Request For Proposal: Preventing Precipitation Ingress to and Damage of the Telescope at the Allan I. Carswell Observatory

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1. Abstract

The purpose of this Request for Proposal is to frame an opportunity to design a solution that would prevent precipitation from entering and damaging the $1M 1-metre telescope at the Allan I. Carswell Astronomical Observatory (AICO) at York University [1].

Elaina Hyde, Director of AICO for astronomical research and outreach, explained how holes in the dome and shutter lead to 3 cm of snow. Currently, members protect telescope electronics by climbing a ladder to roll tarps upon the extremely delicate telescope before pulling the edges evenly and adding garbage bags atop protruding ports: coupled with an excessive use of heaters, this is difficult, time-consuming, and dangerous for the researcher and telescope [1,2]. Potential failures due to moisture include image distortion, mirror degradation, electronic failures of precision instruments, and electrocution: ultimately, reduced observing [3].

Student researchers, AICO directors, telescope manufacturers, monthly public visitors, custodians, and York University generally are influenced by the protection of the telescope. The importance of their astronomy program stems from discoveries of new celestial objects and space exploration [1, 2, 6, 10]. To most effectively address this opportunity, three high-level objectives must be considered for safety, efficiency, and usability. A solution design will (of highest priority):

I. Limit Precipitation Ingress (for maintenance, responsibility and durability) including:
   A. Preventing water from reaching the telescope body, including through the device itself via Ingress Protection standards above IP55. [17]

II. Improve Safety and Process of Protecting the Telescope including:
   A. Reducing arm and back strain by reducing necessary vertical stretch length less than 195.5 cm from the deck, according to MIL-STD-1472G. [24]

III. Be Unobtrusive to Other Telescope Operations (ensuring usability)
   A. Telescopes must be balanced and upright for auto-tracking success.

When considering current potential solutions, they include car covers (which involve human strain and equipment damage through pulling, but are effective) and silica beads (which reduce moisture with quick setup however do not mitigate water entirely).

[1] N. Prosser, H. Karatha, and D. Shue, “Interview with Prof. Elaina Hyde.” Available: https://drive.google.com/file/d/1r3jtl794CGQJpgOc8HJvlSNxiI09K-JZ/view?usp=sharing.

[2] N. Prosser, S. Asad, H. Karatha, and D. Shue, “Interview with Ariella and Sunna.” Available: https://docs.google.com/document/d/1yEPMHc77RQH4_13GBmQ3DU-m_dtJ3JxdQ8tFNy2RE7s/edit?usp=sharing.

[3] R. Liu , “An overview of aluminum protective coating properties and …,” 09-Nov-2009. [Online]. Available: https://wp.optics.arizona.edu/optomech/wp-content/uploads/sites/53/2016/10/An-Overview-of-Aluminum-Protective-Coating-Properties-and-Treatments.pdf.

[6] H. Karatha, “Interview with York University Head Custodian.” Available: https://docs.google.com/document/d/1a71PR4O-r0FbV4W7YjCahoP3u8zh7TaL4rhtS3NFlwM/edit?usp=sharing.

[10] M. Rosenberg, P. Russo, G. Bladon, and L. L. Christensen, “International Astronomical Union,” *IAU*. [Online]. Available: https://www.iau.org/public/themes/astronomy_in_everyday_life/.

[17] Rainford Solutions, “IP ratings explained: IP Rating Chart,” *Rainford Solutions*, 02-Nov-2021. [Online]. Available: https://rainfordsolutions.com/products/ingress-protection-ip-rated-enclosures/ip-enclosure-ratings-standards-explained/.

[24] “Department of Defense | Design Criteria Standard, Human Engineering | MIL-STD-1472G.” *Astronomical Journal*, vol. 71, p. 273, 1966.

2. Introduction

This Request for Proposal explores the need to prevent precipitation ingress to the body of the 1-metre in diameter telescope (“1m”) at the Allan I. Carswell Astronomical Observatory (AICO). As a York University-based observatory focusing on understanding the universe via stellar research and public outreach, leaking domes cause snow, rain, and ice buildup on the interior of AICO’s dome and equipment. This buildup necessitates telescope protection methods, which have proven to be time-consuming and potentially dangerous through interviews with current and retired AICO members. By understanding the lived experience of AICO’s members, and the needs of our stakeholders, we maintained our values and beliefs of usability, safety, responsibility, efficiency, and ingenuity to develop high-level objectives and subsequently detailed requirements to be adhered to when designing a solution to this opportunity with reference designs outlining existing alternatives and their limitations. This RFP presents a thorough guide to develop effective solutions that will assist our stakeholders at AICO with this opportunity of preventing water damage of the 1m.

3. Background Information

The primary step in understanding AICO holistically is appreciating the observatory’s environment, importance, processes, and technologies, which was established by the Director of AICO, Dr. Elaina Hyde.

3.1. York University’s Allan I. Carswell Observatory

AICO is a 54-year-old observatory with equally-old dome roofs, housing two reflecting telescopes of 60 cm and 1 m primary mirror diameters in a pair of domes [1,4]. The 1m was installed in 2019 and is equipped with advanced electronic cameras and spectrographs. The main purpose of the university observatory is astronomical research of variable stars of differing intensities, adding to the York University’s astronomy curriculum. AICO hosts student researchers, high school co-op students, and professors who hope to gain a greater understanding of the origins of the universe using AICO telescopes [1].

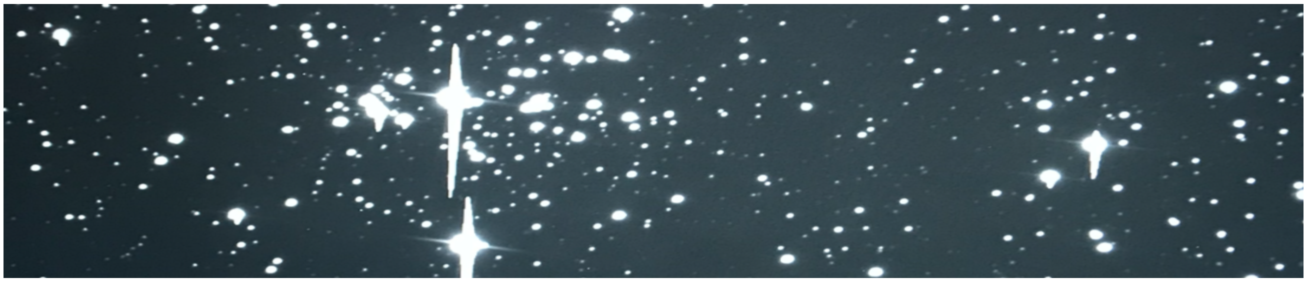


Figure 1. Image of Variable Star Captured at AICO

3.2. Environment and Telescope Specifications

AICO includes a small "warm room" between two domes with computers controlling the reflecting telescopes with primary mirror diameters of 1m and 60 cm contained within. Each dome costs $500,000 [4]. During observation, a long, rectangular, narrow shutter from the edge to the top of the dome is opened. The dome is rotated by switches, providing direct access to the night sky, as shown in Figure 2. We will be considering the dome holding the 1m telescope.

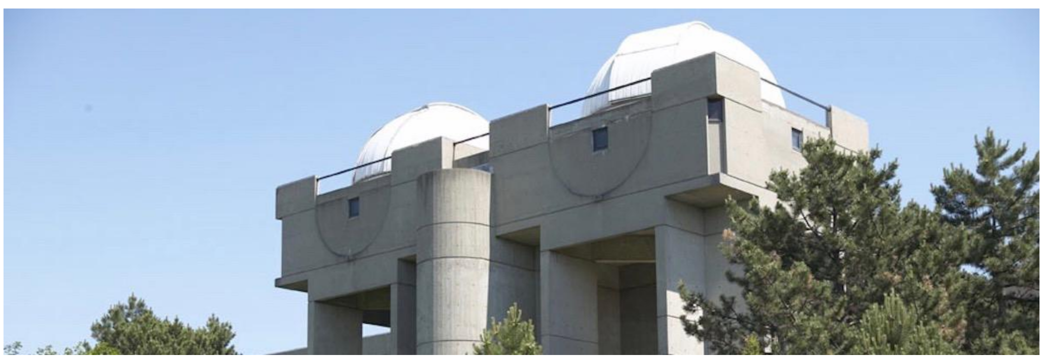


Figure 2. Image of the domes which houses the 1m

Centred in the 22-foot round dome, there is an approximately 2.5 m diameter deck 4.5 m off the ground, with a spiral staircase from the floor. Surrounding the deck are cabinets for eyepiece storage and tables for placing objects [5].

Central on the deck, the 329.6 cm tall and 2600 lbs 1m telescope - named the PW-1000 - is mounted, with a 1m wide concave primary mirror, which reflects light to a convex secondary mirror at the top of the telescope, which reflects light to a rotatable tertiary mirror and thus to charge-coupled devices (CCDs) - integrated circuits with photoelectron emitting and light-sensitive elements to image the sky - eyepiece, or spectrographs [7, 13]. The mirrors are coated with aluminium for protection and reflectivity, and are surrounded by carbon-fibre posts at acute angles with the vertical, which are themselves clamped to a carbon-fibre ring 106 cm in diameter at the top, and a 182.9 cm body centred 158.2 cm above the deck. [3]

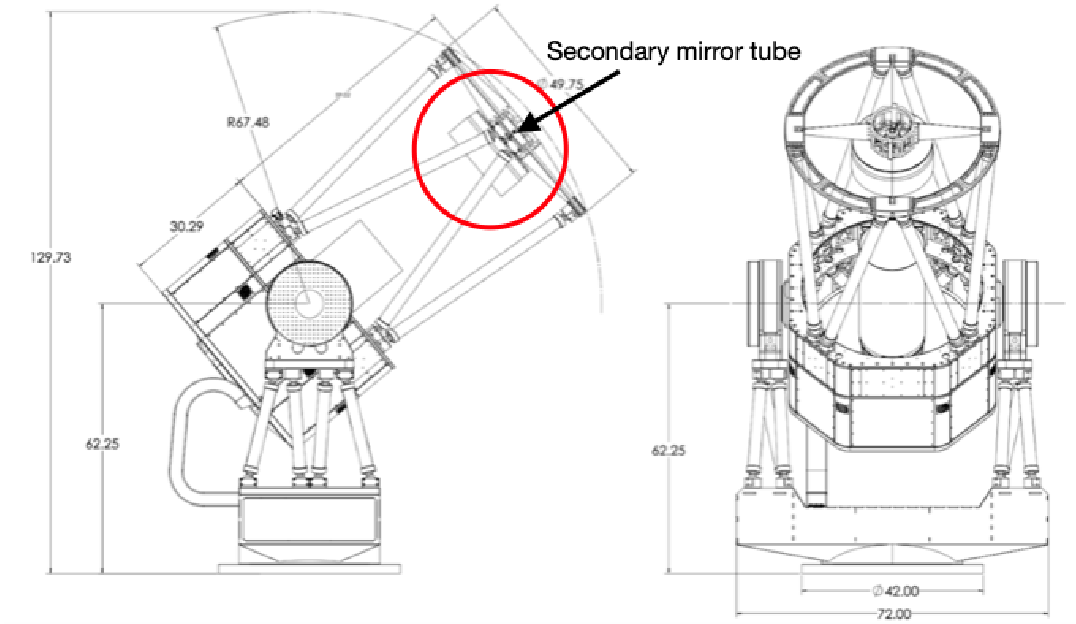


Figure 3. Technical diagram of the PW1000 observatory system, with dimensions indicated in inches.

