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Parametric Methods: Wyoming Renovation

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### Process Script: Semester 01 = External Parameters / Semester 02 = Internal Parameters

<table>
<thead>
<tr>
<th>Semester 01</th>
<th>Semester 02</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proposal</td>
<td>Geo Development</td>
</tr>
<tr>
<td>Argument</td>
<td>CATIA Challenge</td>
</tr>
<tr>
<td>Methods</td>
<td>CATIA Logic</td>
</tr>
<tr>
<td>Assessment</td>
<td>CATIA Process</td>
</tr>
<tr>
<td>Site</td>
<td>Variable Changes</td>
</tr>
<tr>
<td>Ecotect Analysis</td>
<td>Geo Changes</td>
</tr>
<tr>
<td>Program</td>
<td></td>
</tr>
<tr>
<td>Global Parameter ID</td>
<td>Bay Assembly</td>
</tr>
<tr>
<td>9 Scenario Prototypes/</td>
<td>Fabrication Info</td>
</tr>
<tr>
<td>Evaluation</td>
<td></td>
</tr>
<tr>
<td>Local Parameter ID</td>
<td>Design Proposal</td>
</tr>
<tr>
<td>3 Hybrid Strategies/</td>
<td>Conclusion</td>
</tr>
<tr>
<td>Evaluation</td>
<td>Resources</td>
</tr>
</tbody>
</table>
The arrival of parametric digital modeling changes digital representations of architectural design from explicit geometric notation to instrumental geometric relationships. Architects are beginning to shift away from primarily designing the specific shape of a building to setting up geometric relationships and principles described through parametric equations that can derive particular design instances as a response to specific variables, expressions, conditional statements and scripts (Menges 43).
Proposal: 

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**Design Thesis Proposal:**

Primacy will be given to the objective of rediscovering process through utilizing parametric methods for design thinking. What will be explored is the relationship between thinking and doing in architecture, proposing a process which does not separate one from the other but instead removes the distinction between the abstract and the pragmatic. Through these considerations, an emphasis will be placed on processes themselves including; data collection, environmental analysis, scenario prototyping, manufacturing and fabrication methods, material production and assembly techniques. Each one of these processes has a relationship to parametric methods. Parametrics communicates and responds to these processes in an effort to stimulate a design process which is cyclical rather than linear. As information is gathered and introduced into the design process, design decisions are able to be proposed, evaluated and modified based on established relationships. The design process therefore becomes a flexible cycle rather than one which is guided along a linear path.

Parametric thinking involves both external and internal parameters. External parameters have the ability to shape design decisions based on both global and local project specific relationships, while internal parameters are used to engage more dramatically, high-tolerance detailing in which specific components within the design respond to each other. Both processes will be of interest to this project. It will move from suggesting strategies for dealing with external parameters to developing one of the designed strategies through more complex internal parametric relationships. During Phase 1 of the project, both global and local parameters will be identified through a design phase which will establish the information from which initial design strategies will be generated. As each parameter is confronted, relationships will emerge and strategies will be developed through project information.

An emphasis will be placed on Phase 2 of the project. This phase will showcase the direct relationship between parametric modeling and designing for fabrication and assembly. One of the strategies will be further designed through associative relationships; inquiring into potential workability, the act of making, and performance. This process will stimulate the resolution of competing forces and requirements through parametrically invested geometries. Components and inter-components will share in parametric relationships to allow for the geometry to be rationalized for assembly. The intention will be to produce fabrication sets and assembly diagrams, emphasizing the suggested design as a kit of parts. Just as the image on the cover represents a sheet of model parts, the goal will be to understand the design down to the relationship between prefabricated, internal components.

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**In their book series *MOVE*, Dutch architects Ben van Berkel and Caroline Bos argued that architects should become change managers in a world where change is the only constant.**
Introduction:

A selection of parametric method studies will be presented to support the following argument, which was formulated from a lecture given by Michael Speaks at the Architectural Association on March 21, 2006. The information from the lecture was supplemented by three journal entries made by Speaks:

1. *How the New Economy is Transforming Theory and Practice* in Architectural Record (Dec 2000)
3. *After Theory* in Architectural Record (Jun 2005)

The argument begins by establishing that theory is dead to architecture. Just as Colin Rowe proclaimed that form and ideology became separated on their passage from Europe to America, Speaks suggests that theory too arrived as a lighter and more dispersed variation of its European counterpart. This version of theory soon became acquainted with experimental forms in an attempt to, “create a critical, resistant, avant-garde architecture with left-leaning tendencies” (1:75). The architectural vanguard became completely immersed in a process rooted in Deconstruction and Marxism, sharing in an, “almost constitutional aversion to commerce and the marketplace” (3:73). Peter Eisenman led the attack on reconnecting word and form through his journal *Oppositions* from 1973 to 1984. The last effort was made by his protege Greg Lynn in 1993 when he guest-edited the Architectural Design issue, “Folding in Architecture”. In the mid- to late 1990s interest in reconnecting word and form subsided, architecture soon settled into exploring blobitecture and a built environment based on style.

In the same way that theory confronted philosophy, managerial thought now confronts theory. The reign of theory stifled innovation through a separation of thinking and doing. As a response, architecture has now detached itself from theory in the pursuit of a fascination with the new economy and management culture. Speaks proposes that this new model is based on intelligence. We have moved from the liar to the bullshitter to the intelligencer (philosophy > theory > intelligence). Architecture is no longer engaged with ‘truth’ or ‘untruth’, what practices are exploring are plausible truths through either scenario-prototyping or rapid-prototyping. Because these prototypes are not considered final they instead create, “…feedback loops that drive the innovation process itself” (2:15). This process uses a thinking-as-doing mentality which creates a ‘design intelligence’. Prototypes can be tested, redesigned and retested as part of the design process; removing post-rationalization altogether. This process will be evident in the documented precedent (method) studies. What is able to occur is collaboration, where unconsidered variables are exchanged to promote innovation.
The tradition of the master builder did not survive through the Renaissance. Leon Battista Alberti wrote that, “…architecture was separate from construction, differentiating architects and artists from master builders and craftsmen by their superior intellectual training. The theory was to provide the essence of architecture, and not the practical knowledge of construction” (Kolarevic 57). Adding to these separatist efforts was the synchronous development of perspective and orthographic drawings. The master builder became the off-site architect, relaying information through representational methods. As time passed only more and more layers were added between the architect and the ‘construction site’. An emphasis on theory completely detached architects from their tools. Thinking was established as being superior to doing.

“When trying to characterize the human species in the context of evolution, most scientists adopt a simple criteria - though not exclusive to humans, what distinguishes humans from other species is their use of tools” (Silver 0). As early representational tools acted to establish a division between thinking and doing, new digital tools are attempting to do just the opposite. Digitalization did begin in architecture with fairly simple form-finding functions which created dynamic formations disinterested in the potential for realization. Guided by the intelligencer who is motivated by the entrepreneurial-managerial model and is therefore highly interested in realization, digital architecture is being restructured. Architects now see the value in becoming more familiar with the ‘construction site’ (constructability) through utilizing both external and internal parameters in the making of design decisions. A role has been created for the new ‘master builder’; the process engineer.

The process engineer is the intelligencer; tapping into our collective intelligence in order to engineer the development of a project. This involves both scenario- and rapid-prototyping through an engagement with both external and internal parameters. External parameters stimulate scenario-prototyping through the management of project specific relationships, often dealing with issues of; site, context, climate and program. Internal parameters deal more exclusively with the relationships of the assembly, including the optimization and performance of materials and their connections. Whereas external parameters use digitalization to prototype out scenarios on a holistic scale, internal parameters require the exploration of more sophisticated digital tools like CATIA or GenerativeComponents (GC). These parametric software packages are prepared to deal with issues of rationalization and constructability through task-oriented design challenges.

In response to these influences, what has become of interest to this project is the relationship between tools and processes; and their relationship to thinking and doing. All three of the documented method studies utilize a distinctly engineered process to collaborate, prototype and realize their specific project.
Processes are far more interesting than ideas. Ideas are linked to existing codes, operating critically or in alignment with pre-existing systems of ideas. Rather than making a project the implementation of an idea, or the scaffolding of an image, what we are interested in is constructing; engineering processes on different levels. A process is the generation of a micro-history of a project, a kind of specific narrative where the entity of the project forms a sequence. If geological, biological or human history, for instance, have something to teach us, it is that these processes of temporal formation produce organizations of a far higher complexity and sophistication than instantaneous ideas. This is perhaps the most important development brought by information technology to our practice: we can design, synthesize and proliferate specific histories, scripts for a project. Writing a project, introducing a sequential development rather than deploying a form, an image.
>> Methods: >>
Precedent (Method) 1:

**Waterloo International Terminal / Nicholas Grimshaw + Partners / 1993 / London UK**

This project showcases the use of parametrics for high tolerance detailing:

Waterloo terminal exists as a 1200 ft long train shed clad entirely in glass, tapering gradually in width from 150 ft to 100 ft. A variation in platforms produced an asymmetrical geometry which made for an extremely complex design challenge. The structure was forced to rise steeply on one side in reaction to the layout of the tracks. An appreciation for the difficulty of the site can be recognized in both plan and elevation.

