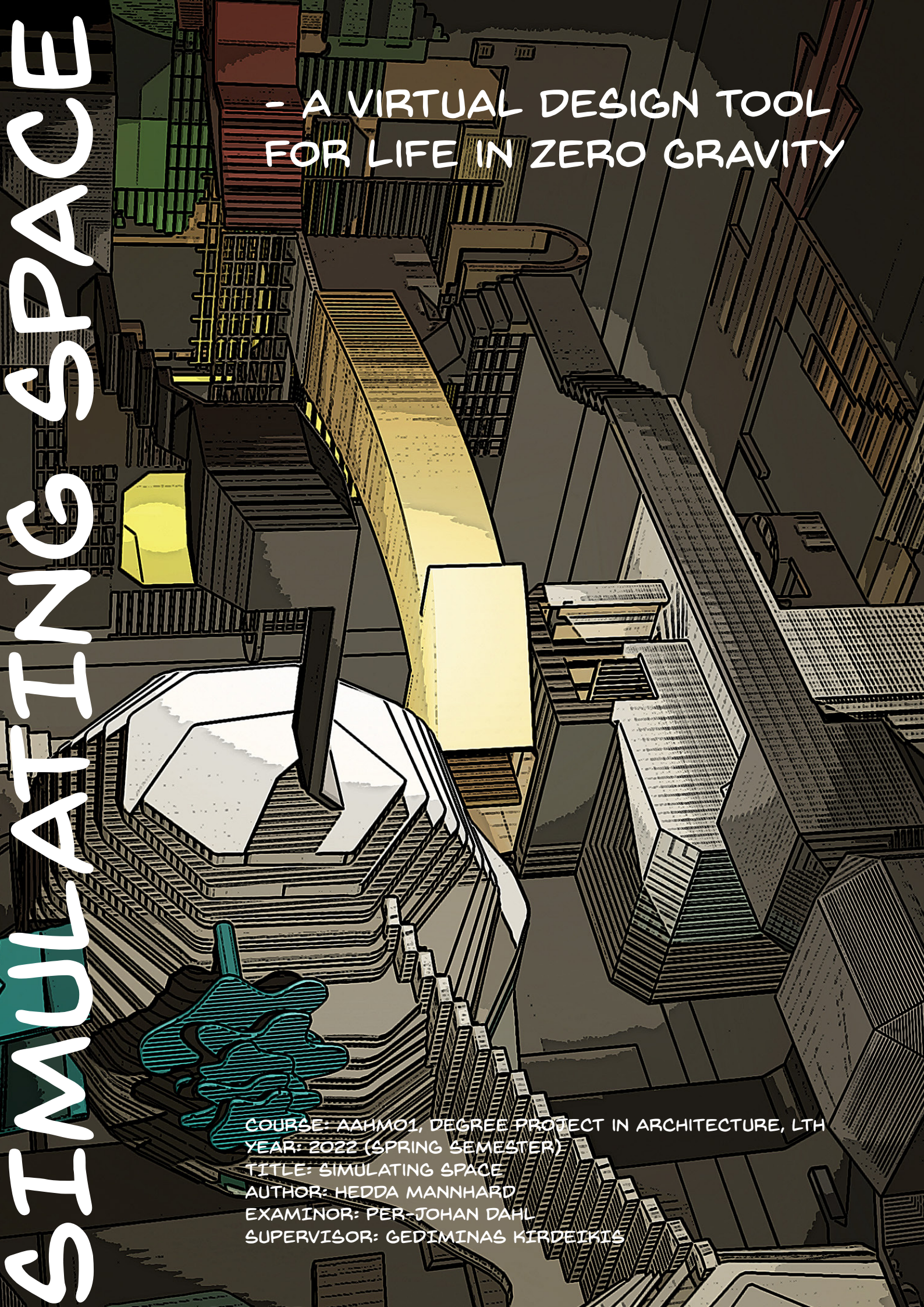
SIMULATING SPACE

- A VIRTUAL DESIGN TOOL FOR LIFE IN ZERO GRAVITY



COURSE: AAHM01, DEGREE PROJECT IN ARCHITECTURE, LTH
YEAR: 2022 (SPRING SEMESTER)
TITLE: SIMULATING SPACE
AUTHOR: HEDDA MANNHARD
EXAMINOR: PER-JOHAN DAHL
SUPERVISOR: GEDIMINAS KIRDEIKIS

