THROUGH A **TECHNICAL** LENS

CRAIG MARTIN

Figure 1. Front cover: Moon

THROUGH A **TECHNICAL** LENS

A Design Thesis Submitted to the Department of Architecture and Landscape Architecture of North Dakota State University.

By,

Craig Michael Martin

In Partial Fulfillment of the Requirements for the Degree of Master of Architecture.

5/8/13

Primary Thesis Advisor

May 7th, 2013

Thesis Committee Chair

May 2013

Fargo | North Dakota

TABLE OF **CONTENTS**

List OF **FIGURES**

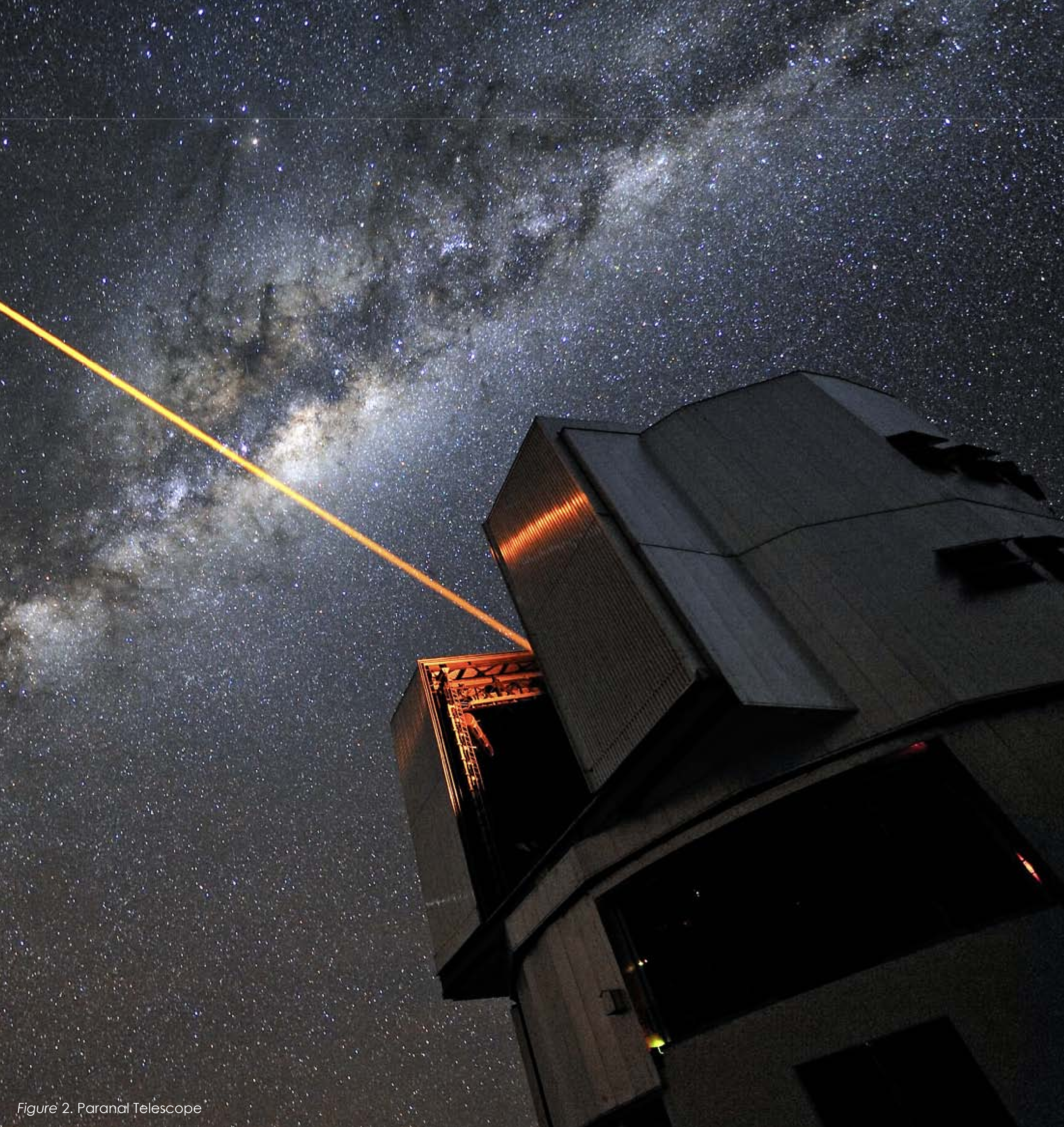


Figure 2. Paranal Telescope

ABSTRACT

Through a Technical Lens will examine how architecture can facilitate advances in modern astronomical technique and equipment, specifically in the building typology of observatories and visitor centers. This design of an observatory will be located at the West Summit of the Beartooth Pass in Wyoming. Technique and technologies in astronomy are rapidly changing; therefore, architecture that can evolve with advances in astronomy will eliminate the need to construct new facilities every time a change occurs. These high-tech buildings must function flawlessly for the users, but they must also minimize the impact on the fragile environment in which they are placed. The architecture of an observatory should use regenerative principles and deconstruction techniques in order to accomplish this balance. Research will be analyzed from the field of astronomy, regenerative design, deconstruction, and modern building practices, with particular focus on considering the future needs of astronomers.

Key Words:

Technology, Technique, Observatories, Astronomy, Regenerative design, Deconstruction

THESIS **PROBLEM STATEMENT**

How can architecture adapt to the changing needs of astronomy research?

Statement of Intent.

STATEMENT OF **INTENT**

The Project **Typology**

The typology for this thesis is an observatory/visitor center.

Claim

As astronomy changes over time so do the techniques it uses. Architecture can adapt to these changes as astronomy develops by reconstructing itself for the future needs of users and the instruments it holds.

- **Actor**: Users and Instruments
- **Action**: Adaptation
- **Object**: Observatories
- **Manner**: Observatories that can change and adapt themselves as techniques in astronomy develop will benefit the user by creating dynamic, flexible environments for advancement.

Premises

Actor: Scientists need adequate and flexible space to conduct their observations. Many observatories do not have sufficient space to house teams of scientists during a typical viewing session. Observational facilities should be centers for astronomers to collaborate and discuss their theories (Brunier & Lagrange, 2005). As astronomical technology develops, so does the need for additional living, working, conferencing, and educational space. This means observatories must adapt in order to ensure that users can utilize the facilities to the fullest potential.

Action: Observatories should be capable of evolving just as quickly as astronomical technology does. Scientists frequently alter astronomical technologies after each project is completed, because telescopes are often designed for only one project. This leaves the observing equipment either unused or only consulted for minimal research purposes. Scientists are constantly changing their equipment based on current research needs, which is why observatories need to be extremely adaptive for the users and their technology. Building materials should have the ability to be easily recycled and remanufactured in order to reincorporate them back into the architecture for future use.

Object: Instrument technology has changed faster than many scientists had anticipated that it would, which has lead to different techniques used for gathering information. Observatories have increasingly become centers where people spend significant amounts of time conducting research. Because of this, scientists need technically advanced buildings that can house entire research labs of computers, staff, and equipment. Rolnick Observatory in Connecticut produced a solution at their facility by adding new buildings that included overnight sleeping facilities and space for better equipment (Harrington, 2005). Providing utility and comfort for users is essential as observatory facilities become homes for many scientists on a regular basis.

Manner: Observatories must plan for the future by becoming building blocks that can be easily changed for future astronomical technologies while simultaneously addressing harsh environments in the most conscious way possible. The architecture must use regenerative design as its main emphasis so it can adapt quickly and efficiently to researchers' needs. Large numbers of visitors will want to explore and engage the site also, so preservation is fundamental to this project as well. As William McDonough points out in the video *The Next Industrial Revolution* (2001), design should never harm a site; rather it should always strive to better it in one way or another (McDonough, 2006).

The **Theoretical Premise/ Unifying Idea**

Observatories can use regenerative design and deconstruction principles to remain relevant to future techniques/technologies and the developing culture of astronomy research. Using these principles will allow architecture to be flexible and adaptable to future advancements in astronomy.

The Project **Justification**

Techniques and technology are the two leading aspects that are shaping the way astronomy views space. They are also shaping the form and function of observational architecture (Lasota, 2011). Interest has shifted from spending money on multiple observatories to collaborating by building larger, more advanced observational facilities like the European Southern Observatory (ESO), known as Cerro Paranal Observatory. As models of advancement in technology and technique in astronomy, observatories must be designed as progressively as possible. Cradle-to-Cradle (the strategy of creating a perpetual cycle of building materials) should be introduced in observatory design. These advanced principles are particularly applicable to observatories; it would be quite ironic for some of the world's most advanced technology to be housed in "dumb buildings." The use of adaptable building technology would allow the scientific community to quickly adjust to new techniques and technologies in these flexible, interchangeable spaces.

The Proposal.

Figure 3. Camera Lens

NARRATIVE

Observatories are spaces of knowledge and places of technique (Gauvin, 2010). Not only are they arenas from which one can observe the cosmos, but they are also symbols of economy, a nation's military power, and of culture. Observatories reflect how a culture regards science and technology. Observatories are often viewed as "cutting edge" or as places of technical development. Europe provided astronomy with an outstanding model for what an observatory could be in the future through its contribution of Cerro Paranal Observatory in Chile.

Cerro Paranal Observatory promotes different techniques of observing. The observatory design is not based on one technique but rather several, and the facility demonstrates how users of these various methods can collaborate to advance astronomy. The observatory is a fantastic example of people from many cultures cooperating on scientific projects. Architecture plays a key role in providing these researchers with places to live and work for extended periods of time.

Collaboration is also prevalent in the design of W.M. Keck Observatory in Hawaii. The directors of this observatory wanted ease of use for learners to be a key factor in the design of their facility, because the group focuses on educating people about astronomy and advancing knowledge in science (Brunier & Lagrange, 2005).

The focus of *Through a Technical Lens* will be to develop the idea that architecture should adapt or change as culture and technique do. Architecture must progress as quickly as astronomy does by allowing for flexible space, implementing remanufactured materials, and creating an atmosphere that is healthy for its users and the environment in which it is placed.

The digital camera provides a useful example of adaptability. Digital cameras are designed to adapt well to new technologies and techniques. As photographers experiment with new photography methods, manufacturers develop new lenses. Every lens is interchangeable; as new lenses are developed, the photographer does not need to purchase a new camera, because the camera is built to host new types of technology. Now, consider if all these lenses were remanufactured after they were no longer needed.

Every piece of the lens could be taken out, refurbished, and made into a new lens. It would greatly decrease the cost for the photographer and the impact on the environment. Similarly, observatories can be compared to the camera body; they could be flexible and adaptable in order to facilitate new techniques. Of course, not all instruments function or fit the same way, but architecture could help bridge the gaps between these new techniques in one critical aspect of astronomy: optical observation. Each time a new technique is developed, architects could assist researchers to transition easily by simply deconstructing and recycling all the parts of the building for the new use.

The design of an observatory in the Beartooth Mountains of Wyoming will demonstrate how architecture can be the facilitator of current and future astronomy techniques and technologies. This site is at an elevation that is high enough for good viewing, it is within driving distance of three major universities, and it is accessible all year round. The facility will be an excellent model for students and scientists of how observatories could operate in the future. Visitors will also be able to experience astronomy through a visitor center that will be part of the overall design. Both groups will be able to experience mountain architecture that does not harm the fragile environment but instead protects the mountain for use by future generations. This observatory will become an example of an adaptable and flexible viewing platform for other observatories around the world.

Figure 4. Nebula 1

Figure 4a. Nebula 2

Figure 4b. Nebula 3

USER/CLIENT DESCRIPTION

The Project **Owner**

The United States Federal Government owns the land the observatory will sit on. The land is part of the Shoshone National Forest run by the USDA Forest service. This organization will own the visitor center, as they have jurisdiction over the land, but the observatory will primarily be run by Montana State University, the University of Montana, and the University of Wyoming. The students and faculty, as well as other scientists, will run the daily experiments within the observatory. The Universities and the Forest Service will work together to ensure proper use of both facilities. Upkeep of the visitor center portion will be issued to the Forest Service, while upkeep associated with the observatory will be attended to by the University Staff. The public will be welcome to use the visitor center as well as partake in tours of the observatory. The goal of the visitor center is to encourage public interest in astronomy and the mountainous environment surrounding the site.

User Groups

Visitor Center:

Visitor Use Assistant
Park Guide
Park Ranger
Seasonal Maintenance
Gift Shop Employee
Visitors
Volunteers

Observatory:

Facilities Manager
Research Engineer
Software Engineers
Electrical Engineer
Instrument Technicians
Astronomers
Volunteer Astronomer Guides
Public Visitors
Students

Parking for both the observatory and visitor center will accommodate a the general public and will include several reserved spots for the observatory. Busses running from Red Lodge and Cooke City will be available during peak hours. The peak usage time is during the summer months: July through October. The park is in full usage at that time, so the visitor center will be open seasonally while the observatory will remain open year-round. The facilities will only be accessible by snowmobile or CAT in the winter months due to road closures between October and April.

Figure 5. Beartooth Pass

MAJOR **PROJECT ELEMENTS**

Visitors Center:

The visitor center will be where the general public will congregate. It will include spaces for education and other informational exhibits. These exhibits will focus on the geology of the Beartooth Mountain Range and the astronomical research being conducted at the observatory.

Main lobby	Gallery
Classrooms	Restrooms
Gift Shop	Storage and Mechanical
Office	Media Room
Small Cafe	Outdoor Viewing Space

Observatory:

The observatory will be the main facility at the west summit of the Beartooth Pass. The observatory will include space for users to live for short periods of time to complete their research efficiently. Large areas will also be developed for the collaboration and education of the users. The public will be able to access the observatory through guided tours. The building will be a fully functioning research facility.

Telescope platforms	Control Room
Offices	Laboratory
Storage and Mechanical	Restrooms
Conference space/Educational space	Library

Living Facilities:

These facilities will be designed to encourage collaboration among users. Recreation spaces will also be included in the living facilities. Because researchers may live at the observatory for periods of one or more weeks, indoor and outdoor facilities will be provided. A kitchen will also be developed for use by those staying at the facility.

Restrooms	Kitchen/Dining
Short stay rooms	Lounge space
Recreation rooms	Entrance/Lobby

SITE INFORMATION

The Beartooth Mountains are located in the northwest corner of Wyoming and are part of the Rocky Mountain Range. These mountains display a variety of sharp rocky peaks, vast alpine meadows, and many glacial lakes.

Red Lodge, Montana is the closest city to this mountain range. While this town is fairly small in population—2,125 (United States Census Bureau, 2010)—it booms in midsummer and during the winter months. People primarily visit Red Lodge during the summer months to experience beautiful U.S. Highway 212, a scenic mountain route that travels from Billings, Montana to the northern gate of Yellowstone National Park.

The site for the visitor center/observatory is located at the west summit of Highway 212, as illustrated in *Figure 7*. The location is on the Wyoming side of the highway but very near the Montana border. At 11,017 feet, the site sits high above the surrounding mountains. The location is excellent for observation due to its high altitude and lack of large surrounding cities, because observatories require dark skies and a higher atmosphere for optimal viewing conditions. The same gases that color sunsets also blur images from ground based observatories (Brunier & Lagrange, 2005). The site can also be easily accessed by vehicles, as Highway 212 leads directly to the west summit.

Figure 6. Beartooth Pass 2

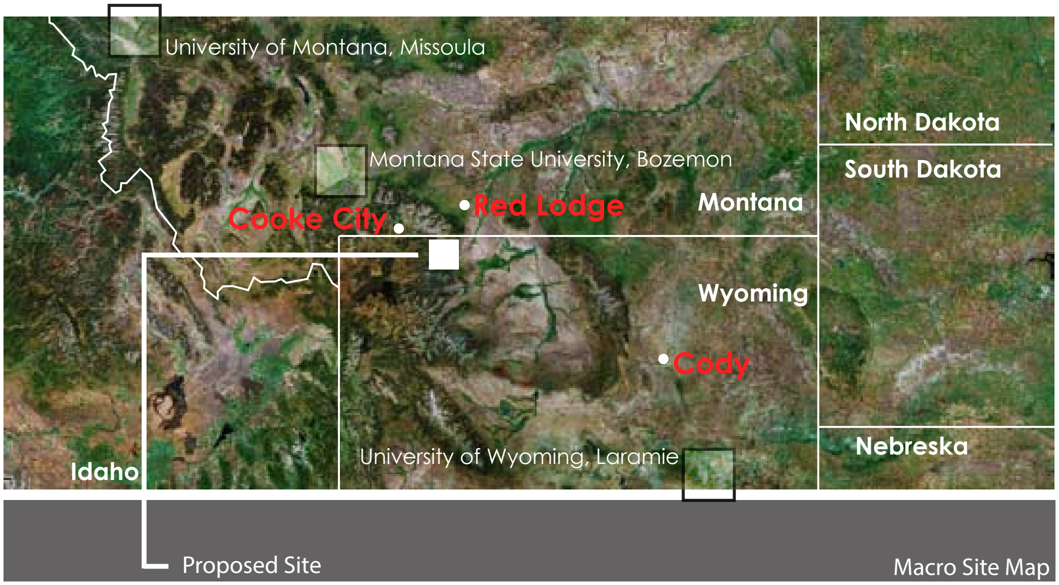


Figure 7. Macro Map

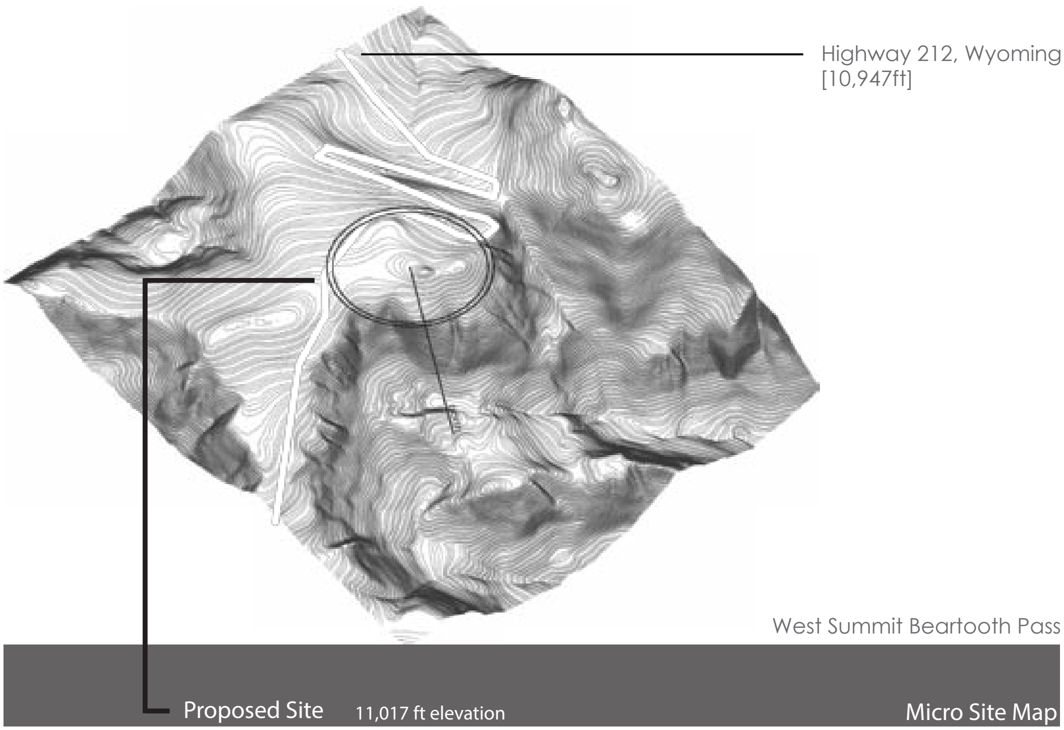


Figure 8. Micro Map

Figure 9. Beartooth Pass 3

SITE INFORMATION: PANORAMA VIEWS

The summit is an ideal place for an observatory given its altitude and 360° views. The site is a 45 minute drive into the mountain range distancing itself from light pollution coming from nearby cities. An open horizon makes for excellent observation in the evening hours. A low horizon also means there is more time to observe.

Is it okay to build on the Beartooth Pass?

The protection of the Beartooth Pass is the responsibility of Corridor Management Plan developed by the Beartooth Pass All-American Road steering committee. The Beartooth Pass is a very sensitive area that many people want to protect from building and other man-made objects. The steering committee clearly states in their intentions that the highway is to be used for education and interpretive activities. They encourage the development of stops along the road that peak visitors interest and bring them to the highway (Beartooth Pass All-American Road Steering Committee, 2002). The Beartooth Pass is split into 4 management zones. The proposed site sits within zone 3. Currently zone 3 is without any kind of interpretive or restroom area. An observatory and visitor center is such a development that would make the road a more educational and interpretive stop. The goals are to protect, preserve, and enhance every part of the Beartooth Pass. This project would help to protect the site and enhance the education of visitors and others within the surrounding communities.

Figure 10: Dark Sky Map

The West Summit as illustrated in *Figure 10* is one of the darkest spots in America. Many of these "dark sky" areas are gone due to growth in America. This particular spot is safe for some time into the future due to its remote location miles from an existing city.

PROJECT **EMPHASIS**

Through a Technical Lens will examine how architecture can adapt to advances in astronomical technique and technology. The project will also examine how an observatory can adapt by means of deconstruction and regenerative design in order to preserve the fragile environment in which this facility is located. The goal is to create a facility that is flexible and adaptable for the users, visitors, and the instruments.

RESEARCH DIRECTION

The direction of research will follow the unifying idea. Research of the unifying idea will include studying aspects of history, typology, site analysis, context, program and technical issues. Regenerative design, deconstruction practices, adaptable buildings and astronomy will all be researched heavily.

DESIGN **METHODOLOGY**

The Concurrent Transformative Strategy is a form of the Mixed Method Strategy and is the most appropriate way to develop my unifying idea. This type of strategy will allow me to choose the best possible case studies, as well as information from sources such as interviews, scholarly journals, articles, graphics, and digital analysis. Both quantitative and qualitative research will inform this project during the entire thesis process.

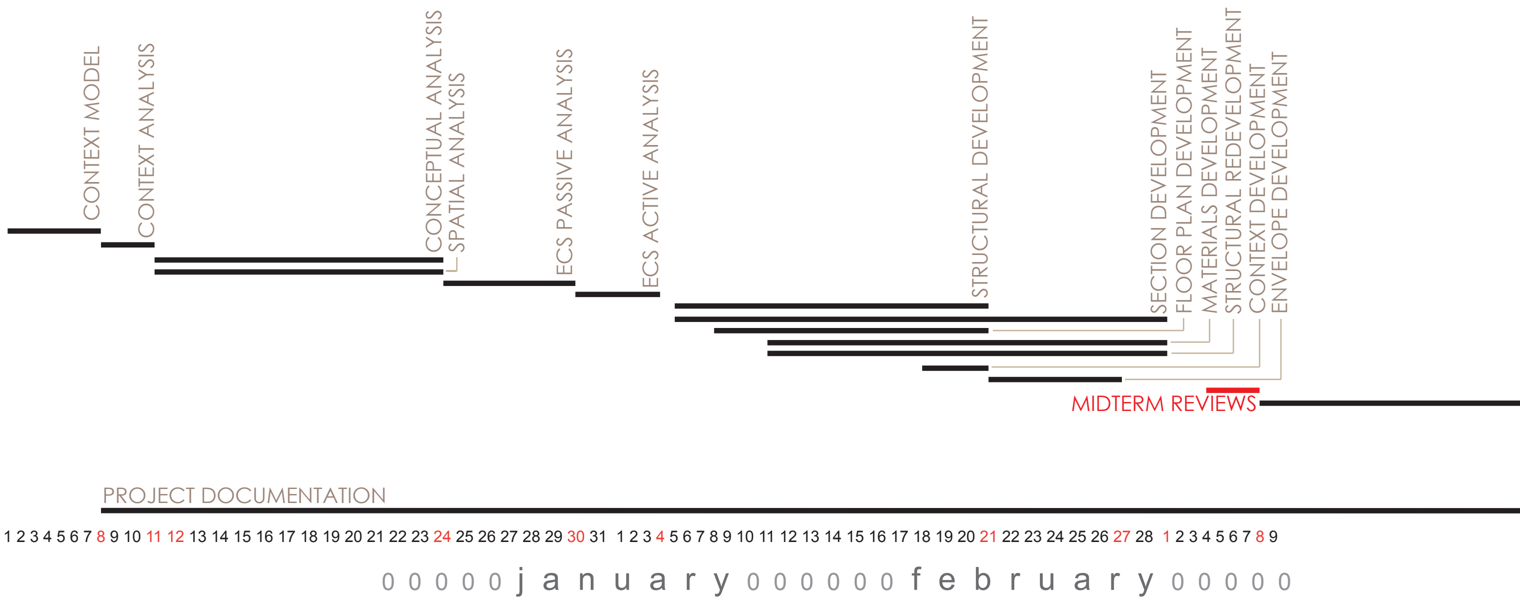
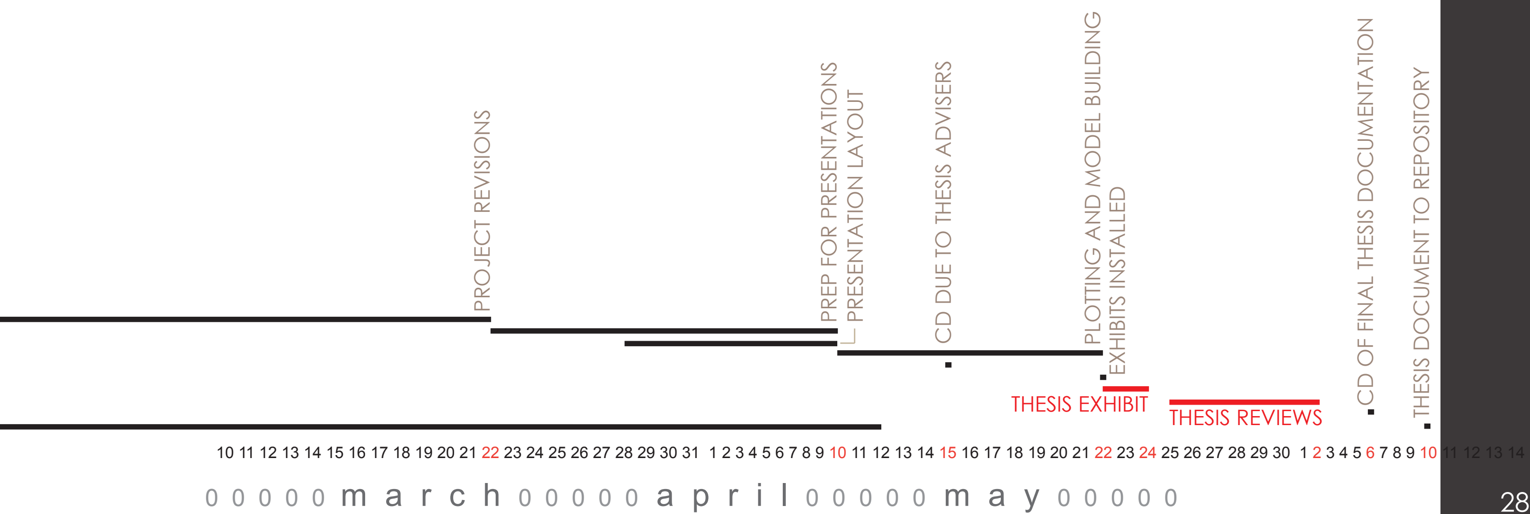


Figure 11: Project Schedule

PLAN FOR **DOCUMENTATION**

As information is developed throughout the entirety of this project, a digital documentation system will be implemented. Hand drawings, models, and any other forms of non-digital material will be converted into digital files for safe keeping and for use in final reviews. Digital photography is another tool I plan to use in the documentation of the physical design process.



STUDIO **EXPERIENCE**

2009-2010 **Second** Year:

▪Darryl Booker
▫Stephen Wischer

▪Teahouse
▪Boathouse
▫Twinhouse
▫Hector International Airport Terminal Addition

2010-2011 **Third** Year:

▪Paul Gleye
▫Steve Martens

▪Recreational Shop
▪Firehouse
▫Rehabilitation Center
▫Dinosaur Museum

2011-2012 **Fourth** Year:

▪David Crutchfield
▫Paul Gleye

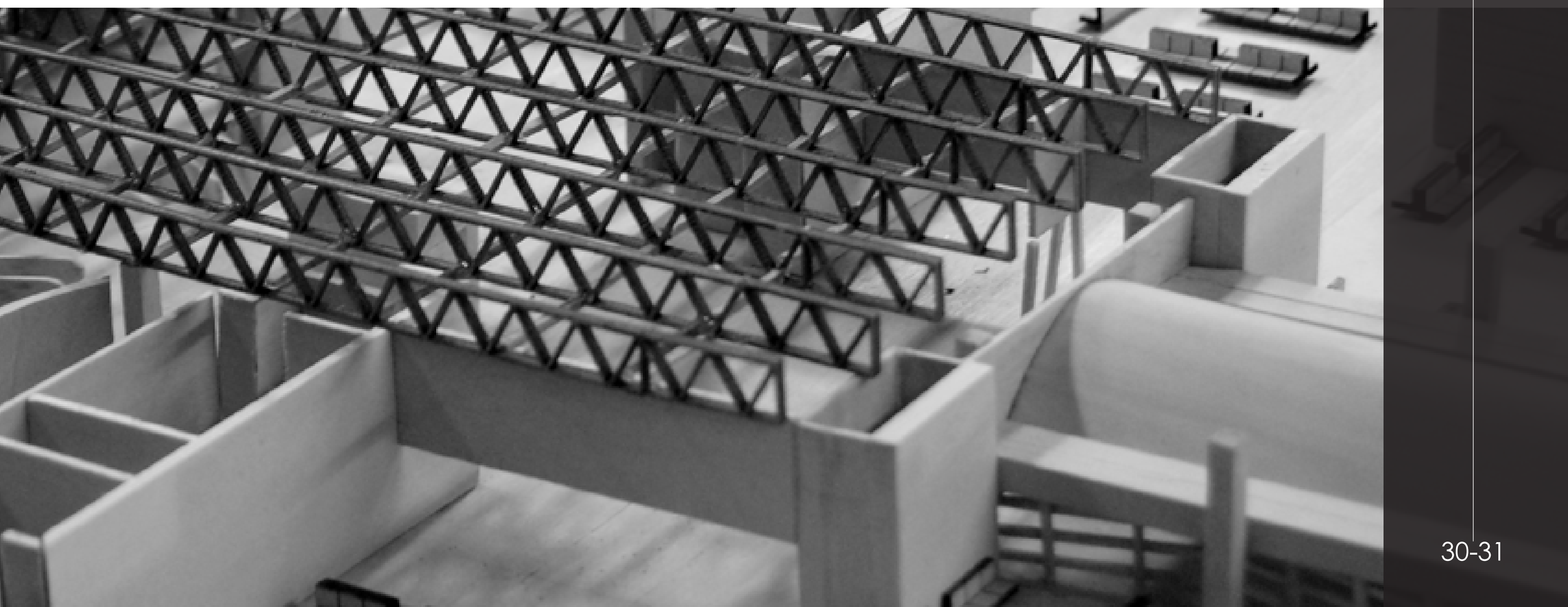
▪High-rise
▫Lille, France Urban Redevelopment

Figure 12: Airport Model

2012-2013 **Fifth** Year:

▪Ron Ramsay

▪Christ the King Chapel
▪Valsignad Lutheran Church



Theoretical Research.

Astronomy

Astronomy is a natural science that studies planets, stars, the universe, and phenomena in space. It is one of the oldest and most respected professions in history. Astronomy seeks to find answers to society's questions regarding how the natural world came into existence, what characterizes the universe and its parts, and whether other varieties of life exist beyond our planet. Finding answers to these questions could help us understand our own planet even better. Astronomy is a relevant and progressive field that is essential for the development of society, and its connections with architecture are important. Where would our knowledge of the sun and its interactions with space come from if astronomy had not existed? The Sun gives life to the Earth, which in turn determines many design necessities, because we as humans can't live without light. Astronomy is important to society because it provides information about the Earth. It is economically strategic to invest in the best equipment possible to become leaders in the world of astronomy. As David Aubon, author of the book *The Heavens on Earth: Observatories and Astronomy in Nineteenth-Century Science and Culture* explains, astronomy gave nations control because those who could explain the heavens could explain how the world should work (Aubon, 2010).

Who were these people that could explain the heavens? Astronomers were great philosophers in ancient times. As technology advanced, astronomy evolved from a philosophic art into an established profession. Today, astronomy is a highly advanced form of science. Astronomers strive to find the best methods of viewing the universe, and throughout history, these techniques have changed immensely. The concept of gazing into space is nothing new, but the methods used to do so have developed significantly. Now, professional astronomers rarely peer through the eye of a telescope; instead, they employ computers and precise imaging software to do the physical viewing. The techniques of astronomy have changed greatly in the past 30 to 40 years, with the advent of computers allowing astronomers to obtain crystal clear images.

The daily life of an astronomer has also changed over the decades. Astronomers are busy professionals, but they are also still physical human beings who require social activity to survive. Accordingly, many modern day observatories work to provide quality living conditions for astronomers. Researchers no longer have to stay in dormitories far away from the equipment they use. Observatories are now constructing facilities dubbed "observatory hotels." These hotels house hundreds of astronomers and offer recreational facilities, restaurants, libraries, work spaces, and research labs. Facilities like these are, in fact, small cities. Cerro Paranal Observatory in Chile housed astronomers in shipping container homes for many years before they finally erected the Paranal Residencia (ESO, 2009). The Atacama Desert, where the observatory lies, is a dry, desolate environment, but the new housing facility has made the observatory quite livable for researchers.

Observatories today use many different techniques for viewing outer space. One technique uses optical interferometry(*Figure 13*) to combine several smaller telescopes to create one large image. This technique can use multiple 2m telescopes instead of one 8m telescope to produce the same image. It does so by combining the light from all the telescopes in a light tunnel beneath the array. While smaller telescopes might not be able to reach as deep into space, they can produce similar images to those of mega observatories by using an array. In fact, the resolution of an image created from 4 different telescopes can be up to 25 times greater than that of a single large telescope. The VLTI (Very Large Telescope Interferometer) at Cerro Paranal uses 1.8m auxiliary telescopes in its array to create images with a resolution 25 times greater than the larger VLT 8.2m telescopes (ESO, 2009).

One technique to help make the best use of these smaller 2m telescopes is called "adaptive optics." Use of adaptive optics helps sharpen the image produced by an optical telescope. Adaptive optics uses sensors on the back of the mirrors to push

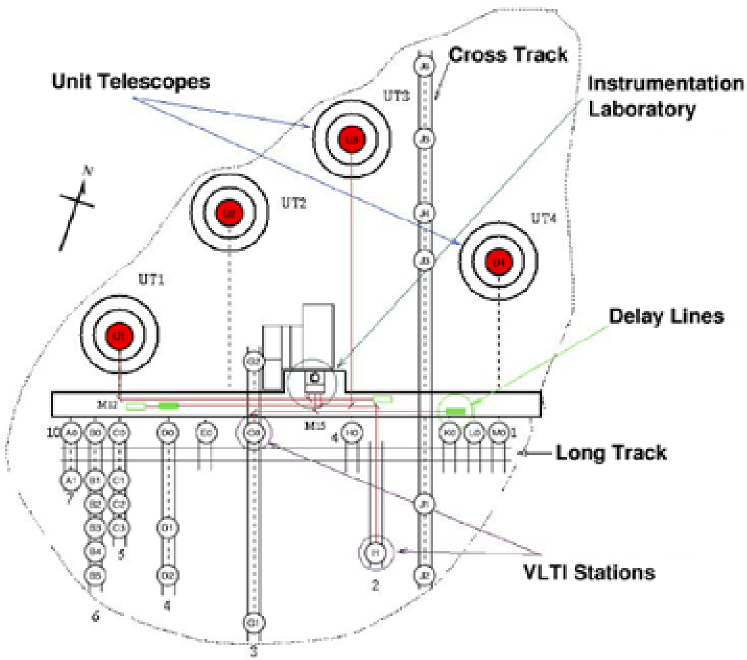


Figure 13: ESO Interferometry

[Research Results]

or pull the surface of the mirror deforming it to a specified amount. This technique allows astronomers to virtually eliminate the atmosphere of the earth, making the images nearly identical in quality to those taken from a space observatory.

The use of optical interferometry for university purposes would greatly increase the capacity to view outer space. Not only would it give students and faculty multiple options for viewing, it could also be used for multiple observations at one time. Array technology like this can be employed in collaborative efforts using multiple telescopes, or the telescopes can be operated in a standalone mode. Technology has already been developed for these types of telescopes to move along a set grid, which also opens the option to view more of the sky. By moving the telescopes around, different viewing angles can be achieved that would not otherwise be accessible with a conventional telescope. This also eliminates the need for architectural space to hold the instruments. Instead, each instrument has its own casing and transport vehicle. This modular design allows the architecture to focus primarily on human interaction and not instrument storage. While spaces are still needed for repairs and possible storm storage, the main bulk of the instruments are separate from the architecture.

A new observational facility must focus on the needs of astronomers and not just the technical requirements of the equipment. Healthy living environments are now the concern of any designer who receives an observatory commission. A strategy called "regenerative design" is giving designers the opportunity to use materials in new ways to create healthy environments. This strategy is changing the way the world views our current "sustainable approach."

Cradle-to-Cradle/ Regenerative Design

With so many new advances in astronomy and with techniques changing so rapidly, is there a way we can reuse components of the observatories for the benefit of the environment and future astronomers? Cradle-to-Cradle is a great strategy to implement within an observatory. Cradle-to-Cradle is the use of materials that are 100% recyclable or remanufactured in a closed cycle in order to eliminate waste (McDonough & Braungart, 2006).

