"Light thinks it travels faster than anything, but it is wrong. No matter how fast light travels, it finds the darkness has always got there first, and is waiting for it."

— Terry Pratchett, Reaper Man

Thesis Heading:

The preservation of light is important for our appreciation of darkness but with the constant increase of light pollution we are threatening the very beauty that darkness is. So, we must design for darkness so we can appreciate its beauty.
There is no darkness without light but an abundance of light destroys darkness therefore we must find better ways to preserve light for the beauty of darkness to be appreciated.

Introduction to the dark

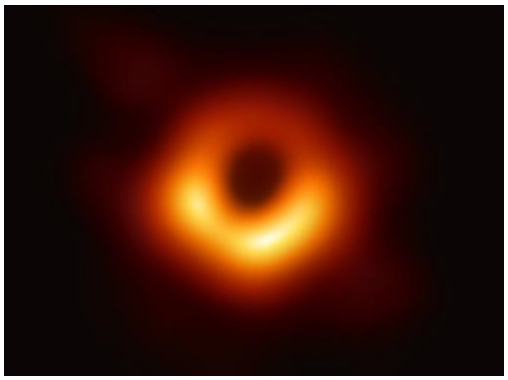

Figure 1 Radio image of the black. (Event Horizon Telescope, 2019).

On 10 April 2019, the first photo of a Black Hole was published by astronomers of the Event Horizon Team at the Harvard-Smithsonian Centre for Astrophysics. The team at the centre had managed to capture the unobservable they had been able to capture total darkness. Even when you shine a light at a black hole you would not see it for all the photons would be sucked into the hole by the extreme gravity, no reflection whatsoever. Thus, what they did was display the ultimate darkness of a black hole by showing the light around it. The light we saw on the photo was that of the bright material circling the hole therefore leading to the conclusion that what they had done by showing us the black nothingness had only been possible through the light matter surrounding it.

Figure 2 Sea Sparkle (Reynolds, 2015).

In the country without all the public lighting and the constantly lit office blocks, we come to appreciate the darkness we forgot. But here again the darkness is defined by light. Standing on a mountainside in the evening overlooking a valley we admire the wide dark view, but our eyes are automatically drawn to the few lights of the farms in the valley and when we look up we can see the milky way in the night sky without interference of the light pollution in the city. Again, standing on the beach at night we feel engulfed by the darkness, but here as well the darkness is defined through our eyes being drawn to the lights of a ship in the distance, the stars in the sky or the bioluminescence of the surf. Figure 2 illustrates the beauty of the darkness that I am mentioning when there is just enough light from both the

Milky Way and the luminesce of the surf to show us how dark the landmass. It is this contrast of lights that show us the darkness.

Definition of Dark

The online definition by the Oxford Living Dictionary defines Darkness as the partial or total absence of light[1]. Merriam-Webster defines dark as being devoid or partially devoid of light: not receiving, reflecting, transmitting, or radiating light[2]. By its very definition darkness can only be explained through there having been an element of light. Therefore it is for humans; light defines darkness and without light the concept of darkness is meaningless.

As Khan notes, even a space intended to be dark should have just enough light from some mysterious opening to tell us how dark it is[3]. To explore the notion of darkness further and its inherent link to light we can look at the threat of light pollution in our environment and the widespread effect this has not just in driving out the darkness but on the circadian rhythms of animals and humans. The use of minimal light within buildings to accentuate and preserve the darkness through the works of Juhani Pallasmaa, Rogier van der Heide, Jun'ichirō Tanizaki, and David Becker. Finally the importance of designing for the future and to honor the darkness through the human embodiment of this through the works of Jun'ichirō Tanizaki and Juhani Pallasmaa in the importance of our appreciation of the beauty within the darkness.

Appreciation of the dark versus Light pollution

It is when we leave the city and go on holiday to the seaside or a mountainous area that we appreciate the darkness of the nights through the countless stars that we are able to view in the night skies.

