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Designing Fictional Spaces: Questionable Architecture that Supports Sustainable Design

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Abstract

This thesis presents the modeling of spaces described in short stories that are difficult to visualize. The three stories are Kafka's "The Burrow", Borges's "The Library of Babel" and Barthelme's "The Balloon." Three dimensional models were created based on the details provided by the authors in each story. Several 2-D images are then generated from these models to match specific scenes. This consideration of these works of fiction provokes the asking of several questions about the science, mathematics and engineering that underpins the stories. In all cases, questions about sustainability arise.

This manuscript is divided into three parts to correspond to each story. Each part includes the following: a story background, a literary/historical analysis of the story, the modeling process, model images, and then questions about the science, mathematics and engineering that arise from the fiction.

Dedication

To Dr. Murray, Dr. Slade, Dr. Kallenberg, Dr. McCombe, & Dr. Bein for supporting this radical thesis idea in the exploration of engineering, art, literature, science, philosophy and mathematics. Also, to Donald Barthelme, Franz Kafka, and Jorges Luis Borges for creating their stories.

University *of* Dayton

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Introduction

Literature of the past has brought society unfathomable stories of design. Stories that are clearly human but however do not seem possible to exist in the physical world with human concept of space. Stories that also raise curiosity as well as critique on how humans are facing current societal problems. Examples of these stories include: Jorge Luis Borges' "The Library of Babel", Franz Kafka's "The Burrow", and Donald Barthelme's "The Balloon". The focus of this thesis will be to design and model the spaces described by these three stories. A background of each story will be discussed, followed by a summarized literature analysis, the modeling process, models, a discussion of STEM questions that arise from each story, and finally how do these stories relate to current times.

The Balloon

Literary Summary & Analysis

"The Balloon" is a short story written by Donald Barthelme in 1968. To summarize the story into a short paragraph; "The Balloon" describes a giant balloon that appeared overnight over more than 45 blocks of Manhattan. Speculation sets the story in the 1920s. The story describes the balloon's size and stature in great detail, however, most of the story is about people's diverse experiences with the balloon. The story is told from a narrator perspective but often switches view points from studying others to describing personal accounts and thoughts. At first, people are scared, nervous, and uneasy about the balloon. But, after some time has passed people start to incorporate the balloon into their daily lives. The balloon existed for 22 days and then was disassembled overnight.[1]

A literary analysis of "The Balloon" was researched to properly understand the story in order to model it most accurately. The literary analysis was structured as a literature review of previously written documents that analyze the story. According to Larry McCaffery, who wrote the journal piece, *"Meaning and Non-meaning in Barthelme's fiction,"* "The Balloon" is a classic example of Barthelme's literary work of being a piece that defies typical literary structure. The piece is written in a fragmented, playful way that does not follow a typical story structure or point of view. The story follows a more chaotic structure which suggests that, possibly, the piece was not supposed to have a meaning at all. If one were to give "The Balloon" meaning it could be seen as a symbol for the modern interconnectedness of humans and how that is expanding with technology. "The Balloon" could be a symbol for human language or the grid system that connects us

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[1] Barthelme, D. (1968). The balloon. *Sixty stories*, 46-51.

all. Or, another interpretation of "The Balloon" is that it is a symbol of the large issues that face society, that sparks diverse reactions from people.[2]

According to Maurice Couturier who wrote a discourse critiquing "The Balloon", Barthelme's *Uppity Bubble: 'The Balloon','"* the story was written from a journalistic point of view but almost becomes a sociological dissertation of the people of New York City of all ages and all psyches. The story borrows from the philosophical study of phenomenology, which is the science of phenomena or a way to explain the consciousness of direct experience with something. Through this lens, the story is a reflection of the study of phenomenology. However, "The Balloon" could also be categorized as a romance. The narrator reveals the reason for the balloon's existence is because of his love for a woman.[3] Overall, "The Balloon" is a nontraditional literary piece that describes a seemingly impossible creation that has intricate effects on human psychology.

Modeling Process & Models

The challenge was how to accurately model "The Balloon" described in the story to capture the story and offer another form of critique. In order to create a new model, research was first conducted to find if previously created visuals of the story existed. The main visual rendering of the story that was found was an illustration done by artist Jon Juarez in 2014 with a collection of dystopian sketches. This illustration was utilized as inspiration for the solid model rendering of the story. Juarez's illustration is pictured in Figure 1 following.

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[2] Meaning and Non-Meaning in Barthelme's Fictions Author(s): Larry McCaffery Source: The Journal of Aesthetic Education, Vol. 13, No. 1 (Jan., 1979), pp. 69-79 Published by: University of Illinois Press Stable URL: https://www.jstor.org/stable/3332090

[3] Barthelme's Uppity Bubble: "The Balloon" Author(s): Maurice COUTURIER Source: Revue française d'études américaines, No. 8, ASPECTS DE LA MODERNITÉ AUX ETATS-UNIS (Octobre 79), pp. 183-201 Published by: Editions Belin Stable URL: https://www.jstor.org/stable/20872743

**Figure 1:** *Barthelme y su Globo* by Jon Juarez[4]

"The Balloon" was modeled using the city block described in the story as starting at Fourteenth Street and extending to Central Park. The city block was downloaded as a solid model already constructed by the free domain website CADMAPPER[5]. The model of "The Balloon" was then drawn in the computer program Rhino and overlaid on top of the CADMAPPER New York city block. The two models were then merged together to create one continuous model. "The Balloon" was designed to look as though it were shaving cream flowing through the buildings because the story describes it as a continuous flowing structure. Below are a series of images that depict the solid modeling creation of the story.