The term cradle-to-cradle has been around for some time. It was coined in the 1970s by Walter Stahel as a phrase to help manufactures understand product life cycles or regenerative design. He later wrote several articles on the cradle-to-grave concept, which describes our current manufacturing style (Product-Life Institute,

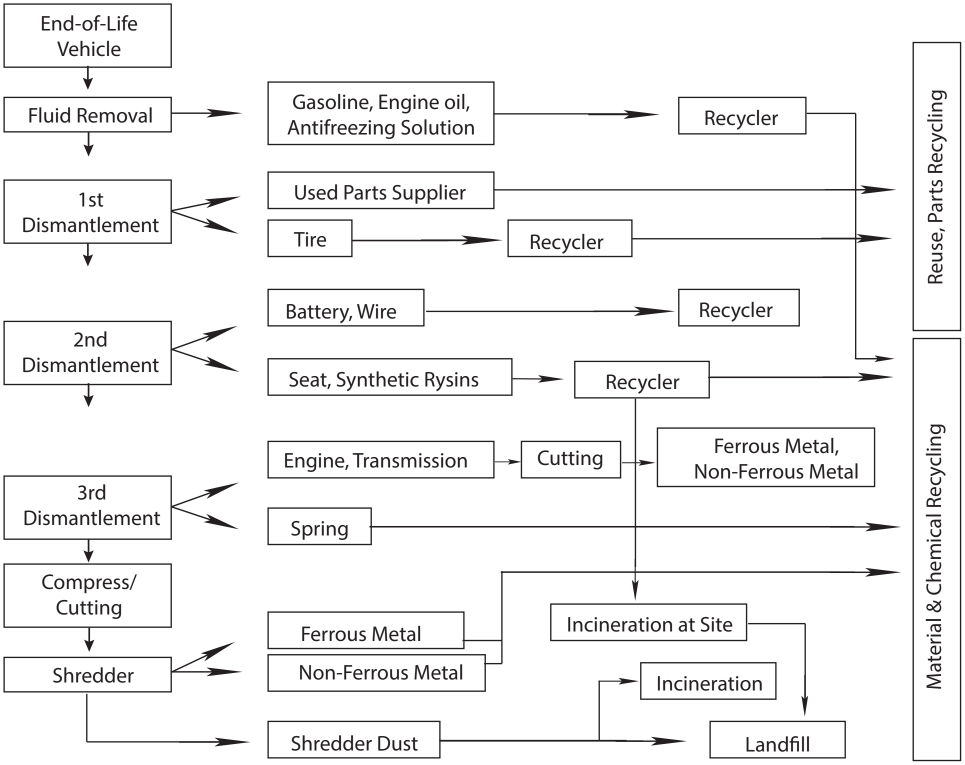


Figure 14. Regenerative Design

2008). Objects are created to be thrown away after a certain period of time. Michael Braungart, a German chemist, took notice of Stahel's articles and decided to make a difference in modern manufacturing. Braungart and architect William McDonough studied the ideas of regenerative design and wrote the well-known book *Cradle to Cradle* in 2002. The book promoted the concept that "waste equals food." Anything that is manufactured could become either a biodegradable nutrient or a technical nutrient. This means the object will either be fed to the earth or it will be fed back into the manufacturing process. The process is a highly-developed design/recycling program to eliminate waste and the use of virgin materials.

The problem today is that recycling is not preventing the extraction of new raw materials from the earth. People do not realize that products that are recycled could actually be hurting the environment. While it may be a way to slow the process of introducing virgin materials into the market, recycling is not doing much more than that. William McDonough calls it "down cycling." Instead of materials being reused many times they simply get reused once or twice and then end up in the landfill. In fact, many of the materials that get recycled are hazardous and even more harmful as recycled products (McDonough & Braungart, 2002). Materials are melted together, creating weaker, less-usable products.

Our current system prompts the question, is there not a way to completely recycle every product correctly so that raw materials don't mix and become polluted? Yes, there is a way to make recycling safe, and Europeans are currently implementing this method in the automobile industry. The European Union has determined that car manufacturers must employ the cradle-to-cradle strategy by the year 2015. By that year, 95% of a vehicle's weight must be completely reused or recycled (Kumar & Putnam, 2008). Already, there have been immense financial improvements for auto-makers and the government. *Figure 14* depicts the process required to make a product cradle-to-cradle instead of cradle-to-grave. Almost every part of the vehicle is designed to be dismantled and reused in some way. While potential problems with certain chemicals and materials mixing do exist, nearly the entire vehicle will be reused in a safe way.

The European Union automobile industry uses the kind of design that architecture ought to employ. Architecture must be designed for disassembly at the end of its life in order to be returned to the earth or recycled back into more products. Architecture can then be a living organism that adapts as its needs do. This concept of regenerative design is beginning to spread within the United States. Firms like William McDonough + Partners and BNIM are taking significant strides in making this strategy their model for design. They have appointed the year 2020 as the year that regenerative design should be used by every industry. Their vision is to implement regenerative design in every architectural project so our environment is healthy for future generations

NASA's Sustainability Base is the latest example of regenerative architecture as an adaptable organism. The project was finished in 2012 and features only products that can be easily dismantled and recycled. The structure is on the exterior of the building, making any deconstruction on the interior extremely easy and quick. This allows the building to adapt to any need it may have in its lifetime. The fact that it also leaves virtually no carbon footprint makes it a leader in the world of scientific buildings. NASA's Jerry Colen writes, "Sustainability Base is committed to advancing technology and innovations that will help solve the critical challenges that are facing Earth" (Colen, 2012). NASA uses closed-loop design in space exploration, so it was appropriate to bring that concept into their architecture here on Earth. The idea of constructing and deconstructing after an allotted time allowed this project to be flexible and innovative.

Adaptive Buildings

Sustainability Base falls into a category of buildings called "adaptive buildings." These buildings are changing the way architecture is designed. Adaptive buildings are included in the category of regenerative design because they are specifically designed to change over time. Spaces are designed to be as open as possible for easy remodeling and deconstruction. While these specific types of buildings are designed to change readily as activities within the building do, they are also designed to change to climate shifts, technology upgrades, and site conditions. Facade design and use of electrochromic windows are two examples of how a building can be designed to change with climate shift (National Institute of Building Sciences, 2012).

Implementation of these technologies and materials will reduce the need for outside energy resources that could add costs and pollution. Space needs, materials, energy plans, and site configurations all play a role in how these buildings will adapt over time. Careful design makes sure these parts of the building can change with minimal effort and cost. The main goal for these types of buildings is to be completely self-sustaining and to replenish the site and the community it resides within.

Deconstruction

Deconstruction is nothing new, but it is recently making waves in the construction industry. "Green" designers are now viewing architecture not as something final, but rather as something that changes throughout its lifetime. Instead of demolition, deconstruction is becoming the standard for disassembling buildings. But even more impressive is the idea that buildings could be designed for future disassembly. High-quality materials can be used in a way that allows them to be easily extracted whenever they are no longer needed. This allows the material to be transitioned into its new form and replaced in any way the users require. High-quality materials will become less expensive because new raw materials will not be needed.

Consider the cost savings and environmental advantages this could mean for observatories. These facilities cost millions—even billions—to build, but they could cost significantly less in the future if many parts were reused to create the new product or observatory. Economically, this strategy is a game-changer. Countries like China will not export their resources if they feel they are in danger of losing them all. Other countries that do not have unlimited resources are discovering that the cradle-to-cradle strategy may be the only way for them to survive. As described above, the European Union created strict guidelines for the automobile industry because they foresaw the end of raw materials. It is expensive and unnecessary to constantly use raw materials to create vehicles, so by creating these guidelines, the European Union has significantly helped their economy. The costs of reusing materials are much lower if they are originally designed to be disassembled. It is entirely logical for every country in the world to apply these guidelines to every industry.

Advantages of Regenerative Design and Deconstruction Practices

The most notable advantage to regenerative design is the social affect it produces. The use of healthy materials within our environments not only makes these places a better place to live, work, and play, but it also helps us reconnect with nature itself. For too long, we have continued to design with harmful products that ruin our environments. Bob Berkebile from BNIM notes that we are at a crossroads within design. We can keep designing the way we currently are and separate ourselves from nature even more, or we can change directions and use regenerative design to reconnect ourselves with nature and the environment that surrounds us (Berkebile, 2012). Too often, buildings use products that contain volatile organic compounds or other harmful chemicals. These chemicals are unpleasant to most people and can cause headaches and nausea. Even common products such as laminates and carpets often use these. However, there are companies that refuse to use these cheap materials. Ensuring that each product is suitable to be used by any human is one advantage that regenerative design displays. Every architect is socially responsible for aiding humanity by choosing only materials that will maintain a healthy environment.

Another advantage of regenerative design is its economic benefit. In the manufacturing industry, cradle-to-cradle techniques can eliminate the need to buy raw materials from outside sources. This holds material within a perpetual cycle that allows manufacturers to cut down on costs. While it may take time to develop product types that are easily manufactured and disassembled for future use, these efforts will pay off financially in the long run. Certification programs are also starting to use concepts similar to cradle-to-cradle to spur changes in the construction industry. Sustainable Materials Rating Technology (SMaRT) is one of these certification programs that are promoting many new products for use today. Another program is the Living Building Challenge. Utilizing these certification programs when designing can also provide incentive because the certifications often incur tax breaks for the user, which can be used as a marketing tool. Also, the general concept of sustainable design is currently a trendy notion, which makes programs like these appealing to many consumers. Offering sustainable design choices improves a company's marketing appeal and its credibility. Architects must make ethical choices that will benefit the user in long-term ways. Up-front costs may be higher using cradle-to-cradle techniques or regenerative design, but in the long run, it could save the client thousands on bills and maintenance. Designing in this fashion will help the economy because it eliminates wasted money on products that do not last over time.

A third advantage is an ecological one, because as cradle-to-cradle suggests, waste equals food. Any waste that is created could be turned into food for the environment. Architecture should never scar the landscape; rather, the two should be in harmony, and a landscape should eventually be left in better condition than when the architecture was first conceived. For instance, water that exits a building should come out cleaner than when it first entered the building. Materials should be carefully chosen to eliminate any contamination of rainwater or snow that may interact with a building. Surfaces that are permeable help filter any water back into the environment. Sites that have already incurred wear from previous uses can be revitalized by designing spaces that allow for site reconstruction. Design can specifically relocate people away from the critical parts of a site. Using sites that have previously been used is one important factor that should be considered when picking a site (National Institute of Building Sciences, 2012). Whenever possible, architects should avoid ruining a site that has not already been built on or used. The site must influence the design within it. Simple design can have a major impact in restoring an environment back to its original condition, and the aim of regenerative design is to make something better than it originally was.

Lastly, there clearly remain more advantages that we cannot even foresee today. Today's design of tomorrow's architecture can contribute to significant social, economic, and ecological advantages. A leader among the many tools and technologies devoted to making our world a more habitable place for future generations, regenerative design is a simple strategy that is already starting to make a considerable difference.

Research Summary

The future is never certain. Astronomy will continue to change in the future, but in what way is difficult to ascertain. Innovators can plan as far as possible into the future, but at a certain point, our foresight ceases and future invention is left to the next generation. Designing to meet this future generation's needs is what makes architecture such a fascinating field. The needs of astronomy today can be met, but anticipating how architecture will meet the needs of astronomy tomorrow is the driving force behind *Through a Technical Lens*. This brief summary will restate the intention of *Through a Technical Lens* as well as discuss the impetus for each aspect of the theoretical research.

Through a Technical Lens examines how architecture could adapt to advances in astronomical technique and technology. The research examines how an observatory can adapt by means of deconstruction and regenerative design in order to preserve the fragile environment and create a space that is flexible and adaptable for the users, visitors, and the instruments.

Astronomy is a highly technical profession. It is known for expertise and precision among the general public. Astronomers today are using increasingly more advanced equipment and greater numbers of astronomers are needed to run highly advanced observatories. The users of these observatories must now travel to more remote places than was previously required in order to reach quality viewing sites. Placing a multi-million dollar facility on top of the highest peak in a mountain range is no longer a question of how but rather when. These remote locations require facilities that help keep astronomers active and living healthy lives while on assignment. Observatories are no longer just buildings to house telescopes but instead they have become hotels, machine shops, and large control rooms dedicated to the science they serve.

Advancements are constantly developing in astronomy. Scientists are changing techniques and making adjustments every time a new observatory is built. *Through a Technical Lens* reviews the method of optical interferometry, because it is a relatively inexpensive technique used to view the stars. Universities often cannot afford mega observatories, but they can afford smaller telescopes. Using interferometry allows these telescopes to put their light together to create an image that is similar in quality to larger telescopes. This is strategic not only economically but also environmentally. Using smaller telescopes will greatly decrease the impact on the environment by minimizing site construction.

Regenerative design is a positive direction which astronomical architecture should embrace. Developing a building that could adapt and change as astronomers needs do promotes the core concept of regenerative design, which uses cradle-to-cradle principles to make healthy and user-friendly decisions in the built environment. One important aspect of regenerative design is choosing materials that do not harm ourselves or future generations. Another key tenet is designing in a way that allows for the complete recycling of materials used within the architecture. Observatories need to remain flexible, because as history has proven, these building types do change, and so do the techniques and technologies housed in them. By anticipating more efficient reconstruction, observatories will meet the needs of the users and costs can be greatly diminished.

Adaptable building allows observatories to not only adapt to user needs but also to changes in climate, site, and energy resources. Buildings should be flexible, especially when they are located in remote locations where they cannot rely on municipal support. They must be self-sufficient in order to survive.

Deconstruction is simply designing in a way that is easy to take a part and recycle after a pre-determined number of years. Designing a kit of parts that can be disassembled based on their recyclable properties should be considered in observatory design, because the observatory will eventually require updating. Building in remote locations also requires designs that can easily be assembled on site. Designing for the building to be taken apart can also make the original assembly much simpler as well.

Finally, *Through a Technical Lens* examined the advantages of each of these theories or design principles. Advantages ranged from economic relief and social ethics to environmental advantages. By using each of these principles and theories, observatories can better serve their users and the sites they are located. Simple design can allow for adaptation in the future that can help stem new advancements and findings in astronomy.

Typological Case Studies.

CERRO PARANAL OBSERVATORY RESIDENCIA

European Southern Observatory(ESO) - Atacama Desert, Chile
Building sq ft.- 107,640
Building Type - Hotel
Year Completed - 2003
Cost - $14,260,400
Lat/Long - 24˚38’25S 70˚23’18W
Architects - Auer und Weber Architecten, Germany

Figure 15. Cerro Paranal Residencia

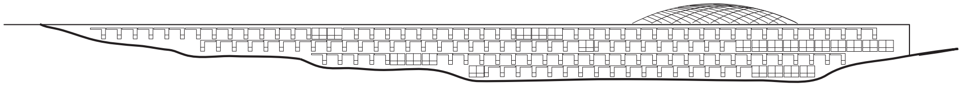


Figure 16a. CPR West Elevation

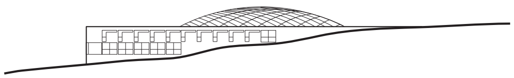


Figure 16b. CPR South Elevation

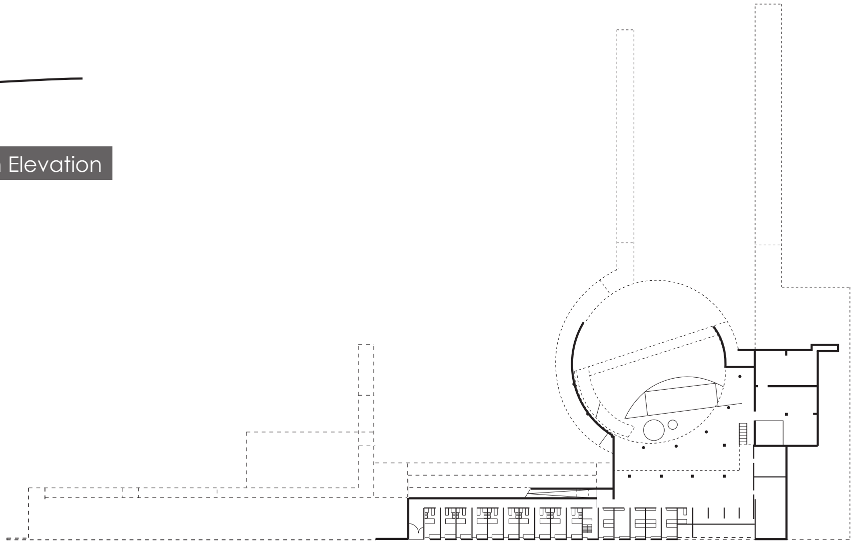


Figure 16c. CPR Level 4

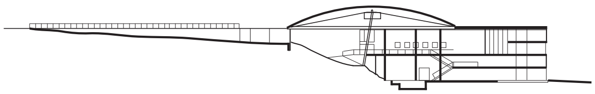


Figure 16d. CPR Section

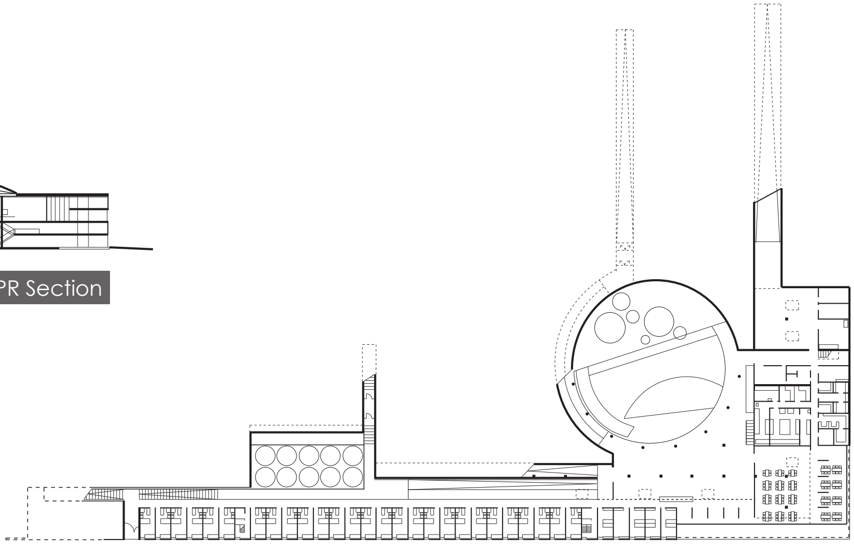


Figure 16e. CPR Level 2

The Residencia at Cerro Paranal is the leading observatory residence in the world. Built in 2003, this hotel protects scientists from the harsh environment of the Atacama Desert in Chile. While the location is ideal for observing the cosmos, the climate is not. However, visionary thinking has changed observatories like this from lone buildings with a telescope into entire cities. This particular case study is a fantastic example of observatory spaces devoted to the users and an observatory that respects the environment around it.

At 107,640 sq ft, the Residencia is a comfortable home to many scientists. In fact, there are usually around 120 scientists at Cerro Paranal each day (ESO, 2009). The hotel features 108 guest rooms, 18 offices, swimming pools, a restaurant, seating areas and a 10,000 sq ft garden area.

Before 2003, guests at Cerro Paranal were living in shipping containers. The climate in the Atacama Desert is extremely dry and windy, making any kind of living and working quite difficult. Creating more suitable working conditions was the primary factor driving plans for the new hotel. Without the hotel, the observatory would have had trouble attracting the scientists it needed to expand and become the world renowned observatory it is today. With the Residencia established, the observatory has become a fantastic place for scientists to play, eat, sleep, collaborate, and work. These amenities make the Atacama Desert entirely more inviting and accessible to anyone

The Residencia boasts a large, 10,000 sq ft garden that not only is pleasant to view but also acts as the building humidifier. The annual precipitation at the Cerro Paranal Observatory is under a quarter inch (about 5–10% humidity), making the garden a life-sustaining part of the architecture. A glass dome above the garden feeds light to the plants within during the day. At night the dome is covered to eliminate light pollution to the nearby telescopes and to keep the humidity within the building (ESO, 2009).

Additionally, the designers needed to consider the sensitivity of the site. Architects Auer and Weber did not want the hotel to stick out in the Mars-like terrain. Instead, they designed it to be as sleek and unobtrusive as possible. A small gully between two hills at the site gave the architects the best possible solution. As illustrated in the drawings to the left, the hotel is a low, stretched building that reaches from hill to hill. Even the materials were selected to match the surface color of the earth to fit in as best as possible. The roof is also covered with the same soil to make it seem as though it seem as though it wasn't there. The only part of the hotel that is visible from the top is the dome of the garden, leaving any new visitor curious to what is below the surface (Auer Weber, 2012).

The Cerro Paranal Observatory is a great case study, because it demonstrates the types of spaces needed for long term stays at observatories. It is also a useful example of a telescope technology called optical array. While the main part of this study focuses on the hotel, another significant aspect is the observatory itself. As illustrated on the next page (*Figure 16k*), the observatory is made up of four large 8m telescopes and four smaller 1.8m auxiliary telescopes. These telescopes all act in an array to create one large image by combing the light in a tunnel below the observatory (interferometry). This technology gives scientists incredible flexibility in their searches. If two or more scientists need to use the telescopes, they can be used in sets of two or three along with the auxiliary telescopes.

Another advantage to having multiple telescopes is the speed it takes to change viewing spots in the sky. An array of telescopes can reach far into space and capture quality images similar to those retrieved by mega telescopes. However, these groups of smaller telescopes can achieve the task in a very quick manner. Viewing time is precious at the Cerro Paranal Observatory, so having quick telescopes is essential for scientists. When using a conventional telescope, moving and focusing takes a much greater amount of time.

What important insights can be deduced from this case study? One key idea is that a site and a building should be symbiotic. Another aspect to note is the advanced variety of technology that Cerro Paranal uses. The collaboration between building and site factors makes Cerro Paranal a progressive, effective model. The careful consideration of the building within the site and the materiality of the structure are combining to demonstrate an advanced example of a symbiotic relationship between an observatory and its site.

The unprecedented array technology used at Cerro Paranal set a new standard in astronomy, and it has pushed the boundaries of how array technology works. Using smaller, moveable telescopes is one technique that could aid the design of an observatory in Wyoming. Using this technology will also open up many new architectural options. Instead of devoting so much space to telescopes, the building design can better accommodate the users and not just the technology.

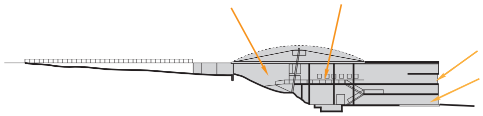


Figure 16f. CPR Natural Lighting

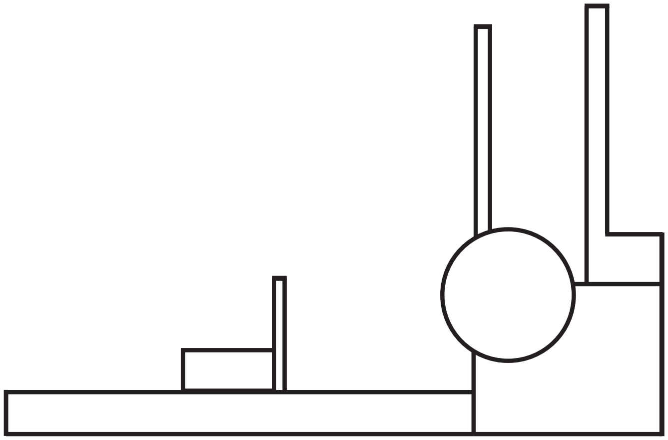


Figure 16g. CPR Geometry

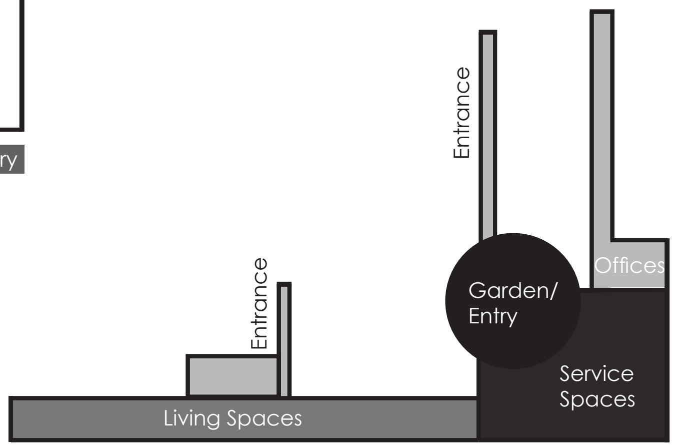


Figure 16h. CPR Hierarchy

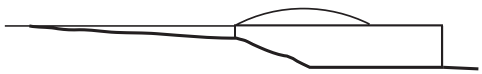


Figure 16i. CPR Massing

The figures on this page represent the spatial relationships that make up the Residencia at Cerro Paranal. The building responds to the surrounding landscape in the shape of an L. The majority of spaces revolve around the main garden(Solid Black Circle) as illustrated in *Figure 16h*. *Figure 16f* show the building receiving plenty of natural sunlight through both the garden area and the rooms.

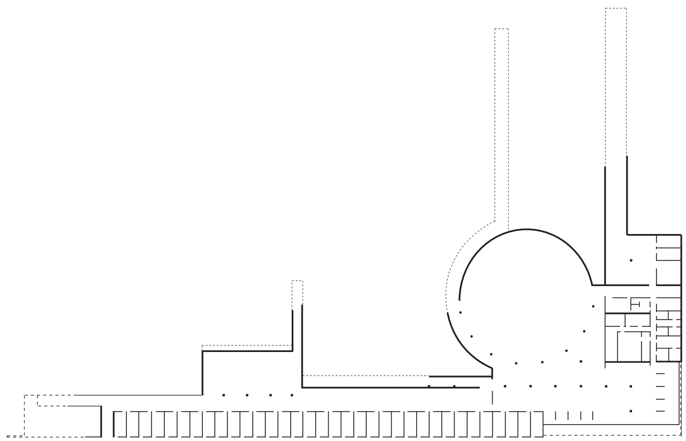


Figure 16j. CPR Structure

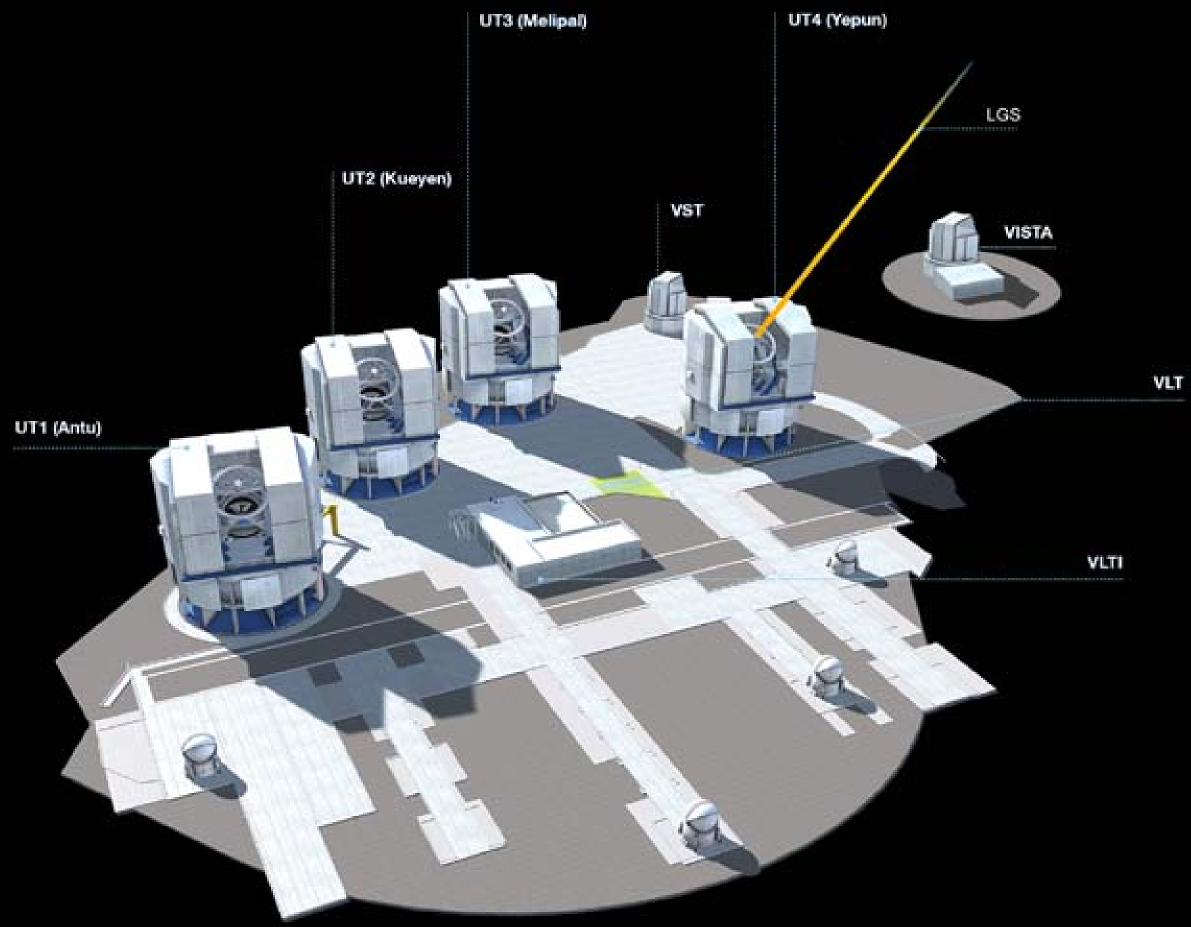


Figure 16k. CPR Interferometry

Figure 16l. CPR Exterior

Figure 16m. CPR Platform

Figure 16n. CPR Garden

Paranal Residencia is an example of excellent living conditions at an observatory. There are four floors of rooms, a large commons area, recreational areas, eating facilities, and large work areas. In the center of the building is a large garden area that not only is stimulating to the eye, but it also humidifies the entire residencia. At such high altitudes in the Atacama Desert the air is dry and thin. The garden is a natural way to cool, and humidify the building.

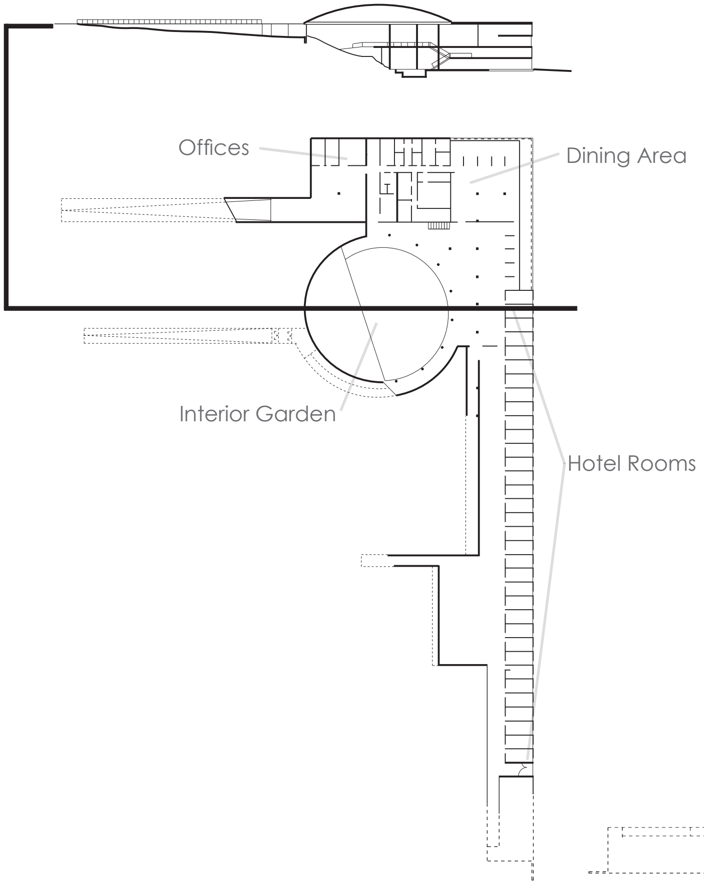


Figure 16o. CPR Plan to Section

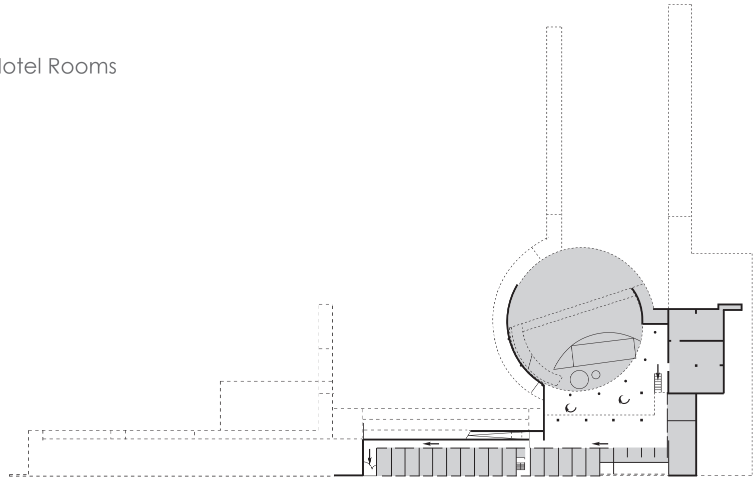


Figure 16k is an illustration of the telescopes at the Paranal Observatory. The layout of the telescopes at Paranal is important to examine as they are an example of an optical array. This array is made up of 4 Very Large Telescopes and several smaller auxiliary telescopes. Note that the smaller telescopes are the first to be used on a track system instead of a stationary placement. This allows them to view the sky at many different angles.

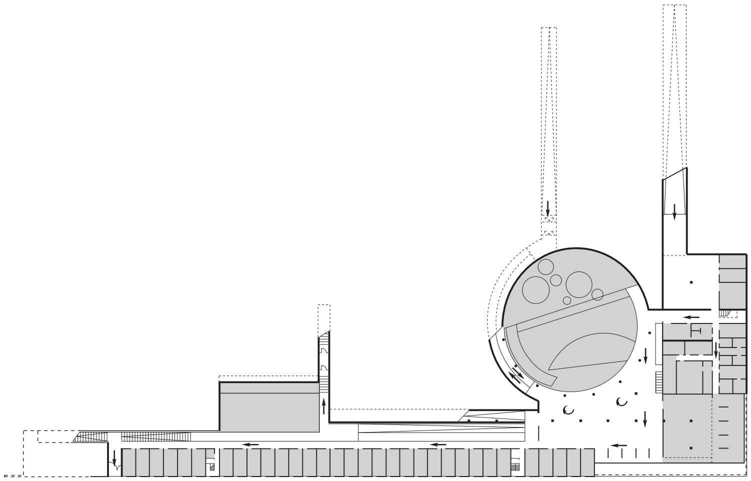


Figure 16p. CPR Circulation

KIELDER OBSERVATORY

Kielder, England
Building sq ft.- 1,500
Building Type - Observatory
Year Completed - 2008
Cost - $720,630
Lat/Long - 55˚13’55”N 2˚36’58.5”W
Architects - Charles Barclay Architects

Figure 17a. Kielder Observatory

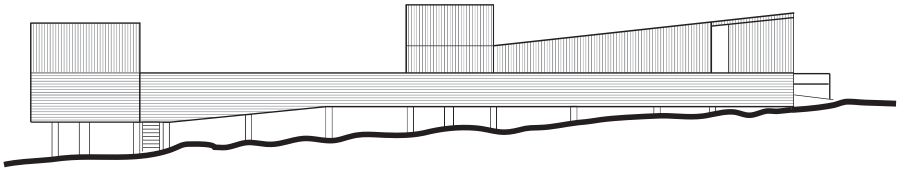


Figure 17c. Kielder North Elevation

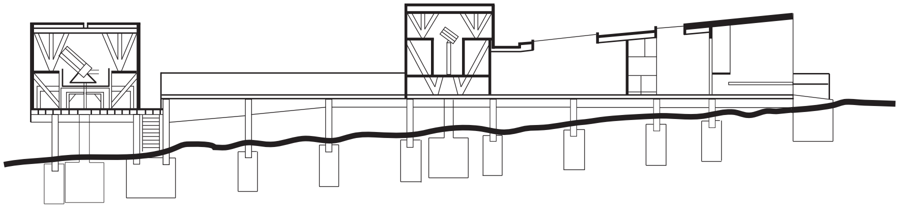


Figure 17d. Kielder Section

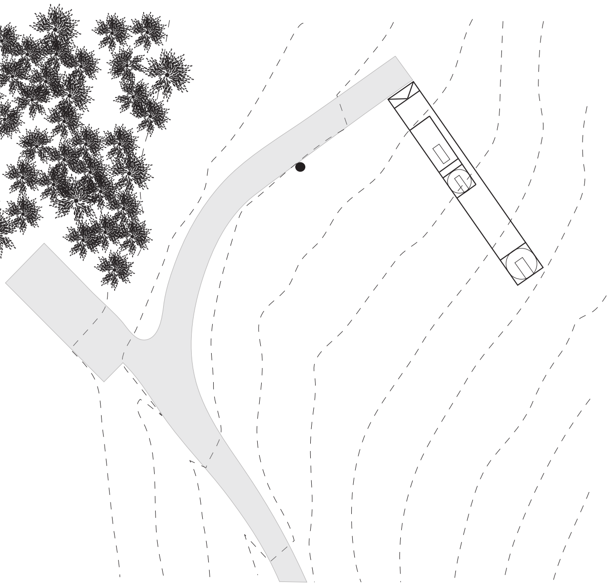


Figure 17b. Kielder Site Plan

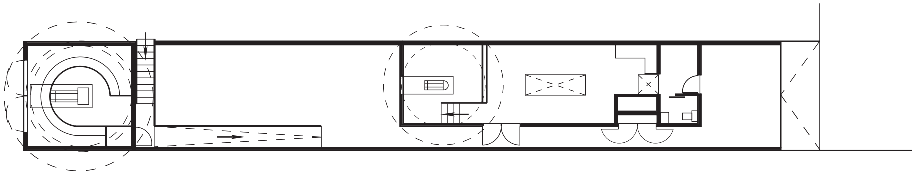


Figure 17e. Kielder Plan

Charles Barclay Architects won the competition for a Kielder Observatory Competition in 2005. Their design was very small and simple, and would be used by amateur astronomers in the Northumberland area of England. The design of the observatory prescribed minimal impact on the environment. The drawings to the left illustrate how the structure is lifted off the site with the use of pillars. This allowed the architects to create an observatory that barely touched the earth, leaving the bystander the impression that the building was being lifted into the sky (Etherington, R, 2008).

While this case study is more limited than the previously examined study, it poignantly shows how an observatory could be designed very simply. The design takes us back to the roots of the very essence of an observatory—a simple structure that houses a telescope and a small warming room. This smaller study may not address details required for the capacity of this thesis project design, but it does highlight important aspects worth noting. One concept is the simple pillars that hold the building up to allow for easy expansion in the future. The building has virtually no negative effect on the site itself and water runoff is not affected. The materials are completely recyclable, making it easy and inexpensive to deconstruct the building if needed in the future.

