



Seasonal Sunlight Chamber: A Lighting Design Concept to Connect Us to the Dynamics of Sunlight and Our Place on Earth

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Abstract. People currently exist mainly indoors, detached from their natural surroundings. During times of rapid growth, globalization and digitalization, it has never been more important to investigate how to reconnect to our natural environment. In this paper we develop a design to investigate how a lighting design concept can act as a tool to understand the geometry of sunlight on Earth and thereby meet human needs to be in touch with the environment. A design is developed by redefining an ancient analogue technology, the sundial. The path of the Sun is translated into a design concept and is demonstrated in a three dimensional time and sight specific prototype. This design concept creates embodied experiences where viewers interact with their ever-changing daylight and surroundings. The aim with this exploratory design is to create a visual tool for learning about complex natural phenomena and understanding our relation to Earth and the Sun. It thereby discusses how a design can put humans in touch with their natural surroundings to satisfy individual biological needs in order to better understand contemporary environmental needs at large.

Keywords: Daylight design · Design research · Natural phenomena · Dynamic sunlight · Dynamic daylight · Sundial · Changing surroundings · Environmental change · Seasonal change · Circadian rhythm · Diurnal rhythm · Lighting design · Exploratory design · Teaching tool

1 Introduction

Exploring the human connection to diurnal changes in daylight is an integral aspect of human evolution and is vital in the development of this design in order to fulfill human needs. Research starts with the impact that the daily and yearly rotations of the earth have on human evolution. The earth rotates at a speed of one rotation around its axis every day and one rotation around the Sun every year. At the root of it, these changes are physical relations between one another. The day, month and year cycles are not tied to time, but they are tied to gravity and laws of motion [1]. In order to survive on Earth, all life, including humans, evolved to adapt to these kinds of external changes: “*For millennia*

before clocks, our only regular way of measuring time had been the alternation of day and night. The rhythm of day followed by night also regulates the lives of plants and animals. Diurnal rhythms are ubiquitous in the natural world. They are essential to life [...]. Living organisms are full of clocks of various kinds - molecular, neuronal, chemical, hormonal - each of them more or less in tune with the others” [1].

As day follows night, our hormones adapt, influencing our neurons, triggering a release of chemicals, resulting in behavior, etc. It is a constant feedback loop. The circadian rhythm exemplifies that the ability to perceive change is at the core of what makes an organism successful at living on Earth. We have developed ways to detect changes that occur in our surroundings. The sense which evolved most with the diurnal cycle of change is the eye’s ability to see light. *“Sight like hearing requires a modulated and crafted form of light for meaning. Stabilize images perfectly on the retina and they disappear. This is a fact of sense psychology. We see only change, movement, life” [2].*

Humans have evolved to have a keen sense for earthly changes. However, changes that happen at a slower time-scale, become visually unnoticeable such as a tree budding or ice caps melting. In this paper, these changes are defined as “earthly changes”. While earthly changes are not visually noticeable to the human eye, we have nevertheless evolved an acute ability to register them and they are vital to humans’ ability to perceive time. Our brain catalogues the gestalt feeling of a space. As Rovelli says, *“The past leaves traces of itself in the present” [1].* We are full of memories which are traces from the past and inform our present experience of our surroundings. The American researcher and lighting designer William Lam continues this thought when he says, *“Our evaluation of any environment is colored by the memory of prior experience in analogous situations” [3].* Humans constantly read their lit environment in order to acclimate to a space. Lam writes about lighting for humans’ biological needs. Among others, *“Location, with regard to [...] sunlight”* and *“Time, and environmental conditions which relate to our innate biological clocks”* are two major biological needs [3]. Lam references Vernon as he says, *“The type of motivation to which perception is mostly directly related is the necessity of maintaining contact with the environment and adapting behavior to environmental change” [4].* The circadian rhythm is a prime example of our biological ability to notice slow, earthly changes. By evaluating one’s lit surroundings, the circadian rhythm allows humans to prepare the body for changes to come.