CONTENT

PART ONE

1.0 INTRODUCTION (3)

1.1 What if? (3)
1.2 Life in space vs. history (7)
1.3 Real life in zero gravity (11)
1.3 Framing the problem (14)
1.3 Method (16)

2.0 REDEFINING ARCHITECTURE (17)

2.0 Wayfinding in complex environments & how we move (17)
2.1 The architectural promenade & virtual space (23)
2.2 Architecture as symbols (29)

PART TWO

3.0 CREATING THE TOOL (32)

3.1 Möbius gallery (48)
3.2 The cartesian garden (54)
3.3 Home (63)

4.0 DISCUSSION (66)

5.0 BIBLIOGRAPHY (68)

1.1 WHAT IF?

The late avant-garde architect Lebbeus Woods said in his lecture Terra Nova 1995: “We inhabit space in which we are not [...]sure how to move” (Noever, 1997, 135), referring to the inherent difficulty in the task architects face when designing for an unpredictable future. Lebbeus Woods was known as the architect who dared to ask “what if?” and for imagining a world radically different from the one we know.

In 1988 Woods was invited, among a number of eminent architects, to design a proposal for Berlin (fig. 2.) During this time, the Berlin wall, separating east from west, would still be standing for another year. This political division of the city was very fascinating for the American Woods. He learned that the U-bahn was the only remaining connection between the two sides of the city. Thus he believed that the underground was where the people would meet in secret and reunite the city by building a series of structures under the streets of Berlin that would form a new community. The structures would create sort of an inverted skyline. The “Inverted towers” that would take form would be built for both work and for leisure time and would be constructed in harmony with the unique seismic, gravitational and electromagnetic forces that characterized this new life under ground. Woods viewed these units, or towers, as laboratories for experimental living. He soon realized that people probably would not be happy about living their whole life underground, and when they would eventually resurface, they would want to bring their knowledge from life underground with them to the surface. For this reason, the inhabitants of the inverted city would build what Woods is calling projection towers(fig. 3.) that would one day forcefully reemerge through the ground. The projection towers would project the energy of the reemergence and the energy of the forces below ground. They would also project physical objects that were meant to shoot out from the tower to go someplace else, like spores or seeds of a new culture being spread by the wind. (Noever, 1997, 136-139)

When Woods a year later, was asked to do a Utopian project for a 21 century Paris it suddenly became clear where his spores from the underground of Berlin were heading. From underneath the streets of Berlin, Woods was about to projectile his seeds up into the Parisian Sky, because Paris according to Woods, was a city of air and light. He started to think about how these shards of material, these fragmented parts that spawned from the projection towers in Berlin would be joined together and what was keeping them afloat without any engines. He proposed how he could make use of the concept of the “magnetic lift” and use the Eiffel-tower as the great piece of iron that it is, to distort electromagnetic fields and create a sort of vortex above the tower. That way the structures would be able to fly, twist and float above and around the tower. (fig. 4. & fig. 6.)(Noever, 1997, 139-142)

This project, like all of his projects, are explorations of architecture on many

FIG. 1. (ZETTEL, 2005)