The following description articulates the role of automatic change propagation in the design of Waterloo:

36 dimensionally different, but identically configured, three-pin bowstring arches were used to make up the canopy structure. Each arch had to be different in response to the irregular site geometry. One generic version of the arch was parametrically modeled based on predetermined design rules which related the size of the span to the curvature of individual arches. Through an assignment of differing values to the span parameter 36 different arches were produced that remained topologically identical. More specifically, two primary elements were involved in the parametric expression; the spanning distances of a minor truss (B) and a major truss (C). The parametric truss scaling factor dictated the size of the reduced truss, while the position of the reduced truss was determined by a parametric relationship which maintained the vertical cast pin dimension of 9.5 ft.

**Truss Scaling Factor:** \( h_x = \left[ \left( 2915^2 + (B + C)^2 \right) \right]^{1/2} \)

“The parametric model could be extended from the structural description of arches to the elements that connect them, the corresponding cladding elements, i.e. to the entire building form. Thus, a highly complex hierarchy of interdependencies could be parametrically modeled, allowing iterative refinement, i.e. the dimensional fine-tuning of the project in all stages of its development, from conceptual design to construction” (Kolarevic 18).
Parametric Diagrams:

The images below attempt to communicate the configuration of the roof geometry. On the left is a captured moment from the parametric model, and on the right are diagrams aiming to illustrate the scaling truss factor (the used parametric equation).

The configuration reflects the asymmetrical layout of the five tracks/three platforms contained within the terminal.

\[ h_x = \left( 2915^2 + (B + C)^2 \right)^{1/2} \]
Component Design:

Owing to site constraints, the complex geometry of the roof design would have required 2000 sizes of glass. An investigation into assembly suggested that the glass size could remain standardized if the discrepancies were accommodated by the overlapping component joints. Shown below is an assembly sketch, a wax casting of the rotating arm component, and images of the finalized/assembled parts.

The parametric model informed the rotation of the component from arch to arch.
Fabrication/Testing/Realization:

Interlocking sequences of telescoping tubes were designed to fit within the trusses to compensate for span changes, these components were fabricated and assembled for testing.

Waterloo International terminal was completed in 1993. It has been documented as one of the first designs to use parametric methods.
Chesa Futura / Foster and Partners (SMG - Specialist Modeling Group) / 2004 / St. Moritz SWITZ

This project utilized a shared parametric model to fuse high-technology with traditional, indigenous building techniques. Foster and Partners served as the process engineer; ensuring that rationalization occurred as part of the design process. Severe winter weather conditions forced the team to develop prefabrication strategies. It was decided that the parametric geometry would be intentionally arc-based to produce a solid model capable of driving advanced CAD/CAM machinery.

Several factors determined the selection of timber as the primary construction material: it is locally harvested, durable, thermally efficient and able to be prefabricated through CNC processes. The pumpkin-like form was derived from a creative response to height restrictions, developable area, sightlines, and the reduction of bulk and envelope area. The form simultaneously exploits the potential of the site and conforms to its constraints. It was intended for the shell form to remain relatively simple, therefore a polar coordinate system was used to produce segmental radiating lines. These lines justified rib positions and window locations.

The parametric model defined the plan and sectional curves through software macros. The macro used a ‘ruler’ which was driven by the identified polar coordinate system to scan plan sectors and record measurements projected onto adjacent section curves. Running this macro built parameter sets which allowed the sectional curve to adapt to any location on the shell form. As a mode of operation, the macro could then output the shell as a solid model with an associated ribbed frame.

The shell was parametrically explored through architectural requirements, thermal insulation and structural bulk. The rationalized solution became the design surface and was signed off on by the architects early in the project. Freezing the shell form enabled refinements to occur within the enclosure using parametric software and offsets from the generating surface. Generative Components was used as the project’s parametric software. SMG credits the software with stimulating a cyclical, rather than linear, design process. The freedom it provided in exploring a multitude of design iterations was the determining factor in optimization efforts.

Six months of every year serve as buildable time in Switzerland. Therefore, a strict phasing schedule was crucial. A concrete basement and a steel table of eight inclined columns were erected during the first six months. During the proceeding winter all components of the shell structure were prefabricated for assembly by Amann in Germany. CAD/CAM machines were used which could descend a variation of 20 tools to cut, drill, rout or bore at any angle with any curvature (single- or double-curved) on a piece of laminated timber up to 125 ft in length. All materials were ready by spring and the shell of Chesa Futura was completed by winter.
Parametric Model:

These images reveal the parametric definition of the shell form. SMG used Generative Components to allow for design flexibility and change control. This was crucial for optimizing the structural and thermal performance of Chesa Futura.

The data sheets on the right convey the following information: parametrically linked plan and section, parameter set for the wall section, radii for the arc-based geometry, and the perfectly tangential surface patches across arc boundaries.
Digital Models:

The exploded model breaks the assembly up into the following sequence: steel table, concrete slab and ribs, spandrels and ring beam, and the shell including fenestrations. A more developed model was produced to communicate assembly details. Each generation of virtual model led to the next physical model. This procession of prototyping out scenarios became routine throughout the design process.
**Schedule:**

A 3-dimensional diagram served to represent the construction and phasing schedule (shown on left).

The last phase of enclosure was to apply hand-cut larch wood shingles to the shell form. Again, macros were used to control the coursing lines of the shingles. They were laid out in flat patterns and then a coursing diagram was produced (shown below in b/w). The shingles were cut from hand-picked local trees selected by the shingle-maker in the Engadine Valley, they will last for at least 75 years.

After producing the entire shell form with an absolute tolerance of 0.5 mm during manufacturing and 20 mm through construction, the shingles were hand-cut by an 80 year-old local expert and later nailed to the battons by his family.
Fabrication/Realization:

Lamination of the timber ribs is shown below, along with the CAD/CAM machinery used to prefabricate the timber frame.

The shell form was completed in 2002, but Chesa Futura was not entirely finished until 2004. Notice the change in fenestration dimensions based on the generated environmental analysis. Large openings occur to bring in solar exposure, while small openings are used to combat wind frequency.
Precedent (Method) 3:

**Camera Obscura - Mitchell Park / Sharples Holden Pasquarelli (SHoP Architects) / 2005 / Greenport NY**

SHoP explores a process model which from the beginning thought parametrically, but did not necessarily utilize parametric software. Their process has always involved developing relationships to/and from parameters to allow for the processes involved in an architectural project to formulate a design response. Specifically, they design techniques for exploiting materials, fabrication methods, assembly processes and project requirements. Instead of providing a “style for the job,” SHoP offers a, “solution for the job” (Reeser 47).

This approach guided Camera Obscura, a project which was completely designed and fabricated within the digital environment. Three parameters dictated the form:

1. Code Requirements
2. Movement Patterns
3. Program (Viewing/Display)

Suitable tolerances were established for the following to begin the modeling process:

1. Program
2. Material Options
3. Fabrication Methods

“These variables came to represent the datum on which design and management of the information in the construction documents would be predicated” (Sharples 34). Correspondence with fabricators and material suppliers was crucial for determining detailing and assembly solutions. Design decisions were resolved through selecting the appropriate software and CNC processes for dealing with the geometry and material selections.

Three categories of drawings were produced:

1. Fabrication Set - indication of component parts and quantities
2. Assembly Diagrams - rationalization of construction scope and sequence
3. Traditional Drawings - illustration of zoning and code compliance
Materials:

These diagrams serve as a material index for the project, all of which are understood to be sharing in a parametrical relationship (not all materials for the full assembly are shown). Meaning, if one part changes, each corresponding part sharing in a relationship with that part is updated using the new information. However, SHoP did not use a parametric application on Camera Obscura, so therefore all updating had to be done tediously by hand. Parametric software offers the ability for the updating to occur simultaneously with design changes.
Component Fabrication:

A component schedule of aluminum fins and shelf supports is shown below along with the nested information to allow SHoP to communicate directly with fabricators. The image shows the pieces being laser cut out of the indicated aluminum sheets.
Assembly Diagrams:

These diagrams act as a set of instructions for the construction team, comparable to the ones found in a model airplane kit. The design for Camera Obscura was communicated as a kit of custom parts.
Fabrication/Realization:

From fabrication to onsite assembly. The Camera was completed in 2005.
>> Assessment: >>
Method 1 / Waterloo Terminal:

The parametric method used for the canopy structure began with one generic truss design. From that, in correspondence with site constraints, a system of relationships developed to generate the overall form, connecting components and the cladding system. The question begs to be asked; how was the first generic truss designed? Both external and internal parametric relationships become traceable once the cyclical process begins. However, what determined the first move? Much of the anxiety surrounding parametrics involves a misreading of the intended process. Derived from already established processes, critics look for an initiating source capable of critically evaluating all design decisions; a linear process. What is being challenged by parametric methods is this linearity. Parametrics offers a cyclical process which feeds off of itself from data collection through realization.

