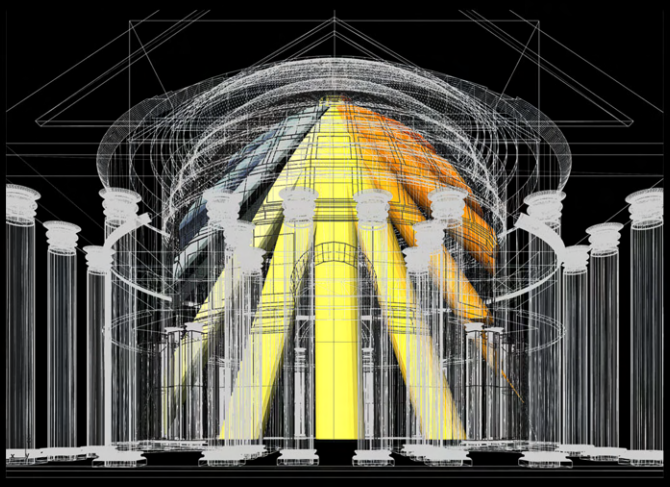
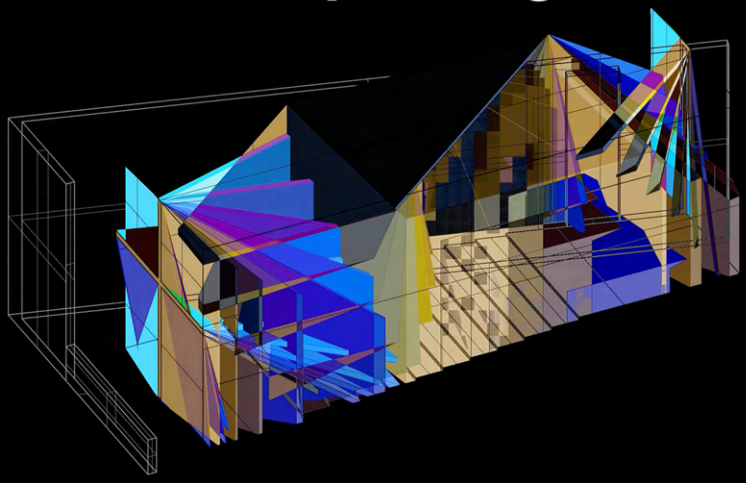
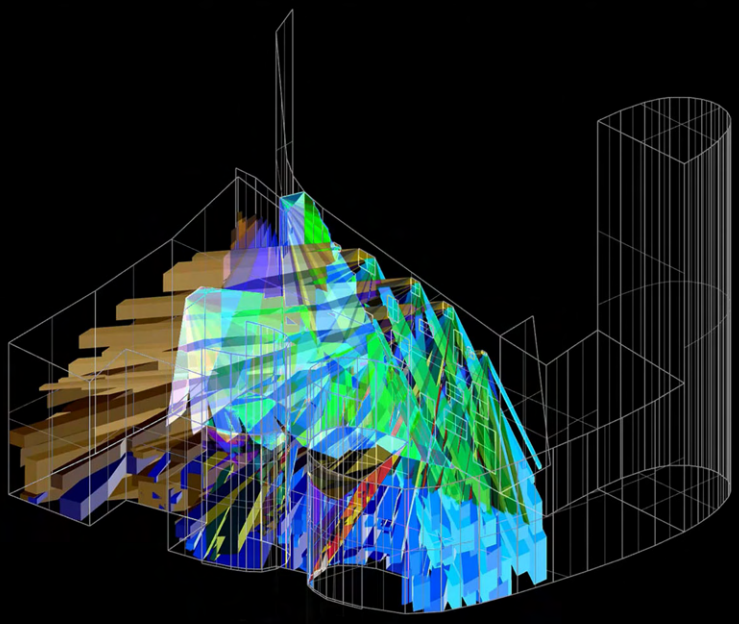


The Shape of Light



How can understanding the ‘shape’ and movement of light help architects design buildings with intentional artistic, spatial and experiential outcomes?



LOUIS WOOD

THE SHAPE OF LIGHT: HOW CAN UNDERSTANDING THE 'SHAPE' AND MOVEMENT OF LIGHT HELP ARCHITECTS DESIGN BUILDINGS WITH INTENTIONAL ARTISTIC, SPACIAL AND EXPERIENTIAL OUTCOMES?

TUTOR
RICARDO CODINHOTO

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FOR THE BEST READING EXPERIENCE, IT IS RECOMMENDED TO VIEW THIS PAPER AS DOUBLE PAGE SPREADS (FACING PAGES).

Abstract

Little else in architecture has such an unrivalled ability to generate mood and sensation than the presence of light. On his Beaux-Arts training, Kahn reminisces: “They gave us an unquestionable feeling of the inseparability of light and building, and the fact that we could construct light”. It is unfortunate then, that the latter half of this statement by Kahn, regarding the architect’s ability to construct light, is so often forgotten. Openings frame views, they order facades, and often, are sized to allow for just the right level of illumination at the working plane. Seldom, in modern day tradition, is the ‘shape of light’ considered of primary concern.

This paper will be an exploratory dive into this very ‘shape of light’. The movement and form of light in buildings. Approached through the development of a novel framework, within which the ‘shape of light’ is visualised as a tangible, three-dimensional form.

The aspiration of this paper is twofold. Firstly, to develop a methodology for exploring the intangible qualities of light through experimental processes. Resulting in a spacial and temporal representation of light in architectural space; where the positive and negative space created by light shapes a three dimensional diagram. Secondly, to critically analyse this representation, in an attempt to uncover new insights into how light shapes spatial and experiential outcomes within buildings.

By considering light with respect to the same spacial criteria as volume and space, can we more deeply understand its role in shaping the architectural experience, and encourage a more considered approach to designing with light?

Table of Contents

Introduction

On his Beaux-Arts training Louis Kahn reminisces: "The Beaux-Arts system included lessons in shades and shadows. These exercises made us aware of light, of shade, and of shadow, of reflected light. They gave us an unquestionable feeling of the inseparability of light and building, and the fact that we could construct light" (Jordy, W, H., 1974). It is the latter of these three sentences taken from a 1974 interview with Kahn that interests me most. Architects frequently discuss the role light plays in shaping space, but rarely the 'shape' of the light itself. When designing the placement of a window in a building, the primary concern shaping that design decision is usually the outwards view. Second only, perhaps, to requirements regarding levels of illumination at the working plane, and the usual daylight factors. The danger with this approach I feel, is that the window can be pushed so far into the realm of the technical, that the emotional or experiential possibilities are limited. As such, 'the shape of light' inside any given space becomes a consequence of design, rather than the result of intention.

"THEY GAVE US AN UNQUESTIONABLE FEELING OF THE INSEPARABILITY OF LIGHT AND BUILDING, AND THE FACT THAT WE COULD CONSTRUCT LIGHT"

LOUIS KAHN, 1974

And here we can draw a distinction between architects; those for whom light is a consequence of more practical concerns, and those for whom it is intention. Kahn's comments about "constructing light" allude to his being an architect of the latter constitution. His geometric 'ruin' facades and subtle diffusing filters are designed, no doubt, with respect to the 'character' of light entering his space - this much can be deduced from his extensive description of the window design at Kimbell museum and the associated quality of light (Kahn, 1969). Of course, considered use of natural light is far from novel in architecture. The temple at Abu Simbel built by Ramses II is illuminated twice a year by a beam of natural light (Britannica, n.d), and the 'Jantar Manta' structures, built across north India in the 18th century, use daylight to measure time, among other celestial events (Gupta, 2019). Of course where the context of buildings is not concerned, we can look to the sundial and its precursor the gnomon, which predates these structures by millennia (Britannica, n.d).

For Kahn, "no space, architecturally, is a space unless it has natural light" (1969). Light was central to his philosophy, it was the "giver of all presences"; it made a material and the material made a shadow (Wurman, 1986). Schielke identifies a link between Kahn's belief that "A plan of a building should be read like a harmony of spaces in light"… "defined by its structure and the character of its natural light" (Lobell and Kahn, 2008), and Kahn's signature 'wrapping' facades. A primary result of which, Schielke continues, is that attention is concentrated on the "effect of light and not its origin" (n.d.). Kahn described this approach as "wrapping ruins around buildings" (1957).

Kahn's architecture was 'shaped' by shadow (Schielke, n.d.), and "shadow belongs to light" (Wurman, 1986). If we are to continue to develop upon this line of understanding; we may arrive at the following question:

HOW CAN UNDERSTANDING THE 'SHAPE' AND MOVEMENT OF LIGHT HELP ARCHITECTS DESIGN BUILDINGS WITH INTENTIONAL ARTISTIC, SPATIAL AND EXPERIENTIAL OUTCOMES?

How can this be approached? The paradox of light is its intangibility; in spite of its presence all around us, everything we see is the result of light, but never the light itself. Therefore, it follows that the difficulty in designing with light, lies in its inability to be visualised. Any analysis must be performed by means of a proxy, for example, light reflecting off a surface. Furthermore, light is viewed in two-dimensions, yet the space it occupies is three-dimensional. What is required therefore, is a method of visualising light itself in three-dimensions; a way of actualising it into something tangible.

Consider the example of simulating 'animal vision' by Vasas et al. (2024) (fig. 2,3). Here, while tackling the question "how do animals see the world?", the researchers developed a method of visually depicting the spectrum of light that extends beyond the visible range. The result? An entirely novel way of observing our environment; elucidating elements previously invisible to the human eye and therefore, providing new possibilities for study. It follows then, that a similar approach could be taken for visualising the 'shape of light' and that doing so could open up new possibilities for analysis of light in architecture.

FIGURE 1 THE RUIN FACADES AT THE INDIAN INSTITUTE OF MANAGEMENT (Ghinitoiu, 2022).

“A GREAT AMERICAN POET ONCE ASKED THE ARCHITECT, ‘WHAT SLICE OF THE SUN DOES YOUR BUILDING HAVE? WHAT LIGHT ENTERS YOUR ROOM?’-AS IF TO SAY THE SUN NEVER KNEW HOW GREAT IT IS UNTIL IT STRUCK THE SIDE OF A BUILDING”

LOUIS KAHN, 1974 (GIURGOLA & MEHTA)

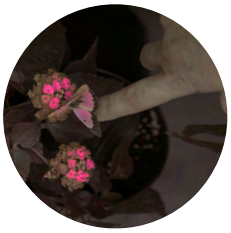

FIGURE 2 SCREENSHOT FROM VIDEO SHOWING THE ULTRAVIOLET REFLECTION OF A BUTTERFLY’S WINGS, AS SEEN BY THE AVERAGE UV-SENSITIVE AVIAN VIEWER (Vasas et al., 2024).

FIGURE 3 SCREENSHOT FROM VIDEO SIMULATING THE VISION OF HONEYBEES (Vasas et al., 2024).

In its final iteration, this approach could become a tool in the design process. But in its early stages, this approach can be applied to case study buildings, in an attempt to see whether the output provides new insights into the experiential effects of natural sunlight.

FIGURE 4 A SIMILAR STUDY: SCREENSHOTS FROM A VIDEO COMPARING THE SAME IMAGE TAKEN IN VISIBLE AND ULTRAVIOLET LIGHT SPECTRUMS. HERE WE GATHER A NEW UNDERSTANDING OF HOW BIRDS MIGHT PERCEIVE EACH OTHER (BBC, 2015).

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Kahn, Corbusier, Ando, Apollodorus of Damascus and the Pantheon.

Kahn.

Few are better known for advocating for the power of natural light in architecture than Louis Kahn. He talks of the way light strikes the side of a building (Giurgola and Mehta, 2975), or how it's 'luminosity' gives a comforting feeling of knowing the time (Kahn, 1969) with such poetic quality that he has become among the most quotable of architects on the subjects. Kahn was an architect deeply concerned with the relationship between light and space and material; Darnthamrongkul (2024) highlights Kahn's celebratory attitude toward the invention of the column, the moment the wall became transparent and let the natural light in. Kahn writes "It was an event so delightful and so thought-wonderful that from it almost our life in architecture stems" (1957).

While he inspired many in his tradition of 'designing with shadow' such as Ando and Zumthor (Schielke, n.d.), Kahn himself acknowledged Le Corbusier as a fundamental inspiration in a 1972 interview, coining his now famous phase "How'm I doing Le Corbusier?" (McLaughlin, 1972).

Le Cobusier.

"In Le Corbusier, light was always a central theme" writes architect Alberto Campo Baeza (2006). He speaks of the impossibility of discussing light in architecture without quoting the Swiss architect. Nowhere is Le Corbusier's ability to direct light demonstrated more clearly than in his sacred buildings. The most famous of which being his Chapel at Ronchamp, a photograph of which adorns the cover of Henry Plummer's first edition of "Masters of Light" (2003) where he names it the "greatest metaphysical work of the century".

"ARCHITECTURE IS THE LEARNED GAME, CORRECT AND MAGNIFICENT, OF FORMS ASSEMBLED IN THE LIGHT."

LE CORBUSIER, 1998

Le Corbusier and Kahn, the early and late modernists, both grappled with the importance of natural light in architecture. Kahn viewed light as a material force, and worked it to expose the true beauty of the material, while Le Corbusier used light, particularly in sacred spaces, to orchestrate an expression of the daily celestial cycle (Plummer and Le Corbusier, 2013).

Campo Baeza also highlights three sketches by the Le Corbusier that "are even more expressive than his words on light" (2006). Drawings of his own chapel at Ronchamp, the Hagia Sophia, and the Pantheon with its "cannon of light" tracing the path of the daily sun.

Pantheon.

Derived from the greek 'πᾶν' pan – all, and 'θεός' theos – god, the word 'Pantheon' literally means 'of all gods' (British Museum, n.d.). It is fitting that when looking for a symbol to represent a temple to all gods, the likely architect, Apollodorus of Damascus, designed a roof that "resembles the heavens" (Rich, 1990), an opening to the sky, and a ***beam of sunlight.***

Despite the Pantheon being of such rich cultural importance, it is only mentioned in two roman sources (Hannah and Magli, 2009). Rendering the true intentions of the designers opaque, nonetheless it is clear that light, natural and direct, is of the greatest importance in shaping the space. It is in some sense the purest built representation of light in architecture.

As Ando writes"; The Pantheon in Rome is, for me, an example of perfect harmony in architecture"… "The purest geometric forms and the natural light imbues the space with life. I believe it is the ultimate harmony between nature and architecture" (Robertson, n.d.).

Ando.

The journey of Tadao Ando is intertwined with both the legacy of Le Corbusier and the pantheon. A self-taught Ando, like Le Corbusier, began his architectural journey with a second-hand book by the Swiss architect bought at the age of nineteen from a local charity shop. He later came across the Pantheon during his travels around Europe in 1965, he was 24 and the Japanese ban on foreign travel had just been lifted. Schielke

(2024) notes how different the intense beam of light from the roman temple must have been to an Ando born in the country of diffuse shoji screen doors and light-filtering verandas.

However different, the pantheon's direct relationship with the sun left a lasting impression on Ando. In a 2021 editorial for Domus he wrote "If you ask me what the archetype of space is, my answer is, 'the volume and direction of light'", specifically referencing the pantheon where "the ever-changing streams of light flow through an oculus according to the sun's movements" (Ando, 2021). He again mentions both the Pantheon and Kahn when asked about his influences in an interview in 2024. Kahn himself was heavily influenced by Japanese architecture (Heathcote).

At his Church of the Light in Osaka (1989), Ando employs, like the Pantheon, this idea of a powerful central opening to the outside. He does so once again in an even more direct reference to the Pantheon at his Hill of the Buddha in Sapporo (2015). Where a central oculus in the corrugated domed structure illuminates, in a sundial fashion, the Buddha statue contained therein. In both of these works Ando makes full use of the architect's ability to shape light, making it as core to the buildings function as form and volume.

While the ancient Roman temple's direct and focused use of light is a clear influence in Ando's work, less obvious is the relationship of his work to that of Kahn. In the 1995 film "Louis Kahn: silence and light", Ando shares his appreciation for Kahn's Indian Institute of Management (1974) stating that the work "is much closer to the essence of architecture" than Kahn's more modern works in the US. He comments on the almost entire lack of glass in the building (fig. 1); "There are openings to the outside on the walls but there is no glass". He continues, stating the resulting light coming through these openings can make an "incredibly dramatic architecture", indeed originally at Church of the Light, Ando preferred to leave glass out of the cross shaped opening (Schielke, 2024).

For Kahn, Le Corbusier, and Ando, their architecture is defined by how they use light to interact with material and shape experience; it has become synonymous with their architectural approach. This not however an exhaustive list of those modern or contemporary architects who direct light in such a meaningful way. The case for designing with light is backed by many other greats, like Zumthor with his take on the 'pantheonic' oculus at his Bruder Klaus Chapel (2008), or Jean Nouvelle with his many faceted screens at his Institute du Monde Arabe (1987) and Louvre Abu Dhabi (2017) to name a few. Indeed however, in modern times, as architect Sourabh Gupta writes, "there are few architects whose works stand out distinctly as being synonymous with light"; Le Corbusier, Kahn, Ando and Zumthor (2019).

In an article for the Architectural Review on the legacy of Kahn, William JR Curtis writes regarding the influence of Ando, Kahn and Le Corbusier; "Ando's typical concrete surfaces were surely inspired by the planes dissolved in light at Salk, but these in turn drew a great deal from Le Corbusier's Carpenter Center for the Visual Arts at Harvard, right down to the handling of grooves and joints". Curtis elucidates the shared legacy of material and light between the three architects and it is for this reason, along with the Pantheon, that their work has been selected as case studies in this paper.

It is my hope that the use of light in these buildings can provide insights into how light can be shaped to create meaning, informing the experimental framework used in this paper.

Research Methodology

The methodology of this paper is based on the following: that by representing light in a solid form, we might learn something new about how it impacts space and therefore how best to design with it. The intangible nature of light presents a challenge in terms of understanding its shape and representing it in traditional two-dimensional drawings and even three-dimensional renders. Thus, if we solidify the path of the light along its journey from opening to surface, we obtain a concrete representation of it, one that is more easily analysed and communicated. This is an experimental approach; the beginning of a new way to represent and analyse light in buildings, and could be further developed into new tools and methods.

Generating these solid forms of light involves using 3D software to model space, generally simplified versions of rooms with openings and any significant internal or external objects that would block the path of the light. Light is then projected through the openings, along a vector determined by a given sun position(s), generating a bounding box that is filled to create one or more solid volumes.

This study focuses entirely on direct sunlight as a subset of natural light; light that has not yet bounced off another surface. This is due to its ability to be sculpted with form, its changing movement with sun position, and its overwhelming impact on architectural space.

This method will be tested in a pilot study using a simple room in order to demonstrate how the concept of light as a solid is being approached, and how key elements such as changing light over time will be represented.

This method will then be applied to select case studies:

- THE PANTHEON
- CHURCH OF THE LIGHT
- NOTRE DAME DU HAUT

The selection of these three buildings as case studies is informed by their status as pillars of architectural innovation in the use of light. As a collection, they provide a wide range of temporal and cultural contexts, while embodying a shared philosophy developed over millennia. This provides an ideal testing ground to validate the methodology's ability to analyse light over varied conditions, and identify common elements.