A second exemplary aspect this case study presents is the wood structure that was easily constructed on the site with minimal effort and effect on the landscape. The only permanent structures are footings at the base of each pillar. The design philosophy of this observatory is very attractive to the general public. The building is easy on the eye and the environment. All the lumber for the observatory was harvested from the Kielder Forest area, which helped the local economy prosper. While lifting the entire building off the earth could accrue expense due to heat loss, this particular building only needs to be heated when in use, so the design is very appropriate in this case.

The circulation of people through the structure is also very simple. As illustrated on the following page (*Figure 17i*), there is a straight corridor that connects all the spaces. The circulation cannot be any simpler, making building use very intuitive.

Another aspect of the observatory that classifies it as a self-sustaining project is its turbine, photo-voltaic panels, and composting toilet system.

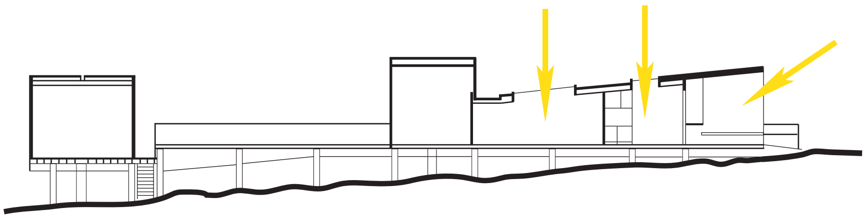


Figure 17f. Kielder Natural Lighting

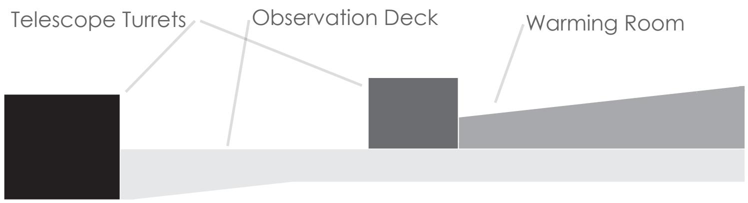


Figure 17g. Kielder Hierarchy

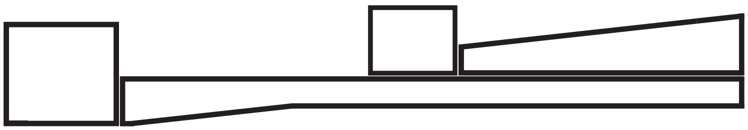


Figure 17h. Kielder Geometry

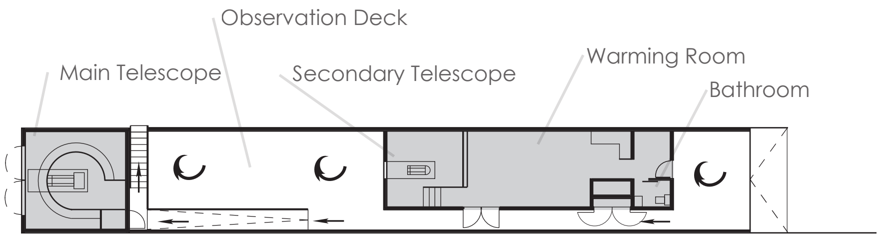


Figure 17i. Kielder Circulation

The building is completely off-grid. This particular observatory doesn't need much energy, because it relies on humans to do most of the physical work. The Kielder Observatory is small enough that the shutters are operated by the people using the building, and the domes rotate by using a crank instead of an electrical motor. The lightweight wood structure makes this possible (Etherington, R, 2008).

As illustrated in *Figure 17f* to the left, natural lighting is essential for this building to remain off-grid. The outdoor seating and the warming room both use natural lighting. The building has two skylights, one above the restroom and one in the main gathering room. The domes both rely on the turrets being open to receive natural lighting.

Another concept shown to the left is the hierarchy of an observatory. The Kielder Observatory is very modern in design and avoids the stereotypical look of most observatories. Many people assume observatories are primarily a large white dome. This is not always the case. The two domes at Kielder are square in shape, but they are both visually the most prominent spaces at the observatory. The rest of the building is fairly low and horizontal in comparison to these two visual nodes. The building respects the typical design of an observatory through its general characteristics, but it is more daring in the material and dome shape than many others, making it one of a kind.

The Kielder Observatory is a helpful case study because it presents useful examples of self-sustaining design. Even though its scale is much smaller than the scope of this thesis design, it shows what simple construction methods like wood structures can offer. Being lightweight both physically and visually, it complements the site it is located on. It does not disrupt the environment or the astronomers. Its spaces are simple but effective, and nothing is wasted. Outdoor space becomes a deck for amateur astronomers to set up their own equipment and also a viewing platform for tourists. Any waste this building does create is decomposed and reused for fertilization. This is a fantastic example of a building working within a site's material parameters and the necessities of the location.

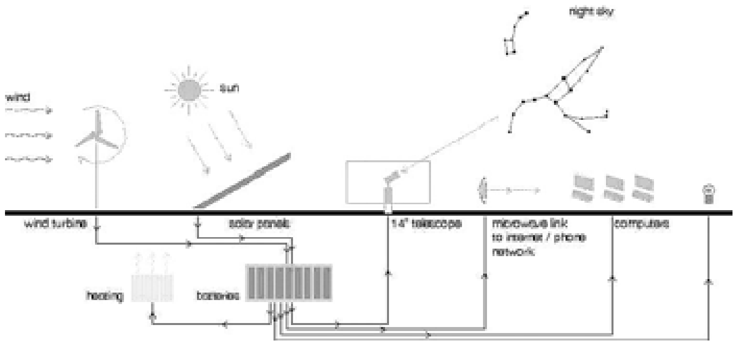


Figure 17j. Kielder Systems

Figure 17j represents the off-grid power sources for the Kielder Observatory. The facility uses a mix of solar and wind power. This observatory is an example of a building designed for deconstruction. The observatory is completely made from timber with simple bolt connections. The building can be taken down and completely recycled for use on another project or it can biodegrade quickly giving nutrients to the soil.


Figure 17l. Kielder 2


Figure 17k. Kielder 1

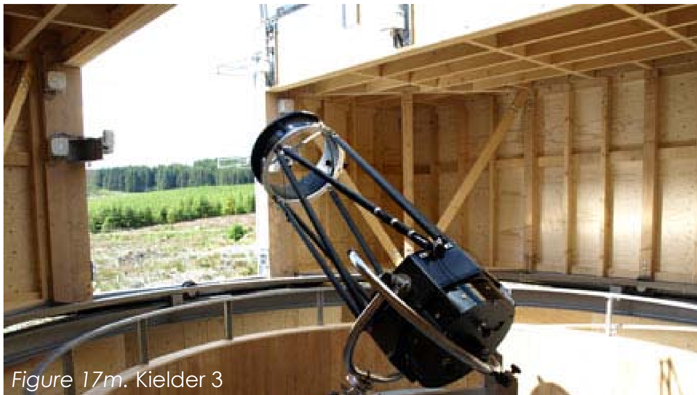


Figure 17m. Kielder 3

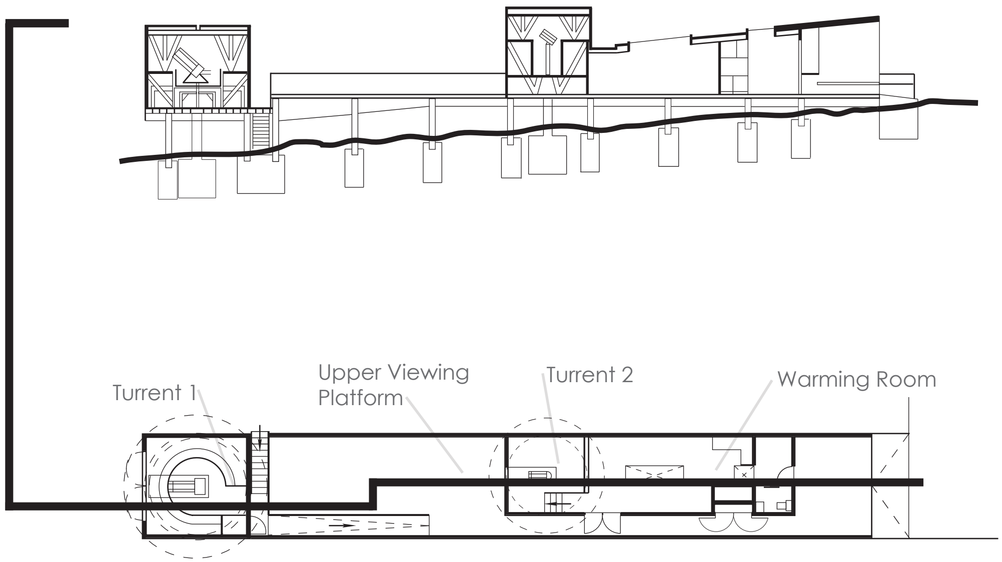


Figure 17n. Kielder Plant to Section

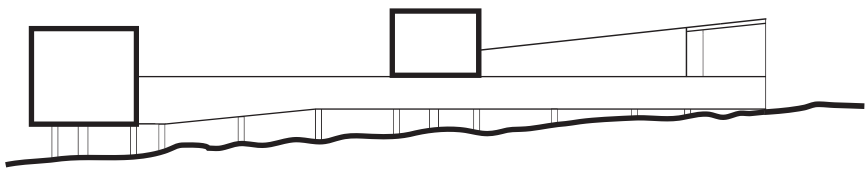


Figure 17o. Kielder Massing

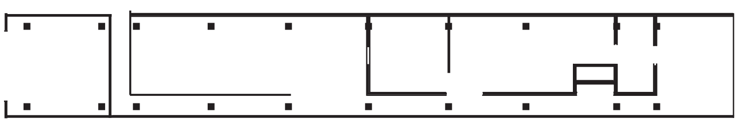


Figure 17p. Kielder Structure

KECK OBSERVATORY

Mauna Kea, Hawaii
Building sq ft.- N/A
Building Type - Observatory
Year Completed - 1993/1996
Cost - $140,000,000
Lat/Long - 19.82636˚N 155.47501˚W
Architects - N/A

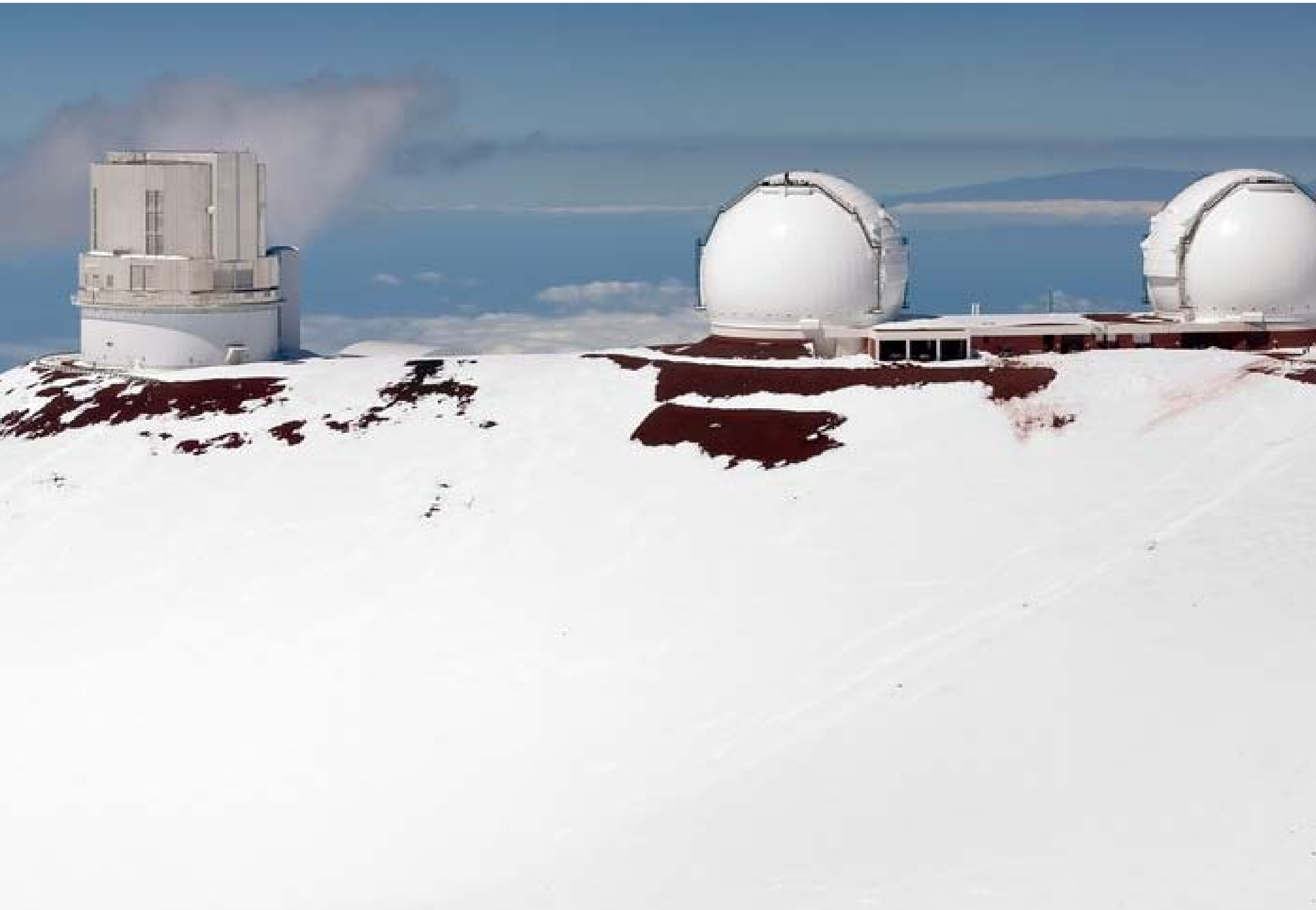


Figure 18a. KECK

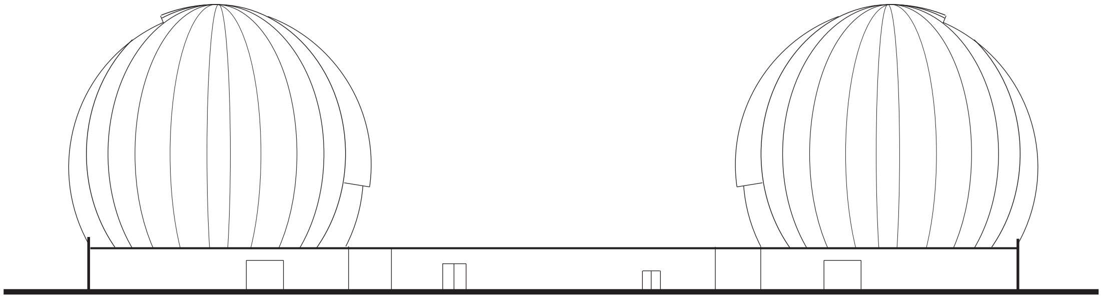


Figure 18b. KECK Elevation

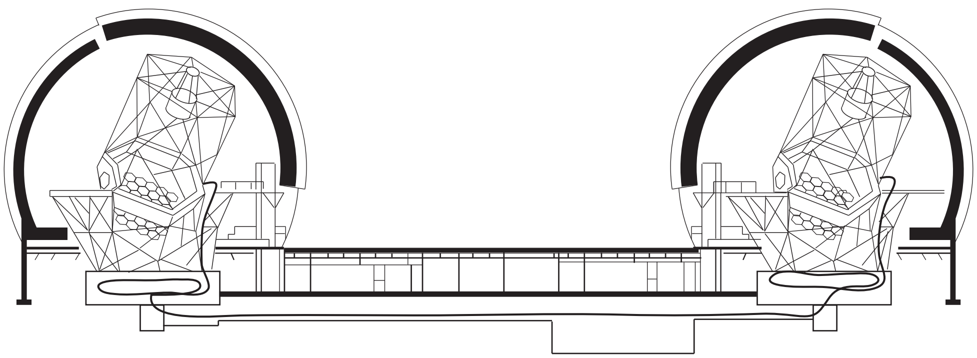


Figure 18c. KECK Section

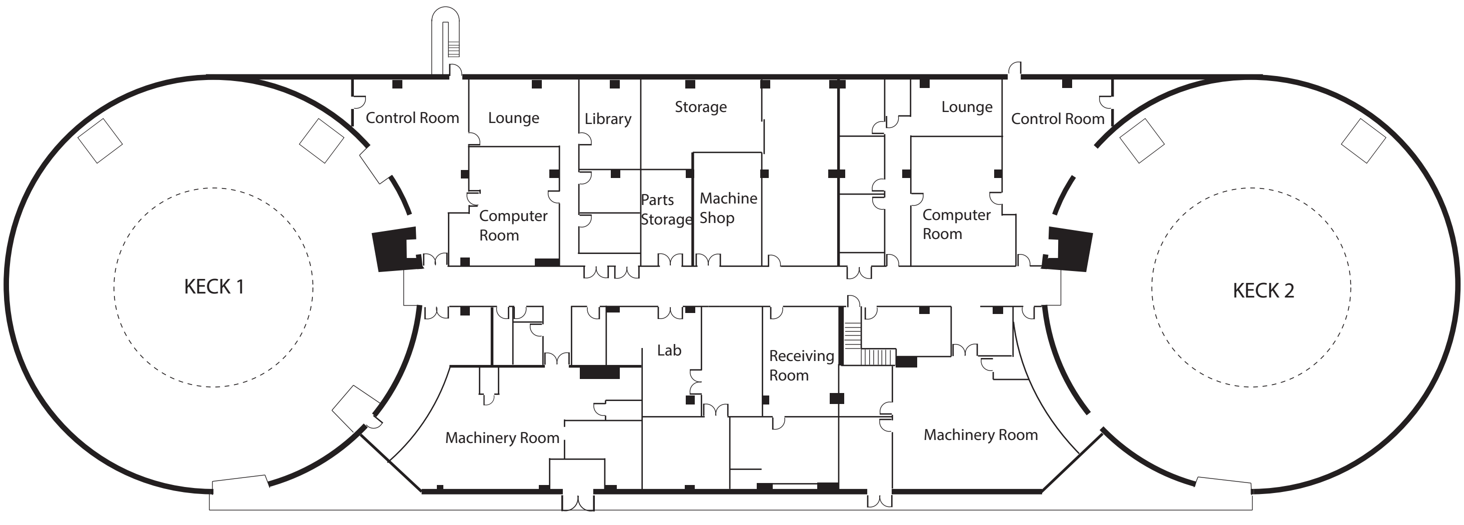


Figure 18d. KECK Plan

The KECK Observatory on Mauna Kea Volcano in Hawaii is the leading American observatory. Using the world's two largest optical interferometry telescopes allows astronomers to peer deep into space with nanometer precision. This observatory is a massive operation initiated by the California Institute of Technology. The entire complex is made up of multiple telescopes, but the main focus of this case study will be on the W. M. KECK Observatory telescopes and supporting facilities

The building itself is very simple in design. Two 10m telescopes sit parallel to each other, with all the supporting spaces in between. Each side of the building has its own control room, telescope, loading dock, and mechanical rooms. The rest of the building is used for mirror replacement, restrooms, staff lounges, a library, labs and a machine shop.

This observatory is known for its massive white domes atop Mauna Kea Mountain. The massive structures open and close with ease, and they both move in perfect unison. Each telescope weighs 300 tons, making this operation very large and complicated. Many full-time technicians and engineers are needed to operate the large observatory.

The site for the KECK Observatory is the Mauna Kea Volcano. The observatory sits at 13,796 ft, well above the clouds and high enough in the atmosphere to eliminate image blurring. The site's location in the Pacific Ocean is also far from cities, thereby eliminating the threat of light pollution.

One aspect this case study ignored was the environmental concerns associated with placing the observatory in its current location. The site was leveled significantly to accommodate bringing in the massive telescopes. The terrain has no vegetation due to the soils and rock produced by the volcano, so there was no direct effect on living organisms, but the builders of the KECK Observatory did destroy natural landscape. For example, they flattened several parts of the Mauna Kea Volcano summit to create a level building surface.

Another concerning part of this project was the lack of human spaces. The building was erected for one purpose: to see the stars. Many considerations like natural lighting were ignored in order to put up a strictly scientific building. Funds for creating suitable human spaces were, apparently, allocated

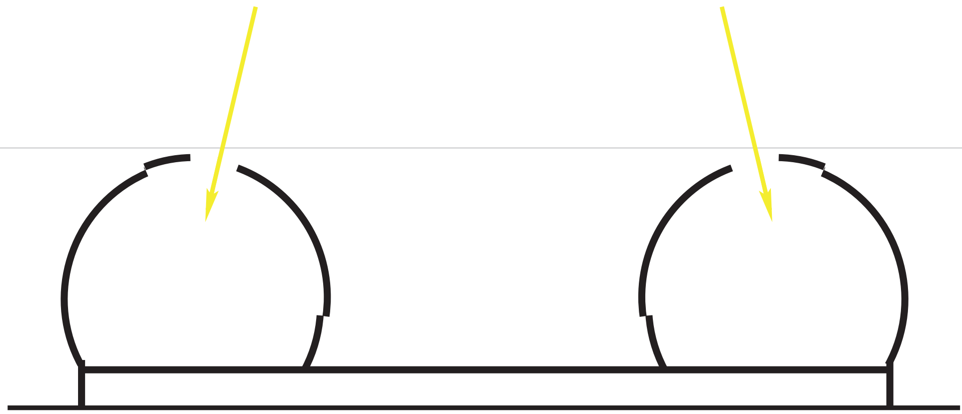


Figure 18e. KECK Natural Lighting

Figure 18f. KECK Hierarchy

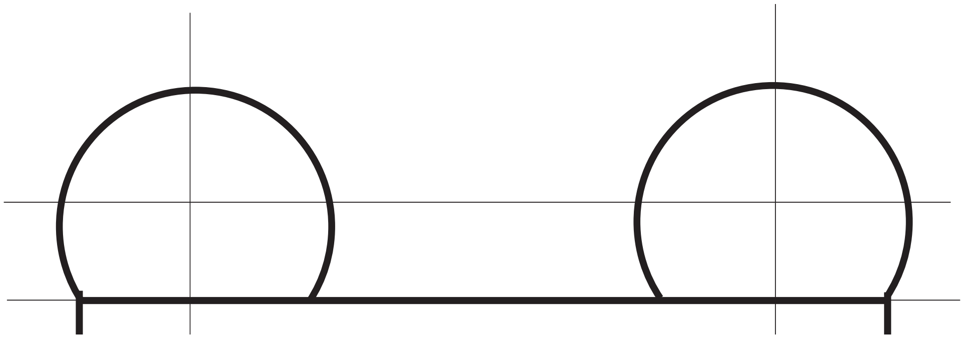


Figure 18g. KECK Geometry

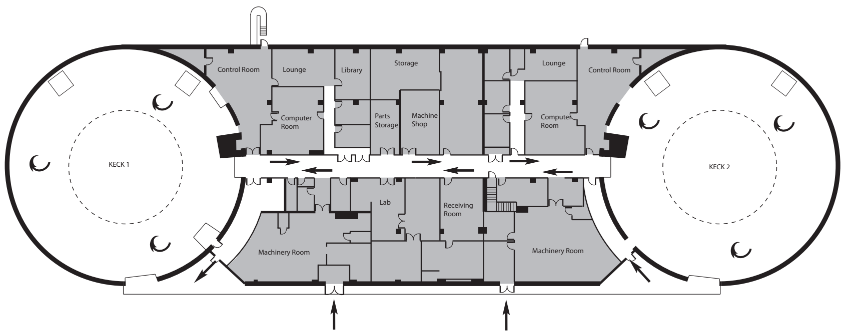


Figure 18h. KECK Circulation

elsewhere. So while this case may be a good example of programmatic spaces, it does not make a good study of healthy spaces.

Even though this case study may have some flaws, it is an excellent representation of the program associated with a large observatory. These spaces include control rooms, mirror replacement rooms, a library, a lounge, a machine shop, a light tunnel, receiving rooms and many other spaces. The design does not feature many spaces devoted to the users, but it does give a look into the mechanical spaces needed to operate a large facility like an observatory. The building is essentially divided down the center, with a wide corridor capable of allowing large mirrors to pass through it. On either side of the hallway are rooms for storage, machine shops, mechanical, labs, and various other spaces. The layout of the building is done fairly well—it is simple and straight-forward.

The materials used for the observatory are primarily steel and concrete. Being close to an ocean port made transportation easy and less expensive than it would be for a traditional land- locked observatory. However, this building did not come without high costs, as indicated by its $140,000,000 price tag (KECK Observatory, 2012). This case study illustrates how materials must be carefully chosen when designing an observatory. Materials taken from the site can be much more affordable and reliable than importing materials from thousands of miles away.

An observatory's design should not only accommodate its equipment but also the people who run it. While KECK Observatory is a world leader in optical astronomy, it is more focused on the technology within and not the people who use the observatory. Other support facilities do house scientists, but developing the area where they work every day should be considered more. A concrete building with no natural lighting is not a healthy environment for working people. This case study is a great example of what technology can do, but it lacks human connection. The observatory is a large computer void of human experience.

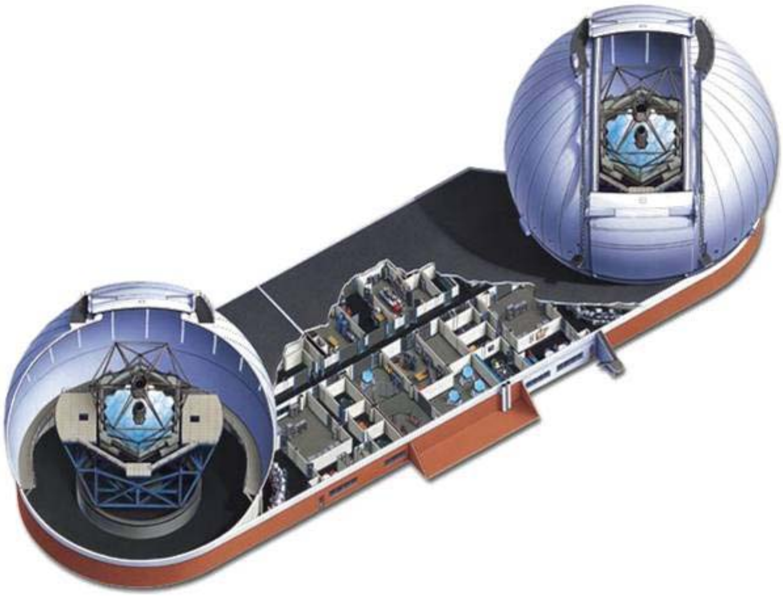


Figure 18i. KECK Axon

Figure 18i is a diagram of the KECK Observatory on the Mauna Kea Mountain in Hawaii. This observatory uses two main telescopes to combine light into one image. It works similar to the VLT telescopes addressed earlier. The support building lies between the two main telescopes. As shown in the diagram the mirrors are made of up segments instead of single large mirrors. This helps control warping due to gravity and heat. Multiple mirrors also makes repair much easier and less costly because each mirror segment is easily replaced and remanufactured.

Figure 18j. KECK 1

Figure 18k. KECK 2

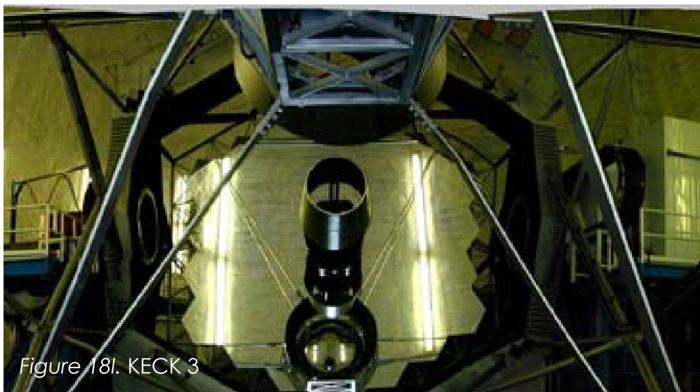


Figure 18l. KECK 3

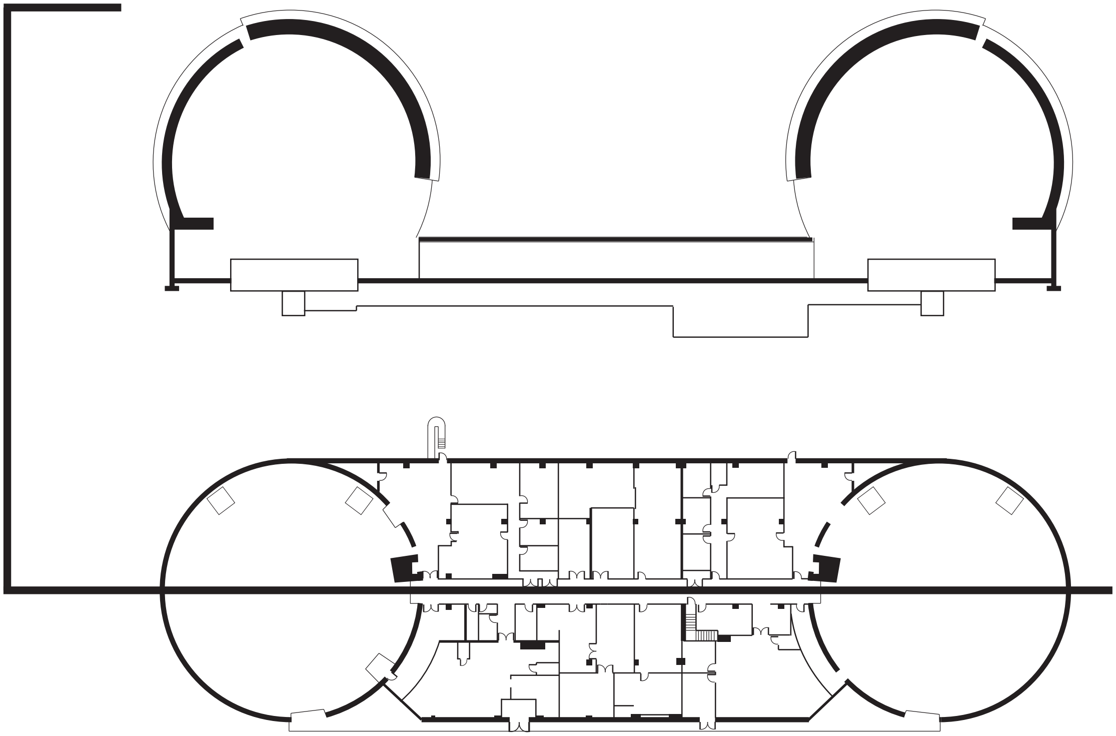


Figure 18m. KECK Plan to Section

Figure 18n. KECK Massing

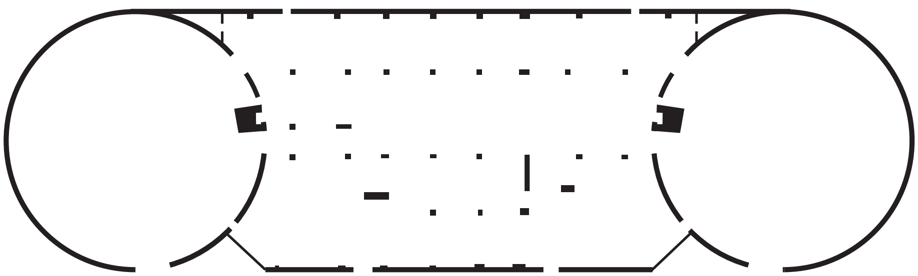


Figure 18o. KECK Structure

JOHN TIZYA VISITOR RECEPTION CENTER

Old Crow, Yukon Territory, Canada
Building sq ft.- 5,000
Building Type - Visitor Center
Year Completed - 2008
Cost - N/A
Lat/Long - 67˚34’12”N 139˚50’24”W
Architects - Kobayashi and Zedda

Figure 19a. John Tizya

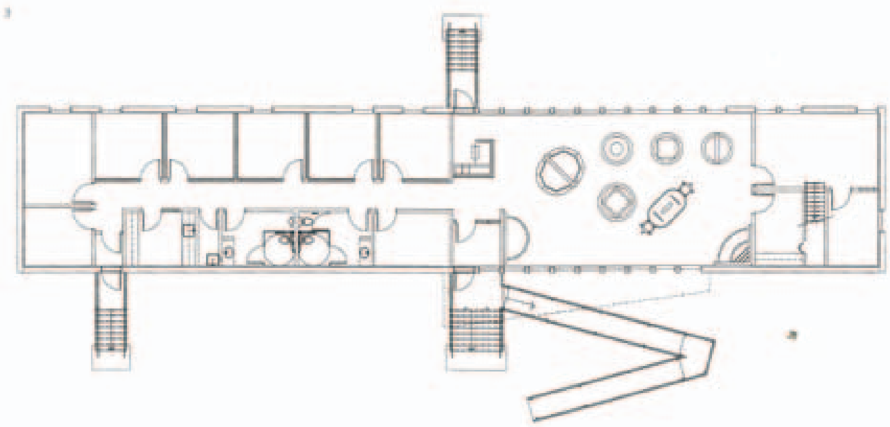


Figure 19b. John Tizya Plan

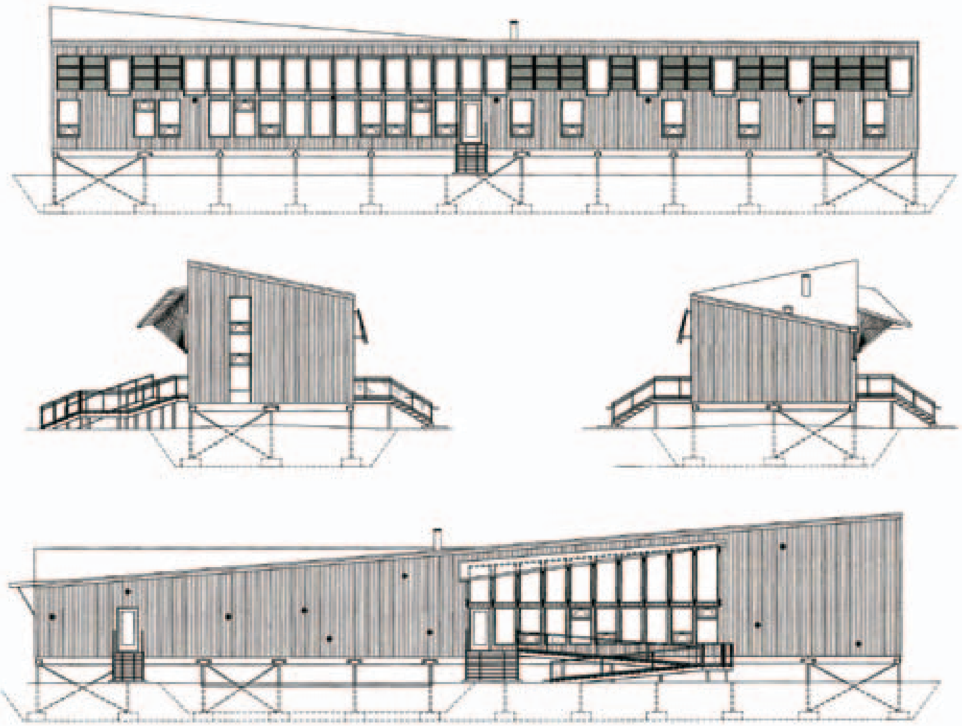


Figure 19c. John Tizya Elevation

The small town of Old Crow is well above the Arctic Circle and is a remote destination only accessible by plane. The village belongs to the Aboriginal Vuntut Gwitchin First Nation. These people's name means "People of the Lakes" according to the Old Crow Town Website (Peter, 2012). Their livelihoods primarily consist of hunting, fishing, and trapping. The visitor center is used for community events held by the people of Old Crow. Exhibits are displayed in the main gallery for visitors to see what the culture of Old Crow is also about. Large windows and clearstory windows open the gallery room to light and express a light airy feel within the building.

The visitor center is very simple in design. The entire building is only 5,000 square feet and consists of a main hall/gallery space, offices, a conference room and restrooms. The main structure consists of glue laminated beams held off the ground by a network of steel stilts. The soil is comprised of permafrost so any direct contact with the soil could result in melting and sinking over time. That is a common trend with building built in the northern most regions and even some in mountainous regions around the world. Simply lifting the building can eliminate damage to the sensitive site as well as future damage to the building.

Many unique alternatives to design appear in remote locations like the Arctic Circle. Since the only way to Old Crow is by plane a design challenge was presented for the John Tizya visitor center. How does one transport an entire building by small plane? Every piece of the building had to fit through a 3ft by 3ft airplane door. The glue laminated beams all came in sections of 10ft and they were spliced together at the construction site. This made for an excellent way to construct the building. Having smaller more manageable parts eliminated the need for large construction equipment saving the owner money in the overall construction cost (Kobayashi Zedda Architects, 2012).

Another way to eliminate waste with this building was through the use of alternative energy resources instead of diesel generators. The entire Village of Old Crow ran off diesel power for many years. The visitor center was the first building in the village to use solar panels to offset the use of diesel. During the summer the village is endowed with 24 hours of sunlight making it an excellent time to store as much energy or sell its energy to other buildings within the area (Decker, 2010). Eliminating more consumption of diesel could help the village offset their carbon footprint as well as decrease costs associated with high heating bills in the long winters.

The images shown here are examples of the simple design used at the John Tizya Visitor Reception Center. Every part of the building was designed to fit within a small aircraft. Lights on the exterior of the building were placed strategically to make the visitor center seem friendly and inviting during those long 24 hour days of darkness in winter. During the summer light penetrates the large windows on either side of the gallery space on when its dark the large overhang can be closed to eliminate heat loss from the building.

Figure 19d. John Tizya 1

Figure 19e. John Tizya 2

Figure 19f. John Tizya 3

The John Tizya Visitor Reception Center is a fantastic example of architecture built in remote locations using minimal construction methods. Architecture on the Beartooth Pass may not need to be designed with the idea that only planes can deliver materials but it does still have restrictions. For instance no trailers over 40ft long are allowed on the Beartooth Pass because of the tight hairpin turns and the lack of turnarounds. It is simply too tight for vehicles of that length to make the trek up the switchbacks. Weight and width restrictions also limit the vehicles allowed. Building in a modular fashion could help alleviate some of the transportation issues.