PlaneWave Instruments, an observatory-class product manufacturer, provided the telescope costing over $575,000 alone as the most expensive element in the observatory, outpricing the cost of the dome [4, 13]. The delicate electronics and precise optical equipment inside the telescope must be kept under specific conditions, generally matching the outdoor temperature without condensation build-up and free from the effects of external factors such as magnetic fields to ensure smooth usage is maintained and damage from atmospheric disturbances are avoided [22].

3.3. Significance of Observatory

AICO is synonymous to the importance of astronomy and scientific research. Exploring the vast expanse of the unknown universe around us satisfies the innate curiosity of society and aids applications of space technology. Akin to visual art, music, and dance, astronomy has value in simply existing and contributing to the enjoyment and inspiration of the masses.

4. Opportunity Description

This RFP focuses on prioritising safety, durability, and efficiency in a design that protects the telescope from precipitation entrance and its process.

4.1. Opportunity Overview (& Impact)

At AICO, the domes are 54 years old, and experience immense wear-and-tear due to variable temperatures in Toronto, their age and frequent motion [4]. As such, holes have formed in the ceiling material itself, on top of gaps forming along the rubber seal between the sliding rectangular shutter and the rest of the dome [1]. This emits precipitation from outside directly towards the central telescope, causing ice crystal formation and condensation on electronics in a combination of precipitation and cold temperatures permeating throughout [1].

Hyde addressed the prominent theme and challenge of leakage through the domes; water and electronics infamously contradict, particularly with an extremely sensitive $1M telescope running on electricity [1]. Corrosion of metal within the telescopic body is also common, leading to increased resistance of the metal with the potential for too much causing damage as fires, for which there is no fix except part replacement. Impure water - as is rain - is also electrically conductive, which would reduce the charge reaching the telescope and thus the intended functions, instead directing current elsewhere in the dome, which may pose danger to humans in the vicinity if not treated properly. Telescope damage leads to reduced usage and thus research, minimizing exploration and discovery of the universe, and suppressing the curiosity of observatory members and the public.

Prof. Hyde mentioned that a maximum of 3 cm of snow has fallen through the cracks of the dome in one night, soiling the carpeted floor and surrounding areas [1].

"The dome is in a very old condition; it has some holes in it so we get snow incursions where we get a few centimetres of snow pileup on top of electronics and various electronics will then fail."
Prof. Hyde, Director of AICO [1].

As retired Director of AICO, Professor Emeritus Paul Delaney explained, the obvious method of addressing this is replacing the domes [4]. However, domes require monthly repair and annual replacement to maintain utmost protection from constant degradation, far exceeding the budget of a public university to an observatory [4]. Consistent dome repair is not possible for AICO, thus telescope protection is needed within the dome to reduce this need.

After speaking with PlaneWave Instruments' technical support expert Bill Dean, it was identified that, for telescopes exceeding 24" in diameter, including the 1m, no protection methods for the telescope directly exist, allowing a unique, brand-new solution to handle and care for the telescope responsibly and safely to be developed [7].

4.2. Current Processes

To prevent precipitation damage to the telescope during storage when not in use, AICO's current process of protecting the telescope from the elements includes the use of:

- Ladders
- Tarps and garbage bags
- Heaters

A singular 16x20 ft plastic tarp as in Fig. 4, weighing 7.54 lbs and intended for general use covers the top of the telescope body, while standard garbage bags are secured around protruding ports not covered by the tarp [5, 9].

To cover the telescope, small mirror covers as in Fig. 4 are placed around the mirror tubes, the tallest two AICO members are required to use a step-ladder (given that the top of the telescope is 134 cm above the average human reaching height of 195.5 cm, the size difference as seen in Fig. 4) to place the tarp atop of the telescope and gently unroll it over the body, pulling the edges until the tarp is centred and the telescope is balanced and upright which watching the protruding components to ensure no equipment is pulled on or damaged [21, 24]. The same process is repeated in reverse for telescope uncovering before use. The tarp and garbage bags are shaken out onto the carpeted floors of the dome before being folded up and stored under a table [2,5].

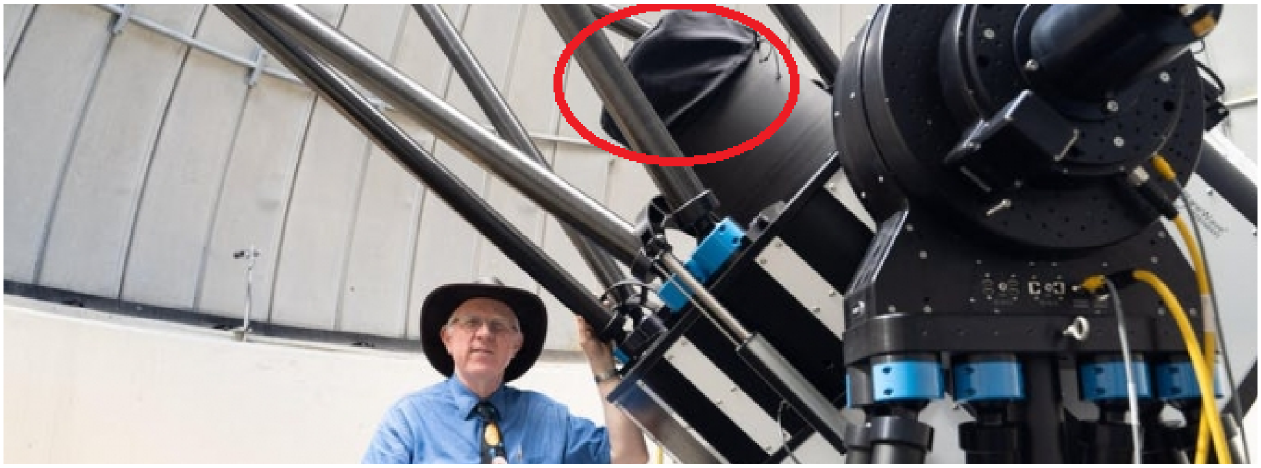


Figure 4. (top) Initial mirror covers before tarping; shows scale of telescope to human height; (bottom) tarp used to cover entire telescope

The final aspect of protecting the telescope from precipitation damage is ensuring heaters are turned on hours approximately 5 hours in advance, to melt ice-formation and begin drying equipment, then using brooms and fans to dry off equipment [2].

4.3. Limitations of Current Process

Valuing safety (hindered by endangering researchers by reaching high on a ladder on a deck without a spotter), efficiency (manually placing the tarps and balancing takes a long time with necessary heater preparation beginning 5 hours in advance, even before telescope setup of calibration and focusing), usability (extreme care is required to ensure the telescope can be used after protection), and sustainability (not being a realistic long-term solution due to the need of two tall members, plus the ideal of maintaining the telescope), there are many areas for improvement in this lived experience.

This process is extremely delicate as the telescope tracking ability is reliant on telescope balance, while it must be ensured that no sensitive mirrors are contacted, which could smudge and scratch and thus prevent clear image capture during research [16]. Imaging devices can be obscured by buildup in openings. Water has the ability to permeate through certain materials and condense through boundaries between the tarp and garbage bags, limiting the effectiveness of the solutions. Heat also has the potential to damage the outer coating of the telescopes [4].

Due to large precipitation, the observatory is cancelled entirely for risk of snow falling onto the telescope and telescope cover and damaging the asset, limiting astrophotography, research and outreach live viewings.

4.4. Reasoning for Chosen Scope

From our value of responsibility, we scoped the scenario to focus on protecting a million dollar piece of equipment that is used to satiate human curiosity for discovery and learning of the universe - focusing on the sustainability of telescope and equipment. We incorporated our belief of engineering and engineering design to be human-centred by focusing on improving usability and safety, not only making the environment more conducive to excellent research, but also safer for researchers.

We began with status quo bias on the repeated idea from multiple sources, including PlaneWave Instruments, [22] and Hyde, on the current idea of a tarp as the only way to overcome precipitation damage, encouraging over-constraining based on the idea of coverings - based on the size, the material, and other related requirements. Instead, we consciously altered our mindset to processes and human-centred design, asking what the tarp *did*, rather than what it *was*, later brainstorming potential non-tarp solutions to initiate discussion on other requirements for general protection.

We were further biased by our combined curiosity and passions for technology, robotics, space and research, which led to inquiring about the telescope and how to maintain it for astronomical research and discovery, directing our chosen opportunity and leading to our chosen scope of telescope protection. The leaking dome and its impacts immediately piqued our interest, and we were able to draw connections and understand AICO when discovering setup and cleanup methods expressed by Hyde based on our chosen focus.

5. Stakeholders

Numerous groups of people have enormous stakes in this opportunity: are influenced by the scenario and could be benefited by the development of a solution. These stakeholders include the design team and proposal team; our primary community, AICO researchers using the 1m telescope; Observatory Directors; PlaneWave Instruments; YorkU custodians, in charge of cleaning the domes and telescopes; and YorkU themselves.