While there is a strong biological need to connect to earthly changes in daylight, there is an even greater need for humanity to understand earthly changes in order to sustain environmental equilibrium on Earth. Instant gratification, more than ever before, seduces people’s focus, in turn causing us to disregard the experience of earthly changes. As the astronomer Carl Sagan says, *“We are very devoted to the short-term and hardly ever think about the long-term” [5].* A focus on slower, environmental changes is being overlooked. With this mass cultural switch, people have become more detached from their place on Earth and the rhythm of the day and year. This becomes particularly crucial when conceptualizing the interconnectivity of humans and the planet which is vital in order to understand the environmental impact humans have on Earth. While seasonal climates are changing, ecosystems are thrown off balance [6]. Understanding the interconnectivity between humans and the Earth’s ecosystems is the first step toward managing a healthy and sustainable environment.

This paper illustrates how a design concept can build a connection between individuals and their environment. Donella H. Meadows explains how we operate within an interconnected world, full of systems which have built our belief systems, physical relations and natural surroundings [7]. Life as we know it is held together by these ever-changing feedback-loops. While generating substantial change is difficult, Meadows says there are different leverage points to “*change the structure of systems*” [7]. The most impactful instrument of change is to alter a mind-set—a “*paradigm*” [7]. This, she argues, is not quantifiable, it is a belief system, an outlook. For an individual, “*All it takes is a click in the mind [...] a new way of seeing.*” [7]. We have all experienced the instant when something clicks into place: comprehension is unlocked and we truly understand something new. These moments often occur during experiences. Experiential learning is a powerful method for learning and “*take[s] place between individuals and the environment.*” [8]. While developing a design, the goal is to create an experience that puts individuals in touch with their environment in order to see their surroundings in a new way. The design approach is inspired by the Exploratorium where “*exhibits [...] let you interact directly with real phenomena*” to “*create inquiry-based experiences that transform learning*” in order to encourage viewers to “*confidently ask questions, question answers, and understand the world around them*” [9]. In this project, an exploratory design is used in order to investigate a natural phenomena – sunlight’s relationship to earthly changes. By learning through exploratory design, viewers can build an appreciation for the immense system on which we live—Earth.

This paper is based on a MSc thesis of Lighting Design at Aalborg University by the first author [10]. It leads to a question for investigation: How can a lighting design accentuate changing moments of sunlight, thus building an understanding of peoples’ place on Earth? Continued research explores ways of using ancient tools that accentuate a changing moment of sunlight in order to develop a contemporary and innovative design that connects people with their place on Earth.

2 Sundial: A Tool to Visualize Change

The Sundial is an ancient analogue technology that uses the predictable relationship between Earth and the Sun to visualize change. It utilizes the straight rays of sunlight in order to mark daily and yearly changes. Blocking sunlight creates a sharp shadow with high contrast between light and shadow. Since sunlight-shadows create sharp edges, one is able to notice the position of the Sun in relation to an object based on the shadow that it casts. In a sundial, the position of the shadow is contextualized in the cycle of the day and year. A mark of sunlight exists in relation to the rotation of Earth around its axis and around the Sun. By using this astronomical tool, we are able to predict where the Sun will be in the sky at any given moment in any place on Earth. By marking the position of sunlight at a given moment, it creates a visual reference to a moment of light in the past and future. It calls attention to the earth’s routine of light. While sunlight is not always visible because of weather conditions, the earth’s rotation allows for the Sun’s movement and position to be predictable throughout a space. The predictability of sunlight’s movement will be referred to as the “*geometry of sunlight*”. Sundials use the geometry of sunlight to offer a visual and spatial orientation to the time of day and year

and place on Earth. The concept of this ancient technology is incorporated in the design development in order to spatially visualize the daily and yearly cycles.

The sundial is traditionally used to quantify change rather than to create an experience of change. However, the experience of earthly changes, particularly in daylight, is not only a human biological need [3], but is vital in understanding the timescale of contemporary environmental changes. Occasionally, there are moments during the day and year that accentuate poignant experiences of light, such as at sunset. Encounters like these remind us of the unique beauty of a particular moment on Earth. Witnessing a precise moment of light draws attention to the change inherent in daylight. Learning from these experiences of unique moments of light ground us in our ever-changing physical surroundings. Concepts of sundials appear in art and architecture throughout time.

“[Light] has been treated scientifically by physicists, symbolically by religious thinkers, and practically by artists and technicians. Each gives voice to a part of our experience of light. When heard together, all speak of one thing whose nature and meaning has been the object of human attention and veneration for millennia. During the last three centuries, the artistic and religious dimensions of light have been kept severely apart from its scientific study. I feel the time has come to welcome them back, and to craft a fuller image of light than any one discipline can offer” [2].

