Australian National University

Environmental Subsystem Design

Prepared For

Advanced Instrumentation and Technology Centre

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Acronyms

ANU Australian National University.

EOS Electro-Optic Systems.

GSL Guide Star Laser.

HEPA High-Efficiency Particulate Air.

1 Introduction

The enclosure containing the two lasers is mounted onto the side of the telescope. It contains several components within it that produce heat, which has a direct impact on the temperature and turbulence air within the enclosure. This is partially mitigated through the usage of liquid-to-air cooling systems attached to the components, however it is not entirely removed. Additionally, the dome is not a controlled environment due to both vents in the walls and the shutter being open during operation, meaning the environment surrounding the enclosure varies significantly. This means that the air quality within the enclosure must be controlled to ensure the propagation of the laser beams is not negatively impacted.

For these reasons, the laser enclosure is required to be a closed system, ensuring that the temperature of the various components will be controlled, as well as controlling the air quality around the laser beams. This also addresses the requirement of ensuring that the air inside the dome, specifically around the primary mirror, will be free from turbulences introduced by heated air from the system.

The following sections detail the specifics of the three subsystems, focussing on the control of air quality through filtration, the control of air temperature within the enclosure, and the cooling of laser components.

2 Air Quality Control Subsystem

The air quality subsystem relates to the air quality within the laser enclosure. For adequate laser propagation, the air needs to filtered to remove particulate matter, and have air flow sufficiently low so as to not introduce turbulence.

2.1 Requirements

The requirements for the design of the laser enclosures air quality controls are taken from the updated system subsystem document [1], and are reproduced here. These requirements are listed in table 1.

Table 1: System Requirements [1]

Reference	Description
1.5.5	The telescope dome dictates that the System shall exist within a dirty and dusty environment.
1.5.2	The telescope dome dictates that the System shall not produce excessive hot air turbulence within the dome
1.5.5	The telescope dome dictates that the System shall exist within a dirty and dusty environment
2.5.5	The Electro-Optic Systems (EOS) Guide Star Laser (GSL) requires air quality to ISO class 7 clean room standards.
3.2.2	The Australian National University (ANU) GSL requires air quality to ISO class 7 clean room standards surrounding the laser-head

2.2 Design Details

To ensure that the air quality is maintained at ISO class 7 clean room standard, we utilise design components from other pre-existing systems. Testing of such a design was unable to be completed without the unit being assembled, so assumptions have been made, however these have been detailed where necessary.

The standard design for a clean room utilises positive air pressure, an area of High-Efficiency Particulate Air (HEPA) filters that the air travels through, and airflow controls to make it as laminar as possible [2]. This is necessary due to the large volume of the room, and the regular traffic that is seen inside. On a smaller scale we see laser enclosure systems similar to this one utilising different combinations of the components. The typical arrangement is a dry-air input valve passing air through a HEPA-filter, maintaining positive pressure [3]. Due to the beadboards and the components on them causing interference to the airflow, we do not typically see a laminar airflow, however the low air velocity and temperature uniformity mitigate this issue [4]. Additionally, due to the size and structure of the system, turbulence within the enclosure is of little concern [5].

The two possible options for the air intake are an open loop or a closed loop system. The open loop system proved to be largely inferior in design, so was removed from consideration.

2.2.1 Closed Loop System

The closed loop system is preferred, due to the simplicity of the system. This is due to the air being recycled, rather than needing to be vented elsewhere, requiring extensive ducting throughout the dome. By placing a HEPA filter and fan on the air intake at the top of the enclosure, with a return-air pipe at the base of the enclosure running the air back through the filter, we remove the need to constantly filter outside air.

This limits the work requirement from the filter, extending its maintenance cycle substantially. A typical filter should be replaced every 2 years, however for a filter with only a small workload, the effective life can be indefinite [6].

The closed loop system has a second advantage, in that the heating and cooling of the enclosure is easier. With the air circulating within the enclosure, the main consideration for heat exchange is through convection from the surface of the enclosure to the dome (or vice versa), and does not need to include the heat lost or gained by taking in outside air constantly.

The single advantage that the open-loop system had over the closed-loop was by venting out air away from the dome (piping the air externally). This had the benefit of removing the heated air at a location away from the system. The fall back of this, however, is that more heat is required to be produced, and the convection of heat from the closure is the same, regardless of the loop chosen. This was further supported by the proposed enclosure cooling design (see section 3.4.2, where the heat will be extracted with the rest of the system heat through the chillers on the entry level.

2.3 Air Flow Requirements

The required air flow for good performance from a HEPA filter is approximately 0.45m/s [7, 8]. Using a filter size of approximately 120mm × 120mm, we get a flow rate of $6.48 \times 10^{-3} m^3/s$, or 6.48L/s.

With an enclosure volume of approximately $1.824m^3$ [9], we see that it takes approximately 282 seconds to fully cycle the air within the enclosure, allowing 12 full air cycles per hour. This is approximately one third of the number of cycles that is recommended for a full size clean room to ISO Class 7 [10], however, this is likely to be sufficient for an enclosure that is mostly closed to the environment, and much smaller in size [5].