5.1. Observatory Researchers

Observatory researchers using the 1m telescope are the key stakeholders directly impacted by the damage caused by leaking roofs and solutions for telescope protection methods. These AICO researchers consist of undergraduate and graduate students, professors, fellows, high school students and volunteers, each conducting the same research and processes, all held to the same level of responsibility for the equipment wielded. Daily, they work in the dome directly with the 1m telescope, preparing the dome and telescope for use by clearing snow, removing protective gear, then aligning and imaging with the telescope remotely via computers to rotate and tilt the angle (known as altitude and azimuth) of the telescope. Once images are taken and the protection re-donned, images are reduced and compiled to remove atmospheric distortion, then analyzed.

In particular, observers focus on variable stars and double binaries; they use the telescope to make discoveries and explore, a curiosity unable to be satiated without safe access to the telescope. Student observers in particular take stake in unrestricted telescope usage, detail and clarity of images, something that must not be hindered, nor observing sessions cancelled. Projects, theses and grades are reliant on observing and unable to be rescheduled for clear days to avoid opening the telescope and risking exposure to the elements, as is frequently done to prevent precipitation from falling atop even the closed telescope; simultaneously, booked slots cannot be shortened for extensive setup and cleanup to maximize image capture abilities and short periods of clear skies.

Their personal safety in covering and uncovering the telescope with tarps is further jeopardized daily, as they deal with wet electronics and reaching high atop ladders without spotters, things students are unequipped nor paid to do; a solution would provide them with reassurance for their physical integrity [2, 5].

5.2. Observatory Director

Hyde, AICO Director, is also a key stakeholder for this opportunity. As Director, Hyde is responsible for the planning and execution of research, outreach and functions at AICO. To best utilize the 1m telescope, significant for general operations, Hyde often has to assist in tarping the telescope which constrains her ability to address more pressing operations at AICO. As the Director as well as assistant professor, damage to the telescopes from leakage through the domes and eventually ice-crystallization can result in costly repairs that may decommission the telescopes for weeks and require her full attention. Such an event directly impacts Hyde as all operations and research must be halted until the repairs have been conducted and she is liable for any damages and the safety of the members, requiring her to initiate requests for new domes. As noted in an interview, Hyde recounts the lack of expertise and knowledge of general repair technicians thus requiring more of her time to seek out qualified repair technicians [1,4].

5.3. Design and Proposing Team

As the design team and space, robotics and research enthusiasts intent on applying physics to develop curiosity we believe in the importance of discovery and exploration to inspire innovation and ingenuity that astronomical research provides. We believe in the importance of telescope maintenance for perpetual use and discovery. We admire originality, something prevalent with this scarcely-solved opportunity. Our core values include repairability, particularly of the telescope, and human safety, as without safety, no activities - no research and exploration - can occur. Responsibility is a huge focus, of taking ownership and taking care of the environment around us - hence our decision to work with protecting a $1M telescope - as is usability, with the former unable to occur if the researchers are unable to smoothly and quickly enact the designed solution. Finally, our goal is to help those that we work with at AICO, and we desire to make an improvement in their lives; as such, we feel responsible for proposing a solution that may benefit the safety, sustenance and perpetuation of research of the Observatory.

5.4. PlaneWave Instruments

PlaneWave Instruments, the company who custom-designed the 1m telescope, consists of a team of technical support and quality control members, control testers, machine manufacturing facilities and installation members, plus telescope engineers: a team of passionate astronomers building mounts, telescopes and telescope systems. With their mirrors, rapid motion control and automatic pointing, tracking and correction technology, they are known to value speed, self-sufficiency and high resolution (quality) of their telescopes, on top of efficiency, with 1-day installations and imminent repair support - all for the sake of helping the observers research as much and thoroughly as possible.

Were the telescope to be damaged by precipitation, PlaneWave would work with the Director on the repair and replacement of parts, re-coating mirrors with aluminum if corroded by water solutions or oxidized, reducing reflectivity, requiring ultimate precision and high safety protection of personnel when dealing with fried and wet components amid cables and slippery - million-dollar-worth - mirrors and equipment. They require better sustainability of the telescope under extreme conditions, not only to protect themselves, but also their reputation and credibility, leading to further business with their mission of excellent imaging without limitations adhered to. Their goal can be met with sufficient protection services that would prevent mirror and optical damage and atmospheric disturbances, enabling sharper universe observations and discovery [7, 12, 13, 14].

5.5. University Custodians

Water damage requires cleaning, and thus YorkU custodians are in charge of cleaning all 457 acres of YorkU, including the dome around the telescope, drying surfaces, cleaning dome carpets, and fixing roof leaks.

With a solution to protect instruments, potential damage to expensive equipment is decreased, as even the reflective mirrors can be damaged by so much as a feather duster. Depending on the water riddance process designed by the team to avoid water falling back on the telescope, soiling of carpets may be increased, requiring more work, or reduced, decreasing mold and buildup of liquid elsewhere, requiring less technical and intensive work. Custodians at AICO deal in close proximity to and with electronics while damaged and wet, leading to risks of electrocution and bodily damage due to impure water conductivity; protecting electronics reduces the need to dry and clean such hazards, creating a safer experience for all [6].

5.6. York University

YorkU itself has highly considered the process of protecting the telescope, as a public university in the GTA that houses AICO and the 1m telescope, and that paid $500,000 in the purchase for the largest telescope on any Canadian university campus [1].

YorkU funds the observatory activities, and has little money to allocate for annual - even monthly - repairs of $500,000 domes: without telescope protection, to ensure the $1M 1m telescope is maintained, the domes would require expensive resealing due to continuous dome motion on top of rubber wear-and-tear from weather variability [4]. If a protection were to exist, frequent replacement would be unnecessary, even among leakage, as the telescope would be maintained without external considerations. Additional money and funding available could also then be provided for research advancements, upgrades in software and technology and research positions that can develop greater understandings of the universe and enhance student curiosity, exploration and impact. Also, academic institutions are responsible for on-campus student safety, including electrical damage and ladder safety: accommodations must be provided for academic continuation, thus the process of telescope protection from the human perspective - ensuring utmost safety - is priority.

5.7. General Public

Biases regarding how the public engages with the AICO led us to believe that there is little public engagement with researchers, but after hearing about the number of public showings and volume of students in astronomy clubs, and the influences of astronomy, these assumptions were alleviated.

The general public involves everyone that engages with the outreach of the observatory, the taxpayers that have funded the observatory, people who appreciate astronomy, and the entire world. Astronomy's influence on the public sphere extends beyond a public appreciation of what lies beyond the world we know; it aids in space exploration, creates new technology including eye diagnosis devices through moving fluids, and inspires future generations to learn more about what lies beyond. People wish to learn of celestial objects and attend seminars and viewing nights hosted by the AICO, so their education is directly influenced by the instrument allowing them to do so being able to work despite precipitation. Additionally, the public needs the researchers that host these sessions to not be harmed accidently due to their telescope protection process. When observing the online presence of the York University Astronomy Club, it is clear that the influence of the AICO extends beyond the researchers and inspires people from all walks of life. Having direct results from observing is also necessary for taxpayers and students to see where their money is directed and what it is used for. Meanwhile, a similar solution to prevent water damage may be extremely effective in helping humanity, including in protecting houses and expensive home-devices from leaks and floods [4].

6. Design Requirements

By defining justified requirements and scoping an authentic and substantiated understanding of the engineering opportunity we can represent the outline to a solution that can protect the telescope and its users, and benefit the aforementioned stakeholders.

6.0 High Level Objectives

Our high-level objectives include:

- 6.1: Limit Precipitation Ingress (Maintain Telescope Quality)
- 6.2: Improve Safety and Process
- 6.3: Be Unobtrusive to Other Telescopic Operations (Ensuring Usability of Telescope is Maintained)

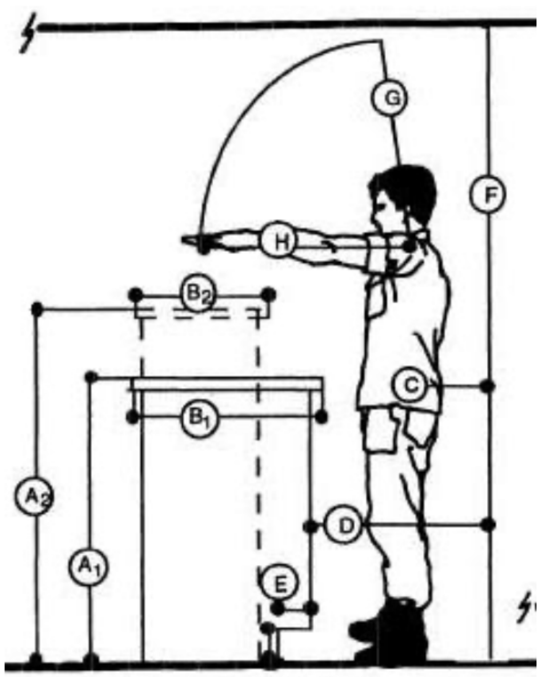
Note: the phrasing “and/or” within “set-up and/or takedown” does *not* imply that the requirement can pertain to only one of setup or takedown - it merely insinuates that the requirements still holds if the process is modified such that for set-up and takedown, one, both or neither are possible for potential solutions by the design team. If neither set-up nor takedown are included in the design, the requirement including this phrasing is automatically met.