Drawing conclusions.

Visual analysis of the case studies aims to answer the following. Using the methodology, can we understand to a deeper degree; the shape of light in architectural space, how it changes over time, and explore how light creates certain spatial and experiential outcomes.

This will be done through the use of top-down turntables, eye-level perspectives and sequential views, which will allow for the development of a narrative in each space.

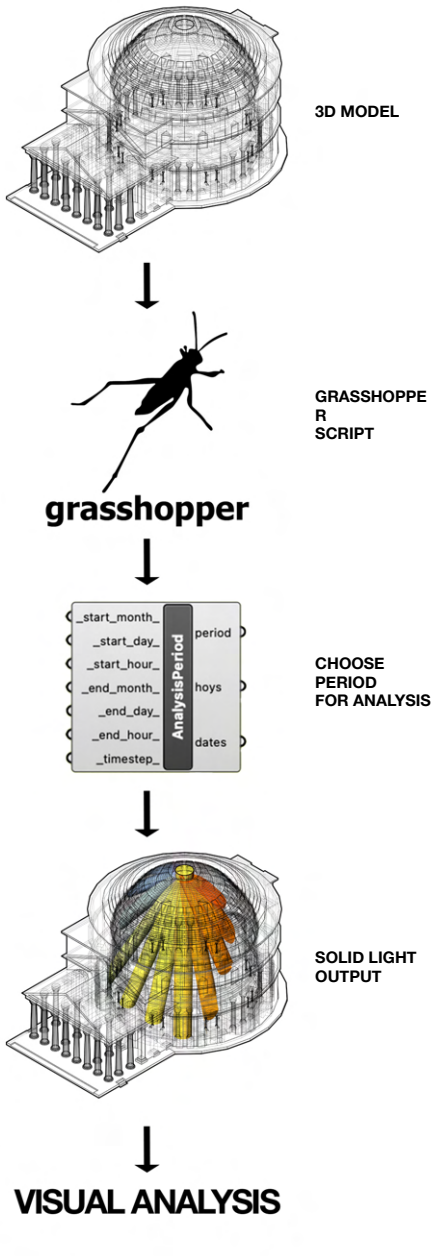


FIGURE 5 DIAGRAM OF METHODOLOGY PROCESS.

QR code access for all project videos.

Pilot Study

The methodology of this paper is highly experimental. Therefore, it follows that preliminary studies are necessary to assess the validity of the methods employed to address the research question.

The main section of this paper consists of applying the methodology to select case studies. The resulting analysis will aid in understanding the symbolic role of light in the building, and its experiential implications. The following pilot study however, was structured to establish the following:

- THE COMPUTATIONAL METHOD BY WHICH DIRECT SUNLIGHT IS MODELLED IN A CHOSEN SPACE,
- HOW THE EVOLUTION OF LIGHT THROUGHOUT THE DAY IS REPRESENTED,
- HOW THE FINAL LIGHT SCULPTURES WILL BE PRESENTED,
- THE POSSIBILITY OF INCLUDING ARTIFICIAL LIGHT SOURCES. ULTIMATELY THIS DID NOT PROCEED TO THE MAIN STUDY.

The Movement of the Sun.

The following figures and video attachment model the movement of the sun (solar azimuth) around a room throughout the course of a day. Black polyester thread runs along a parallel path from the sun's position (fig. 6,7,8,9) to the window corners. It is by projecting this path through the room, or building, that the 'shape' of light is found (fig. 10).

QR code to access pilot study physical turntable

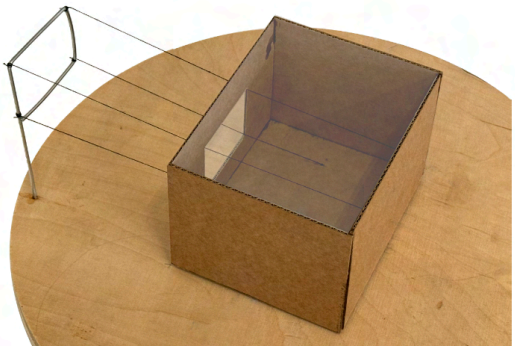


FIGURE 6 MODEL DEMONSTRATING HOW SUNLIGHT ENTERS A ROOM ALONG PARALLEL PATHS.

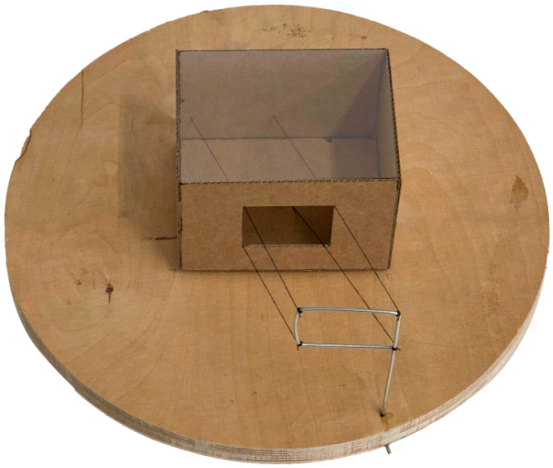


FIGURE 7 TOP VIEW OF PILOT STUDY MODEL.

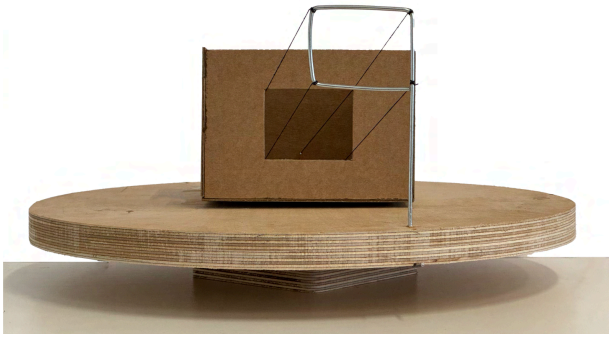


FIGURE 8 FRONT VIEW OF PILOT STUDY MODEL.

FIGURE 9 INTERNAL VIEW OF PILOT STUDY MODEL. BLACK THREAD FORMS THE BOUNDS OF THE ‘SHAPE OF LIGHT’.

FIGURE 10 WOODEN SCULPTURES PRODUCED BY TAKING THE FORM OF THE BLACK THREADS AGAINST THE SHAPE OF THE ROOM. THIS FINDS THE ‘SHAPE OF LIGHT’ FOR A GIVEN SUN POSITION.

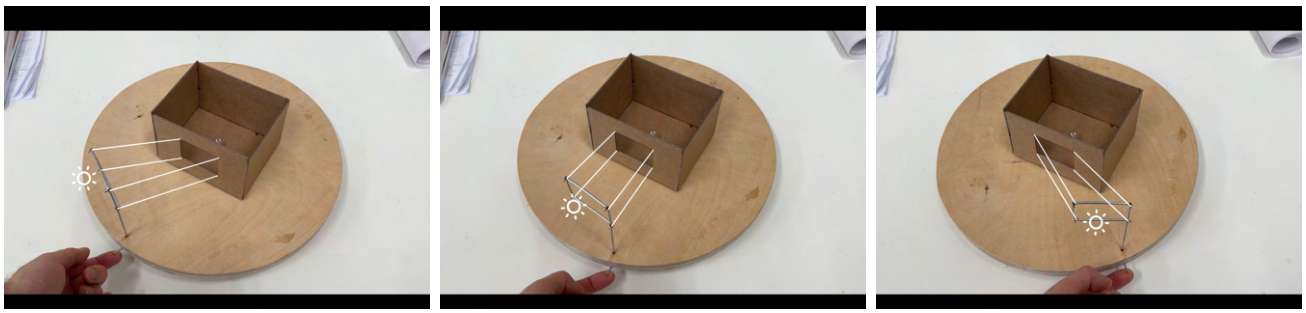


FIGURE 11 SCREENSHOTS FROM PILOT STUDY TURNTABLE VIDEO.

The Digital Model.

As shown in figure 11, to map the 'shape of light' over time, many different sun positions must be accounted for. Therefore, for use with more complex buildings, a digital method of representing solid light was required. Figure 13 shows the initial grasshopper script developed for the pilot study. It is broken down into the following components:

1. SUN GENERATION

2. INPUTS

3.1 DIRECT LIGHT MAP
(NOT USED IN MAIN STUDY)

3.2 NATURAL LIGHT GEOMETRY

3.3 ARTIFICIAL LIGHT GEOMETRY
(NOT USED IN MAIN STUDY)

4 COLOUR ASSIGNMENT

1. Sun Generation.

Creates a sunpath based on geolocated EPW data (fig. 14).

2. Inputs.

The referenced building geometry.

3.1 Direct Light Map.

This component maps the internal surfaces of the space, indicating how much light each surface received. This is a more traditional type of analysis and did not fit with the experimental nature of finding the 'shape of light'. As such it did not proceed to the main study.

3.2 Natural Light Geometry.

Projects a solid through any openings along a sun position vector to create a solid beam of light (fig. 15).

3.2 Artificial Light Geometry.

A preliminary test for artificial light sources, simulating the presence of external street lighting. The key difference between this artificial light and sunlight lies in the distance between the light source and the observer, resulting in a significantly wider shape (fig. 16). Although this test was not conducted further, it's worth noting the profound impact this artificial light has on the interior space compared to sunlight, which forms a far narrower beam (fig. 15,16).

4. Colour Assignment.

The final element of the script colours the beams of light based on the time of day they would appear in the building. Warmer colours denote the morning sunlight and cooler colours denote the evening light.

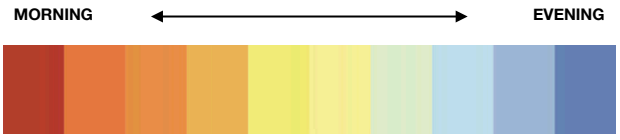


FIGURE 12 COLOUR KEYS FOR GEOMETRY BASED ON TIME OF DAY.

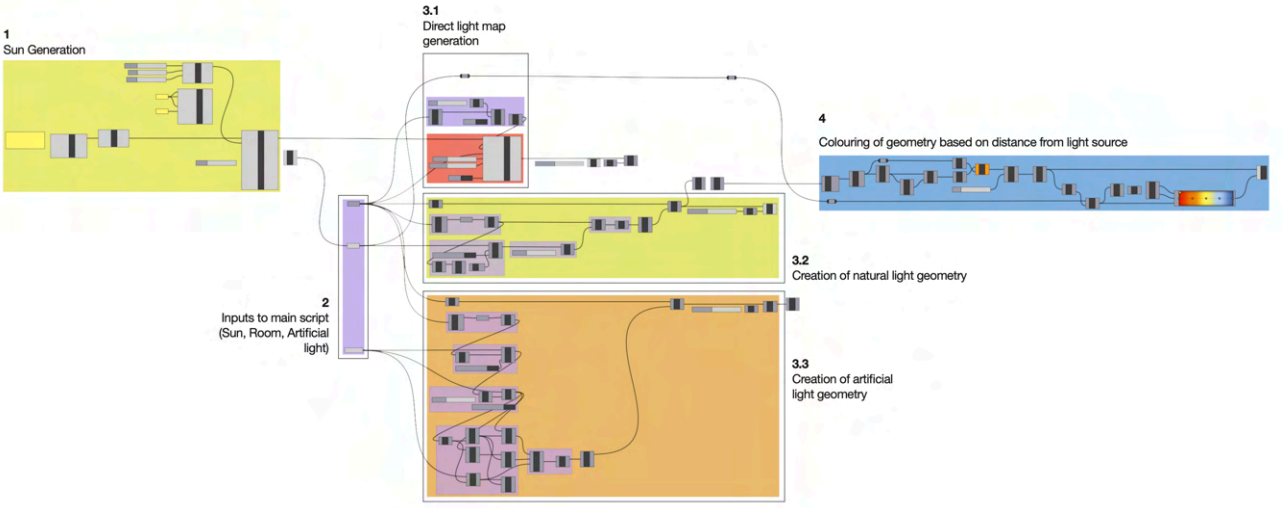


FIGURE 13 INITIAL GRASSHOPPER SCRIPT DEVELOPED DURING THE PILOT STUDY. THIS SCRIPT INCORPORATES SEVERAL ASPECTS THAT DID NOT PROCEED TO THE MAIN STUDY.

THIS SCRIPT WAS THEN TESTED ON A DIGITAL VERSION OF THE PILOT STUDY MODEL AS FOLLOWS:

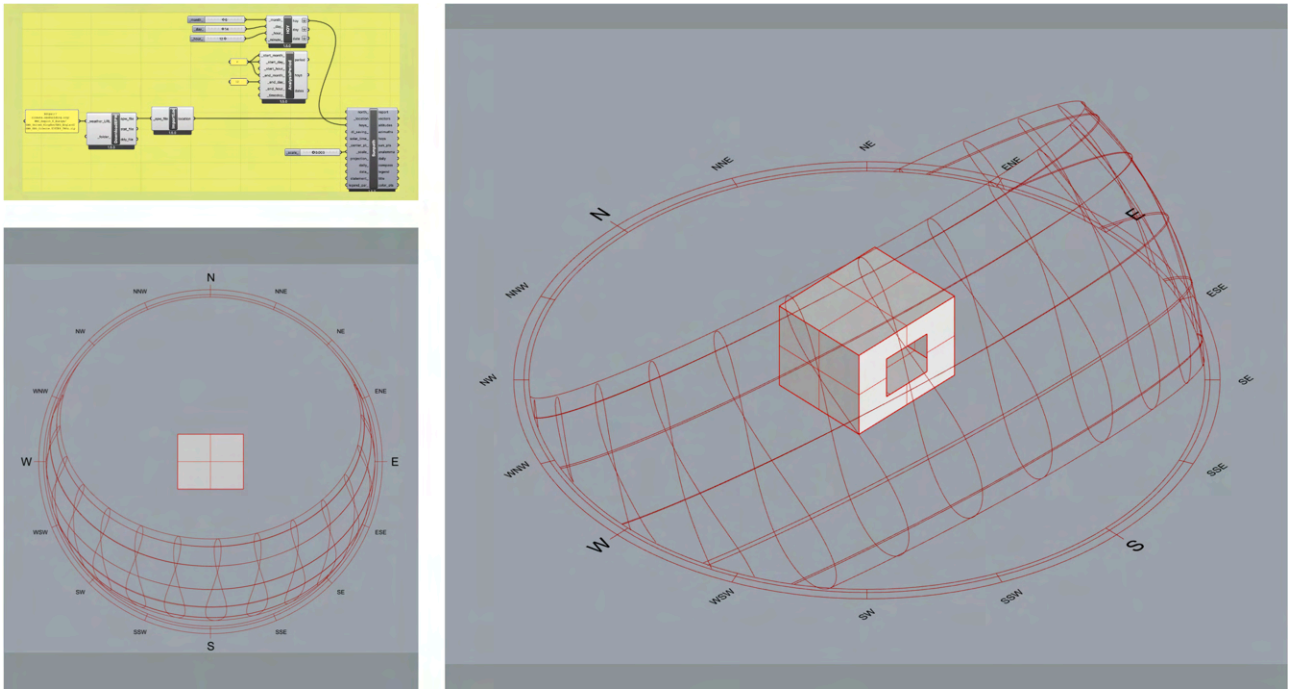


FIGURE 14 EPW DATA GENERATING A SUNPATH AROUND MODEL.