If the performance proves to be insufficient, it is recommended to include a second filter in parallel with the first, increasing the number of cycles to 24 per hour, however this is likely to be unnecessary.

3 Enclosure Temperature Control Subsystem

This section looks at different methods for control of the ambient air temperature within the enclosure. This is important to control due to high temperature variation, as well as temperature critical components such as the components of the cooling system that lie within the enclosure. Specific temperature control systems for individual components are detailed in section 5.

3.1 Requirements

The interior of the dome sees large fluctuations in temperature, due to the high seasonal variation of temperature that is seen at Mt. Stromlo, paired with relatively poor insulation on the dome. The peak interior temperature observed is 30±2° [11], and the minimum temperature is predicted to be below zero [12].

The requirements for the design of the laser enclosures temperature controls are taken from the updated system subsystem document [1], and are reproduced in table 2.

Table 2: Enclosure Temperature Control Requirements [1]

Reference	Description
1.5.3	The telescope dictates that the System shall account for temperatures up to 30±2°C.
2.5.1	The EOS GSL requires ambient temperature between 0°–40°C, but could work in lower temperatures.
3.2.3	The ANU GSL requires an operating temperature of 10° - 30°C
3.2.4	The ANU GSL requires a non-operational temperature of greater than 5° C

The temperature requirements for the ANU GSL lies within that of the EOS GSL, so we use this as our guideline for temperature control. The required temperature during operation for the ANU GSL is between 10° and 30°C [13], with a non-operating minimum temperature of less than 5°, without introducing antifreeze to the cooling system [13]. Due to the recommended chillers being unable to operate with antifreeze [14], we set the minimum temperature to 10°.

To maintain these temperatures, there are three proposed solutions. These are utilising insulation around the enclosure, introducing a temperature control system for the enclosure air intake, or a hybrid of the two. These are detailed in sections 3.2 to 3.4.

3.2 Enclosure Insulation

Using an insulating material for the side panels was one of the recommended approaches for temperature control [5]. We begin by analysing the system if insulation is not used, to determine if it is feasible to not use.

This is is dependent on which air-flow model is used. If the closed loop air control system is selected, we can find an approximate solution for the temperature by taking the heat loss through the enclosure walls. If the heat entering the enclosure from the heating element is greater than that leaving, we can conclude that this device will be able to heat the system.

One of the proposals for enclosure walls was the Kentek Blackout Windows [15], which are a polymer based compound. These panels have a thickness of 6mm, and will have a total surface area of approximately 9.52m^2 [9]. The thermal conductivity is not provided by the manufacturers, however similar materials have conductivities of between 0.15 and 0.5 $(W/m \cdot K)$. We take the higher value for this, setting it at $0.5(W/m \cdot K)$.

Using the lowest allowable enclosure internal temperature of 10°C, and lowest enclosure external possible of 0°C, we get:

$$\begin{aligned}
\dot{Q}_c &= -\kappa A \left(\frac{T_2 - T_1}{L} \right) \\
&= -0.5 \times 9.52 \times \left(\frac{10}{0.006} \right) \\
&= -7.94kW
\end{aligned}$$

The volume of the air within the enclosure will be approximately 1.824m^3 (1.2m × 1.9m × 0.8m)[9]. The properties of the air within the enclosure are a specific heat of 1.004 $(kJ/kg \cdot K)$ [16], and a mass of $1.275kg/m^3$. This gives us a total air mass of 2.33kg. From this, we can calculate the total energy that can be lost before the enclosure has dropped to the external temperature:

$$\begin{aligned}
Q &= c_v m (T_2 - T_1) \\
&= 23.38kJ
\end{aligned}$$

This gives us an approximate time of 3s for the system to equalise temperature with the dome. This assumes a constant rate of convection, which will drop rapidly as the temperature differential decreases, however it is clear that a large volume of energy will be lost at a very fast rate. This is not suitable, as the power required to maintain this temperature would take over 30% of the available power in the dome [17], and would cause a large heat release around the telescope, which is to be avoided [?]. This indicates that insulation is required.

One of the proposed insulation materials is provided by Askin [18], which offers various width panels, giving different heat loss values. Again, we used the surface area of $9.52m^2$, and temperatures of 10° internal and 0°C external.

This gives us a set of thermal loss for different thickness's, listed in table 3.

Table 3: Heat Loss by Thickness

Thickness (mm)	Heat Loss (W)
50	65.66
75	45.34
100	34.62
125	28.00
150	23.50
175	20.24
200	17.80

From these values, we determine that insulation significantly reduced the heat loss from the enclosure. Unfortunately, we note that this is by no means sufficient to maintain the temperature. Repeating the same calculation as above for the temperatures to equalise, we find that the equalisation time for 50mm is slightly under 6 minutes, and slightly over 20 minutes for 200mm. As temperatures below zero would likely be maintained for several hours, we note that insulation on its own is insufficient.

3.3 Enclosure Active Temperature Control

Active temperature control requires both heating and cooling capabilities. The preferred method is to utilise a small heating element as part of the air intake system (detailed in section 2), as well as a liquid-air cooling unit connected the the main component chiller units (detailed in section 5).