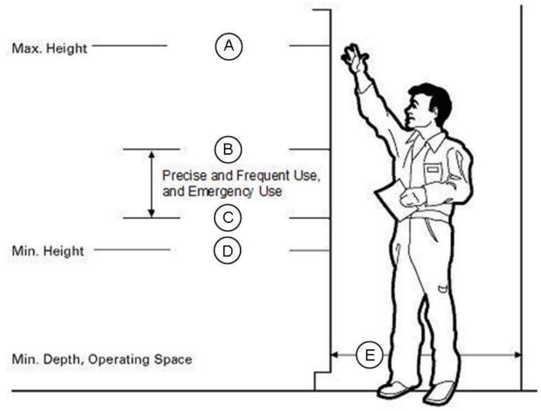
Objectives	**Metrics**	**Criteria**	**Constraint**
6.1 Limit Precipitation Ingress (Maintain Telescope Quality)			
6.1.1 Prevent precipitation and moisture from reaching telescope body	*Ingress Protection (IP) standard of design, refer to IP scale rating [17]*	*Higher second number (water protection) of IP rating is better*	*Devices should not be rated lower than IP55 [17]*
Justification:			

According to [17], a rating of IP55 represents protection from water jets in any direction, more pressure than of stable snow and rain, as is needed. Any lower amount of protection (i.e. only being protected from light water spray) would not be sufficient to protect the telescope from up to 3 cm of snow, as material would then not act as waterproof and would allow precipitation to seep through and damage the telescope. Any design with an IP rating of 55 or above would in turn not allow any leaking precipitation (in the form of drips of water or slow snow buildup through small holes accumulating) to permeate through and contact the telescope [17].			
6.1.2 Limit water falling onto the telescope during device removal/takedown/etc. **Justification:**	*Number of 1 cm (standard water droplet size) in diameter drops of water fallen onto telescope during removal of device (if drops are larger, calculate the size and thus number of 1 cm drops encompassed by larger drop)*		*Number of drops onto location of telescope must be zero*
Another concern of the current system involves the potential damage caused by the removal of wet tarps, and the subsequent dripping of water onto the delicate telescope components. Therefore the proposed solution must prevent water entirely from landing on the telescope during the removal of the telescope protection device, so as to not negate the impact of the telescope protection mechanism designed and to ensure telescope maintenance, ensuring the damage detailed in Section 4.1 are avoided. [15]			
6.1.3 Prevent water entry through connections/joints/edges/seams in device **Justification:**	*Total surface area of joints/connections/edges/seams in entire design*	*Less area is better*	
Lowering the size of components where water may fall through the device onto the telescope at weaker locations - namely seams, edges and connections where waterproof (see 6.1.1) materials may be bent or joined together - will ensure that there are less potential breaches with more pure material of high waterproofing standard, which can protect the telescope by limiting water ingress, and also helping the			

observatory team when they have to check the telescope for water damage every morning with fewer points of interest to look for. Furthermore, according to The Guardian fashion subsection on seams, fewer points of connection limits weak spots that can tear or break easier than the rest of the material, leading to more durable designs that are less likely to break and emit water to the telescope [11].

Objectives	**Metrics**	**Criteria**	**Constraint**
6.2 Improve Safety and Process			
6.2.1 Require few people for design set-up and/or takedown	*Number of people required to setup and remove design*	*Less people is better*	
Justification:			
Requiring more people to aid in operating the device, etc. decreases efficiency because there must be coordination between people and lowers usability for individual researchers if more than one person is required for set-up. Meanwhile, an average of two people work with the telescope at a time [1]. With more people physically handling the telescope daily the chances of crowdedness and damage are also increased.			
6.2.2 Involve low human risk to set-up and/or remove design	*Vertical reach height required for setup (cm)* *Number of steps up required to setup or remove designw*	*Lower maximum reach heights are better [23]*	*Should require handling less than 139.7 cm from deck (i.e. to shoulder height) [24]* *Must require less movement than up to 195.5 cm from deck when reaching up [24]* *Must have to take 0 steps up to don/doff the design*
Justification:			
According to MIL-STD-1472G, 195.5 cm is the maximum height (as seen in fig .2) an average woman can reach (the shorter of male and female average reach heights with an AICO team of over 50% women), while it is recommended that one does not reach up higher than 139.7 cm (fig .1, H) in an ideal scenario to avoid arm and back strain and injury when conducting precise, delicate work repetitively [24].			





Dimension	Value
Maximum height (A)	188 cm (74 in)
Preferred max. height 1/ (B)	139.7 cm (55 in)
Preferred min. height 1/ (C)	86.4 cm (34 in)
Minimum height (D)	76.2 cm (30 in)
Preferred min. depth 2/ (E)	106.77 cm (42 in)
Minimum depth (E)	94 cm (37 in)

NOTES:
1/ Preferred dimensions are for those controls that require precise, frequent, or emergency use.
2/ The dimensions listed accommodate the central 90 percent of the anticipated user population.

Figure 5: Military Standard Safe Reaching Heights [24]

Ladders and steps are dangerous, especially when reaching up without a handhold on elevated decks with simple single-bar railings below waist height, and without a spotter (i.e. if there are 2 members, each of whom have the potential to be donning and/or doffing the design, depending on the design). As such, to entirely avoid researcher risk with user potential to be carrying the design and leaning over the telescope depending on the finalized design, two of the most common causes of ladder injuries according to the government of Oregon, no steps must be taken [23].

6.2.3 Reduce time consumption in terms of setup and/or cleanup of the process	*Setup and cleanup time [minutes]*	*Less time is better*	*Should be lower than current time (~5 min)* *according to [1]
Justification:			

If the process takes an excessive amount of time, it directly lowers the efficiency of the process since researchers will have to cut out more time from their schedule to accommodate this time. Minutes were chosen as the units under the assumption that the process should not cost hours of the researchers' time. Excessive amounts of time lowers usability because realistically the researchers would not adopt that solution due to the lack of ability to complete research work in limited time available during booked slots at night.

Objectives	**Metrics**	**Criteria**	**Constraint**
6.3 Be Unobtrusive to Other Telescopic Operations (Ensuring Usability of Telescope is Maintained)			
6.3.1 Not impede on sensitive components (particularly the telescope's mirrors and the secondary mirror tube at the top) **Justification:**	*Surface area of contact between telescope mirrors/short secondary mirror tube and design (cm^2)*		*Must be zero* (to avoid ANY damage and degradation to the telescope, which would then require repair and replacement of mirrors and coatings, an expensive and dangerous task including acid use to remove existing coating that would harm, rather than protect)
According to Hyde, the primary and secondary mirrors of the telescope are extremely sensitive, and although the mirror covers are very good it is still unsafe for any objects or parts to lie atop them [1]. Aluminum protective coatings are on front of the mirror (unlike bathroom mirrors), thus any touch from above can scratch or degrade the coating and render it unreflective and the telescope unusable [16]. As stated by Dean in an interview, the secondary mirror tube containing the mirror at the top of the telescope is open and accessible top-down, and thus easily susceptible to damage from materials atop the telescope [7].			
6.3.2 Be magnetically neutral **Justification:**	*Number of magnets involved in design* (which each produce their own magnetic fields known to damage telescope operations)		*Must be zero* (to avoid ANY extraneous magnetic field and electricity disturbances other than natural magnetic fields and those created by moving charges)

Small magnetic fields cause huge problems: feedback loops through the building and popped circuit breakers. One of the most damaging things for telescopes, magnetic field when present with the existing electric field through the telescope exerts forces on the charge and deflects current via the Hall Effect, creating a voltage that may melt wires and disrupt the flow of electricity through the telescope, causing failure and the inability to electrically manoeuvre and use the telescope [18, 22]. Magnets further exist in the tertiary mirror to lock it pointing to one of two ports, thus to avoid forces attracting/repelling this mirror in unwanted directions, and to ensure light directly reaches cameras and eyepieces, external magnetic fields must be minimised [12, 13].			
6.3.3 Keep telescope movement unrestricted **Justification:**	*Ratio of maximum angle from vertical of telescope* with *design, relative to maximum angle from vertical without design of 90° (minimum of ratios from all directions) [18]*	*Larger ratios preferred*	*Ratio must be greater than or equal to 0.78* (Telescope has a range of motion to reach the horizontal, however with the base of the dome and buildings in the horizon obstructing views, the maximum possible angle used at AICO to see astronomical objects is 70° from the vertical, according to Withers. Any more is unnecessary, however not detrimental. [2])
In order for the continued function of the telescope it is necessary that the telescope is able to reach its required elevation and rotational angles in order to observe all desired objects in the night sky. The possible angles for observing must not be hindered such that observable items cannot be captured.			
6.3.4 Maintain similar temperatures between telescope and outside environment **Justification:**	*ΔT, the difference in temperature between the temperature difference in the dome and outside with the device, and the temperature difference within the device, measured in* ℃ *[15]*	*Smaller relative temperatures is better*	*Temperatures should not differ by more than 1.5*℃ (to thus not cause clarity differences by more than 2 points as per the “seeing” scale in Fig. below)

According to Dean, the temperature between the inside of the dome should be comparable to that of outside, to reduce condensation (which may reduce image quality) on the telescope lens as well as reduce distortion effects from convective air currents [7]. In a study by researcher Robert McClure at the David Dunlap Observatory in Ontario, when the temperature is lower above the telescope than in the telescope, there is a linear relationship of clarity vs change in temperature, the strong correlation (with correlation coefficient of 0.38) peaking around when the temperatures are balanced (ΔT = 0): [15]

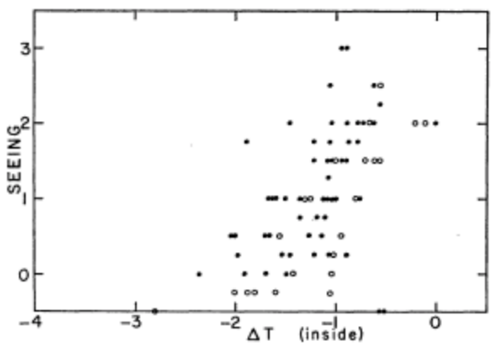


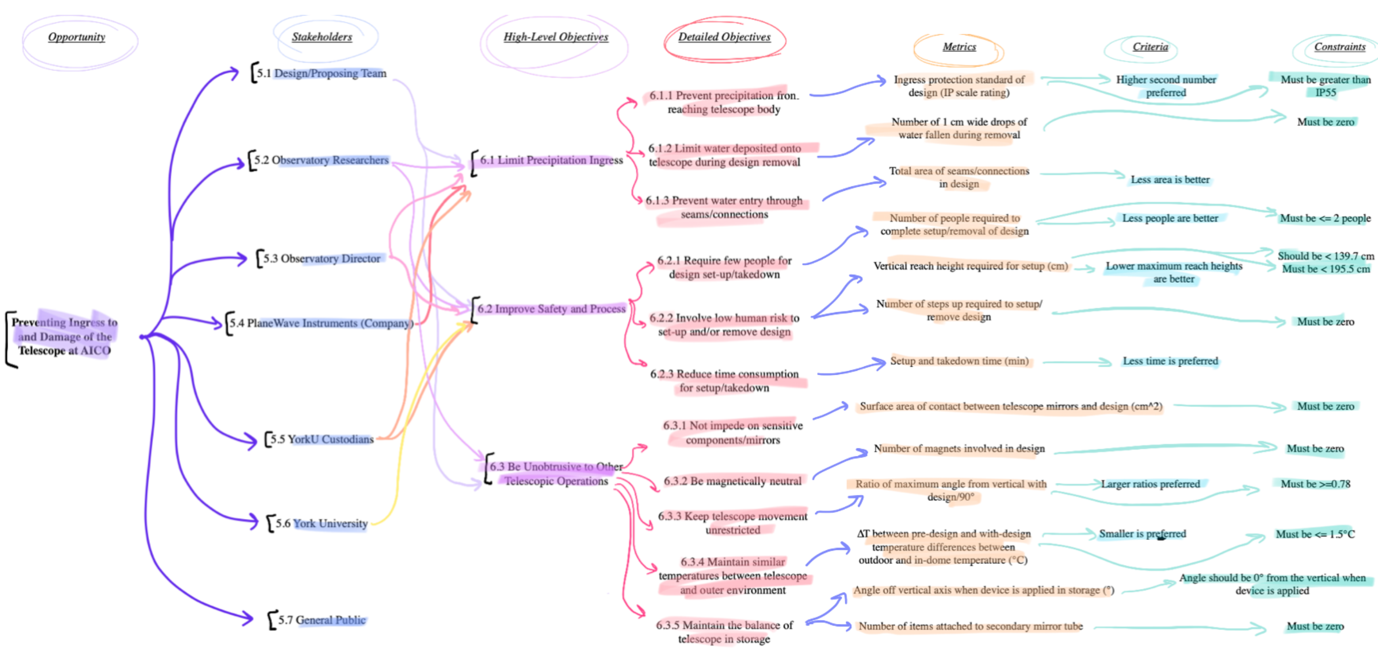
Figure 6: David Dunlap Observatory Temperature Difference vs. Clarity Study Results = Linear Correlation [15]