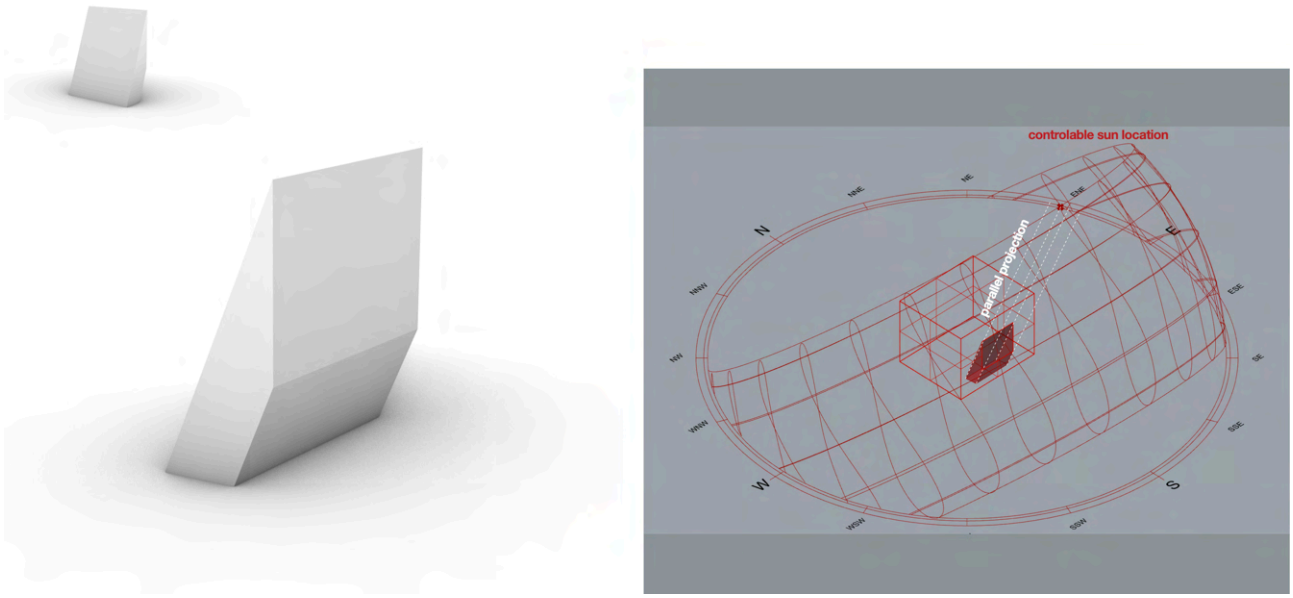


FIGURE 15 CREATION OF NATURAL LIGHT GEOMETRY. LEFT TO RIGHT: FINAL FORM, PROCESS

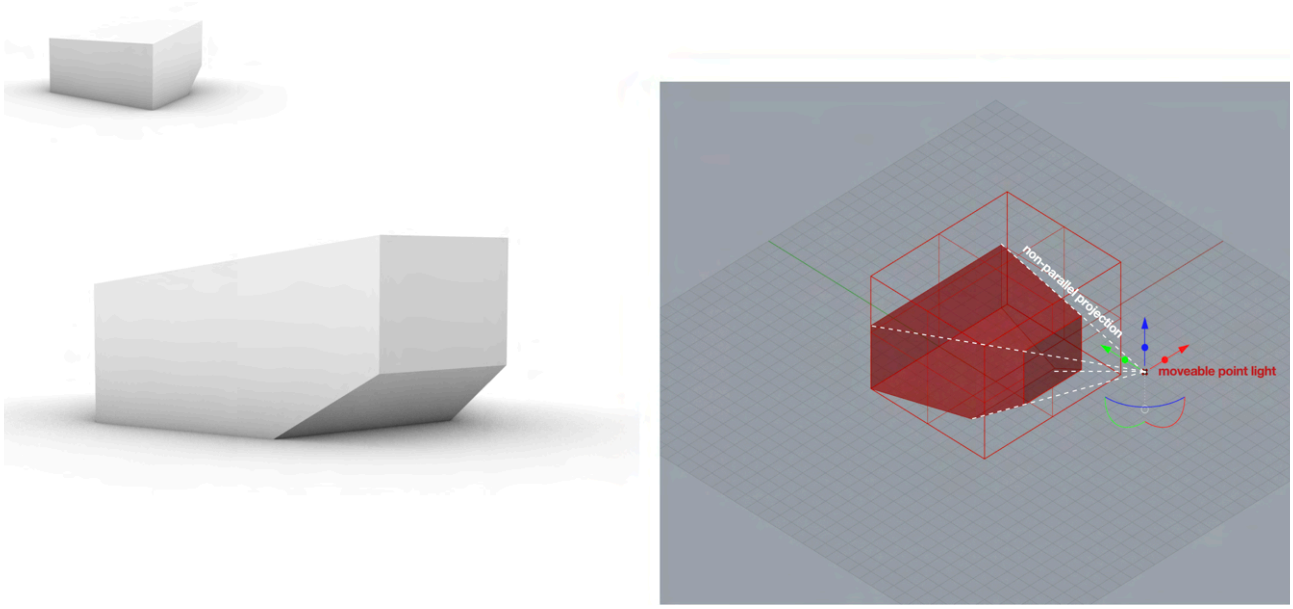


FIGURE 16 CREATION OF ARTIFICIAL LIGHT GEOMETRY. LEFT TO RIGHT: FINAL FORM, PROCESS

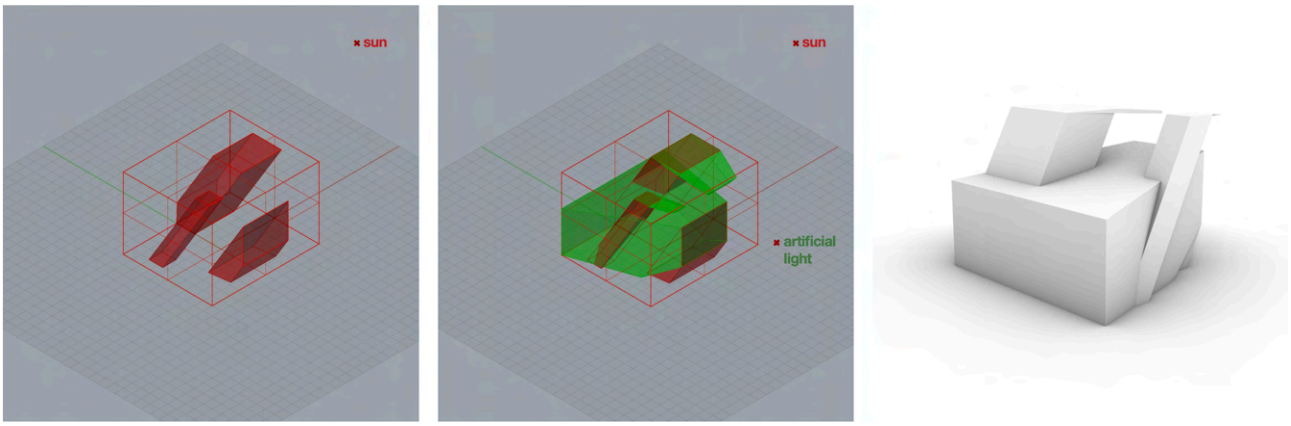


FIGURE 17 INTRODUCING MULTIPLE OPENINGS. TEST WHERE NATURAL AND ARTIFICIAL LIGHT ARE COMBINED INTO ONE MODEL. LEFT TO RIGHT: NATURAL LIGHT, ARTIFICIAL LIGHT, FINAL FORM.

A NEW GRASSHOPPER SCRIPT WAS THEN CREATED (FIG. 18) TO REMOVE UNUSED FEATURES AND TO INCREASE RENDERING SPEED. IT WAS THEN TESTED ON THE FOLLOWING ROOM IN FIGURE 19 TO PRODUCE THE FINAL OUTPUT OF THE PILOT STUDY.

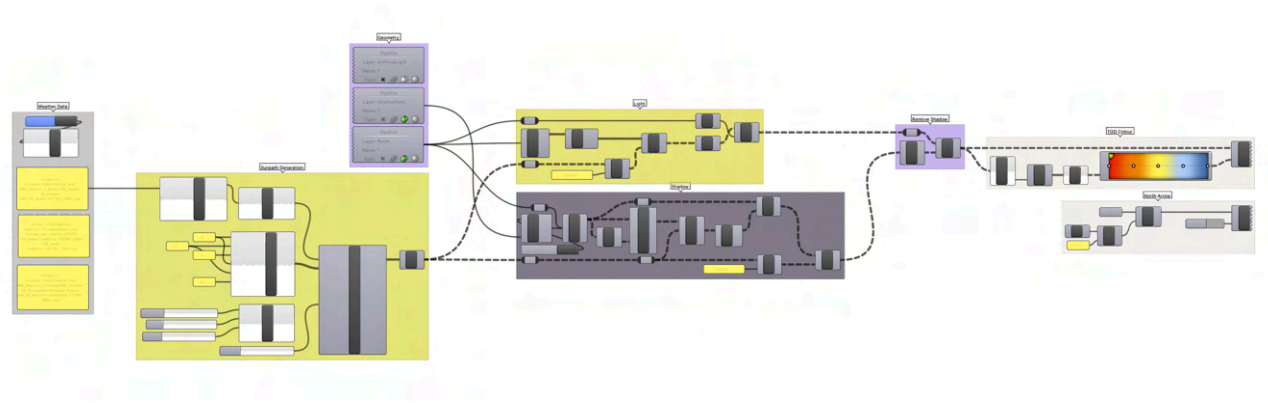


FIGURE 18 FINAL SCRIPT TO BE USED WITH CASE STUDIES. SEE APPENDIX FOR MORE DETAIL

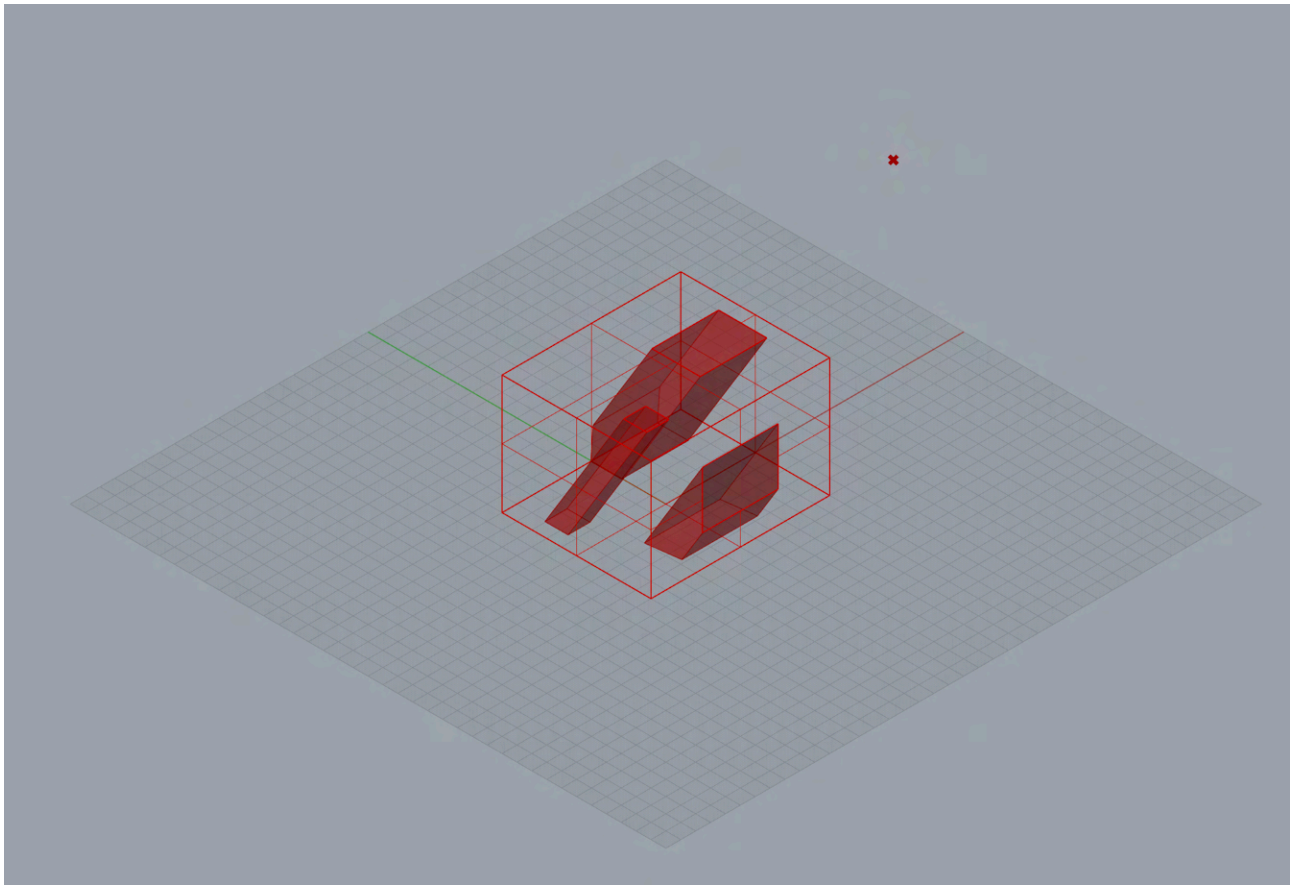
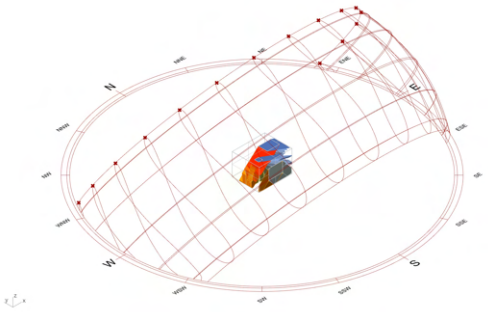
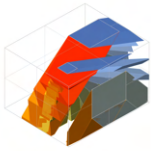
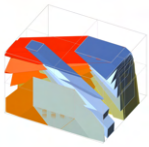
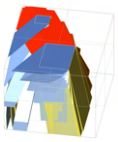


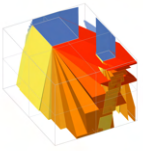
FIGURE 19 MODEL WITH MULTIPLE OPENINGS. TO BE USED WITH THE FINAL SCRIPT TO GENERATE THE DIGITAL PILOT STUDY OUTPUT.











QR code to access pilot study digital turntable

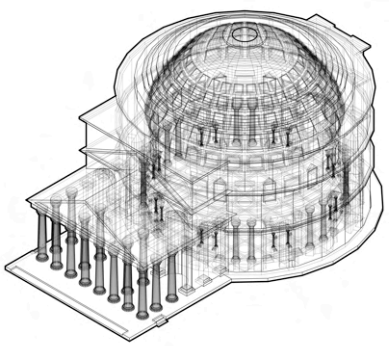
MORNING ◄——► EVENING

FIGURE 20 PILOT STUDY 'SHAPE OF LIGHT'. THIS FIGURE SHOW THE RESULTS OF THE DIGITAL SECTION OF THE PILOT STUDY: A ROOM WITH A WINDOW AND TWO ROOF LIGHTS, SIMULATED OVER THE SUMMER SOLSTICE (JUNE 21) IN 1 HOUR INCREMENTS AT A LATITUDE OF 35°. THIS DEMONSTRATES THE FORMAT IN WHICH THE CASE STUDIES WILL BE PRESENTED.

Case Studies

THE PANTHEON
ROME, ITALY
APOLLODORUS OF DAMASCUS

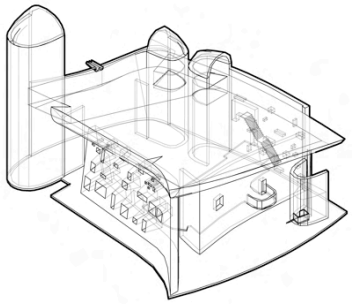
FIGURE A



LATITUDE 42°

NOTRE DAME DU HAUT
RONCHAMP, FRANCE
LE CORBUSIER

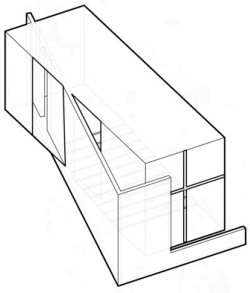
FIGURE B



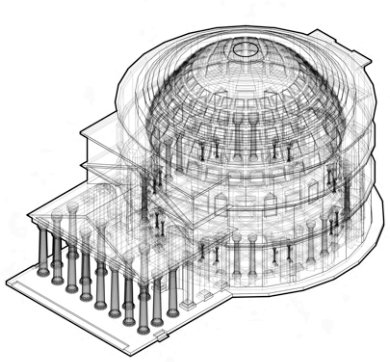
LATITUDE 48°

THE CHURCH OF THE LIGHT
OSAKA, JAPAN
TADAO ANDO

FIGURE C



LATITUDE 35°



The Pantheon

ROME, ITALY
APOLLODORUS OF DAMASCUS

This light source in the pantheon is the so-called oculus, a circular opening 8.3m wide on the top of the cupola and is the only source of direct sunlight. Pre-Roman and early Roman tradition had temples oriented between the arc of the winter solstice sun and due South (Hannah and Magli, 2009), which allowed direct sunlight to enter the space every day of the year. It is noteworthy then that the Pantheon is oriented due North, resulting in it being in darkness for most of the year. Consequently, this orientation emphasises the significance of the light received through the oculus. A possible explanation was proposed by Hannah and Magli (2009), suggesting that the Pantheon was, to some extent, inspired by a 'hemicyclium' sundial (fig. 22). Indeed the concave quarter-sphere and rod-like gnomon bears some resemblance to the coffered dome and light beam as seen in section (fig. 23).

FIGURE 22 HEMICYCLIUM, WITH ITS SHADOW CASTING GNOMON (ZEYREK, 2020).

Although the Pantheon is clearly not a precision instrument, the movement of the sun is intricately connected to its form, and during certain times of the year produce notable phenomena where the illumination calls attention to certain elements of the building. Hannah and Magli (2009) describe the movement of light in the following way. The sunbeam depicts an arc moving from west to east which:

- Remains on the upper hemisphere during autumn and winter.
- Touches the base of the entrance around 21 April.
- And reaches the floor and wanders across it in the central hours of the day from the end of April to the end of August.

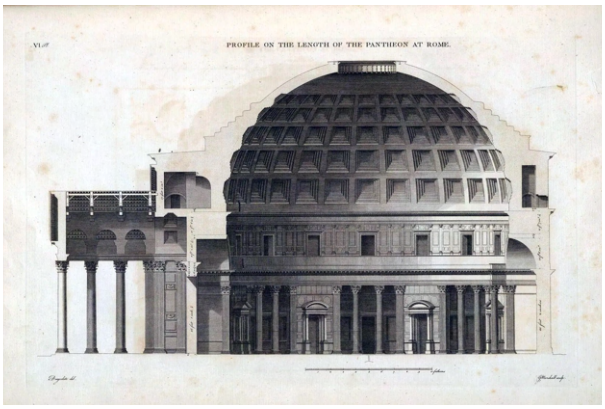


FIGURE 23 PANTHEON SECTION (DESGODETZ, 1779, P. 33).

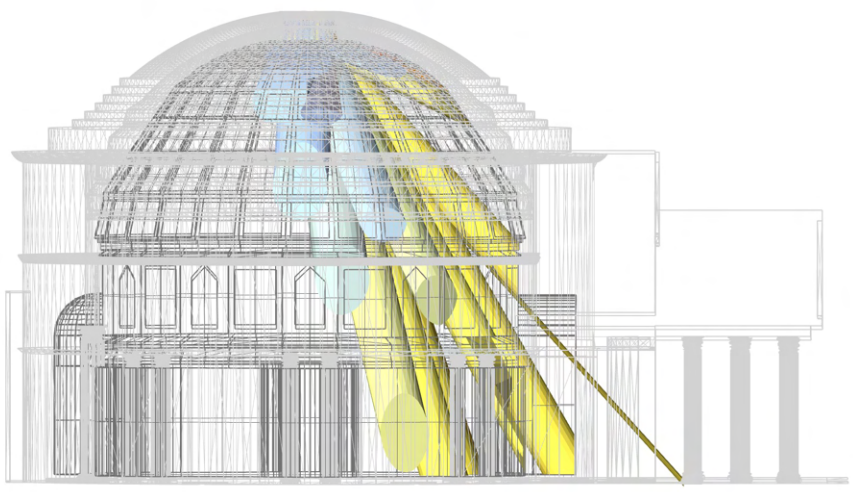
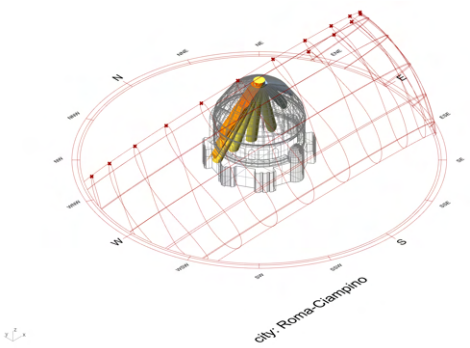


FIGURE 24 ELEVATION OF THE PANTHEON WITH ALL STUDIED LIGHTING CONDITIONS OVERLAYED. THE SOUTH ORIENTED PORTICO RESULTS IN THE SUNBEAMS BEING DIRECTED TOWARDS THE ENTRANCE.

The Shape of the Light.

When visualising the ‘shape’ of these lighting conditions (fig. 24), the sundial analogy becomes more apparent; however, in this instance, the Pantheon functions as an inverted sundial. Unlike traditional sundials that indicate time through the absence of light; casting a shadow, the oculus of the Pantheon projects a ‘sun-beam’; illuminating the interior surface. We can also deduce another possible explanation for the Pantheon’s orientation; by inverting the traditional plan, the ‘sun-beams’ are all directed towards the entrance. This allows for a particular entrance sequence that will be discussed later in this chapter.

