min.~~	×				[12] (difference with [13])
3.1.15	~~The Toptica GSL dictates that coolant used must have a pressure drop of at most~~ [redacted] ~~bar through the LH.~~			×		[13]
3.1.16	~~The Toptica GSL dictates that coolant used must have a pressure drop of at most~~ [redacted] ~~bar through the EC.~~			×		[13]
3.1.17	~~The Toptica GSL dictates that coolant used must have an inlet pressure of~~ [redacted] ~~bar to the LH.~~		×			[13]
3.1.18	~~The Toptica GSL dictates that coolant used must have an inlet pressure of~~ [redacted] ~~bar in the EC.~~		×			[13]
3.2.1	~~The Toptica GSL dictates that the System shall incorporate an uninterrupted power supply for 15 minutes of autonomous backup power.~~		×			[14] Preference.
3.2.2	~~The Toptica GSL dictates that no more than 1kW of power be provided to the Toptica GSL and it's peripherals.~~				×	[12].
3.2.3	~~The Toptica GSL dictates that coolant used by the System must have a maximum conductivity of~~ [redacted] ~~μS/cm.~~	×				[13]
3.3.1	~~The Toptica GSL dictates that the output beam waist diameter be 3 mm.~~	×				[12]

Reference	Description	Verification				
		I	A	D	T	Comments
3.3.2	~~The Toptica GSL dictates that the output beam has a wavelength of 589.159nm.~~	×				[12]
3.3.3	~~The Toptica GSL dictates that the output beam waist location be [redacted]±[redacted] m.~~	×				[13]
3.3.4	~~The Toptica GSL dictates that the max pointing be 0.16mrad RMS.~~	×				[12]
3.3.5	~~The Toptica GSL dictates that the max lateral shift be 50 μm RMS.~~	×				[12]
3.3.6	~~The Toptica GSL dictates that the output beam has a wavelength of ±5pm.~~	×				[12]
3.3.7	~~The Toptica GSL dictates that the output wavelength stabilised to the peak of the sodium D2a line have absolute wavelength accuracy of ±40MHz.~~	×				[12]
3.3.8	~~The Toptica GSL dictates that the output beam have an ellipticity of < 7%.~~	×				[12]
3.3.9	~~The Toptica GSL dictates that the continuously-broadened D2a centred envelope max line width when averaged over 10ms be [redacted]MHz FWHM.~~	×				[13]
3.3.10	~~The Toptica GSL dictates that the beam output power be ≥20W.~~		×			[12]
3.3.11	~~The Toptica GSL dictates that the beam line-width be 5MHz~~	×				[12]
3.3.12	~~The Toptica GSL dictates that the D2b line output power be [redacted]% of total output power.~~		×			[13]
3.3.13	~~The Toptica GSL dictates that the D2b line central frequency be [redacted]GHz higher than the D2a line.~~		×			[13]
3.3.14	~~The Toptica GSL dictates that the minimum in-band power within ±1MHz of the D2a peak be ≥[redacted]%.~~		×			[13]
3.3.15	~~The Toptica GSL dictates that the minimum long term power stability (average over 1s) be ≥[redacted] RMS.~~		×			[13]
3.3.16	~~The Toptica GSL dictates that the maximum intensity noise (on a 10ms time line) be ≤[redacted]% RMS.~~		×			[13]
3.3.17	~~The Toptica GSL dictates that the maximum output beam wavefront error over an area of the diameter equal to twice the wave diameter be < 70nm RMS.~~		×			[12]

Reference	Description	Verification				
		I	A	D	T	Comments
3.3.18	~~The Toptica GSL dictates that the output beam asymmetry at all distances be between [redacted] and [redacted].~~		×			[13]
3.3.19	~~The Toptica GSL dictates that the minimum polarisation ratio be 100:1.~~		×			[12]
3.3.20	~~The Toptica GSL dictates that the polarisation direction have an accuracy of [redacted]°.~~		×			[13]
3.3.21	~~The Toptica GSL dictates that the maximum polarisation direction variation (averaged over 1s) be [redacted]° P-P.~~	×				[13]
3.3.22	~~The Toptica GSL dictates that the maximum linear polarisation stability be 5°.~~	×				[12].
3.3.23	~~The Toptica GSL dictates that the re-pumper amplitude be no greater than 10%.~~	×				[12]
3.3.24	~~The Toptica GSL dictates that the toggle shift away from D2a be done at [redacted]GHz.~~		×			[13]
3.3.25	~~The Toptica GSL dictates that the toggle away from D2a be undertaken in ≤[redacted] s~~		×			[13]
3.3.26	~~The Toptica GSL dictates that the maximum instability of all other beam properties be ≤[redacted]%.~~		×			[13]
3.3.27	~~The Toptica GSL dictates that the ratio of maximum relative optical inside the 580-600nm range to outside the 580-600nm range be ≤[redacted].~~		×			[13]
3.4.1	~~*See Confidential Version for Toptica Control Requirements.*~~	×				
3.5.1	~~The Toptica GSL dictates that the LH and EC be located within an ambient temperature no less than -10°C.~~				×	[12]
3.5.2	~~The Toptica GSL dictates that the LH and EC be located within an ambient temperature no greater than 20°C.~~				×	[12]