As seen, temperature differences cause observing impairment.

6.3.5. Maintain the balance of the telescope in storage	*Angle off the vertical axis when device is applied in storage (°)*		*Angle should be 0° from vertical when device applied*
Justification:	*Number of items attached to secondary mirror tube*		*Must have 0 items on secondary mirror tube*

Typical observatory telescopes include counterweights to ensure that a telescope is in balance. Storing a telescope while unbalanced will cause the automatic tracking system to not work properly. As mentioned by Dean from PlaneWave, adding anything that applies a force or moment to the telescope will automatically cause the telescope to tilt off balance, which, according to a BBC Sky at Night magazine for amateur astronomers, the balance ensures the night-sky-tracking follows the proper latitude at which the telescope is placed for accurate object finding and observing [7, 19]. The secondary mirror is found near the top of the telescope in the hollow part, so adding any mass to that part of the telescope will cause the telescope to tilt because there is no potential to attach a counterweight to the hollow area of the telescope without damaging the mirror; adding mass creates a moment and rotation that forces the telescope off balance, as explained by Dean [7].

Fig. 7: Visual Representation of Requirements



7. Reference Designs

7.1. Dew Heaters

Dew heaters are used on small telescopes to reduce moisture condensation on the lens of the telescope, which could distort the view of observers. These devices are low watt wrap around the objective lens of the telescope (as well as the finderscope and eyepieces, if desired). [24] These heaters heat the lens of the telescope and prevent moisture accumulation. Under the assumption that a larger version can be made to support the telescope at AICO, the AICO telescope is an open telescope with bars that limit someone from being able to attach this heater to the actual lens or the mirror tubes (damaging to the telescope due to 6.3.1). This method continues to put researchers at risk of getting their arms stuck between the vertical bars (fails 6.2.2), and this method does not protect the telescope from precipitation like rain or snow because it only effectively works under humid conditions when telescopes are susceptible to moisture due to the atmosphere (fails 7.2) Furthermore, the heaters would be difficult to control and would cause large temperature discrepancies and disturbances (fails 6.3.4). [25]

Figure 8. Dew Heaters (black straps) on main telescope and guide scope [25]

7.2. Car Cover

Car covers are used to protect the exterior of vehicles from outside elements including rain, dust and snow. The process of utilizing the tarp is quite simple; the user unwraps the water-repellant tarp, with some assistance places it on top of the object, and covers the object from all sides. This process is reversed when the tarp needs to be taken off. Although effective in protecting against precipitation, the tarping process may be strenuous especially when dealing with bigger cars including pickup-trucks and minivans (fails 6.3.1). Furthermore, like a bedsheet, much force is needed to hook one side and pull it to the other side. This would negate 6.3.1, pulling on components that could break the device were it not strong like a car. Moreover, several people would be needed to cover such a large item in one go, failing 6.2.1.

Figure 9. Car covering draping over vehicle. [19]

7.3. Snow Gun

CO_2 snow cleaning, a residue-free and nondestructive cleaning method, involves the formation and acceleration of small dry-ice crystals onto a surface. This works because of the combination of shear stress forces the large released snowflakes and force generated between hot air and cold surfaces. Although this is an effective method for removing dust, it does not at all provide a method for stopping the entry of precipitation into the telescope because it is simply a telescope cleaning method. However, it prevents dust buildup on the lens of the microscope, and it would only be done once in a while. Therefore, on the basis it does not remove the water that can enter the telescope and is not a daily solution, it does not fulfill the requirements for creating a design that effectively engages with the identified opportunity. [20]

Figure 10. Large Area Snow Gun Model K1-10LASU-C [20]

7.4. Desiccant Silica Gel

Desiccants eliminate humidity from the air to create a moisture-free environment. When attempting to find a truly absorptive material, the first material that comes to mind is the desiccant silica gel. The issues that arise from solely placing these beads everywhere on top of the lens will be that they have potential to leave residue on the lens and mirrors, failing 6.3.1, and cleaning them up afterwards involves extensive human effort and reach into the telescope itself. Furthermore, beads are unruly and, on an air bearing, little force would be needed to move the telescope, thus rolling of beads and movement of free packets could unbalance the telescope and lead to improper auto-tracking (fails 6.3.5). Finally, it will take lots of time to ensure that every small bead is removed from the lens with the large number required to dry the whole telescope (failing 6.2.3). Also, there is a max absorbance of these beads, so there is still potential for water to enter the telescope (fails 6.1.1). [26]

Figure 11. Image of a Silica Gel packet

8. Conclusion

The opportunity focuses on protecting the telescope at the Allan I. Carswell Astronomical Observatory (AICO) from precipitation damage due to a leaky dome. The team's core engineering values of safety, effectiveness, sustainability, and efficiency should be upheld in the proposed design, such that the result satisfies the three high-level objectives. The prevention of moisture buildup in the AICO's telescopic systems is crucial in allowing the unhindered and continued use of the 1-metre telescope.

By providing a solution to the opportunity stated, there will be an overall improvement to the lived experience of the various stakeholders at the AICO, including both academic and scientific research groups, facility members, and even the general public. Not only would the continued operation of the observatory add to scientific development, but it would also give the public the opportunity to learn what university funding goes into, as well as the various outreach programs which encourage participation in the STEM fields.

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10. Appendix

Figure 1: Zoom Meeting Screenshot with Professor Hyde [1]

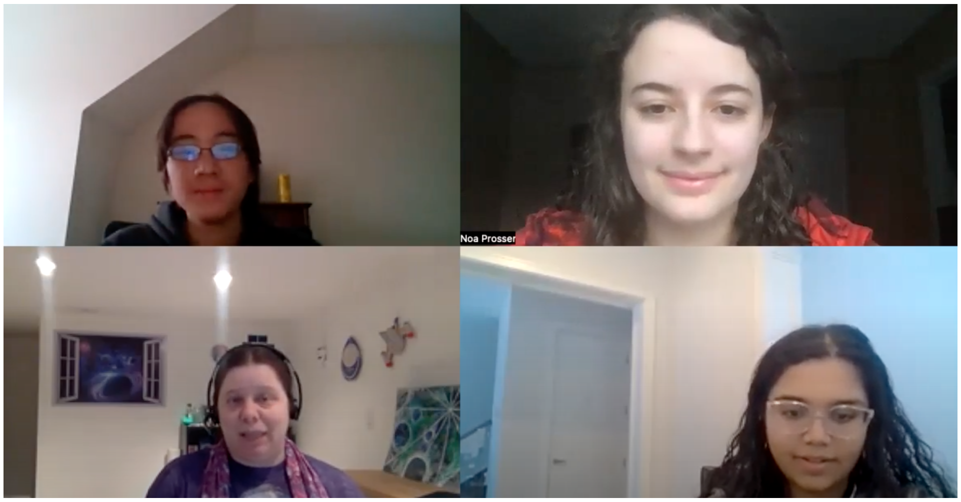


Figure 2: Questions for Interview with Professor Delaney [2]

- Solid infrastructure around telescope, expensive - keep dome in good shape is expensive ongoing
- Old!
- Rotation, opening, closing - seals need to be replaced annually or monthly - expensive
- Universities don't have much money
- 54 year old domes -
- Brand new dome - 7 m in diameter, 1/2 million dollars, replacing seals up and down shutters and around apron of dome, 10s thousands - customized
- Tried replacing 20 years ago
- Material rubberized compound - in Canadian climates, more drastic, not freezing ice rain, rubber from extreme temps wears down faster # environment harsher
- Observatory budgets don't
- Larger observatory, every year maintenance, money covers
- At York common to small observatories university of Victoria, similar leakage, had to protect telescope with tarps -
- Dome design - fewer sea,either side of shutter
- Clamshell design protect, overlap dome opening - minimize number of entry points
- Minimum number of seams, improve quality
- Telescope itself - minimize external vibrations
- Balance, environment within dome allowing free movement azimuth and altitude
- Temperature environment comparable to outside to minimize condensationExchange air in dome. Bigger observatories - fan ventilations, replace air to not ending up with condensation
- Ash dome
- Alberta company - info about quality control in observatory dome structure to protect telescope (computerized) added flexibility to do remotely - doesn't have to be city environment, could be more hostile
- Public into science realm. Funded by public (uni) appreciate what science and engineering get up to
- Univ observatory important
- Talk about research training, impact
- Research has benefits to society
- Energize students
- Engagement from observatory encourages participation in stem

Figure 3: Interview Questions and Answers from Ariella and Sunna [3]

- Please describe the tarping processes (HOW? How does the tarp process work, what is it made of, how big is it, how do they store it, etc.?)

We get a couple tall people who just put the tarp over the telescope, it doesn't cover the whole thing so we also have a couple garbage bags that we put over each port/instrument to protect them too. The tarp itself is huge, probably a couple meters on each side. As far as I know its just a normal tarp, I don't know what its made of. It spends most of its time on the telescope, so we don't really store it, when we take it off we usually just put it in some corner in the dome to keep it out of the way.