The heating and cooling will be controlled by a simple temperature sensor and controller device, such as [19]. This will ensure adequate operation of the system.

When looking at the size of heater required if no insulation is present, we immediately see that it is impractical. 4kW of heating is required to maintain the temperature, which would require installation of 2 separate 2kW heaters inside the enclosure (this is due to the 2.4kW limitations on single phase power). A 2kW heater is sizeable, and would make the design far more complex than simply introducing insulation.

3.4 Hybrid Insulation and Heating

The most practical solution is that of using a small heating element, a small cooling radiator, and insulation on the laser enclosure panels.

3.4.1 Heating

To calculate the performance, we take values from one of the proposed devices, the Pfannenberg 10-30W heater [20]. The model used in the following analysis uses the 30W model. The surface area of the device is approximately 0.06074m^2, giving a large surface area for heat convection, and the maximum operating temperature is 140°. The device has a duty-cycles of 100% when operating.

We note that for using the 30W model, we are able to sufficiently maintain the heat for insulation of 125mm or greater. However, due to enclosure requirement 1.1.2 limiting the overall depth of the system to 1000mm [1], it is preferable to limit the insulation width to 75mm. Using 75mm panels keeps the the total depth at approximately 950mm, giving a larger room for error for manufacturing tolerances. To achieve the heating requirements, we include a secondary 30W heating element, which ensures heating can be achieved with the 75mm insulation, as well as including a buffer for any inaccuracies in the measurements.

It is further noted that these two heaters could be replaced by any number of heaters totalling to 60W power, provided the total surface area is equal.

To ensure that the device is capable of operating without error at maximum temperature, we must ensure that it does not exceed its maximum temperature. Using the previously calculated values, we use *Newton's Law of Cooling* to calculate the surface temperature.

$$\dot{Q}_C = hA(T_b - T_f) \tag{1}$$

where

$$\begin{aligned} h&: \quad \text{Convection Heat Transfer Coefficient} \\ A&: \quad \text{Surface area of device} \\ T_b&: \quad \text{Temperature of the surface} \\ T_f&: \quad \text{Temperature of the fluid} \end{aligned}$$

For a slow moving gas, we use the model of free convection, giving a value for h of between 10 and 20 $(W/m^2 \cdot K)$ [16, 21], which could potentially be increased if needed, however it is ideal to minimise this to both reduce air turbulence, as well as to decrease the vibrations caused by the fan.

As the device temperature will be dependent on the heat exchange with air, and that the temperature will be maintained using PID control at a minimum of 10°C, we calculate the body temperature assuming maximum supplied power. Putting these values into equation 2 for maximum and minimum h, we find:

$$T_{(B,30W,\min)} = 108°\text{C} \qquad T_{(B,30W,\max)} = 60°\text{C}$$

These temperatures are all below the device maximum of 140°C, indicating that it is capable of providing the maximum rated power without issue.

From this, we determine that the hybrid system is capable of heating the enclosure sufficiently.

3.4.2 Cooling

To ensure that requirement 3.2.3 is achieved, active cooling is required for the entire enclosure. This can be achieved by the use of a radiator, connected to one of the coolers detailed in section 5. As the temperature requirements of all components have not yet been determined [13], the exact temperature of the cooler it will be connected can not yet be determined.

The radiator proposed [22] does not list a surface area for the component, however due to the design of the radiators, this will be greater than that of the heating element. The radiator has fins in a grid pattern with a spacing of less than 1mm between each fin, so by calculating the surface area for fins at a spacing of 1mm, we obtain a conservative estimate. The radiator is 120mm × 120mm × 40mm, giving a total of 14,400 grids. Each grid has a surface area of 40mm × 1mm × 1mm, giving a total surface area per grid of $40mm^2$. This gives the radiator a total surface area of $2.304m^2$, almost 40 times that of the heating element.

Additionally, as the cooler is 17°C, this gives a temperature differential of 13°C between the radiator and the temperature to maintain within the enclosure (30°C).

Using *Netwon's Law of Cooling*, we can find the heat transfer from the enclosure into the radiator:

$$\dot{Q}_C = hA(T_b - T_f) \tag{2}$$

$$= 10 \times 2.304 \times 2 \tag{3}$$

$$= 299.5W \tag{4}$$

The heat entering the system, given 75mm insulating panels with $R = 2.1$ [18], is:

$$\dot{Q}_C = \frac{A(T_b - T_f)}{R}$$

$$= \frac{9.52 \times 2}{2.1}$$

$$= 9.07W$$

From these we can see that the radiator will be more than sufficient at removing the heat entering the enclosure, and includes a significant buffer over the anticipated maximum temperature. It also does not introduce a significant load on the coolers, as only 10W of cooling capacity is required.

3.5 System Controller

To ensure that the system is operating at the lowest possible workload, a PID controller may be used, such as [19]. This uses a temperature probe to monitor the internal temperature, and activates the heating when a temperature of 5°C is detected, and the cooling system when a temperature of 30°C is detected. The heating element is a simple on-off control, however the radiator will require a valve to be shut off, restricting the flow of water. The exact radiator control method is still to be determined.

Finally, the fan may be shut off or have the fan-speed minimised when heating or cooling is not required, which will reduce the vibrations in the system.