Reference	Description	Verification				
		I	A	D	T	Comments
3.5.3	~~The Toptica GSL dictates that the System be located at an altitude of no greater than 4300m above sea level.~~			×		[12]
3.5.4	~~The Toptica GSL dictates that the LH temperature must not deviate by more than 1.5°C from the surrounding ambient air.~~				×	[15]
3.5.5	~~The Toptica GSL dictates that the LH must not be exposed to a relative humidity of less than [redacted]%.~~				×	[13]
3.5.6	~~The Toptica GSL dictates that the LH must not be exposed to a relative humidity greater than [redacted]%.~~				×	[13]
3.5.7	~~The Toptica GSL dictates that coolant used in the LH must be [redacted] vol% glycol with water additives.~~	×				[13]
3.5.8	~~The Toptica GSL dictates that coolant used in the EC must be [redacted] vol% glycol with water additives.~~	×				[13]
3.5.9	~~The Toptica GSL dictates that coolant used in the LH must have an inlet temperature no greater than 15±0.75°C.~~				×	[12]
3.5.10	~~The Toptica GSL dictates that coolant used in the EC must have an inlet temperature no greater than [redacted]±[redacted]°C.~~				×	[13]
3.5.11	~~The Toptica GSL requires that the area in which the System is located has an anti-static floor.~~	×				[6]
3.5.12	~~The Toptica GSL requires that the area in which the System is located has a non-conductive floor.~~	×				[6]
4.1.1	The ANU GSL dictates that the System shall account for a LH of 610 × 305 ×305 mm (l×w×h).	×				[16]
4.1.2	The ANU GSL dictates that the System shall account for an auxiliary EC of at maximum 900 × 900 ×1750mm (l×w×h).	×				[16]
4.1.3	The ANU GSL dictates that the ANU GSL LH be field replaceable.			×		[16]

Reference	**Description**	**Verification**				
		I	**A**	**D**	**T**	**Comments**
4.1.4	The telescope dictates that the ANU GSL be connected to a power supply via 1 standard power socket	×				[16]
4.5.1	The ANU GSL requires that area in which the laser is located to have anti-static floor.	×				[16]
4.5.2	The ANU GSL requires that area in which the laser is located to have non-conductive floor.	×				[16]

Table 1: Requirements Verification Matrix

1.3 Conflict Identification

Conflicts between the requirements identified above are presented here in Table **??**. This table lists the numeric references for requirements which are in conflict, describes the nature of the conflict, and lists potential solutions. When listing the conflicting requirements, brackets are used to indicate that requirements conflict when considered cumulatively.

Conflicting Requirements	**Conflict Description**	**Potential Solutions**
1.1.11 and 1.1.12 with 2.1.8, ~~confidential Toptica dimensions~~, 4.1.2, 2.1.12, 2.1.13	Space constraints for auxiliary equipment (electronics cabinets and coolers).	There is enough floor space and all of the cabinets are within the height restriction at the present time.
1.2.2 with 2.2.1, 2.2.2, 2.2.3, 2.2.4, 2.2.5, ~~Confidential Toptica requirements~~	Limitations of the available power draw. All lasers together at maximum power draw need [approximately 36A] ~~over 40A~~ at standard 230V.	Determine the exact power draw available as it may not be an issue. Do not operate more than one laser at a time.
1.5.3 with 2.1.16 and 2.5.4	Vibration limitations due to multiple GSL systems. Vibrations are too big for the EOS laser, need more information on ~~Toptica GSL and~~ ANU GSL.	Physical isolation of GSL systems through vibration absorbing mounts [or relocation of oscillators]
1.5.2 with 2.5.8 ~~and (confidential Toptica 3.5.4)~~	Humidity could reach higher than tolerable limit.	Construct a climate-controlled environment around the System.
1.5.4 with 2.5.5	Air quality may not be sufficient for laser propagation. Need to measure air quality in dome.	Construct a climate-controlled environment around the System.
1.3.2 and 1.3.3 with 2.3.1 and ~~(confidential Toptica~~, and ANU GSL requirements)	Possibility that laser beams don't conform to Australian safety standards	Ensure that any free laser beams conform with AS/NZS 2211.1:2004 and ANSI Z16.1-2014.
1.2.3 and 1.2.4 and 1.2.5 with 2.2.1 and 2.2.3 and 2.2.4 and 2.2.5, **??**, and ~~(Toptica GSL power socket requirements)~~	Required power sockets exceeds available. While there are sufficient sockets in the dome, there may not be enough on the Observation Floor, where most of the equipment will be.	Extension cords and power boards. U: Problem severity reduced by removal of Toptica. Some EOS components may be placed on different floors (Clarification)

Conflicting Requirements	Conflict Description	Potential Solutions
1.1.5 with 2.1.2, 2.1.3, 2.1.6, 3.1.1, 3.1.5, (ANU GSL size and weight)	The size and mass of the System may place an unacceptable stress on the bolts mounting it to the telescope.	Additional supports loading either the Observation floor or off the top of the telescope.
1.4.1 and 1.4.3 with (~~Toptica and~~ ANU GSL) communication protocols	The communication protocols of the ANU GSL may not be CAN or Ethernet standard.	Custom interfaces can be developed if necessary.
1.5.1 with 2.5.9, 3.5.2, (confidential Toptica 3.5.1-3)), 2.5.10, 2.5.2 2.5.3	The temperature of the System might exceed the ability of the System to cool it adequately. The dome is not actively cooled and can reach a temperature of 28° [Possibly 30deg - to be discussed].	Install additional coolers/increase cooler workload/Turn things off.
The telescope dome floor with 2.5.6, 2.5.7, 3.5.11, 3.5.12, 4.5.1, 4.5.2	The telescope dome floor is conductive and may produce static electricity	Non-conductive and anti-static mats.
1.4.7 and 1.4.6 with (System compatibility with CAN bus protocol)	Possibly unable to achieve remote control due to incompatible communication protocols	Develop bespoke interface between systems.
1.4.5 with 2.4.1, 2.4.4, ~~(confidential Toptica)~~	That there may be less Ethernet ports in the dome that link to the EOS Control Room than are required by the System.	Install extra ports

2 System Specifications

	EOS GSL	~~**Toptica GSL**~~	**ANU GSL**	**Total**	**Required by Telescope/Dome**
Laser Head Mass (kg)	450±150	~~80~~	MSIR		<2000
Laser Head Size (mm^3)	(1800×800×800)	~~(925×720× 440)~~	MSIR		MSIR
Electronics Cabinet Mass (kg)	MSIR	~~600~~	MSIR		1
Electronics Cabinet Size (mm^3)	(500×500×1750)	~~(930×910×1726)~~	'likely to be no bigger than (930×910×1726)' [16]	(500×500×1750) + (930×910×1726)	2
Cooler Mass (kg)	30 + 40	-	-	30 + 40	1
Cooler Size (mm^3)	(653×483×26) + (487×232×620)	-	-	(653×483×26) + (487×232×620)	2
Power Draw (W)	2400+2000+1500	~~≤1000~~	MSIR		MSIR
Power Sockets	2±1+1+1+1+1	~~1~~	MSIR		14

Table 3: Subsystems v Key Requirements

1. While the mass of any of these individual components is not constrained by the telescope or dome, the total mass of the System is constrained by (1.1.9).
2. While the size of any of these individual components is not constrained by the telescope or dome, the total size of all these components is constrained by the total space within the dome.