The second most admired part of the visitor center was its use of solar panels. Fuel costs are extremely high in Old Crow because of the transportation used to move fuel. Using alternative means of energy helped offset the building reliance on diesel fuel and it even sells energy back to other customers at a lower price than the fuel does. While one cannot rely completely on solar panels for energy at an observatory it can help lower the cost of fuel transport for diesel generators. The more renewable resources the observatory could use the better. The Beartooth Pass has at least 6 hours of usable time of a solar panel every day. This makes this form of energy much more reliable than something within the Arctic Circle. Other forms of energy from wind and geothermal could also be considered at the proposed site in Wyoming.

CASE STUDY **CONCLUSIONS**

Case studies are used to compare and contrast ideas of how buildings could be made. They are looked at to inspire and teach from an experience point of view. This section will briefly discuss why each case study was chosen, how it pertains to the project and how it compares to the other case studies presented.

The **European Southern Observatory at Cerro Paranal** is one of the leading observatories in the world. It has pushed the boundaries of how observatories are designed and built. It is the perfect example of a complex devoted to human activities as well as the scientific activities it houses. ESO took the initiative to design for the scientists and not just the equipment, making this observatory very attractive scientifically and environmentally. While the extent of the remote location of this observatory drove the design of the hotel, it is still a great example of human spaces needed within an observatory.

Compared to the other case studies shown, the ESO at Cerro Paranal is the best in terms of human spaces within a building. Large expanses of windows allow astronomers to look out over the landscape. Astronomers are given their own rooms along with a study. A large garden and pool pumps the hotel with much needed humidity. None of the other cased studies showed this devotion to human space. The observatory at the Beartooth pass will take into consideration the types of space humans needed in order to work efficiently and collaborate.

The **Kielder Observatory** was a necessary case study because it showed the importance of using local materials in a non-wasteful way. Even though the project was considerably small compared to the other case studies it expressed that an observatory can be built economically and it can be built in a way that minimizes its impact on the environment.

The only other case study that showed this commitment to healthy environmental design was the John Tizya Visitor Reception Center. Both these projects excelled in the quality of their design. Nothing was left to waste with these two projects. Every design decision was made because the architects cared about costs, the environmental impacts, and they cared about the quality of their work. This quality of design needs to be prevalent in the design of an observatory on the Beartooth Pass. The environment is to fragile not to take these design considerations into effect.

The **KECK Observatory** is one of the world's leading observatories and yet their working conditions are not the best out of these case studies. Technology took over with this huge operation. This case study however was the best example of spaces needed within an observatory. The program was a wonderful look into the operations on an observatory from restrooms, mirror rooms, libraries, to control rooms. The scale was much more appropriate than the other case studies for an institutional observatory. This program greatly influenced the spaces needed for the Beartooth Pass.

The **John Tizya Visitor Reception Center** is a wonderful example of remote design. This case study looked at the conditions the building had to face in the Arctic Circle. Remote conditions like these called for different building methods that could be used on the Beartooth Pass. Transportation was an issue for the visitor center so every piece of the building was designed to fit within an airplane. This design also considered the harsh climates the building would be constructed in so the whole building was designed to be easily assembled. This could reference back to the deconstruction principles discussed earlier in the theoretical research. If this building were to be deconstructed it could easily be taken down and recycled. The interior spaces could also be rearranged it needed given its simple floor plan. The visitor center part of the thesis design will greatly benefit from this case study. The program is very similar to what the visitor center might be at the observatory as well.

Historical Context.

HISTORICAL CONTEXT

Astronomy

Astronomy is a science that has been around since the dawn of man. Interest in the cosmos is an integral part of human nature. The explorative nature of humans has long caused them to analyze what lies beyond the atmosphere of earth. Places like Stonehenge and Chaco Canyon continue to intrigue people because the society in those places was clearly captured by the study of astronomy. Entire villages were devoted to the study of the sun, stars, the moon and other planets. These places remind us of astronomy's ancient roots. Building on the curiosity of these early civilizations, we now have modern observatories that allow us to see far off galaxies.

Galileo is considered the father of modern observational astronomy. He crafted his own telescope from designs by Dutch spectacle-maker Hans Lippershey. Galileo first used his new contraption to spy on enemy ships in 1609, but soon after he discovered he could use it to observe the moon and stars. Galileo made several discoveries' that were unpopular with church doctrine and other philosophers of his time. However, despite this initial resistance against his findings, Galileo's discoveries sparked interest in many other people around the world. Galileo had developed a way to look into the stars (Brunier & Lagrange, 2005).

Not long after Galileo's first observations, many different types of lenses and observatories were appearing. By 1640, many observers stopped using Galileo's traditional lenses and started using convex lenses, which greatly improved visual performance. Images were much clearer than before. Larger lens started appearing, and observatories were being built all around the world.

With many new observatories being built, a trend started that we know today as modern observational astronomy. Optical instruments were the main form of observation, but many different types of astronomy that even work outside the optical spectrum started to develop. X-ray, radio, infrared, and sub millimeter telescopes all observe different elements in astronomy, including heat from stars and sounds from outer space. Techniques kept changing and will continue to change as different needs arise.

The United States has proven throughout history to produce some of the world's best observatories. In 1950, a truly giant telescope first appeared. The 5m Mount Palomar telescope was the largest of its kind. George Hale was the influential astronomer behind the development of several large telescopes on Mount Palomar. He dedicated his work to developing the world's largest telescope. The Mount Palomar 5m telescope became an icon for modern observatories around the world. He pushed the boundaries of what modern astronomy could produce, which influenced the whole industry to develop highly advanced observational instruments.

Edwin Hubble was one the few astronomers that worked alongside George Hale in the early 1900s. He discovered the existence of galaxies outside our own, opening up the world of astronomy to a truly huge universe. He developed a classification system that helped astronomers understand the content, history, shape, and brightness of many distant galaxies. Edwin Hubble passed away in 1953 as a pioneer in astronomy (Edwin Hubble Biography, 2003). He influenced the Hubble Space Telescope, one of the most well-known in history, producing some of the best images of space known to mankind.

Figure 20. Palomar Observatory

While space observatories are amazing because they can take high-resolution images without the earth's atmosphere interfering, this is an expensive and risky endeavor. There is still a push to keep putting space observatories beyond earth's atmosphere, but there is also incentive to make ground-based observatories because of the small cost in relation to creating and maintaining space observatories.

Ground-based observatories are functioning better than ever and can compete with space observatories on an image clarity level. Throughout history, ground-based observatories have continued to develop in many forms and sizes. Keck Observatory in Hawaii is a great example of how ground-based observatories have changed. In the past a single telescope was needed to produce good images. Today at the Keck Observatory, two telescopes working together are in use with adaptive optics systems making most images crystal clear. Changes in the way lenses are made have allowed for astronomers to view deeper into space.

Another observatory that made history was the European Southern Observatory (ESO) in Chile. This observatory was finished in 2007 and includes four 8m telescopes, all capable of working together making this the largest array of all telescopes. It also includes four auxiliary telescopes used in unison with the larger 8m telescopes. It has been six years since the observatory was built, and it is still one of the best in the world for reaching deep space. Still, there are already plans for a new observatory very near ESO. The CCAT will be a 25m telescope and is slated to have its first viewing in mid 2013. It is has been planned to be the largest telescope in the world. Its goal is to observe further than any other telescope and to take surveys of distant galaxies.

From people creating rings of stone to observe the stars to today's mega observatories, humans have come a long way in their techniques of viewing the cosmos. It is astonishing how the development of technology has allowed humans to look millions of light years into other galaxies

Astronomy in Wyoming/Montana

Astronomy has been practiced within the Wyoming/Montana area for quite some time. Atop the Bighorn Range in Wyoming lays a "medicine wheel" created by the indigenous people 300–800 years ago as illustrated in *Figure 21*. The wheel is believed to align with solar patterns throughout the year. It is made from a crude construction of stones on a much smaller scale than Stonehenge, but the two have similarities (Bighorn Medicine Wheel, 2008). Small rings along the outside rim of the circle line up with the center of the main circle. The axis they create points to specific solar phenomena during the year. The set of rings is a crude way of studying the stars, but 600 years ago this observation was more of a ritual than a science. People were able to mark the time of the year based off the sun and the stars. Today, astronomy in Wyoming and Montana has advanced well beyond the past technology used in the medicine wheel; the University of Wyoming and the University of Montana use increasingly sophisticated systems to record the cosmos.

The University of Wyoming has several observatories that have been in operation since 1977. WIRO (Wyoming Infrared Observatory) is one facility that has been a leader in the world of infrared observations. The University also operates the Red Buttes Observatory and Star Observatory, which are dedicated to undergraduate and graduate work. Several other observatories are run by astronomical societies and private parties throughout the state. The University of Montana also has a department of astronomy that runs a small telescope built in 1970 at Blue Mountain Observatory.

Figure 21. Medicine Wheel


Figure 22. WIRO

The 1970s were an influential period in the development of astronomy at the University of Wyoming. Robert D. Gehrz, now part of the University of Minnesota, founded the infrared astronomy program at the University of Wyoming. He and Frank J. Low (the father of infrared observation) endeavored to build an infrared observatory(shown in *Figure* 22) that could rival the observatories located at Kitt Peak in Arizona. Wyoming became their location of choice because of its clear and cold night skies. After several years of searching for the perfect location, they finally settled on Jelm Mountain in western Wyoming. The site was a former US Forest Service fire lookout station. After paying the reasonable price of one dollar, the mountain top belonged to the University of Wyoming, and development plans and construction commenced. This telescope is still a leader in infrared observations, with the ability to operate in standard optical configurations as well. The drawback to this observatory is the lack of space for observers and astronomers. The observatory was not designed for the capacity of students using the facility today (Gehrz, 2008).

The University of Montana faces a similar situation. They built their observatory in 1970 on Blue Mountain just outside of Missoula, Montana. The observatory was built on a small budget, and no renovations have occurred since 1970. The observatory is still used for research and many public viewings occur during the summer months drawing in large crowds. On some nights, up to 250 people will attend the star parties at Blue Mountain (University of Montana, 2012).

These observatories are all within a short driving distance of the proposed site for this thesis. Because the proposed observatory is based on interferometry and these other observatories are small scale optical/infrared telescopes, this site would make for an excellent telescope array. As history proves, observation is excellent in Wyoming because of the cold, dry climate. Many excellent sites within Wyoming have been home to observatories, and while these observatories may be smaller, a new, larger collaborative observatory could be possible. The proposed site is geographically located between the University of Wyoming, the University of Montana, and Montana State University. All three of these universities have astronomy departments that could utilize a large scale project like the one proposed. By creating an array of telescopes, the universities could collaborate on one large research project or use the telescopes individually.

Beartooth Pass

The "orphaned highway" is considered the most beautiful road in America. It stretches from Red Lodge Montana to Yellowstone National Park. The Beartooth Pass received the "orphaned highway" nickname because of the absence of ownership since its opening in 1936. Over the years thousands of people have ventured to this magnificent road to drive along some of the highest terrain accessible by automobile in America.

The road was originally designed as an entrance to Yellowstone National Park from Montana. The only way federal funding could be secured was if the road became an approach road for Yellowstone. Today, the funding has paid off and the road has become its own destination as thousands of people drive along the scenic Highway 212 every year. Red Lodge and Cooke City, Montana were two towns that have reaped the benefits of the highway. These towns turned from mining to tourist towns in only a few years, bringing in money from tourists passing by. Hotels soon popped up along Highway 212 just outside of Red Lodge. As the automobile developed, more people made the trip to drive along the pass. Soon the pass became accessible to anyone for the three summer months it was open each year.

Construction on the Beartooth proved to be very difficult and dangerous. Two contractors, McNutt & Pyle and Morrison-Knudsen became the primary builders on the road. It took the contractors five difficult years to construct the entire highway from Red Lodge to Yellowstone National Park. Winters were tough and many workers left in fear that they might die from the severe weather. Conditions at the McNutt & Pyle camp were less than satisfactory, eventually leading to Morrison-Knudsen taking over both contractors' work. Blasting into the bedrock was dangerous, and several landslides stalled the construction of the road.

Finally, on June 14, 1936, the road was opened to the public, and people could drive from Red Lodge up to the 10,947ft summit and back down the other side toward Yellowstone National Park. It was an experience many wanted to try.

Several landslides have threatened to close the road since its opening. In 1950, the entire road was rebuilt and paved. In 2005, a large mud slide took out a significant portion of the road near the switchback terrain, resulting in an entire year of construction.

Today the road is still open for travel from late May to October each year, depending on snow coverage. The road has become a place for many skiing and snowboarding enthusiasts. Wildlife is prevalent along the alpine meadows, so many people stop to watch and take photographs. The summit of the Beartooth pass (location of the proposed site) is one stop along the road that many enjoy. The summit offers wonderful views of the surrounding peaks, valleys, and lakes. The future of the road seems optimistic and many people are working on preserving and updating visitor amenities along the highway for future generations. A positive relationship with locals and visitors keeps the Beartooth Pass alive today.

The history of the Beartooth Pass site will play into the design of the observatory. Snowfall records, historical context, and site history will all need to be addressed. As mentioned above the Beartooth Pass is closed each year from October to May. The observatory will be open throughout the whole year making travel accessible only by snowmobile and snow cat. Large amounts of snow have historically fallen on this site making the design of the observatory congruent to precipitation conditions. The visitors center will focus on the geological history of the site as well as astronomy and what researchers are trying to find at the observatory.

Figure 23. Beartooth Pass History

Thesis Project Goals.

THESIS PROJECT **GOALS**

Academic Goals

Learning is the most essential part of the thesis. The reason we focus our time and money on one project for such a long time is because we want to learn how architecture can influence the world. Academia is devoted to learning what the world needs and desires from their built environment. It is a time when professional practicalities such as money and feasibility are out ruled by the creative impulse of a design student. While we must comprehend what the world will require from us we must also take this precious time focus on what we as students feel is the future of architecture. For me learning about astronomy has become something of an obsession. Science and technology will always be a part of our lives as designers and architects. We rely on the findings of such professions to influence our own.

Coming into this project with little knowledge on the construction of observatories allowed me to assess what I feel is relevant and important in astronomy. Devoting a semester of research is never enough but it does give me a grasp on where the world of astronomy is going. Academically my goal is to understand what astronomy is and how I can interpret my understanding through the medium of an architectural design. I also wanted to design a project with a tough location. My dream has been to do a design for a mountainous region. I feel we often dwell too much on our own regional understandings and not enough on what is outside the Midwest. A goal at the beginning was to design outside of my comfortable regional area and to find somewhere that could prove a challenge environmentally.

Professional Goals

We must all take pride in our thesis projects as we know this is one way of landing a job in the near future. I want to show employers that I can design as well as research various types of architecture. This project is the perfect time to polish marketing skills as well as writing skills needed in the future.

I plan to use this project to boost my portfolio and hopefully land me a job. While it may seem like an odd building typology for this area it could hopefully open opportunities in the scientific community of design. Working for a firm that shows precision and expertise in their designs would be ravishing.

The physical design of this thesis will show knowledge my understanding of building construction and site design. I want architects to see this as a conceptual project that could one day be built hypothetically. If I can convince someone that this project is real and worthy then I have done my job as an architectural thesis student.

Personal Goals

Personally this project is about having fun and exploring different mediums for presentation in architecture. This is the last year of school I could potentially ever have. The time is available to explore options for models, drawings, cinematography and photography. I have always been interested in what I can see, hear, touch and smell, so exploring architecture in all the senses intrigues me.

Exploring the world over the past year has made me realize how much there is still to see and experience. Traveling through Europe, the Middle East and parts of western America has opened my eyes to various kinds of architecture. Particularly, seeing architecture in the Alps of Europe inspired me to focus on a thesis in the Rocky Mountains of the United States. Personally I would love to design within mountainous regions and this project is the first step toward opening more opportunities to do so in the future.

Beartooth Summit Site Analysis.

Qualitative Site Content

One hour into the wilderness from Red Lodge Montana exists the summit of the Beartooth Pass. This site has been marked by man since 1936 when highway 212 cut its way into the landscape. The site is one of the most beautiful places in America accessible by automobile. At 11,000 feet the site has remarkable views of the terrain with nothing in sight but mountains and lakes.

Throughout history people have driven past this site on their way to America's famous recreation area, Yellowstone National Park. As one approaches the summit vast alpine meadows sprawl out across the mountain tops. Sharp cliffs linger to the side of the roadway forcing one to slowly take in the landscape. Remnants

Figure 24. Site 1

Figure 26. Site 3

Figure 27. Site 4

Figure 25. Site 2

of snow exist in midsummer covering parts of the meadows. The air is brisk and the wind bites through sweatshirts and jackets. The top consists of large boulders, tundra, and a few goats. The site is very desolate but very rich in what it offers to visitors. Views beckon from every angle and the sky is as wide open as one can get. A large turnaround with parking spots welcomes those who wish to stop. Small foot trails disappear over hills and rocky terrain into the mountains. As one opens their car door they instantly understand the grandeur of the mountains.

This grandeur is understood through the rock formation. The glaciers coming through this area pushed and pulled the land, morphing it into what we see today. Inspiration for me comes from this morphing and reshaping for me. I see the land as something constantly changing and adapting as conditions do. This site helped direct the theoretical ideas of architecture that could influence astronomy in the form of observatories. Inspiration is also drawn from the textures of the land, the smells of the cool fresh air, the grand sights, the loud breeze across the landscape and the taste of cold dry air.

Grids: No man made grid environment is visible from the top. The only built surfaces in existence are the road, the parking lot and a small weather station on an adjacent peak. Smalls walking paths made by goats and humans suggest a pattern of travel across the site. Other than that no form of the built environment exists. These existing man-made paths should be addressed in the design in order to eliminate the impact on the site. The parking lot could be used with minimal impact on other parts of the site.

Textures: As one walks across the site they notice the rough textures. Boulders and hilly terrain are strewn about. The textures all enforce the idea that this area is claimed by nature. The only smooth textures come from the gravel parking area. Even shadows show the texture of the landscape by exaggerating the size of boulders and hills. Parts of the site almost seem lunar in a way or Mars like. The buildable area is determined by these textures. It takes a lot of energy to clear the way for a building so the design

will address this by carefully placing itself on the site.

Geometry: Formal man-made geometries are hard to find at this altitude on the Beartooth Pass. Jagged rocks seem to burst from the surface of the ground as if they are being pushed from below. These rock formations seem as though they are still moving and changing. Inspiration from these geometries could be used in the final design of the structure. The power of the site comes from the changing rock formations. Building forms and even interior spaces could branch off the idea of pushing or pulling out of the earth.

Shade and Shadow: As shown in the climate diagrams, shadows from the two peaks on the site cast shadows over a small section of site. During the day the site is nearly free of all shadows. The north cliff area of the site is the only area that hardly ever receives sunlight on a daily basis due to the steep terrain. The sunlight from site could be used to power the building. Using solar power is one way to address energy concerns. Another is to use the sun to heat the building during the day through passive design. Orienting the building with south facing windows will greatly decrease the need for heating.

Section: The Beartooth Pass summit has an impressive elevation change as illustrated below. A 500 ft. cliff to the north side of the site acts as a natural barrier.

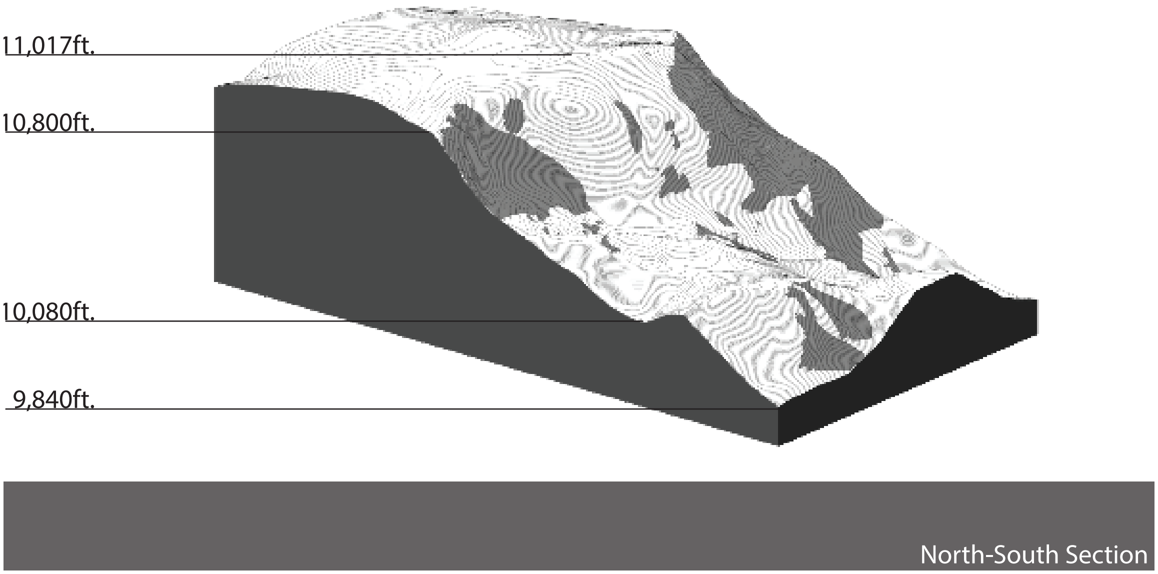


Figure 28. North-South Section

To the east, south and west the slope is much more gradual with a gentle rolling alpine meadow. Water runoff happens along several gullies toward the north of the site and to the south. The cliff area on the north side of the site holds snow all year long due to being shaded almost 24 hours a day. This snow or water run off could be harvested for use in the final design of the building. This water could be used run toilets, water plants, and even for cleaning purposes.

Built Features: One small weather station stands at the top of the adjacent peak to the proposed site. The station is designed to be a durable heavy construction that can be trucked or air lifted in. The building sits on three concrete blocks that lift it off the fragile tundra. This is an excellent way to put a building on this site. The only other built feature on the summit is the parking area/turnaround. The parking is all gravel with several signs and some wood guardrails. There are no other signs of a built environment on the site. The nearest building is about 3 miles away and that includes a gas station, hotel, gift store and machine shop. Modern amenities are close but are limited due to the remote location.

Figure 29. Existing Building

Figure 30. Site 5

Figure 31. Site 6

Light Quality: The light quality at the site in excellent when no clouds are present. The sky becomes a deep blue and it is completely clean and free of smog or other related toxins. The UV rays from the sun are very strong at this altitude and can do more damage than one might expect. The light color is 10,000 to 12,000 Kelvin meaning the sky will appear darker than when at sea level. The blue is much more vibrant because there is less atmosphere for the light to filter through.

Vegetation: Above 9,500 feet you will find nothing but the tundra or alpine meadows. Life at the 11,000 ft. altitude cannot sustain anything more. The lichens and low growing grasses are the only plants that can grow in the windy cold climate. After all, snow covers the ground nearly 10 months out of the year in many parts of the alpine meadows. Illustrated below are examples of the brown grasses and the bright green lichens that grow over the rocky terrain. From a distance it seems as though everything is brown and not very lively but upon looking closer one see's many different colors in the plants that do grow. In fact many lichens like the ones below almost seem to glow with vibrant colors. This ecosystem is fairly rare so having an opportunity to drive and see it is something grand. It shows how life can hang on when the weather is trying to extinguish it.

Figure 32. Site 7

Figure 33. Site 8

Water: Lakes cover the area around the site. From the site one can see many lakes 800 ft. below. Upon entering the site one notices how cold and desolate this area truly is by the leftover fields of snow. The rainy season is very short in this area but the snowy season is long and harsh. The water runoff is in almost every direction from the center of the site. Much of the water runs off either the north or south side of the larger area around the site. Below is an image of the snow pack melting on the northern most side of the site. The water from the snow flows down a gully on the north side of the site and drains into a basin area at the bottom of the cliff. Several lakes exist at the bottom from all the snow melt during the initial parts of the summer.

Figure 34. Site 9

The water from the snowpack is very clean as seen below in the images of the lakes. Pollution from automobiles and humans is the only thing that could be visible in the water but from the naked eye the water is crystal clear.

Figure 35. Site 10

Figure 36. Site 11

Wind: At the summit of the Beartooth pass the winds can very powerful. Winds in excess of 50 mph are not uncommon and a strong 25-30 mph wind is often found at the top. Because the site is above the tree line vegetation is not there to help slow the wind. The cliffs and mountain peaks also help funnel air creating turbulence at the top. It is not uncommon for damaging winds to affect the area. This wind could be used to power the building. The challenge would be to harness the wind without damaging the turbines with the severe speeds. The combination of snow and wind is what makes this site dangerous during the winter. Blizzard conditions can instantly wipe out any hope of driving down the Beartooth Pass for a day or two at a time. This is one reason the proposed observatory must include living facilities.

Human Characteristics: Trails lead all around the site suggesting a human and animal existence. The gravel drive and parking spots along with a few signs are the only other suggestions of humans on the site. A trend with the trails suggests people like hiking to the edges of the site. The assumption would be humans enjoy walking to the edges. People want to see what is at the edge. The only problem with everyone walking on the site is the damage to alpine grasses. The final design of the observatory needs to consider where people may enter or walk. The use of designated paths or ramps could help alleviate the distress to plants. These paths could also take the form of large patios or decks that capture the beautiful views.

Distress: With humans comes distress. The site does show distress primarily from humans creating trails and from vehicles parking on the site and not on the road. This distress is typical of any national park land feature. An attempt can be made to keep people off the site but curiosity often lures people back onto the fragile terrain.

Snow and snow melt cause erosion on the north side of the site. There are many gullies and run-off ditches where water has eroded the top soil. The plants are very thin and sparse so vehicles parking on top do kill them. A few areas show plant distress near the parking area.

Wildlife: Goats were very prominent the day of the site visit. Many were lying in the sun warming themselves. Other animals include Elk, Grizzly Bears, Marmots, Wolves, Deer, Coyotes, and Big Horn Sheep. The animals seemed to not mind any attention humans were giving them. While the final design must eliminate feeding areas it must also be careful not to disturb large trails from goats or bears.

Quantitative Site Content

Soils: 2-5 centimeters of loose sandy soil
Subsoil consists of medium density sand/clay mixture
Bedrock: granodiorite, quartz monzonite, gneiss, and migmatite
Soil Classification: Class B - permeable with a moderate rate of water transmission (USDA, 2012)

The boulders shown in the photographs are remnants of the glacial activity on the west summit of the Beartooth Pass. This area was once completely covered and as the glacier moved it turned over large granite blocks. The areas with less than 50 percent slope consist of the Eutrocryepts-Cryorthents-Rock outcrop complex. These areas are the best to build on because their slopes are significantly less but they also contain native alpine grasses that are sensitive to building.

Figure 37. Eutrocryepts

Eutrocryepts-Rubble land-Enentah family complex, 50 to 70 percent slopes. While these slope may be hard to build on they do eliminate the harm done to alpine grasses within the site. The boulders can cause problems because of their loose nature. The builders would need to take this into consideration to remain safe on the site.

Figure 38. Eutrocryepts Rubble

Figure 39. Summit

Utilities: No utilities exist at the site. The observatory will need to be 100% off grid in order to sustain itself. The one building that is on the site is a weather station using solar photo voltaic cells to produce energy. Solar or wind power could be used to harness energy from the site. Other alternatives like hydrogen or natural gas generators could also be used with little harm to the environment.

Vehicular Traffic: Approximately 1,200 vehicles travel by the site on any given day between May and October. This number of course fluctuates as the season continues. The site has 21 parking spots currently (Beartooth Pass All-American Road Steering Committee, 2002).

Pedestrian Traffic: As described before many people hike from the West Summit of the Beartooth pass so pedestrian traffic can be moderately high during the summer months. Many cyclists ride past the site as well. A bus service to the top could help alleviate some of the traffic and reduce the number of parking spots needed on the site.

Topographic Survey: Slopes on the main part of the site range from 0-50% making the site steep in some areas. The northern part of the site ranges from 50-100% making the terrain impossible to hike. Water runoff can occur quickly during heavy

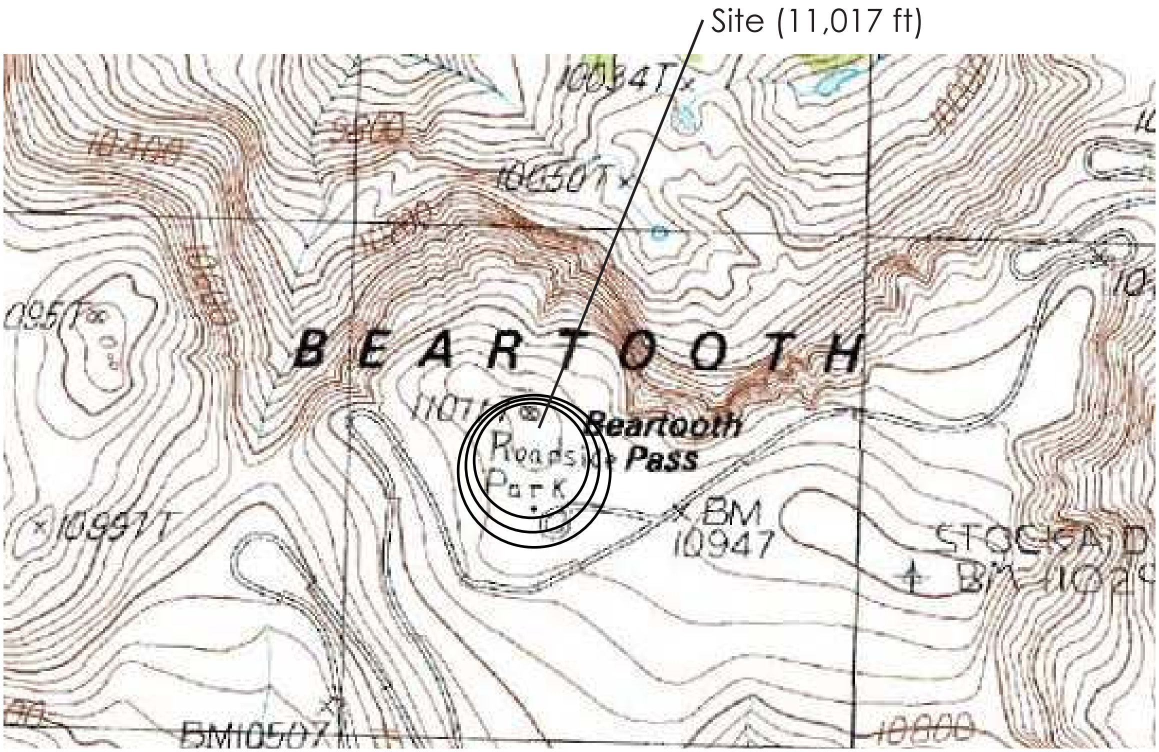


Figure 40. Topography

rainfall. The soil does classify as type-B making the surface permeable so soil doesn't completely erode away. An illustrated slope analysis map is provided within the climate data section of this manual.

Plant Cover: Plants able to survive alpine conditions are among the few at the site. Below is a list of the known species according to a soil and vegetation rehabilitation study on the summit of the Beartooth Pass. The survey was 25m square and consisted of several different types of seed and soils to determine which grew faster after a typical construction process. These plants could all survive on little water, only 40 to 80 days of growing time with frosts in between and winds in excess of 50 mph (ERO Resources Corporation, 2002). The following were typical plants on the site that performed well:

Tufted Hairgrass	Alpine Bluegrass
Alpine Timothy	Sheep Fescue
Spike Trisetum	Woolly Pussytoes
Rocky Mountain Sage	Lupine

Figure 41. Alpine Grasses

Figure 42. Tufted Hairgrass

Site Character: The thing that characterizes the site most are the views, the pure surfaces without human structures and the grand mountains. The site is characterized by sharp jagged rocks along with mellow alpine meadows. Signs of change within the site are paths worn into the surface by humans. Erosion has occurred but it seems natural in the way it has cut through the earth. Wear and tear is showing at the site because of all the people walking across it.

Figure 43. Large Site Map

Site Reconnaissance

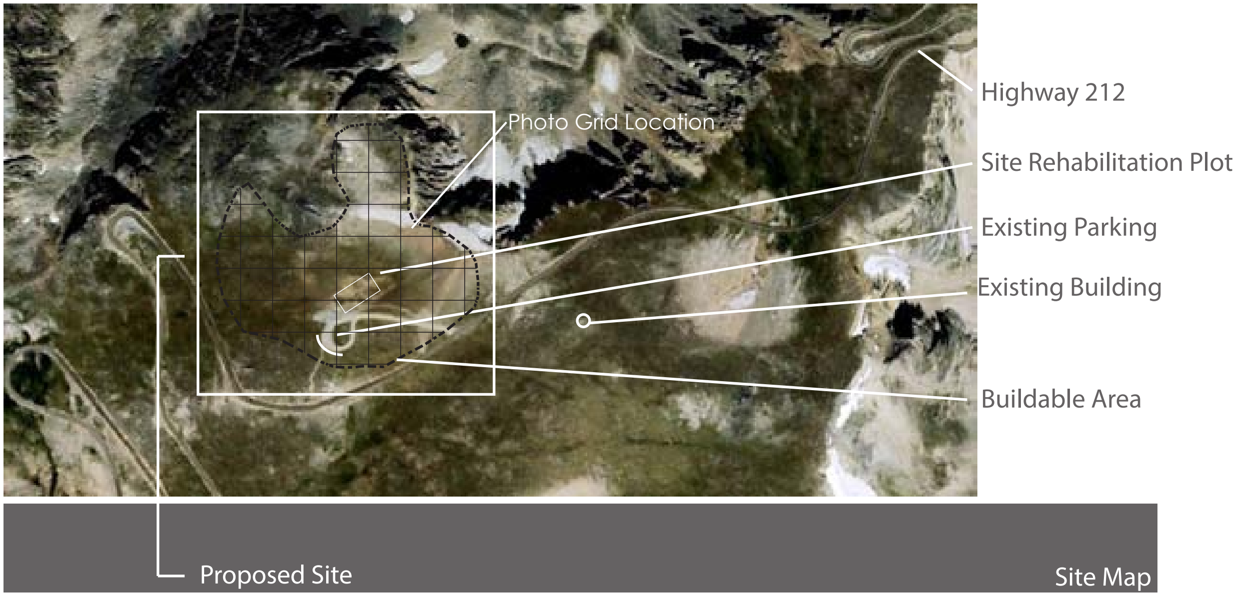


Figure 44. Site Map

West

Figure 45. Site Recon

Climate Data.

As illustrated in *Figures 46 and 47* the average temperature is significantly less than at lower altitudes. These low temperatures will need to be considered when it comes to heating the building. The observatory will need to be built with materials that exceed the standard R-value ratings for buildings at lower altitudes. Materials with values higher than R-40 are preferred. Natural cooling can take place within the telescope dome itself. The use of vents with smaller air-conditioning systems will greatly reduce the carbon footprint of the observatory as well.

The humidity at the site is fairly normal. The winter months may bring lower humidity levels that could potentially be off set by using plants within the building.

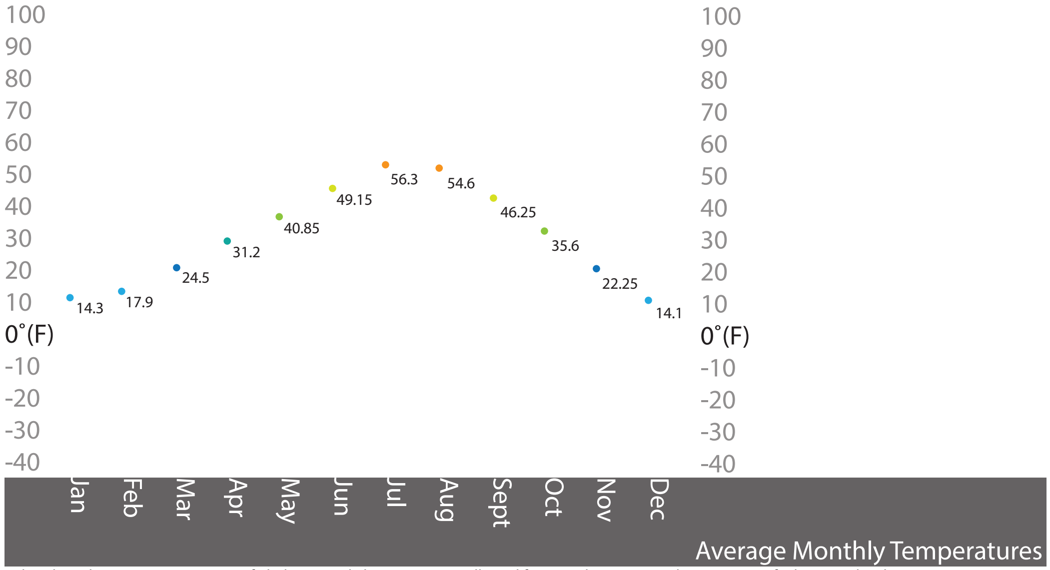


*Chart based on temperatures 3,000 ft. below actual elevation. Data collected from Cooke City, MT - Elevation: 8200 ft above sea level

Figure 46. Average Monthly Temperature

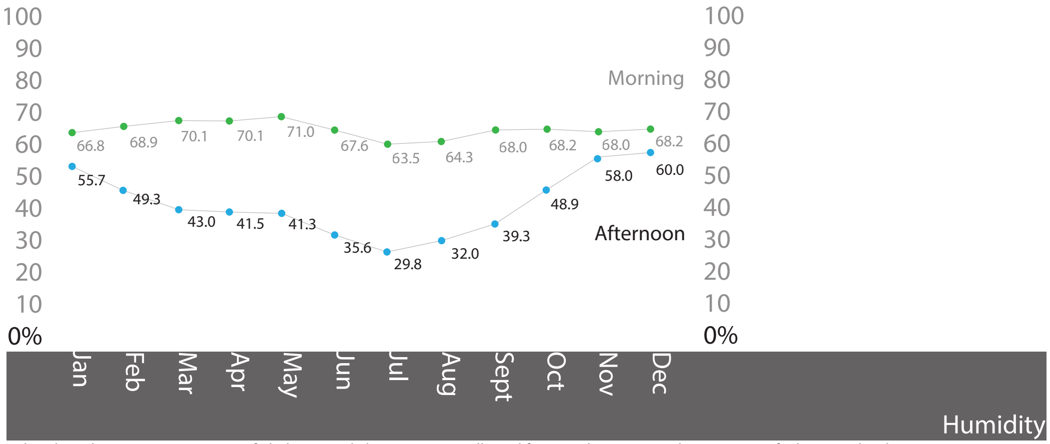


*Chart based on temperatures 3,000 ft. below actual elevation. Data collected from Cooke City, MT - Elevation: 8200 ft above sea level

Figure 47. Humidity

As illustrated in *Figure 48* the average precipitation is lower than that of the national average. While the average rainfall isn't very much the average snowfall is much greater. The Beartooth Pass can average 15 ft of snow by springtime. Being the site is at the very peak wind could potentially blow snow to lower elevations but drifting could cause problems around the observatory. The paths and entrances to the observatory will need to take this into consideration by either being lifted or covered.