The ‘first move’ has been deemed inconsequential by Grimshaw + Partners, a judgement commonly held by parametric practices. Engineering the process of the design is given priority over the initial move; not to suggest that a critically just initial move never existed. What is being implied here is that the design for Waterloo Terminal never intended to rely on a critical evaluation from one initiating source, instead design decisions were left to become critical of each other within the cyclical process. The design team operated under a slew of information meant to guide a collaboration of decisions. Therefore, it is possible to suggest that the initial move was rendered unsubstantial in comparison to all other moves. It is intended that this design thesis project will conduct a similar approach.

Method 2 / Chesa Futura:

What will be drawn from this parametric method study is its treatment of traditional building materials and techniques. These traditions were not abandoned but incorporated into modern (pre)fabrication processes and assembly strategies. Material selection did not occur as a post-rationalization effort. In contrast, the materials were chosen as part of the initial data (collection) design phase. The potentialities and constraints of timber construction were then able to be synchronously exploited through an acknowledgement of quantifiable information. As designs were generated, it was understood that CAD/CAM processes were only capable of working with a piece of timber up to 125 ft in length. This data was used to write scripts for the output of the ribbed frame structure. Rather than allowing outside sources to later value-engineer the design into a buildable assembly, the information was used as part of the parametric design process to ensure realization.

Many of the environmental concerns surrounding Chesa Futura will also be present at the design thesis project site. The parametric method used by Foster + Partners set up a process which evaluated the generated shell form designs based on predetermined thermal criteria. As a result, the final form was optimized for thermal performance. In addition to the overall form, further details were addressed through environmental strategies. Window sizes and placement were articulated in response to climatic data and the entire assembly was raised off of ground level to allow snow to accumulate and pass underneath it. It will be of interest to utilize prefabrication methods in a comparable effort to work with the severe winter weather conditions of the site. The goal will be to prefabricate in the winter, for ease of assembly in the spring.

Method 3 / Camera Obscura:

The emphasizing point of this particular parametric method study was its use of parametric thinking. It is often overlooked that in order to utilize the potential of parametric software the designer must first become a parametric thinker. The relationships do not establish themselves, they are designed. SHoP used Rhino in a way that broke the design up into a custom kit of parts. The layering system of their model created a family tree, similar to the ones generated in advanced parametric software. However, the information was not linked for change control. The result was an extremely labor-intensive process which forced designers to become familiar with parametric modes of thought. Manually updating component information in separate layers engaged the designers with the kit of parts and intentionally directed their attention to ideas of assembly.

It is also pertinent to discuss the documentation produced for Camera Obscura. Materials and fabrication methods were predetermined in an effort to establish unknown variables early on in the project. Therefore, the design was formed through the use of the materials in a virtual sense. The form was not generated through a solid mass gesture, it was instead developed as a mass gesture of component behaviors. This was showcased in the production of fabrication sets and assembly diagrams; a strategy that is of great interest to this design thesis. It was of primary importance that the designers have a working knowledge of the processes used by fabricators and contractors so that the design could either be informed by the processes, or the processes could perhaps be informed by the design. This cycle pushes innovation in architecture.
BIM vs. BIM:

Parametric software builds an information model. These information models should be used to create design intelligence, not to further standardize our built environment. One tool does not offer a solution to the architectural process. By attempting to standardize a process, we standardize the output. This is what digitalization did to architecture in the 90s. By knowing a specific software (usually FormZ or Maya), and specific tools within that software (or even scripts), extremely dynamic forms were able to be generated. Outputs in the academic environment became predictable from school to school. Unfortunately, theories and concepts could very easily be applied to these forms without any ability to rationalize the geometry for realization. Progressive architecture was forced to live in a virtual environment using a concept-to-form led process. The intelligencer questions this concept-to-form led model, and in doing so, questions the place of theory in architecture. Has it (theory) overshadowed our need to understand the physical realities of architecture? Yes.

The intelligencer is operating under a thinking-as-doing process model which is driven by the potential for realization. As was demonstrated by the preceding method studies, and is perhaps even more evident in the work of Frank Gehry or Thom Mayne, rationalization of complex geometry has become part of the design process. Architecture is beginning to physically exist in a progressive state through the use of parametric software. This point must be emphasized; parametrics is used as a design tool to investigate complex design issues, not for the standardization of a process. There is not one parametric software capable of answering all questions. The process engineer is not a specialist but an individual equipped with the intelligence of many tools, using the appropriate software when needed.

This project will use the following digital tools:

**EcoTect (Analysis) ➔ Rhino (Design) ➔ CATIA / Digital Project (Rationalization)**

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Residential Building / Site Architects / Johannesburg, South Africa

- Standardized plans and sections
- Repetition of cataloged components
- Used for process efficiency

Federal Building / Morphosis / San Francisco CA

- Resolution of complex geometry
- Customized component detailing
- Used for process innovation
Site:
Site Introduction:

The Medicine Bow National Forest spreads through the southeast corner of Wyoming. It is comprised of: Pole Mountain, the Medicine Bow Mountains, the Sierra Madre and the Laramie Mountains. The Medicine Bow Mountains, politically divided by the state border of Wyoming/Colorado, stretch from Cameron Pass in northern Colorado to Interstate 80 in southern Wyoming. The highlight of these mountains is the Snowy Range, a five mile strip of high peaks dividing the land between Centennial and Saratoga, WY.

The selected site is located within the Snowy Range at an elevation of 9200’, positioned approximately 5 miles from Centennial (population 195). It sits in the lower portion of the subalpine zone (9000’-11000’) where trees are still a dominant feature. It is not until the upper region that forests become thin.
Shown below are USGS topography maps of the Medicine Bow Peak and Centennial quadrangles (1:24000). These quadrangles are found in Carbon county and Albany county in the southeastern portion of Wyoming.
Highway 130 cuts through the Snowy Range mountains heading from Centennial to Saratoga, Wyoming. Barber Lake Road intersects with Hwy 130 approximately 3 miles after it leaves Centennial, Barber Lake itself can be found 2 miles off of the highway. The image below shows Barber Lake Road (cyan) as it passes the lake and continues on to become a private road for 11 cabins. The chosen site (red) resides between the road and Libby Creek (blue).
1:500 contour drawings of the site which sits 15 degrees off of true North. The site dimensions are: 98’ x 140’ x 128’ x 145’. The second image establishes that there is an existing structure (a private cabin) on the site. 90 trees sit within the property lines.
Centennial, Wyoming is located at the base of the Snowy Range mountains 45 minutes west of Laramie. As is indicated by the map, image 00 looks toward the mountain range from Hwy 130. Images 01-10 reveal a sequence of progression down Barber Lake Road to the site.
Views from the NE and NW.
Views from the SW and SE.
Site Constraints / Opportunities:

- Property Area: 16135 sq ft
- Libby Creek: 15' wide
- Barber Lake Rd: 10' wide
- Existing Trees: 90 trees
- Existing Cabin: 1000 sq ft
- Elevation Change: 18' Ridge
Ecotect Analysis:
Climate Analysis:

Each of these graphs illustrate a specific weekly average weather condition taking place over the course of a 52 week year. The graphs represent a Typical Meteorological Year (TMY) for the state of Wyoming. This TMY Weather Data was obtained from the U.S. Department of Energy. A typical meteorological year is derived from recording climate data over a 30 year period for each hour of each day. This data is averaged to create a typical condition for every hour of climate data. The significance of this hourly data is that it has helped quantify the typical climate conditions that will affect thermal loading and the energy consumption of the built environment.

**Average Temperature** shows low conditions (<32°F) occurring from November to February, while highs during the summer months do not exceed 80°F.

**Average Relative Humidity** shows the lowest average humidity levels (40%) occurring midday with peaks in the morning around 70%.