Note: Once again, the comment 'MSIR' indicates that more information is required. In this table, this comment has been used to indicate that many requirements for the ANU GSL are still unknown.

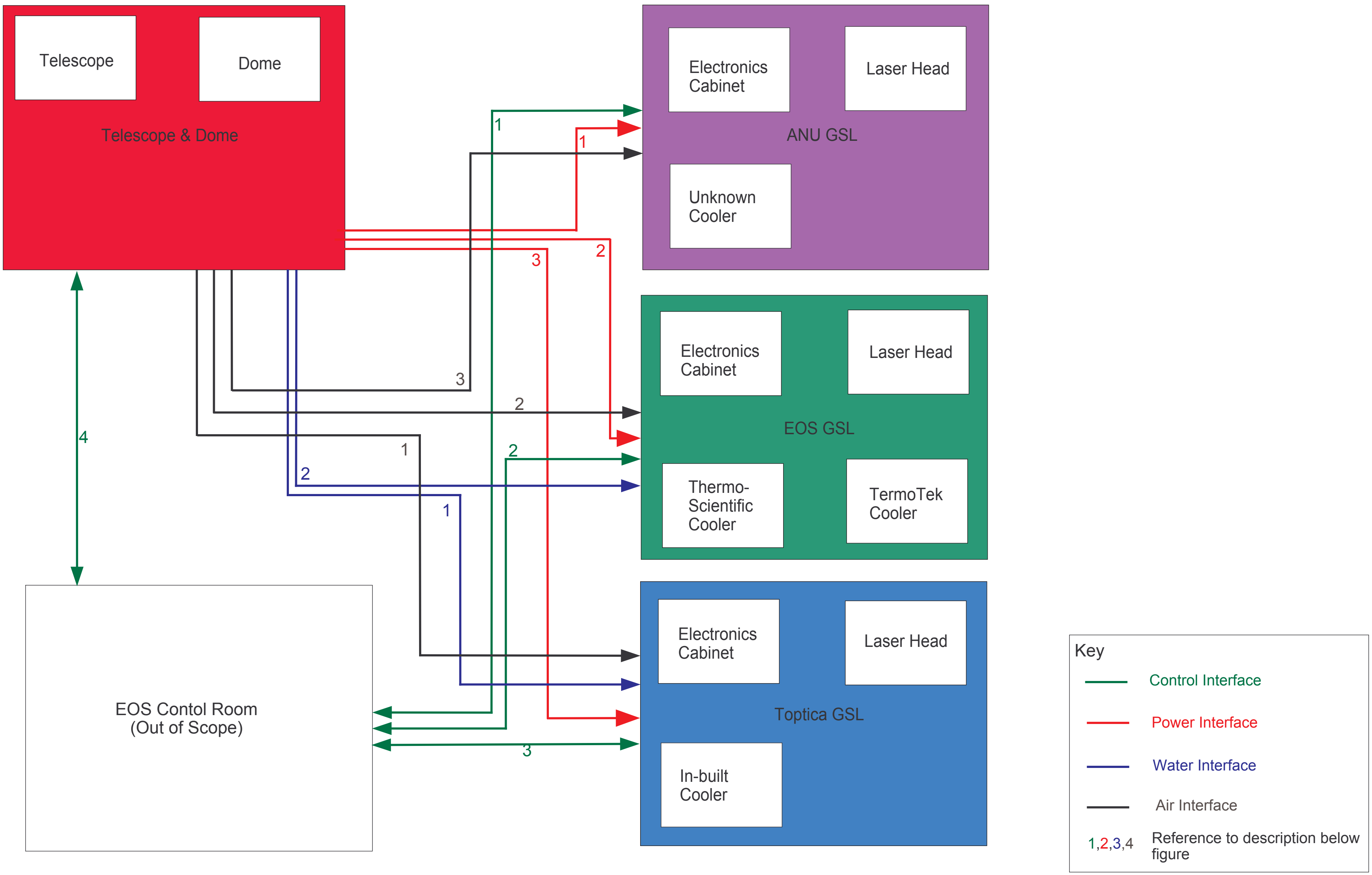

Figure 1: High Level System Interface

2.1 High Level Interface Description

The High Level Interface shown in Figure 1 illustrates how the various components within the System will need to interact. The numbers in the figure are a reference to the descriptions provided below in Table 4.

Reference	Description	Interface	Requirem
1.	Control interface between ANU GSL and the EOS control room	CAN interface via Ethernet	(1.4.1), (1.
2.	Control interface between EOS GSL and EOS control room	CAN for control and Ethernet for SSH.	(2.
~~3.~~	~~Control interface betweenToptica GSL and EOS control room~~	[redacted]	
4.	Control interface between Telescope/Dome and EOS control room	CAN interface via Ethernet	(1.
1.	Power interface between Dome and ANU GSL	1 socket, UNKNOWN power draw	
2.	Power interface between Dome and EOS GSL	2±1 socket(s) for the electronics cabinet, 1 socket for the laser head, 2.4kW power draw for the GSL, 1 socket and 2kW for the Thermo-Scientific Cooler, 1 and 1.5kW socket for the Termotek Cooler	(2.2.1), (2.
~~3.~~	~~Power interface betweenDome and Toptica GSL~~	[redacted] ~~socket(s) and ≤1kW for the Toptica GSL and it's peripherals~~	~~(3.2~~
~~1.~~	~~Water interface between Dome and Toptica GSL~~	~~MSIR: ask James Webb~~	

2.	Water interface between Dome and EOS GSL	2.8L of water in the TermoTek cooler to be replaced when required, 2L of water in the Thermo-Scientific cooler to be replaced as required	(2.1
1.	Air interface between Dome and ANU GSL	Unknown Requirements	
2.	Air interface between Dome and EOS GSL	Air quality to ISO class 7 clean room standards	
~~3.~~	~~Air interface betweenDome and Toptica GSL~~	~~Air with an ambient temperature of between-10°C and 20°C~~	~~(3.~~

Table 4: High Level Interface Description

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[1] Mark Blundell. Personal Communication 24/03/17.