- How long would you say it takes to dry/clear the dome of ice/snow?

Depends on the conditions. On good days we just open/close the dome once or twice, and rotate it back/forth a bit to knock snow off, and this will only take a few minutes. If there's moderate amounts of snow/ice we do this multiple times, often opening the dome part way (until it starts making screeching noises when the motor is having a hard time with the ice/snow), then closing, then opening again and repeat until you can open and close fully without any issues. This can take up to 30+ mins sometimes. On especially bad days we have to have someone from facilities go up on the roof and clear snow off the dome manually before we can open it. We also turn on some heaters in the dome a couple hours before we go up to try and melt some of the ice, and park the dome so that the shutter is facing the Sun and that melts away some of the ice.

Figure 4: Interview answers extracts from [4]:

Questions:

How sensitive are the mirrors, and how protective are the specific mirror covers? How thick/what are these made of? (Is it safe for any items/coverings to lie atop the mirrors/mirror covers?)
- Extremely sensitive, 1m mirror covers are very good, but it is NOT safe for anything to go on top of them

Do magnets affect the telescope in any way? (is there a threshold)
- Yes, even small magnetic fields cause huge problems, in particular can cause feedback loops through the building and even make circuit breakers pop

Why is the telescope open instead of being enclosed?
- weight

What is the exact purpose of the covers/tarps?
- Stops ice/rain etc from touching telescope body

What is the exact process of how the tarps are put on?
- With a small ladder, they are carefully draped on

What is the exact process of how the tarps are taken off?
- Just like above but in reverse, requires 2

What risks may exist (to the observers and the telescope) when covering/uncovering the telescope?
- Must be very careful tarp does not catch/pull any equipment
- (Ladder, reaching up)

What are the weight limits on the telescope (i.e. how much extra weight could we put on the telescope before something breaks, etc.)?
- None safely, the telescope if finely balanced and cannot have any extra weight on the body

Are there any constraints with adding things onto the dome itself?
- Only in that it is difficult to mount to a curved, cold, leaky surface

Are there any constraints with adding things/hooking things onto the telescope itself?
- Many, see previous weight/balance

How does the moisture come into the telescope?
- Through holes in dome, gaps along shutter… or in worst case if shutter is left open

Figure 5: Interview with York University Custodian from [5]

Custodians only work on the ground floor
He has not gone to the observatory for several years

- Anyone works at Allan I. Carswell Observatory?
    - All custodians work within the observatory because they are on shifts
- Dimensions of telescope? Dimensions of dome? How high off dome floor is deck?
    - Unknown because he only works on the ground floor
- Carpeted floors? Intentional holes in deck?
    - Carpeted ground floor with the deck that has no holes
- How do they get rid of precipitation/dry the observatory?
    - There are leaks across the campus and leaks within the observatory at a similar rate.
- How do they find the current situation? Difficult to clean moisture? Is it difficult to clean the observatory (including drying the observatory) with all the devices cluttering the environment?
    - It is the same anywhere else on campus
    - He is not aware of the precipitation that is often found on the floor of the observatory
    - He is told by the observatory staff how to clean the area so he has no problem with the equipment
    - The floor is also tiled at parts

Figure 6: Source extract from Interview with Planewave Instruments Customer Support [6]

- Planewave (made telescope) - (Hotline Phone) (BILL - technical support)
    - +1 (310) 639-1662
    - What are the specifications of the York University telescope?
        - Coatings/materials and degradation?
            - Silica is the substrate
            - Enhanced aluminium
            - Dust is okay - reflectivity, negligible?
            - Manual cleaning - Snow Gun (freezing carbon dioxide and it is a stream used to clear off the dust).
            - Other method: takes a lots of Kleenex, Dawn Detergent and distilled water
            - Heat?
                - Not
                - Condensing water vapour, encoder redheads and reads - if fogged, contamination within water vapour deposited - mirrors - silica, no potential to damage - mirror subtract fused silica
                - Enhanced aluminium coatings for reflective coating
                - Corrector lens coating
                - Space heater = not a problem
                - Heating near telescope, local telescope - convective heat loop (visual/in imaging) - want mirrors be at operating temperature equilibrium with environment
    - Temperature Limits?
        - If there is condensing water vapour, the encoder rings become fogged
        - If there is any contamination that is deposited when evaporated, the mirror would not be damaged in that situation
        - Space heaters work out
        - Local turbulence will be seen in the telescope
        - We want the equilibrium temperature with the room fro the telescope
- How does this differ from the specifications of other university telescopes?
    - High resolution
    - Fast slew speed
    - Tracking
    - Direct drive motors - lower cost
    - Direct drive motors are novel and are not found in
    - High resolution occurs in fast smooth feeds
    - You can use lots of different softwares

Figure 7: Source extract from [7] (about CCDs):

Photodetectors

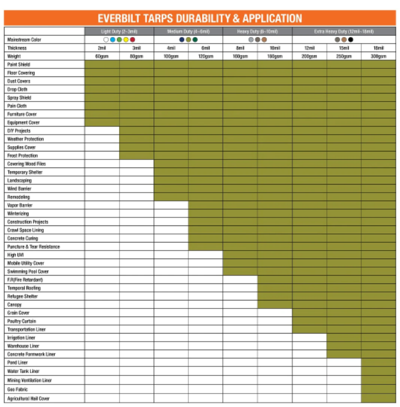
Rongqing Hui, in Introduction to Fiber-Optic Communications, 2020

4.5.2 Charge-coupled devices

Charge-coupled device, known as CCD, is another very popular photodetector commonly used for digital imaging and video (Theuwissen, 1995). Unlike a pn junction-based photodiode, CCD is based on a metal-oxide-semiconductor (MOS) structure.

Fig. 4.5.4A shows an example of CCD structure with a p-type semiconductor body, a thin silicon dioxide insulating layer and an array of gating electrodes. A positive bias voltage applied on a gate electrode repels holes away from the area underneath the electrode, creating a depletion region. Incoming photons are able to generate photoelectrons in the depletion region as illustrated in Fig. 4.5.4B. These photon-induced charges are then shifted programmably in the horizontal direction to one side of the array so that they can be electrically amplified and collected. Charge shifting can be accomplished by progressively shifting gate voltage along the array as shown in Fig. 4.5.4C–F. The gating electrodes of CCD made for imaging are usually arranged in a two-dimensional (2D) array as illustrated in Fig. 4.5.5. As the imaging sensor, CCD is usually mounted on the focal plane of a camera. After each exposure, a charge distribution pattern is created on the 2D plane of the CCD, which is proportional to the intensity distribution of the image. The

Figure 8: Source extract from (Home Depot) [8]:



Specifications

Dimensions

Size (ft)	16x20	Space between grommets (ft.)	3
Tarp Width (ft.) x Tarp Length (ft.)	20 x 16		

Details

Color Family	Blues	Color/Finish	Blue
Durability	General purpose	Features	No Additional Features
Grommet Material	Aluminum	Kit	No
Material	Plastic	Package Quantity	1
Product Weight (lb.)	7.54	Returnable	90-Day

Figure 9: Source extract of day in the life of Astronomers [9]

Astronomy in Everyday Life

By Marissa Rosenberg, Pedro Russo (EU-UNAWE, Leiden Observatory/Leiden University, The Netherlands), Georgia Bladon, Lars Lindberg Christensen (ESO, Germany)

Also see Rosenberg, M., Russo, P., Bladon, G. & Christensen, L.L., Astronomy in Everyday Life CAPjournal 14, 2013

Introduction

Throughout History humans have looked to the sky to navigate the vast oceans, to decide when to plant their crops and to answer questions of where we came from and how we got here. It is a discipline that opens our eyes, gives context to our place in the Universe and that can reshape how we see the world. When Copernicus claimed that Earth was not the centre of the Universe, it triggered a revolution. A revolution through which religion, science, and society had to adapt to this new world view.

Astronomy has always had a significant impact on our world view. Early cultures identified celestial objects with the gods and took their movements across the sky as prophecies of what was to come. We would now call this astrology, far removed from the hard facts and expensive instruments of today's astronomy, but there are still hints of this history in modern astronomy. Take, for example, the names of the constellations: Andromeda, the chained maiden of Greek mythology, or Perseus, the demi-god who saved her.

Now, as our understanding of the world progresses, we find ourselves and our view of the world even more entwined with the stars. The discovery that the basic elements that we find in stars, and the gas and dust around them, are the same elements that make up our bodies has further deepened the connection between us and the cosmos. This connection touches our lives, and the awe it inspires is perhaps the reason that the beautiful images astronomy provides us with are so popular in today's culture.

There are still many unanswered questions in astronomy. Current research is struggling to understand questions like: "How old are we?", "What is the fate of the Universe?" and possibly the most interesting: "How unique is the Universe, and could a slightly different Universe ever have supported life?" But astronomy is also breaking new records every day, establishing the furthest distances, most massive objects, highest temperatures and most violent explosions.

Pursuing these questions is a fundamental part of being human, yet in today's world it has become increasingly important to be able to justify the pursuit of the answers. The difficulties in describing the importance of astronomy, and fundamental research in general, are well summarized by the following quote:

"Preserving knowledge is easy. Transferring knowledge is also easy. But making new knowledge is neither easy nor profitable in the short term. Fundamental research proves profitable in the long run, and, as importantly, it is a force that enriches the culture of any society with reason and basic truth."

Figure 10: Source extract from [10]

Mend a ripped seam

★☆☆☆☆

15 minutes
Professional cost £6.33
DIY cost Free
Difficulty:

Seams are found on the sides, crotch or back of garments -

the stitching can undo or the fabric can tear. If it is just the stitching, you can sew it back together; if the fabric has torn, you need to reinforce it.

Sewing up seams

Unpick any loose threads and match up the seam. Pin in place. Thread a needle with about 60cm of thread folded in half and knot the two ends together. Start sewing along the old stitching line, using backstitch (see page 8). Keep the stitches as small as you can and make sure you sew through both the layers.

Repairing torn fabric seams

If the fabric is ripped it can be hard to repair without making the garment smaller. If there is a bit of slack though, you can use this in the repair: just match the edge of the rip with the opposite seam and sew a few millimeters away from the raw edge. If not, mend the hole first.