**Average Cloud Cover** shows a range of 40-60% occurring most frequently with peaks of 80% late in the year. These percentages effect direct solar radiation levels.

**Average Wind Speed** shows wind speeds peaking in the afternoon with more dramatic speeds occurring during the winter.

**Average Direct Solar Radiation** shows peaks (220 BTU/h*ft²) occurring June through September and valleys (158 BTU/h*ft²) occur throughout the winter.

**Average Diffuse Solar Radiation** shows peaks (95 BTU/h*ft²) occurring April and May, while valleys (31 BTU/h*ft²) occur during the early winter months.
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Wind Temperature:

The diagrams shown below depict the temperature and speed of the wind per hour over the course of a seasonal period. This information establishes that wind is most frequently being directed at the site from the northwest.

**Winter Wind**
- Coolest: <32°F, Northwest
- Warmest: 59°F, Southwest
- Fastest: >32 mph, Northwest

**Spring Wind**
- Coolest: <32°F, Northwest
- Warmest: 68°F, Southeast
- Fastest: >32 mph, Northwest

**Summer Wind**
- Coolest: 68°F, West
- Warmest: 77°F, South
- Fastest: >32 mph, West

**Autumn Wind**
- Coolest: <32°F, Northeast
- Warmest: 77°F, South
- Fastest: >32 mph, Northwest
Wind Frequency:

The diagrams shown below depict the amount of wind and speed of directional winds over the course of a seasonal period. The data extracted from these wind diagrams will be used in the design process to determine overall orientation, element placement and the potential exploitation of natural ventilation.

**Winter Wind**
- +80 hrs
- 16 mph
- Northwest

**Spring Wind**
- +88 hrs
- 10 mph
- Northwest

**Summer Wind**
- +131 hrs
- 10 mph
- Northwest

**Autumn Wind**
- +138 hrs
- 13 mph
- Northwest
Sun Path:

Environmental simulation provides these stereographic images of the annual movement of the sun. The generated diagrams show the existing structure and its relationship to the sun's rotation. Shown below are two contrasting positions at 9 am; June 1st and December 1st. These images are the beginning of a solar analysis which will examine shade and shadow, daylight, direct/indirect solar radiation, and optimum orientation on the site. The information produced will help to inform glazing decisions and shading strategies.
Shade/Shadow:

Featured below are two images which correspond to the sun path diagrams on the preceding page. These diagrams are intended to show onsite shade/shadow trends. The trend indicates that, due to contextual issues, when the sun is most needed for thermal comfort it has moved to a position which produces more shade/shadow on the site. The actual tree canopy would produce an even more dramatic presence of shade/shadow. This is important information to consider because the sun’s heat is a crucial part of heating this cabin.

June 1: 9 am

December 1: 9 am
These 6 diagrams show the movement of shade/shadow on the site as the sun transitions from 9 am to 12 pm to 3 pm on June 1st (Row 1) and December 1st (Row 2). Onsite shade/shadow becomes more dramatic during the winter months as the sun’s position moves lower and further South.
Daylight Analysis:

*Daylight Factor* shows values ranging between .65% - 17.66%, the average being 2.81%. The Daylight Factor is simply a ratio of the illuminance at a particular point within an enclosure to the simultaneous unobstructed outdoor illuminance. Generally a daylight factor above 5% will give the impression of a lit space. The daylight factor is meant to represent the worst-case design scenario, the calculation assumes all light is diffused.

*Daylight Levels* show the amount of daylight entering the existing cabin structure, these are estimated illumination levels. The daylight levels are calculated by using both the daylight factor and direct sunlight. The levels suggested here range from 52 - 1500 lux (5 - 140 foot candles). These levels are extremely poor considering the Illuminating Engineering Society of America (IESNA) recommends at least 30-50 foot candles for casual reading. Outdoor sunrise/sunset levels are found to be approximately 70 foot candles (1 foot candle = 10.76 lux). The diagrams below indicate that a majority of the spaces only have access to a range of up to 18 foot candles, these are extremely poor lighting conditions.
Direct/Indirect Solar Radiation:

*Direct Solar Radiation* accounts for all solar radiation entering a space through fenestrations and/or all other transparent or translucent surfaces.

*Indirect Solar Radiation* calculates additional gains from incident solar radiation on opaque external surfaces. The solar radiation acts to raise the external surface temperature which in turn increases the conducted heat flow.
Optimum Orientation:

This position is calculated based on the average daily incident of radiation on a vertical surface for tested orientations during overheated periods and underheated periods. These periods are automatically generated for the three most overheated months and the three most underheated months of the year. The optimum orientation takes advantage of solar gains when they are most needed and avoids them when they are not.

The yellow strip will be used to influence design decisions. This represents the most optimum angle for any built structure on the site to receive solar radiation for thermal comfort.
The existing structure has evolved through three stages.

**STAGE 1: 1932**
- 01 Kitchen
- 02 Communal Space
- 03 Bedroom 1

**STAGE 2: 1960**
- 04 Bedroom 2
- 05 Bathroom 1

**STAGE 3: 1988**
- 06 Utility Closet
- 07 Bedroom 3
- 08 Bedroom 4
- 09 Bathroom 2

**Original Structure: 520 sq ft**
- 01 Kitchen
- 02 Communal Space
- 03 Bedroom 1

**Modification 1: 200 sq ft**
- 04 Bedroom 2
- 05 Bathroom 1

**Modification 2: 280 sq ft**
- 06 Utility Closet
- 07 Bedroom 3
- 08 Bedroom 4
- 09 Bathroom 2
Identified below are the modifications made to the original structure.
This project will transition back to the original 1932 structure. An addition will be proposed to replace both the 1960 and 1988 modifications.
Identified User: One woman will begin using the cabin as her permanent residence from May to October every year.

Current Program: The cabin currently supports 2 users in 1 private room. There is an existing living space and kitchen.

Design Scenario: A transient group of 21 people will begin visiting the cabin during her stays in the summer and fall.

Added Users: 11 Males / 10 Females

Needed Lodging Space: 2 additional lodging spaces will be needed; a private room and one communal sleeping space.

Comfort Zone (Perpendicular): An approximated diameter of space needed by an individual when perpendicular to the ground plane is 4' for a male and 3' for a female.

Comfort Zone (Parallel): When the subjects become parallel to the ground plane both sexes are given an elliptical shape of 8' in length and 3' in width.

The diagrams below explore program in plan. On the left are studies of existing spaces, and on the right those spaces have been expanded to support a greater number of comfort zones. Based on the identified user group, these studies are meant to begin both an analysis of the existing program and a suggestion of potential modifications.
To further explore the diagrams, the study was reconducted in 3-dimension. As is indicated, the addition will have to involve at least 1300 sq ft not including bathrooms or indoor/outdoor spaces. The proposal below considers: an expansion of the shared living space, a new area for transient lodging, and the addition of a new private room. If the transient lodging space considers a ‘bunkbed’ system, the suggested spaces could support up to 14 people.

Existing Communal Space
265 sq ft

Existing Transient Lodging
115 sq ft

Existing Bedroom 1
150 sq ft

Proposed Additional Space
265 + 350 = 615 sq ft

Proposed Additional Space
115 + 335 = 450 sq ft

Proposed Additional Space
150 + 75 = 225 sq ft

It is common for transient lodging to employ a ‘bunkbed’ system. Should the spatial requirement expand for support?
The sun path diagram is placed on top of the site plan below as an overlay to emphasize the importance of the land south of the existing structure. This southern land will receive solar exposure from late morning to late afternoon. The 2 most opportune areas for new construction are located S of the cabin and are portrayed in pink below; the numbers are meant to quantify the space in terms of square feet. These numbers will be used as a reference in defining the program.

These areas have the greatest potential to relate to the 3 most dominant features on the site: the sun path, southside elevation change, and Libby Creek. It is important to consider the potential of quantifiable space when determining program requirements.
Proposed Working Program:

The original cabin supported 2 users in 1 private room. As the additions were made capacity expanded to accommodate 10 visitors. The goal for this design thesis will be to rethink and redesign the two additions which took place in 1960 and 1988. The suggested program is based on information from the previous additions, user group and design scenario. An expansion will occur to support a total of 16 people. This will accommodate multiple variations of the user group (1 permanent resident / 21 expected guests).