SUMMER SOLSTICE



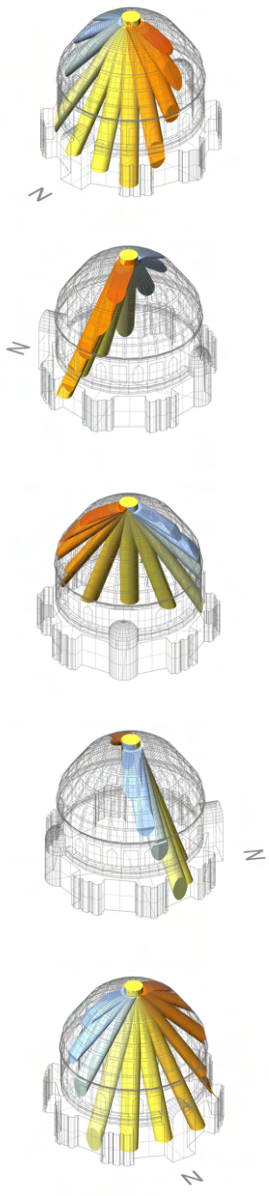
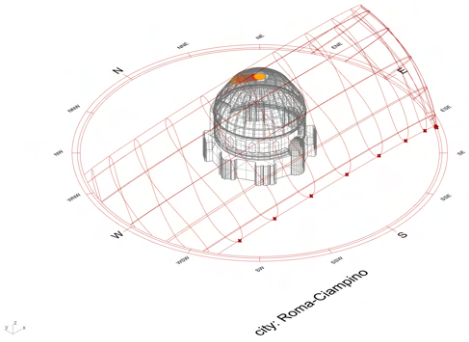


FIGURE 25 SUNPATH ON JUNE 21. THE SUNBEAM ARCS ITS LARGEST PATH.

WINTER SOLSTICE



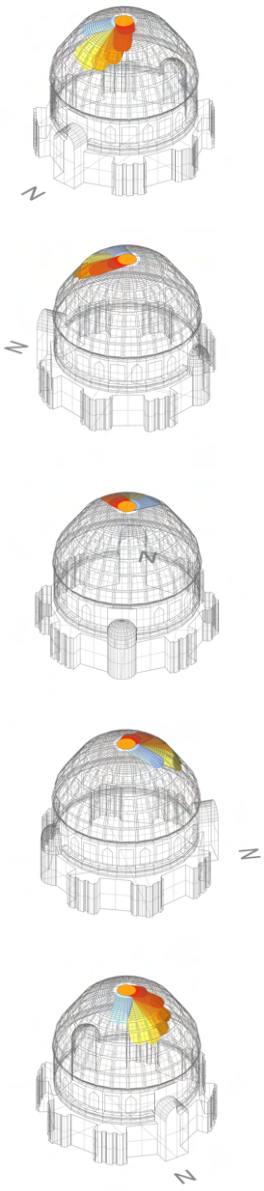
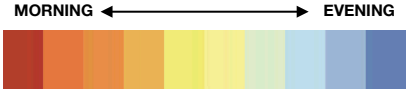


FIGURE 26 SUNPATH ON DECEMBER 21. THE SUNBEAM REMAINS ENTIRELY ON THE DOME.

QR code to access video



The model suggests that the experience of entering the pantheon would be highly temporally dependant. At midday on the spring equinox the sunbeam passes through a grille above the door and illuminates the floor of the portico (Fig. 27.1,32); and during the summer months, the midday light would have been clearly visible through the open doors (Fig. 27.2). At all other times the interior would have appeared dark from outside. In this way, the Pantheon becomes a building that beckons to the passerby only during certain hours of certain months (fig. 27).

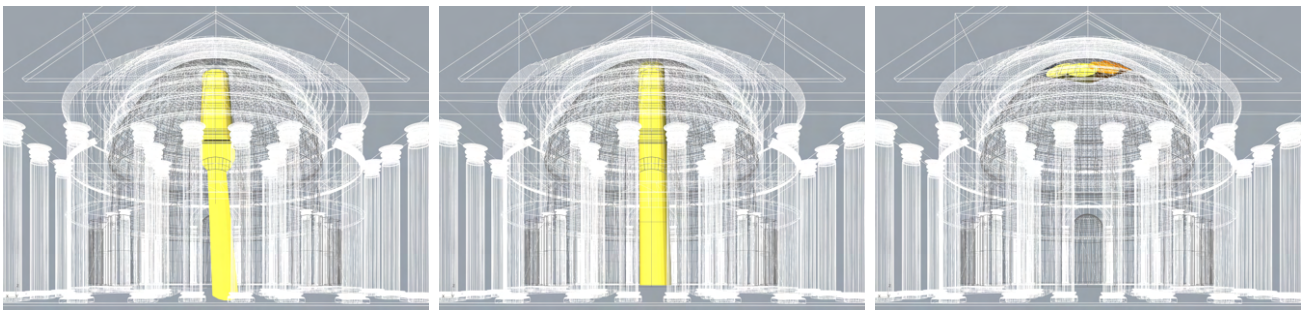


FIGURE 27 COMPARISON OF LIGHT VISIBLE FROM OUTSIDE THE PANTHEON. LEFT TO RIGHT: SPRING EQUINOX, SUMMER SOLSTICE, WINTER SOLSTICE. IN THE FIRST TWO CONDITIONS, THE 'SUN-BEAM' WOULD BE VISIBLE THROUGH THE ENTRANCE, NOT SO IN THE FINAL CASE.

In the aerial view of the summer solstice condition (fig. 25) as well as figure 30, the light is seen to fan out from the oculus, forming a large 'colonnaded' sweep. The light, as seen in this model, acts almost as a continuation of the portico colonnade. This is captured well in figure 30, and seen in the eye-level views (Fig. 28), where the light creates an enfilade-like sequence, increasing in size from the already grand corinthian columns to a 'god-like' scale inside the building. In this way, light is the final element in the entry sequence of the temple; making the final link between the sacred space and the entities to whom it was dedicated. The entry sequence (fig. 28,29) shows clearly how one's vision would be drawn upwards towards the oculus, and therefore towards god, particularly in the summer months when this movement of vision would follow the already visible sun-beam.

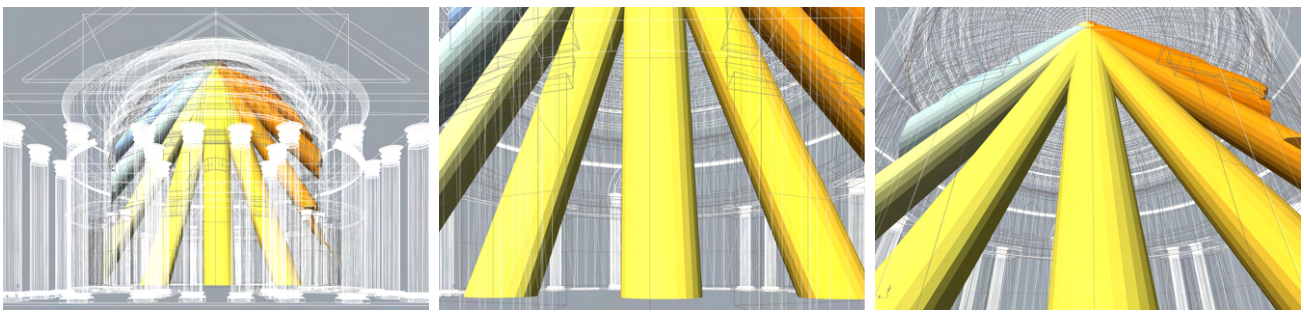


FIGURE 28 ENTRANCE SEQUENCE DURING THE SUMMER SOLSTICE. LEFT TO RIGHT: EXTERNAL VIEW, ENTRANCE VIEW, LOOKING UP TOWARDS THE OCULUS. THE ARRAY OF LIGHT VISUALLY MIRRORS THAT OF THE PORTICO COLUMNS, AND CONVERGES UPWARDS TOWARD THE OCULUS.

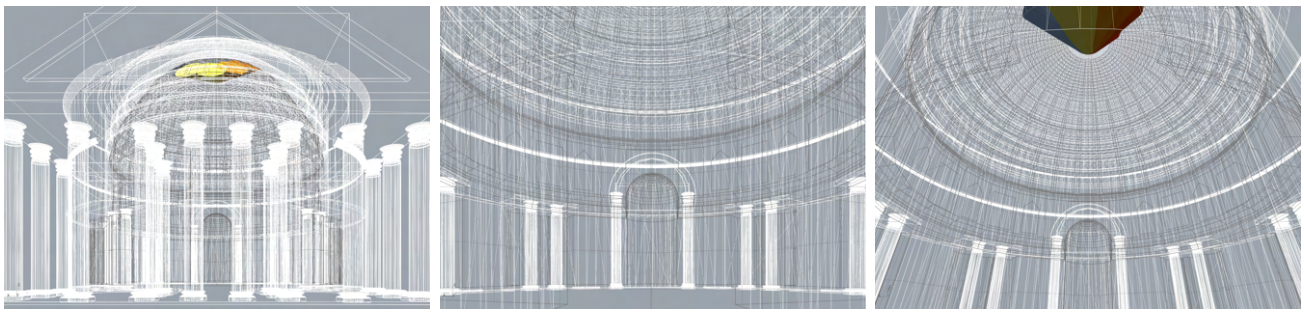


FIGURE 29 ENTRANCE SEQUENCE DURING WINTER SOLSTICE. LEFT TO RIGHT: EXTERNAL VIEW, ENTRANCE VIEW, LOOKING UP TOWARDS THE OCULUS. THE ENTRANCE SEQUENCE IDENTIFIED DURING THE SUMMER MONTHS IS FAR LESS VISIBLE IN WINTER.

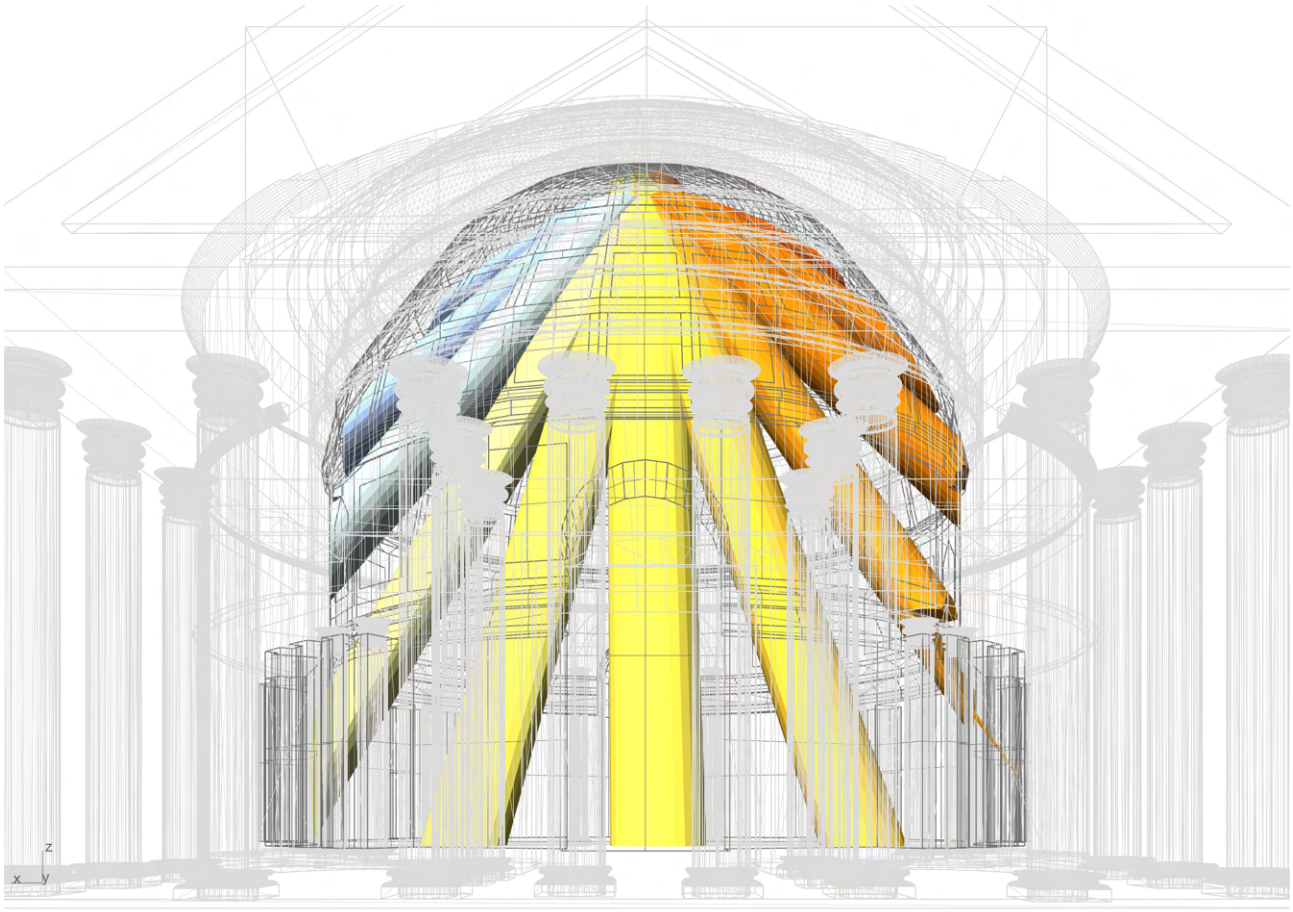


FIGURE 30 ENTRANCE VIEW DURING THE SUMMER SOLSTICE. THE MIDDAY 'SUN-BEAM' WOULD BE VISIBLE THROUGH THE ENTRANCE. ON APRIL 21, THIS 'SUN-BEAM' MOVES FORWARDS INTO THE ENTRANCEWAY, PLACING "ROME AMONG THE GODS".

As previously discussed, on the dates of the equinox's, the 'sun-beam' passes through a grate above the entrance (fig. 32,34). This is the only time in which the sunbeam breaches the confines of the Pantheon's walls. And on April 21st, the traditional date of Rome's foundation (Ovid, *Fasti* 4: 721-862 as quoted by Hannah and Magli, 2009), the sun-beam illuminates the door of the Pantheon (fig. 31,33); thereby creating a direct connection between the entrance of the Pantheon and the oculus. Hannah and Magli describe this as placing "Rome among the Gods" (2009). Where light acts as the medium by which this connection is made.

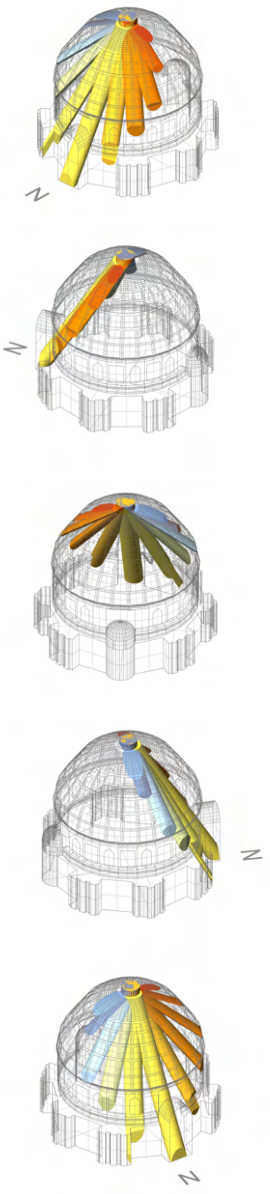


FIG. 31 SUNPATH ON APRIL 21. DIES NATALIS. THE MIDDAY SUNBEAM FALLS DIRECTLY ON THE ENTRANCE TO THE PANTHEON.

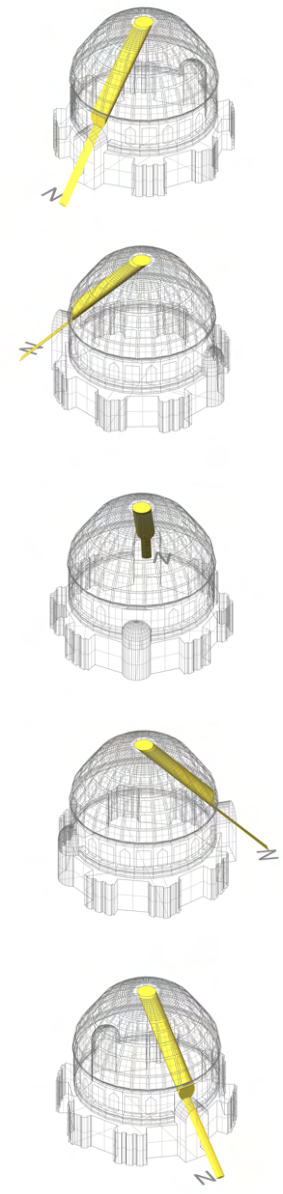


FIG. 32 SUNPATH AT NOON ON THE SPRING EQUINOX. THE SUNBEAM PASSES THROUGH A GRATE ABOVE THE ENTRANCE DOOR AND REAPPEARS ON THE GROUND OF THE PORTICO.

FIGURE 33 THE SUN-BEAM ON APRIL 21 (nonac.eos, n.d.).

FIG. 34 SUNBEAM PASSING THROUGH THE GRATE ON THE SPRING EQUINOX (De Franceschini, 2014, p. 6).

The internal experience of the Pantheon is well documented. The internal view (Fig.35) shows how the sun-beam arcs across the inside of the dome, the arcing effect is far more pronounced during the summer months. This constant sundial-like motion means that upon repeat visits, one may acquire the ability to know the time of day, and even year, by looking at the position of the sunbeam (Hannah and Magli, 2009). In this way the Pantheon uses the changing effects of natural light to cement a connection between itself, and the celestial movements of the gods. Here, the role of light transcends the functional, and becomes an active component in the spiritual symbolism and experience of the Pantheon.