In 2018 more than half of the world's population lives in urban areas, a number that is expected to increase to 68% by 2050 (United Nations, 2018). This increase in habitation of urban environments will result in a significant rise in a little known but very common pollution known as light pollution. Light pollution is the over and often unnecessary use of light that comes from our cities and urban environments. This is caused by the 24 hour lifestyle that our society has evolved to in the technical revolution of the 20th century. Light pollution is the side effect of industrialised civilisation and resulted in the inappropriate or excessive use of artificial light[4].

[1] Oxford Living Dictionary, 2019. *Definition of darkness in English by Oxford Dictionaries.*

[2] Merriam-Webster, 2019. *Definition of Dark by Merriam-Webster.*

[3] Khans' reason for never having tried to design a pure dark space in that you need a fraction of light to understand the darkness of the space. [Schielke, T, 2013. *Light Matters: Louis Kahn and the Power of Shadow].*

[4] The components of light pollution include glare: excessive brightness that causes discomfort; Sky-glow: brightening of the night sky over inhabited areas; Light Trespass: Light falling where it is not intended or needed; Clutter: bright, confusing and excessive groupings of light sources. IDA, 2019. *Light Pollution.*

This abundance of light is inefficient in both its intended illumination and its waste of electricity to create the light. We can better understand the effects though looking at Figure 3 where the reach of a single street light is shown. The infographic illustrates the different components of light pollution and what "good" lighting looks like. This is just the pollution from one street light. The effect of this waste becomes much greater as we head further into our city centre from all the lights we use to illuminate our central hubs. To further emphasise the extent to which we have become reliant on the overabundance of light in our surrounds we can refer to Figure 4, Before and during the 2003 Northeast blackout, a massive power outage that affected 55 million people in the USA. We are able to see the extent of light pollution on the surrounding environment through the sky-glow and glare from the street lights in the lower right corner of the 'before' image.

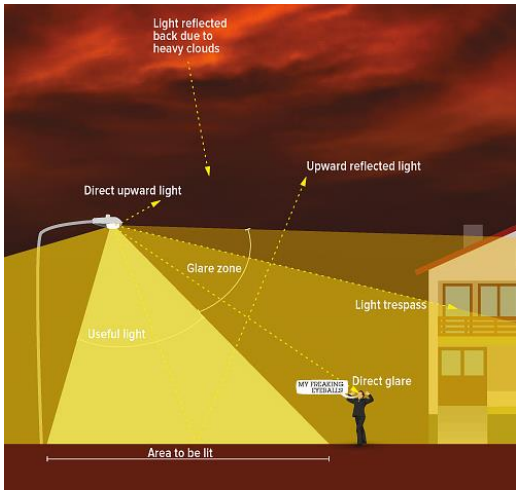

Figure 3. Image by Anezka Gocova, in "The Night Issue", Alternatives Journal 39:5 (2013).

The extent of light pollution in our skies can be seen back in a news story from 1994 when an earthquake resulted in a total power outage in Los Angeles numerous calls came into emergency centres and even the Griffith Observatory received numerous phone calls from distressed people. Crowds poured into the streets in the predawn hours looking up at the sky. The people had made those distressed calls as they were seeing what they described as a 'giant silvery cloud' that was never observed above the city before. Not to worry, they were assured by the astronomers it was merely the Milky Way[5]. Such was the pollution in our skies back then, it makes it hard to imagine what the extent of light pollution has become now. Brighter it is not always the better solution.

Figure 4. Photo by of Todd Carlson.

The State Government of the USA state of Tucson passed laws [in 1972] restricting light pollution and as a result emerged as the centre of the so-called dark-sky movement. It is now the home of the International Dark-Sky Association, which works to raise awareness about light pollution and to promote the design and marketing of outdoor lighting that has a minimal impact on the night skies.

> *"Its original roots were in protection of dark skies for astronomical purposes, but very early on the Dark-Sky Association began working with industry and*

[5] Sharkey, J., 2008. *Helping the Stars Take Back the Night.*

> *designers," said Christian K. Monrad, who owns an electrical engineering company in Tucson and is president of the association's board.*[6]

Though these laws having been made many years ago have not been effective enough as shown in Figure 5. That shows photographs of the progression of glare over the years in the Tucson area, as seen from Kitt Peak taken before the laws were introduced in 1959 and after in both 1980 and 2003. You can see the regulations were not effective enough to stop the ever growing light pollution in our expanding cities.