[2] Nick Herald. Personal Communication 24/03/17.

[3] EOS Space Systems. Eos dome solidworks models.

[4] Firestone. Marsh mellow vibration isolation design manual. Website. URL `http://www.airsprings.com.au/products/firestone-marsh-mellow-isolators/`.

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[10] TermoTek. Termotek p300 series chiller. Manual. URL `http://www.termotek-ag.com/uploads/tx_usertermotek/P300_01.pdf`.

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[14] Domenico Bonaccini Calia, Axel Friedenauer, Vladimir Protopopov, I Guidolin, Luke R Taylor, Vladimir I Karpov, Manfred Hager, Wallace R L Clements, Bernhard Ernstberger, Steffan Lewis, and Wilhelm G Kaenders. PM fiber lasers at 589nm: a 20W transportable laser system for LGS return flux studies. In Brent L Ellerbroek, Michael Hart, Norbert Hubin, and Peter L Wizinowich, editors, *SPIE Astronomical Telescopes + Instrumentation*, pages 77361U–77361U–12. SPIE, July 2010.

[15] Martin Enderlein, Axel Friedenauer, Robin Schwerdt, Paul Rehme, Daoping Wei, Vladimir Karpov, Bernhard Ernstberger, Patrick Leisching, Wallace R L Clements, and Wilhelm G Kaenders. Series production of next-generation guide-star lasers at TOPTICA and MPBC. In Enrico Marchetti, Laird M Close, and Jean-Pierre Véran, editors, *SPIE Astronomical Telescopes + Instrumentation*, pages 914807–914807–11. SPIE, July 2014.

[16] Céline d'Orgeville. Personal Communication 24/03/17.

Appendix

A Power Spectral Densities

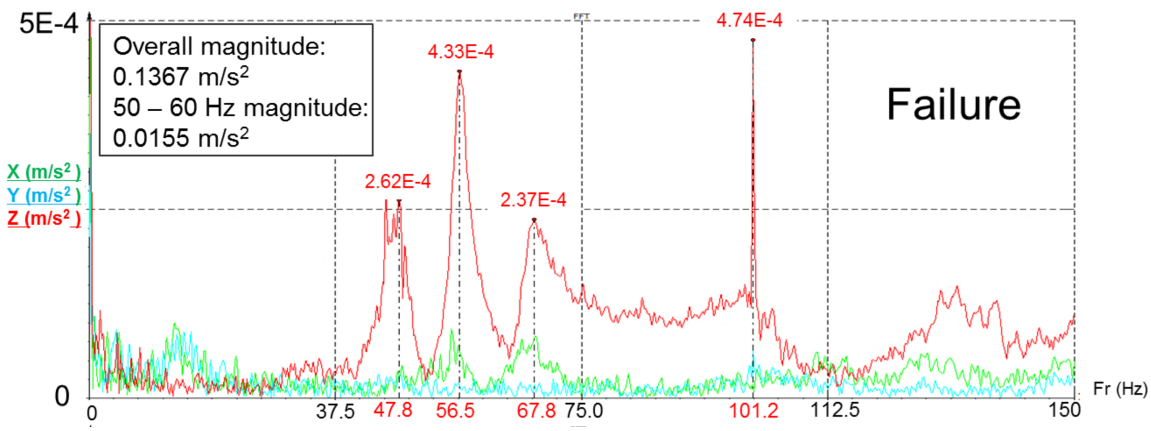

Figure 2: Power spectral density which caused the EOS GSL to fail in 2015.

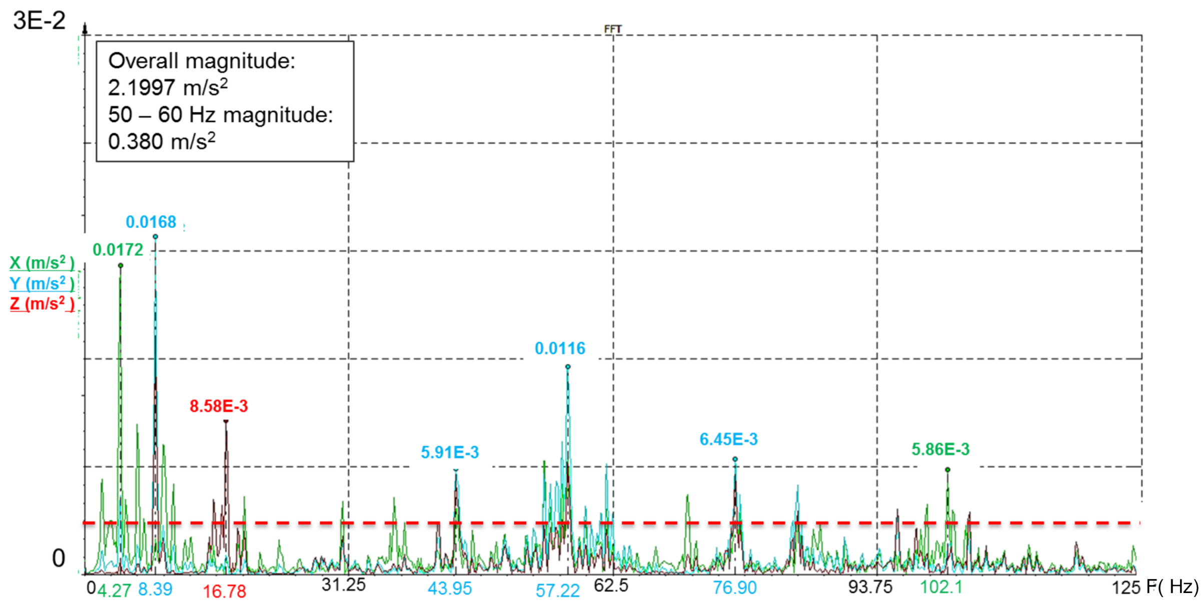

Figure 3: Power spectral density of the vibration of the mounting plate on the telescope while tracking a target. Red line indicates level of peaks from figure 2.