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[4] Juarez, J. (2014). The Arthaus Blog, Online: http://blog.myarthaus.com/jon-juarez-illustrations-expressive-trembling-trace/
[5] "Worldwide Map Files for Any Design Program." *Cadmapper*, cadmapper.com/.
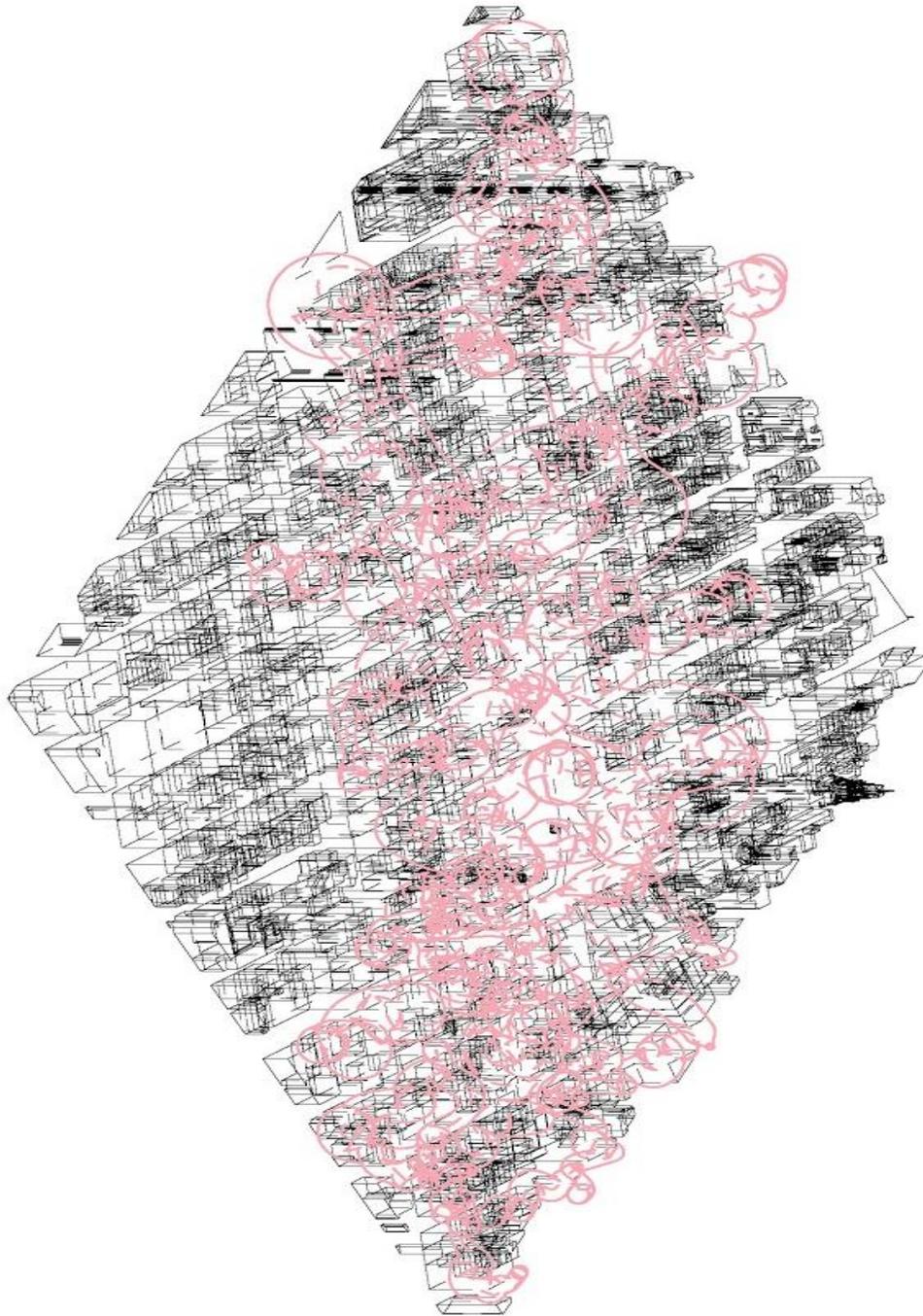
**Figure 2:** "The Balloon", Initial Sketch
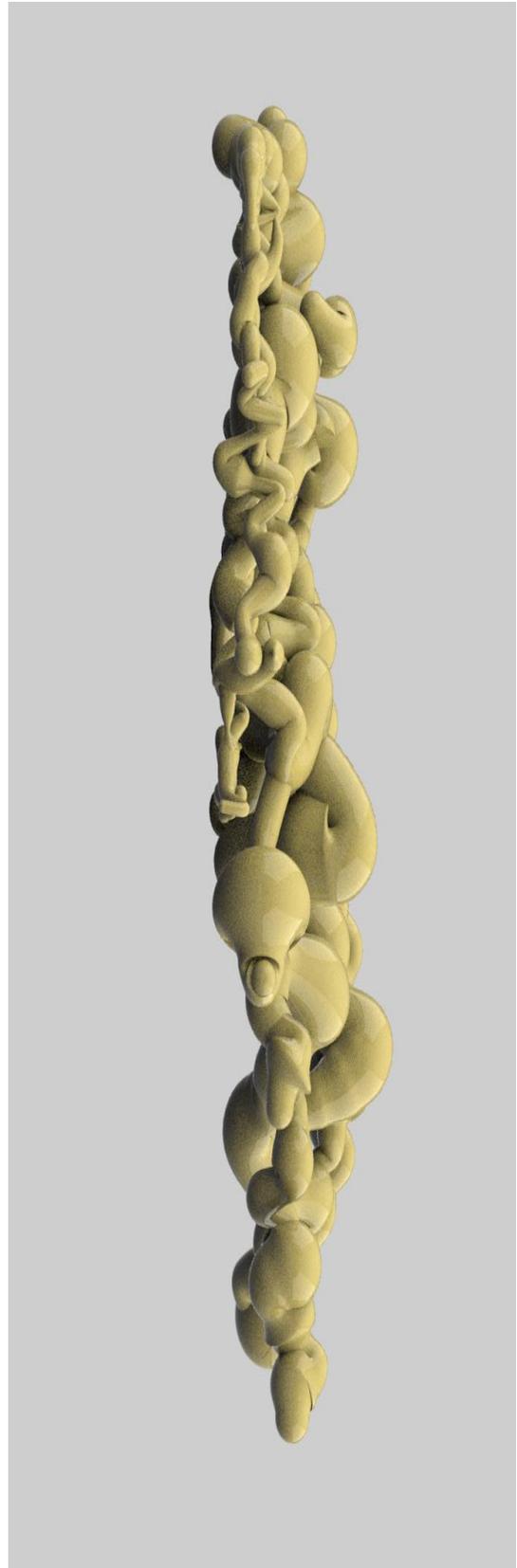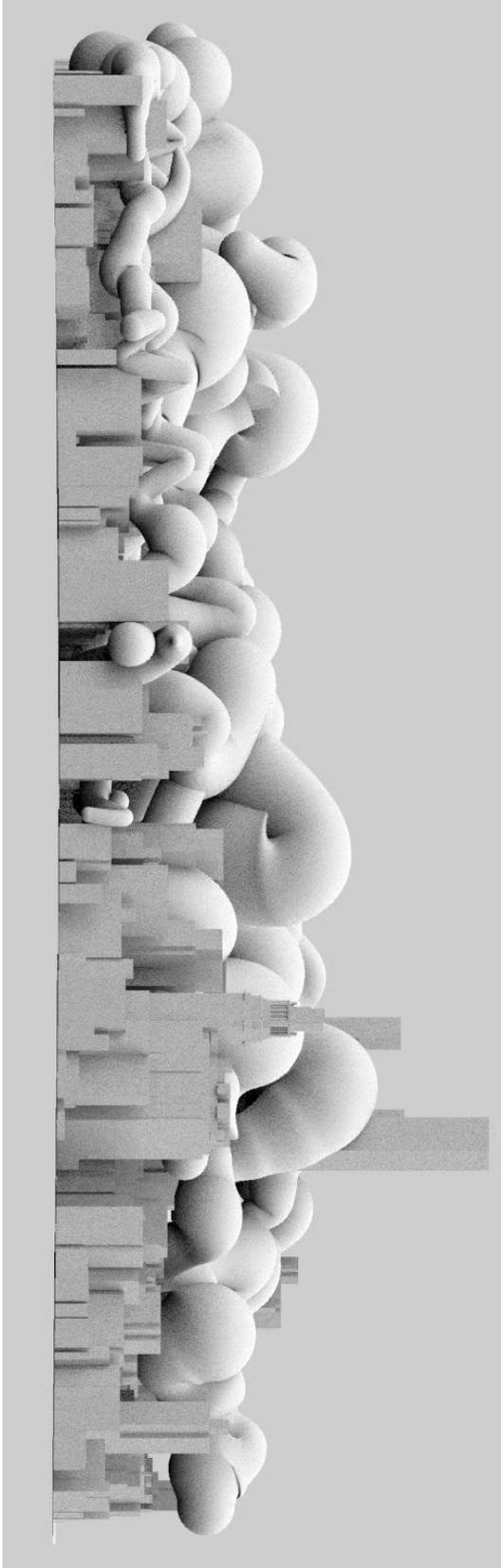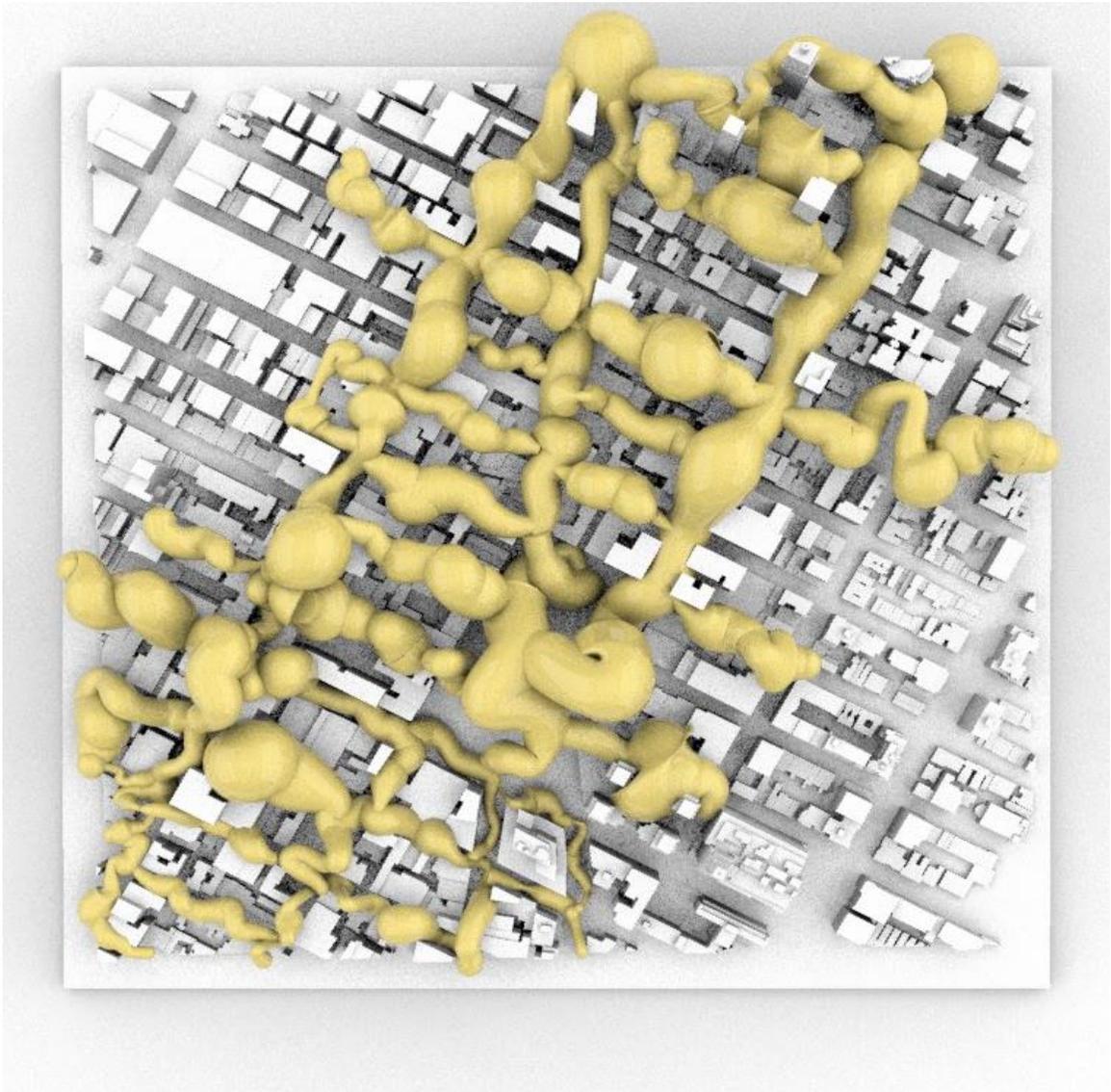
Figure 3: "The Balloon", Solid Models Series

After the three-dimensional solid models of "The Balloon" were generated, the two-dimensional captures of these models were utilized to create visualizations of specific scenes described in the story. This approach allows for the addition of important features described in the story. For the creation of these images, photos archived in the New York City Public Library from 1920s Manhattan were used as backdrops.[6] The images created

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[6] "1920s Manhattan Image Archive." *New York City Image Archive: New York Public Library*, secure.nypl.org/site

correspond to quotes from the story *"The Balloon"* and the quotes are listed beneath each image.
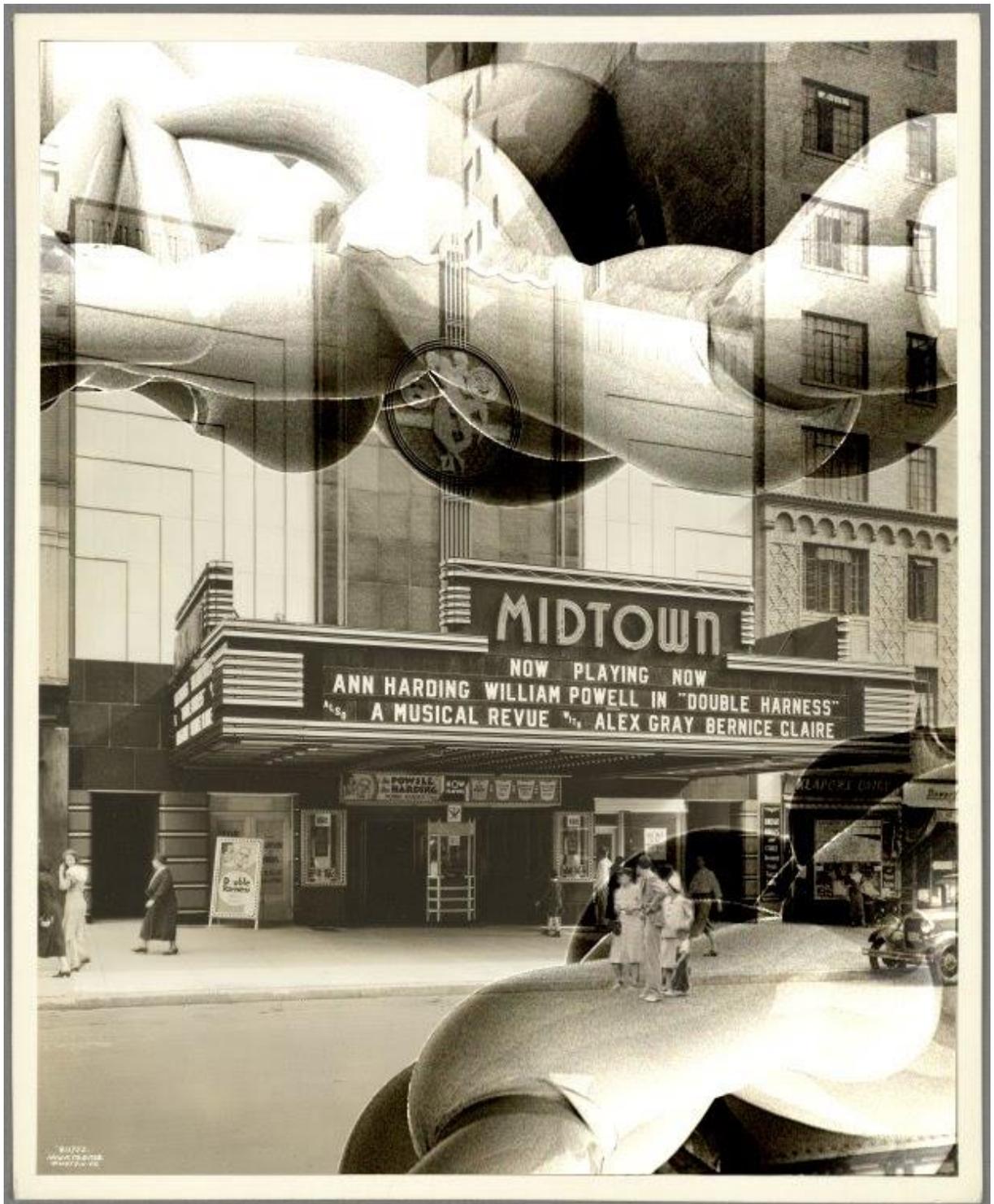
"The upper surface was so structured that a 'landscape' was presented, small valleys as well as slight knolls, or mounds; once atop the balloon a stroll was possible, or even a trip from one place to another."