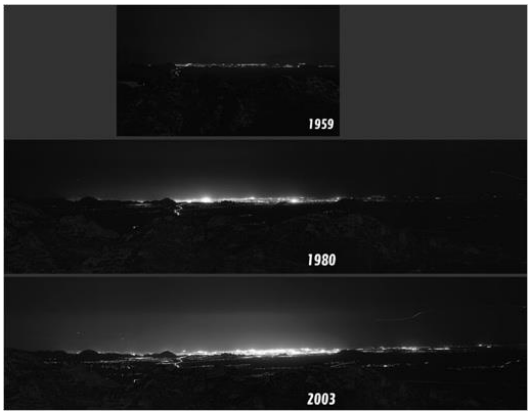

Figure 5. Credit Bill Schoening, J.C. Golson, Mark Hann and NOAO/AURA/NSF.

Nadia Drake, a science journalist, has noted about light pollution;

> *if light bulbs have a dark side, it's that they have stolen the night. The excess light we dump into our environments is endangering ecosystems by harming animals whose life cycles depend on dark. We're endangering ourselves by altering the biochemical rhythms that normally ebb and flow with natural light levels. And in a primal sense, we've lost our connection to night time skies, the tapestries into which our ancestors wove their star-studded stories, timed the planting and harvesting of crops, and deduced the physical laws governing the cosmos.*[7]

This is an issue that has also been echoed in *The Eyes of the Skin: Architecture and The Senses* the work of Juhani Pallasmaa. He explains under the heading of 'The Significance of the Shadow' that homogenous bright light paralyses the imagination in the same way that homogenisation of space weakens the experience of the being, and wipes away the sense of place. The human eye is most perfectly tuned for the twilight rather than bright daylight[8].

Society has developed a mind-set that for us to be more secure we need more light yet with more light there is more glare and thus as Pallasmaa says it becomes an effective method of mental torture is the use of constantly high levels of illumination that leaves no space for mental withdrawal or privacy; even the dark interiority of self is exposed and violated[9]. It is from the consistently lit light sources that we have also begun to impact not only on our urban environment but more dangerously on our sleep-wake cycles, the circadian rhythm. Circadian rhythm is the biological cycles that repeat themselves daily and are regulated through environmental signals, the most important one being all living organisms on Earth exhibit circadian rhythms, which are biological cycles that repeat themselves on a daily basis and are

[6] Kitt Peak facility, operated by the National Optical Astronomy Observatory, quickly decided that they had to be more than stargazers working nights on a mountaintop. [Sharkey, J., 2008. *Helping the Stars Take Back the Night.]*

[7] Drake, N., 2019. *Our nights are getting brighter, and Earth is paying the price.*

[8] (Pallasmaa, 2005, p. 46)

[9] On a society of surveillance and in a culture, that seeks to control its citizens [Pallasmaa, 2005, p. 49]

regulated or entrained by environmental signals, the most important one being the natural, 24-hour, light-dark cycle[10].

The effects of light pollution on our body is still being investigated but early data is showing that it is affecting the way we sleep, metabolise and function. Exposure to light suppresses the secretion of melatonin, a hormone that influences circadian rhythms, and there's some experimental evidence that lower melatonin levels might have an association with types of cancer[11] It is not just our bodies that are feeling the effects of light pollution it is having some far more serious, even deadly, consequences for our wildlife. Light pollution is affecting some animals breeding and migration patterns which in turn affects our wildlifes' delicate ecosystem.