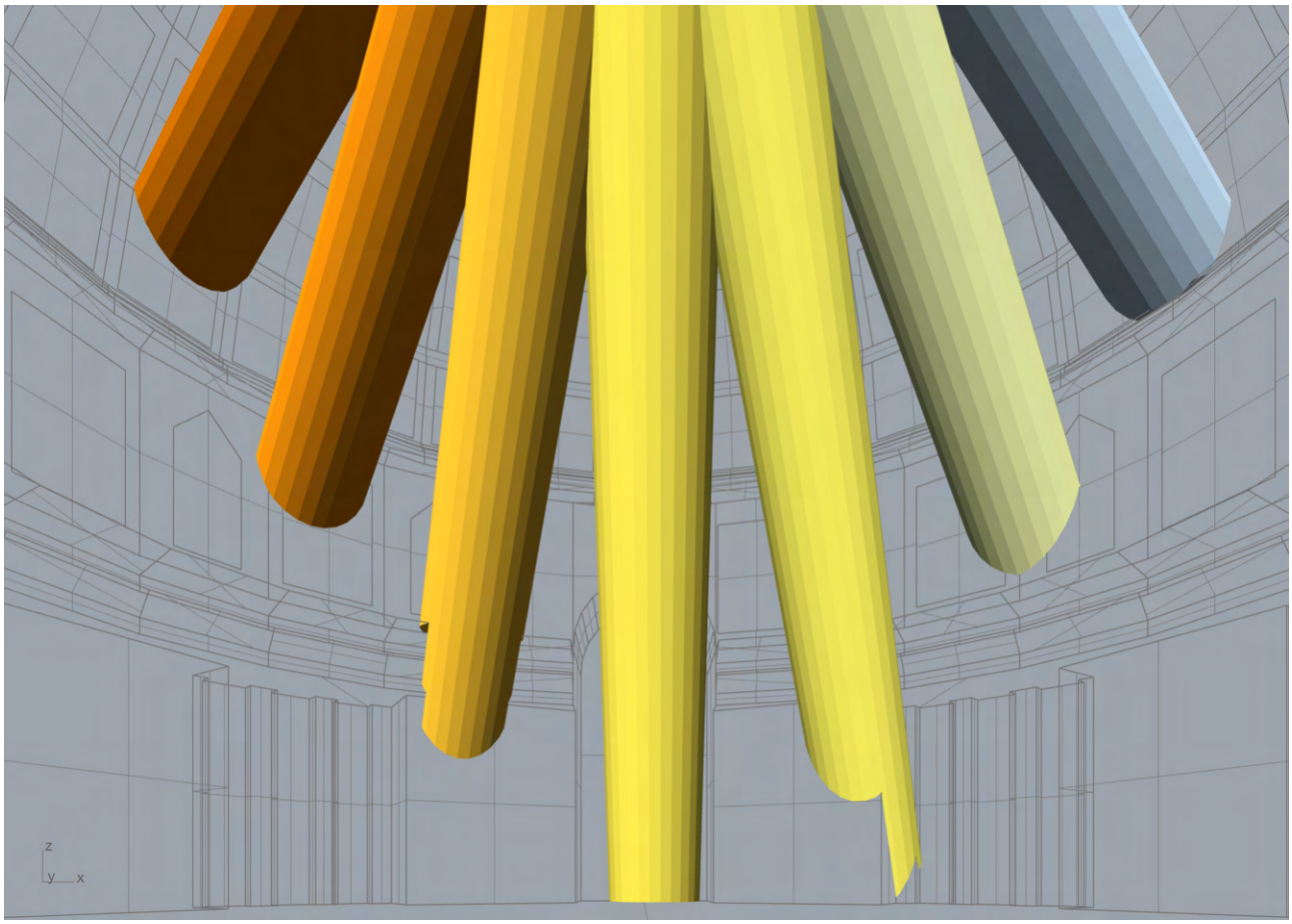
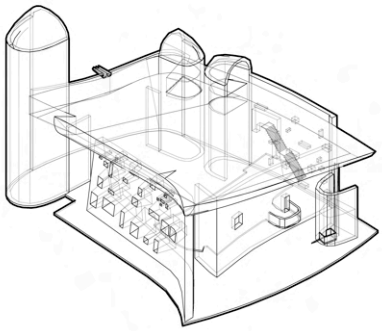


FIGURE 35 INTERNAL VIEW ON APRIL 21. THE 'SUN-BEAMS' ARC IN A SUNDIAL-LIKE FASHION ACROSS THE INTERIOR OF THE TEMPLE. THE CENTRAL MIDDAY BEAM, CONNECTS THE ENTRANCE TO THE OCULUS; BRIDGING ROME, AND THE INDIVIDUAL, TO THE GODS.



Notre Dame du Haut

RONCHAMP, FRANCE
LE CORBUSIER

Much like the Pantheon, Le Corbusier's chapel at Ronchamp draws upon the daily evolution of light, albeit in a more complex manner. The building, while primarily a single volume, is divided into smaller apsidal chapels, where each volume receives a different light from its own allotted portion of sky (Plummer, 2003).

Like the Pantheon, the sun draws a ring of light around the space as the day progresses. However in the case of Notre Dame, this paradigm is inverted, the light bursts into the church through carved openings; peering from the outside in. In this way Le Corbusier's space is more introverted. Where the Pantheon looks up to the gods, Notre Dame looks inwards, toward the individual. Plummer says of the light in Notre Dame; "Instead of serving as a tool of religious persuasion"… "light has become a quiet force to visually resist and elude, erode and outshine, the Church´s mandate"… "while exerting its own dazzling powers to draw attention out to the sky and its commonplace marvels" (2013). Both spaces use light to explore the divine, yet they accomplish this by leveraging the contrasting extremes of light's experiential possibilities.

Some notes about accuracy.
The nature of this type of analysis is necessarily simplified. The stained glass and clerestory windows are not modelled, neither are the 'brise-luminère' that diffuse and reflect light in the apsidal chambers (Plummer, 2003). The grand chapel and the north wall receive no direct sunlight and are therefore excluded from this analysis. Nonetheless, the model captures the primary gestures of the light in Le Corbusier's chapel.

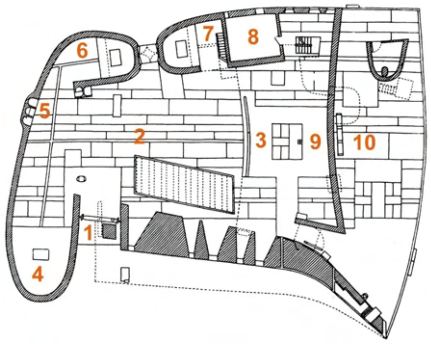
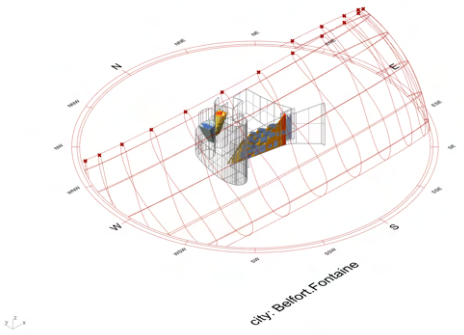
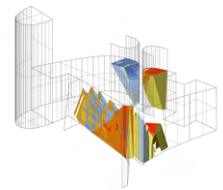
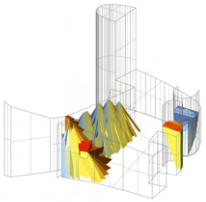


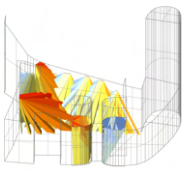
FIGURE 36 PLAN OF THE RONCHAMP CHAPEL: 1: MAIN ENTRANCE, 2: NAVE, 3: MAIN ALTAR, 4: GRAND CHAPEL, 5: CONFESSIONALS, 6: EVENING CHAPEL, 7: MORNING CHAPEL, 8: SACRISTY, 9: CHOIR, 10: THE BACK CHOIR EXTERNAL SPACE (Bianchini, n.d.)

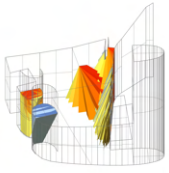
SUMMER SOLSTICE











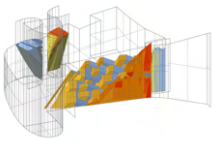
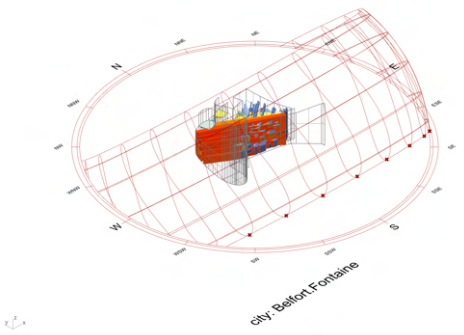
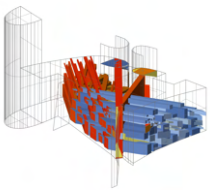
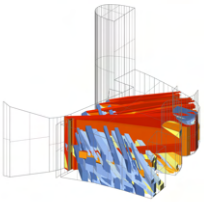


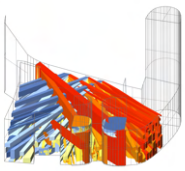
FIGURE 37 SUNPATH ON JUNE 21.

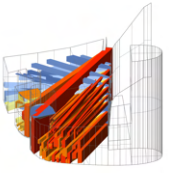
WINTER SOLSTICE











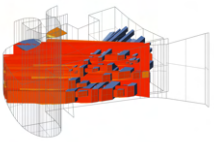


FIGURE 38 SUNPATH ON DECEMBER 21.

QR code to access video

MORNING ◄——————► **EVENING**

The Shape of the Light.

I will propose that the light in Notre Dame is a dance choreographed around the experience of sitting at the nave. Taking a view sat at the nave looking towards the alter (fig. 41), we are met with two primary openings; a square window and a slit between the east and south walls. In the second instance, an inordinate amount of light floods into the space (fig. 41.2), for the slit is far larger than any other window at ground level, flooding the anterior of the nave with sunlight. This is clearly of primary importance to the worshipping experience given the intentional skewing of the pews; away from the alter and towards the opening. For Plummer, this distracts the worshipper from the "liturgy, towards something equally spiritual but free of depiction" (2003). Figure 41.2 shows how this frontal opening would draw the attention of a worshipper sitting at the nave away from the alter.

As if to counter the intensity of this gesture, a single ray of light penetrates downward from the aforementioned square window (fig. 41.2). Towards but never reaching the alter. As if to periodically pull the eye from ahead, towards the alter and then upward to the source of light; to god perhaps. A similar effect to the Pantheon's oculus. Figure 39 demonstrates a potential viewing sequence from the perspective of a worshipper sat at the nave.

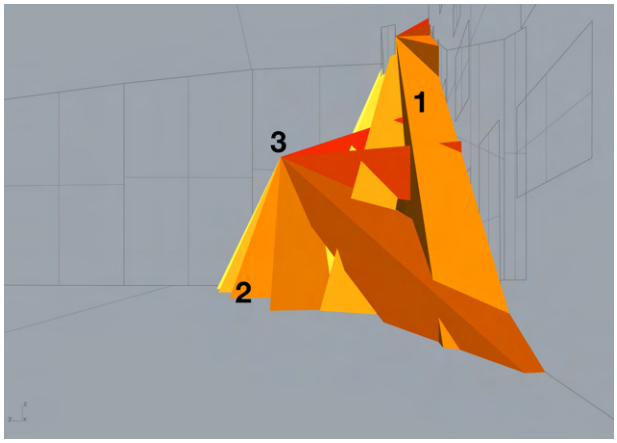


FIGURE 39 POTENTIAL NAVE VIEWING SEQUENCE. 1: VISION FOCUSED ON MAIN SLIT OPENING WITH HIGHEST AMOUNT OF LIGHT. 2: VISION PULLED BACK TO BASE OF ALTER WHERE LIGHT FROM SQUARE WINDOW LANDS. 3: VISION DRAWN UPWARDS TO SQUARE OPENING.

FIGURE 40 LEFT, MIDDLE, RIGHT: SQUARE WINDOW, SLIT WINDOW, NAVE SEATING (Maher, 2017).

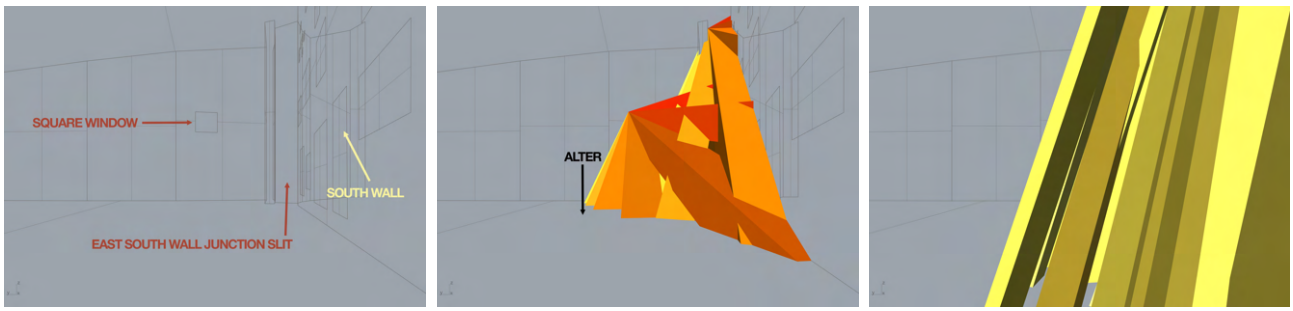


FIGURE 41 VIEW FROM NAVE FACING EAST. TOP TO BOTTOM: NO LIGHT, LIGHT FROM EAST WALL, LIGHT FROM SOUTH WALL. THE EAST WALL ILLUMINATES THE ALTER AND HEAD OF THE NAVE WHILE LIGHT FROM THE SOUTH WALL DAPPLES OVER THE CONGREGATION.

In the afternoon, as the sun rotates around the building, the south wall projects a multi-coloured array of illuminated features onto the nave (fig. 41.3,43,44). The stained glass fittings redirect and recolour individual strands of light like components of a prism. It is also worth noting the extreme differences in the Summer and winter conditions in the South wall as seen in figures 37,38. The varied relief shapes of the windows capture different moments of the sun (Plummer, 2003), creating a vastly different lighting experience throughout the year.

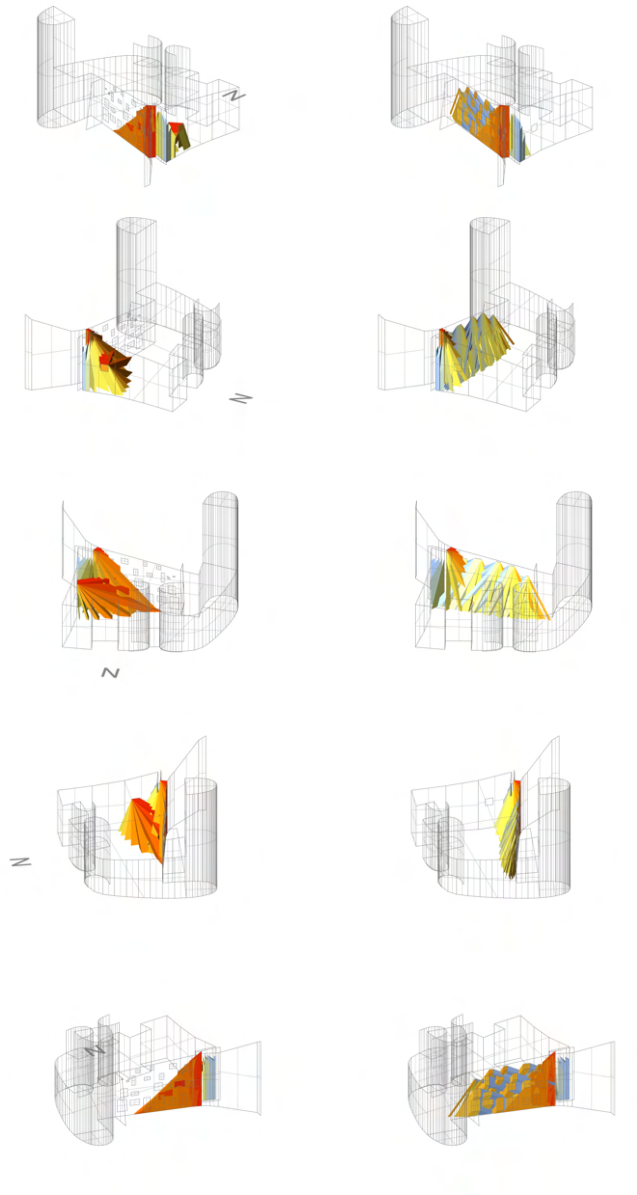


FIGURE 42 SUNPATH ON JUNE 21 EXCLUSIVELY THROUGH THE EAST WALL. THE LIGHT LANDS PRIMARILY ON THE NAVE SEATING.

FIGURE 43 SUNPATH ON JUNE 21 EXCLUSIVELY THROUGH THE SOUTH WALL.

FIGURE 44 ARRAY OF SOUTH WALL WINDOWS ILLUMINATING THE NAVE (Bednorz and Monheim, n.d.).

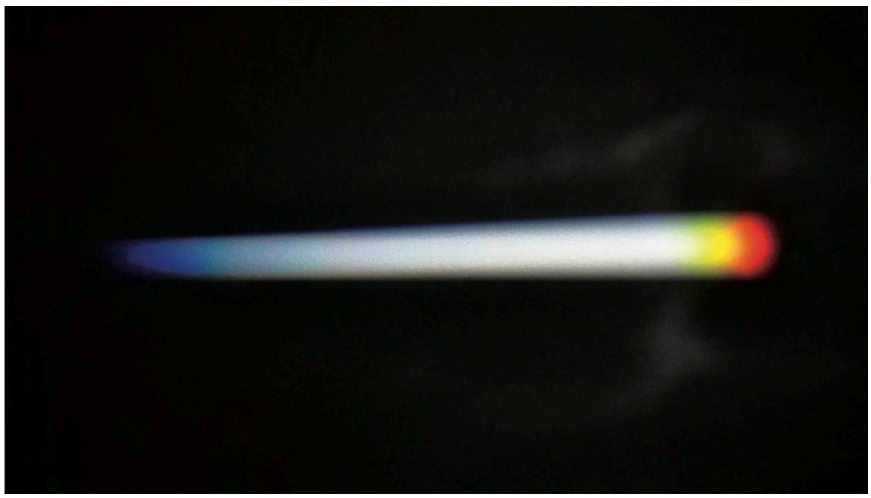


FIGURE 45 LIGHT REFRACTED THROUGH A PRISM HITTING THE WALL. (KEY, 2013, P. 11)

The apsidal chapels are not privy to the same dynamics of light as the main chamber. Instead, they are lit in a binary manner. The east chapel is illuminated in the morning (fig. 47) and the west chapel in the evening. Despite their discrete function, when sitting at the nave, this light from the apsidal chapels would be visible; seeping out from behind the internal walls as seen in figure 48. As such they play their part in the choreography of the chapel, “captivating human attention and drawing it in like a beacon” (Plummer, 2003).

Le Corbusier’s chapel choreographs light as a living force, celebrating its ability to change. The varied scale, colour and shape of the opening conditions reflect this philosophy, scattering light across space and time. Differentiating the various subspaces of the church (Foundation Le Corbusier, n.d.). The contrasting nature of light in the main space and apsidal chapels reflects the churches ability to cater for both collective and individual worship, and through careful control of lighting elements, Le Corbusier shapes the experience of the worshiper using light. This completes what Plummer calls the “space-time orchestration” of the chapel (2003) as illustrated in figure 46.

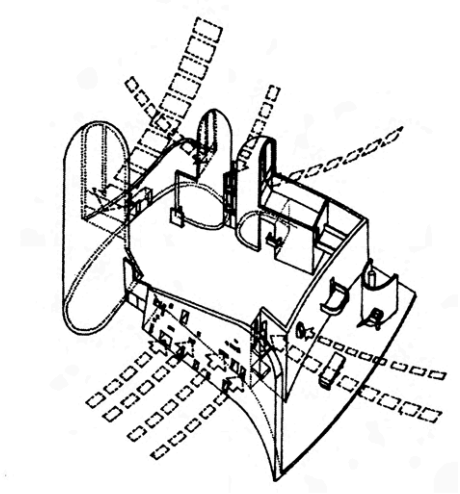


FIGURE 46 DRAWING SHOWING THE MULTITUDE OF DIRECTIONS FROM WHICH LIGHT CAN ENTER THE CHAPEL (Plummer, 2003, p. 239).