3.6 Temperature Control Design Recommendation

The proposed design for the hybrid-system consists of a HEPA filter, fan, cooling radiator, and heating element in series in the air intake of the system. These are to be controlled by a PID temperature controller, which will activate the heater or cooler when the corresponding temperature limit is reached.

4 Air Intake Design Recommendations

The air intake system, including HEPA filter, fan, radiator, is to be in series at the top of the enclosure. The design ordering can be seen in figure 1. The arrangement is shown connected to the enclosure in figure 2[1].

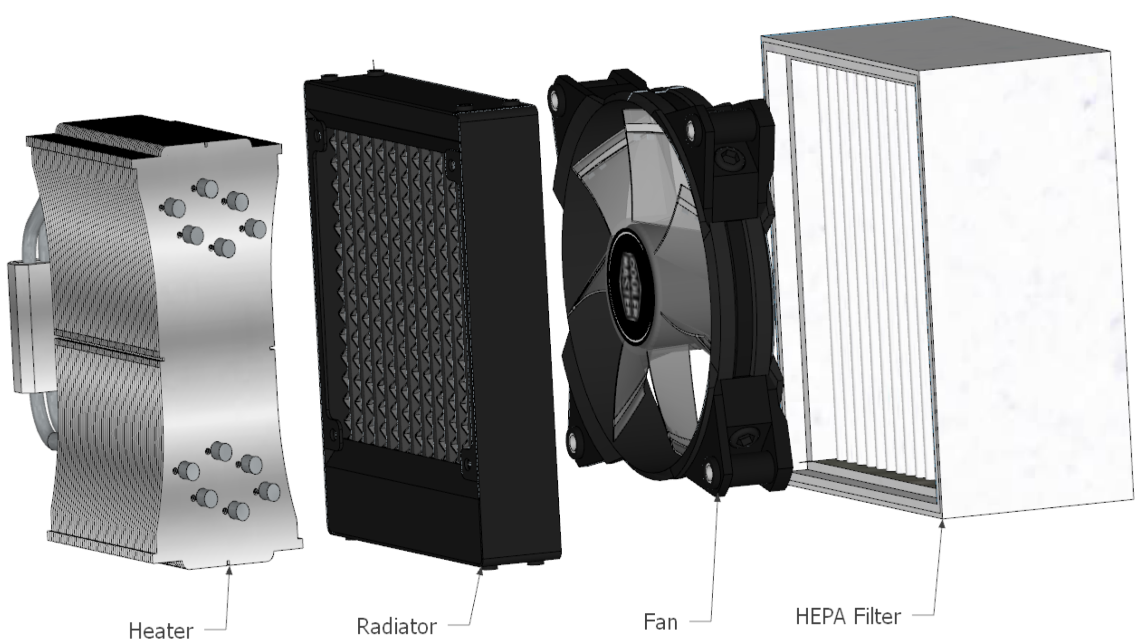

Figure 1: Air Intake Design

[1]Models sourced from https://3dwarehouse.sketchup.com/?hl=en

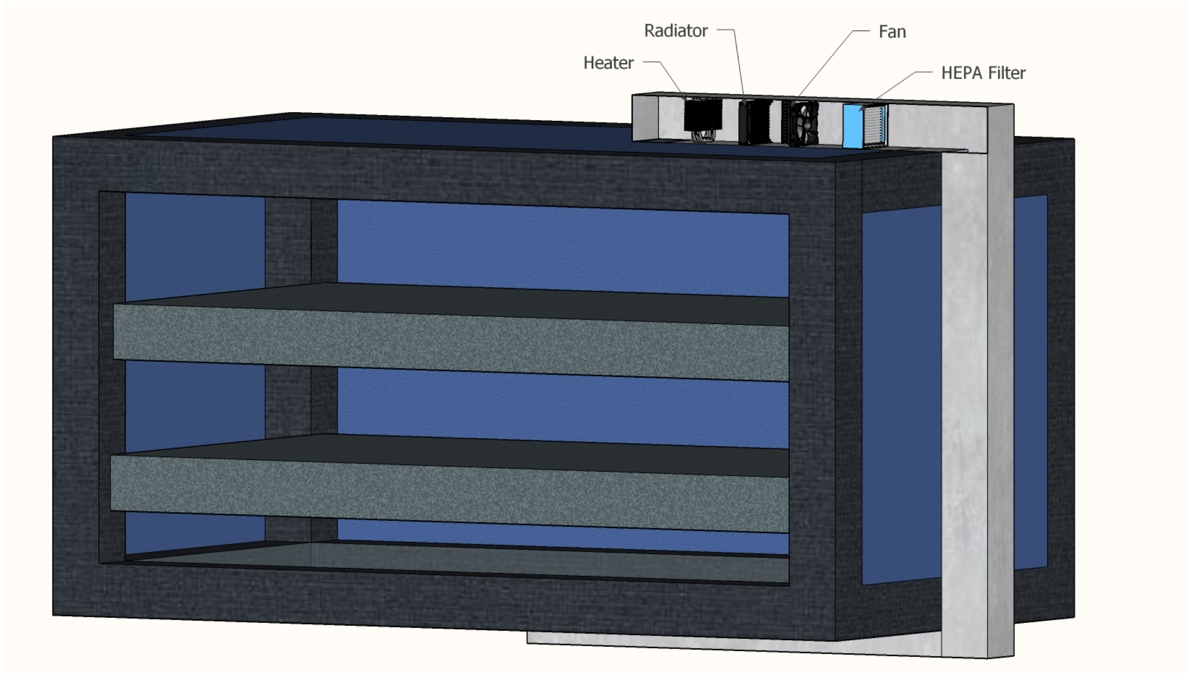

Figure 2: Air Intake Design

The further work required for this subsystem is to complete a vibration analysis, to ensure that the vibrations introduced by the fan will no impact the performance of either laser. This could be achieved by either limiting the fan-speed, or isolating the intake from the enclosure. The vibration tolerances for both lasers are required to complete this.

5 Component Temperature Control Subsystem

The EOS and ANU GSL have several components within them that require specific temperatures for operation, namely the amplifiers and oscillators. Both require continuous input of water at the specific temperatures to maintain this, through the installation of nearby chillers to extract and dispose of waste heat.

5.1 Requirements

The ANU GSL requires a certain volume of water at two specific temperatures for the oscillator and amplifiers, while the EOS GSL in its current state requires only one specific temperature for these components. However, due to the most likely location of the oscillators being inside the cleanroom, and the inability to route cooling pipes through the cable wrap, a fourth cooler will be required. This results in a total of three or four potential temperatures [13, 14], with four different chillers or heat exchangers required to be installed, as each can only maintain a single temperature. However, it is likely that the oscillator components will be mounted in the clean room outside of the dome [23], which has its own cooling systems, reducing the number of required chillers to three. In the case that the ANU laser components both require the same temperature, or the same temperature as the EOS GSL, then this number could be even further reduced. Therefore, several different cooling designs are needed, which cover all possible scenarios.

Tables 4, 5, and 6 contain the component cooling-related requirements and parameters for both lasers, taken from the updated system subsystem document [1].