> *Light pollution is considered an important driver behind the erosion of provisioning (for example, the loss of light-sensitive species and genotypes), regulating (for example, the decline of nocturnal pollinators such as moths and bats) and cultural ecosystem services (for example, the loss of aesthetic values such as the visibility of the Milky Way). As the world grows ever-more illuminated, many light-sensitive species will be lost, especially in or near highly illuminated urban areas (Hölker, et al., 2010).*

Kellie Pendoley an environmental scientist has researched how light pollution is affecting the sea turtle population in Western Australia. She says hatchlings use the illuminated horizon to find the ocean and that any artificial light behind the beach can cause confusion. "Artificial light is very attractive to baby turtles as they emerge from their nest in the sand. They'll crawl towards that instead of to the ocean. So, they either don't make it to the ocean and die, or it takes them longer to get there" (Dengate, 2018). Pendoleys' research on turtle hatchlings is not the only research that has been done into the effects of light pollution, La Trobe University in Melbourne has researched the breeding of wallabies and other studies have also shown a change in plant germination cycles from artificial light. Research published by La Trobe University in Melbourne found that light pollution was causing some wallabies to delay giving birth by a month, putting them out of sync with the food resources they need, and putting their joeys at risk. The ecological effects of artificial light on plants is also beginning to be documented. Scientists and commercial nurseries have been using artificial light to grow plants for a long time, and recently published research has found that the rapid increase in outdoor lighting could be disrupting the natural light cycle that wild plants have evolved under [12].

As pointed out it is important to preserve the darkness and prevent light pollution from our cities. I am also aware however that we will always be a 24 hour city at least for now because

[10]In humans and the vast majority of animals, patterns of light and dark reaching the back of the eyes are converted to neural signals that promote synchronization of the body's "biological clock" with the local time on Earth. [Figueiro, M., Gonzales, K. & Pedler, D., 2016. Designing with Circadian Stimulus. *Circadian Stimulus,* October].

[11] Some studies suggest a link between exposure to light at night, such as working the night shift, to some types of cancer, diabetes, heart disease, and obesity. [Anon, 2018. *Blue light has a dark side]*

[12] Dengate, C., 2018. *The Dark Side of Light: How light pollution is damaging our world.*

that is what our global economy has developed into. So, we must begin to find ways in which we can use our understanding of technologies, old and new, to create efficient and clever lighting applications for our buildings, public spaces and streets. We appreciate the darkness of the night because we see the light from the stars in the Milky Way but this may not always be the case as darkness is under threat from the very source that enables us to understand how dark a space is: light. If we do not begin to design with darkness in mind them we will drive out the darkness from our daily existence and the effects that this will have on our circadian rhythm and long term survival will be critical. So, we must understand that we do need light to define the darkness but we must take caution to not entirely wipe away the darkness.

Lighting Techniques

Light pollution is a phenomenon that started in the 20th Century when the use of electrical lighting became widespread. Before the era of electrical light architects would design their buildings always aware of how the natural light entered and lit the interior. A practice called "daylighting" where one should think of the room that they are illuminating as a secondary luminaire which illuminates the eye. Just as they examine the optical properties of the primary sources, whether luminaires or windows, in order to understand how they will distribute flux within the room, so they may examine the optical properties of room surfaces to understand how they will interact with the distribution of direct flux and present light to the eye[13]. Examples of perfect daylighting can be seen in the past architecture before we had developed proper systems of lighting. The examples following of Oculus and the Spanish architect Gaudí look at daylighting through windows and architectural devices.

Figure 6. The Oculus in the Pantheon, Rome. (Knudsen, 2004)

All most all books and articles about daylighting start with the example of the Oculus in the Pantheon in Rome. It shows how the architects in the antiquity already made great use of the natural light. The old Roman temple that is now a church was built in 126AD by emperor Hadrian. It is in the centre of the building in the rotunda where the unknown architect has used the natural light by letting it in through a circular hole in the domed roof. This is called an Oculus and has since then been repeated many times in architectural buildings around the world. I had read about the Pantheon but was not prepared for the actual experience when I visited Rome a few years ago. Even on a cloudy day the circle of light is very distinct and impressive how it slowly moves around the 43-meter-wide rotunda. The beam of light is like

[13] Cuttle, C. .. .. 2. & ., 4., 2010. Towards the third stage of the lighting profession. *Lighting Research and Technology,* Issue 42, p. 73–90.

an antique spotlight but gives enough peripheral light to light the whole of the building so that during the day there is no necessity for artificial lighting.