"It was also argued that what was important was what you felt when you stood under the balloon; some people claimed that they felt sheltered, warmed, as never before, while enemies of the balloon felt, or reported feeling, constrained, a 'heavy' feeling."
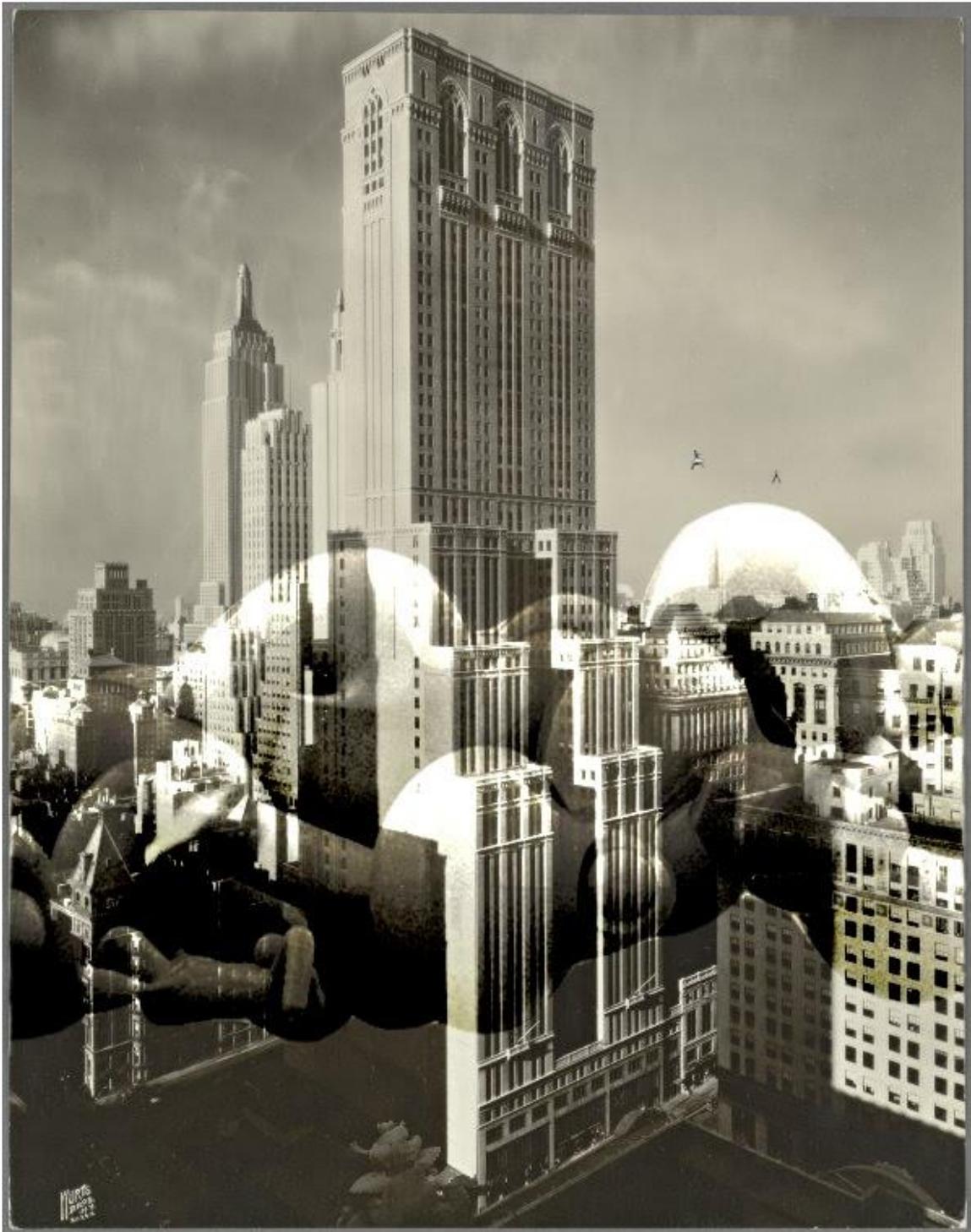
"Bouncing was possible, because of the pneumaticity of the surface, and even falling if that, if that was your wish."
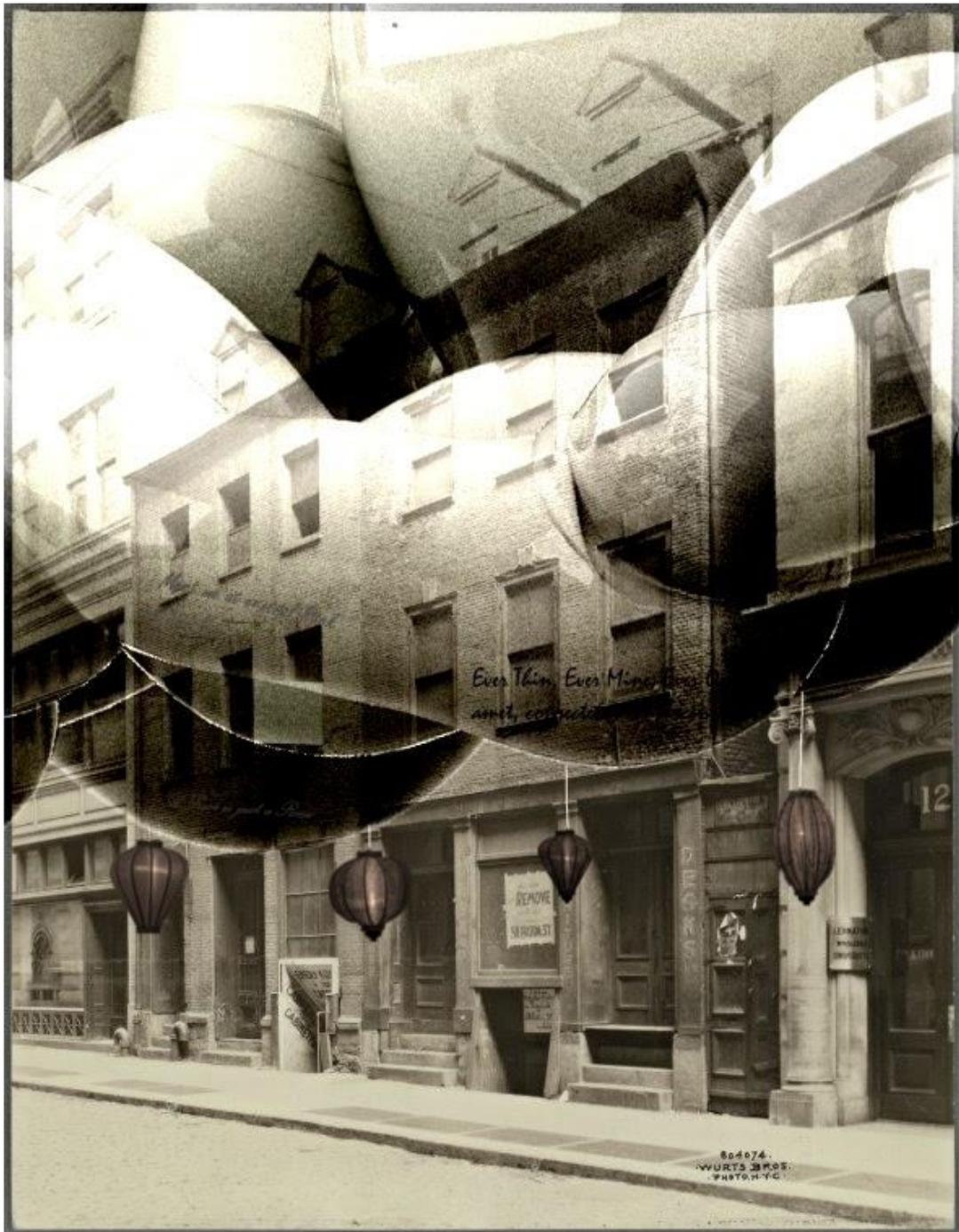
"It was agreed that since the meaning of the balloon could never be known absolutely, extended discussion was pointless, or at least less purposeful than the activities of those who, for example, hung green and blue paper lanterns from the warm gray underside, in certain streets, or seized the occasion to write messages on the surface, announcing their availability for the performance of unnatural acts, or the availability of acquaintances."

"A deliberate lack of finish, enhanced by skillful installation, gave the surface a rough forgotten quality, sliding weights on the inside, carefully adjusted, anchored the great, vari-shaped mass at a number of points."

STEM Questions from "The Balloon"

"The Balloon" raises several engineering questions about this fictional structure. How large would this balloon be? What is the largest balloon in history and how does this fictional balloon compare? How much helium would have to be used to fill this balloon? How much weight would be needed to ensure it would not float away?

The dimensions of this fictional balloon-

Using google maps to chart the street distance of Manhattan New York from 14th street to Central Park gave: 2.27 miles

"The Balloon" is described to be as tall as a standard room although this would fluctuate because the helium would only expand to the limitations of the surrounding structures. Therefore, an estimate was made for the balloon to be approximately 15 feet tall as an average height to use for calculations.

$$2.27 \; miles{\wedge}2 \; \times 5{,}280 \; \frac{ft}{mile} \; \times \; 5{,}280 \; \frac{ft}{mile} \; x \; 15 \; ft \; = 949{,}259{,}520 \; cu. ft$$

$$\approx \boldsymbol{1{,}000{,}000{,}000 \; cu. ft} \text{ in total size}$$

The largest balloon in history was the 1987 Virgin Atlantic which was 2.3 million cubic feet.[7] This would be about 435 times smaller than the fictional Balloon in the story.

A standard large helium tank contains 125 $cu. ft$ of helium. Therefore, this fictional balloon would require **80,000,000 large tanks of helium to fill**.

The average lift of 1 cubic feet of helium can lift 28.2 grams.

$$(1{,}000{,}000{,}000 \; cu. ft \; \times 28.2 \; grams) \div 448 \; \frac{grams}{lb} = 62{,}946{,}428.57 \; lbs$$

$$\approx \boldsymbol{60{,}000{,}000 \; lbs \; to \; weigh \; down \; the \; balloon}$$

Sustainability Questions that Arise from "The Balloon"

Currently, the Earth's supply of helium is depleting. Helium is a nonrenewable resource. Helium is less dense than air, once it escapes a container it is lost to the atmosphere. Helium is too expensive to recapture once it has escaped. Helium is important for medical and scientific purposes, not just for the use of filling balloons. Helium is used in every MRI (Magnetic Resonance Imaging) machine, and in cryogenic research to obtain super cool temperatures. Helium is also utilized in the production of silicon chips which make up the base of every computer and solar cell.[8] Helium is created inside the Earth's crust when uranium and thorium decay over millions of years.[9]

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[7] "The History Of Hot Air Balloons." *Virgin Balloon Flights*, www.virginballoonflights.co.uk/history-of-ballooning/.

[8] Halperin, W. P. "The Impact of Helium Shortages on Basic Research." Nature Physics, vol. 10, no. 7, July 2014, pp. 467–470. EBSCOhost, doi:10.1038/nphys3018.

[9] Lee, Bruce Y. "How The Helium Shortage Will Impact Your Healthcare." *Forbes*, Forbes Magazine, 26 May 2019

Helium is only found predominately in three locations. Seventy-five percent of the world's helium now comes from these locations: Ras Laffan Industrial City in Qatar, ExxonMobil in Wyoming, and the U.S. National Helium Reserve in Amarillo, Texas. In the past, governments around the world have tried to stock pile helium in storage facilities such as the Helium Reserve in Texas. This reserve has been depleting since 1995 and is expected to be shut down and disposed of in 2021.

The demand for helium globally is increasing annually. Helium is projected to increase in demand by 4% each year, which cannot be supported by the Earth's current extraction points and stock piles.[10]

"The Balloon" by Barthelme could also be interpreted as a commentary on the helium shortage that is currently facing humans today. Although the shortage is public knowledge, people are not changing their behavior or expressing significant concern about the issue. Retail stores are continuing to sell balloons, helium tanks, etc. Parades are continuing to fill large scale balloons with helium. We behave as if we do not mind depleting the resource.