Table 4: Laser Cooling Requirements [1]

Reference	Description
2.1.11	The EOS GSL requires that 10±2 cooler pipes must enter the EOS GSL breadboards collectively.
2.1.12	The EOS GSL requires 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.
2.1.15	The EOS GSL requires that a deionised water and OptiShield Plus solution be used as a coolant.
2.1.16	The EOS GSL requires that any coolant additives be 100% soluble in de-ionized water.
2.1.17	The EOS GSL requires that the cooler is re-filled with ≤2.8L of water as necessary.
2.5.9	The EOS GSL requires that the amplifier components of the 1342nm laser assembly be kept at a temperature of 17±1°C.
3.2.1	The ANU GSL requires less than 800W of cooling.
3.2.5	The ANU GSL requires a combined flow rate of 8L/min.
2.1.19	The EOS GSL requires that Ethylene Glycol is not used in the coolers.
3.2.7	The ANU GSL requires cooling at potentially two different temperature points, for the amplifiers and the oscillators.

Table 5: Laser Cooling Parameters

Component	Temperature	Cooling	Location	Other
EOS GSL Oscillator	Likely 17±1°C	Combined with amplifier, ≤400 W, possibly as low as 30-50 W	Likely to be placed in the clean room, out of scope	OptiShield Plus solution, no ethylene glycol
EOS GSL Amplifier	17±1°C	Combined with oscillator, ≤400 W, possibly as low as 30-50 W	Laser enclosure, telescope third floor	OptiShield Plus solution, no ethylene glycol
ANU GSL Oscillator	Unknown	Combined with amplifier, ≤800 W. Combined with amplifier, flow of 8 L/min	ANU electrical cabinet, first floor, or laser enclosure, third floor	Unknown
ANU GSL Amplifier	Unknown	Combined with oscillator, ≤800 W. Combined with oscillator, flow of 8 L/min	Laser enclosure, telescope third floor	Unknown

5.2 Chiller Selection

It is ideal that the chillers for the EOS GSL be able to use the OptiShield Plus solution [14], a corrosion inhibitor which is added to the water in the cooling loop. Two different families of chillers compatible with the Optishield solution are currently being used by EOS to cool the laser in the lab, the Bayvoltex and Termotek Chillers. It was suggested that these are the most suitable to be used in the dome, due to their proven history in cooling the lasers, as well as meeting all the requirements [14, 24].

At this stage of the project, no similar requirements have been provided for the ANU laser, due to it still being in the early stage of development. It is assumed however that it will require a similar system as the EOS laser, due to the similarly delicate nature of its design, as well as for ease of installation and maintenance.

The following are the chillers and heat exchangers considered for use in the design, both those currently being used by EOS for the GSL in the lab, and other recommended models.