Figure 7. Gauí Yard. (Terrones, 2016)

Looking at Spanish Architect Antoni Gaudí as an example of an architect who made smart use of natural light in his design of the central light well of the Casa Batlló. When he was asked to renovate a house for the Batlló family in Barcelona he came across the problem that the plot for the house was long and narrow making it hard for natural light to enter the 5-storey house. A large stairwell or atrium was placed in the middle of the house to enable an abundance of light to enter down to the lower levels rather than just the top floor. Similar to the Oculus allowing a circle of light inside this has allowed a hole of light to penetrate all levels. In tandem with the large well Gaudí designed the tiles in a manner that took into account the lightness of the light on the upper floors being much brighter than that of the lower levels and ground. The tiles were arranged to compensate for this, with lighter tiles on the ground and to lower levels and darker tiles on the upper levels. These tiles allowed for an illusion of uniformity in colour to play out. Looking back to the architecture from the past we are able to gain an insight in to how we can better design for the future and systems to combat the threat of light pollution in our urban environments.

Following on from the natural appreciation of the dark there are also architects and writers who are known for their exploration and appreciation of the darkness such as Peter Zumthor, Juhani Pallasmaa and the writer Jun'ichirō Tanizaki. Zumthor explores the use of light as a method and/or element of carving into the darkness focusing on the shadows that are the result of introducing light in to a void of black. Pallasmaa and Tanizaki explore light and shadow through food and the differences between Western and Oriental design cultures. There is also three lighting designers who I will be examining through their thoughts on how we use light currently and the way we can use architectural principals to preserve the dark. Rogier van der Heide a Dutch public and commercial lighting designer whose TED Talk on 'Why light needs darkness' explores the importance of preserving darkness. Another designer: Daan Roosegaarde and his collaboration with infrastructure company Heymans on their 'Smart Highway'. And finally the Chair of Certified Lighting Designer (CLD) David Becker who designed the lighting for the Saffire Lodge located in Freycinet during 2011-12.

An example of very local light and energy saving is the Glowing Lines project by Dutch designer Daan Roosegaarde which exhibited for a three year period between 2012-2015, with the intention for the system to be relaunched throughout the Netherlands and eventually internationally. Together with the infrastructure company Heymans Infrastructure, Roosegaarde developed glowing lines as part of his bigger project "Smart Highway" [Figure 8]. In contrast to the abundance of floodlights that you see on most highways for the N329 near Oss in Netherlands: the only lights on the highway are in fact in the lines of the highway itself. The lines are made from a special luminescent paint that is charged through the day by solar energy and then once it becomes dark they glow for up to 8 hours. "A phosphorescent jewel gives off its glow and colour in the dark and loses its beauty in the light of day, were it not for shadows, there would be no beauty" (Tanizaki, 1977). Tanizaki referring to the bright glow from the specks of gold in Japanese jewellery boxes under a candle light in an otherwise dark room through the shadow of light that lands upon it. We can draw a modern parallel of this to Roosegaarde's Glowing Lines, where the glow emitted from the lane lines is more brilliant under the artificial light from headlamps.

Figure 8. Glowing Lines 2012-2015, Smart Highway Project (Roosegaarde, 2012).

Daylighting is allowing enough natural light into a space throughout the light hours in our day. However, it is not just natural light that we should be designing in mind with we should more importantly design from darkness, as this is where we are pushing the boundaries of our circadian rhythm by living and working past sundown. The result is the need for artificial illumination and the crux of light pollution origins. This can be noted in the hospitality industry where the routine of guests does not always follow the circadian cycle and where illumination needs to be present for directional and safety purposes. To design around the issue of directional lighting and light pollution the industry needs to develop ways to enable guests to have the best experience while also preventing the extent of light pollution in the surrounding environment and into the sky. Exploring daylighting and designing for the dark it is possible to examine David Becker's lighting design for Saffire Freycinet in Tasmania with his use of large windows that allow for maximum natural light throughout the day as well as offering guests a spectacular view over Coles Bay.