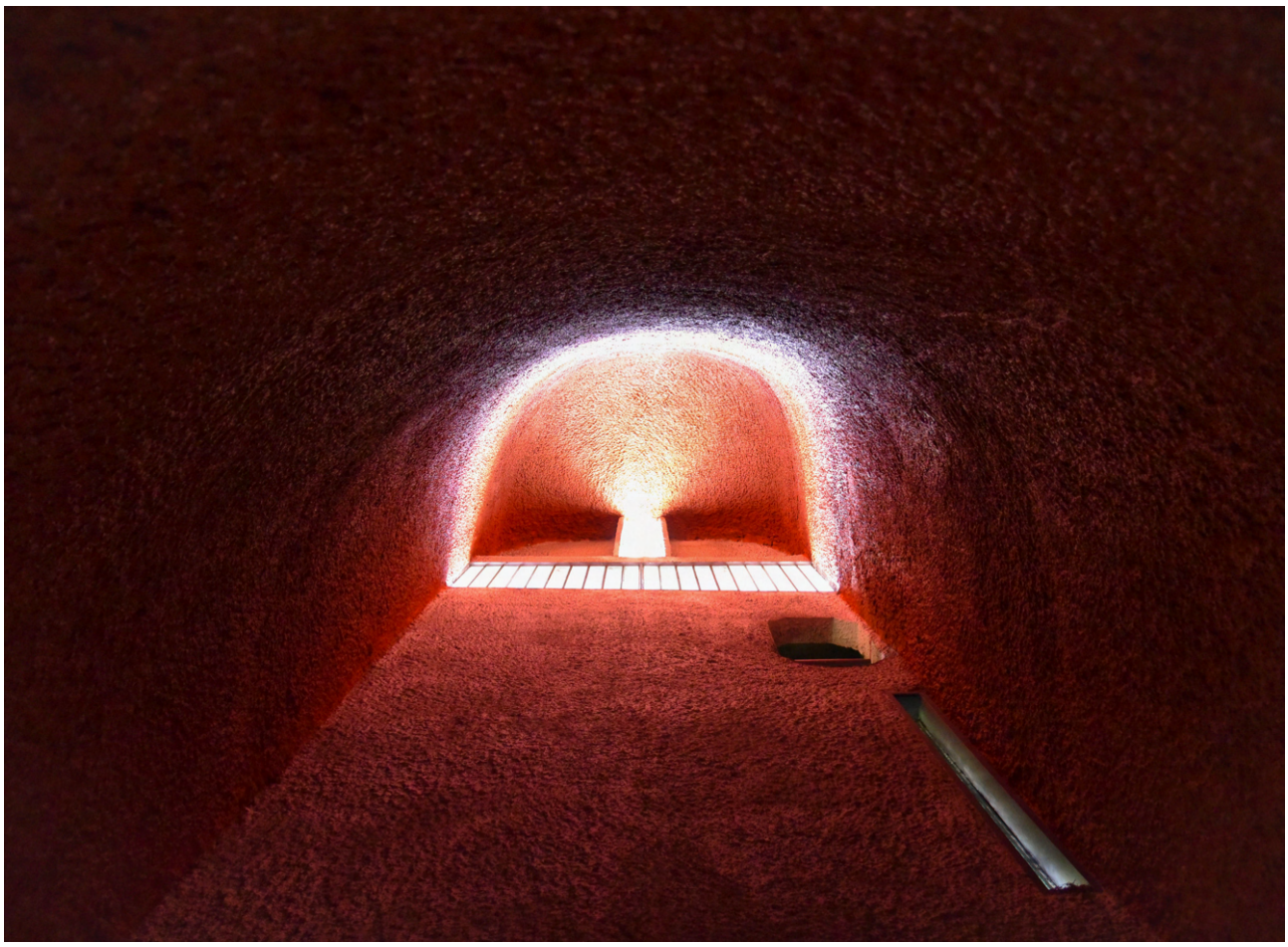


FIGURE 47 THE LIGHT CATCHING SCOOP OF THE MORNING APSIDAL CHAPEL (Maher, 2017).

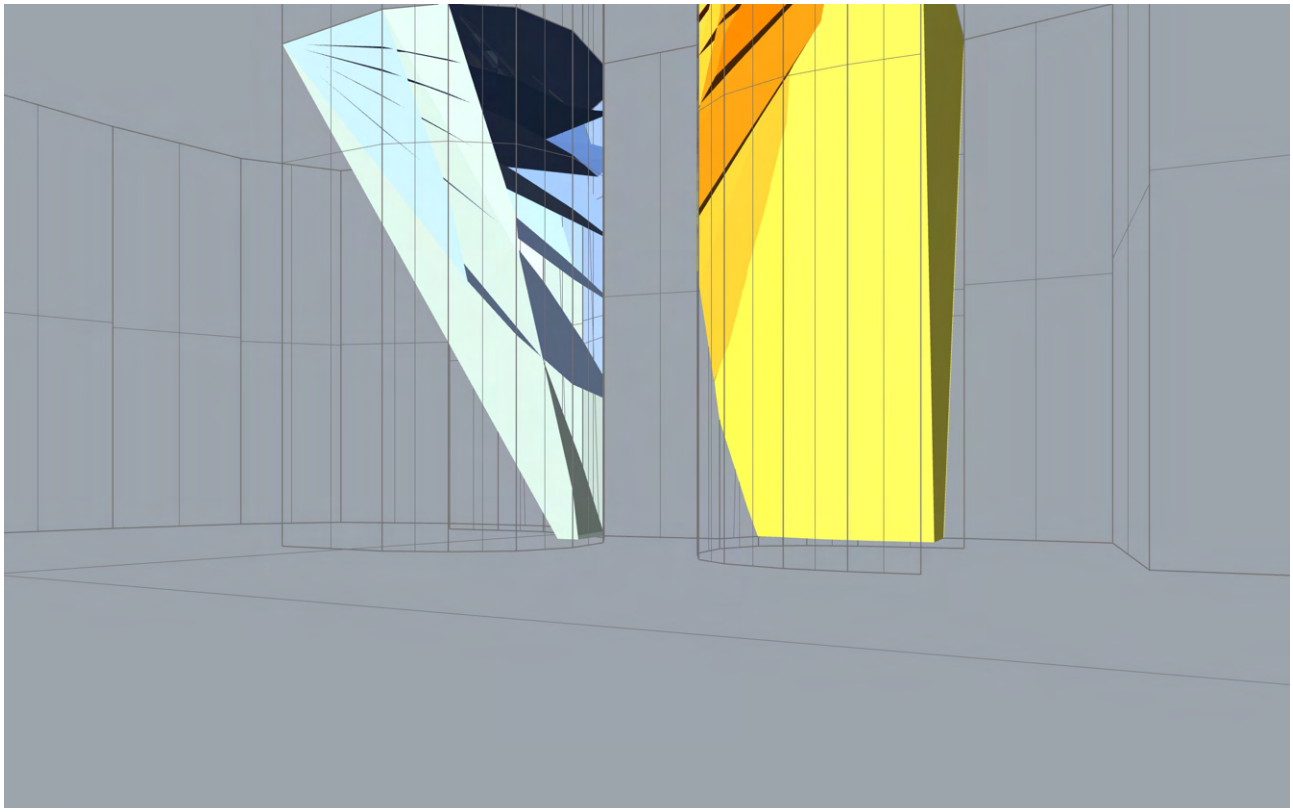
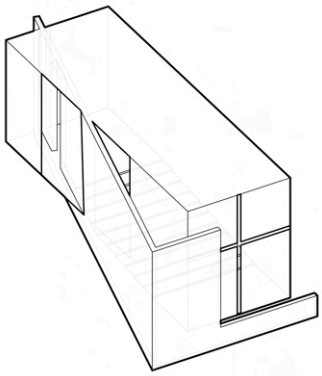


FIGURE 48 VIEW OF APSIDAL CHAPELS FROM NAVE. INTERNAL WALLS ARE MODELLED AS TRANSPARENT. LEFT TO RIGHT: EVENING CHAPEL, MORNING CHAPEL.



The Church of the Light

OSAKA, JAPAN
TADAO ANDO

There exists a contradiction within Ando's church; a tension between the orthogonal and the oblique. An angled wall spanning both interior and exterior slices through the pure form of the church. This wall leaves behind openings; it pierces windows through the church. The only additional point of light is the cross window, cut into the wall behind the alter, that forms the icon of the crucifix of light.

The Shape of the Light.

The light inside the church is tied invariably to the meeting of these it's geometries. Ando writes "there are few light gaps in this space, as the idea is for light to contrast with an environment of darkness" (1997). Figure 49 shows that the light contrasts its environment not only in luminosity but also form. It is irregular and angled; where the beams of light meet the walls and floor, they splay out into triangular slices dissimilar to the pure shape of the church. One may ask; is this contradiction intentional?

The light forms slices, thin elements that arc along the dark concrete over time. There are three main series of slices (fig. 49). The crucifix, focused around the alter, the vertical element, focused around the entrance, and the horizontal clerestory light that enters between the angled wall and the ceiling. It is worth noting that these discrete 'shapes' of light are horizontal, vertical, and crossed respectively; as if emphasising further, their independence from one another.

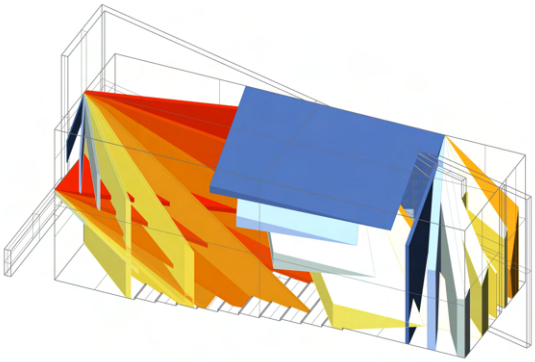
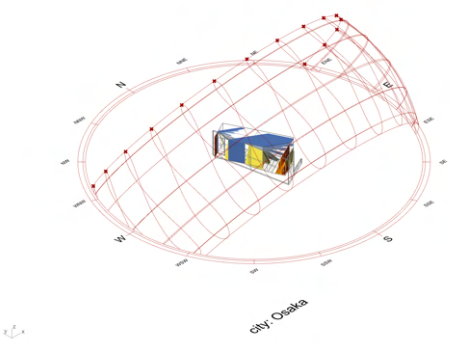


FIGURE 49 MODEL SHOWING THE THREE MAIN SWEEPING BLADES OF LIGHT. LEFT TO RIGHT: THE ALTER CRUCIFIX, THE HORIZONTAL SIDE WINDOW SLIT, THE VERTICAL ENTRANCE LIGHT. COLOUR DENOTES DIRECTION OF SWEEP.

SUMMER SOLSTICE



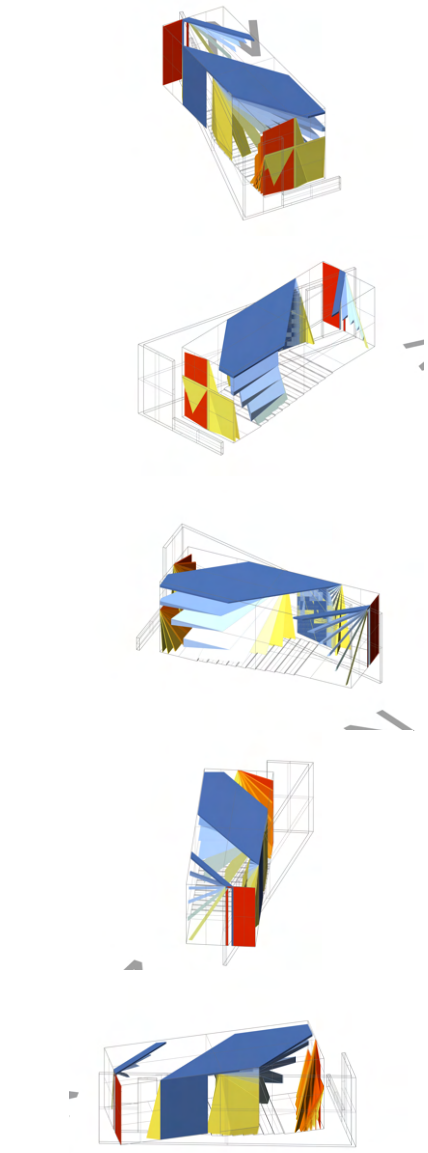
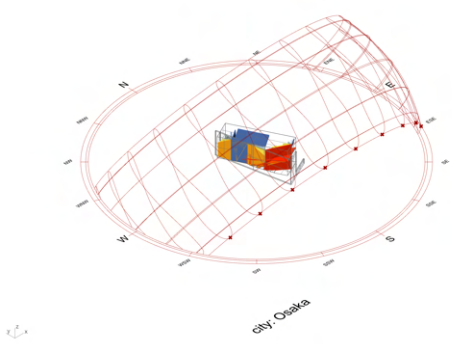


FIGURE 50 SUNPATH ON JUNE 21

WINTER SOLSTICE



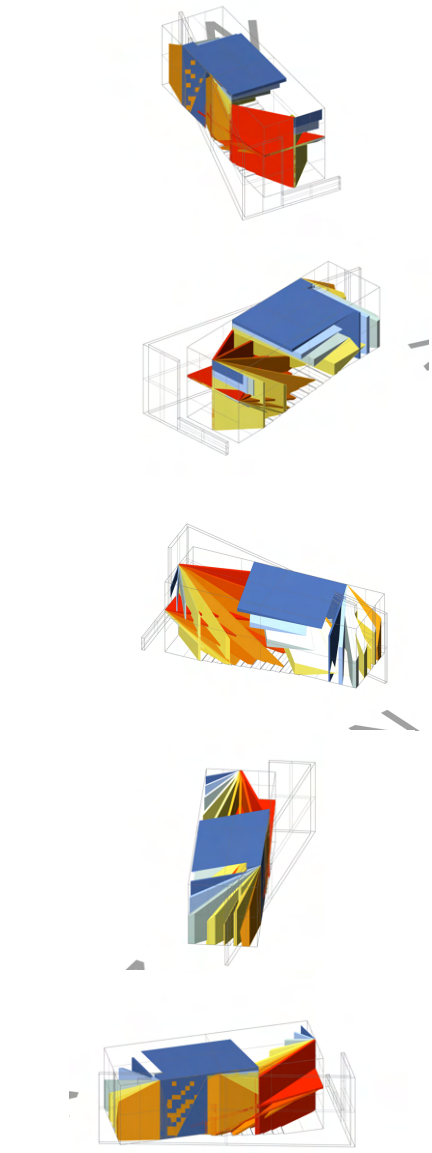


FIGURE 51 SUNPATH ON DECEMBER 21. THE LIGHT PROJECTS MUCH FURTHER INTO THE SPACE.

QR code to access video

When combining my own analytical models with that of Bruno (2017), we see yet another contradiction. We find the alter to be the darkest space in the church, despite its position directly in front of the crucifix window. Bruno's model tells us that first four meters in front of the cross have a yearly average illuminance of below 100lux (fig. 55). In fact, it is the very darkness of the alter space that allows the dramatic icon of the cross of light to exist (fig. 54). The ambient darkness contrasts with the direct sunlight, and when projected into the church, the light takes on a distinct life; separate from the concrete on which it lies. Indeed Ando is very aware of this fact, he comments on the glory of light, "only when it is lit against the background of the deepest darkness" (as quoted in El Croquis, 2000). He seems to go as far as to position the angled wall to ensure darkness against the crucifix of light. Figures 52 shows that without it, the alter space is flooded with light in the summer months through the side window. Perhaps this fact elucidates the purpose of the angled wall.

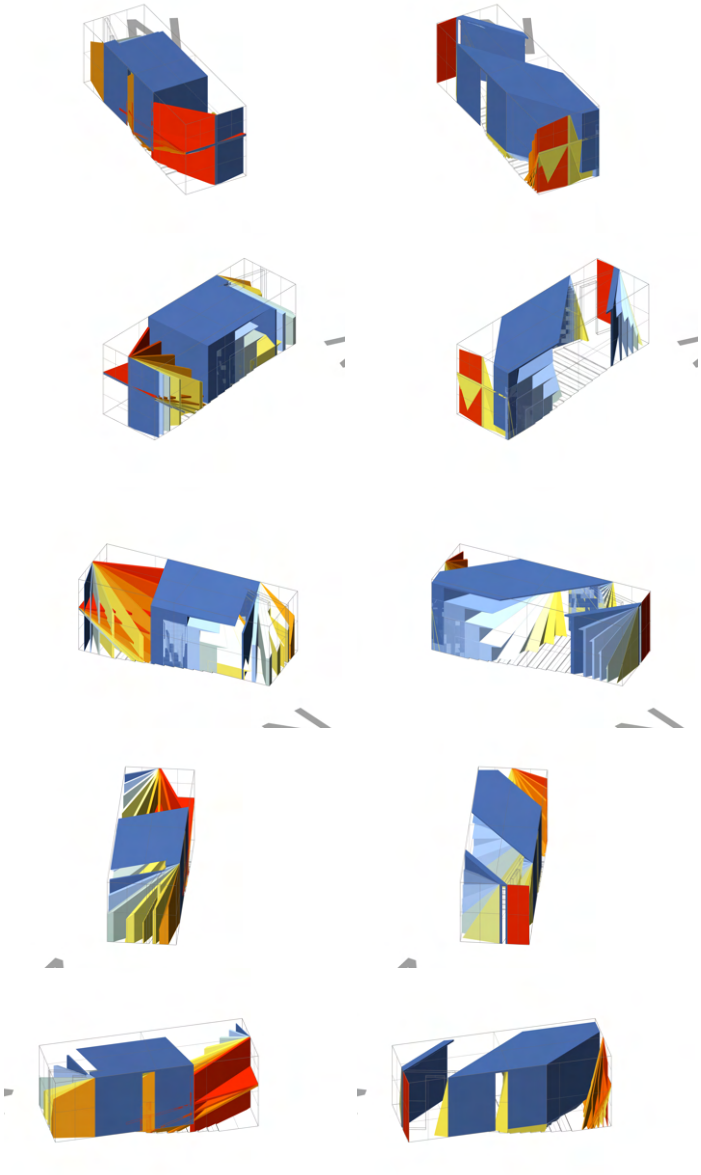


FIGURE 52 SUNPATH ON DECEMBER 21, WITHOUT THE EXTERNAL WALL. THE 'BLADE' SHAPE IS GONE FROM THE SIDE WALL LIGHT AND REPLACED WITH A LARGER RECTANGULAR FORM.

FIGURE 53 SUNPATH ON JUNE 21, WITHOUT THE EXTERNAL WALL. A SIMILAR RESULT.

FIGURE 54 THE CRUCIFIX OPENING CONTRASTING AGAINST THE DARKNESS OF THE CHURCH (Morimoto, 2015).

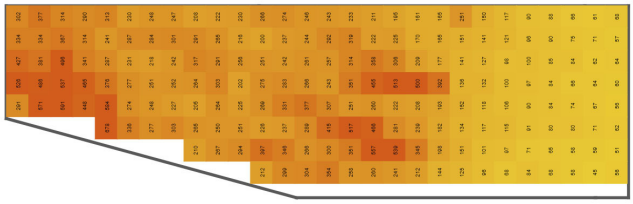


FIGURE 55 AVERAGE ILLUMINANCE OF FLOOR OVER A YEAR. ALTER ON RIGHT HAND SIDE OF IMAGE. 60X60CM RESOLUTION (Bruno, 2017a).