The site does encounter cloud cover as illustrated in *Figure 49.* As a note the information for this cloud cover chart was collected from Cooke City, MT which is 3000ft lower than the proposed site. No data was directly taken from the site location. One can assume the cloud cover is similar if not less at this higher altitude. While some cloud cover does occur the observatory will not be terribly affected.

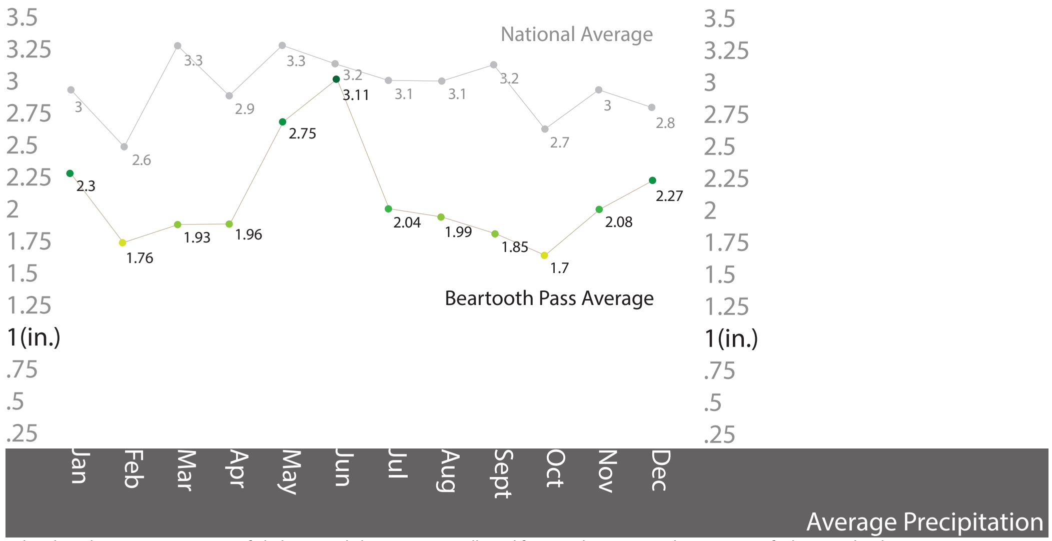


*Chart based on precipitation 3,000 ft. below actual elevation. Data collected from Cooke City, MT - Elevation: 8200 ft above sea level

Figure 48. Precipitation

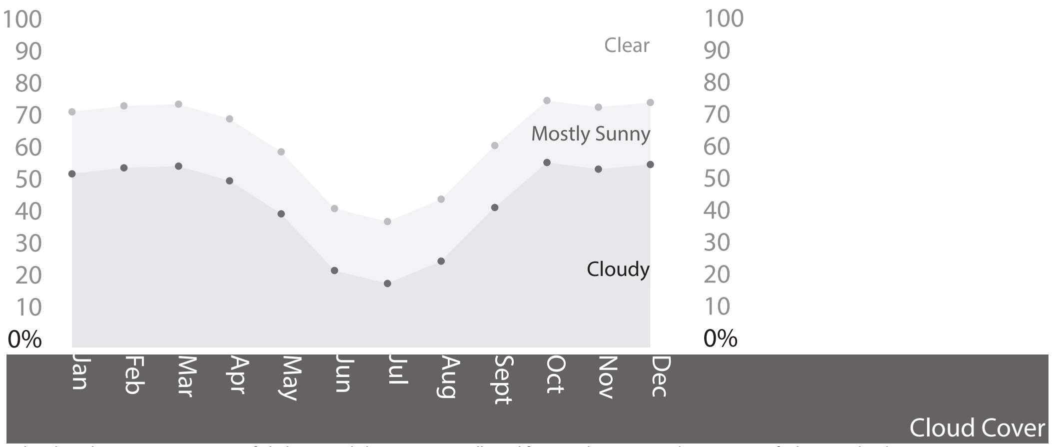


*Chart based on temperatures 3,000 ft. below actual elevation. Data collected from Cooke City, MT - Elevation: 8200 ft above sea level

Figure 49. Cloud Cover

As illustrated in *Figure 50* the average snowfall is fairly high during the winter months as well as into the summer. The site does experience snowfall year round. A ski resort a few miles away operates specifically in the months of June and July due to this high altitude phenomenon. Snow accumulations will need to be addressed when designing building entrances. Elevated and protected entrances will help protect the building and visitors from harsh conditions.

The site has wonderful opportunities to take advantage of the sun. There are no trees or buildings to block sun to the site. Using a solar array could potentially harvest enough energy to power the building during the day.

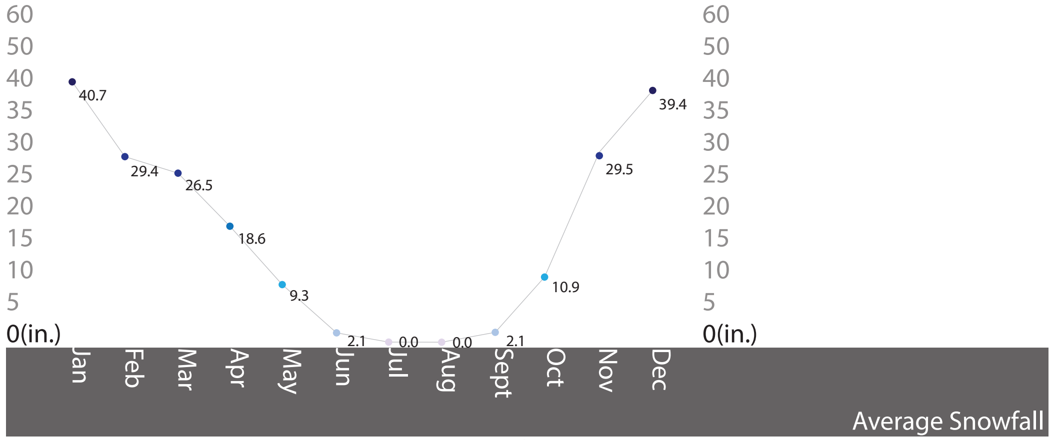


*Chart based on precipitation 3,000 ft. below actual elevation. Data collected from Cooke City, MT - Elevation: 8200 ft above sea level

Figure 50. Snowfall

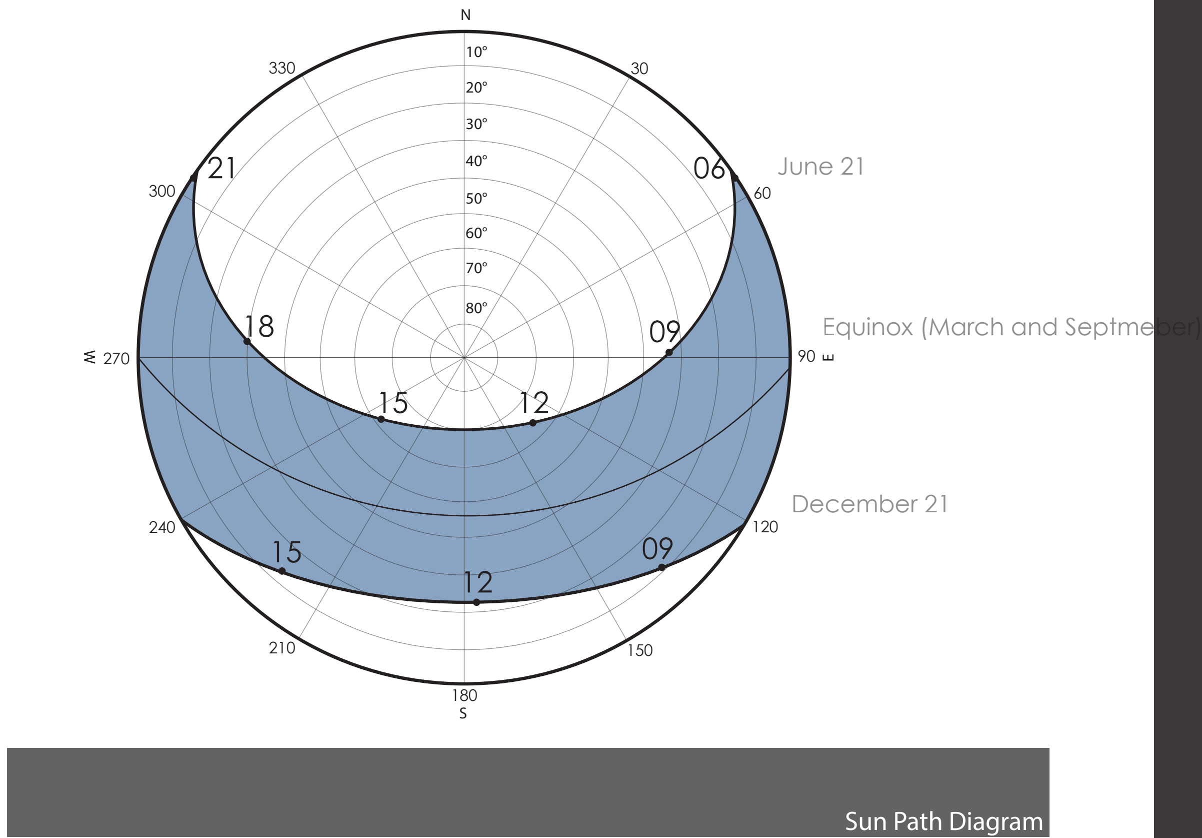


Figure 51. Sun Path Diagram

As illustrated in *Figure 52.* the average maximum wind speed is fairly quick. The winter months seem to produce the most wind making the site climate extremely harsh. The combination of both wind and snow will require the building to be designed with the site features in mind. Using the peak of the mountain to block wind from the north and west can greatly reduce heating costs. Using materials that specifically block snow and wind such as rain screen systems can also block the walls from cold penetrating winds.

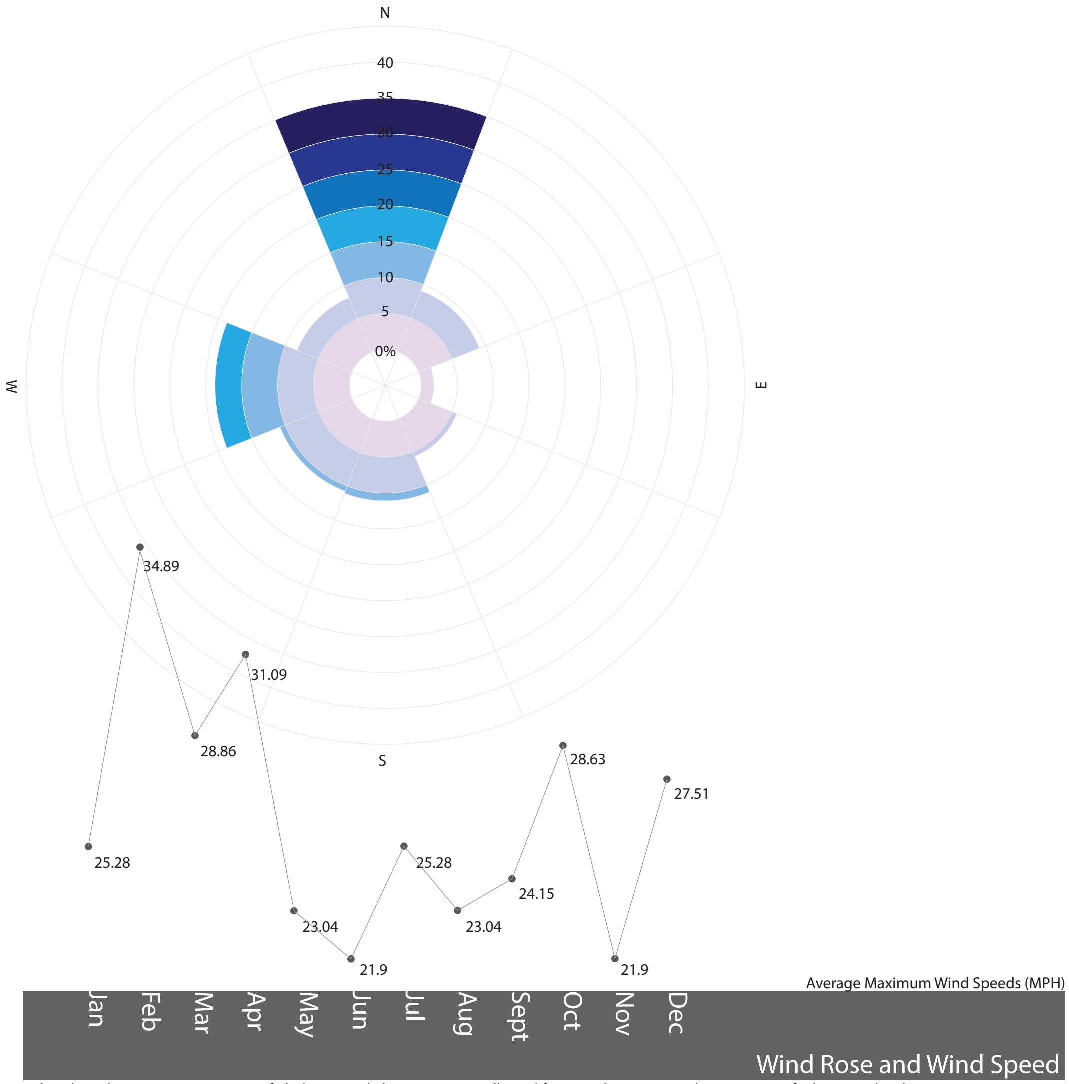
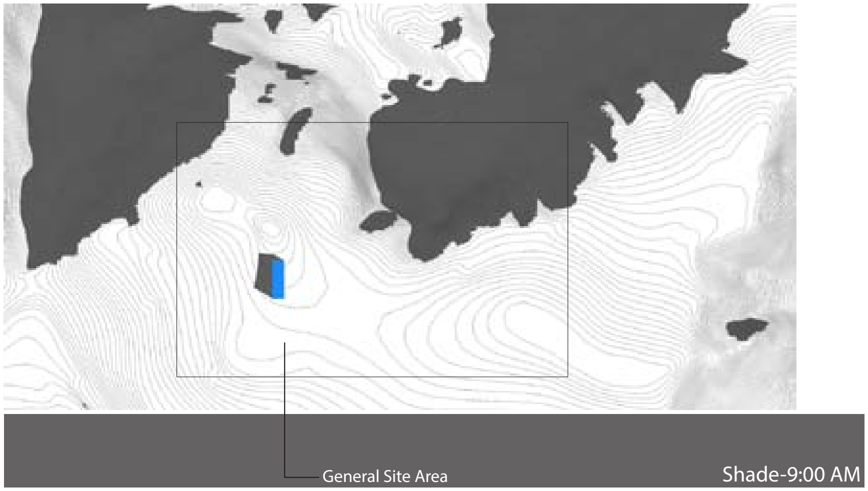
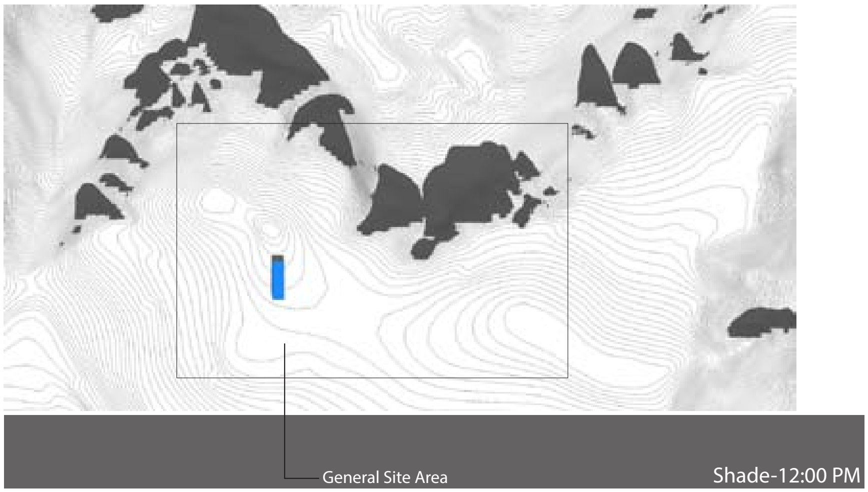


*Chart based on temperatures 3,000 ft. below actual elevation. Data collected from Cooke City, MT - Elevation: 8200 ft above sea level

Figure 52. Wind Rose and Wind Speed


General Site Area
Shade-6:00 AM


General Site Area
Shade-9:00 AM


General Site Area
Shade-12:00 PM

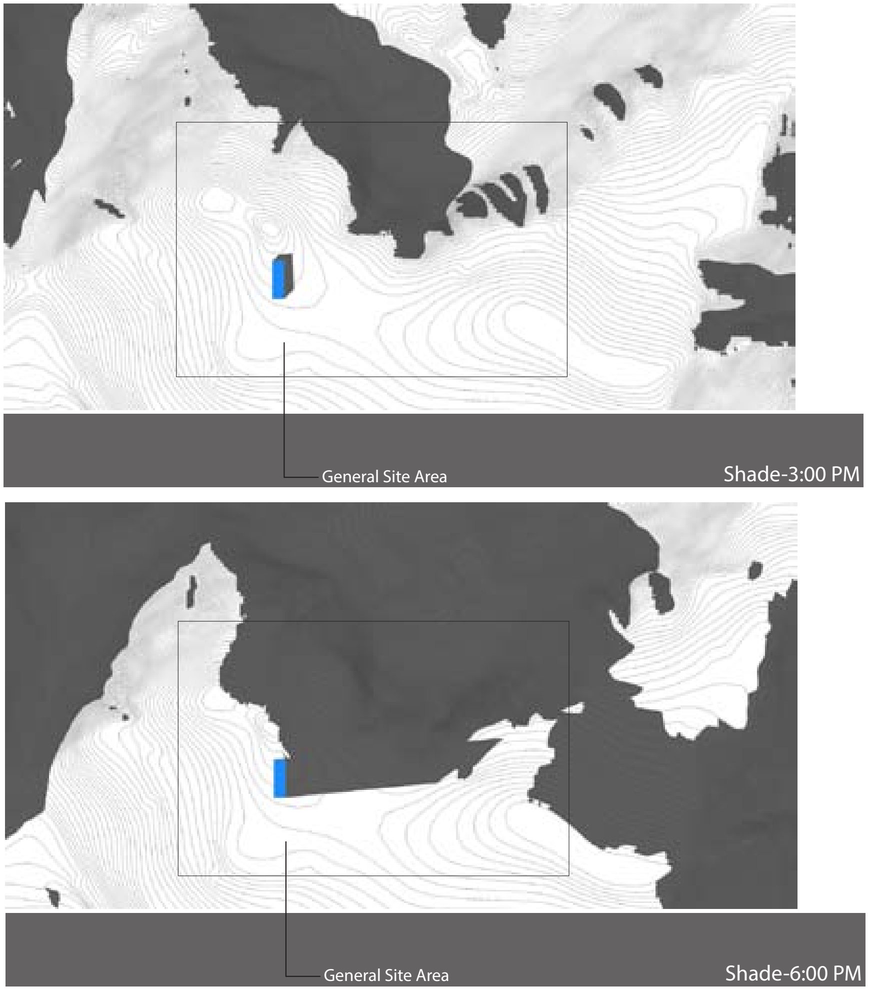


Figure 53. Shade Diagrams

The shade and shadow charts on these two pages show the sun during the spring and fall equinox. The site is primarily within the sun the entire day. A solar array could be placed near the southern most part of the site to take advantage of solar energy.

As illustrated in *Figure 54* the air currents are fairly steady from the north west region of the site. This map shows the yearly average wind direction. The north west winds arrive via a long canyon. The winds typically blow up the cliff faces and onto the site. Gentle breezes come from the south as show in *Figure 52*.

Figure 54. Topography and Air Movement

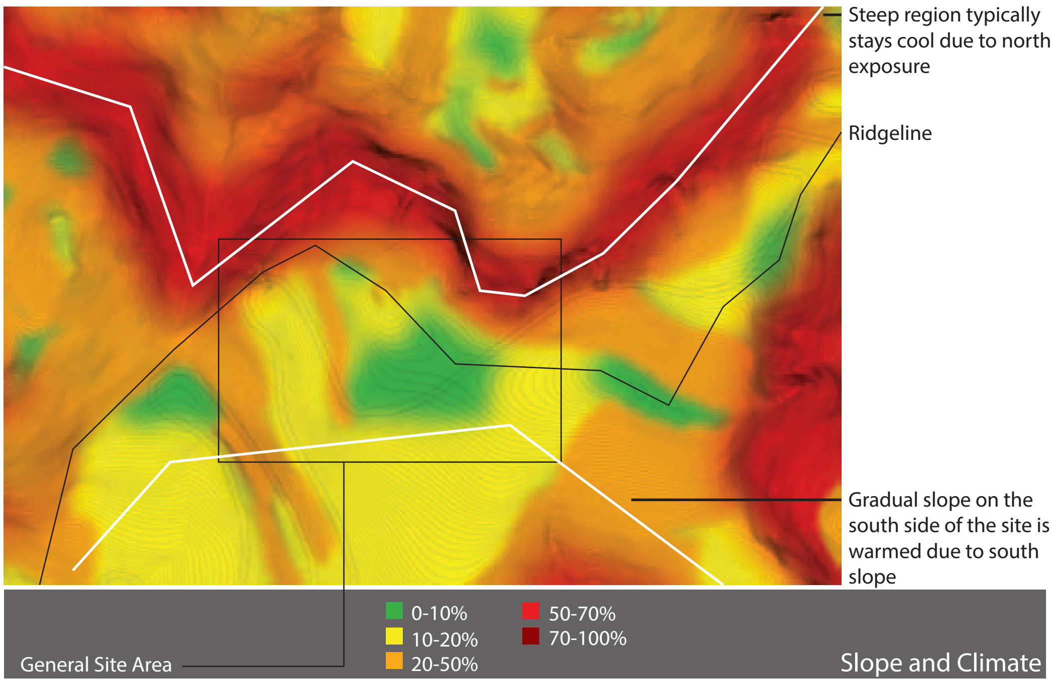


Figure 55. Slope and Climate

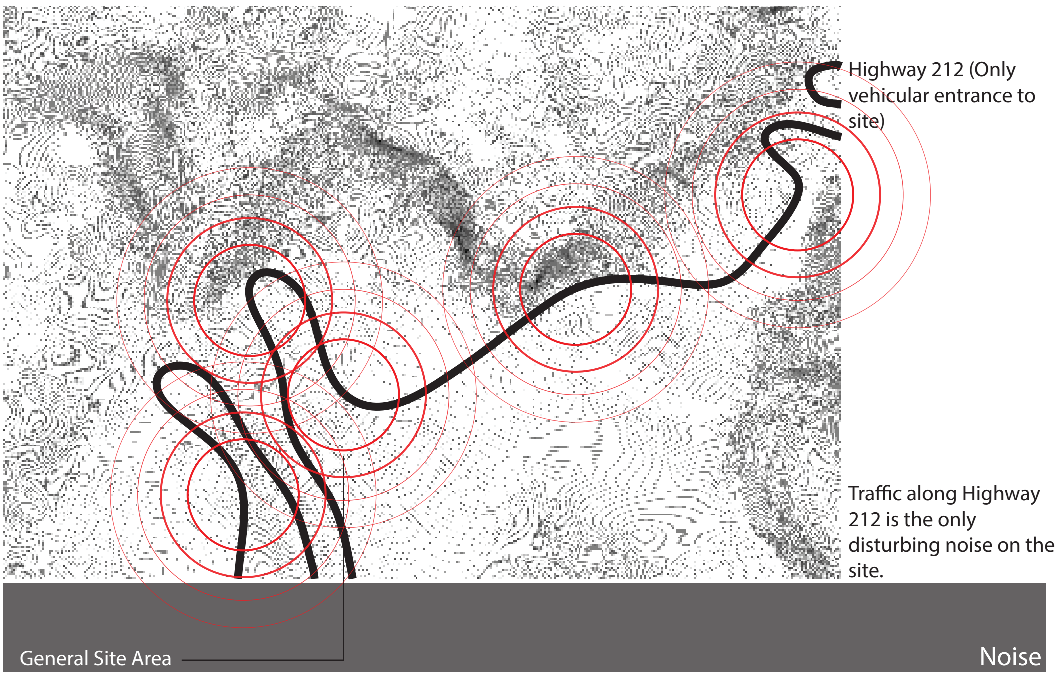


Figure 56. Noise

Programmatic Requirements.

PROGRAMMATIC REQUIREMENTS

Visitor Center Area:

400 sf	Entrance Lobby
120 sf	Reception
240 sf	Office
3,000 sf	Gallery
500 sf	Classrooms
500 sf	Gift Shop
500 sf	Restrooms
70 sf	Custodial
100 sf	Storage
5,430	

Observatory Hotel:

400 sf	Lobby
8,000 sf	Guest Rooms
1,000 sf	Restrooms
300 sf	Lounge
1,200 sf	Offices
800 sf	Kitchen
2,000 sf	Dining
1,200 sf	Recreation Room
70 sf	Custodial
1,200 sf	Mechanical
200 sf	Storage
16,370 sf	

Observatory:

2,000 sf	Control Room
480 sf	Office
3,000 sf	Mechanic Shop
400 sf	Mirror Room
1500 sf	Library
1,000 sf	Storage
9,000 sf	Garage/Receiving/Waste
500 sf	Restroom
2,000 sf	Mechanical Room
8,000 sf	Main Dome and Coude Room
27,880 sf	
50,000 sf to 60,000 sf	Total Complex sf.

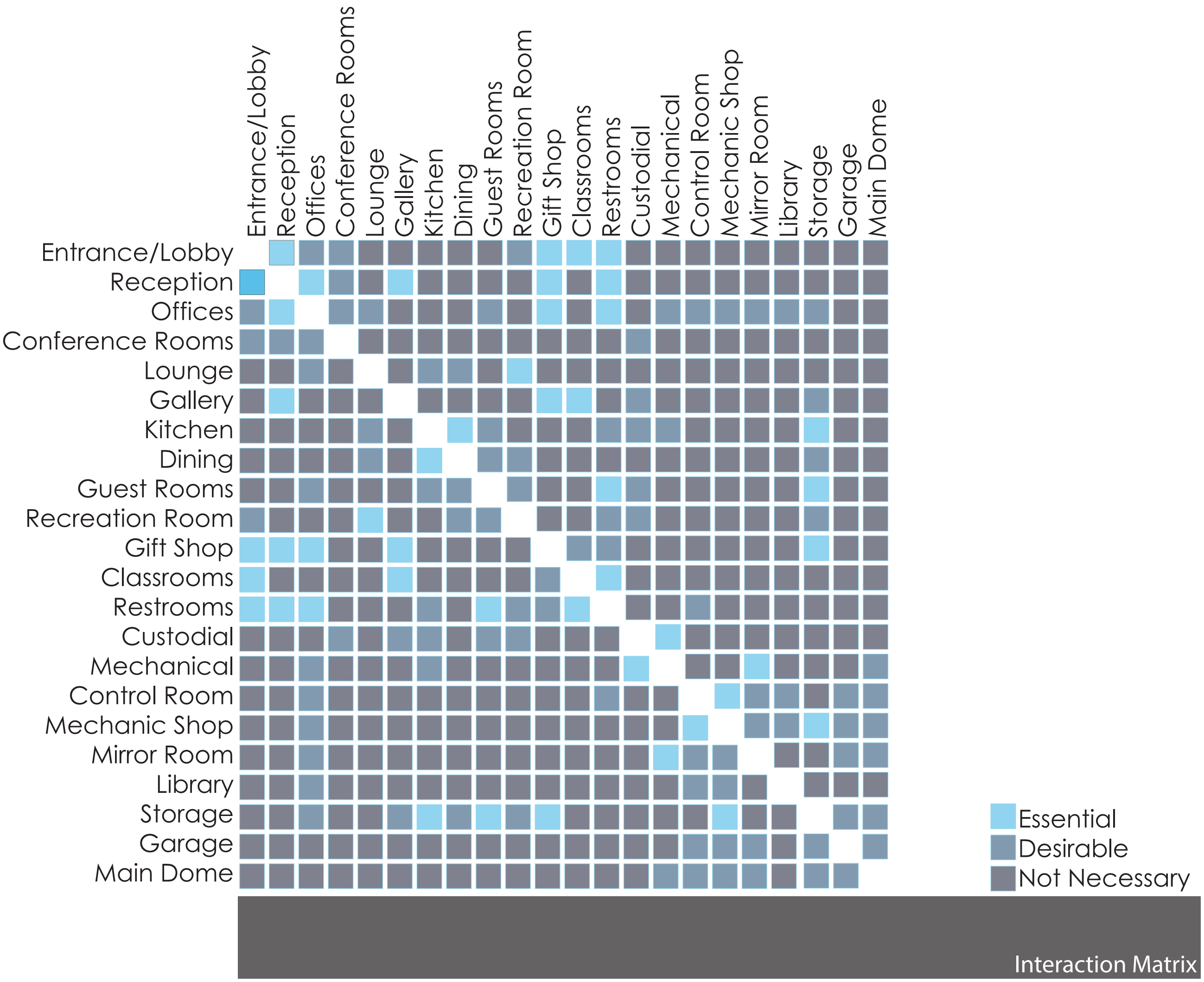


Figure 57. Interaction Matrix

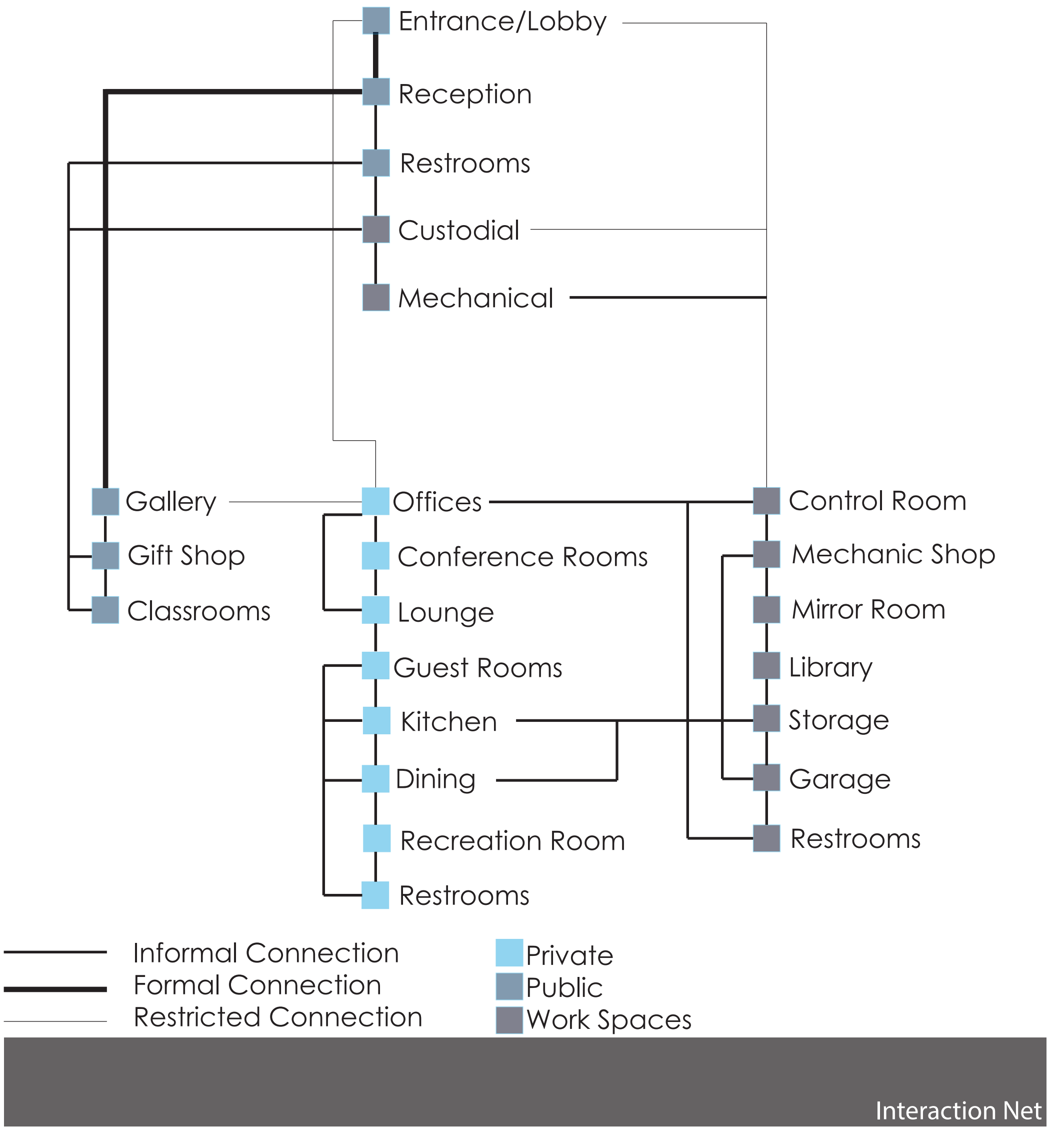


Figure 58. Interaction Net

Design Process.

The first step in this design process was to understand the site in a 3 dimensional form. The topography model below was created using 150 layers representing 10 contour intervals. The model shows about 1500 feet of elevation from the canyon floor to the peak where the proposed site is located. This model helped me understand how water and snow would runoff during the summer season. The model also helped the exploration of the cliff areas. The buildable areas were better expressed through the 3 dimensional model rather than a sketch or image.

Figure 59. Topo Model 1

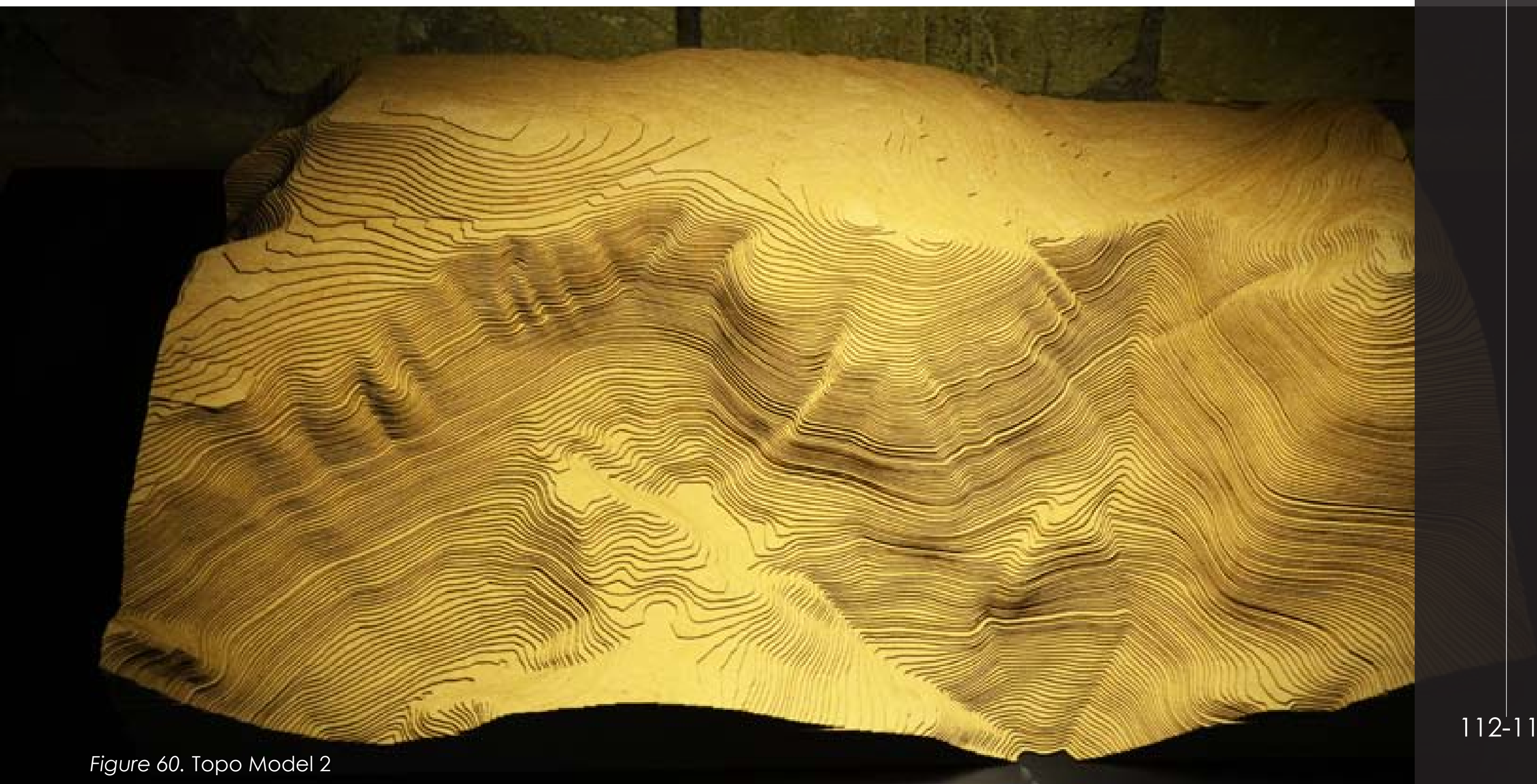


Figure 60. Topo Model 2

Finding inspiration in the site was the next step in the final design process. I wanted to understand how the site was formed. To do this I used the idea of glaciers carving and smoothing the landscape. *Figure 61* below was an artifact used to relate the metaphor into something physical. The steel pipe is representative of earth. The wooden handle with the three bolts spins around the steel carving away very slowly. A rough grinding is felt through the handle as one spins more and more.
Eventually the steel will catch on the bolts giving the sensation of large rocks catching on the ice of a glacier. Over time a smoothing and polishing takes place similar to glaciers moving across the landscape. The idea of this glacier was evident in the final design of the observatory through the use of pathways. The site is cut using a very prominent ramp system that also helped elevate people above the snow during the spring time. The ramp cut through the site as well as the building separating the public from the private. The grinding is similar to the up and down walking movement on the ramps. The pathways are rarely flat in order to stay true to the site.