Although "The Balloon" by Barthelme was written nearly five decades ago, it is still able to be translated to the current state of the world. "The Balloon" studied how humans continued on with their daily lives and utilized the balloon for their benefit. Several of the reactions towards the balloon were positive as humans simply adapted to their circumstances. This is paralleled to how humans are facing the helium shortage today. We prevail, we adapt. Recent technology in the field of geology is able to scan the Earth's crust for helium reserves that were unable to be discovered before now. Also, helium production plants, such as the ones that appeared in Qatar in 2016, are now able to produce more than 25% of the world's current demand.[11] What is most inventive to combat the helium shortage is the new science developing around using a combination of nitrogen and hydrogen to replace helium in cryogenic research. This combination is able to reach the super cooling temperatures for which helium is utilized. This switch in chemicals remains an area of active research.[12] Human ingenuity and the ability to adapt to changing circumstances is represented in "The Balloon" and the helium shortage.

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[10] Groat, C. G. & Richardson, R. C. (co-chairs, Committee on understanding the impact of selling the Helium Reserve) Selling the Nation's Helium Reserve (National Academies Press, 2010).
[11] Carmin Chappell, Jordan Smith. "The Worldwide Helium Shortage Affects Everything from MRIs to Rockets - Here's Why." *CNBC*, CNBC, 21 June 2019,
[12] Pratap, Amit. "Helium Shortage Opens the Door to Alternatives." *Laboratory Equipment*, vol. 52, no. 12, Apr. 2015, pp. 28–29. *EBSCOhost*

The Burrow

Literary Summary & Analysis

"The Burrow" was written by Franz Kafka in 1931. The story is set in a mossy forest area, underground in a burrow. The main character is a predatorial creature that has spent its entire life building and sculpting this burrow in which it lives. The text never explicitly states whether the protagonist is a human or an animal. The protagonist has several animalistic qualities but it goes through a series of introspective revelations throughout the story. The protagonist suffers from intense fear, anxiety, paranoia, and possibly depression. Throughout the entirety of the story the protagonist fears another being will infiltrate its burrow and attack. The protagonist becomes obsessive over its burrow and obsessive of a particular noise it may or may not have heard from afar. It is unclear whether the noise is a true threat or a figment of the protagonist's imagination. The story is unfinished, it does not have a true ending.[13]

Kafka's circumstances at the time he wrote this story are important because they give insight into possibly why the story was written. Kafka was dying of tuberculosis. The story is most often analyzed as a reflection on the emotions of the impending death of an animal or man. The narrator of the story, the protagonist, has wants and needs that are animal but experiences highly emotional human like bouts throughout the story. One could say the protagonist, or Kafka himself, is experiencing the stages of death and grief.[14] The story also reflects the theme of hero versus antihero. This is because the story is designed to have the reader support the protagonist when in reality the protagonist is a psychologically unstable predator. Another common analysis of the story is that it is a metaphor for the human mind being disconnected from the external environment and how that could cause negative effects. "The Burrow" is a critique on the human connection to nature and how it is the downfall of the human and society.[15]

Modeling Process & Models

There were many questions that had to be answered to model Kafka's burrow. The burrow was described in great detail. There needed to be several tubular paths, over fifty pods/rooms, a labyrinth next to the main entrance, a decoy entrance, and a castle keep which was the large room at the heart of the burrow that had ten entrances leading to it. Artisitic license was taken in placing the burrow inside the casing shaped like half of a

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[13] Kafka, F. (2012). The complete stories. Schocken. *The Burrow (1931).*

[14] Snyder, Verne P. "Kafka's 'Burrow': A Speculative Analysis." *Twentieth Century Literature*, vol. 27, no. 2, 1981, pp. 113–126. *JSTOR*, www.jstor.org/stable/441134. Accessed 28 Jan. 2020.

[15] Weigand, Hermann J. "Franz Kafka's 'The Burrow' ('Der Bau'): An Analytical Essay." *PMLA*, vol. 87, no. 2, 1972, pp. 152–166. *JSTOR*, www.jstor.org/stable/460873. Accessed 28 Jan. 2020.

brain because the story is predominately about psychology more than anything else. A brain was downloaded from a free source website of solid models called GrabCAD.com. The brain was created from a real MRI image taken of the original creator's brain. The brain model was uploaded into Rhino and then altered and sliced in half to open up as a window. The burrow was then built within the brain casing starting with the tubes, then the pods, then the castle keep. Finally, the pieces of the model were joined into one continuous mesh. The look of the burrow was based on mole burrows and inspired by a preexisting model which was a small rendering of part of the burrow. Pictured below is the other model titled "The Architecture of a Burrow" by artist Wolf Novotny[16]. A sketch of a typical mole burrow is also shown[17].
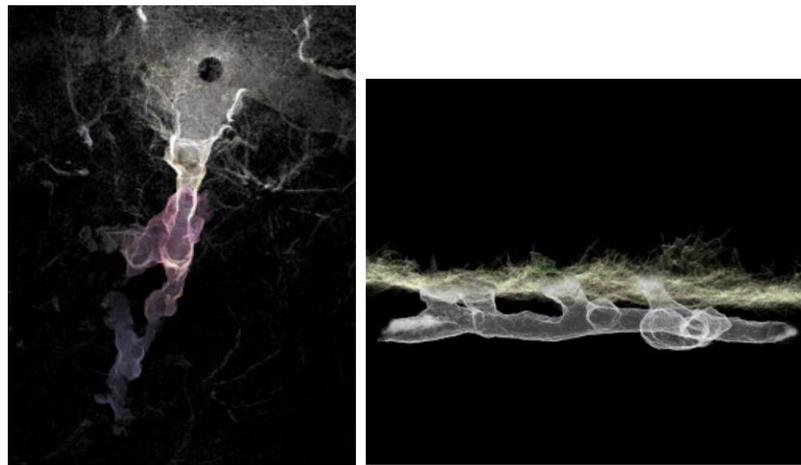

Figure 4: Novotny, W. "The Architecture of a Burrow."
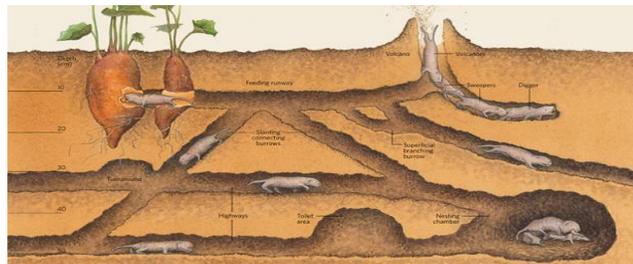
**Figure 5:** Standard Mole Burrow

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[16] Novotny, W. "The Architecture of a Burrow." Archiprix Project: P19-0684, www.archiprix.org/2019/qview/?id=4202
[17] https://photos.the-scientist.com/legacyArticleImages/2012/06/06_12_Digging_side.jpg

The initial sketch of the burrow was as follows:
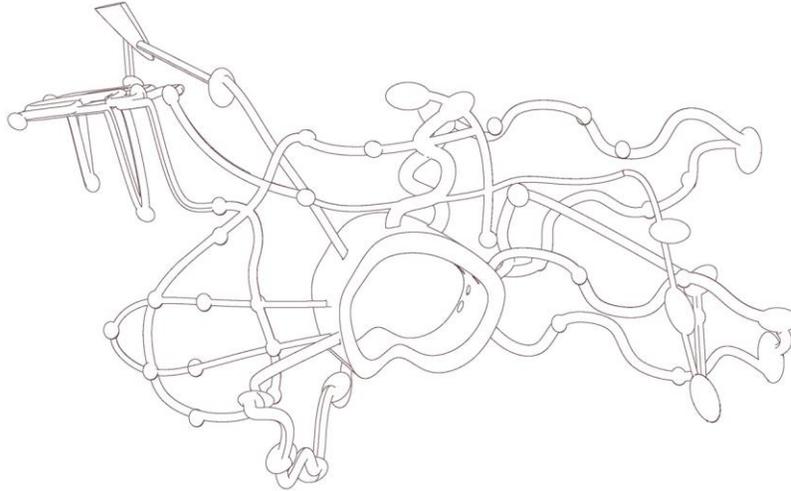
Figure 6: The Burrow, Initial Sketch

The burrow was joined with the brain shell and rendered into a solid model. It was rendered as a white model with shadows, a two-tone wire mesh model, and then a mulch and dirt earth tone model to simulate if it were truly in a mossy forest.
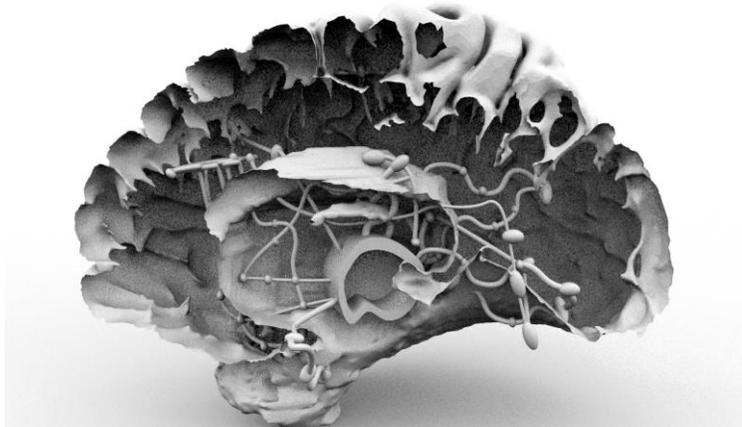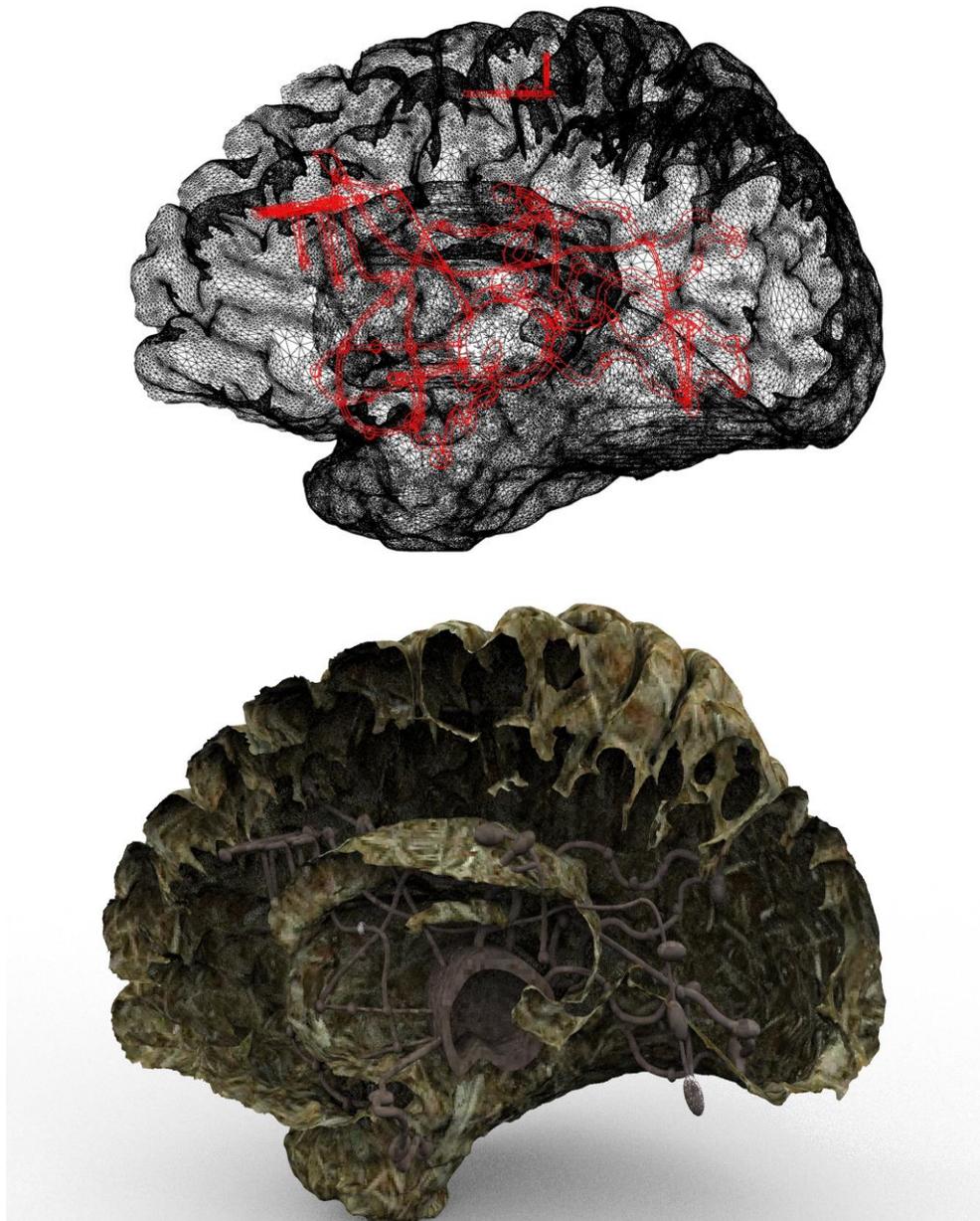
Figure 7: The Burrow, Rendered Models Collection