Artists and architects accentuate the dynamics of daylight in order to connect viewers to their place on Earth. The following artists, architects and historic sites act as inspiration for developing an exploratory design that focuses on creating a space to experience changes in sunlight.

A historic monument in Ireland called Newgrange, is aligned with the mid-winter sunrise. During this time, sunlight enters 18 m through the space, clearly accentuating a magical moment during Ireland’s dark winters [11]. James Turrell creates *Skyspaces* to observe the dynamics of daylight [12]. In the stillness of his architectural spaces, the changes in daylight become central. Chris McCaw creates photographs where the Sun burns a hole into a film negative creating a time lapse or map of the Sun’s movement throughout the course of a day [13]. The Finnish architect Pallasmaa describes natural light as a vital light source for humans but also as something we often take for granted. He expresses excellent architecture as something that makes us aware of the surroundings by letting us experience light in all its nuances and feel its presence in space [14]. Lastly, the Danish architect Jan Utzon explores this phenomenon in his own house in Mallorca. The house is built to accentuate the dynamics of daylight over the course of the day and year [15].

Referring to phenomenological philosophy, these projects do more than just create a visual experience of the movement of light. Light interacts with the space, creating embodied experiences from which to learn from while being present in the space [16]. They develop atmospheres that change with their viewers.

3 The Exploratory Design

3.1 Design Concept

To investigate how to create a better understanding of earthly changes an exploratory design is developed. The method refers to Schöns reflection-in-action [17] and the Exploratorium [9]. The concept for the exploratory design is to investigate how to use sundial technology to develop a design that meets the human biological need for experiencing and understanding earthly changes in daylight [3]. By experiencing changes in sunlight, viewers observe their connection to their surroundings. This design sets out to investigate natural phenomena and create a visual experience of “*change, movement, life*” [2]. Experiencing these rhythms of light connects people to rhythms of life. As daylight slowly changes, people’s emotional and physical states change accordingly. Based on the research presented in the introduction and the artistic and architectural inspirations derived from sundials, a set of criteria are determined for creating the design concept: the design must be created in relation to the geometry of sunlight throughout a space and use sunlight to accentuate daily and seasonal changes.

Using these criteria, a structure is developed to create a space where viewers experience changes in sunlight. The design is built based on its relation to the Sun and exemplifies direct sunlight as it enters into a structure. Sunlight enters into a long rectangular opening on the top of the space and casts a stripe of sunlight down the side and bottom of the structure. Over the course of a day, the stripe of sunlight enters through the opening, and moves down the west wall. It aligns with the floor precisely at midday. After midday the sunlight moves up the east wall. Midday is the only time when light does not hit the walls (see Fig. 1).

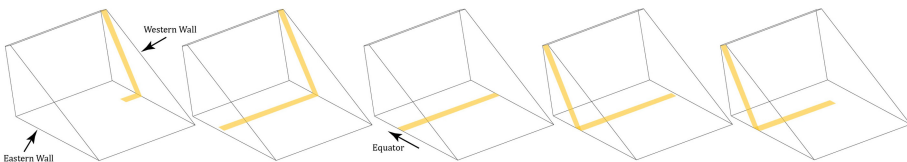


Fig. 1. Figure shows the sunlight as it moves through the space before midday (left), at midday (center) and after midday (right). The opening faces toward the equator (180°S in the Northern Hemisphere and 0°N in the Southern Hemisphere). This image depicts the light moving through the space in the Northern Hemisphere. Figure by Emma Strebel.

Over the course of six months, sunlight moves from the southernmost point to the northernmost point of the floor. Every year, the sunlight moves throughout the space and back again, filling the entire space with light twice per year (see Fig. 2).

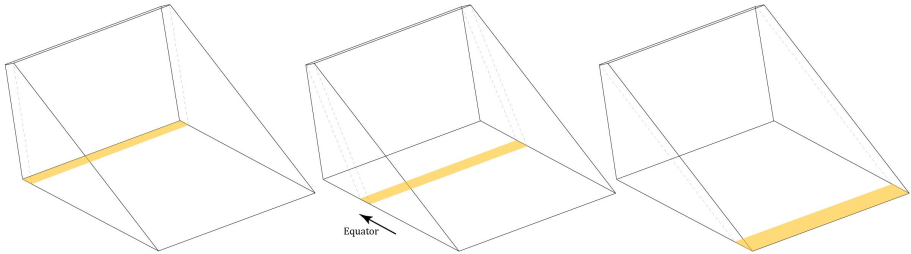


Fig. 2. Figure shows the sunlight as it moves through the space at midday over the course of 6 months from June solstice to December solstice. Figure by Emma Strebel.