The wooden handle represented the astronomy portion of the design. The process of viewing the cosmos is very refined today with all the technology at hand. The wooden handle is the part of the artifact that is smooth to the touch just like the polished mirrors used in astronomy. It gives the feeling of this very refined, clean texture. This idea of clean and refined texture came through in some of the material choices. The exterior cladding was a composite cement rain screen panel in the color white. Not only did this give a visual clean, modern look to the building but it also has a smooth texture when one was standing next to it or touching it.

Figure 61. Artifact

The next piece of inspiration was found at midterm. This was a literal look at the rock formations on the site. Concrete was used because of it similar nature to stone. It is a material from the earth so it was appropriate when casting my interpretation of the rock formations. This layered and angular look became the front entrance to the observatory. The space between each concrete sheet inspired the design of an entrance with a strong roof line. The interior spaces replicated the strong mass and void feel similar to a cave. The metal panel system on the entrance was also derived from the colors of nebulae as shown on renderings. As people approach the entrance the idea that these large masses will move their eyes toward the skies and the materials would use a particular color from a nebulae came about. This part of the design was to peak visitor's imagination and interest in what lie behind the front doors of this observatory.

Figure 62. Concrete Mass

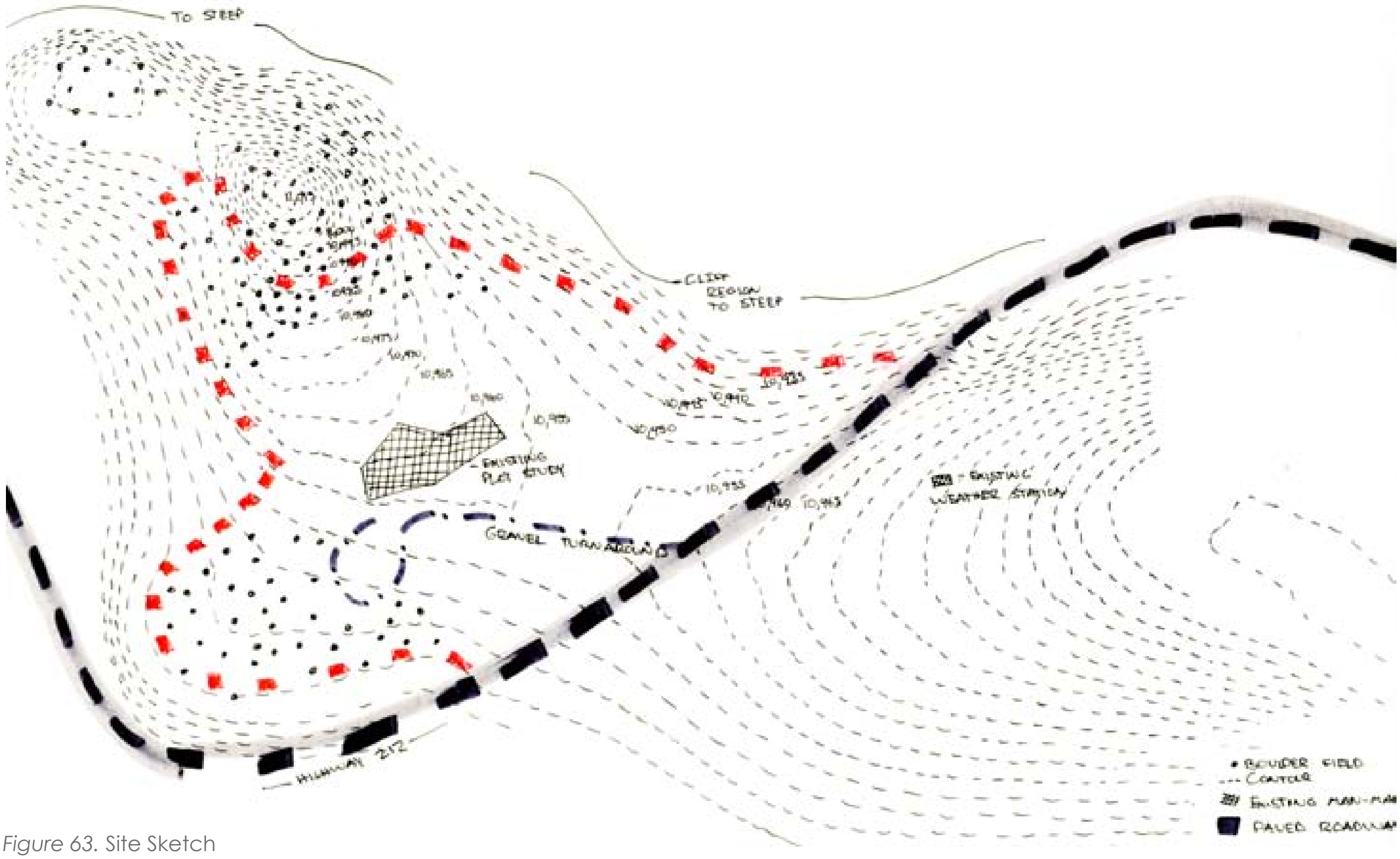


Figure 63. Site Sketch

The design process started with sketching appropriate design areas. *Figure 63* shows the buildable zone within the red dashed area. The surrounding areas are steep cliffs and rubble as shown with the darker dotted areas. Highway 212 was a prominent boundary that framed the south east side of the site. The buildable area also took into consideration the peak that could block the building from harsh winds and snow accumulations.

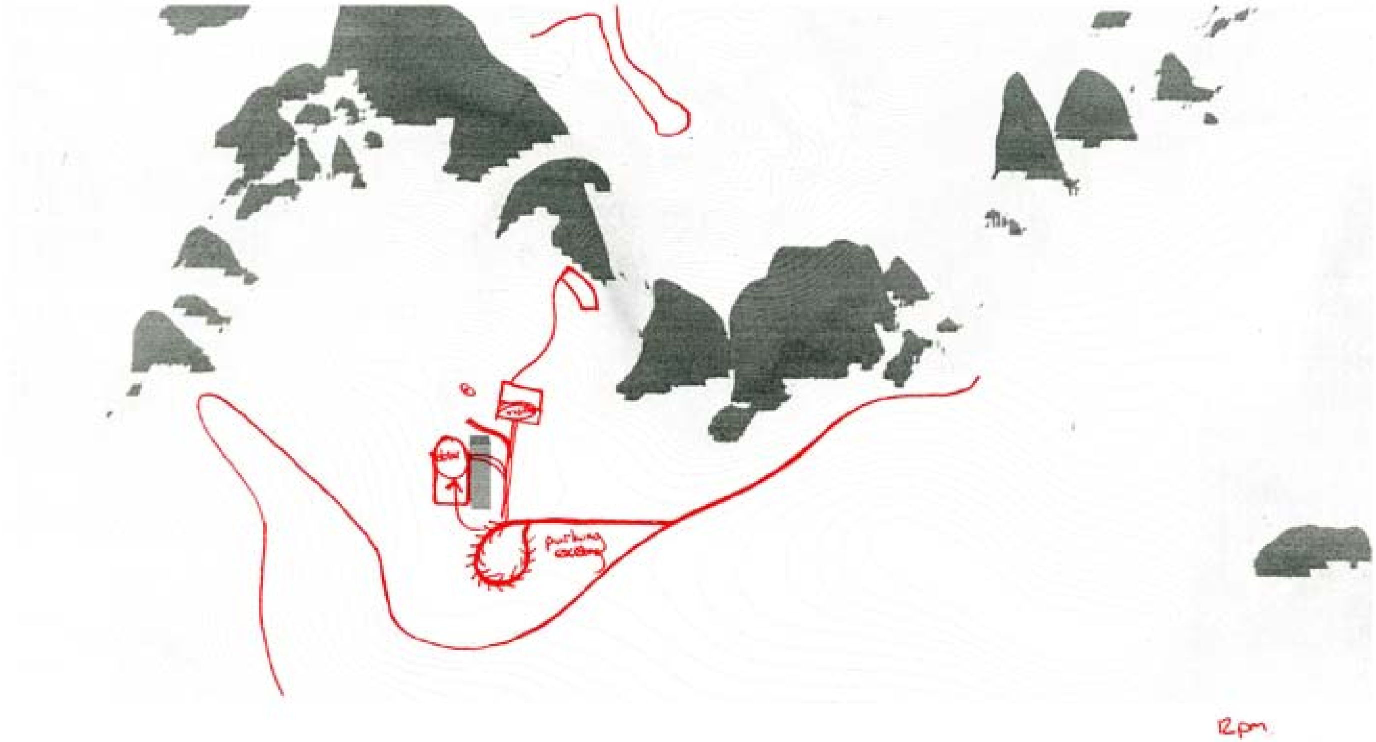


Figure 64. Pathway Sketch

Figure 64 shows an initial sketch of path ways throughout the site. These pathways could form how one enters or approaches the building. The red lines also suggest paths from the building. Visitors to the site could use these paths to get fantastic views of the surrounding area.

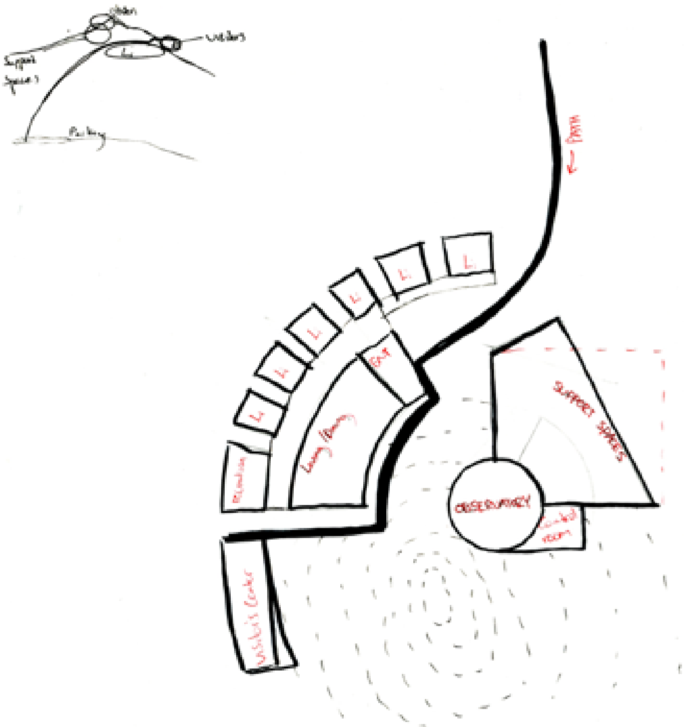


Figure 65. Radial Plan Sketch

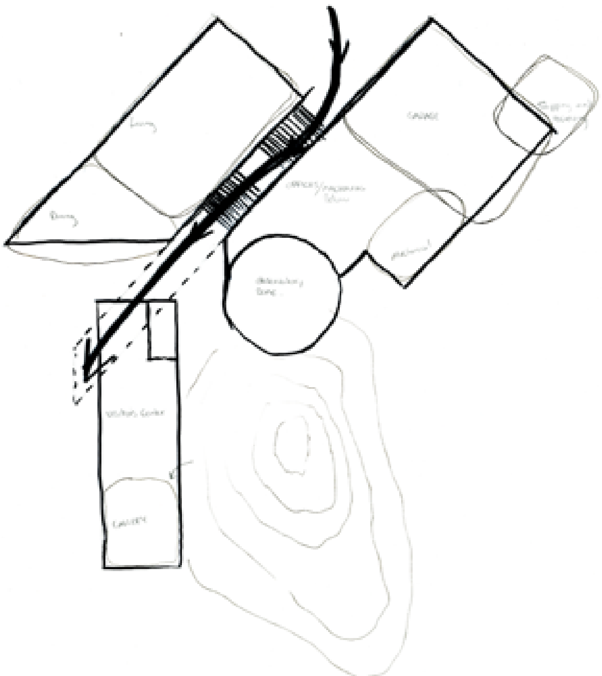


Figure 66. Angular Plan Sketch

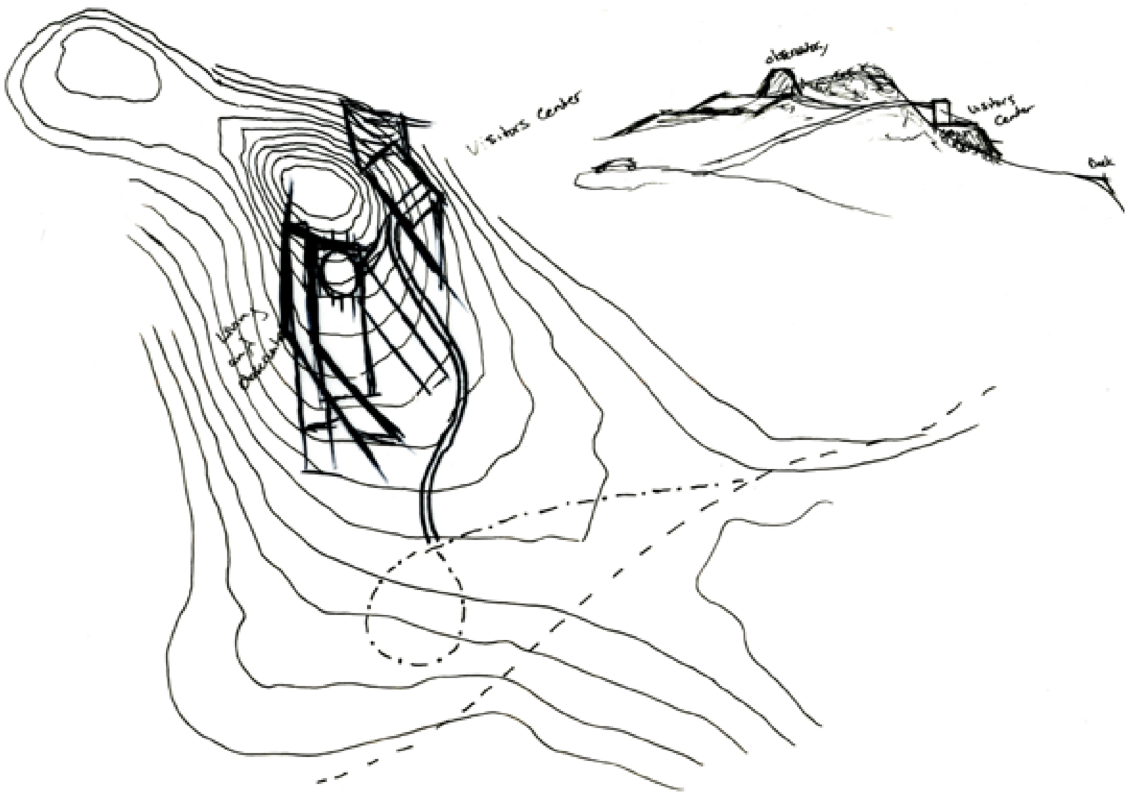


Figure 67. Sketch with Elevation

These sketches were initial design ideas. The observatory seemed to split into two or three different parts at this point in the design process. The parts became the observatory, the observatory hotel, and the visitor center. It seemed appropriate to divide these three parts because of their programmatic requirements. *Figure 67* shows a sketch of the building using the hillside to block harsh winds.

These models were all made to represent the sketches produced in a 3 dimensional way. Structure was a focus for several models as illustrated. Smaller massing models were also produced to study the relationships between site and the built environment.

Figure 68. Structure Sample

Figure 69. Structural Column 3d Print

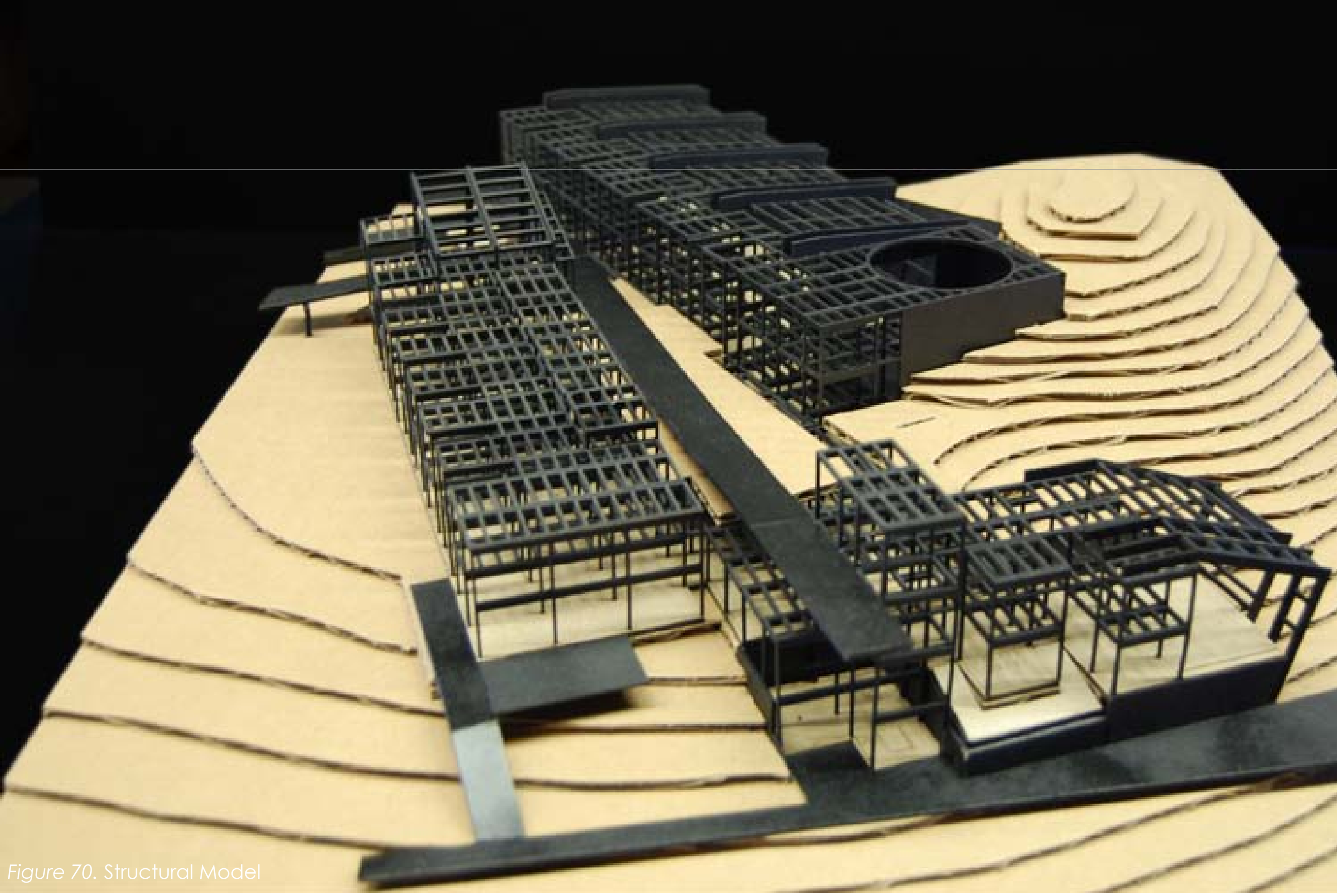


Figure 70. Structural Model

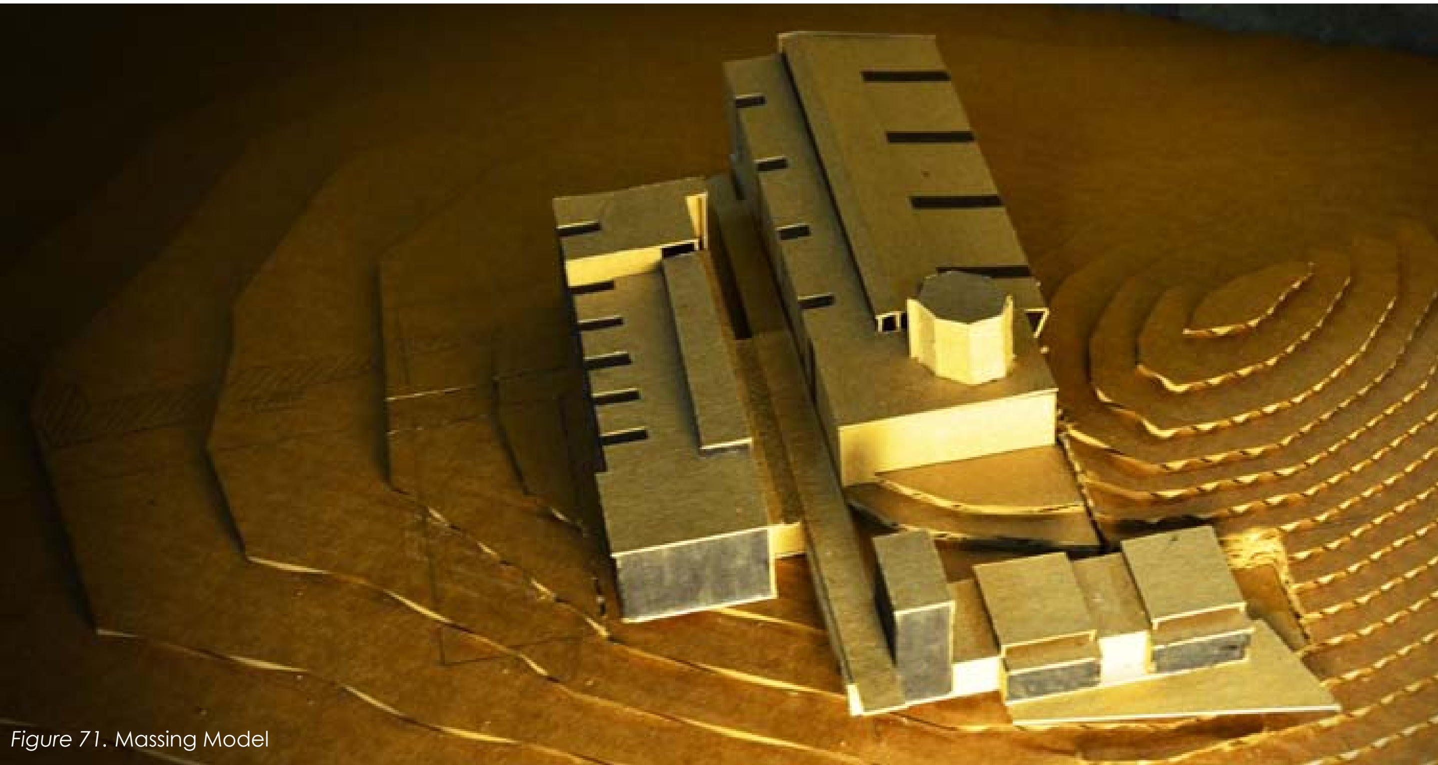


Figure 71. Massing Model

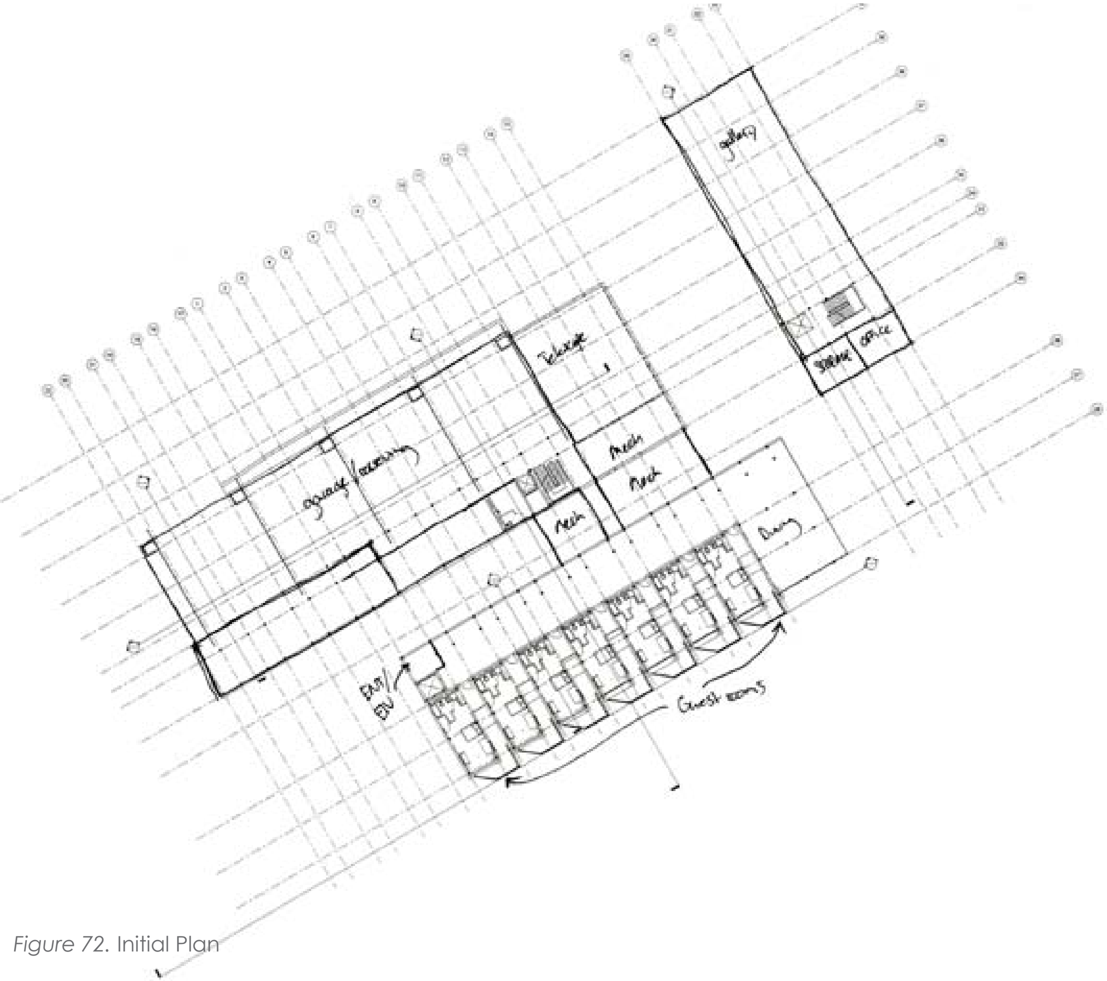
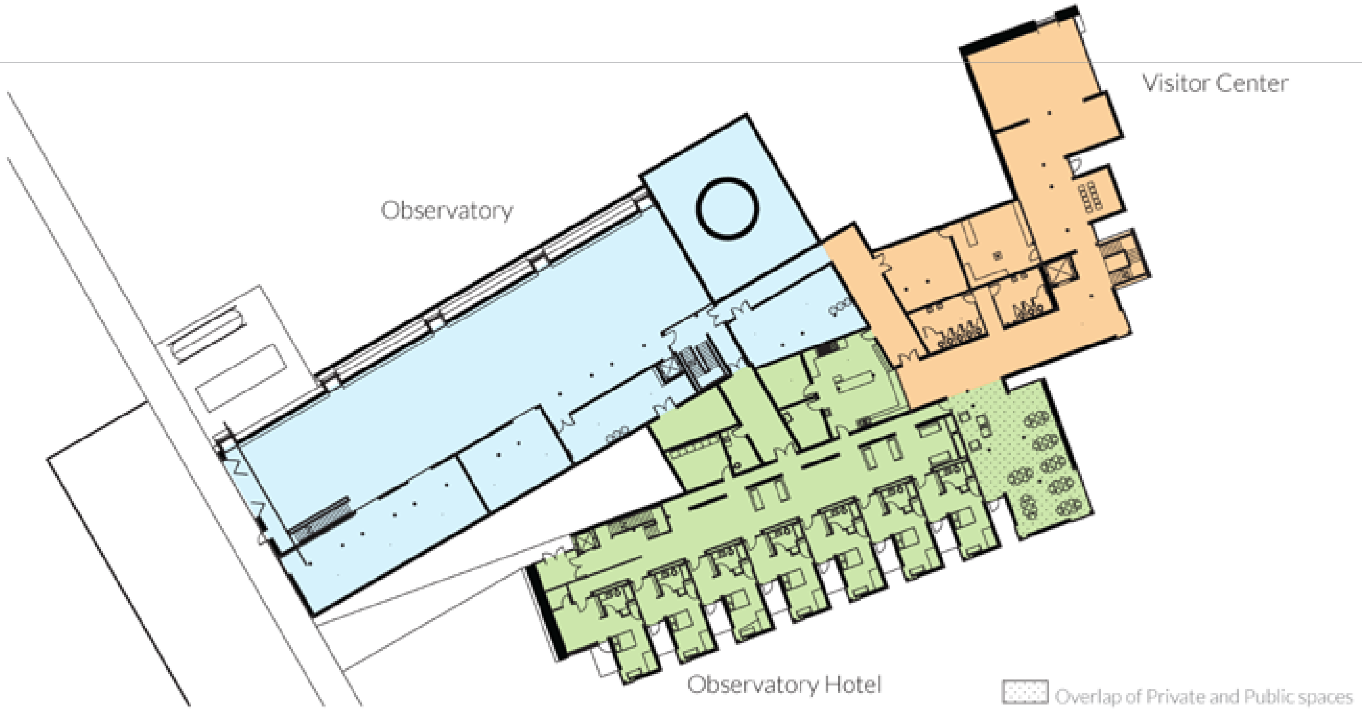


Figure 72. Initial Plan

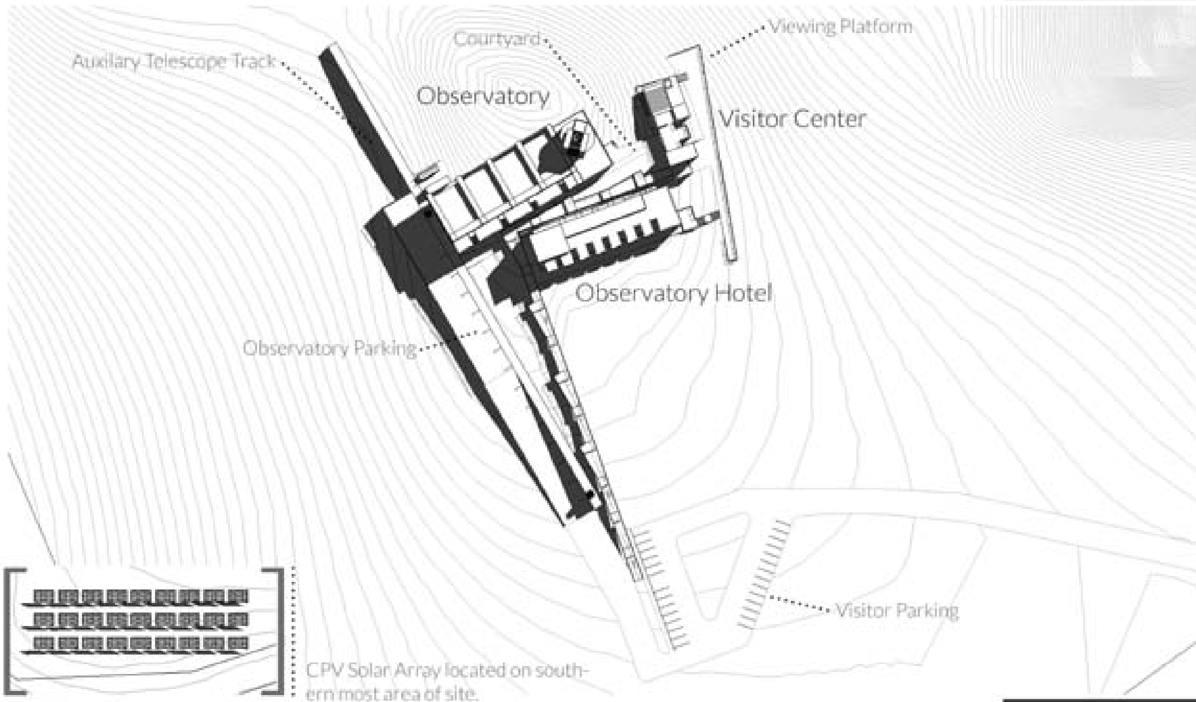
Figure 72 shows the initial use of Revit in the design. This solution was the precursor to the final design. The observatory hotel found its place on the site as well as the visitor center. The final design looks different then this because the observatory moved from the north to the west side of the site.

Figure 73 was the midterm design. This narrowed down the idea of how people moved through the site using ramps. The visitor center was situated with the best views and the observatory hotel was designed to take in as much sunlight as it could during the morning to afternoon period. The midterm design also showed the use of a concentrated photo-voltaic array to power the building during the day. At night a hydrogen power plant would take over to power the telescopes.



Spatial Plan.

Figure 73. Midterm Spatial Plan



Plan Site.

Figure 74. Midterm Site Plan

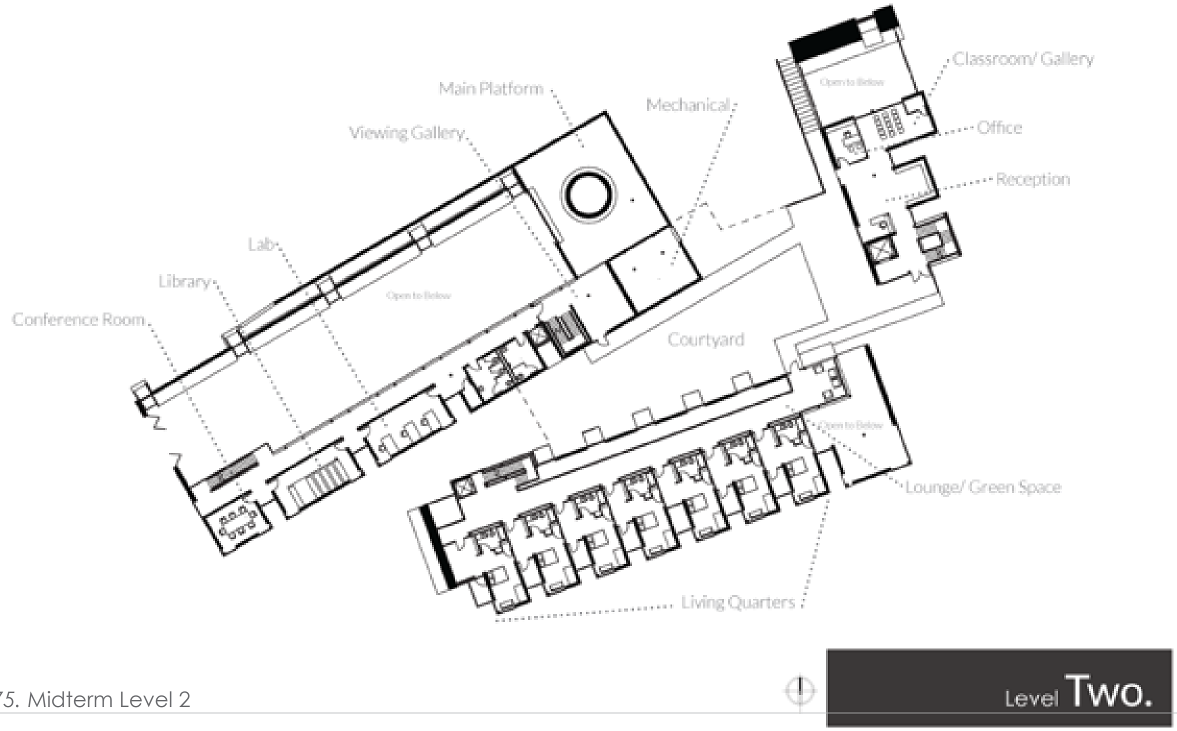


Figure 75. Midterm Level 2

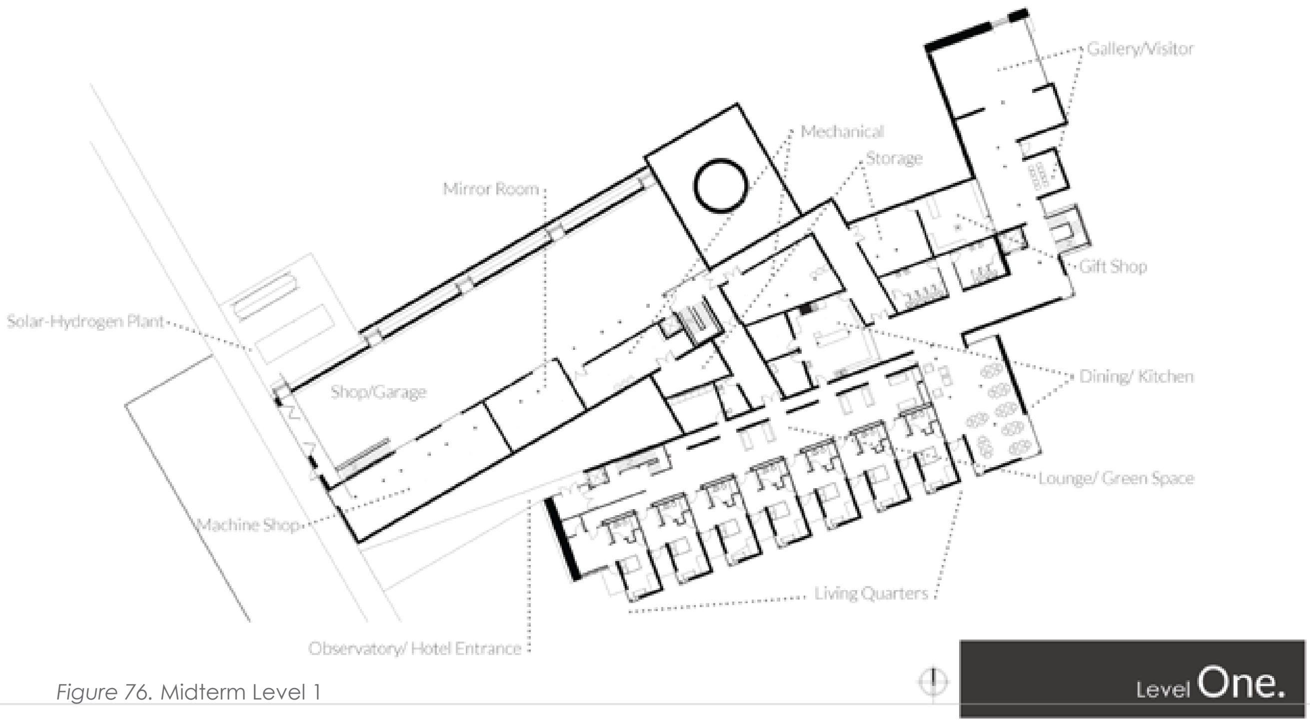
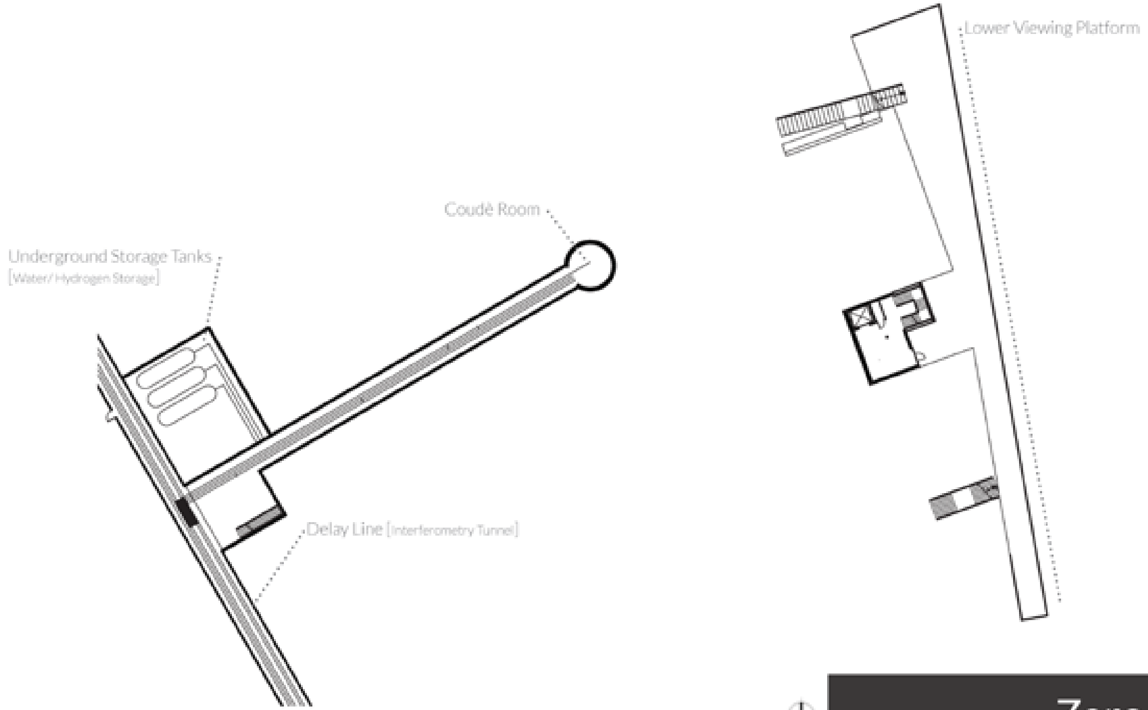
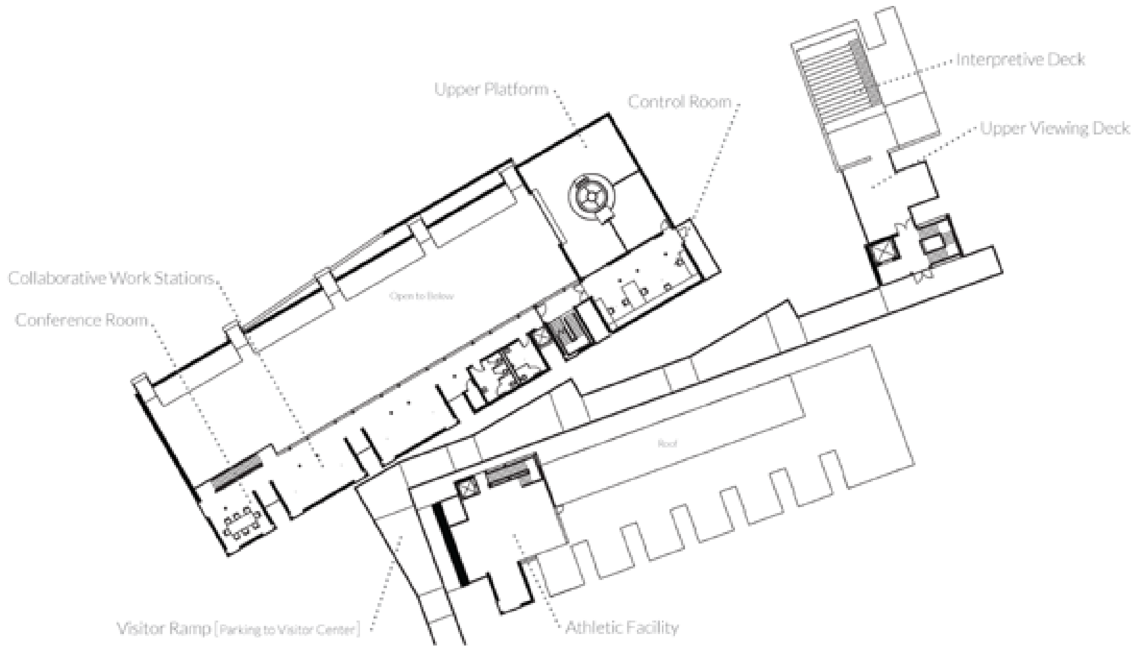