B Main Shutter

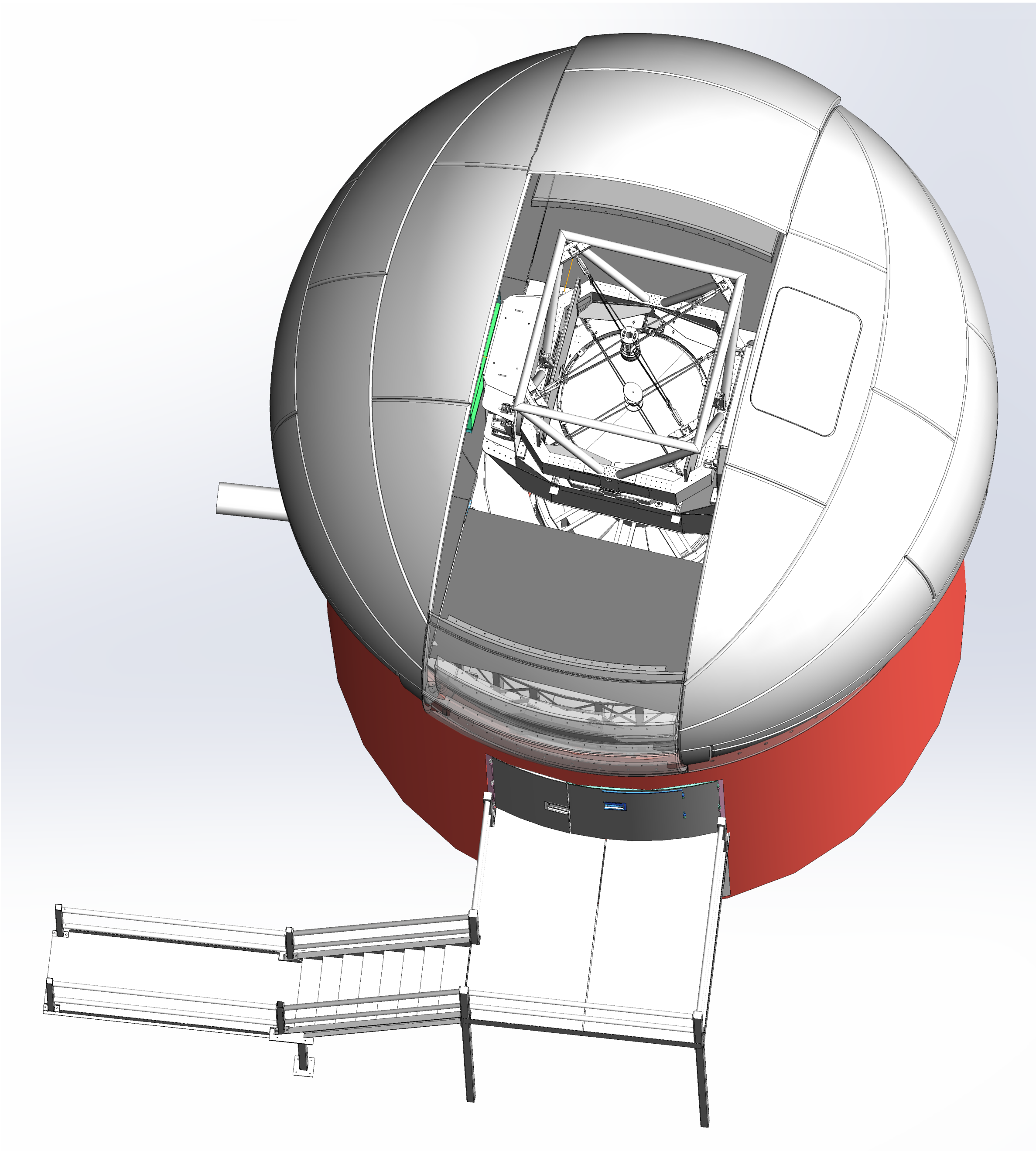

Figure 4: Main shutter of EOS 1.8m telescope

C Telescope levels

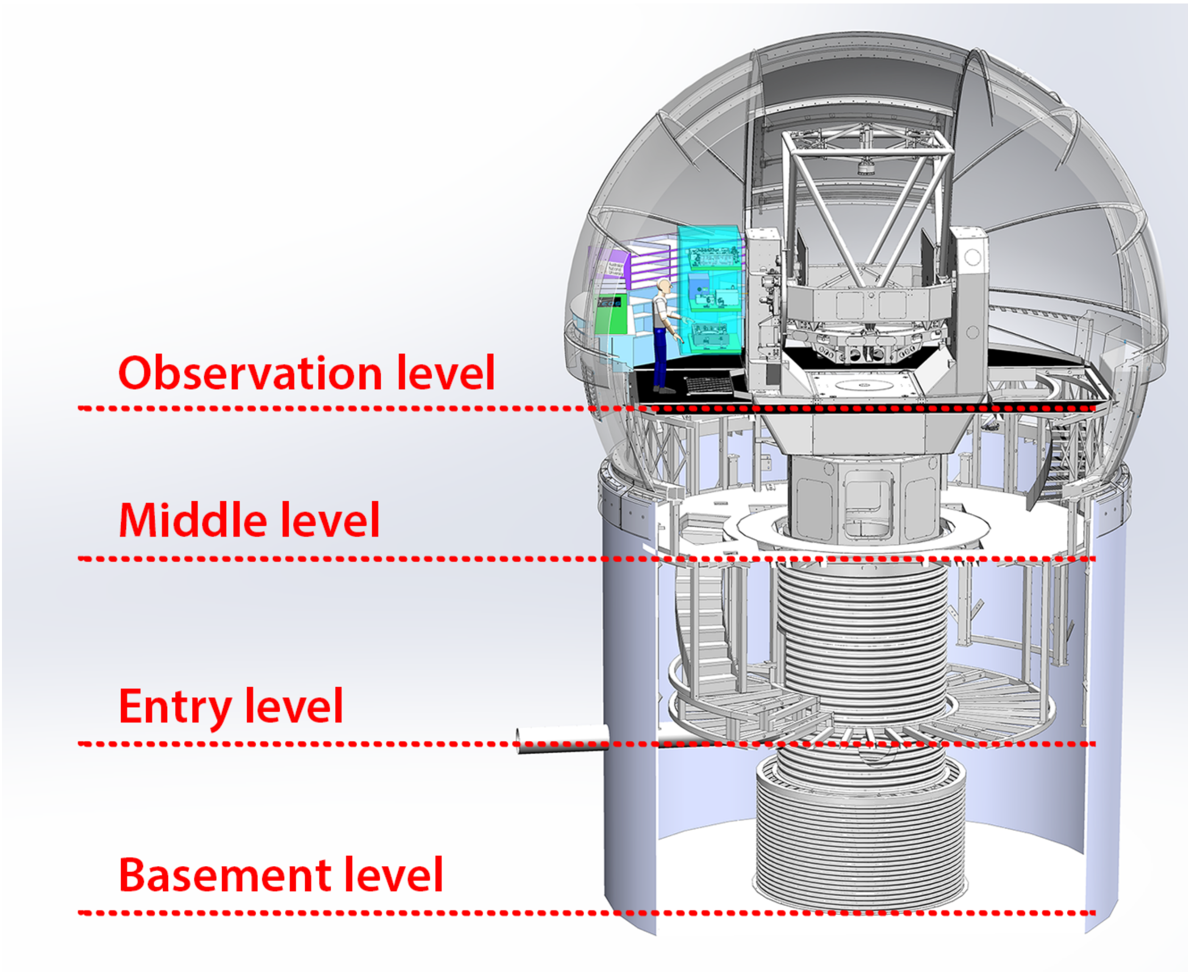

Figure 5: Entry, middle and observation floors of the EOS 1.8m telescope

D Mounting Plate

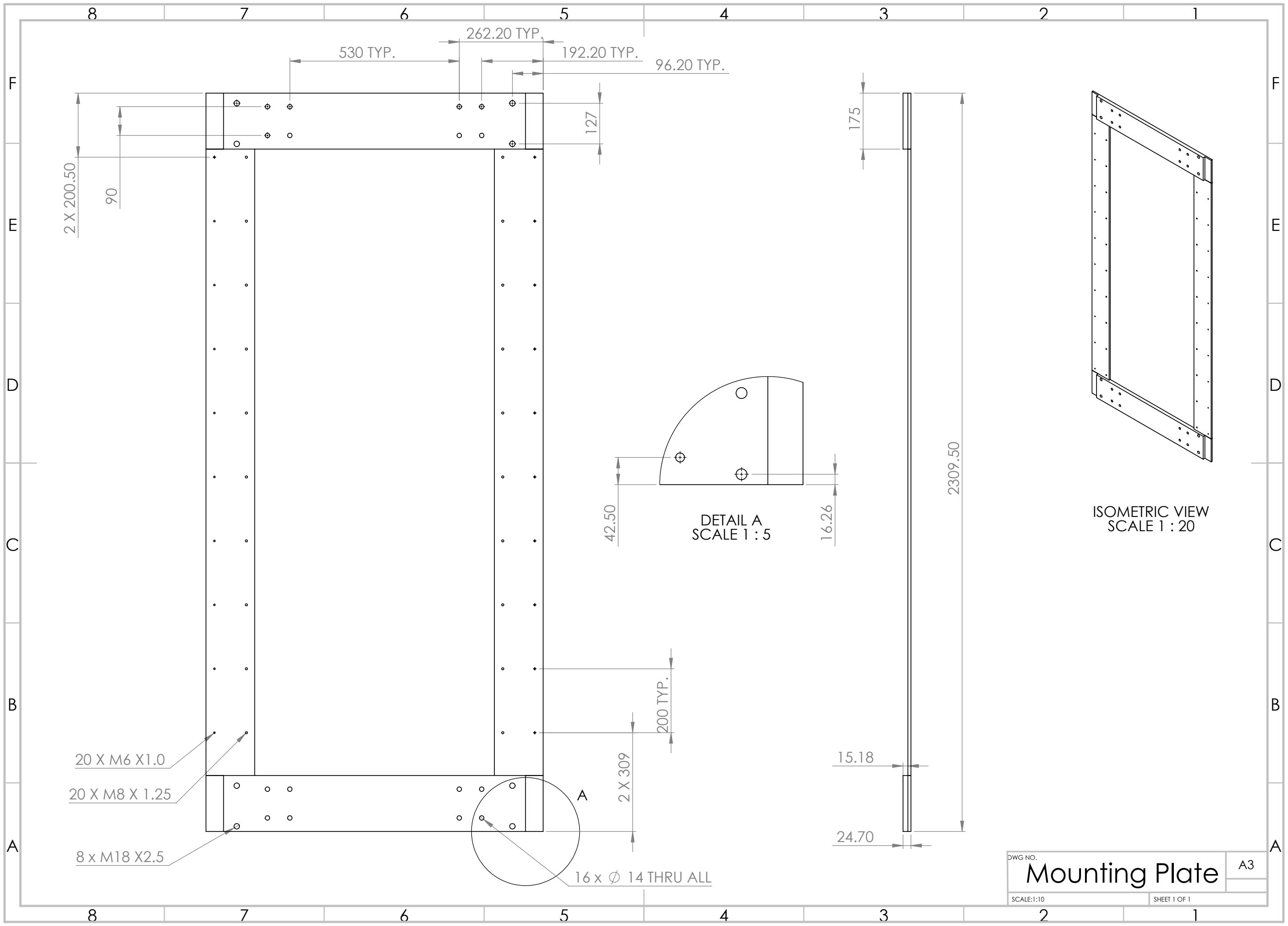

Figure 6: Mounting Plate of EOS 1.8m Telescope