David Becker, director of Point of View was charged with the task of lighting the interior and the complex curves and glass walls of the exterior. His aim was to use as little light as possible

and to focus on the guests' ability to see the magnificent view[14] of the Freycinet Peninsula [Figure 9]. He explained his process and reasoning for his lighting design in his visit to UTS, Ultimo on the 30th of May 2019. In his design he pushed the constraints so far as to be intentionally under national lighting regulations in order to achieve the design outcome that could be called luxury in minimal lighting. Becker said, "a minimum we could get away with…very dark space at night time…glow of surfaces creates light"[15] It is the purpose of Saffire Lodge to be a retreat from urban life. That has resulted in the agenda of Becker's' lighting design of light to be scarce and "preserving the darkness of the environment as much as possible" (Dickson, 2010). As Tanizaki writes in his book In Praise of Shadows "If light is scarce then light is scare; we will immerse ourselves in the darkness and there we discover its own particular beauty." It is through emersion low light levels with the darkness enveloping us in a comforting feel that we can understand and appreciate it. As he again comments further along in his book writing "So benumbed are we nowadays by electric lights that we have become utterly insensitive to the evils of excessive illumination". In order to regain our lost senses of the darkness we must begin designing to maximise daylight as this will show the constraints through which we can design the light. To design with the future and human embodiment of darkness in mind we need a luminous source to enable us to fully appreciate the darkness that surrounds us in the nights.

Figure 9. View from foyer of Saffire Lodge

Figure 10. Bedroom lighting and view (Dickson, 2010)

While researching this I came across many articles and books on smart light design. But when it comes to the use of daylighting, I would like to mention one resource that I intend to use every time I want to use Daylighting in a project. That is the Daylighting Pattern Guide[16], a website created by the New Buildings Institute in cooperation with the universities of Idaho and Washington. It shows the many possibilities of the use of natural light and provides clear examples of where this has been done in situ. It is resources such as these that are providing the stepping stone to creating a smarter lighting design world for emerging designers who need to understand of how the layout of a space and the lux present can affect the way a space it lit and help in reducing the amount of light pollution created.

[14] Extract was taken from online source, Architecture Au, cited in bibliography but was first published in the December 2010 Issue of Artichoke where this article has taken the extract from.

[15] ……[Voice recording of 86321: Investigations Guest Lecture, Int. Arch on the 30th]

[16] (New Buildings Institute, 2019)

A state-of-the-art example for the use of light is the Nvidia Campus in Santa Clara California. Nvidia is a company that leads the world in Graphic Video Hardware and Artificial Intelligence. For the design of the lighting of their new campus in 2017 the latest techniques in virtual reality modelling software were used. The result was a building that uses all the lighting techniques old and new. Abundant daylighting with high glass facades and triangular glass panels in the roof. Similarly, to the Saffire Freycinet, with its large water facing glass wall to maximise the amount of daylight entering even when overcast the light will enter into the space. Photometric monitoring to create a constant ambient light environment. Motion detector lighting has been installed to prevent unnecessary lighting. Also, reducing the amount of energy waste with having lights unnecessarily on when sections of the building are not in use. Led lighting in the form of lensed lines for directional up lighting.

Figure 11. Entrance to Nvidia (Office Tour, 2017).

Figure 12. Overview of Nvidia Campus (Office Tour, 2017).

Summary

The importance of when creating good architecture should always include considerations for lighting systems that will minimise the light pollution produced by buildings in the night and twilight hours of the day. We can learn from the past when architects created all sorts of clever designs to use the natural light in their buildings. Modern technologies have given us a whole new toolkit to create buildings and spaces with less light pollution and energy waste. Light with less energy by using LED (Light Emitting Diodes) lights and CFL (Compact Fluorescent Lamps). We have light only when we need it thanks to motion detection and the smart use of new types of reflective material. We have light only where we need it with directional techniques and reflective surfaces. If we as designers can master this in our urban environments then we can open our eyes to the beauty that is in darkness. We can again view the Milky Way and the moonlight on the surf at night. We can begin to re-appreciate what we have lost through the fast evolution of technology and allow the darkness to envelop and embody our senses. Lessening our importance of light and focusing instead our attention in the shadows and darkness through the minimal light that will be emitted. We must for a brighter future, honour the darkness.

“There is no dark side of the moon really. As a matter of fact, it's all dark.”

Pink Floyd – The Dark Side of the Moon

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