Following the creation of the three-dimensional solid models of The Burrow, the two-dimensional captures of these models were utilized to create visual illustrations of specific scenes described in the story to add important features. For the creation of these images, stock photos of mossy forests were used as backdrops. The images created correspond to quotes from the story that appear beneath each image.
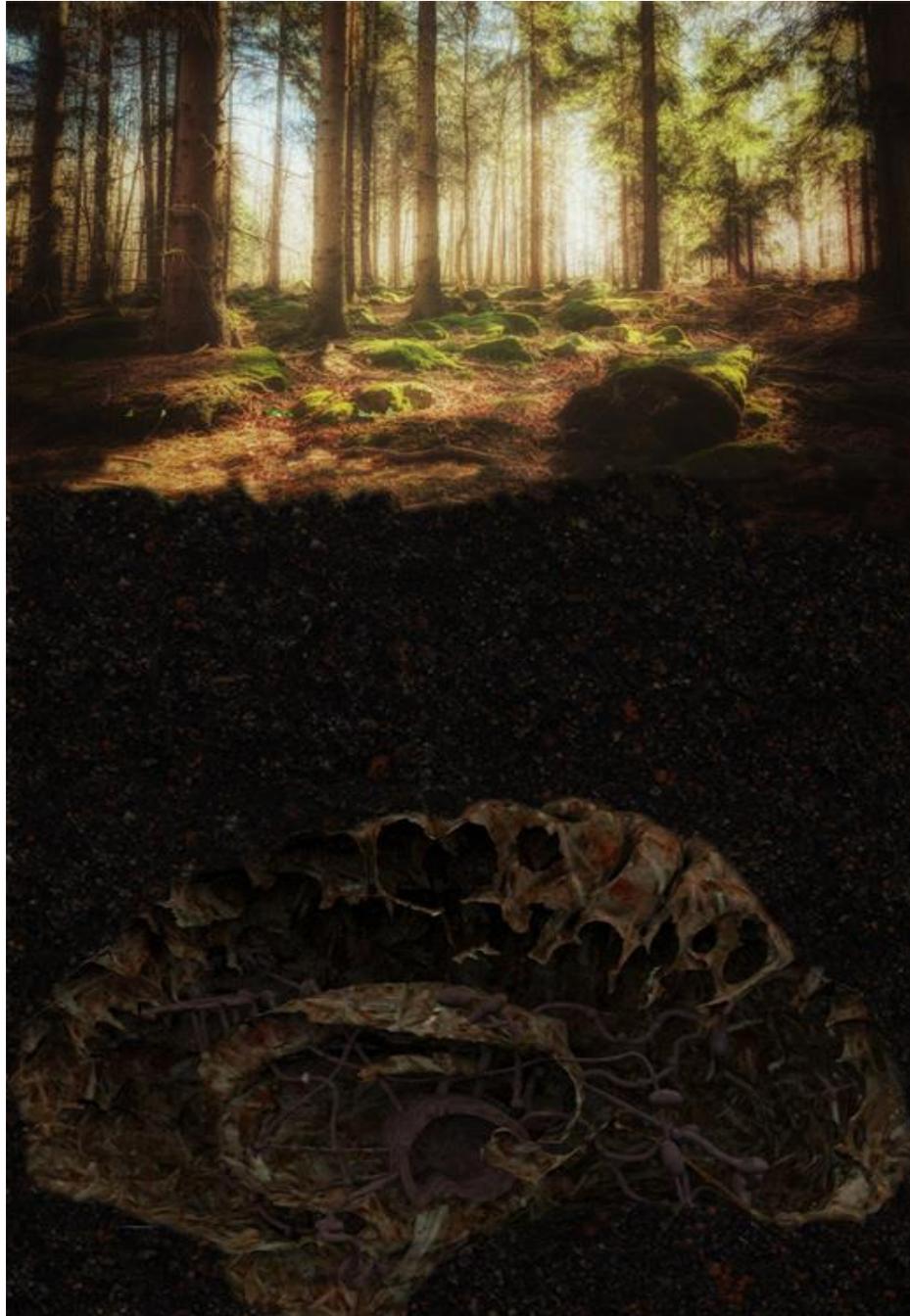
"And I tear myself free from all my doubts and by broad daylight rush to the door, quite resolved to raise it now; but I cannot, I rush past it and fling myself into a thorn bush, deliberately, as a punishment, a punishment for some sin I do not know of. Then, at the last moment, I am forced to admit to myself that I was right after all, and that it was really impossible to go down into the burrow without exposing the thing I love best, for a little while at least, to all my enemies, on the ground, in the trees, in the air."
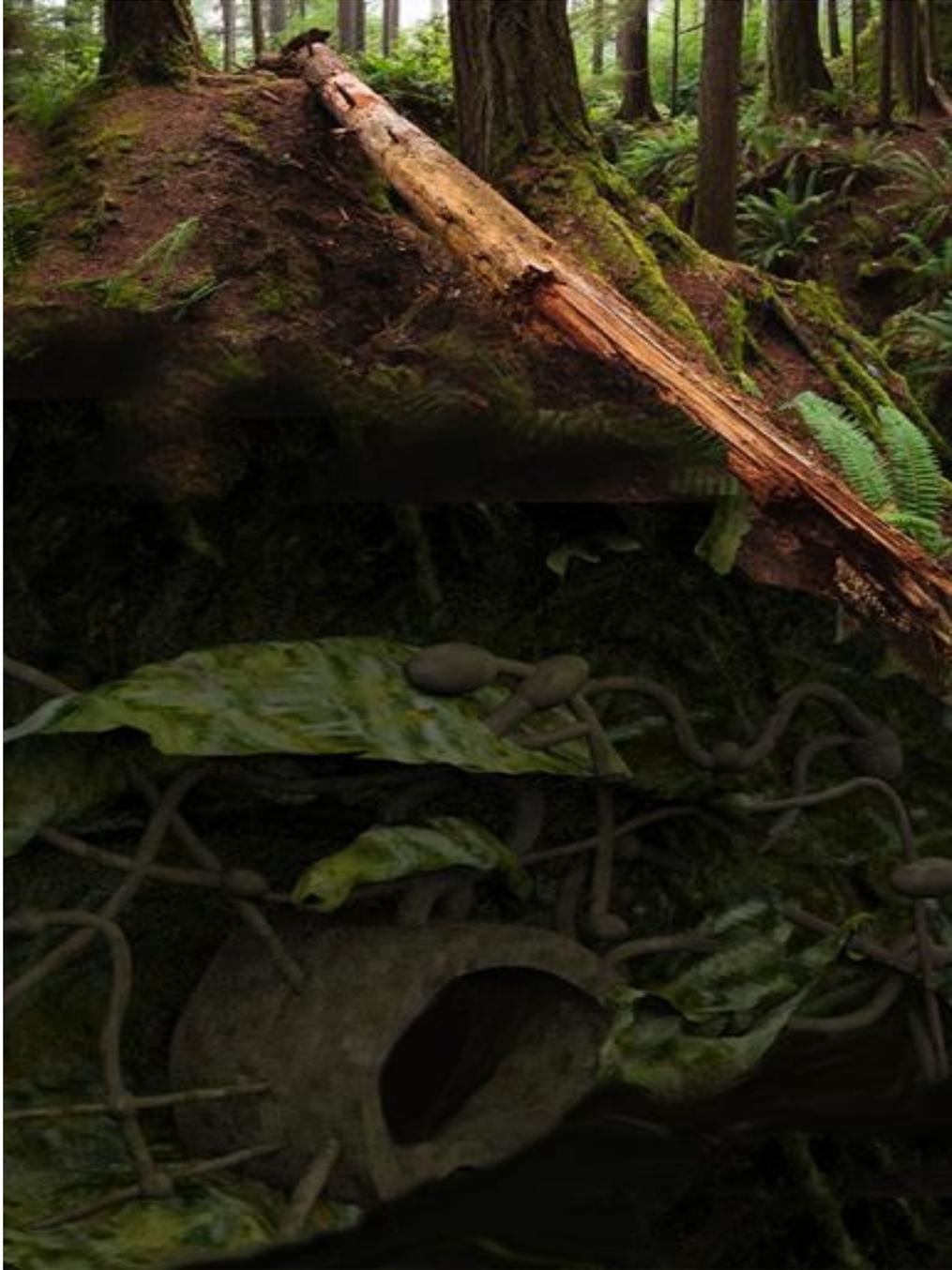
"Had I hoped, as owner of the burrow, to be in a stronger position than any enemy who might chance to appear? But simply by virtue of being owner of this great vulnerable edifice I am obviously defenseless against any serious attack. The joy of possessing it has spoiled me, the vulnerability of the burrow has made me vulnerable; any wound to it hurts me as if I myself were hit. It is precisely this that I should have foreseen; instead of thinking only of my own defense -- and how perfunctorily and vainly I have done even that -- I should have thought of the defense of the burrow."

"In the Castle Keep I assemble my stores; everything over and above my daily wants that I capture inside the burrow, and everything I bring back with me from my hunting expeditions outside, I pile up here. The place is so spacious that food for half a year scarcely fills it."

"So I must thread the tormenting complications of this labyrinth physically as well as mentally whenever I go out, and I am both exasperated and touched when, as sometimes happens, I lose myself for a moment in my own maze, and the work of my hands seems to be still doing its best to prove its sufficiency to me, its maker, whose final judgment has long since been passed on it."

STEM Questions from The Burrow

"The Burrow" raises several engineering questions about the possibility of its existence and the creature that built it. How long would the burrow be? How far underground? How much food could the burrow store if the story states it holds a year's supply? Can humans exist on meat alone if this creature is in fact human? How long would it take an average human to create this Burrow?

To figure out the size of the burrow a calculation was made to relate a mole to an average human. The calculations are as follows.

Average size of a mole is 0.47 lbs.[18], and the average size of a human is 137 lbs.[19].
$$137 \div 0.47 = 291.49 \approx 300$$
Mole burrows can extend 2.7 acres.[20]
$$2.7 \ acres \ x \ 300 = \textbf{The Burrow would be 810} \ acres$$
Mole burrows extend 10 inches underground.
$$10 \ inches \ \times 300 = 3,000 \ inches = \textbf{250} \ \textbf{\textit{feet underground}}$$

To find out how much food would be stored for the human sized burrow another calculation was completed to average the amount of food a human and a burrow would eat annually.