Figure 76. Midterm Level 1



Level **Zero.**

Figure 77. Midterm Level 0



Level **Three.**

Figure 78. Midterm Level 3

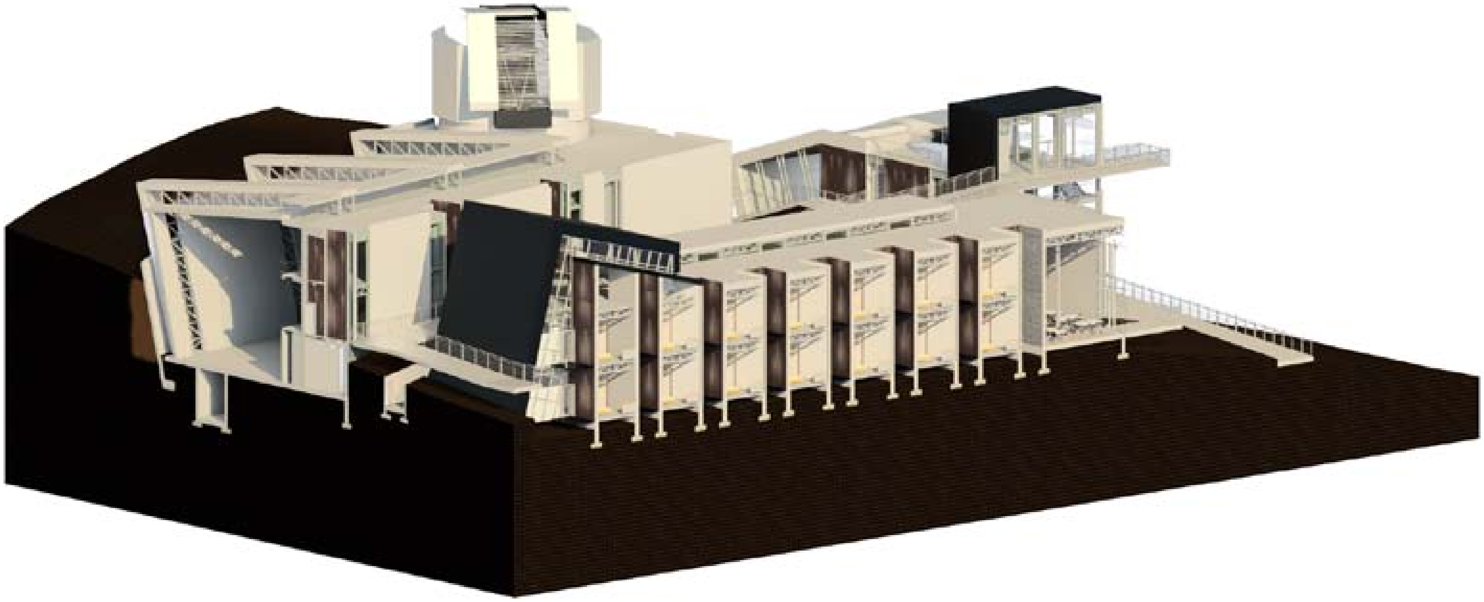


Figure 79. Structural Perspective

The section shown is from the midterm review. This design showed the observatory being cut into the hillside on the north west corner of the site. While this solution worked functionally it did not satisfy the needs the final design could. The observatory, observatory hotel, and the visitor center worked better in the final design because they were all connected by a single entrance lobby. *Figure 79* showed all three parts as seperate "buildings" making the connections tough during the winter. The telescope was placed in an area that was hard for people to view and sunlight was blocked by the Observatory Hotel. Another problem arrived when phase 2 would be implemented. The garage section would have very little room to add on to because of the slope of the mountain. By turning it 90 degrees as shown in the final design phase two could easily be implemented. The hillside was much less steep.

Living walls became a focal point in the Observatory Hotel. These added comfort for the people using the facility as well as kept it humidified throughout the year. This midterm rendering showed how materials could help make the spaces within the facility bright and welcoming.

Figure 80. Midterm Interior

By midterm the structural system was chosen for the building. The observatory would use a light-weight aluminum column and beam system. This cut down on transportation costs getting materials to the site as well as made construction quick and efficient during the few summer months. Each beam is light enough for 2 construction workers to set into place and bolt together. Future sections could easily be added when needed. This system was also chosen because it could be easily recycled and remanufactured to fit future specifications.

Aluminum Life Cycle: Construction...Deconstruction...Recycled...Remanufactured

Figure 81. Structural Diagram

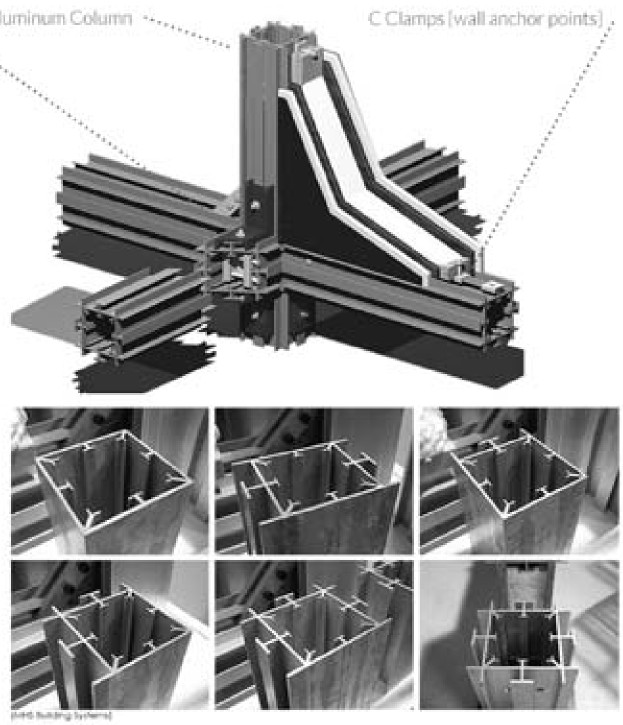
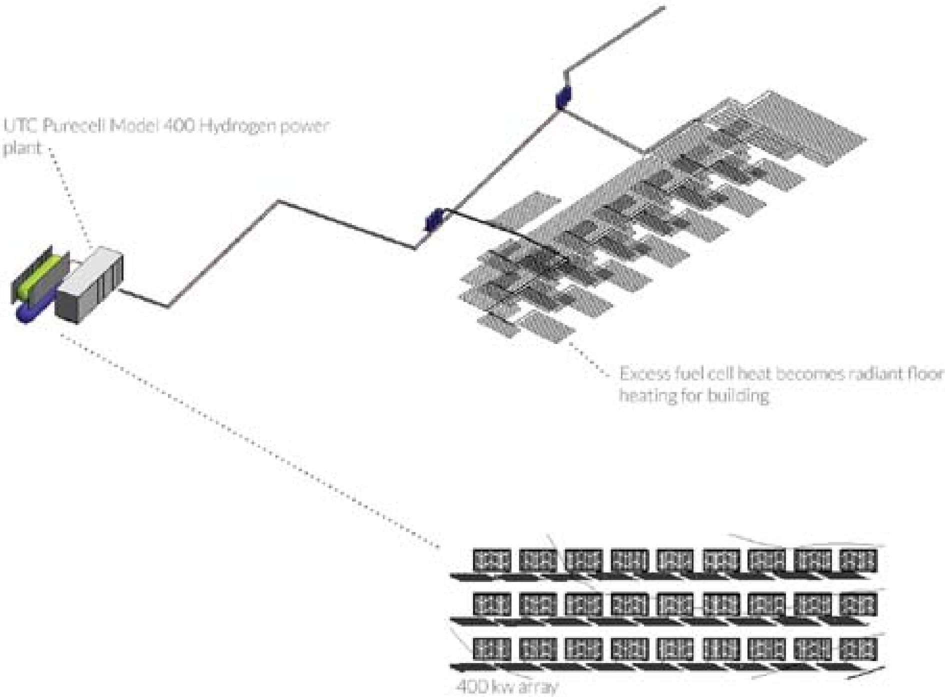


Figure 82. Structural Detail

Flex Structure.

The Absaroka Observatory was designed to be completely off-grid. The nearest connection to a power grid is 20 miles away through National Forest land so an alternative energy source was needed. The design called for solar power along with a hydrogen plant to satisfy the 400kw power demand. The excessive heat from they hydrogen plant would then be used to heat a radiant floor system.



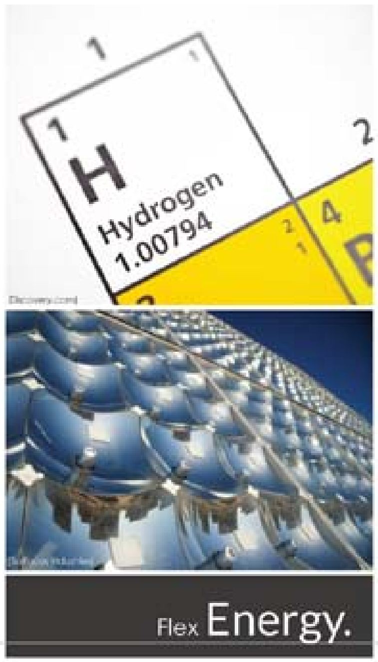


Figure 83. Energy Diagram

Final Design.

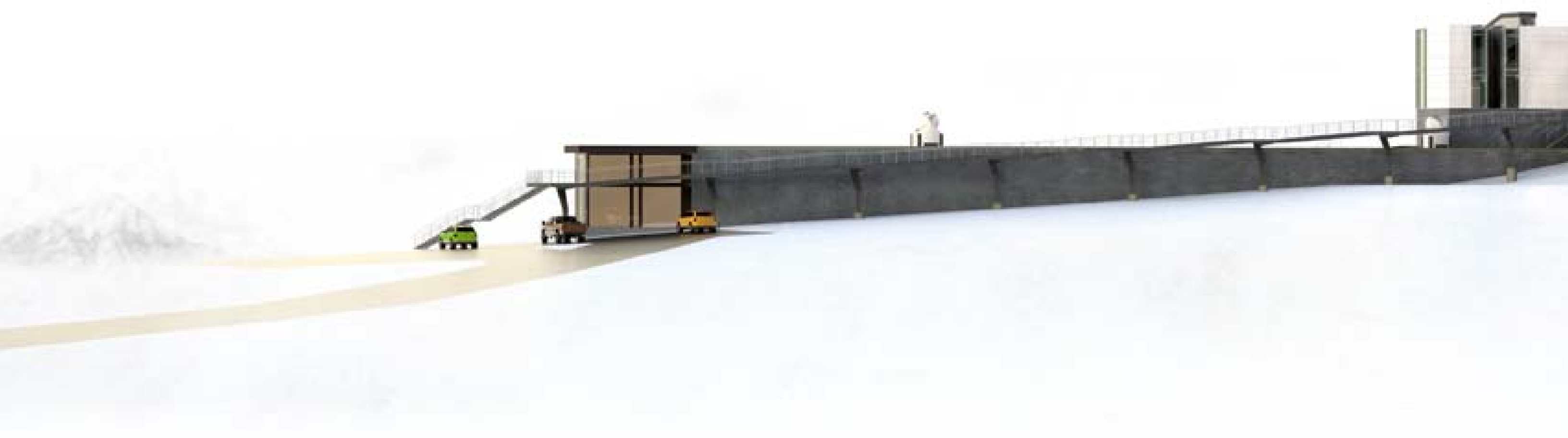


Figure 84. Exterior Observatory

Figure 85. Observatory Entrance


Ramp stimulates high altitude feeling as well as enhances the feeling of gravity. The ramp also carries guests above the snow field to the visitor center.

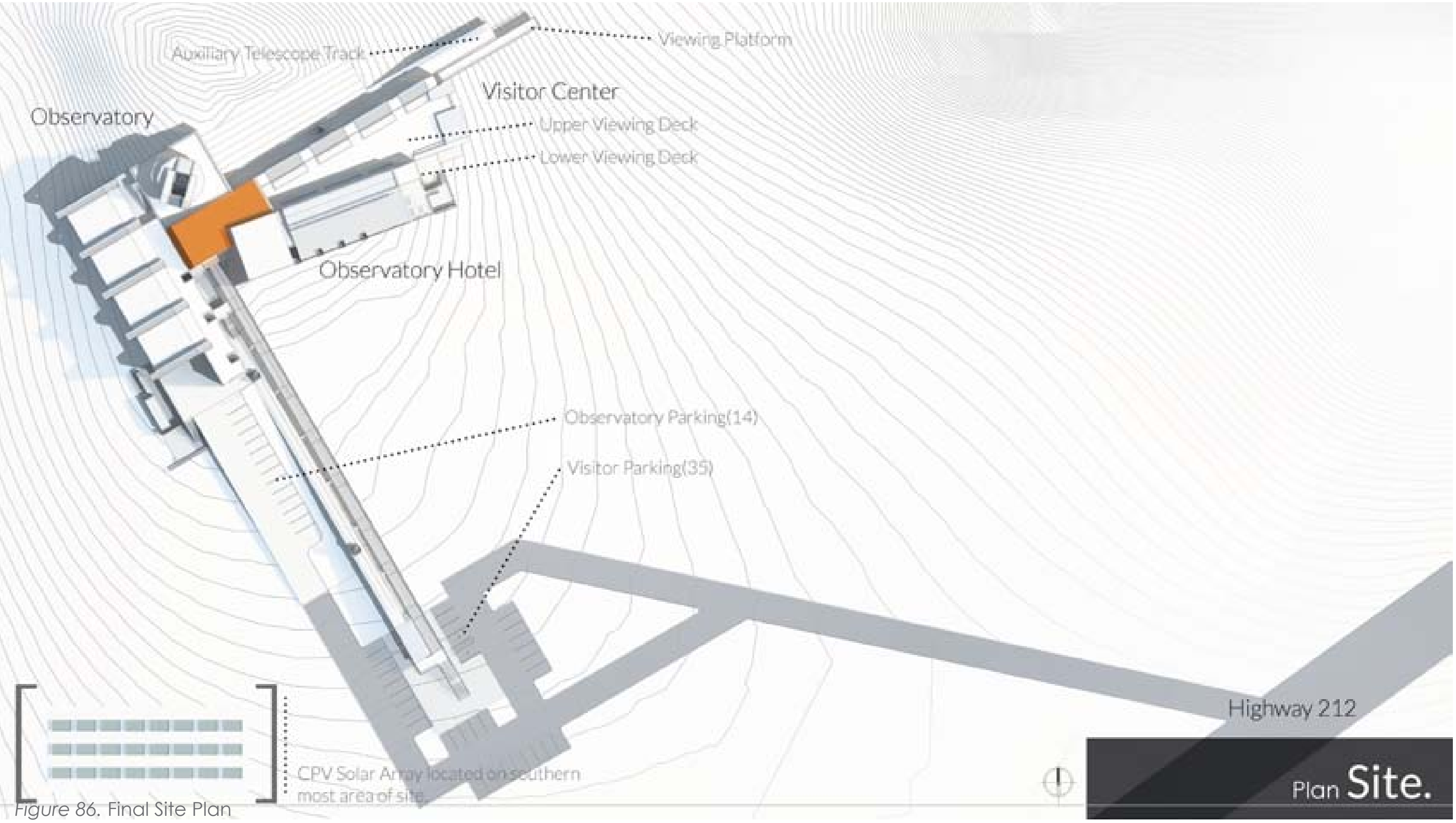
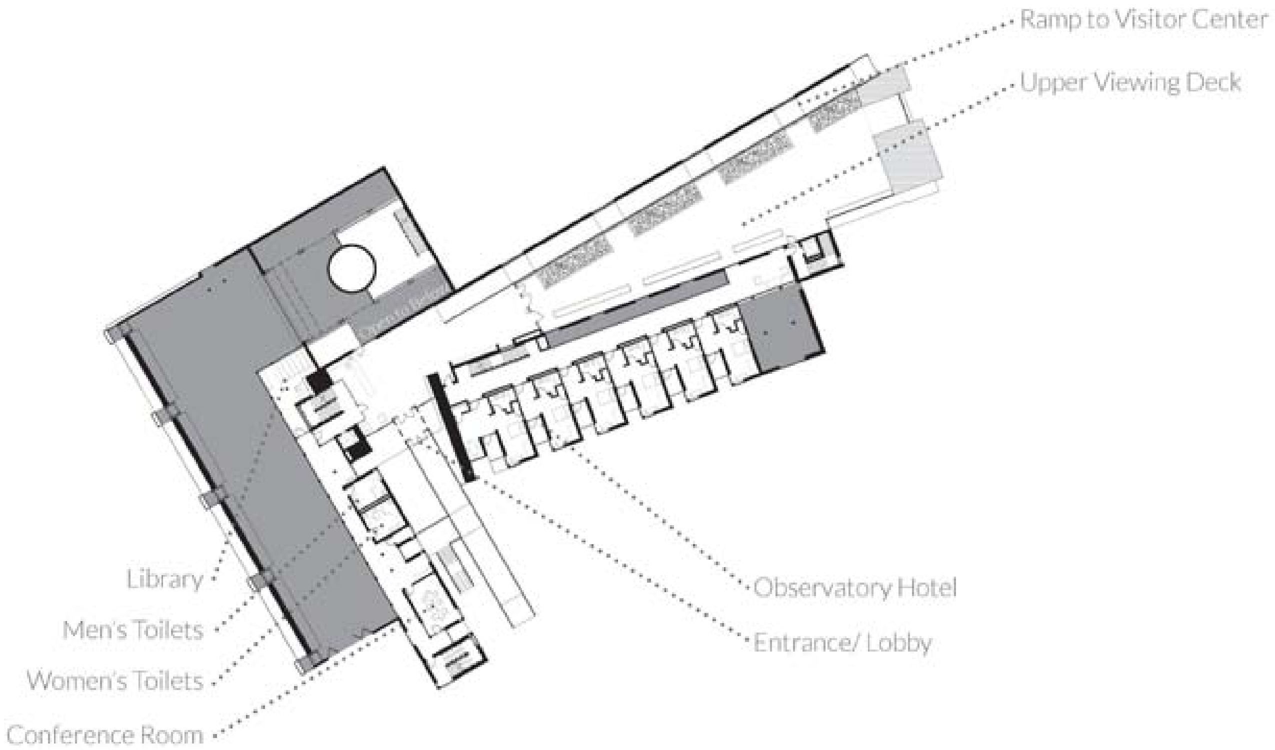
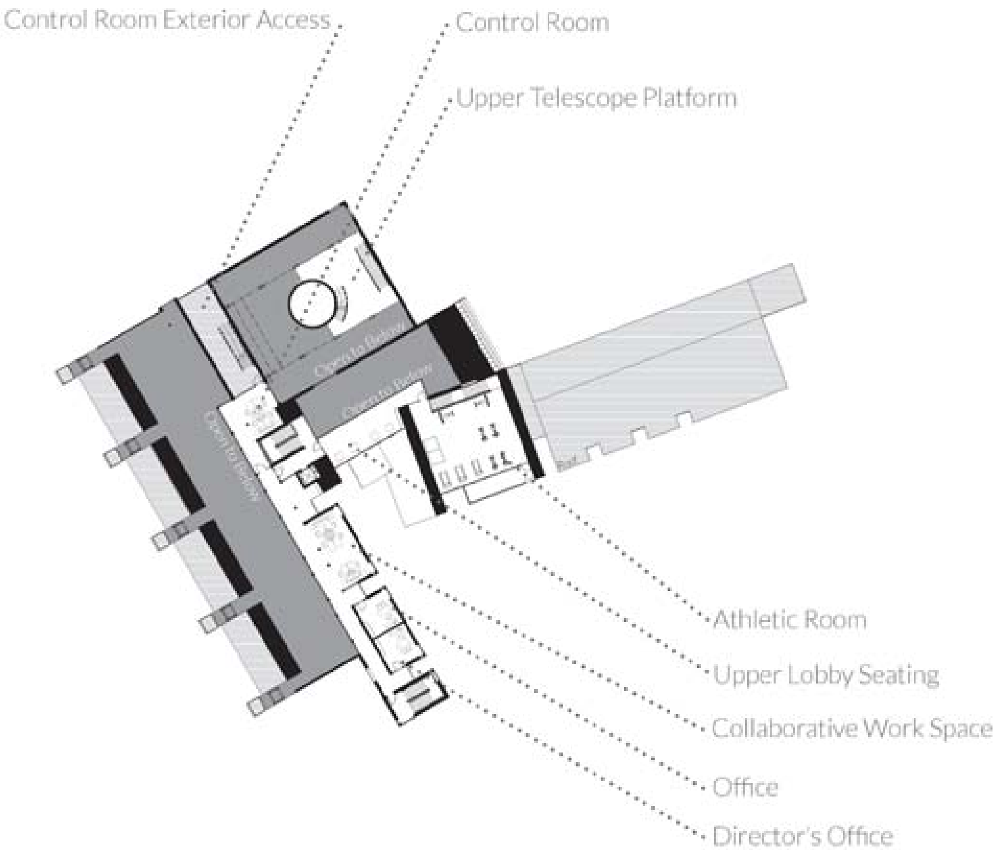


Figure 86. Final Site Plan



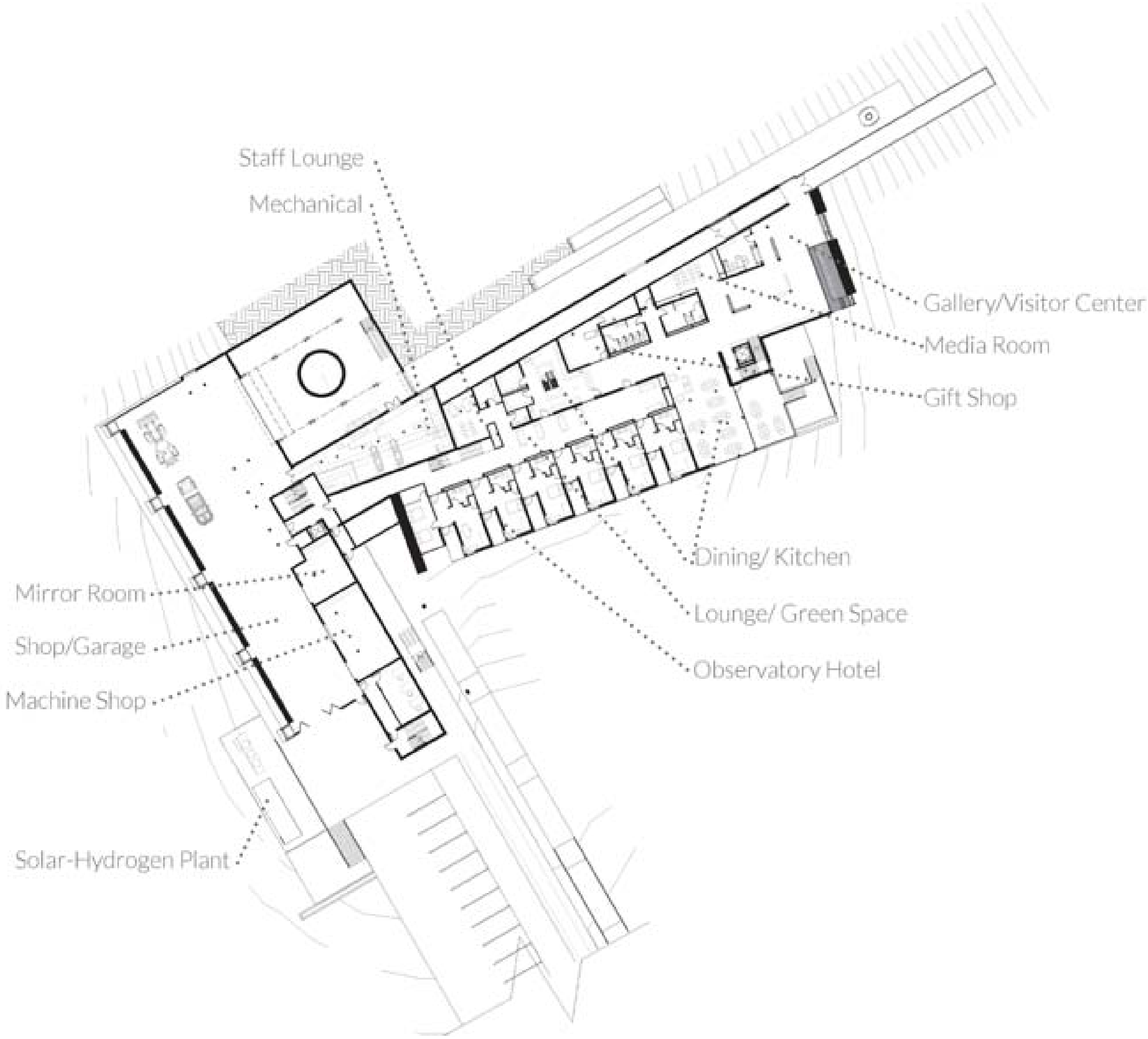
Level **Main.**

Figure 87. Final Level Main



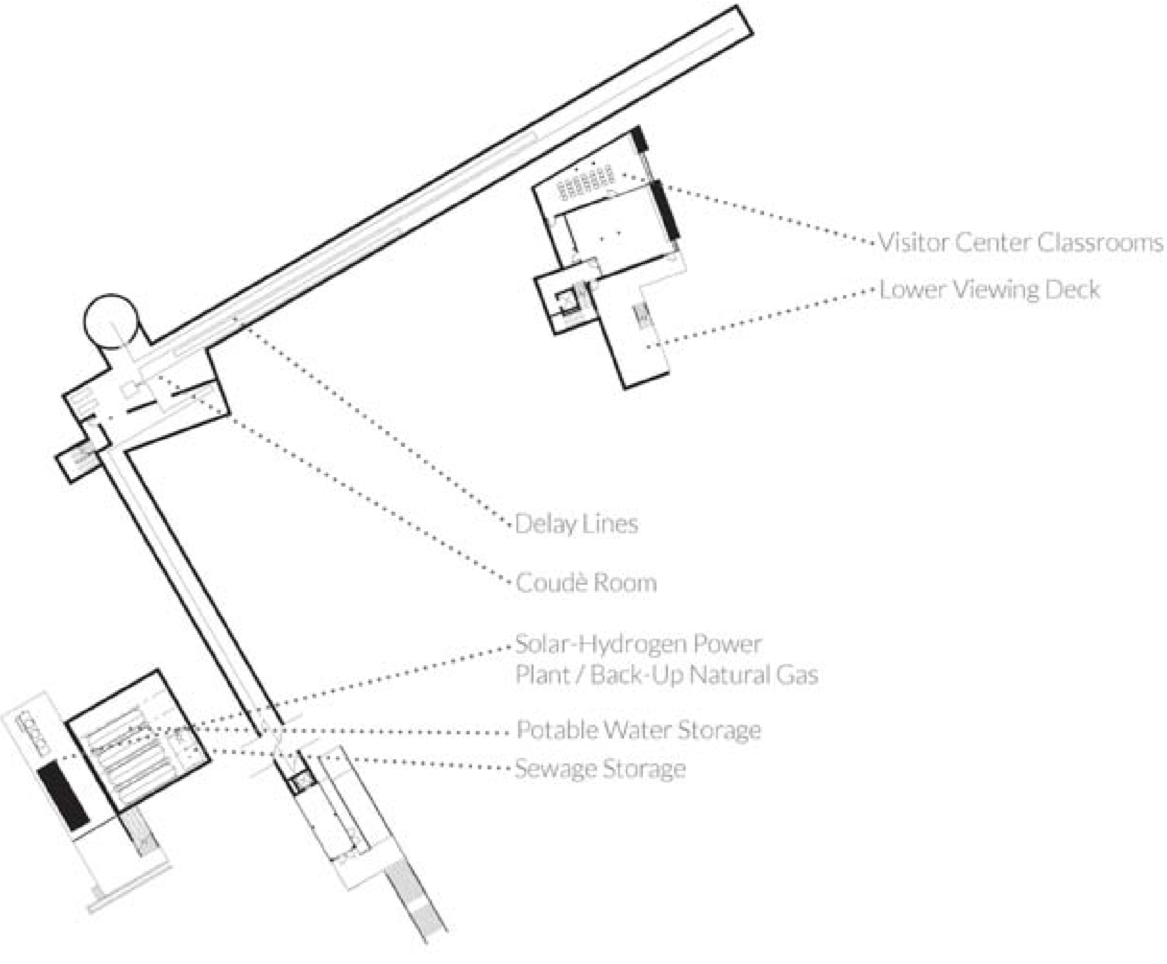
Level Upper.

Figure 88. Final Level Upper



Level **Lower.**

Figure 89. Final Level Lower



Level Lower 2.

Figure 90. Final Level Lower 2

Figure 91. Ramp to Visitor Center

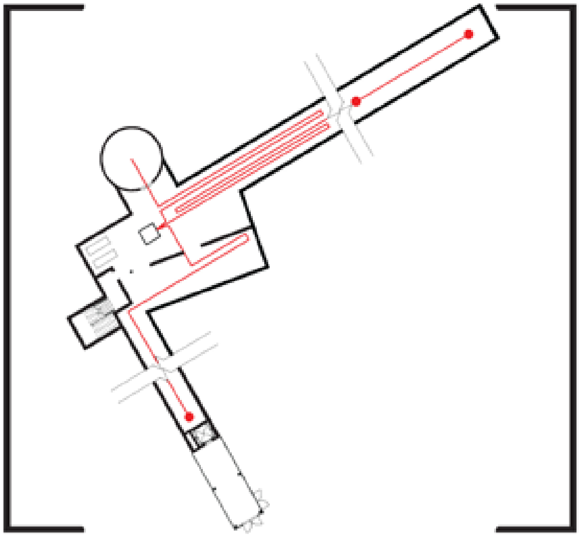
Bench seating also acts as sky-light for spaces below.

Upper Viewing deck allows amateur astronomers to view the night sky.

Low frequency red lights help lower light pollution for the main telescopes.

Figure 92. Upper Viewing Deck

Interferometry is the combination of light using multiple telescopes. Light travels through the telescope reflecting off a series of mirrors as illustrated. The light from all three telescopes must travel the same distance to the main receptor within the coudè room. The image created from combining the light is higher quality making interferometry a powerful tool for smaller observatories such as this one.