The following program has been defined:

01 Extension of communal living space = 400 sq ft - This space will have a relationship with the existing living space
02 Bedroom 1 becomes private guest room = 000 sq ft - The existing bedroom will become a private room for 2 guests
03 Addition of Bedroom 2 / Studio = 300 sq ft - Bdrm 2 will become the sleeping quarters/studio for the resident
04 Addition of Bathrooms 1/2 = 200 sq ft - 1 will serve Bdrm 1/Bdrm 2, the other will serve the transient lodging
05 Addition of transient lodging (12 beds) = 600 sq ft - This room will support minimal sleeping spaces for 12 guests
06 Addition of defined outdoor space = 300 sq ft - Currently there is no defined outdoor space, this will be added

Total Modifications = 1800 sq ft
Global Parameter ID: >>
Data Set:

**Site**

- Elevation: 9200'
- Orientation: 15° E of N
- Distance to Centennial, WY: 5 miles
- Distance to Laramie, WY: 35 miles
- Dimensions: 98' x 140' x 128' x 145' = 16135 sq ft
- Used Area: 520 sq ft
- Unused Area: 15616 sq ft
- Southside Elevation Change: 18'
- Shortest Distance (Barber Lake Rd to Cabin): 65'
- Shortest Distance (Cabin to Libby Creek): 70'
- Shortest Distance to Neighboring Cabin: 120'

**Climate**

- Average Temperature: High = 80°F / Low = <32°F
- Average Relative Humidity: High = 70% (morning) / Low = 40% (midday)
- Average Cloud Cover: 40-60% / Increases to 80% = Early Winter
- Average Wind Speed: Peaks = Afternoon / Speed Increases = Winter
- Average Direct Solar Radiation: Peaks = Jun-Sep / Valleys = Early Winter
- Average Diffuse Solar Radiation: Peaks = Apr-May / Valleys = Early Winter
- Average Annual Snowfall: 250" (Nov-May)
- Coolest Wind Temperature: Winter/Spring (<32°F - NW)
- Mildest Wind Temperature: Fall (50s - NW)
- Warmest Wind Temperature: Summer (80s - NW)
- Most Frequent Wind: Northwest
- Fastest Wind: Winter (NW)
- Sun Path: 60° Position Change (Jul-Jan)
- Optimum Orientation: 10° W of N

**User ID / Original Structure / Program**

- Users: 1 Permanent / 21 Guests
- User Group: Transient
- Usage: Summer / Fall
- Original Capacity: 2 guests
- Current Capacity: 10 guests
- Suggested Capacity: 16 guests
- Original Area: 520 sq ft
- Existing Area: 1000 sq ft
- Suggested Area: 2320 sq ft
- Original Glazing Area: 116 sq ft
- Original Glazing Percentage: 8%
External Parameters - Global ID:

These comprehensive parameters will serve to critically evaluate all positioning scenarios through the first evaluation stage.

Site Constraints
- Parameter 01 **Topography**: The southside elevation change will shape design decisions.
- Parameter 02 **Libby Creek**: The design will approach and engage the presence of Libby Creek.
- Parameter 03 **Existing**: The design will be effected by onsite trees. Neighboring sightlines will be considered.

Climatic Data
- Parameter 04 **Solar Position**: The new addition will take advantage of sun exposure to increase thermal performance.
- Parameter 05 **Snow Loads**: The design will respond to the presence of heavy snow loads/large volumes of melted snow.
- Parameter 06 **Wind Analysis**: The collected wind data will influence the designed form and material selections.

Program
- Parameter 07 **Transient Users**: The temporal nature of the resident and guests will be handled through the design.
- Parameter 08 **Resident/Guest**: The relationship between transient lodging and permanent resident spaces will be explored.

END OF SEMESTER 01
- Design Strategy 01
- Design Strategy 02
- Design Strategy 03

Materials
- Parameter 09 **Properties**: The performance qualities and relationships of materials will influence detail strategies.

Components
- Parameter 10 **Fabrication**: (Because the site is remote, components will be prefabricated and shipped to the site for assembly) The use of specific fabrication methods will aid in the making of design decisions.

Assembly
- Parameter 11 **Techniques**: The techniques used for the assembly of prefabricated parts will influence design ideas.

END OF SEMESTER 02
- Strategy Detail 01
- Strategy Detail 02
- Strategy Detail 03
(Global) Parameter ID Conclusion:

The most important data can be merged into one principal diagram.

Diagram = Sun Path + Optimum Orientation + NW Winds + Dominant Site Features (Southside Elevation Change + Libby Creek)
How will the project proceed based on the determined global parameters?

The most important information collected through the data design phase was the solar analysis; including the sun path diagrams, daylighting levels and solar radiation averages. The generated data concluded that the existing cabin does not receive an adequate amount of exposure to the sun. Site visits have confirmed that this information is correct. However, in a subalpine climate, solar exposure is crucial for both thermal comfort and to achieve proper daylighting levels. In such a distinctive context, solar exposure is also often targeted in an effort to connect interior spaces with the exterior environment.

As is shown in the images below on the left, there is an available space directly south of the cabin which is illuminated by the sun from late morning to late afternoon (this was also determined by the sun path diagrams). The images capture the solar angle as it sweeps across the site. Contextual issues force solar exposure to enter the site at a very high angle. **The location of the discovered opportunities for solar exposure have made the southside elevation change the most crucial feature on the site.**

![Images showing solar angles and elevation changes](image_url)

**Global Parameter Guidance:**

The following relationships have been established and will be evident in all proposed scenario prototypes:

01 Orientation will sit 10° W of N in response to the most **optimum direction** for solar exposure (Parameter 04)
02 Program organization will occur S of the existing structure in response to the location of the **sun path** (Parameter 04)
03 The sun path will force all strategies to respond to the **southside elevation change** (Parameter 06)
04 Property lines stop the proposals from having any direct relationship with Libby Creek, however it will be approached (Parameter 02)
05 Formal decisions will recognize the existence of **neighboring sightlines** which are directed from the E side (Parameter 03)
06 Snow loads will begin to be addressed through the shaping of all **roof designs** (Parameters 05)
9 Scenarios:
Proceeding Lineage (Phase 1):

The established external (global) parameters will guide the development of 9 scenario prototypes. The phrases; ‘on it’, ‘in it’ and ‘above it’ are equating the word ‘it’ with the landscape in response to the southside elevation change (Parameter 06). This ridge has been identified as the most dominant site feature.

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Scenario Prototypes:

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Parametric Methods: *Wyoming Renovation* >> Scenario Prototypes
Scenario 01: ON IT

Total Forecasted Area - 1645 Sq Ft
Percentage of Site Altered - 10.2%
Number of Trees Removed - 11

PROS: Takes advantage of the changing landscape by gradually moving down the southside ridge towards Libby Creek. This creates an opportunity for the design to utilize views of the creek. Large surfaces are available for solar exposure.

CONS: Privileged views are given to the transient lodging space, while more frequently used program spaces are cut off from the creek.
**Scenario 02: ON IT**

Total Forcasted Area - 1690 Sq Ft
Percentage of Site Altered - 10.5%
Number of Trees Removed - 12

PROS: The design sits within a very opportunistic area for solar exposure. It has an interesting response to the elevation change by becoming double-height as it approaches the creek. This opens up a large surface for views of the creek.

CONS: Large surface areas will have to respond to the northwest winds and to neighboring sightlines.

Surfaces Normal to Opt. Orientation: 560 SF
Surfaces Normal to Sun Path: 1400 SF
Surfaces Normal to Northwest Winds: 450 SF
Privileged Views to Forested Areas / Creek

West Elevation - Tree Canopy Diagram
Scenario 03: **ON IT**

Total Forcasted Area - 1615 Sq Ft  
Percentage of Site Altered - 10.0%  
Number of Trees Removed - 12

Surfaces Normal to Opt. Orientation: 715 SF
Surfaces Normal to Sun Path: 1850 SF
Surfaces Normal to Northwest Winds: 375 SF

PROS: All program spaces have sightlines directed at Libby Creek. The communal living space separates the private and transient lodging. Large surface areas are available for solar exposure.

CONS: There is no interaction with the elevation change. The roof design would have to better consider the prescence of melting snow.
Scenario 04: **IN IT**

Total Forecasted Area - 1675 Sq Ft
Percentage of Site Altered - 10.4%
Number of Trees Removed - 9

### Surfaces Normal to Opt. Orientation: 1800 SF

- **PROS:** Large surface areas respond to both the sun path and the suggested optimum orientation angle. Reduced surface areas serve to combat NW winds. It is possible for an outdoor space to occur on top of the transient lodging portion of the design. The roof design would be excellent for shedding melted snow loads.

- **CONS:** The communal living space may not have a view of the creek if it has to be located underground.