The seasonal geometry of sunlight determines the angles of the north and south walls of the structure. Depending on the latitude of where the piece is installed, the angles of the north and south walls are different. While the size of the opening and the difference between the angles of the north and south walls stay the same with a consistent 47° , the shape of the entire structure changes relative to the ground (see Fig. 3 and 4). In Denmark, for example, the midday sun on June solstice has an altitude of 58° which is the angle of the south wall, and the midday sun on December solstice has an altitude of 11° which is the angle of the north wall (see Fig. 5).

The north and south walls are determined by the angle of the sunlight at midday on June solstice and December solstice. No matter where one is on Earth, the difference between these angles is 47° . The area that is created is a seasonal sunlight chamber which becomes the design (see Fig. 3, 4 and 5).

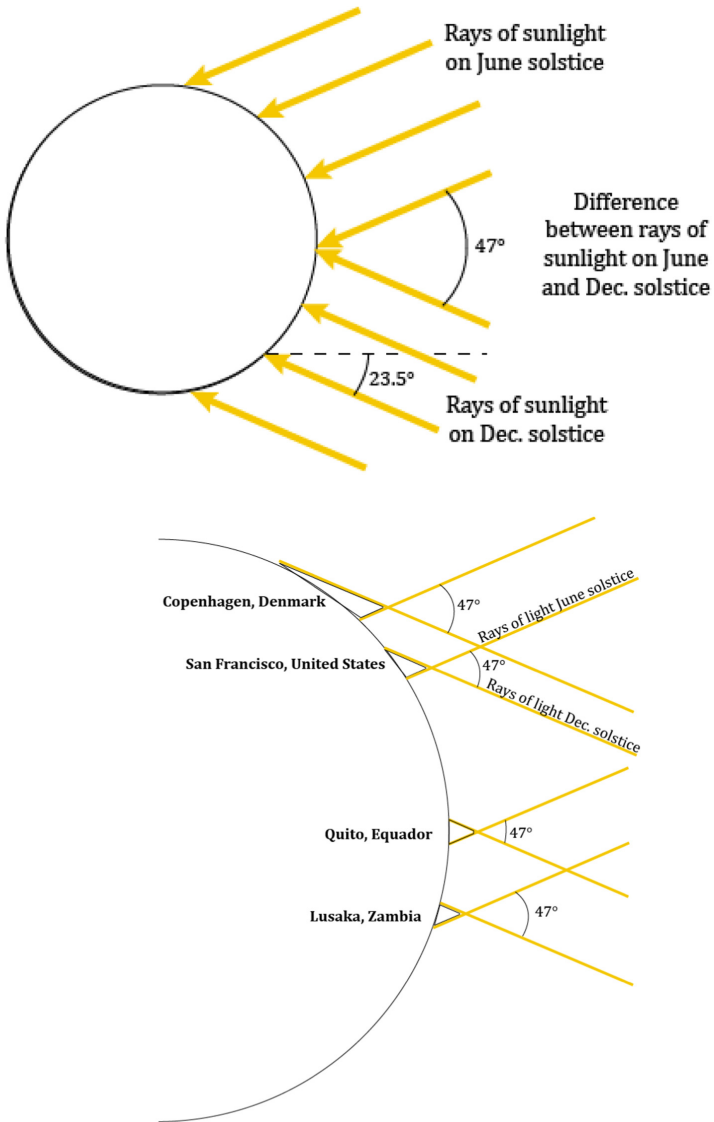


Fig. 3. Figure shows the change in angle of sunlight depending on season. The rays of light on the solstices create the angles of the north and south walls of the structure. Since sunlight hits the earth in parallel lines, the difference in the angle of sunlight hitting the earth between the solstices is always 47°. Figure by Emma Strebel.