Table 6: Chillers and Heat Exchangers

Chiller	Cooling	Power Usage	OptiShield Compatible	Other Notes
Termotek P-300 Series [25]	Liquid-Liquid or Liquid-Air 10-35 degrees, 0.1 stability 300-3500 W cooling 0.5-16 l/min flow	575-2000 W 240 V Single-Phase 50 or 60 Hz	Yes	$8000+, the most expensive model.
Bayvoltex Rack-Mounted Chiller [26]	Liquid-Liquid or Liquid-Air 5-35 degrees, 0.1 stability 500-1700 W cooling 8.3 l/min flow	720-1800 W 120 V Single-Phase 60 Hz	Yes	The most widely-used model by EOS.
Bayvoltex Fluid to Fluid Heat Exchanger [27]	Liquid-Liquid 5-50 degrees, 0.1 stability 20,000-100,000 W cooling 8.3-37.8 l/min flow	600-2300 W 120 or 230 V Single-Phase 60 Hz	Yes	Heat-exchanger, so incapable of cooling on its own and requires chilled water input.
Thermo Scientific Polar Series Chiller [28]	Liquid-Air -25-80 degrees, 0.1 stability 500 W cooling 21 l/min flow	500 W 220 V Single-Phase 50 or 60 Hz	Unknown	Very low noise and vibration output, can also heat in addition to cooling.

5.3 Direct Cooling Design

One design proposed, and the preferred system by EOS, [14] is to use a similar cooling system to that which is currently in the EOS laser lab. This is seen in figure 3. The Termotek and Bay Voltex chillers meet all of the necessary requirements, and a system with individual chillers for each is easy to implement, install, and maintain. However, it is more expensive due to having to purchase and install three individual chillers.

The first floor of the telescope is partially insulated from the upper floors, making it an ideal place for the liquid-air chillers to be placed without affecting the air temperature of the upper floors, and causing turbulence.

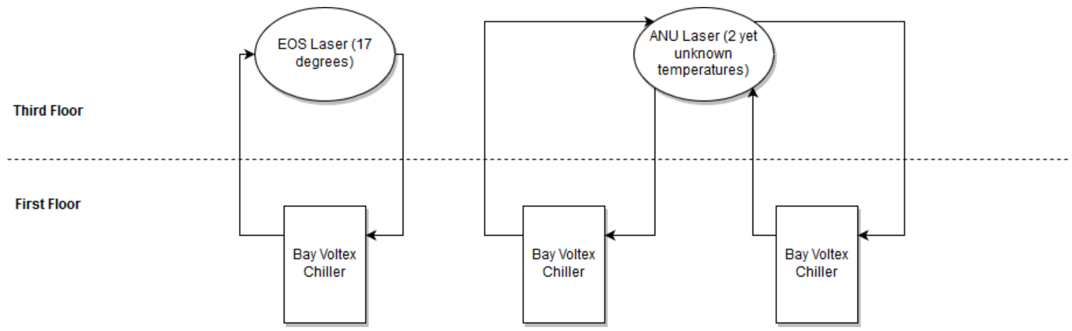

Figure 3: Design with Individual Chillers

Due to the fixed temperatures set in each chiller at installation, even if only one of the lasers were operated at a time, it is not possible to create a system to reuse the chillers for both lasers. The chillers that can be used for this system are the Termotek and Bay Voltex, with the appropriate thermal cooling power for each application (≤400 W, ≤800 W), cooling solutions, and flow rate. In addition, if the final design of the ANU or EOS lasers have very sensitive vibration or heating requirements, the Thermo Scientific Chiller could be used instead.

The proposed design for the system is to install two MC017-19 Bay Voltex Chillers, one connected to each of the lasers, and to install one MC025-19 Bay Voltex Chiller, connected to the ANU laser; this is because the ANU laser requires a potential maximum of 800W of cooling, and the MC017-19 Chiller has a capacity of 500W; depending on the csplit between the two components the MC025-19 Chiller, with its capacity of 800W, may be necessary instead.

This is the preferred system, due to the strong thermal stability, small space requirement, minimisation of cables to be routed, and general design simplicity and flexibility. This draw back is price and the amount of chillers, however, this is a valid trade-off. EOS is currently using a wide array of chillers in the laser lab and across their other labs; if it is possible to obtain these and use them for the system, this would save significant costs and difficulty.

5.4 Direct Cooling Logistics

Depending on the final required cooling, the assumption in this design is that two MC017-19 Bay Voltex chillers will be required, as well as an MC025-19 chiller; other listed models are also suitable depending on new requirements. The chillers are to be installed on the first floor, in the same location as the Auxiliary Electrical Cabinet, due to it being a liquid-air system, and the first floor being partially insulted from the upper levels; if the increased air temperature from the chillers is determined not to be a problem, they could be placed on the upper level instead, significantly reducing the amount of water pipes required.

Due to relatively small dimensions ($432 \times 559 \times 400$mm each), space constraints are not a serious problem for them. The Bay-Voltex Chillers all require 720 Watts of power and a single power socket connection each; there are six power sockets on the top floor, three on the second, and eight on the bottom. In addition, the power supply to the dome is 240 V single-phase AC; contacting the manufacturer is recommended, as they can produce chillers with different voltages and frequencies, or offer other solutions, such as converters. An RS-232 cable will be connected from each of them to the main control switch as well, in order to enable remote monitoring of the cooling operation. In addition, it will be necessary to install roughly 60 metres of water pipes along the middle of the telescope, six pipes measuring ten metres each, to connect the chillers and enable water flow to the laser components on the top floor and back.