### Surfaces Normal to Sun Path: 2175 SF

### Surfaces Normal to Northwest Winds: 350 SF

### Privileged Views to Forested Areas / Creek

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West Elevation - Tree Canopy Diagram
Scenario 05: **IN IT**

Total Forecasted Area - 1665 Sq Ft
Percentage of Site Altered - 10.3%
Number of Trees Removed - 14

**PROS:** The design reaches out to interact with Libby Creek. No current views are disrupted.

**CONS:** Program spaces do not relate well. Views are restricted by it being primarily submerged underground. Solar exposure may be reduced by the overlapping of the landscape into the design.
Scenario 06: **IN IT**

Total Forecasted Area - 1680 Sq Ft  
Percentage of Site Altered - 10.4%  
Number of Trees Removed - 10

- **Surfaces Normal to Opt. Orientation**: 150 SF  
- **Surfaces Normal to Sun Path**: 1800 SF  
- **Surfaces Normal to Northwest Winds**: 400 SF

**PROS:** The transient lodging shields the other spaces from the NW winds. All views from the existing cabin remain intact.

**CONS:** No privileged views in any direction from the new structure. Snow would completely cut off solar exposure. Surfaces capable of receiving solar exposure are located slightly off from the most opportune areas on the site.

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West Elevation - Tree Canopy Diagram

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### Scenario Prototypes

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Scenario 07: **ABOVE IT**

Total Forcasted Area - 1600 Sq Ft  
Percentage of Site Altered - 10.0%  
Number of Trees Removed - 10

**PROS:** The most frequently used spaces become linked, while the transient lodging makes a separate gesture beneath. Large amounts of surface area are available for solar exposure. Views are privileged to the creek and the SW forest. Melted snow is allowed to pass under the structure.

**CONS:** Surface areas become exposed to the exterior climate, rather than being submerged underground. The design consumes a portion of the existing cabin.
Scenario 08: **ABOVE IT**

Total Forcasted Area - 1500 Sq Ft  
Percentage of Site Altered - 9.0%  
Number of Trees Removed - 7

**PROS:** The design floats above Libby Creek. All program spaces have views out into the natural environment. The transient lodging space becomes a barrier between neighboring sightlines and the more frequently used program spaces. Melted snow is allowed to pass under the structure.

**CONS:** Large surface areas receive NW winds. Slope of roof design directs melted snow towards the existing cabin. Little interaction with the southside ridge. Surface areas are exposed underneath the structure because it is elevated above the landscape.

---

**Surfaces Normal to Opt. Orientation: 200 SF**

**Surfaces Normal to Sun Path: 1600 SF**

**Surfaces Normal to Northwest Winds: 600 SF**

**Privileged Views to Forested Areas / Creek**

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**West Elevation - Tree Canopy Diagram**

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Scenario 09: **ABOVE IT**

Total Forecasted Area - 1625 Sq Ft  
Percentage of Site Altered - 10.0%  
Number of Trees Removed - 9

**PROS:** Large amounts of surface capable of receiving solar exposure are located within opportune areas on the site. All program spaces have privileged views. The communal living space separates the resident and transient lodging from one another. The transient lodging section acts as a barrier, cutting off neighboring sightlines.

**CONS:** Pieces of the design could have a more substantial relationship with the southside elevation change.

---

West Elevation - Tree Canopy Diagram
Scenario Prototypes: Rankings - Parameter Specific Analysis:

1. Parameter 04 (Solar Position)

2. Parameter 01 (Topography)

3. Parameter 02 (Libby Creek)

4. Parameter 05 (Snow Loads)

5. Parameter 03 (Existing)

6. Parameter 06 (Wind Analysis)

7. Parameter 08 (Resident/Guest)

8. Parameter 07 (Transient Users)
Scenario Prototypes: Rankings - Comparative Analysis:

1. Positive: Submerged Lodging
2. Positive: Privacy Barrier
3. Positive: Grouped Program
4. Positive: Cantilevered Program
5. Negative: Blocked View
6. Negative: No Interaction w/ Ridge
7. Negative: Interrupted Space
8. Negative: All Program Submerged
9. Negative: All Program Submerged
External Parameters - Local ID:

These localized parameters define specific rules that each hybrid strategy will respond to in their approach.

**Parameter 01  (Global - Solar Position / Existing)** Solar exposure will be gained through the roof design

**Performance Implications:** It has been determined through the global analysis that contextual issues, mainly the mountainous topography and the tree canopy height, will make it nearly impossible to achieve solar exposure through any of the four elevations. Therefore, to address thermal comfort and proper daylighting levels within the enclosure, solar exposure will have to be addressed through the roof design. The angle of the roof will shift in order to capture daylight from late morning to late afternoon, targeting specific spots through the tree canopy. In an effort to strengthen the analysis done on the existing cabin, the proposed roof will morph into the southern portion of the cabin’s main pitched roof. The goal will be to bring light into the current living space.

**Architectural Effects:** One of the effects that will be achieved is a simulation of the filtering of light through the forest’s tree canopy. A hybrid structural system will be used for filtration; altering between the use of opaque, translucent and transparent materials. Formal decisions will also aid in the effort to produce this effect.
External Parameters - Local ID:

Parameter 02  (Global - Topography / Resident/Guest)  **Transient lodging will be submerged underground**

**Performance Implications:** The transient lodging space will be submerged into the southside ridge (oriented from E to W), allowing only the south elevation to protrude out of the landscape toward Libby Creek. This rule has been developed to address the size and use frequency of the lodging space. The large strip of space will most often remain uninhabited; guests will primarily use it as their sleeping quarters only. The move underground attempts to seal off three of the elevations from any climatic exposure, therefore allowing the earth to aid in temperature control. The exposure of the south elevation will be used to bring proper daylighting levels into the space.

**Architectural Effects:** The space will have a ‘cave-like’ effect, allowing for guests to share in a relationship with the creek in a private, nearly detached, space. Privacy will be found in the depth of the space as one chooses to move further away from the south elevation. Submerging the lodging primarily below grade will open up views for all other program areas. It will maintain a linear ‘bar’ form to accent the movement of the ridge around it. The narrow strip of program space will also lend itself to the design of minimal sleeping compartments for guests.

Parameter 03  (Global - Topography / Libby Creek)  **Above ground program spaces will cantilever off of ridge**

**Performance Implications:** The move to raise the design off of the ridge will help the melting snow find the elevation change and drain into Libby Creek. Although this creates more exposed surface area underneath the cabin, it guarantees that those elevated spaces will always be capable of receiving sunlight; never being sealed off by snow drifts.

**Architectural Effects:** As the program spaces become elevated they will be forced to reach out toward the creek. The property lines cut off the design from having any direct relationship with Libby Creek, however this parameter sets up an effect where the spaces begin to hover over the most advantageous site feature. These cantilevered spaces will always remain exposed to share in a relationship with the exterior environment.
External Parameters - Local ID:

**Parameter 04** (Global - Wind Analysis / Snow Loads / Transient Users) **Western elevation will act as a snow drift guide/barrier**

*Performance Implications:* Because of the temporal nature of the user group, it will not be a goal to completely seal off the west elevation from NW winds (the cabin will primarily be used during the summer and fall months of the year). However, as the NW winds deposit snow drifts diagonally across the site, an effort will be made to collect and guide them towards Libby Creek. This parameter responds to the quantity and frequency of snow in the Snowy Range mountains. A large surface area will be used to direct snow to the south ridge. As the snow melts, it will more easily find Libby Creek. It is crucial for the melting process to be considered as large volumes of snow (appx. 250"/yr.) may restrict access to the cabin in the late spring/early summer.

*Architectural Effects:* The opacity of the west elevation will slowly deteriorate as the wall section moves from north to south away from the most intense NW winds; opening up prime western views to forested areas. In this direction, Libby Creek can be seen as it travels down the mountain through the site. The way in which the snow will be collected may produce an effect which raises the ground plane toward the roof line during certain times of the year, perhaps burying the new addition within the snow mass. Western views out of the cabin could potentially be sealed off through the winter and early spring months (November-April/May). This emphasizes the importance of southern sightlines out of the cabin.
External Parameters - Local ID:

Parameter 05  (Global - Existing)  **Eastern elevation will act as a privacy barrier**

**Performance Implications:** A large surface area, with minimal fenestrations, will be used to shut off neighboring sightlines from the east. This wall will be part of the resident bedroom space. The wall will maintain a thick, opaque section to aid in the storage of solar radiation. Trapping heat which is brought in through the roof design.