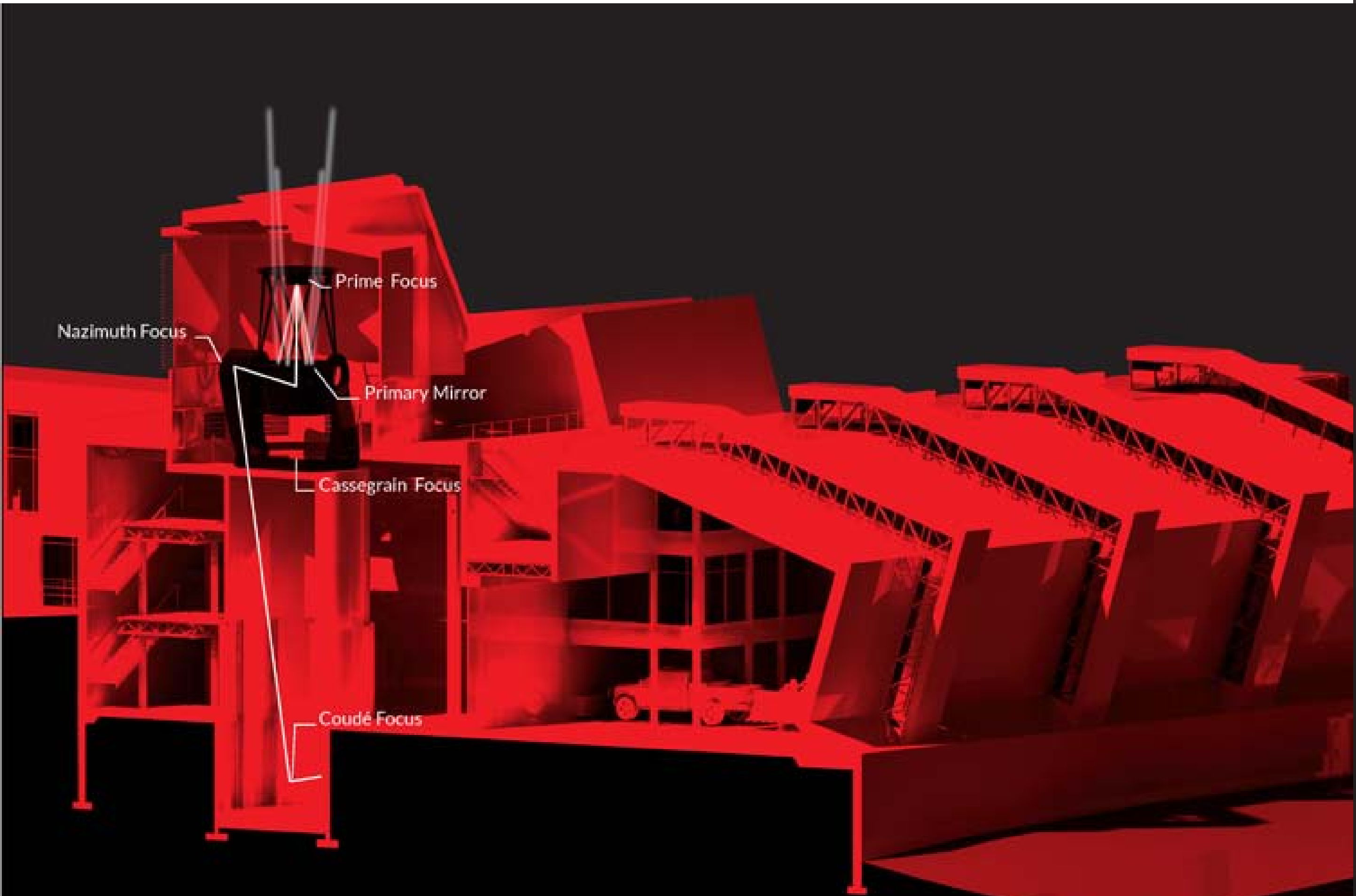
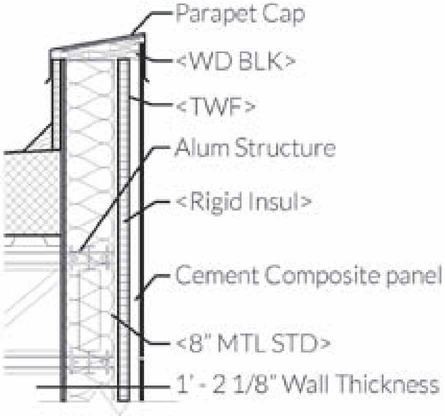


Figure 93. Section through Telescope



R55

Swiss Pearl

Cement composite w/MTL STD backup

- Low energy manufacturing
- 100% recyclable
- Easy deconstruction

Figure 95. Wall Detail

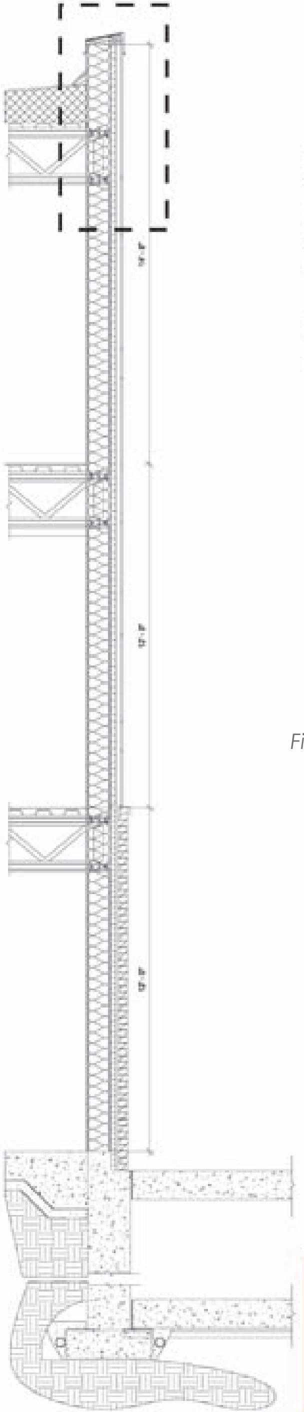


Figure 94. Wall Section

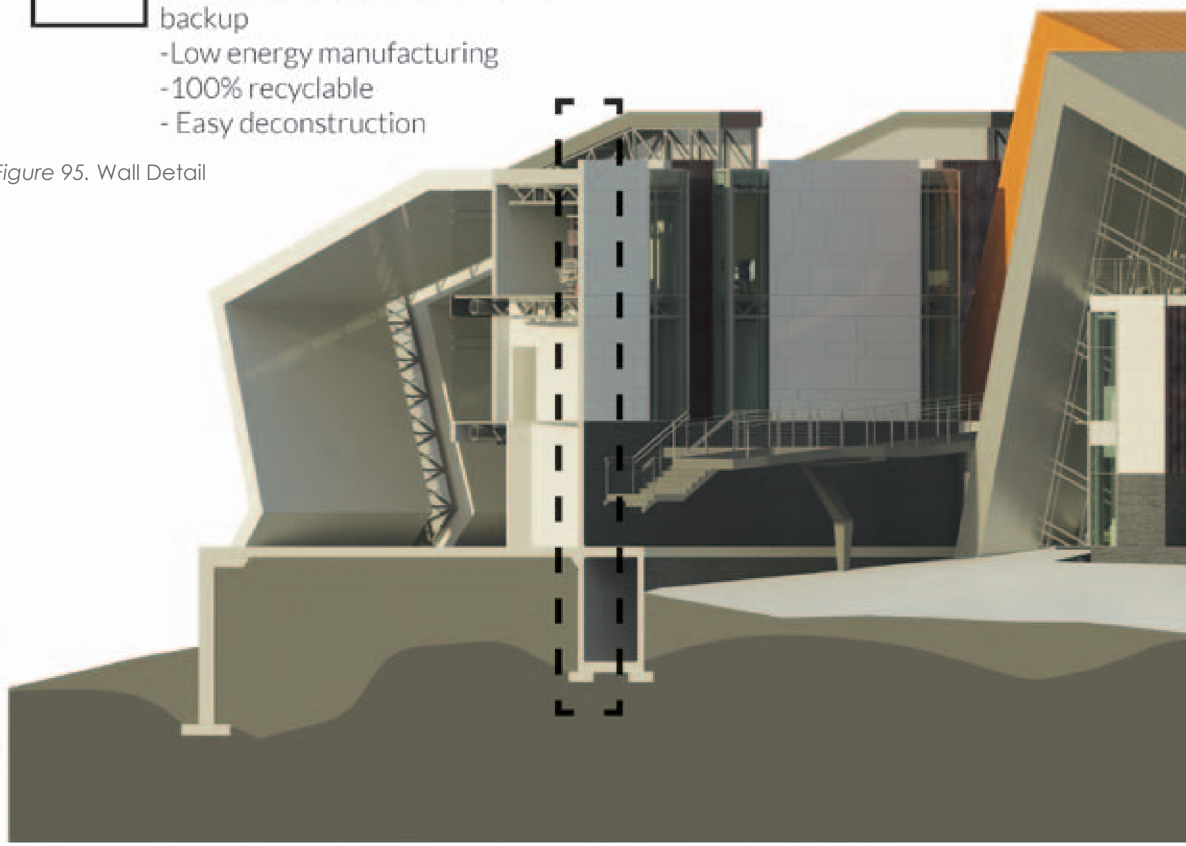
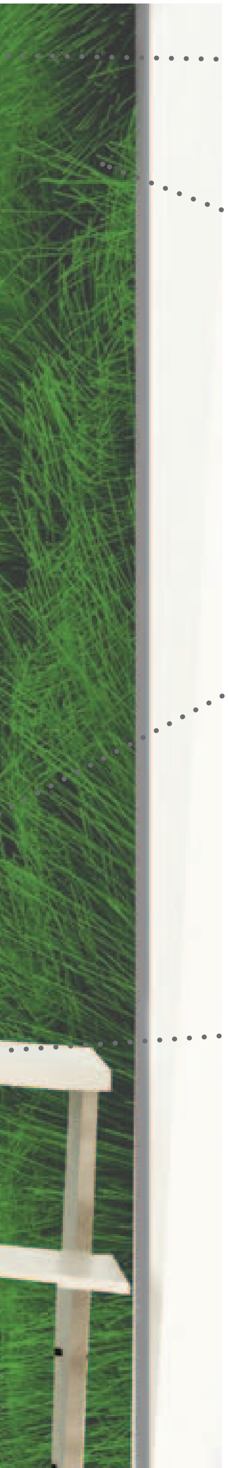


Figure 96. Section Perspective

Building Sections

Figure 97. Interior Observ Hotel



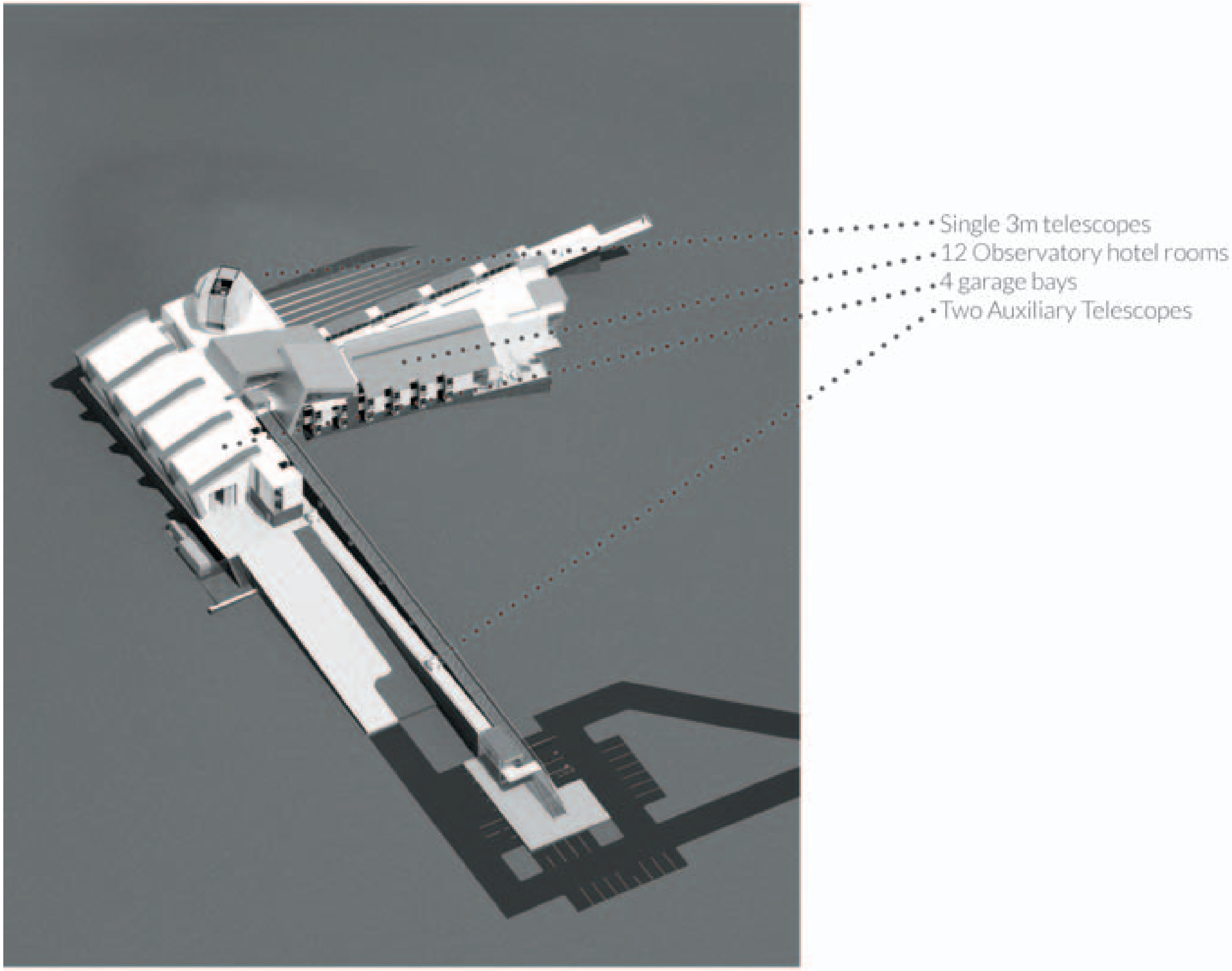
Fabric ceiling clouds are easily dismantled and refurbished at the end of its life cycle.

Living walls help humidify the living space. Natural plants help comfort people in harsh conditions.

Aluminum structure is celebrated in the main lounge areas.

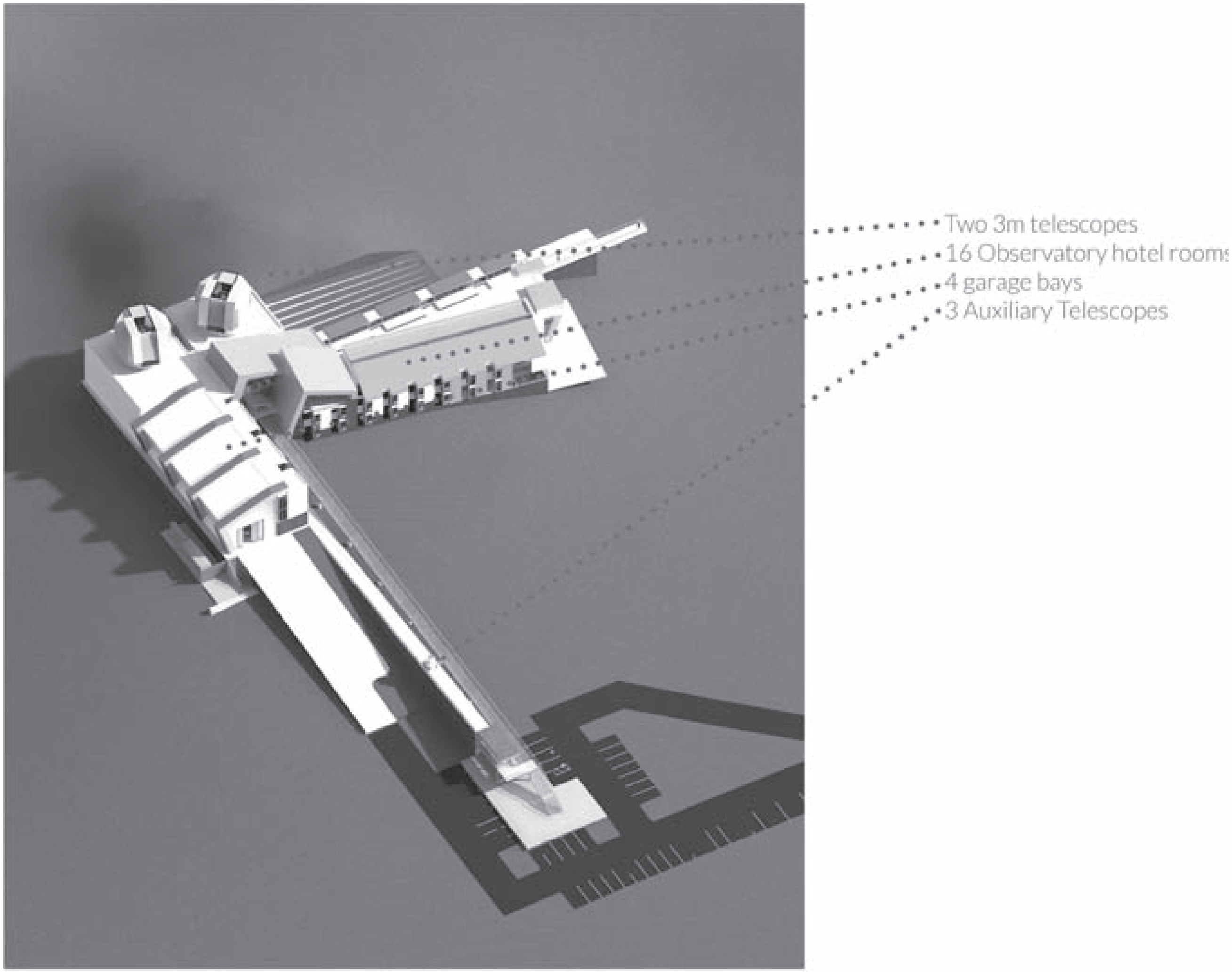
Upper Concourse **Observatory Hotel**

Light colored walls and dark flooring ties to earth and sky.



Proposed Design

Figure 98. Proposed Design



Phase 2 Design

Figure 99. Phase 2 Design

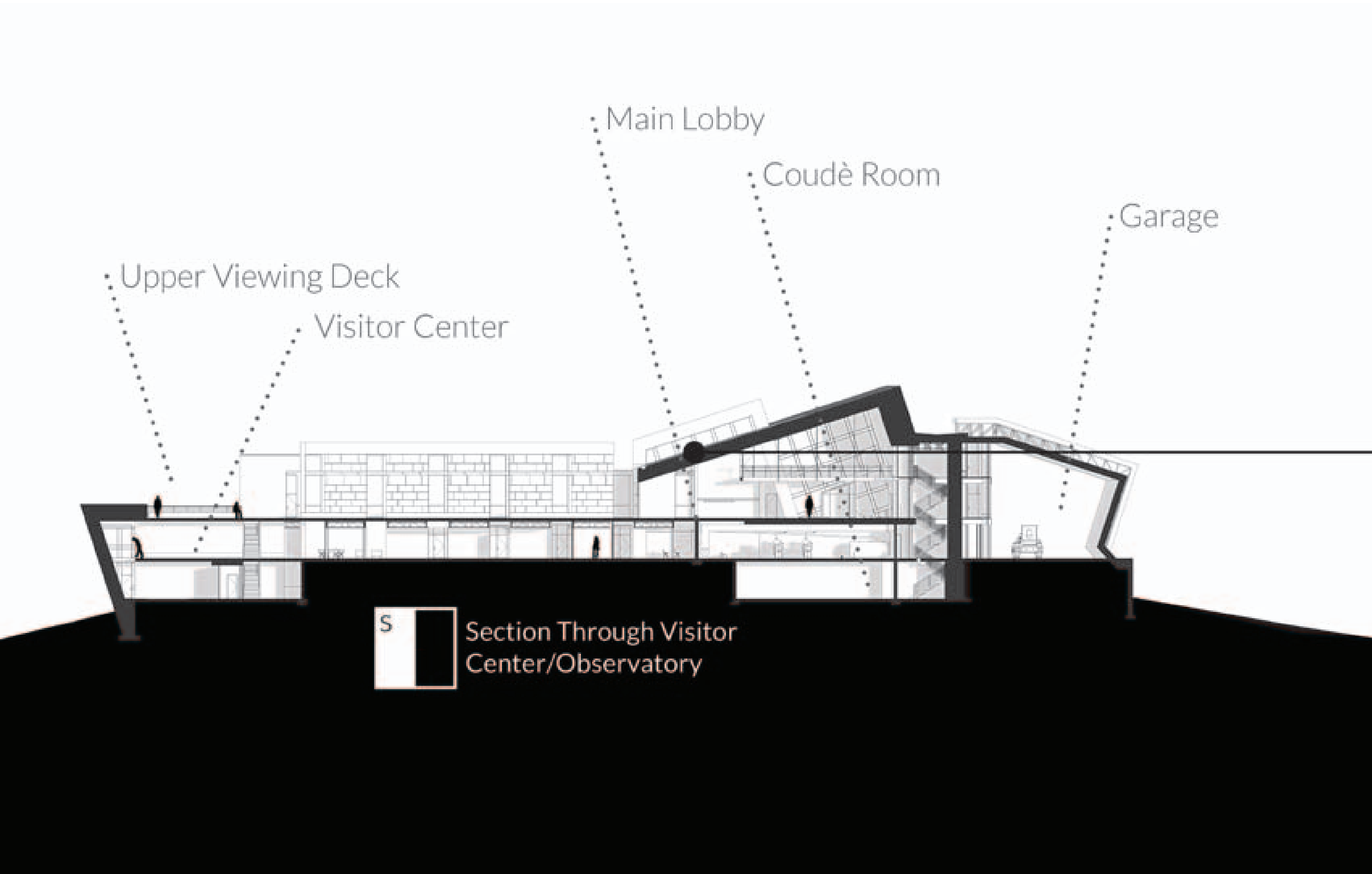


Figure 100. Section Drawings

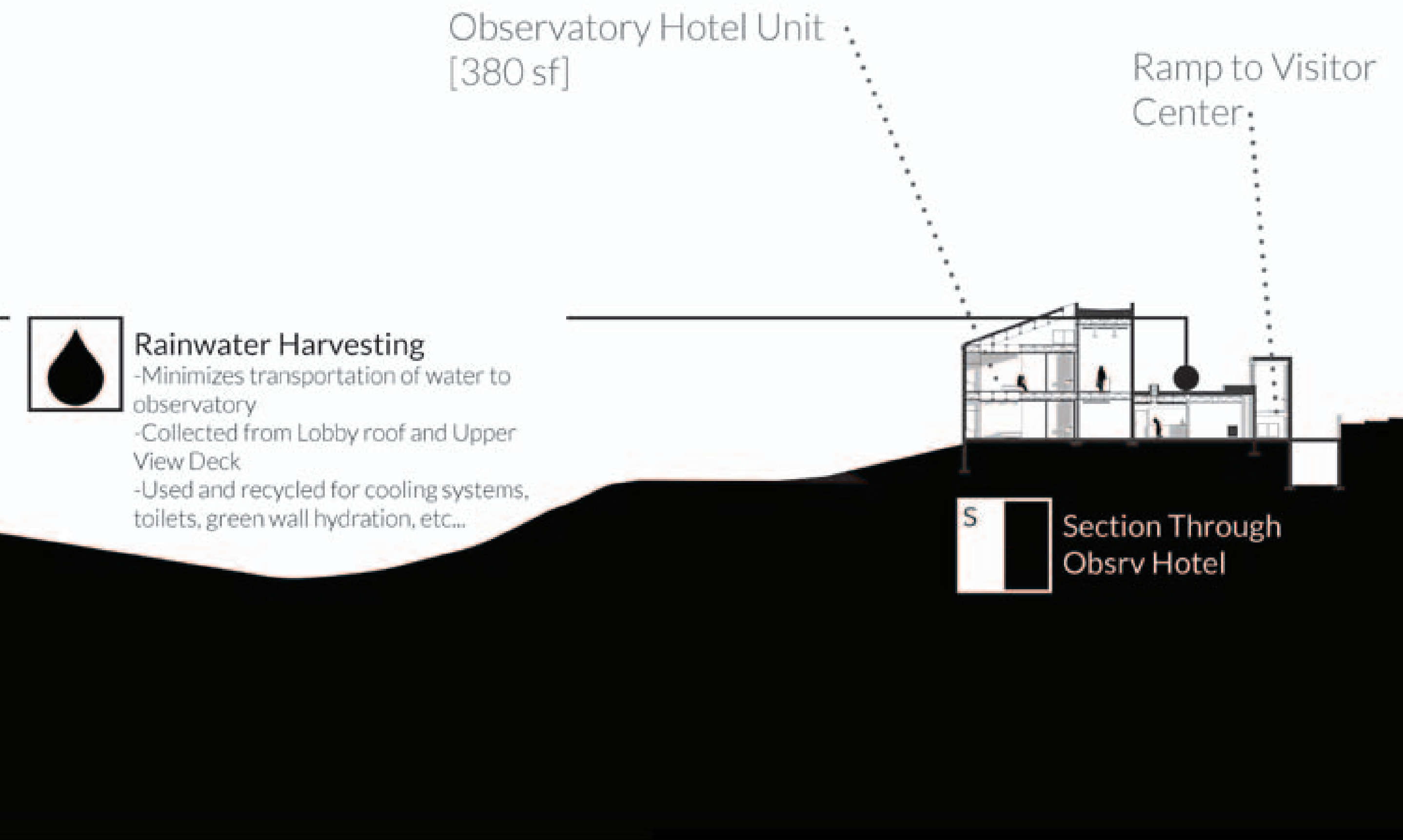

Observatory Hotel Unit
[380 sf]
Ramp to Visitor
Center
Rainwater Harvesting
-Minimizes transportation of water to observatory
-Collected from Lobby roof and Upper View Deck
-Used and recycled for cooling systems, toilets, green wall hydration, etc...
S
Section Through
Obsrv Hotel

Figure 101. Final Topo Model

Figure 102. Column 3d Print

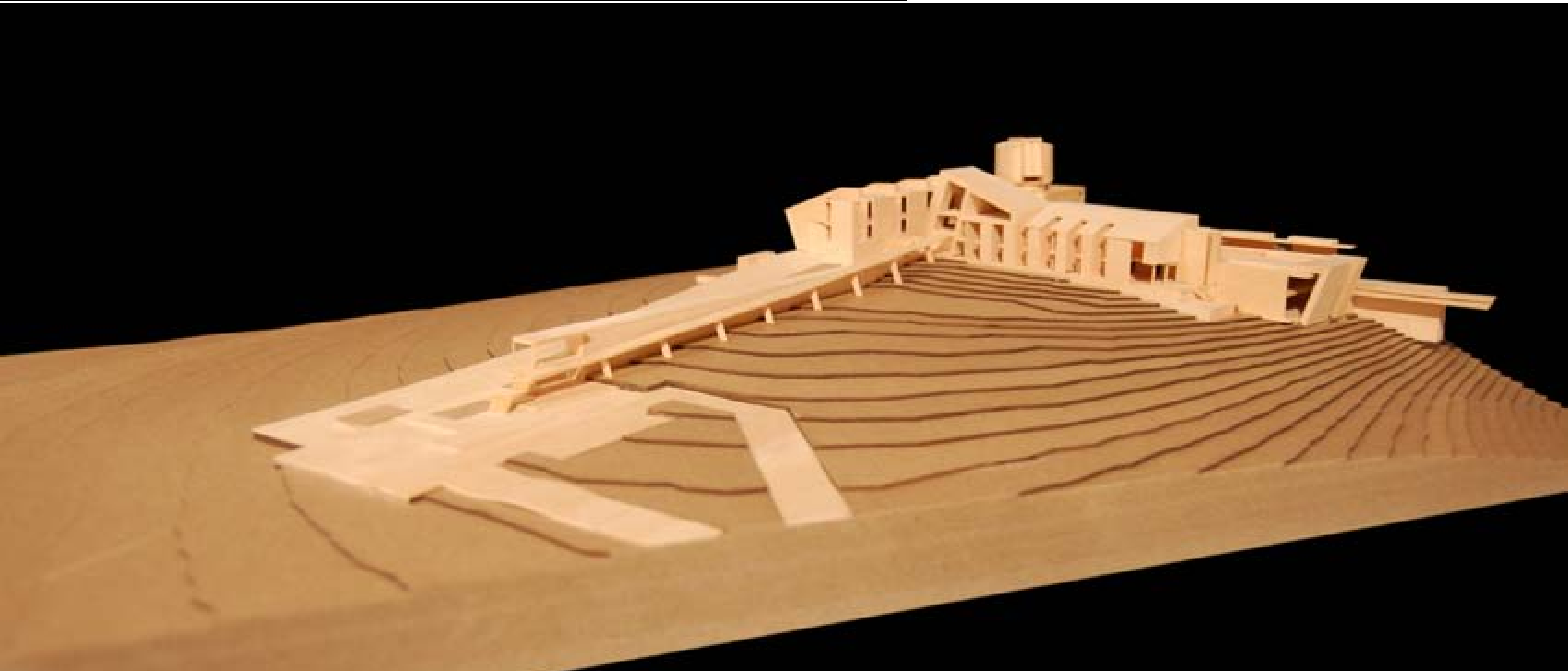


Figure 103. Final Model

Presentation Models.

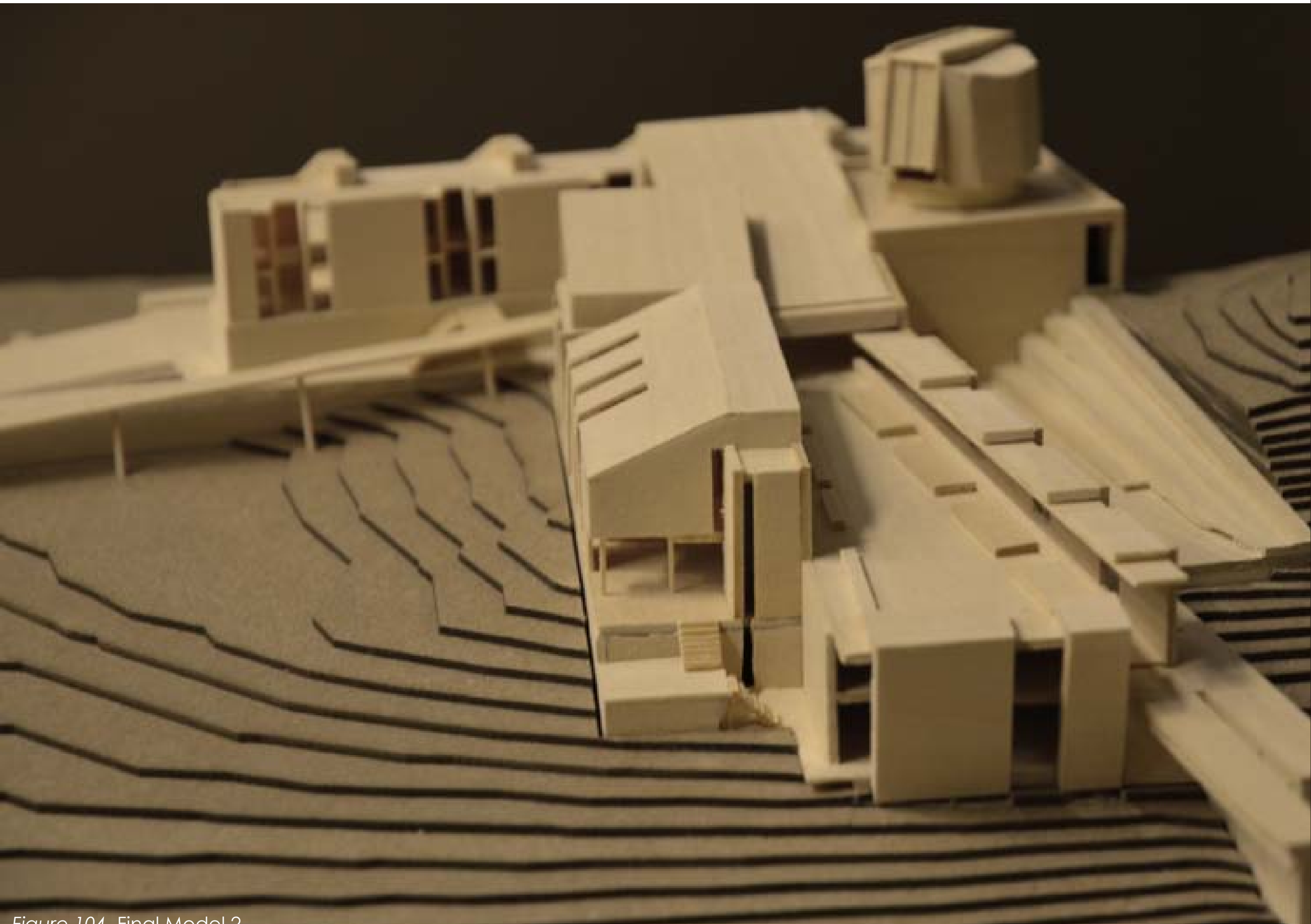


Figure 104. Final Model 2

Presentation Display.

Figure 105. Installation 1

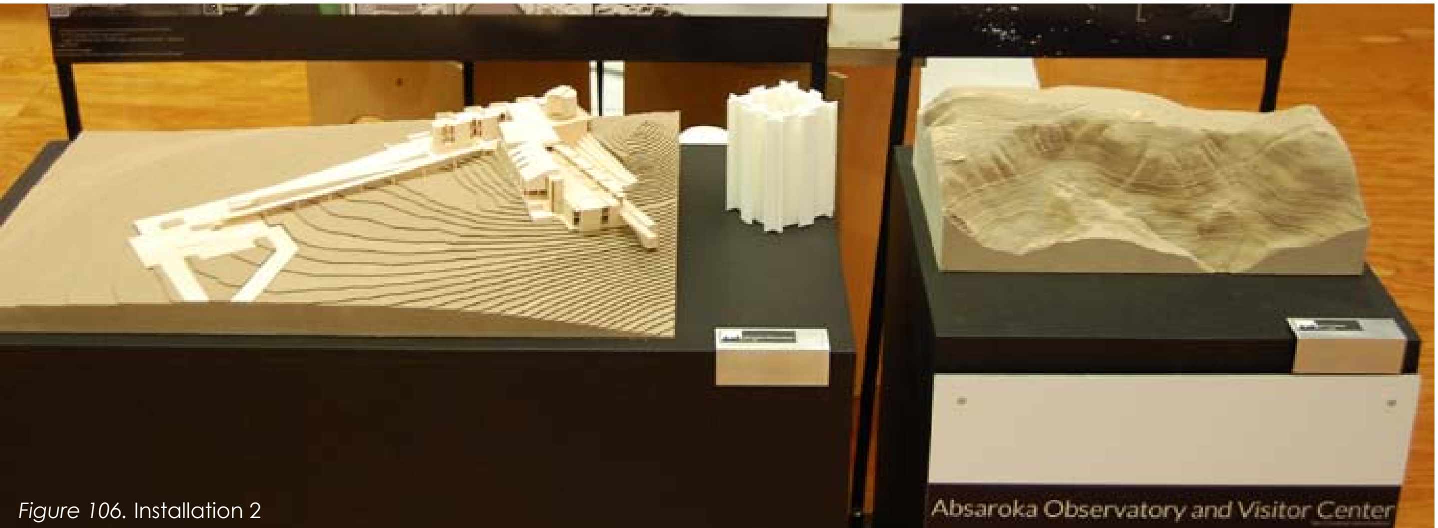


Figure 106. Installation 2

REFERENCES

Aubon, D. (2010). *The heavens on Earth: Observatories and astronomy in nineteenth-century science and culture*. Durham, NC: Duke University Press Books.

Auer Weber Architects. (2012, August 21). Projects. Retrieved from Auer-Weber: www.auer-weber.de

Beartooth Pass All-American Road Steering Committee. (2002, January). Corridor Management Plan. Retrieved from Central Federal Lands Highway: http://www.cflhd.gov

Berkebile, B. (2012). Bob Berkebile: Regenerative design. *EcoHome, 5*. Retrieved from http://www.ecohomemagazine.com/vision-2020/regenerative-design

Bighorn Medicine Wheel. (2008). Retrieved from Stanford: http://www.solar-center.stanford.edu

Brunier, S., & Lagrange, A.-M. (2005). *Great observatories of the world*. Buffalo, NY: Firefly Books.

Chekalin, I. (2011, January 19). European Southern Observatory images. Retrieved from http://www.eso.org/public/images/

Colen, J. (2012, July 5). Sustainability Base. Retrieved from NASA http://www.nasa.gov/externalflash/sustainability-base/

Decker, J. (2010). *Modern north, architecture on the frozen edge*. New York, New York: Princeton Architectural Press.

Delirium. (2012, September 19). Retrieved from http://www.abinesh.com/delirium/

Etherington, R. (2008, July 24). Kielder Observatory. *Dezeen Magazine*. Retrieved from http://www.dezeen.com

Edwin Hubble Biography. (2003, March 25). Retrieved from http://www.edwinhubble.com

ERO Resources Corporation. (2002). Final 2001 *Monitoring Report, Montana Borrow Area, Gardner Headwall, and West Summit Revegetation Test Plots for the Beartooth Highway*. Retrieved from ERO: http://www.eroresources.com/

ESO. (2009, December 3). *European Southern Observatory*. Images Retrieved from www.eso.org

Feireiss, K., & Feireiss, L. (2008). *Architecture of Change: Sustainability and Humanity in the Built Environment*. Berlin, Germany: Gestalten Verlag.

Fernandez, J. (2006). *Material Architecture*. Burlington, MA: Architectural Press.

Gauvin, J.-F. (2010, April 7). Keep looking: Astronomy as a nineteenth-century cultural pillar. *Endeavor, 34*, 41-43. Retrieved from http://www.sciencedirect.com

Gehrz, R. D. (2008, August 19). A brief Oral History of the Wyoming Infrared Observatory. (U. o. Minnesota, Interviewer) Retrieved from http://physics.uwyo.edu/chip/wiro

Google Maps. (2011). Retrieved from http://maps.google.com/

Grosvold, D. (2011, July 28). *Arkansas Oklahoma astronomical society.* Retrieved from http://www.aoas.org/filemgmt/index.

HarperCollins. (2009). *Collins English dictionary: Complete & unabridged 10th edition.* Glasgow: HarperCollins. Retrieved from http://dictionary.reference.com/browse/observatory

Harrington, P. (2005). Bringing the stars down to Earth. Astronomy, 33(11), 88.

Hoy, T. (2012). Self-Powered Smart Building uses Hydrogen Technology. *Cosmos.* Retrieved from http://www.cosmosmagazine.com/

Hudepohl, G. (2012). ESO Images. Retrieved from http://www.atacamaphoto.com/search/index.php

KECK Observatory. (2012). *The Observatory.* W. M. Keck Observatory. Retrieved from www.keckobservatory.org

Kobayashi Zedda Architects. (2012). *John Tizya Visitor Reception Centre*. Retrieved from Kobayashi+Zedda: www.kza.yk.ca/projects

Kronenburg, R. (2007). *Flexible, Architecture that Responds to Change*. London, UK: Laurence King Publishing Ltd.

Kumar, S., & Putnam, V. (2008, October). Cradle to cradle: Reverse logistics strategies and opportunities across three industry sectors. *International Journal of Production Economics, 115(2),* 305-315. Retrieved from www.sciencedirect.com

Lasota, J.-P. (2011). *Astronomy at the frontiers of science*. Paris, France: Springer Science and Business Media.

McDonough, W., & Braungart, M. (2002). *Cradle to cradle*. New York: D&M Publishers.

McDonough, W., & Braungart, M. (2006). T*he Cradle-to-cradle alternative.* Retrieved from www.mcdonough.com/writings/cradle_to_cradle

Montana Department of Transportation. (2005, May 5). Historical Photos. Re trieved from Mt.Gov: http://www.mdt.mt.gov

Morhaim, S. (Director). (2011). The Next Revolution [Motion Picture]. United States: Bull Frog Films.

National Institute of Building Sciences. (2012). *Living, Regenerative, and adaptive buildings.* Whole Design Building Guide. Retrieved from www.wbdg.org

Novak, C. (2013). Aluminum: A Sustainable Structural Choice. *Architectural Record.* Retrieved from http://continuingeducation.construction.com/

Palomar Observatory. (2011, March 2). National Optical Astronomy Observatory. Retrieved from ast.noao.edu

Product-Life Institute. (2008). *Cradle-to-cradle.* Product Life. Retrieved from http://www.product-life.org/en/cradle-to-cradle

Svenvold, M. (2007). The Zero-Energy Solution. *The New York Times.* Retrieved from http://www.nytimes.com/

United States Census Bureau. (2010). *2012 Demographic profile.* Retrieved from http://www.census.gove/popfinder/

University of Montana. (2012). *Public observing nights.* Blue Mountain Observatory. Retrieved from www.physics.umt.edu

USDA. (2012). Web Soil Survey. Retrieved from Unites States Department of Agriculture: http://websoilsurvey.nrcs.usda.gov

Western Regional Climate Center. (2012, November 20). *Cooke City climate data.* Retrieved from http://www.wrcc.dri.edu

PERSONAL **INFORMATION**

315 Main Ave. Apt. 205
Moorhead, MN 56560

320.808.9171

craig.martin.1@ndsu.edu

Hometown: Alexandria, MN

North Dakota State University may be a hometown University but it has proven to place professionals around the World. Its a place to grow and go...

Through a Technical Lens