E Observation Floor Hatch

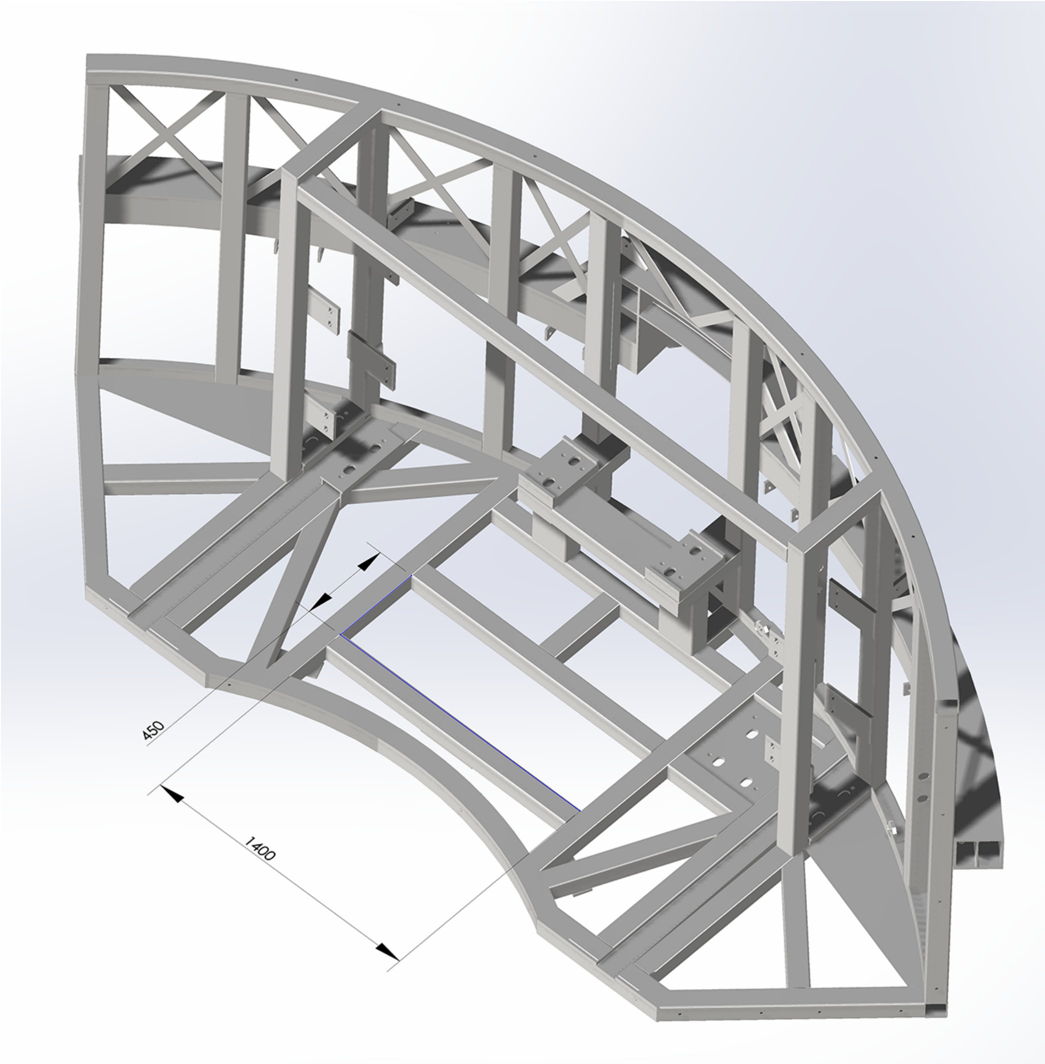

Figure 7: Removable floor hatch on observation floor in EOS 1.8m telescope

F Observation Floor Bench Space

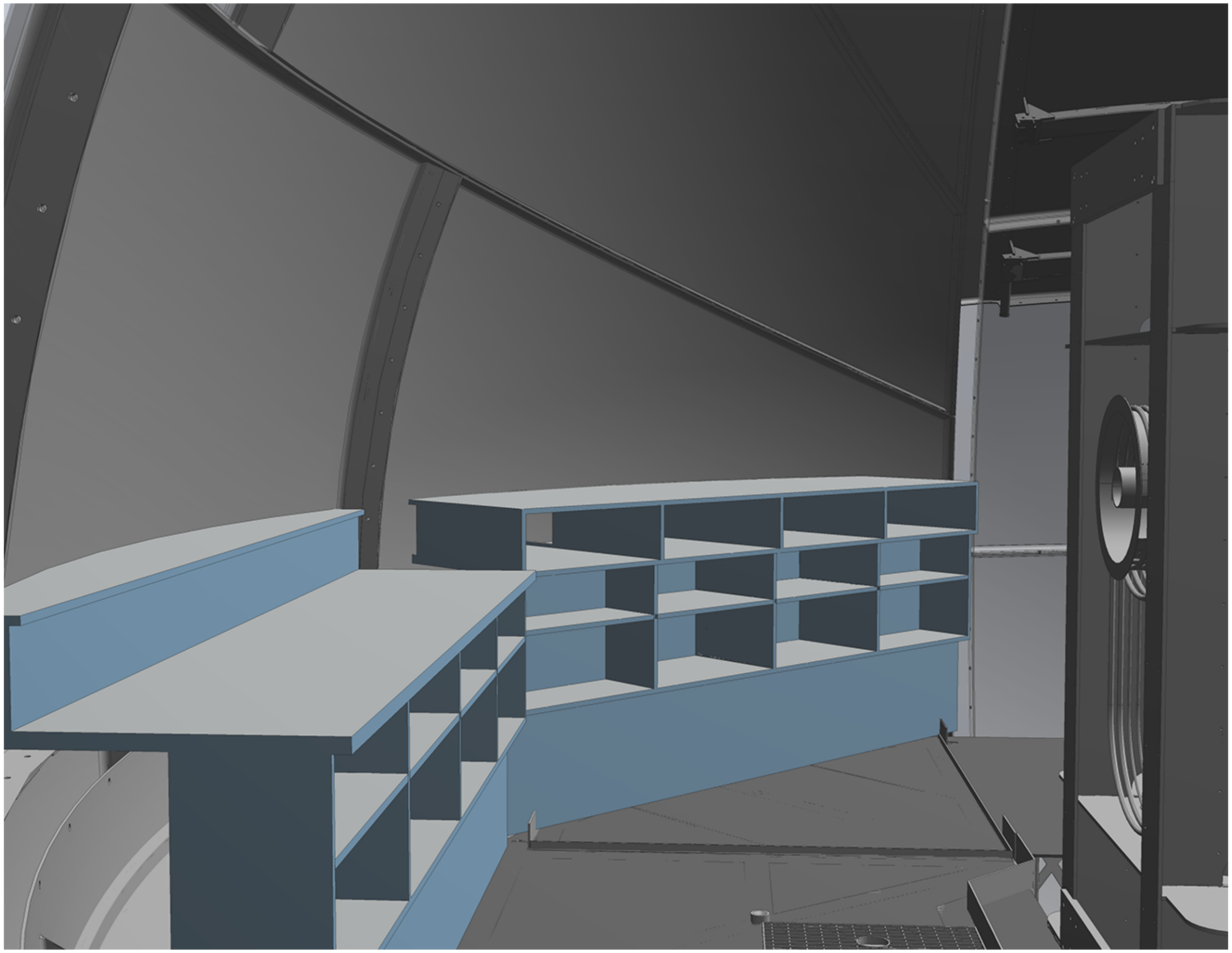

Figure 8: Bench space available on the observation floor

G Photographs of Observation Level