Average male eats 1 ton of food every year.[21] Moles eat their body weight in a year.
$$\frac{2000 \ lbs + 0.47 \ lbs}{2} = \textbf{1,090} \ \textit{\textbf{lbs of food would be stored inside the Burrow}}$$

A current trend is a carnivore diet in which the only source of nutrients is meat. Research remains scarce about this diet but humans are able to survive on protein alone. However, negative medical effects can occur from this diet such as gout and kidney complications.[22]

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[18] "Facts About Moles: Mole Facts: Havahart US." *Havahart*, www.havahart.com/mole-facts#diet
[19] "The world's fattest countries: how do you compare? – Telegraph" *Telegraph,* www.telegraph.co.uk
[20] Old Farmer's Almanac. "Moles." *Old Farmer's Almanac*, www.almanac.com/pest/moles
[21] Aubrey, Allison. "The Average American Ate (Literally) A Ton This Year." *NPR*, NPR, 31 Dec. 2011, www.npr.org/sections/thesalt/2011/12/31/144478009/the-average-american-ate-literally-a-ton-this-year.
[22] Kirkey, Sharon. "Can You Really Live on Meat Alone? Everything You Need to Know about the Carnivore Diet." *National Post*, 29 Nov. 2018, nationalpost.com/health/can-you-really-live-on-meat-alone-carnivore-diet.

To figure out the amount of time it would take to dig this fictional burrow another calculation was found. The average shovel load of dirt is equal to about 0.5 cubic feet, and it takes 25 seconds per shovel load. [23]

$$1.23 \; miles \; x \; 5,280 \frac{feet}{mile} x \; 250 \; feet \; x \; typical \; human \; shoulder \; size \; 1.6 \; feet$$
$$= 2,597,760 \; cu. \, feet$$
$$2,597,760 \; cu. \, feet \; \div 0.5 \; cu \; feet = 5,195,520 \; cu. \, ft$$
$$5,195,520 \; cu. \, ft \; \times 25 \frac{sec}{cuft} = 29,888,000 \; sec \div 60 \; sec/min = 2,164,800 \; mins \; \div$$
$$60 \frac{min}{hr} = 36,080 \; hours \; \div 24 \frac{hr}{day} = \textbf{1,503 \; days} \; \textit{if you took no breaks and worked}$$
$$\textit{nonstop and the dirt was removed automatically.}$$

Sustainability Questions that Arise from The Burrow

"The Burrow" touches on a popular sustainable building design type which is underground living. The protagonist does almost all activities underground. Underground building has been in existence since the start of humanity when indigenous people lived and stored food in underground structures. Now, sustainable design is looking toward building underground for the substantial energy savings that result. Building underground saves energy for two primary reasons: surrounding a structure with soil moderates extreme temperatures from outside air and reduces temperature changes. Therefore, heating and cooling a structure is substantially decreased.[24] Most of the barriers behind people pursuing underground building are psychological. People tend to believe underground living is dark, damp, dirty, and cold. In short, life is similar to that of The Burrow. Relating underground building to Kafka's literary piece: Does living underground foster a feeling of dread that can build to insanity? Modern day design would argue no. Current design is altering this perception of underground living through innovation and creativity. Two examples of underground building that is occurring today and accounting for the psychological effects that can occur from subterranean living are outlined below.

The first example is that of Elon Musk's Boring Company that has formulated a plan for solving traffic inefficiencies experienced all over the world and pronounced in Los Angeles. The Boring company proposes underground tunnels that view the traffic problem three dimensionally. This would enable humans to travel to more places in a shorter amount of time. Their logic is that underground tunnels are able to grow sustainably, do not divide communities like roads, highways and overpasses do, are weather proof, and allow for increased traffic speeds. Eventually the tunnels can be

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[23] Zimmerman. "How to Calculate How Long to Dig a Hole." *Hunker*, Hunker.com, 18 July 2017, www.hunker.com/13425749/how-to-calculate-how-long-to-dig-a-hole
[24] Wampler, Louis. *Underground homes*. Pelican Publishing, 1980.

conformed into a hyperloop of high-speed travel for passengers.[25] The Boring Company's plan for underground tunnels for traffic is effective in minimizing the human psychological effects of going underground by having humans travel for a short period of time in a brightly lit tunnel. Also, they are planning on lining the tunnels with a white polymer coating and having them be brightly lit to simulate a tunnel above ground. The Boring company has successfully tested their first tunnel in Hawthorne California.

Figure 8: The Boring Company's Test Underground Traffic Tunnel

For the second example, SeArch architects, together with Christian Müller, designed a subterranean home, Villa Vals. The home has been labelled an act of genius in the architecture community. This home is built into the side of a Swiss Alp foothill. The entire structure is incased underground except for the patio that is angled to view the surrounding mountains and valley. The project was built with the external view being at an incline to allow the sunlight to reach all corners of the internal house. This creates the illusion that the inhabitants are not underground, even though they most certainly are. This home also takes advantage of the thermal efficiencies that are gained from being concealed in soil. The following figures are of Villa Vals.[26]

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[25] "FAQ." *The Boring Company*, www.boringcompany.com/faq.

[26] *Christian Müller Architects / Projects: Villa Vals Worldwide*, www.christian-muller.com/CMA_Projects-VVW.html#.

Figure 9: Villa Vals Home Design[27]

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[27] "Gallery of Villa Vals / SeARCH CMA - 1." *ArchDaily*, www.archdaily.com/43187/villa-vals-search-cma/501205d228ba0d5581000236-villa-vals-search-cma-photo?next_project=no.

The Library of Babel

Literary Summary & Analysis

"The Library of Babel" was written by Jorge Luis Borges in 1941. This short story describes the universe as a semi-infinite, and possibly infinite, library. All of human existence is contained inside this library and any book that ever has or will be written is there. The library is made up of hexagonal rooms each identical to the next. Borges states, "The Library is a sphere whose exact center is any one of its hexagons and whose circumference is inaccessible," (pg.2). In each room there are four book shelves that have five shelves on them, a railing, a view of a spiral staircase, one entrance, one exit, halls that connect each room, a chamber for sleeping, and a restroom chamber. Each shelf contains 32 books. Each book has 410 pages, 40 lines per page, and 80 characters per line created from 25 symbols. Travel through the library, room to room is efficient, therefore indicating that travel from room to room is a short path. Librarians live in the library and spend their time in various ways. Some search endlessly for particular books, some try to catalogue books and create maps of the library, and some librarians lose their minds and commit suicide. Overall, the story is a description of this fictitious library told from a singular librarian's point of view.[28]

"The Library of Babel" has several literary interpretations. For the purposes of this thesis, an exploration into the author, Borges, provides significant insight into why the story was written and its potential meaning. Borges grew up in Buenos Aires, Argentina where he spent most of his childhood in his parent's library. As an adult, from 1937-1946 including the time he wrote Library of Babel, he worked in a library cataloging books. Borges was a visionary and was living a life filled with unhappiness due to the ignorance of his peers and a government he could not connect to. "The Library of Babel" frequently touches on themes of depression and solitude, perhaps exposing internal reflections of Borges. Another popular theory for the story's meaning is as a metaphor for chaos theory. Chaos theory is described as a school of thought in mathematics and philosophy that behind each 'chaos' or 'random' event is in fact ordered purposeful structure. In other words, events are deterministic but unrecognizably so. The Library's qualities depict a model of chaos theory.[29]

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[28] Borges, Jorge Luis, The Library of Babel, Internet Archive, Online: https://archive.org/details/TheLibraryOfBabel (as of 4/9/2015).

[29] Perla Sassón-Henry. "Borges' 'The Library of Babel' and Moulthrop's Cybertext 'Reagan Library' Revisited." *Rocky Mountain Review of Language and Literature*, vol. 60, no. 2, 2006, p. 11. *EBSCOhost*, doi:10.2307/4143854.

Modeling Process & Models

Many models are available for "The Library of Babel". All models of "The Library of Babel" discovered in this research are based off of standard interpretations of two- and three-dimensional physical reality. After careful consideration of the story, many of the Library's features are explainable by embedding the building in four dimensions, largely due to the paths of travel described in the text. Thus, the model of the library is a three-dimensional shadow projection of a truly four-dimensional object.

Some proposed two-dimensional floor plans of the Library are shown below:
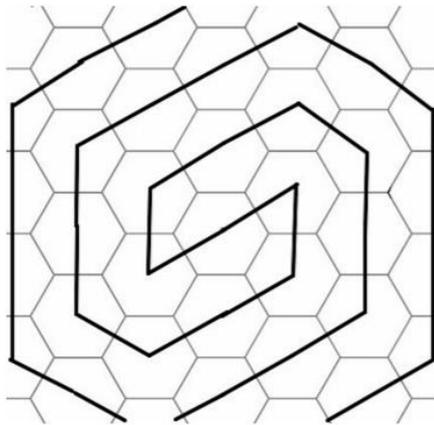
Figure 10: *A Spiral Path-Bloch*   **Figure 11:** *Bloch's idea of movement through the Library*
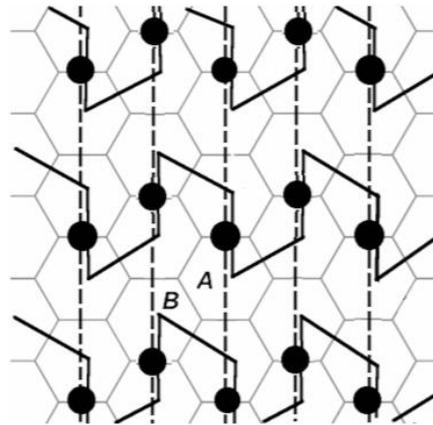
These two models were concocted by Bloch and Goldbloom in their book *The Unimaginable Mathematics of Borges' Library of Babel.*[30] The problem with these two floor plans is that the conceivable walking distance can be infinitely long and travelling between floors as described in the story as always efficient. Motion needs to happen in all directions in order for the library to be as described and be efficient between each hexagon.

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[30] Bloch, W. G. (2008). The unimaginable mathematics of Borges' Library of Babel. Oxford ; New York : Oxford University Press, 2008.
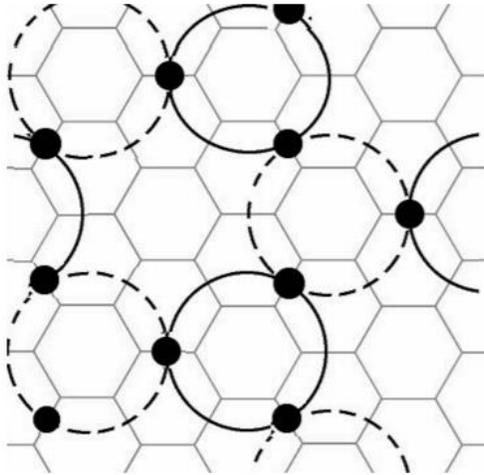
Figure 12: *Rice+Lipka Model*   **Figure 13:** *The Universe ©*
                                            Rice+Lipka Architects
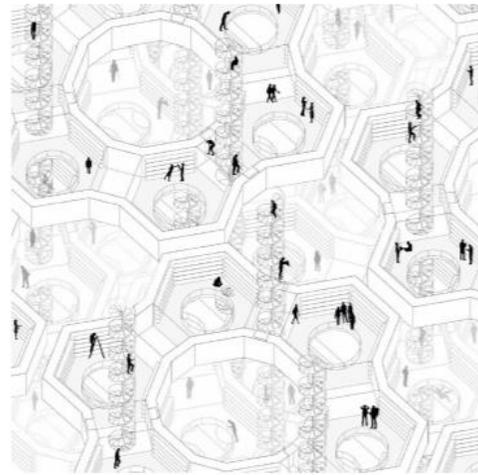
This second model series was completed by the Rice+Lipka architectural firm[31]. This is a better attempt because to travel up and down a librarian would use the staircases marked by the dots on the hexagons. As shown in the three-dimensional model (Figure 4) this model does not satisfy another rule listed in the story in which all of the libraries are hexagonal shaped and not empty. In this model the galleries are dodecagons (12-sided) and have nothing inside of them.

There have also been several virtual reality/simulations created to model "The Library of Babel". Pictured below are samples from a simulation created by Johnathan Millen which has given the user the ability to travel in all different directions.[32]

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[31] Bernheimer, Kate, Fairy Tale Architecture: The Library of Babel, Places Journal. Online: https://placesjournal.org/article/fairy-tale-architecture-the-library-of-babel (as of 4/9/2015).