Termotek chillers, Thermoscientific, and other models of Bay Voltex chillers are also suitable depending on any changes in requirements or new requirements for the ANU laser; if any of the individual ANU laser components requires more than 500 W of cooling, the MC025-19 BV chiller would be required instead, or if the vibration proves a serious issue, the Thermoscientific chiller is designed to solve that problem. Also, if the final design moves the EOS oscillators from the clean room to the dome, a fourth chiller would be necessary. As EOS likely has chillers available too, including those currently used for the testing of the laser, different models could be used if they are already available. The inputs to the ANU laser also might be different; it is possible that the oscillator of the ANU laser will be instead placed in an electrical cabinet, separate from the laser enclosure, requiring the cooling to be distributed there instead.

5.5 Heat Exchanger Design

One alternative recommendation [24] was that the design incorporate the use of Bay Voltex heat exchangers. This was suggested because they are very reliable at maintaining a specific temperature, as well as meeting all other requirements of the cooling system.

Figure 4 is a design involving the use of three Bay Voltex Heat Exchangers to maintain individual temperatures, with a chiller on the first floor to provide the liquid cooling.

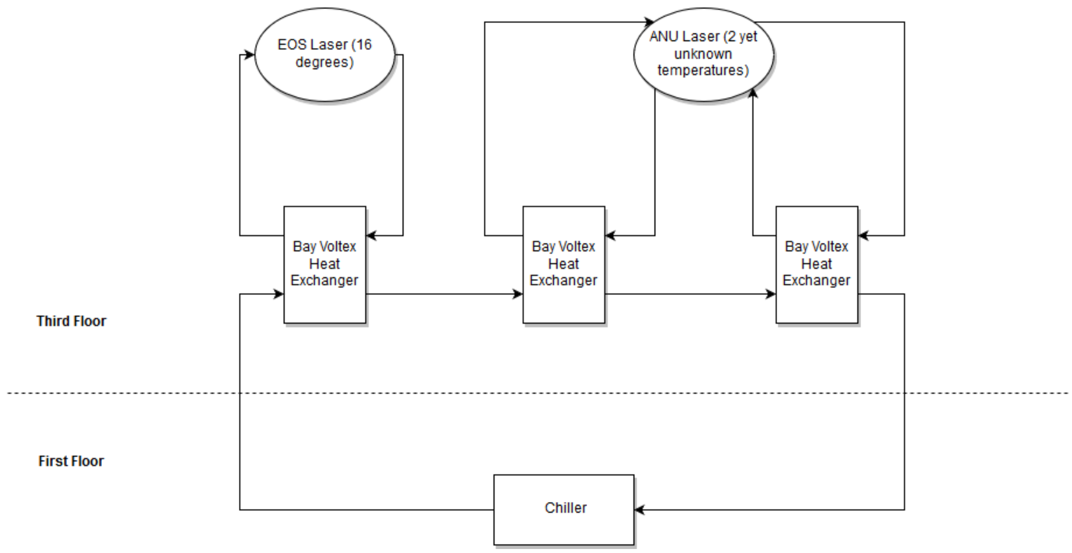

Figure 4: Design with Heat Exchangers and First Floor Chiller

The chiller depicted in this design could be a EXC-800 chiller (or two, if both lasers are required to operate at the same time), or any other chiller capable of providing water at a low enough temperature in a liquid-air system.

Figure 5 is a design showing another recommended variant, this time without the chillers and instead with a connection from the observatorys main cooling loop. Note that this will require an expensive installation procedure.