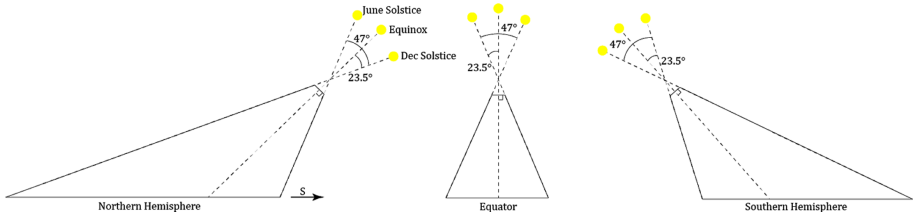
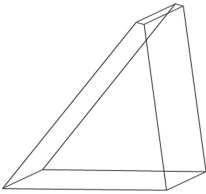
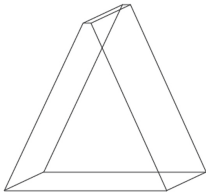


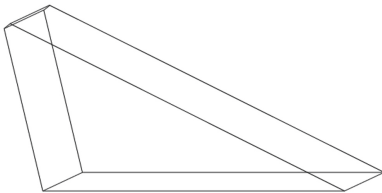
Fig. 4. Figure shows the general shape of the structure depending on whether the design is located north, south or on the equator. Depending on where the structure is located, the opening faces a different direction. The opening is always perpendicular to the angle of sunlight at midday on the equinox. Figure also shows that the north and south walls are angled with 47° difference. Figure by Emma Strebel.



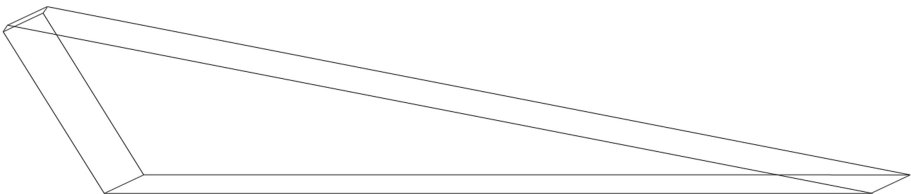
Lusaka, Zambia
 June Solstice Midday: altitude 51° at 0° N at 12:08
 Dec Solstice Midday: altitude 82° at 180° S at 12:04



Quito, Ecuador
 June Solstice Midday: altitude 66° at 0° N at 12:15
 Dec Solstice Midday: altitude 67° at 180° S at 12:11



San Francisco, United States
 June Solstice Midday: altitude 76° at 180° S at 13:11
 Dec Solstice Midday: altitude 29° at 180° S at 12:09



Copenhagen, Denmark
 June Solstice Midday: altitude 58° at 180° S at 13:11
 Dec Solstice Midday: altitude 11° at 180° S at 12:07

Fig. 5. Figure shows the shape of the design as it were located in different places on Earth. Figure by Emma Strebel.

The variations in the shape of the structure visualize the acute differences in sunlight based on its location on Earth. Far from the equator, the angle of the sunlight is shallower and thus, the angles of the north and south walls are shallower. Since the structure is built in relation to its location on Earth, each aspect of the design is dependent on that location. Regardless of whether the sun is shining or not, the differences in the design's structural form visualizes the differences in sunlight at different places on Earth.

3.2 Prototype

A prototype is created to examine how the sunlight moves throughout the space. The calculations of the north and south walls are specific to the location of San Francisco. The mockup is made out of diffuse plexiglass so that the structure is not transparent but the direct sunlight is visible from the outside. In this iteration, the prototype hangs from two C-stands so that the opening faces 180° south and the bottom is level to the ground. Once the prototype is set up, the movement of the sunlight is documented through the structure close to June solstice (see Fig. 6) and near December solstice (see Fig. 7). Due to the parallel rays of sunlight, this design is scaleable to any dimension. While this prototype is under a cubic meter, the design would operate the same way as a room viewers could enter into.



Fig. 6. Photos demonstrate the design prototype using Lighting White 60% plexiglass. The top image shows light entering into the structure precisely at midday near to June solstice. The following three photos show the light as it enters into the structure after midday. Photos taken by Emma Strebel.



Fig. 7. Photo shows light entering into the structure at midday as the season nears December solstice. Photo taken by Emma Strebel.