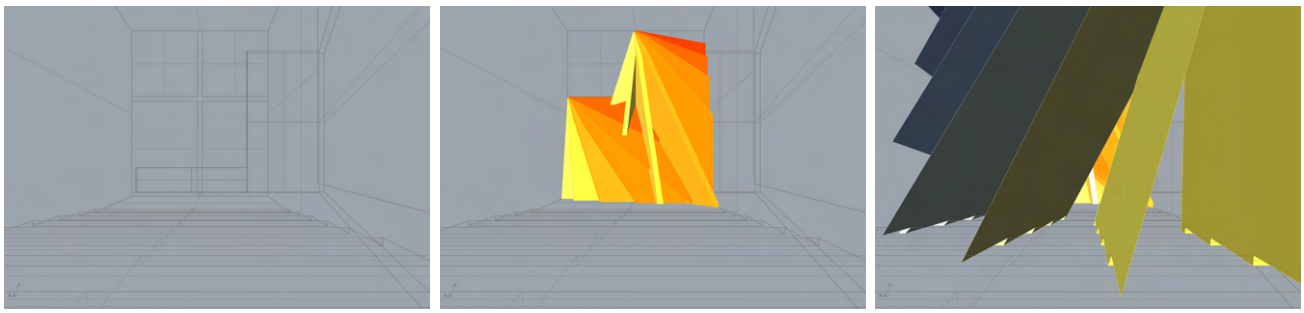


FIGURE 56 VIEW FROM NAVE TOWARDS ALTER. LEFT TO RIGHT: NO LIGHT, CROSS LIGHT FALLING ONTO ALTER, MIDDAY-EVENING LIGHT ARCHING ACROSS THE NAVE.

Here we can draw parallels to Le Corbusier's chapel at Ronchamp. When looking from the perspective of a worshipper (fig. 56), light falls onto the alter in the symbolic form of a cross (fig. 56.2), and once again the gaze is drawn upward, towards the source of the light. In this case, it is nature, or the outside environment that Ando is calling attention to in the abstract form of the cross (Ando, 1997). He writes that it is the natural light that brings change into the space (as quoted in Jodidio, 2012); echoing his comments on natural light imbuing the Pantheon with life (Robertson, n.d.). Perhaps this is his contemporary take on the Japanese concept of Komorebi; "sunlight leaking through trees" (fig. 58,59); leaving dappled spots of light on the concrete, alive and changing over time. To augment this primary gesture, once again, the midday light falls from the south-west opening onto the nave (fig. 56.3), albeit in a more monotone manner than the chapel at Ronchamp. This slice of light arcs across the space like the second hand of a watch, illuminating different seating positions over time. We can see Ando himself sat in this light in figure 57.

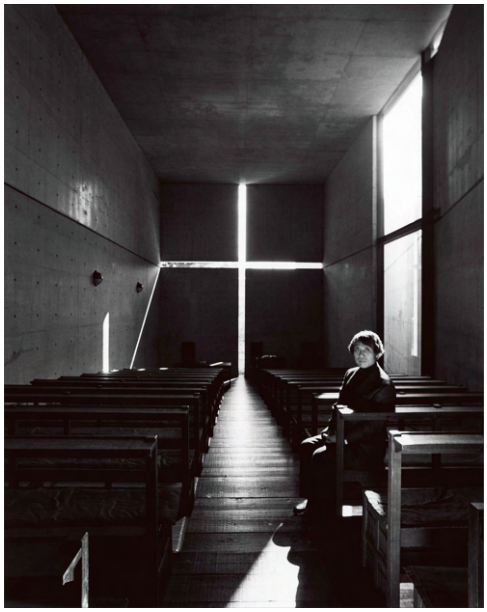


FIGURE 57 TADAO ANDO SITTING IN A SLICE OF LIGHT (Araki, 1989).

FIGURE 58 KOMOREBI (Trees Sunlight, n.d.).

FIGURE 59 LIGHT LEAKING THROUGH THE CRUCIFIX OPENING (Bergmann, 2006).

The majority of the building, as seen in figure 60, is dim enough to be in the mesopic region of vision. Known also as “twilight vision”; in this range, colour perception and visual acuity deteriorate (ERCO, n.d.). Conversely, the outside, as seen through the windows (fig. 60), is light enough to be in the full colour range of vision. Perception of form in a space this dim is achieved primarily by differentiation in brightness, rather than colour. By reducing the levels of light in the church, Ando forces the worshiper into a heightened state of luminous awareness; where the thin slices of light become all the more visceral. As artist James Turrell comments, “we are made for twilight… it is not until very low levels of light that our pupils dilate… we begin to feel light, almost like touch” (as quoted in Pallasmaa, 2008). Kahn also argued that to “transcend its physical limitations” a building needed a ‘monotone’ quality; too much colour would interfere with light’s “subtle and marvellous changes through the day” (as quoted in Plummer, 2003).

FIGURE 60 SCREENSHOT FROM FALSE-COLOUR VIDEO. BLUE-CYAN REPRESENTS MESOPIC VISION RANGE. EVERYTHING ABOVE GREEN REPRESENTS PHOTOPIC VISION RANGE (Bruno, 2017b).

Ando’s church exemplifies the eastern approach to space and light. Whereas in the west, a light-filled space may be de facto the norm; Ando, and many in the Japanese tradition, begin with darkness. He first creates a dark concrete cave, then he introduces thin slices of natural light, where they create the greatest impact against the background of darkness. The light here is abstract; it is less obviously the result of the sun orbiting the building. While the Pantheon’s form is dictated by the movement of light; the light in Ando’s church is dictated by the form. The movement of light enhances specific areas of space; the alter, the entrance - the form shapes the light.

The Church of the Light is an essay exploring the effects of tension between light and darkness; and how careful control of form can sculpt light and experience. Ando immerses the viewer in a heightened state of perception, where the dimly lit spaces enhance the presence of light; making it a tactile and tangible element through deliberate use of contrast.

WE ARE MADE FOR TWILIGHT… IT IS NOT UNTIL VERY LOW LEVELS OF LIGHT THAT OUR PUPILS DILATE… WE BEGIN TO FEEL LIGHT, ALMOST LIKE TOUCH”

JAMES TURRELL

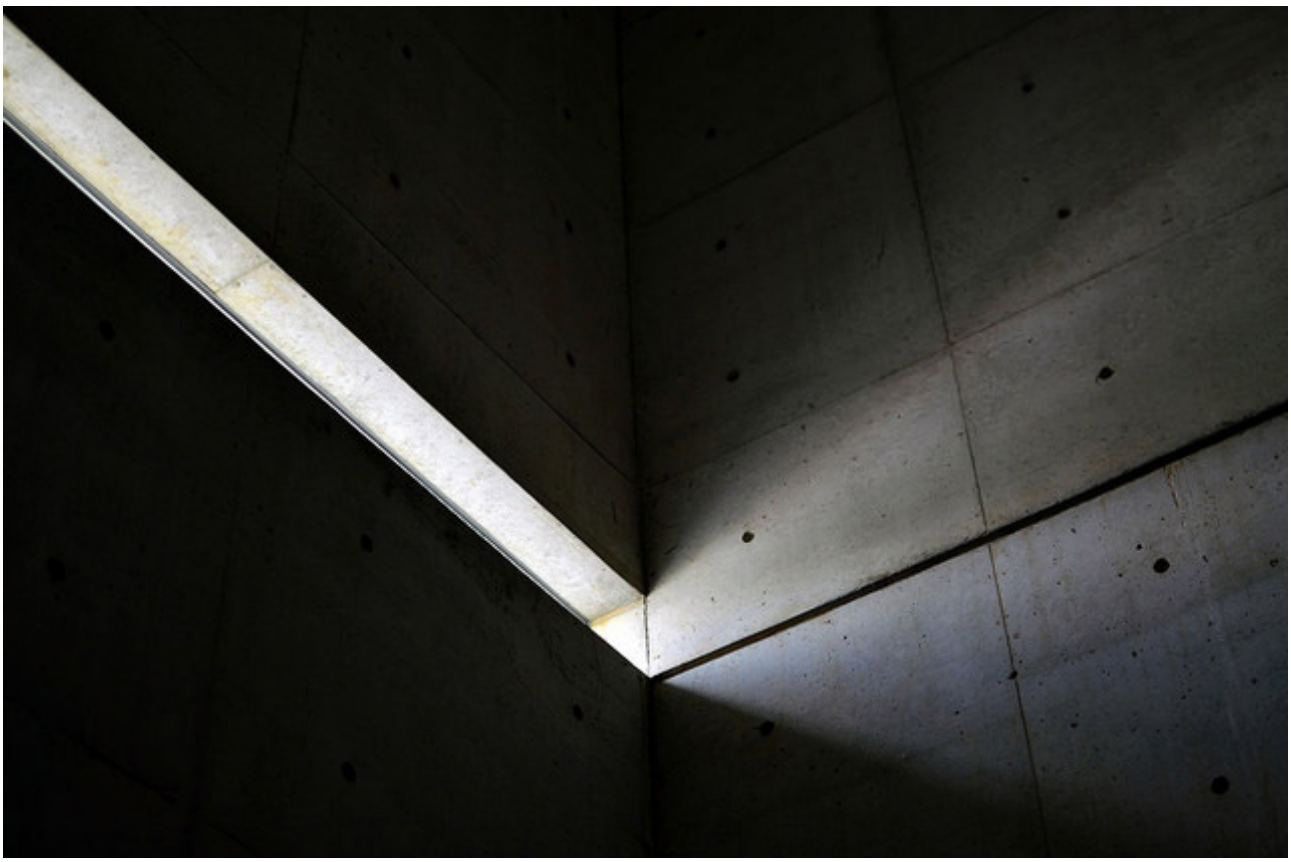


FIGURE 61 A SLICE OF LIGHT IN ANDO'S CHURCH. ONE CAN ALMOST IMAGINE REACHING OUT AND TOUCHING IT (Morimoto, 2015).

"THE CONSTRICTED LIGHT APPEARS TO OPEN UP AGAIN ONCE IT HAS PASSED THROUGH THE THRESHOLD, ACHIEVING ITS OWN INDEPENDENT PRESENCE IN THE SPACE"

KEY, 2013

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Conclusion

To conclude, I will once again return to the distinction between designing with light as an intention versus as a consequence of other design decisions. Through analysis of light in architectural space, this paper elucidates the ways in which light impacts the experiential qualities of a space; revealing the transformative potential of incorporating light as a primary driver in the design process. Light can be shaped with intention beyond technical efficiency and architects like Kahn, Le Corbusier, and Ando exemplify this intentionality.

The analysis of the three case studies demonstrate how light can be a primary, intentional force in the spatial experience. The Pantheon uses light's awe-inspiring scale to build a connection to the gods. Notre Dame du Haut celebrates the cosmic choreography of light, playing with intensity and colour to invite introspection and spiritual connection. And Ando's Church of the Light exemplifies how contrast can transform light into an almost tactile experience, and how sunlight's natural qualities can introduce life into space.

By taking an experimental approach to analysing light; one that models light's intangibility as tangible, three-dimensional forms, it is possible to visualise a new perspective on the spatial and temporal effects of light. Allowing for deeper analysis of form and movement over time than that of traditional means. It invites designers to rethink their relationship with light, consider a paradigm where light is material, and shape it with intentionality.

This research lays the groundwork for the development of new design tools that integrate three-dimensional modelling of light into the design process; thus enabling designers to experiment with light and form simultaneously, throughout the design process. Beyond the realm of architecture, this paper may influence artistic explorations that explore light as a material substance; the "thing-ness of light" as described by James Turrell (quoted in Pallasmaa, 2008). Or in the fields of urban planning and interior design, where the 'shape of light' could inform the placement of buildings or internal walls and furniture.

I will conclude by saying that the process of writing this paper has revealed to me the power of light as a force to shape experience. And that architects and designers who utilise this force to its fullest potential, can push the boundaries of what is possible in both form and sensation.

What follows are some images created throughout the process of writing this paper that I believe encapsulate the spirit of each case study…

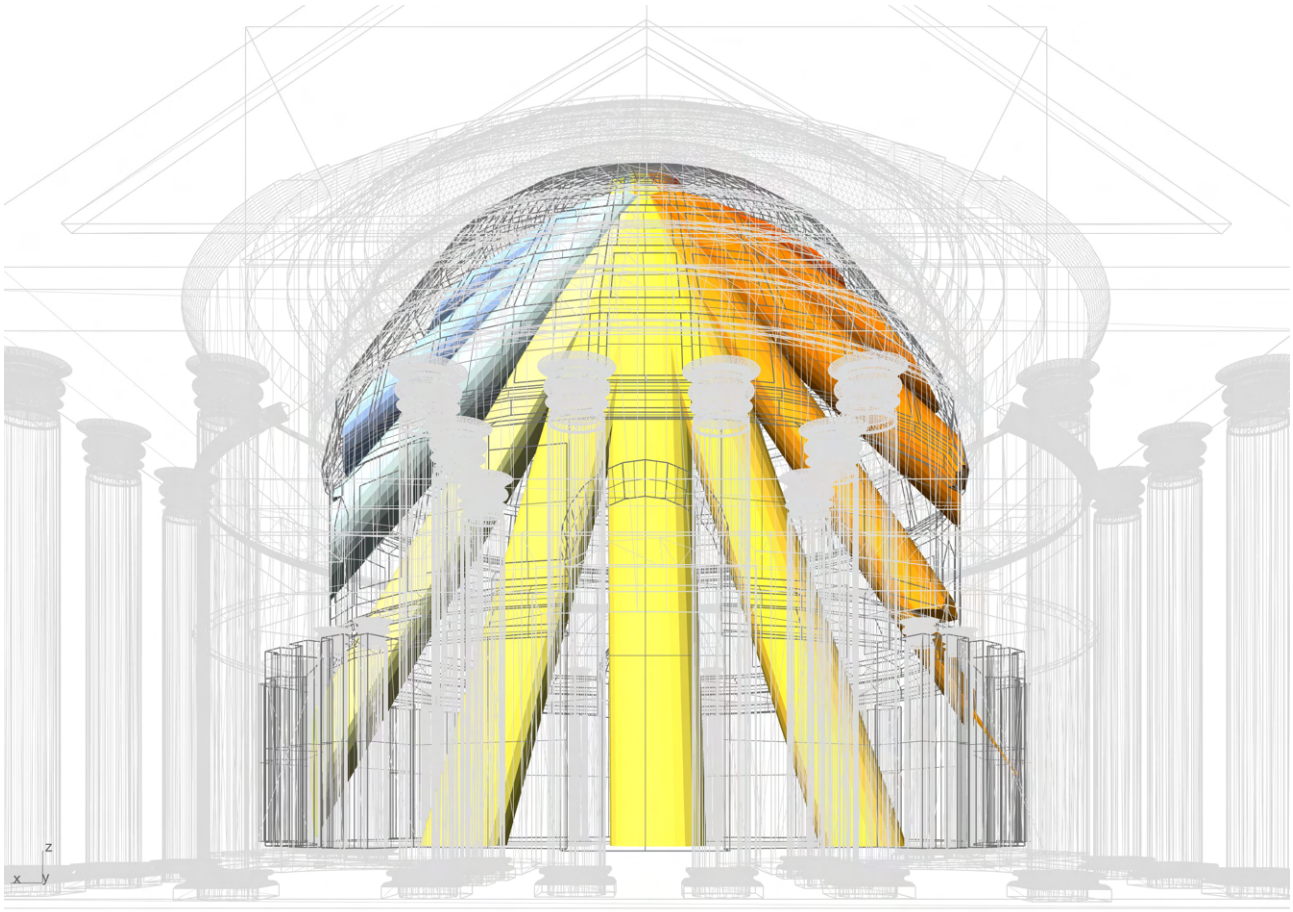
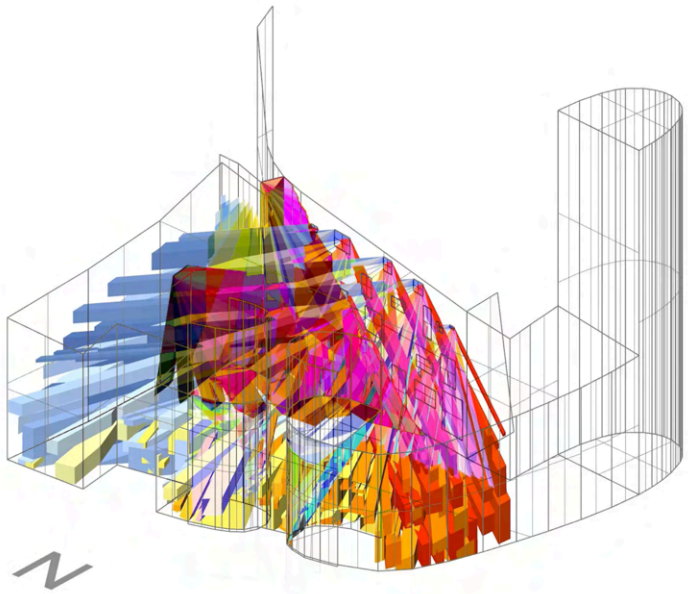


FIGURE 30

THE SCALE OF THE PANTHEON



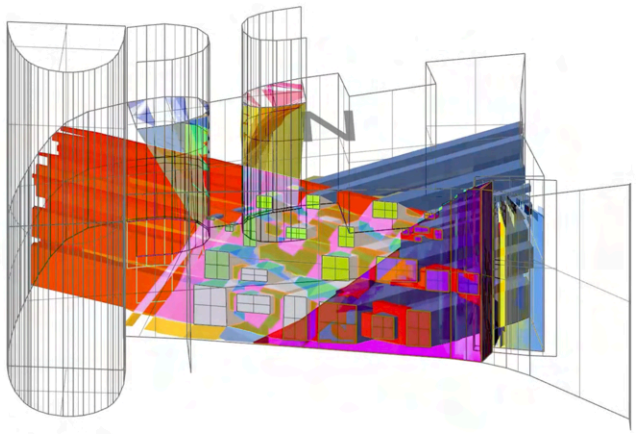
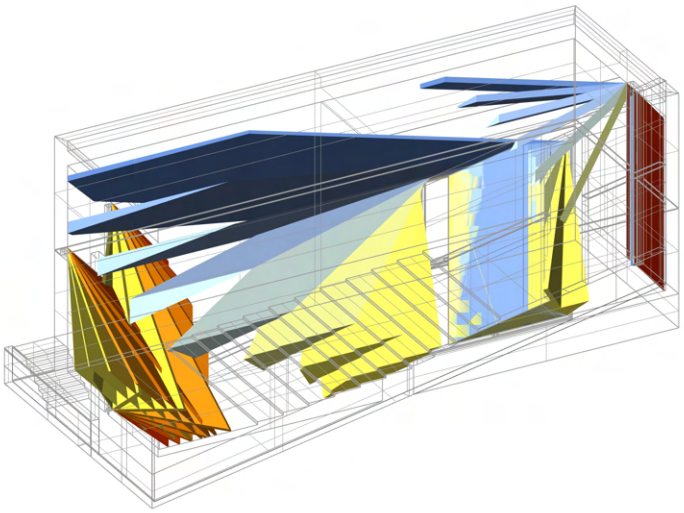