(a) Observation level: side view

(b) Observation level: second bench space

Figure 9: Photographs of observation level of EOS 1.8m telescope

H Photograph of Mounting Plate

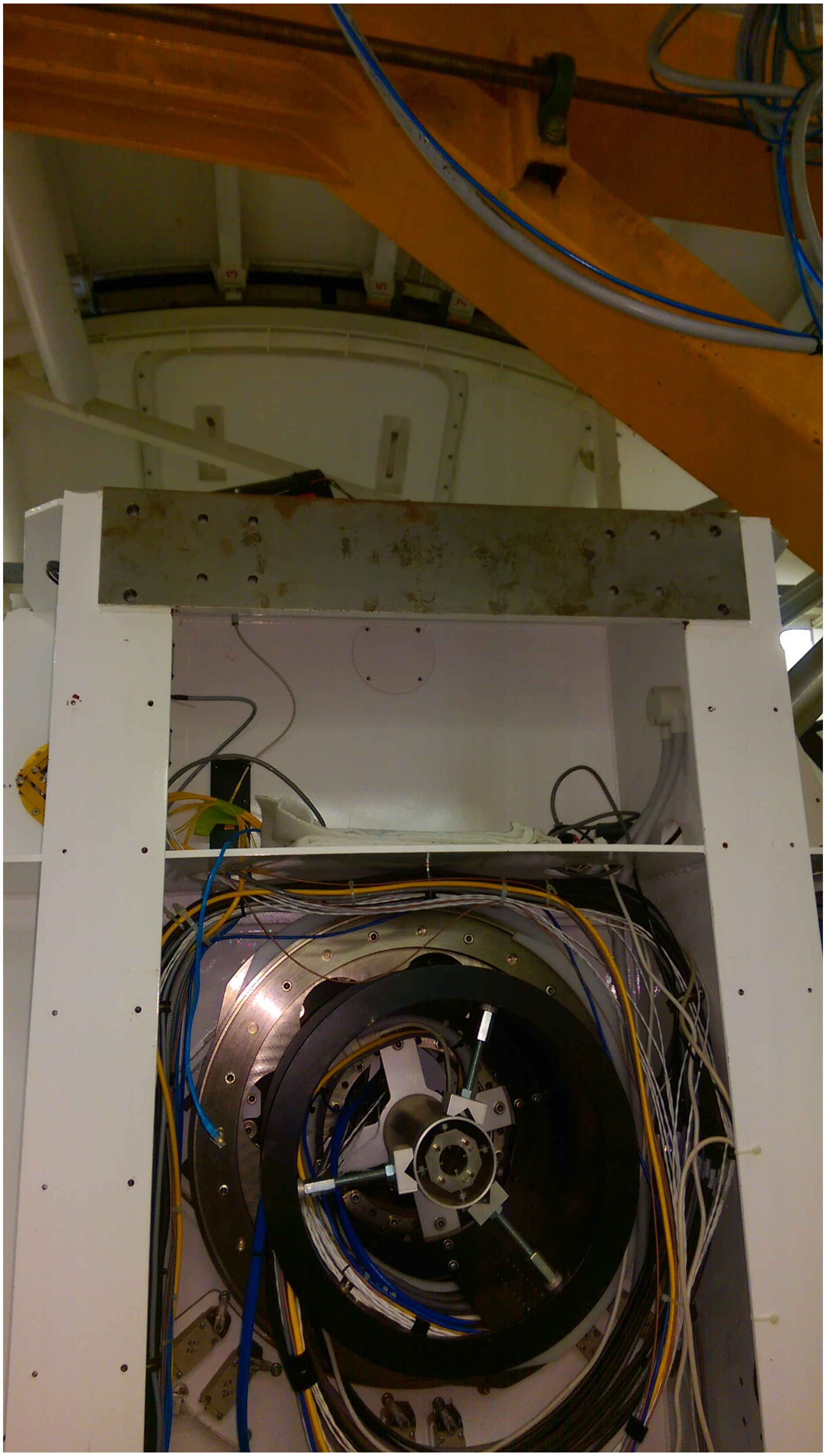

Figure 10: Photograph of mounting plate (observation level)

I Photographs of Middle Level

(a) Middle level floor space (b) Middle level floor height (c) Middle level floor height

Figure 11: Photographs of middle level highlighting floor space and height

J Photographs of Entry Level

(a) Entry level floor space (b) Entry level floor space (c) Entry level floor space

Figure 12: Photographs of middle level highlighting floor space and height