Figure 11: Source extract from PlaneWave Instruments [11]

Figure 12: Source extract of cost of the telescope [12]

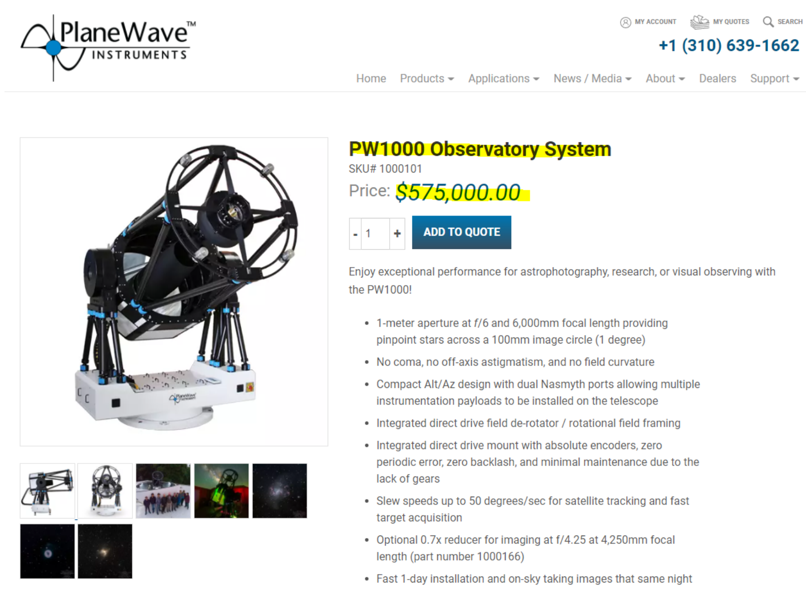


Figure 13: Source extract from Planewave Instruments [13]

Services

Installation

PlaneWave Services is pleased to offer domestic and international installation for any PlaneWave system, as well as equipment from a long list of trusted, third-party manufacturers, including:

- Scientific cameras
- Prefabricated domes and roll-off-roof observatories
- Solar-telescopes
- Color, photometric, and narrow-band filters
- Spectrographs and spectrometers

Pre-installation consulting services are available, including:

- Observatory design and planning
- Equipment recommendation and selection based upon your observational needs
- Local contractor selection
- Contractor guidance, specific to concepts and practices unique to observatory construction

Due to the potential complexity of many installation scenarios, the discussion will be necessary before an estimate or quote can be offered.

Figure 14: Source extract the David Dunlap Observatory processes [14]

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A Study of Factors Affecting Seeing at the David Dunlap Observatory

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(Received 18 January 1966)

Measurements of short-period temperature fluctuations show that thermal turbulence inside the dome of the 74-in. telescope provides the major contribution to poor seeing at the David Dunlap Observatory. Measurements of the temperature gradient in the dome demonstrate that this turbulence is produced by temperature differences between the interior and the exterior of the dome. Measurements from a weather tower and a captive balloon show that the best seeing is observed at times when a strong temperature inversion is present in the lowest layers of the atmosphere.

I. INTRODUCTION

As a contribution to the Canadian 150-in. telescope project (Petrie 1964), a study has been undertaken of the physical factors which might affect the size of the seeing disk in a large telescope. The present investigation is concerned with seeing effects produced in the lower atmosphere and in the telescope dome. The influence of the upper atmosphere on seeing will be discussed in a subsequent paper. For previous work on the physics of seeing the reader is referred to a number of review papers presented at IAU Symposium No. 19 on Site Testing (Rosch 1962), and to papers by Stock and Keller (1960), by Meinel (1960), and by Winibush (1961).

II. OBSERVATIONS OF SEEING

Seeing observations were carried out at the Cassegrain focus of the 74-in. telescope at the David Dunlap Observatory, in conjunction with spectroscopic observations. The image quality was estimated visually by comparing the diameter of the seeing disk with the length of the Hilger spectrograph slit, in accordance

a cast aluminum block. The block was large enough so that its temperature would not normally change by more than about 1 deg over a period of half an hour. Any microthermal fluctuations near the ground were therefore completely damped out. The over-all sensitivity of the equipment was such that differences as small as 0.1 Centigrade degree could easily be measured.

During some nights a captive balloon was used to study the temperature stratification in the lower 200 ft of the atmosphere.

Temperature recordings were made approximately every hour during 31 nights throughout the period 21 June to 10 August 1963 when the telescope was in regular use. Two variables, "ΔT" and "Amplitude," were measured on these temperature tracings. ΔT is the mean temperature difference between the top and the bottom of the tower during the 20-min interval. The nighttime temperature was almost always found to be higher at the top of the tower than at ground level (ΔT positive). Amplitude is the mean of the maximum amplitudes of the temperature fluctuations at successive intervals along the chart.

During each recording of temperature, the seeing

Figure 15 Source extract of various telescopic lens coating [15]**:**

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Primary mirror aluminization

Next time you are in your bathroom, take a close look at the mirror. If you look carefully, you will see that the reflective surface of the mirror is on the *back* side of the glass, and is protected. If you clean your bathroom mirror, you only touch the front surface of the glass - not the coating itself. If you look closely at reflections from your bathroom mirror, you will see that there are actually two reflections - the main reflection from the reflective surface at the back, and a second, fainter reflection, from the front surface of the glass.

Telescope mirrors are different. The reflective coating is on the front of the glass, so don't get two images of every star we look at. This means that the coating is much more fragile. The coating is exposed to the air, dust, and moisture. It is difficult to clean it without damaging it. All telescopes have to recoat their mirrors every few years.

Most telescopes coat their mirrors with a very thin layer of aluminum. The exceptions are the Gemini Telescopes, which recently coated their mirrors with silver.

The first step in recoating a telescope mirror is removal of the old coating, along with any dirt or other substances attached to the mirror.

Figure 16: Source extract of coating properties [16]:

An Overview of Aluminum Protective Coating Properties and Treatments

Ron Liu
OPTI 521
November 9, 2009

Introduction

Aluminum is the most widely used non-ferrous metal. It is low cost and has a unique set of fine material properties that have made it ideal to be used in many common applications; such as in structural components and mirror reflectors. Pure aluminum has a low tensile strength but when it is chemically treated and alloying with other metals, it can exhibit significantly improved strength and other mechanical properties. Aluminum alloys are especially important in the aerospace, transportation and architectural industries where result of their high strength to weight ratio. Nonetheless, pure aluminum naturally oxidizes to provide thin layer of barrier oxide for corrosion resistance. However, in harsh environment, aluminum must be chemically treated to provide enhanced protection. Moreover, types of treatment can vary substantially depending on different application requirements.

Background

Aluminum is one of the most abundant metals found on Earth, and the recent advancement in the efficiency of extracting aluminum from ore has made it relatively cheap to procure. It has about one-third the density and stiffness of steel; it is ductile and can be easily machined. Naturally, pure aluminum reacts readily with oxygen in air creating a thin barrier oxide layer known as the aluminum oxide next to the metal surface that is about 2-3 nanometers thick. This barrier oxide layer stabilized the surface and prevents it from any further reaction with its environment and is an excellent electrical insulator. However, when it is exposed to harsh environment such as in the presence of aqueous salt, the corrosion resistance can be greatly reduced. Therefore, it must be further treated for enhanced protection.

Aluminum is also common used in mirror coatings. It is one of the few metals that retain its full silvery reflectance in finely powdered form, making it an important component for mirror coatings. Aluminum mirror finish has the highest reflectance of any metal in the 200–400 nm ultraviolet and the 3000–10000 nm infrared spectral ranges. However, its reflectance in the 400–700 nm visible range is slightly lowered compared to silver and tin and in the 700-3000 near infrared when compared to silver, gold and copper. Regardless

Figure 17: Source extract for Ingress Protection (IP) Rating used for [17]:

First Digit	Intrusion Protection	Second Digit	Moisture Protection
0	No protection.	0	No protection.
1	Protected against solid objects over 50mm, e.g. accidental touch by hands.	1	Protected against vertically falling drops of water, e.g. condensation.
2	Protected against solid objects over 12mm, e.g. fingers.	2	Protected against direct sprays of water up to 15 degrees from the vertical.
3	Protected against solid objects over 2.5mm, e.g. tools & wires.	3	Protected against direct sprays of water up to 60 degrees from the vertical.
4	Protected against solid objects over 1mm, e.g. wires & nails.	4	Protected against water splashed from all directions, limited ingress permitted.
5	Protected against dust limited ingress, no harmful deposits.	5	Protected against low pressure jets of water from all directions, limited ingress permitted.
6	Totally protected against dust.	6	Protected against strong jets of water, e.g. on ships deck, limited ingress permitted.

Figure 18: Source extract of handbook [18]:

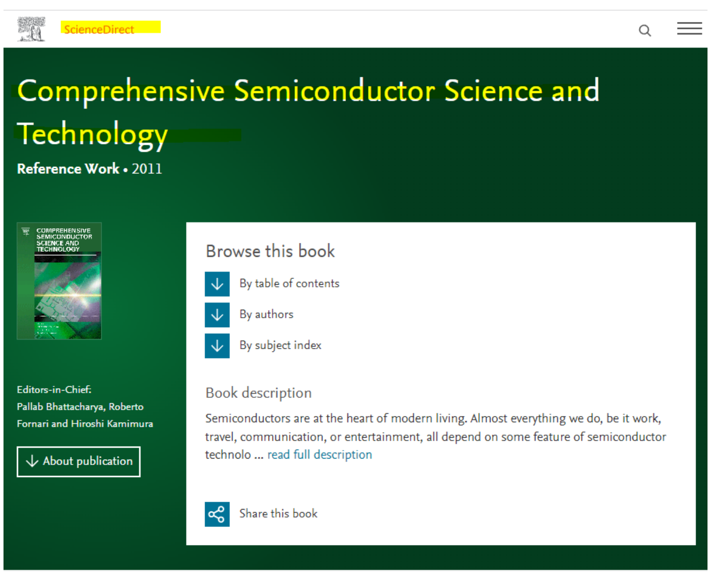


Figure 19: Source extract from [19]:

By Steve Richards
Published: May 5, 2020 at 8:23 am

Why does my telescope need a counterweight?

Steve says: "Telescope mounts allow the telescope to follow celestial objects as they traverse the sky. On an altaz mount, which moves horizontally and vertically, the weight of the telescope sits immediately above the mount.

However, with an equatorial mount one of the axes – the right ascension axis – is tilted at an angle that matches your latitude.