[32] Millen, Jonathan K., Library of Babel, Online: http://www.jonmillen.com/babel/BabelWeb.html using the Unity webplayer at http://www.jonmillen.com/babel/BabelWebGL.html

Figure 14: Virtual Simulation of user in Library [8]   **Figure 15:** View of exits

The modeling process in this work was partially based on the data collected from these previous works. To capture the sense of four dimensions required looking elsewhere for possibilities, and a soccer ball as a single floor (or shell for the floors "below" it) provided the inspiration.

Figure 16: Standard Soccer Ball

A soccer ball as pictured above was utilized to create the pathway and shape of the library. A soccer ball has hexagon shapes on its surface that are able to connect in one continuous path as the story sets as a rule.
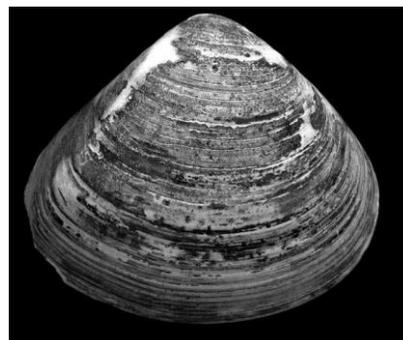
Figure 17: Layered Shell

A shell was used for inspiration of the model because of the ability for a shell to build off of layers and maintain the shape of an arc. The library rooms were stacked upon one another as shell layers to demonstrate the semi-infinite qualities of the library as well as travel possibilities in all directions.

The Library went through several iterations beginning with the creation of one room in the 3D modeling software Rhino. The room is a solid modeled hexagon with the center carved out to create a room-like space. There is an exit and entrance, four book shelves, an open hexagon shaped hole through the center of the room, and a railing and staircase. The railing and staircase were downloaded from open sources on GrabCAD.com and imported into the room design.
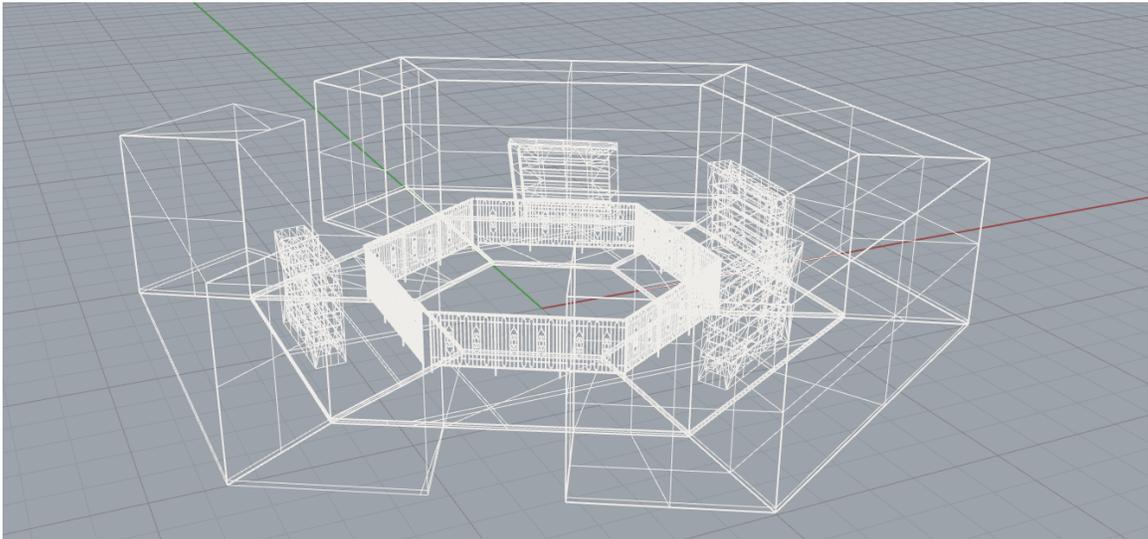

**Figure18#:** Layered Shell Library of Babel Model
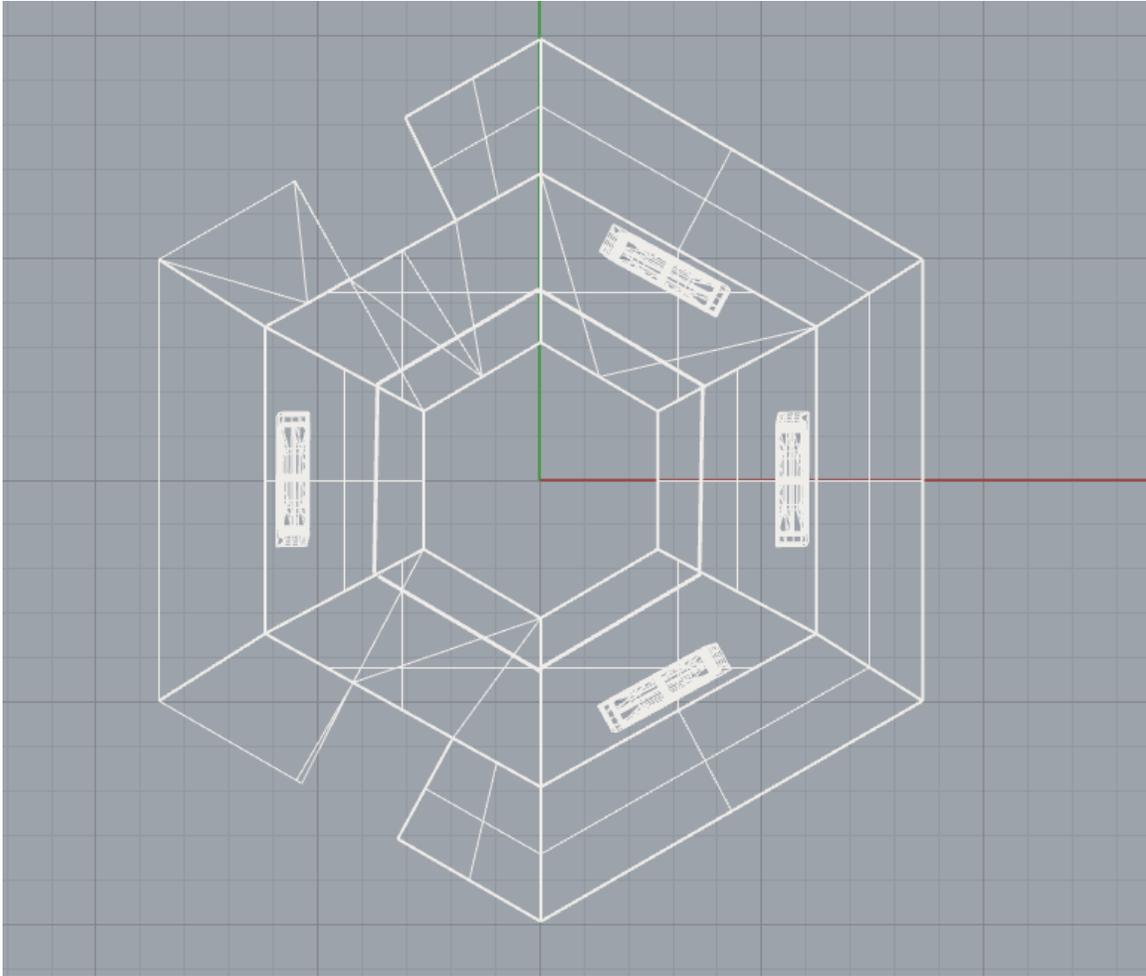
Figure 19: Layered Shell Library of Babel Model

The Library room model was then used as a building block in the final model. This room was duplicated and stacked upon itself in layers. These layers were repeated vertically, and then the final structure was bent slighlty to simulate the slight curvature that would occur in this type of library design. Similar to the curvature of the Earth's suface, the Library would have a slight curvature that the inhabitants (human or librarian) would not notice. The shortcomings of the library model is that the rooms were unable to be made exactly identical because of the specific path that had to be created between each room to follow the story rules, exits and entrances to each room were placed in different locations.
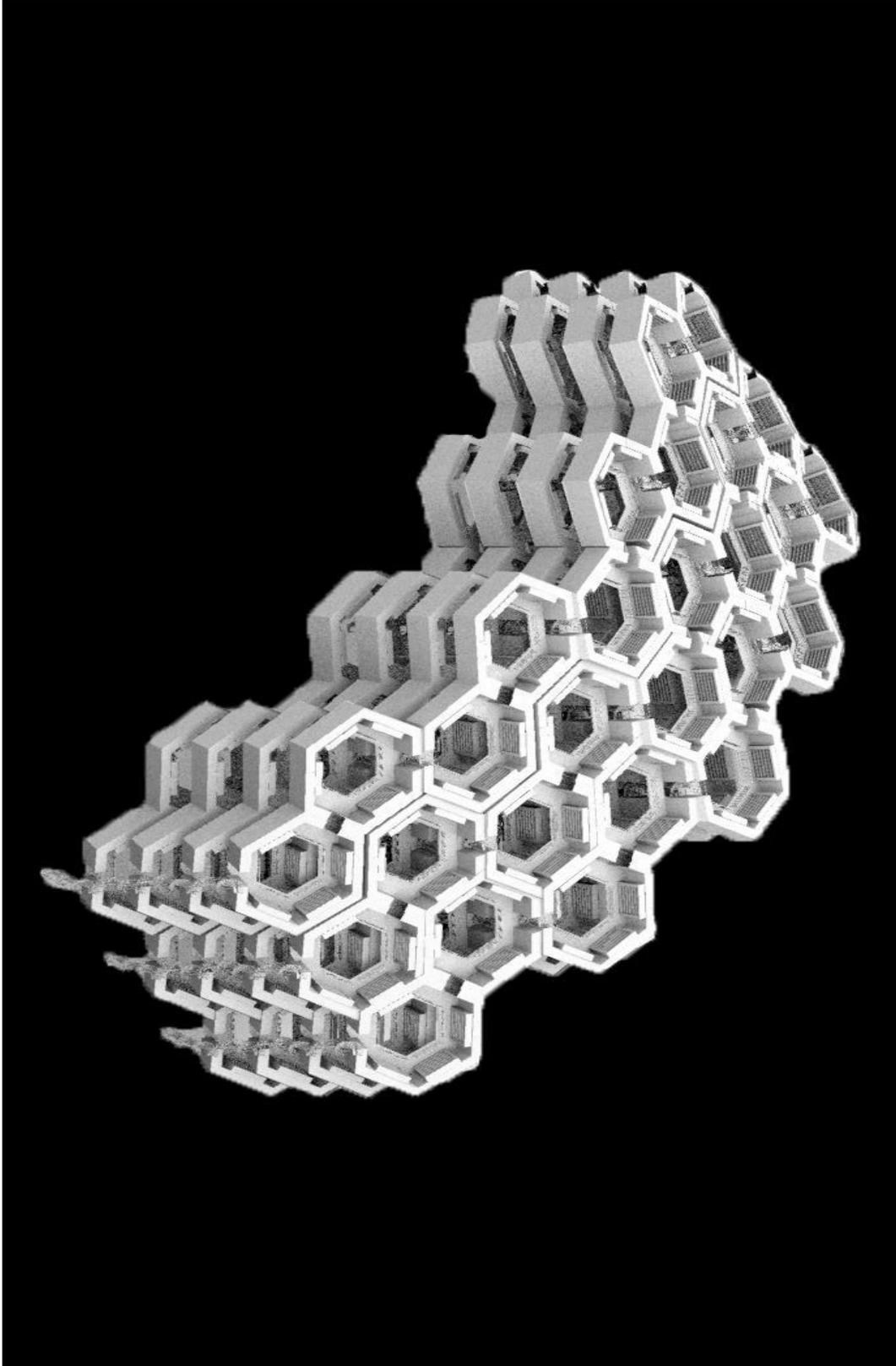
Figure 20: Layered Shell Library of Babel Model

The other model of the library created was one to demonstrate the possible look of the library from an external or satellite view as the 'soccer ball' shape. Creating this multi-shell soccer ball was possible by creating one shell to begin with through the use of mirroring abilities in the modeling program. This shell was then scaled to three different sizes and aligned inside the original shell to connect the staircases of each shell. Red indicates the path of travel through the library in Figure 21. There was one continuous path that linked all rooms of this library model with eighty rooms present to demonstrate the semi-infinite qualities of the library. Unfortunately, the solid modeling program Rhino used to create the model was unable to handle more 'shells' than four because it exceeded the processing capabilities of the program.