The design specifically accentuates the experience of solar midday. Just as people enjoy watching the transition that takes place at sunrise and sunset, this design creates a space to observe midday: the moment when a particular place on Earth transitions from rotating toward the Sun to rotating away from the Sun. It disconnects viewers from time as an objective truth, and rather connects people to the inherent changes that are always occurring around us. The design specifically highlights one moment at one particular place on Earth. It develops a connection to the human biological need to experience changes in daylight. The design offers a meditative space to experience the dynamics in sunlight and learn about our profound relationship to earthly changes. While sunrise and sunset are inherently climactic changes in the experience of light throughout the day, midday often goes unnoticed. As the earth constantly rotates, no two consecutive moments of sunlight are the same. This design calls attention to the midday change—midday is the only moment at which the light hits the floor of the structure without hitting either of the east or west walls. Without this significant design element, midday would go unnoticed. Furthermore, the design highlights both solstices (when the beam of light reaches the southern and northern walls), which are also moments that would otherwise go unnoticed.

At any moment that someone encounters the design, it offers a visual comparison. For the first half of the day, the sunlight inches down the wall and across the structure. While the sunlight is constantly changing throughout the entire day, the moment of anticipation is for midday. The climactic moment builds up anticipation and offers a visual comparison for prior and following moments. Over the course of a year, this design frames the light in a way which highlights Earth's more gradual rotation towards and away from the Sun. It visually represents where the earth is on its journey around the Sun. Over the course of one year, the position of the sunlight starts at the south

wall, moves toward the north wall, and then reverses to move back to the south wall. This element of the design accentuates seasonal changes in light. Experiencing these changes strengthens people's understanding of their ever-changing surroundings.

4 Discussion

This exploratory design is developed to meet the human need to experience natural change when indoors and build an understanding of environmental change at large. The aim is to create an experience that enables us to learn more deeply about the rhythms of daylight and thereby stimulate biological needs for connecting humans to nature. In doing so, viewers become familiar with the earth's timescale of change and learn about the interconnected systems we exist within [7]. Combining Lam [3] and Böhme's [18, 19] theories on biological needs and atmosphere, the design creates an atmosphere that tracks changes in sunlight in order to fulfill the biological need to connect to daylight. While creating a design, the goal is to illustrate how a tool can accentuate a moment of sunlight in order to help people notice a changing moment on Earth and learn about the relation between humans and the universe. The design detaches changes in sunlight from clock time as we know it and creates an awareness of the way sunlight moves through a space in order to accentuate the viewers' experience on Earth. By connecting to changes in sunlight, humans learn the importance of building a connection to their place on Earth.

This design concept can be implemented for site specific installations. The proposed design concept is a basic design that can be altered in many ways. In any scale or iteration around the world, the design offers an experience for learning more intimately about the relation between humans and the universe.

This paper proposes an exploratory design method to demonstrate how to use the geometry of the sunlight in order to create a spatial design that enhances the human connection to Earth and the natural rhythms of the day. In a broader context, this approach focuses on biological needs, developing an architectural space where experiencing the dynamics of the daylight connects us to our surroundings [3]. This method develops sustainable design grounded in one's natural surroundings in order to conceptualize the rhythms of the earth. These principles focus on experiential and exploratory learning [9] and can be integrated into architecture and lighting design beyond this particular project in order to investigate natural phenomena. Working with the geometry of sunlight at particular locations on Earth generates architecture that is better able to connect people to their surroundings. With a deeper connection to earthly changes, humans become more in tune with diurnal rhythms, and their connection to daylight and sunlight. In doing so, architecture and lighting design is able to enhance the human connection to light and "*set the internal world to the external world*" and visa versa [20]. With this fundamental connection, viewers build an understanding of the timescale of the earth's environmental changes and the interconnectivity of our place on Earth.

5 Conclusion

This paper sets up an exploratory design to investigate how to develop a lighting design rooted in the geometry of sunlight that connects humans to the rhythm of the day and year.

The design explores the movement of the earth and the position of the Sun in relation to one's location on Earth. By applying this natural scientific approach, the design creates a space centered around the experience of earthly changes in sunlight. It marks one moment of change at midday, the slower rotation of an entire day and the even more gradual fluctuations throughout the year. With these comparisons, viewers depart from their familiarity of clock time by connecting to visual changes and routines in sunlight. These connections help develop an understanding of the earth's constant fluctuations. Change has enabled our evolution, intertwined us with light and will continue to define our experience of life on Earth. As humans increase their impact on the earth's ecosystems, understanding its timescales has never been so important. This understanding is a step toward the human need to empathize with and take care of the environment at large. The design demonstrates how a design can be a tool that informs viewers about the complex and fundamental interaction between the earth, Sun and human. It develops a space to acquaint humans with the inner workings of sunlight, in turn connecting us to our place on Earth and in the Cosmos.

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