**Architectural Effects:** Sealing off the east elevation will force the new addition to open up to the south and west. Formal gestures will target these directions in order to offer the resident and guests the most sought after views on the site; the creek (south) and the forest (west). As the new spaces open up to the south and west, the dichotomy of wanting exposure during the day versus privacy at night will have to be addressed. This environment remains beautiful by day but in contrast, becomes intensely dark by night, creating a certain level of vulnerability within the lit program spaces. A selective approach will have to be taken in locating fenestrations; recessed openings will be targeted.
External Parameters - Local ID:

Parameter 06  (Global - Existing) **Existing program spaces will not be interrupted**

**Performance Implications:** The intention will be to leave everything but the roof of the existing structure intact, with minor alterations occurring for the attachment/extension of spaces. This will reduce the amount of disruption produced onsite to the current environment.

**Architectural Effects:** What will be the resulting effect is an ‘attachment’ structure. The new proposal will make little effort to become visually, or physically, integrated into the existing cabin. The existing cabin will remain for several reasons; because the Forest Service will not allow it to be torn down, because it seems unnecessary to tear it down, and because its presence captures ‘the cabin’ as it existed in 1932.

Parameter 07 / 08  (Global - Resident/Guest) **Extension of living space will connect to current communal area / Studio addition will connect to current bedroom / Transient lodging space will be attached to the living space extension**

**Performance Implications:** These parametric relationships will ensure that the program spaces remain in close proximity to each other in response to the extreme conditions of the subalpine climate zone, even in the summer temperatures drop to uncomfortable levels as the sun disappears. There is no need to create unnecessary volumes and surface areas to control. It will also be beneficial to have one restroom available to all three of the above ground program spaces, and one singled out for the more transient guests below.

**Architectural Effects:** In doing this, the spaces become controlled by the resident. She will often times be the only one occupying this very isolated cabin. The effect will be a sense of security. The architecture will seemingly begin as one unified element, incorporating into it both program spaces, which then separates into distinctly different formal moves as Libby Creek is approached.
Hybrid Strategy 01:

01 Living Space
02 Bathroom 1
03 Studio / Bdrm 2
04 Outdoor Space
05 Transient Lodging
Hybrid Strategy 02:

01 Living Space
02 Bathroom 1
03 Studio / Bdrm 2
04 Outdoor Space
05 Transient Lodging
Hybrid Strategy 03:

01 Living Space
02 Bathroom 1
03 Studio / Bdrm 2
04 Outdoor Space
05 Transient Lodging
Strategy Selection:

The following diagrams illustrate why Strategy 02 has been chosen to be developed during Phase 2 of the project. Strategy 02 has the most potential to respond specifically to the external parameters during design development.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>01</th>
<th>02</th>
<th>03</th>
<th>04</th>
<th>05</th>
<th>06</th>
<th>07</th>
<th>08</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presence</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
</tbody>
</table>

Positive: Views are set up as one moves through the spaces (Parameter 06)

Positive: Cross-ventilation can occur through each tube. The public tube can utilize NW winds (Parameter 04)

Positive: Snow coming from the NW can be collected to open up views and movement in/out of the spaces (Parameter 04)

Positive: The angle of the tube separation establishes an outdoor space on top of the transient lodging tube (Parameter 03)

Positive: A barrier occurs to shut off neighbor sightlines. The cabin is forced to open up to prime views (SE/SW) (Parameter 05)

Positive: Tube geometry presents opportunities for solar exposure to be brought into the spaces during specific times of the day (Parameter 01)
Response to Geometry:

The new geometry will respond to the geometry of the original 1932 cabin and its additions. Specifically, the roof geometry will remain the cabin’s dominant feature and the new program spaces will act-like extensions off of the original structure.

Roof Geometry =

![Typical Cabin Geometry](image1)

![Transition of Geometry](image2)

Image of existing roofline looking NE. The roof transitions from a pitched roof into a sloping, one-directional surface.

The new addition will be inspired by this same geometry. The roof will become faceted in order to transition from a traditional pitched roof into a more pure ‘box’ form. The facets will be used to shed snow loads and to open up specific opportunities for solar exposure.

![Image of existing extensions which span off the front of the cabin looking SE.](image3)

The new addition will use the same language, creating 2 extensions off the back of the cabin. Extension 1 will house the communal living space. Extension 2 will house the permanent resident’s bedroom and bathroom.

The submerged program space will respond to the geometry of these 2 extensions.

Gray Fill = Opportune surface areas for solar exposure in response to the path of the sun through the site. These areas will utilize a custom glazing system in order to bring light into the program spaces below.
Geometry Phasing:

This sequence shows how the geometry changed as new information was considered.

- Roof facets added to consider snow / sun path
- Geometry begins to slope away from existing in order to collect shedding snow, to emphasize the cantilevered extensions and to setup views
- Submerged tube bends in response to privacy issues and view opportunities
- Roof portion of submerged tube slopes to the SW in order to take snow/rainfall away from what begins to be defined as a rooftop outdoor space

- Staircase is added as a fourth tube to create a link between the communal living space and the transient lodging
- Fenestrations begin to be considered to setup views through each tube and to address cross-ventilation
- Slope of tubes change in response to new design features
- Facets are added to submerged tube in order to establish a similar language between it and the 2 extension tubes
- SE face of submerged tube becomes recessed in consideration of privacy and indirect sunlight; bend fades to create a flush SE face

- Form changes dramatically as the structural system (steel rib spacing) is considered for issues of constructability (materials are selected)
- Facets are removed from staircase to express its independence from extension tubes
- Foundation wall is raised to meet, and support, tube Extension 1 and to become a retaining wall for the rooftop outdoor space
- Private outdoor space is established for tube Extension 2 (off of resident's bedroom) and glazing is removed from its SW face for privacy
- Geometry of submerged tube changes drastically in response to overall geometry changes; more facets, bend returns, a walk out platform appears, and an outdoor space is added to SW end
Geometry Phase 4:

This represents the final design phase before moving into CATIA to resolve the specific design challenge of the assembly; the relationship between the steel ribs and the custom SIPs panels.
CATIA Challenge:
Connection Detail (Ribs to SIPs):

Using an advanced parametric program like CATIA can help architects to resolve very specific design challenges to ensure that their designs are not later value-engineered back into a standard or conventional solution. Shown below (top) are standard details used by Precision Panel to assemble their Structural Insulated Panels (SIPs).

Below (bottom) is the detail being used by this project, where a replicated steel rib interacts with the SIPs in order to provide proper structural support for the geometry. This relationship is the specific design challenge that will be resolved by CATIA. CATIA is extremely helpful with advanced replication. In this particular case, the steel ribs and SIPs will be parametrically linked to rationalize the geometry as it transitions along the tubular form.

The use of CATIA enables new construction techniques to be developed. Instead of accepting conventional details which yield similar forms, new forms can be investigated through CATIA by pushing the materials to behave in unconventional ways.
Ribs to SIPS Relationship:

These images are screen snapshots taken from Rhino. What is being shown here is the inadequacy of Rhino to fully rationalize the ribs to SIPS relationship. It would be impossible to accurately forecast the location/angle of each SIPS pocket (connection moment through each rib) in Rhino. As is pointed out below, the ribs are not accurately responding to the form and they, at times, collide with one another. However, the benefit of using Rhino in design development is that it communicates directly with CATIA.

The shots shown below reveal early stages of the rib placement which attempts to acknowledge the 4’ module of a standard SIPS panel. This layout will later be developed further to fit into the assembly logic of CATIA.

The particular rib that is identified above indicates an error in the rib layout. All of the ribs will be adjusted later to respond to the tube kink, which must have one rib that spans across to connect its 2 kink points. In the shot above, the ribs are not responding to the kink in a logical way when considering issues of constructability.

The identified ribs above (left) show 2 ribs that have collided due to inaccurate spacing. This rib layout is, therefore, unworkable. If the project were to proceed in Rhino, a new model would have to be generated using a new spacing dimension.

The identified rib above (right) shows a rib which is not in alignment with the change in geometry. All ribs that are not perpendicular to the form are inaccurate. This would present an impossible challenge in Rhino to correct.
>> CATIA Logic: >>
Logic Diagrams 1/2:

The diagrams below capture steps 1 and 2 in setting up the design logic for working in CATIA.

*Diagram 1* establishes the point of radial symmetry at the tube kink. This helps in determining the bounding box (also shown).

*Diagram 2* uses the radial point to determine the final rib layout. The spacing increments begin at 4’ in response to a standard SIPs panel dimension. However, this distance is forced to adjust to the kink in the geometry; later the increment dimension returns to 4’.
Logic Diagrams 3/4:

The diagrams below capture steps 3 and 4 in setting up the design logic for working in CATIA.

*Diagram 3* responds to the bounding box and rib placement in order to determine offset points for the outline of the final geometry.

*Diagram 4* locates the base connections for each rib in correspondence with the final geometry. The connection point is indicated with a black dot below.
Composite Diagram:

This diagram was ultimately used in CATIA as the reference geometry.
CATIA Process: >>
Driving Geometry:

The splines (white) function as the driving source for the driven geometry (rib section). Offset planes have been used to locate points to define each spline.