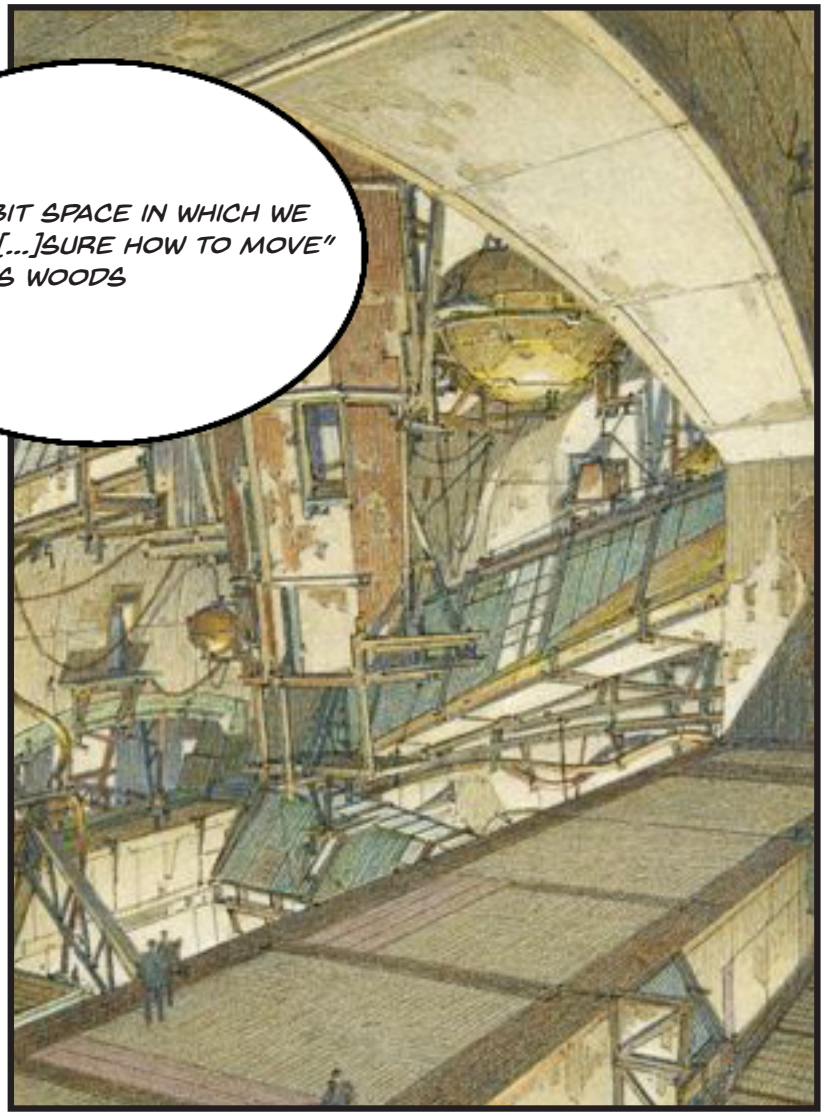


FIG. 2. UNDERGROUND BERLIN, LEBBEUS WOODS 1988

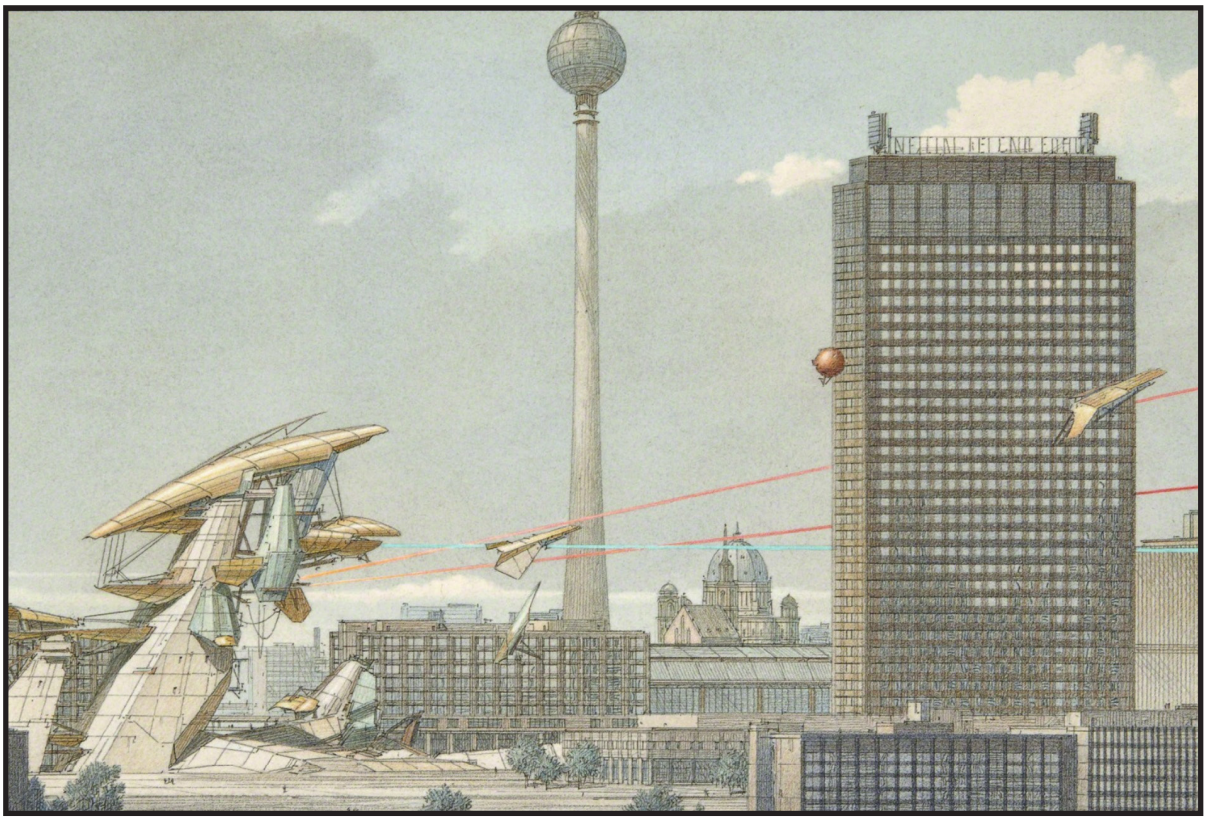


FIG. 3. PROJECTION TOWER, *UNDERGROUND BERLIN* 1988 (WOODS, LEBBEUS)

levels and are much about the contradictions in the combination of simple Euclidean geometry with something more ambiguous and strange. He wasn't interested in architecture that served an existing idea of living, but that rather strives to introduce entirely new ways of living.

In 1953, 8 years before the then 27 year old Soviet Jurij Gagarin became the first person ever to visit space (Rymdstyrelsen, 2022), the Dutch artist M.C. Escher made his lithography print called "Relativity"(fig. 5.). In this mathematical work of art, he connects 3 different worlds with their own gravity field. He, or anyone else during this time, had no sensation of what a multiple gravity space, or a zero gravity space for that matter would feel like. Still he could imagine a space where there's no real sense of up or down, left or right or where a wall could be a floor from another point of view.