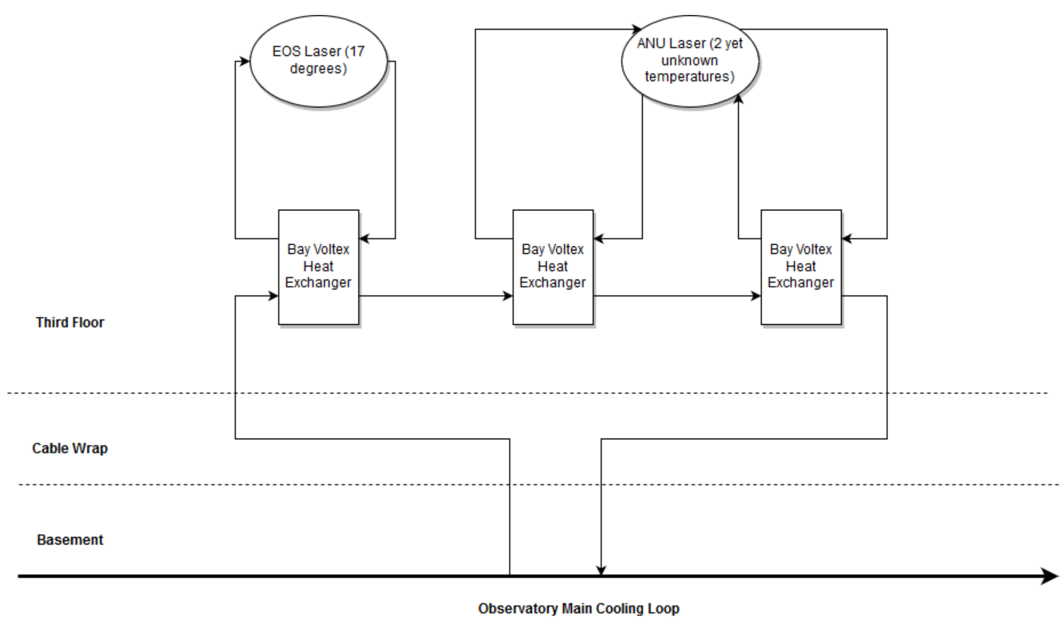

Figure 5: Design with Heat Exchangers and Main Loop

There are several drawbacks with this design when compared to the design above; the piping required to connect the observatorys main loop to the 1.8m telescope is likely to be both expensive and difficult to install, more so than installing a chiller on the first floor. Additionally, as the lasers are on the rotating part of the dome, they will need to have the water piped through the cable wrap, which has not been done before and will require the use of very thin pipes (between 0.25 and 0.5 inches) [24] This will significantly limit the water flow rate. However, an individual pipe should be able to provide 1kW of cooling [24], so a single pipe should be sufficient for each component at each temperature. The low flow rate through the cable wrap is then mitigated through the use of multiple pipes.

This design should only be considered if there are other projects planned for the 1.8m telescope that are also likely to require large amounts of liquid cooling.

5.6 Recommendations

The current design recommendation is the direct cooling design detailed above, which uses individual chillers with their own cooling loops for each individual components that requires cooling. This is the most flexible and easily-modified and installed design, which makes it ideal for the project. This design is the easiest to adapt for requirement changes that may occur.

As more requirements become available, the design is likely change. Once the exact flow rates, cooling capacity, and temperature requirements become available, the most suitable chillers can be selected for them. It is also possible that the number of components requiring cooling, or the location of them, will change.

Future Tasks:

1. The next team should update the chiller selection if necessary based on the final cooling requirements of the lasers.
2. It is also recommended to consult with EOS to determine which chillers are available, and whether they would be willing to allow their use for the ANU GSL as well.
3. The cooling system will require different pipes for the liquid water loop, depending on the final selected design, chillers, and flow rates.
4. The control system for the cooling system has been modelled with the Bay Voltex Chillers as an RS-232 cable going to the control switch and then control centre, from which it is monitored. When a specific chiller is selected, the protocols, control method, and operating procedure for it should also be specified.
5. This design places the chillers on the insulated first floor. If the final design is updated to place them in a different location, the heat being vented in the air may need to be considered.

6 Flooring around Enclosure

The enclosure is required to have anti-static, non-conductive flooring surrounding it. This is to ensure no damage will occur to the components during maintenance when the enclosure walls are removed.

The requirements from the updated system subsystem document relating to this this are shown in table 7.

Table 7: System Requirements [1]

Reference	Description
2.5.6	The EOS GSL requires that the area in which the System is located has an anti-static floor
2.5.7	The EOS GSL requires that the area in which the System is located has a non-conductive floor

A mat, such as [29] will meet these requirements. To ensure that the mat covers a sufficiently large area, the recommended size for the mat is seen in figure 6. This will ensure that nobody is able to touch the inside of the cabinet while not standing on the mat.

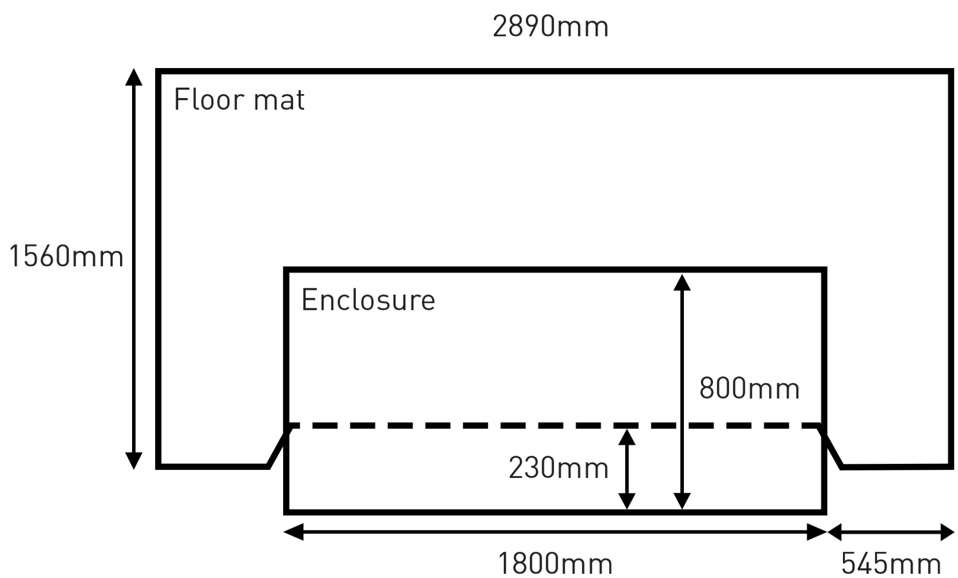

Figure 6: Anti-Static, Non-Conductive Floor Mat

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Appendix