(Unrolled Tree Capture = ‘Structure’ part file; containing all of the driving geometry and its corresponding parameters)
Design Volume Geometry:

The volume lines (heavy white) were constructed by connecting the points previously located in space by the driving geometry.

(Unrolled Tree Capture = Identified parameters for potential change control of the geometry)
Design Volume Surfaces:

The surfaces (orange) help to further define the design volume and setup the potential for ‘intersection’ lines to be developed.

(Unrolled Tree Capture = Volume lines used to establish the ‘filled’ surfaces)
PowerCopy Sections:

The section lines (light white) mark the location of each rib placement. These lines establish the position of each powercopy as it updates/adjusts.

(Unrolled Tree Capture = PowerCopy planes labeled as Bays 1 through 17)
Driven Rib Geometry:

The ribs (grey) single out the 6 sections capable of being powercopied along the driving geometry.

(Unrolled Tree Capture = ‘Rib (Bay 3)’ part file; stores all of the rib information including its parameters)
PowerCopied Ribs:

The ribs (grey) are the result of each powercopy. Each one is unique and updates/adjusts itself to the driving geometry (form).

(Unrolled Tree Capture = ‘Product 1’ file; containing all part files including 15 ribs)
Driven SIPs Geometry:

The SIPs (beige) are parametrically linked to the rib sections. Each pocket connection is unique within the system.

(Unrolled Tree Capture = ‘SIPs (Bay 3-4)’ part file; stores all SIPs information including its parameters)
PowerCopied SIPs Panels:

The SIPs (beige) are the result of each powercopy. Each one is unique and can be manufactured from this information.

(Unrolled Tree Capture = List of all SIPs part files within the 'Product 1' file)
>> Variable Changes: >>
Automatic Change Propogation:

The examples on the right show 3 versions of the design which have responded automatically to variable changes in the predetermined parameters.

1. Kink angle has been changed to reduce the size of the form based on the axis of symmetry
2. Low ridge point and several corner heights have been changed to raise the overall ceiling height
3. High ridge point (connection point at existing roof) and the offset dimension of the window bulge has been changed to accentuate the ridge line and enlarge the overall floor area
>> Geo Changes: >>
CATIA Impact (Roof Plan):

This diagram shows how the geometry of the roof has been shifted in plan by the CATIA model. The grey outline represents the initial design phase in Rhino, while the brown outline reveals the changes made by the CATIA logic. The corner points were set up using parameters, so they can be adjusted later if needed, but they will always be forced to respond to the rib layout (light grey).
Bay Assembly:
Bay Section Callout:

The outputted information from CATIA was brought back into Rhino to develop detailing of the bay section.
Glazing System Assembly Sequence:

1. Stl Wedge Connected to Channel Cap
2. Intermittent Stl Riser
3. Alum Mullion w/ Internal Drains
4. Insulated Glazing Unit
5. Custom Stl Arm / Drainage Channel
6. Custom Copper Cladding (MetaPERF Surface)

Selected Assembly Diagrams:

1. Plate Connection Detail
2. Shelving Bracket Detail
3. Base Connection Detail
Custom Components (CATIA Generated):

The image on page 114 represents a sheet of model parts, which has served as a guide for the project. The goal was to arrive at a point where the design could be understood down to the relationship between internal parts. Some of those parts (Bays 11-12) are shown here. They have been generated by CATIA and are ready for fabrication.

Nested Information (Optimized Object Positioning) =

The steel ribs were divided into Parts A and B which would be assembled using steel plates. Each piece has been nested (using RhinoNest) in 4’ wide steel sheets; optimized for the predetermined material dimensions to eliminate waste. The pieces would be cut using a 5-axis router.

(Steel Plate / Part A / Part B)
Custom Cladding Panels (CATIA Generated):

The gradient indicates a transition in the percentage of solar exposure passing through the panel based on the quantity and sizing of the perforation holes. More light is needed toward the existing cabin, therefore the panels open up as they move away from the end of the tube extension.

MetaPERF is a surface finish which punches custom perforation holes into steel panels.

The panels have been generated by CATIA and are ready for fabrication.
>> Design Proposal: >>
Site Plan / Floor Plans:

<table>
<thead>
<tr>
<th>Number</th>
<th>Room</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>Kitchen</td>
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<tr>
<td>02</td>
<td>Entry</td>
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<tr>
<td>03</td>
<td>Bedroom 1</td>
</tr>
<tr>
<td>04</td>
<td>Living Space 1</td>
</tr>
<tr>
<td>05</td>
<td>Bathroom 1</td>
</tr>
<tr>
<td>06</td>
<td>Bedroom 2</td>
</tr>
<tr>
<td>07</td>
<td>Private Balcony</td>
</tr>
<tr>
<td>08</td>
<td>Mechanical / Storage</td>
</tr>
<tr>
<td>09</td>
<td>Mechanical / Storage</td>
</tr>
<tr>
<td>10</td>
<td>Outdoor Space</td>
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<tr>
<td>11</td>
<td>Living Space 2</td>
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<td>17</td>
<td>Bathroom 2</td>
</tr>
<tr>
<td>18</td>
<td>Outdoor Space</td>
</tr>
</tbody>
</table>

Parametric Methods: *Wyoming Renovation >> Design Proposal*
Interior Renderings:

2 View from existing, looking down Living Space 1

3 View SE, looking out of Bedroom 2

2 View SW, looking out of Living Space 1
>> Conclusion: >>
Conclusion Statement:

This project has explored a parametrically-driven design methodology. The process has in fact been guided by rules and relationships through collecting and generating data. What has been engineered is a process, not a linear method which has been led from concept (or research) to form. The design is a direct manifestation of the established parametric relationships rooted in the project itself, forcing it to become architecture about architecture where the critical analysis is derived from the interjected cycle of information. In doing this, the proposed parametric design challenges conventional modes of practice by introducing digitalization as a way to manage, exchange and manipulate information. Just as theory confronted philosophy, new digital practices are using managerial thought to confront theory.

It has been suggested that this project asserts a ‘post-critical’ attitude toward design in that it opposes truth-seeking and the application of diluted theories/research to abstract forms. The term which is preferred by this project is ‘projective’ architecture; or, in other words, it advocates for an architecture invested in the hope for realization where the choice has been made to embrace the constraints of architectural practice in order to produce innovative design solutions capable of being projected into the ‘real’. ‘Projective practices’ argue that the architect marginalized him/herself through a refusal to become immersed in the complexity of the architectural process itself. What parametric design offers is an emphasis on process over the initial, conceptual starting point or the end, marketable product.

Another term which accurately defines this investigation is ‘new pragmatism’. The word ‘pragmatic’ has often had a negative connotation in architecture. But, what has been learned by this project through parametrics is that pragmatism can very much be about innovation, rather than standardization. Through the 70s, 80s and early 90s critical theory further separated thinking from doing in architecture, allowing it to feel secure existing in a purely conceptual state. That is no longer the case. The architectural vanguard now includes such ‘projective practices’ as; OMA, Foreign Office Architects, SHoP, Morphosis and Gehry Partners who use a thinking-as-doing mentality to create a ‘design intelligence’. All of these practices engage pragmatism as a way of developing new building technologies which often address issues of structural and environmental performance.

As a quote by FOA stated in the opening argument (pg 9), “Processes are far more interesting than ideas…”, this project has learned to abandon architecture’s strong relationship to marketing, which through theory and form-making has used digital tools as a way of marketing conceptual ideas, and instead it has opted to pursue a process-oriented design successfully aligning itself with more physical practices like engineering and, environmental and industrial design. What must be understood from this project as a process case study, is that parametrics is a design method. One must first learn how to think parametrically, to think in terms of design relationships, before parametric software can be utilized.

The parametric software is just the next step, another source of information which feeds into the design cycle. The software encourages the resolution of geometric relationships through parametric modeling. It is, therefore, capable of addressing very specific and unique design challenges. The goal was never to seek out a specific piece of software, and learn it. The objective was to tap into our collective intelligence, utilizing technology and available resources, to confront both external and internal project specific relationships. To do this, one tool was not targeted, but instead an effort was made to become equipped with the ability to understand the logic behind working with ‘our tools’ which have produced the next phase in digital architecture.

\[ \text{tools} \leftrightarrow \text{processes} \quad / \quad \text{thinking} \leftrightarrow \text{doing} \]
Resources:
Resource Credits:


www.centennialwoods.com
www.eikongraphia.com
www.fosterandpartners.com
www.grimshaw-architects.com
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