FIGURE 62

THE COLOUR OF THE CHAPEL



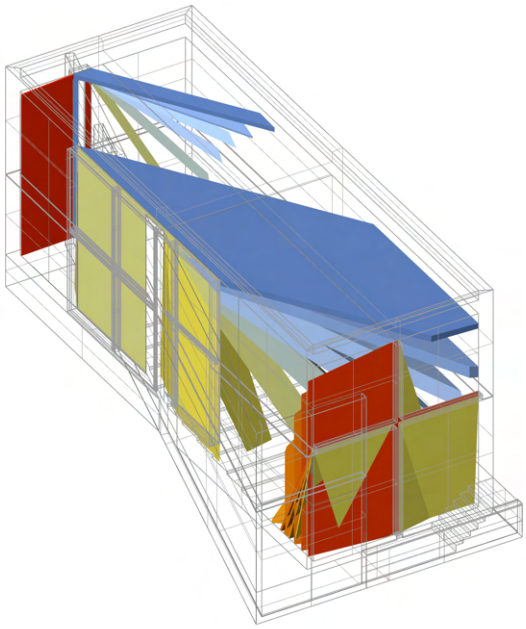


FIGURE 63

THE PRECISION OF THE CHURCH

Appendix

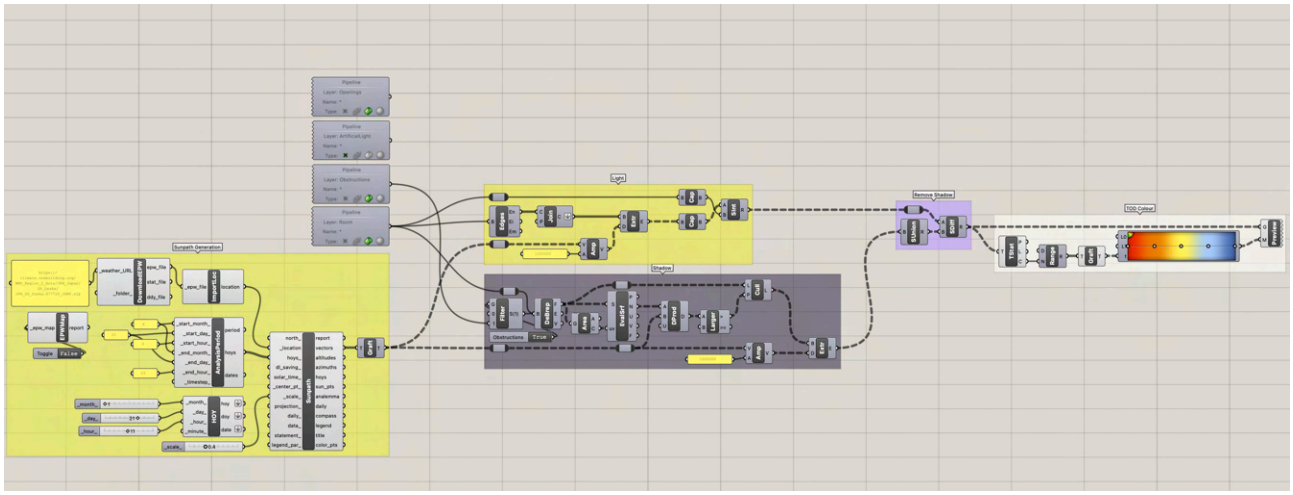


FIGURE 64 FINAL GRASSHOPPER SCRIPT FOR GENERATING THE SHAPE OF LIGHT.

GENAI WAS USED IN A MINOR CAPACITY TO REFINE HIGH-LEVEL IDEAS AND STRUCTURE. ALL OUTPUTS WERE CRITICALLY EVALUATED AS PER ANY SOURCE OF INFORMATION.

Reference List

Ando, T., 2021. *Tadao Ando: "Conquering light"* [Online]. Milan: Editoriale Domus. Available from: https://www.domusweb.it/en/speciali/guest-editor/tadao-ando/gallery/2021/01/04/tadao-ando-conquering-light-editorial-1053.html [09/12/24].

Ando, T., 1997. CHURCH OF THE LIGHT. IBARAKI, OSAKA. [JAPAN]. Arquitectura *COAM*, 311, p. 75.

Britannica., n.d. Abu Simbel [Online]. Chicago: Encyclopædia Britannica, Inc. Available from: https://www.britannica.com/place/Abu-Simbel [09/12/24].

Britannica., n.d. Sundial [Online]. Chicago: Encyclopædia Britannica, Inc. Available from: https://www.britannica.com/technology/sundial [09/12/24].

British Museum, 2021. Gods and Goddesses of the Greek and Roman Pantheon [Online]. London: British Museum. Available from: https://www.britishmuseum.org/blog/gods-and-goddesses-greek-and-roman-pantheon [09/12/24].

Bruno, M. [Michele bruno], 2017a. LinkedIn [Online], 05/12/2017. Available from: https://www.linkedin.com/pulse/daylighting-history-architecture-church-light-tadao-ando-bruno/ [30/12/24].

Bruno, M., 2017b. Luminance evaluation - vernal equinox - Church of light - Tadao Ando architect [Online]. Available from: https://vimeo.com/245969640 [30/12/24].

Bruno, M., 2017c. render animation - 2 solstices and an equinox [Online]. Available from: https://vimeo.com/245976251 [30/12/24].

Campo Baeza, A., 2006. In the light of the light avalanche of Le Corbusier [Online]. Madrid: Minerva. Ed. Available from: https://www.campobaeza.com/texts/page/9/ [09/12/24].

Darnthamrongkul, S., 2024. Challenging Orthodoxy: Facade Ideas in the Work of Louis I. Kahn and Robert Venturi. ProQuest Dissertations & Theses.
Facade

El Croquis., 2000. *Tadao Ando 1983-2000 Space, Abstraction & Landscape*. Spain: El Croquis.

ERCO., n.d. Mesopic vision (twilight vision): Definition [Online]. Available from: https://www.erco.com/en/designing-with-light/lighting-knowledge/visual-perception/mesopic-vision-twilight-vision-7467/ [30/12/24].

Giurgola, R. & Mehta, J. (1975) *Louis I. Kahn*. Boulder, Colo: Westview Press.

Gupta, S., 2019. *Choreography of light and its conversation with an architect* [Online]. Delhi: STIR Design Private Limited, Inc. Available from: https://www.stirworld.com/think-opinions-choreography-of-light-and-its-conversation-with-an-architect#:~:text=In%20modern%20times%2C%20there%20are,and%20the%20Swiss%20Peter%20Zumthor. [09/12/24].

Heathcote, E., 2024. Tadao Ando: the self-taught contemporary architecture master who 'converts feelings into physical form' [Online]. Bath: Future Publishing Limited Quay House. Available from: https://www.wallpaper.com/architecture/architecture-director-ellie-stathakis-gift-guide-for-urban-explorers [09/12/24].

Jodidio, P., 2012. Tadao Ando : Complete Works 1975 - 2012. Cologne: Benedikt Taschen Verlag.

Jordy, W.H., Salk, J., Rossi, A., Isozaki, A., Andō, T., Venturi, R., Scott Brown, D., Gill, B., Frampton, K., Kanopy and Kanopy, 2014. *Louis Kahn: silence and light.* San Francisco, California, USA: Kanopy Streaming.

Kahn, L., 1957. Architecture is the Thoughtful Making of Spaces. Perspecta, 4, pp.2–3.

Kahn, L., 1969. L'architecture d'aujourd'hui. N° 142.

Kahn, L.I. and Johnson, N.E., 1975. Light is the theme : Louis I. Kahn and the Kimbell Art Museum. Fort Worth, Texas: Kimbell Art Foundation.

Key, R., 2013. What is a design language in the service of the experience of light? Exegesis.

Le Corbusier, 1998. *Towards a new architecture*. Rev. ed. Oxford: Architectural.

Lobell, J. and Kahn, L.I., 2008. Between silence and light : spirit in the architecture of Louis I. Kahn. 2008 edition. Boulder, Colo: Shambala.

Magli, G. and Hannah, R., 2011. The Role of the Sun in the Pantheon's Design and Meaning. Numen [Online], 58(4), pp.486–513. Available from: https://doi.org/10.1163/156852711X577050.

McLaughlin, P., 1972. How'm I doing, Corbusier?. Vol. 71, No. 3. Pennsylvania: The Pennsylvania Gazette.

Pallasmaa, J., 2008. Tangible Light. Daylight and Architecture, 6, 8-13.

Plummer, H., 2009. The architecture of natural light. London: Thames & Hudson.

Plummer, H., 2003. Masters of light. Vol. 1, Twentieth-century pioneers. Tokyo: A+U.

Plummer, H. and Le Corbusier, 2013. *Cosmos of light : the sacred architecture of Le Corbusier*. Bloomington and Indianapolis: Indiana University Press.

Rich, J. W. (Ed.). (1990). BOOK 53. In Cassius Dio: The Augustan Settlement: Roman History 53.1–55.9 (pp. 22–67). Liverpool University Press. https://doi.org/10.2307/j.ctv10tq4w9.7.

Robertson, E., n.d. TADAO ANDO: “THERE IS NO SUCH THING AS CREATION FROM NOTHING” [Online]. Berlin: Black Ink GmbH. Available from: https://the-talks.com/interview/tadao-ando/ [09/12/24].

Schielke, T., n.d.. Louis Kahn and the Power of Shadow [Online]. Japan: Window Research Institute. Available from: https://madoken.jp/en/series/31192/#:~:text=Kahn's%20archetypal%20forms%20trace%20back,column%20bring%20light%20between%20them. [09/12/24].

Schielke, T., 2015. Light Matters: Le Corbusier and the Trinity of Light [Online]. Santiago: Arch Daily. Available from: https://www.archdaily.com/597598/light-matters-le-corbusier-and-the-trinity-of-light [09/12/24].

Schielke, T., 2024. When Sunlight Meets Tadao Ando’s Concrete [Online]. Santiago: Arch Daily. Available from: https://www.archdaily.com/915270/when-sunlight-meets-tadao-andos-concrete [09/12/24].

Foundation Le Corbusier., n.d. *Chapelle Notre-Dame-du-Haut, 1950* [Online]. UNESCO. Available from: https://lecorbusier-worldheritage.org/en/chapelle-notre-dame-du-haut/ [08/01/2025].

Vasas, V., Lowell, M.C., Villa, J., Jamison, Q.D., Siegle, A.G., Katta, P.K.R., Bhagavathula, P., Kevan, P.G., Fulton, D., Losin, N., Kepplinger, D., Yetzbacher, M.K., Salehian, S., Forkner, R.E., Hanley, D. and Patricelli, G.L., 2024. Recording animal-view videos of the natural world using a novel camera system and software package. *PLoS biology* [Online], 22(1), pp.e3002444–e3002444. Available from: https://doi.org/10.1371/journal.pbio.3002444.

Wright, L., Cantacuzino, S., Amery, C., et al, 1974. *Architect: Louis Kahn. The Architectural Review*, 155(928), pp.329.

Wurman, R.S., 1986. What will be has always been : the words of Louis I. Kahn. New York: Access Press and Rizzoli.

Figures

Figure 1 Ghinitoiu, L., 2022. *Indian Institute of Management* [Online]. Available from: https://afasiaarchzine.com/2017/02/louis-kahn-2/ [08/01/2025].

Figure 2,3 Vasas, V., Lowell, M.C., Villa, J., Jamison, Q.D., Siegle, A.G., Katta, P.K.R., Bhagavathula, P., Kevan, P.G., Fulton, D., Losin, N., Kepplinger, D., Yetzbacher, M.K., Salehian, S., Forkner, R.E., Hanley, D. and Patricelli, G.L., 2024. Recording animal-view videos of the natural world using a novel camera system and software package. *PLoS biology* [Online], 22(1), pp.e3002444–e3002444. Available from: https://doi.org/10.1371/journal.pbio.3002444.

Figure 4 *The Hidden World of Ultraviolet Light Colour: The Spectrum of Science[online]*, 2015. London: BBC. Available from: https://youtu.be/AroQUYd0ZUU?si=Mh8kHZQEEnjCO4QJ.

Figure 22 Zeyrek, S., Year. *2,000-year-old sundial unearthed in southern Turkey's Denizli* [Online]. Available from: https://www.dailysabah.com/life/history/2000-year-old-sundial-unearthed-in-southern-turkeys-denizli [08/01/2025].

Figure 23 Desgodetz, A., 1779. Les edifices antiques de Rome dessines et mesures tres exactement.

Figure 33 nonac.eos., n.d. *21st of April - Dies Romana - Pantheon - Rome - Italy* [Online]. Flickr. Available from: https://www.flickr.com/photos/nonac_eos/17212033976 [08/01/2025].

Figure 34 De Franceschini, M., 2014. *The Pantheon in Rome. New images of Light Phenomena.*. Article. ALSSA.

Figure 36 Bianchini, R., n.d. *Plan of the Ronchamp Chapel* [Online]. Available from: https://www.inexhibit.com/case-studies/notre-dame-du-haut-chapel-ronchamp-le-corbusier/ [08/01/2025].

Figure 40 Maher, N., 2017. *Main Alter* [Online]. thewoodhouseny. Available from: https://www.thewoodhouseny.com/journal/2018/6/20/the-chapel-at-ronchamp [08/01/2025].

Figure 44 Bednorz, A. and Monheim, B., n.d. Ronchamp [Online]. Available from: https://www.daylightandarchitecture.com/light-and-materials/ [08/01/2025].

Figure 45 Key, R., 2013. What is a design language in the service of the experience of light? Exegesis.

Figure 46 Plummer, H., 2003. Masters of light. Vol. 1, Twentieth-century pioneers. Tokyo: A+U.

Figure 47 Maher, N., 2017. *Main Alter* [Online]. thewoodhouseny. Available from: https://www.thewoodhouseny.com/journal/2018/6/20/the-chapel-at-ronchamp [08/01/2025].

Figure 54 Morimoto, H., 2015. *Church of the Light* [Online]. Het gallery. Available from: http://www.hetgallery.com/church-of-the-light.html [08/01/2025].

Figure 55 Bruno, M. [Michele bruno], 2017a. LinkedIn [Online], 05/12/2017. Available from: https://www.linkedin.com/pulse/daylighting-history-architecture-church-light-tadao-ando-bruno/ [30/12/24].

Figure 57 Araki, N., 1989. *Tadao Ando* [Online]. Available from: https://www.metalocus.es/sites/default/files/metalocus_tadao-ando_iglesia-de-la-luz_32_a.jpg [08/01/2025].

Figure 58 Trees Sunlight., n.d. *Trees Sunlight* [Online]. pxfuel. Available from: https://www.pxfuel.com/en/desktop-wallpaper-wejep [08/01/2025].

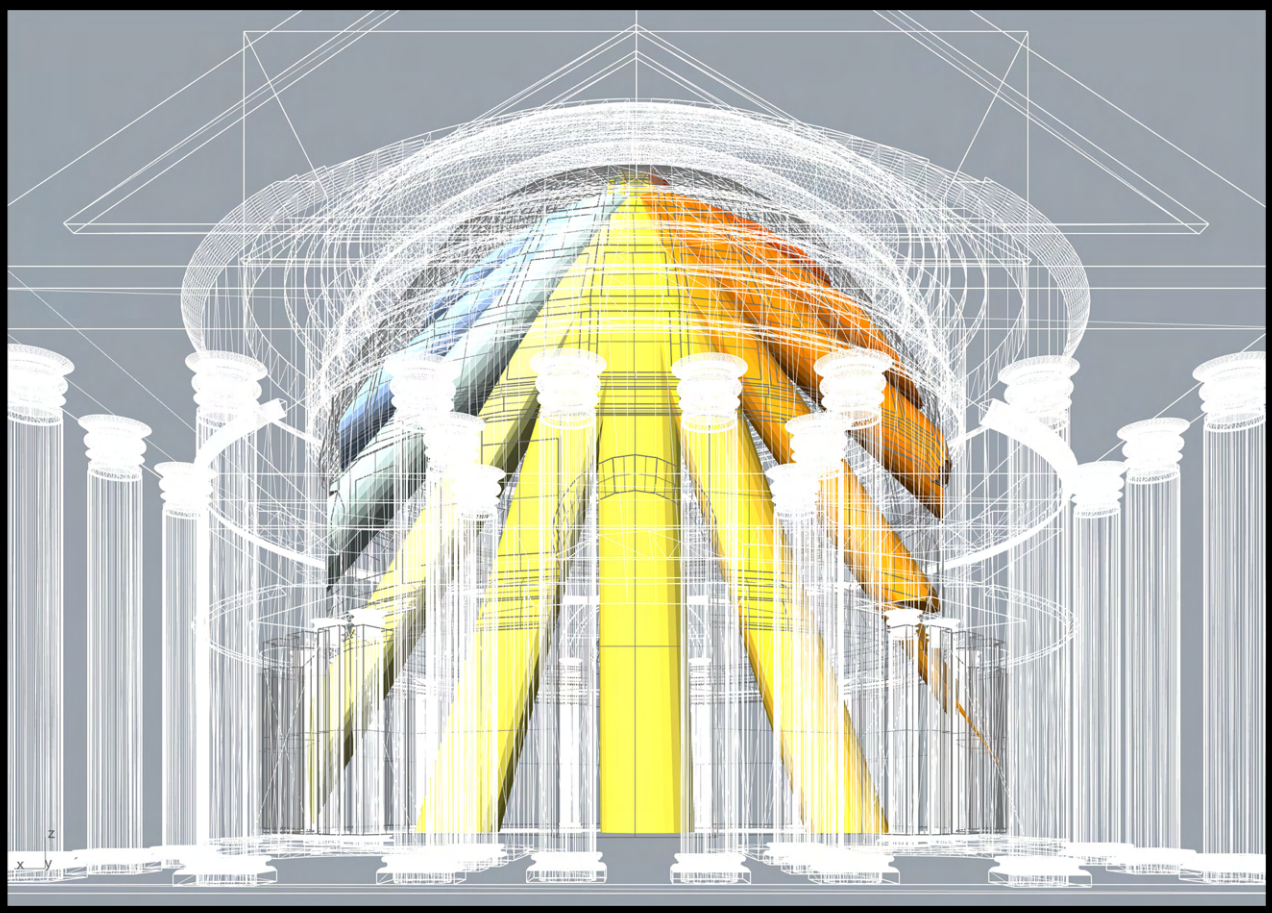
Figure 59 Bergmann., 2006. 茨木春日丘教会の教会堂である「光の教会」のシンボル、光の十字架。[Online]. wikipedia. Available from: https://commons.wikimedia.org/wiki/File:Ibaraki_Kasugaoka_Church_light_cross.jpg [08/01/2025].

Figure 60 Bruno, M., 2017b. Luminance evaluation - vernal equinox - Church of light - Tadao Ando architect [Online]. Available from: https://vimeo.com/245969640 [30/12/24].

Figure 61 Morimoto, H., 2015. *Church of the Light* [Online]. Het gallery. Available from: http://www.hetgallery.com/church-of-the-light.html [08/01/2025].

All other figures by author.

The Shape of Light



How can understanding the ‘shape’ and movement of light help architects design buildings with intentional artistic, spatial and experiential outcomes?

END

LOUIS WOOD