This change in orientation places the weight of the telescope off to one side of the right ascension axis.

So to stop the telescope from rotating downwards under the effect of gravity, a counterweight placed on an extension bar is required to exactly balance the weight of the telescope tube."

Figure 20: Source extract of cleaning procedure of telescopes [20]:

Telescope Cleaning

Introduction
Carbon Dioxide Snow Cleaning offers a quick, effective, and inexpensive way to clean large telescope mirrors. Astronomers have cleaned mirrors ranging in size from several inches up to 25 feet (8 meters). This application is based upon the low velocity CO_2 snow cleaning mode. Here, we use a larger expansion zone that changes the initial CO_2 snow exiting the orifice from a high velocity, small dry ice ,to a large snowflake with a low velocity. This mode is aimed at removing particles from microns on up and is quite effective. Organic removal is not likely in this mode. Furthermore, the working distance is much greater than with the high velocity mode. Users can operate several feet from the mirror making sure there is no risk of contacting the mirror.

The equipment for this is similar as the high velocity mode but with a different ofice and nozzle assembly. We use the same hose and on/off gun as shown on the equipment page.but use a smaller orifice that has a larger internal diameter. This nozzle lets the stream exit into an polymer expansion tube, usually an inch in diameter. This means the stream striking the mirror will be larger than 1 inch. Note, we will show a two inch nozzle below, for larger mirror cleaning.

Below, we show the equipment, provide two videos, and then show the price list. Note, that universities and research laboratories within the US can qualify for discounts.

Equipment and Prices
The basic low velocity CO_2 snow cleaning system is based upon the equipment for the standard K1-10 shown on the equipment page. We leave off the asymmetric Venturi nozzle and add the simpler low velocity nozzle and expansion zone tube. Overall, the image below, shows the various items for the low velocity and high velocity CO2 snow cleaning modes. Demonstration videos are below

Large Area Snow Unit Model K1-10LASU-C

Slot Nozzle

Figure 21: Source extract from [21]:

Weight Of Objects

Heavier loads place greater stress on muscles, discs, and vertebrae.

Where possible, use mechanical means such as forklifts or hand trucks to transport heavy items. Ramps can be helpful in moving heavy items from one level to another. Materials that must be manually lifted should be placed at "power zone" height: about mid-thigh to mid-chest of the person doing the lifting. Ensure that proper lifting principles (see above) are used. Try to order supplies in smaller quantities and/or break loads up into smaller, lighter quantities where possible. Is the container itself heavy? Perhaps a smaller or lighter container is available. Limit weight you lift to no more than 50 pounds. When lifting loads heavier than 50 pounds, use two or more people to lift the load.

Awkward Postures

Bending while lifting causes several problems for the back. It adds the weight of the upper body to the weight of the object being lifted. Bending and/or reaching moves the load away from the body and allows leverage to significantly increase the effective load on the back, leading to stress on the lower spine and muscle fatigue. Carrying loads on one shoulder, under an arm, or in one hand creates uneven pressure on the spine.

Move items close to the body and use the legs when lifting from a low location to minimize bending and reaching. Ensure proper housekeeping is taking place so that you may get as close to your lifting load as possible. Store and place materials that need to be manually lifted at the "power zone": mid-thigh to mid-chest height. This can be accomplished by placing objects on shelves, tables, racks, or stacked pallets; or by using ladders or aerial lifts where necessary to elevate yourself and minimize overhead reaching. Roll-out decks in truck beds can be utilized to bring materials closer to the employee and eliminate the need to crawl into the back of a truck. Ensure that proper lifting principles (see above) are used, including avoiding twisting and holding the load close to the body.

High-Frequency and Long-Duration Lifting

Holding items for long periods, even if loads are light, increases the risk of back and shoulder injury since muscles can be starved of nutrients and waste products can build up. Repeatedly exerting, such as when pulling wire, can fatigue muscles by limiting recuperation times. Inadequate rest periods do not allow the body time to recover.

Plan ahead when beginning work that will require high-frequency and long-duration lifting. This way, the work can be organized in such a way so as to minimize the time workers spend holding loads. Adequate rest breaks can be planned in, as well as job rotation between employees. This includes both rotating tasks (employees trade off on differing tasks) and team work (two or more employees work together doing different parts of the same activity to reduce strain). Planning can also include the pre-assembly of work items to minimize the time spent handling them during the actual work.

Inadequate Handholds

Inadequate handholds, such as boxes without handles or oddly-shaped loads, make lifting more difficult, move the load away from the body, lower lift heights, and increase the risk of contact stress and of dropping the load.

Where possible, utilize handholds such as handles, slots, or holes that provide enough room for gloved hands. Try to use materials that are packaged with proper handholds (your supplier may be able to provide different containers), or move materials into containers with good handholds. Wear protective equipment to avoid finger injuries and contact stress. Ensure that gloves fit properly and provide adequate grip. Suction devices are helpful in lifting junction boxes and other materials with smooth, flat surfaces. Other tools may be available that can create temporary handles.

Environmental Factors

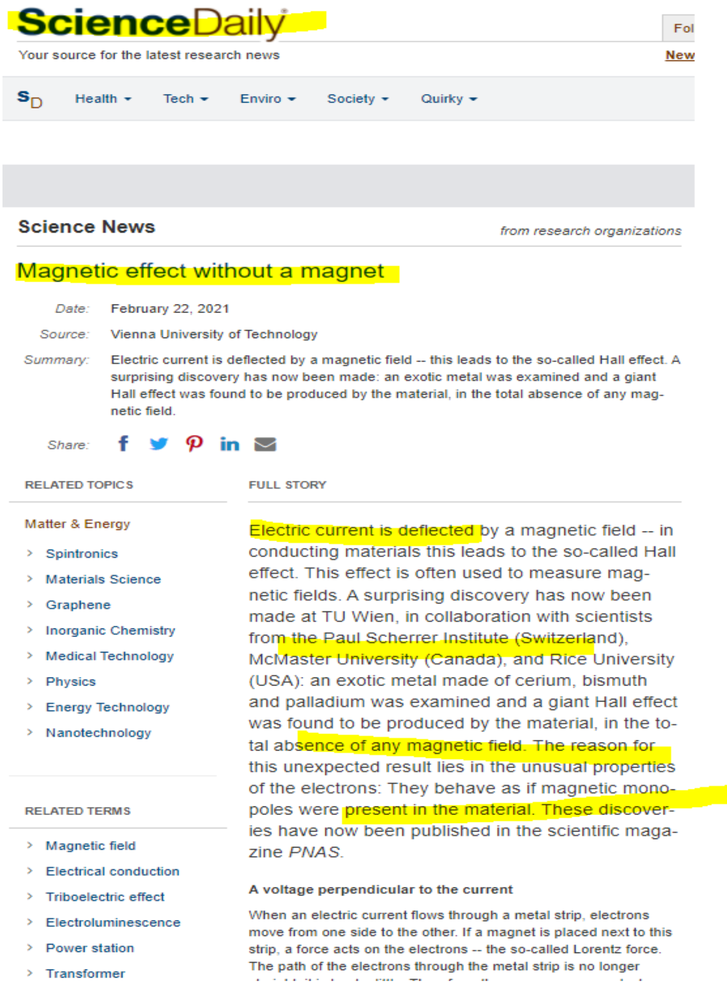
Be aware of extreme temperatures that can affect lifting and material handling. For example, muscle flexibility decreases in cold temperatures, and hot temperatures can lead to heat stress. Low visibility or poor lighting increases the chance of trips and falls.

Do what you can to adjust work schedules to minimize exposure to extreme temperatures or low visibility. Wear appropriate clothing for the temperature in which you will be working. Drink lots of water to avoid dehydration in excessive heat. Provide proper lighting for areas with low light and try to perform work during daylight hours when possible.

Additional Resources

- OSHA Ergonomics eTool: Materials Handling: Heavy Lifting
- OSHA Ergonomics eTool: Ergonomic Principles Index – Lifting
- UCLA Ergonomics

Figure 22: Source extract from [22]:



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Magnetic effect without a magnet

Date: February 22, 2021

Source: Vienna University of Technology

Summary: Electric current is deflected by a magnetic field -- this leads to the so-called Hall effect. A surprising discovery has now been made: an exotic metal was examined and a giant Hall effect was found to be produced by the material, in the total absence of any magnetic field.

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- Electroluminescence
- Power station
- Transformer

FULL STORY

Electric current is deflected by a magnetic field -- in conducting materials this leads to the so-called Hall effect. This effect is often used to measure magnetic fields. A surprising discovery has now been made at TU Wien, in collaboration with scientists from the Paul Scherrer Institute (Switzerland), McMaster University (Canada), and Rice University (USA): an exotic metal made of cerium, bismuth and palladium was examined and a giant Hall effect was found to be produced by the material, in the total absence of any magnetic field. The reason for this unexpected result lies in the unusual properties of the electrons: They behave as if magnetic monopoles were present in the material. These discoveries have now been published in the scientific magazine *PNAS*.

A voltage perpendicular to the current

When an electric current flows through a metal strip, electrons move from one side to the other. If a magnet is placed next to this strip, a force acts on the electrons -- the so-called Lorentz force. The path of the electrons through the metal strip is no longer

Figure 23: Source extract from [23]:

Hazards are conditions or actions that can cause injuries or illness.

Ladders are one of the most commonly used and abused tools. Every year hundreds of people are hurt at work while using ladders. In order to prevent injuries from using a ladder you must know how to identify the hazards that cause injuries and what to do to correct or eliminate them. Some of the hazards related to ladder use are:

- *Reaching or learning too far rather than moving the ladder.*
- *Placing the ladder on boxes or pallets to make it taller.*
- *Climbing the ladder while carrying items.*
- *Using the wrong ladder for the job, such as using a step ladder as a straight ladder.*

- *Standing on the very top step or rung.*
- *Placing an extension or straight ladder at the wrong angle.*
- *Worn or damaged ladders.*
- *Exceeding the ladders weight limit.*
- *Throwing tools to a worker who is on the ladder.*
- *Using metal ladders in areas where contact with electrical wires could occur.*

Since the major hazard of a ladder is falling, here are a couple of other hazards that can cause falls:

- *Raising or lowering someone with the forklift.*
- *Working unprotected at heights greater than ten feet.*
- *Using things like boxes and chairs instead of a ladder.*