Figure 21: Multi-Shell Soccer Ball Library of Babel Model

The Path that can be taken on the library to enter and exit each room in a continuous path can be demonstrated in Figure 22 following.
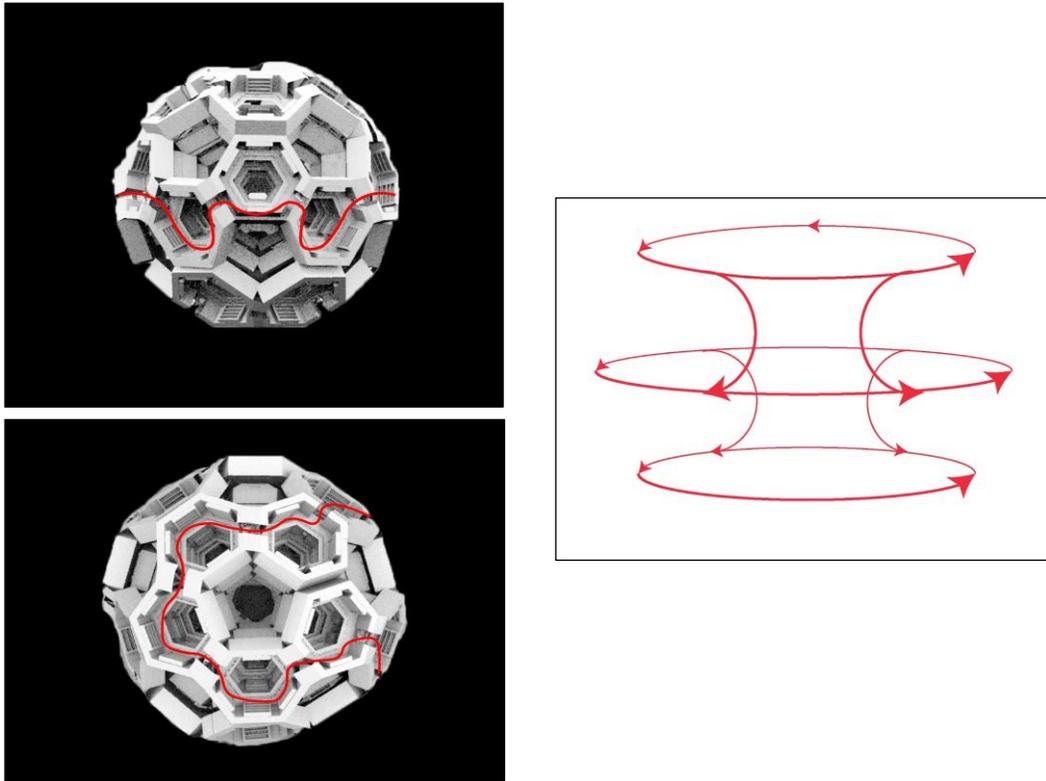
Figure 22: Direction of Travel for "The Library of Babel" Multi-layered Soccer Ball Model

Finally, an internal view of the Library as if peering down over the railing of a room was generated to demonstrate other features of the story such as the light orbs that would appear in each room and the scale of being inside this library.
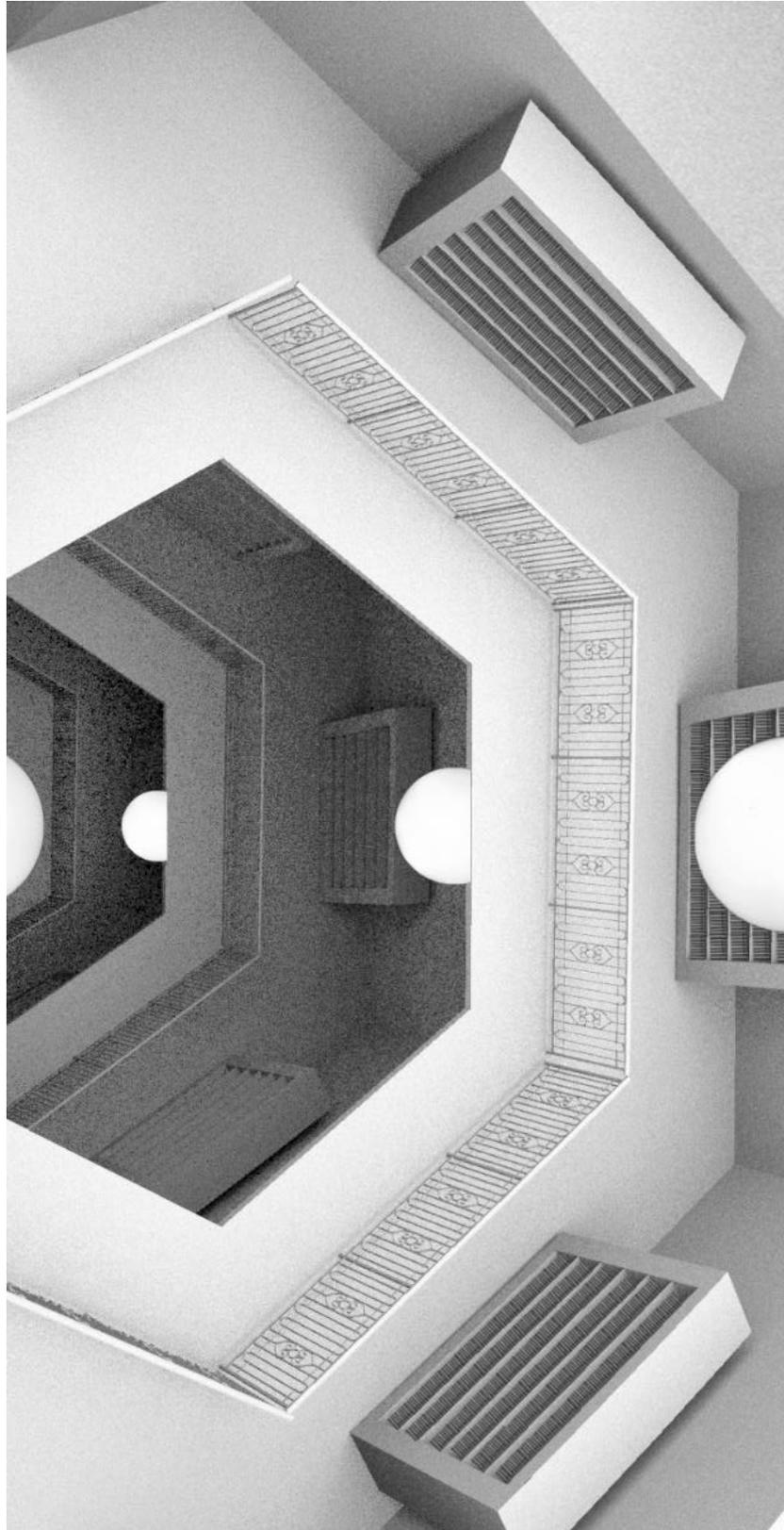
Figure 23: Internal view of "The Library of Babel" Model

Mathematical Questions from The Library of Babel

"The Library of Babel" is a mathematical wonder. Just how large would this Library be if it is semi-infinite? How many books would there be? How many rooms?

If "The Library of Babel" is the universe with every book ever written from 25 symbols, 410 pages, 40 lines, and 80 characters:

$$410 \times 40 \times 80 = 1,312,000 \; characters$$
$$25^{1,312,000} \approx \mathbf{10^{1,834,078}} \; \boldsymbol{books \; would \; be \; present \; in \; the \; Library}$$

If each room has 4 book shelves inside of it with 32 books on each of the 5 book shelves:

$$4 \times 5 \times 32 = 620$$
$$\# \; of \; Rooms = \; \mathbf{10^{(1,834,078-3)}} = \mathbf{10^{1,834,075}} \; \boldsymbol{Rooms \; in \; The \; Library \; of \; Babel}$$

In the world today, the number often used to represent the largest encounterable quantity is the googol. The googol is the largest number we as a human race currently have in the lexicon. It is equal to $\mathbf{10^{100}}$.

The Library of Babel would be 18,340 googols of rooms.

Sustainability Questions that Arise from The Library of Babel

"The Library of Babel", viewed through a design lens, would likely be categorized as utopian design. For context, utopia is defined from the Oxford Dictionary as "an imagined place or state of things in which everything is perfect". This again, aligns with the chaos theory that was discussed previously in the literary analysis of the story. The notion that chaos was actually intended by a grander plan. Typically, culture views utopia as a negative construct, with cold sterile design. However, utopian design is a pillar that upholds Urban Design.[33] Amir Ganjavie, an Urban Design and Architecture professor at Penn State University authored the scholarly journal article titled, *The Role of Utopian Projects in Urban Design*, in which he argues on behalf of the importance of a utopian school of thought in planning. He claims that every urban designer should use utopian principles to design for the future human. Utopian design is valued because it provides critique about the current state of culture, society, and the typical human, by taking what

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[33] Amir Ganjavie. "The Role of Utopian Projects in Urban Design." *Utopian Studies*, vol. 25, no. 1, 2014, pp. 125–149. *JSTOR*, www.jstor.org/stable/10.5325/utopianstudies.25.1.0125. Accessed 6 Mar. 2020.

is currently happening and projecting into the future. Utopian design can provide an approach in which catastrophic scenarios could be circumvented and can be used as a powerful education tool for the average citizen to contemplate the future. Utopian urban planners of the past have been able to recognize the problems of their times and how they would or would not be sustained. For example, adding sidewalks to separate automobiles from pedestrians, and the zoning laws of particular areas to categorize city and rural areas were, at their origin, utopian design.

Today, the creation of sustainable cities is a popular Utopia city model. The plans surrounding what makes a city sustainable were created by thinking about how to perfect the human condition and efficiency overall. As the Earth faces substantial environmental and energy concerns, the adoption of sustainable concepts in the growth and redevelopment of cities is vital to ensure human existence and prosperity.[34] Our other option is one of humans living among waste, disease, and destruction. Sustainable cities could include solar panels covering every roof, expanded green space, vertical farming, gray water filtration, natural and recycled building materials etc. A city that is already adopting these future forward ideals is Singapore. Singapore has emerged as a model of green building for cities around the globe. Certified green buildings account for more than a fifth of the floor area of the city/state and follows a generous incentive scheme to encourage its citizens to build in an environmentally friendly fashion[35]. "The Library of Babel" is a highly efficient, seemingly waste free, utopia. Which raises the question, is "The Library of Babel" a projection of humanity in the distant future?

Conclusion

This thesis explored the spaces described by three works of literature. These stories in particular displayed STEM features that were interesting to explore and discover new questions from. This thesis also married the field of engineering to English in a diverse way. If this research were to continue, this process could be repeated for several other stories that describe complex spaces as well as raise curiosity about STEM questions. In this process, art and science can continue to influence each other in a cyclic pattern. More stories with questions are out there and available to draw conclusions from. Also, these three models could be taken further into different mediums to create more content to study. The models have potential to be 3D printed, and scaled up and down to discover other features of study. The models are not perfect representations of each story, and it is unclear if they ever could be. These stories have enough content to continue to iterate models several more times and continuously discover new questions and critiques about the stories and the current state of the world.

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[34] Haughton, Graham, and Colin Hunter. *Sustainable cities*. Routledge, 2004.
[35] Mike Ives, et al. "Singapore Takes the Lead In Green Building in Asia." *Yale E360*, December 16, 2013.