(Escher in het paleis, 2022) *Relativity* makes me wonder; How do the figures in his drawing experience the world around them? What does the transition between gravity fields feel like? M.C Escher raised a lot of questions, perhaps unknowingly about how we experience zero gravity environments, With rapid climate change with rising oceans and the destruction of our common home on earth, we will most likely in a near future be forced to inhabit space in which we are still not sure how to move. In this thesis, I will attempt to answer some of the questions raised by MC Escher by exploring how we can design better space interiors for life where the prerequisites are radically different, because just like Lebbeus Woods also said: "I think, you know, architecture should not just be something that follows up on events but be a leader of events." (Manaugh, 2022)

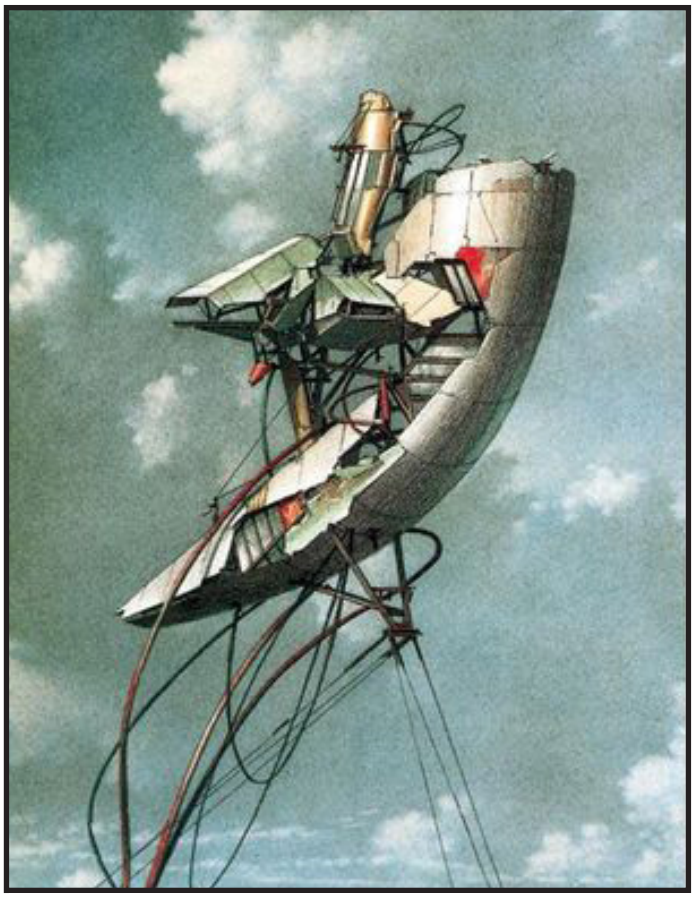


FIG. 4. AERIAL PARIS 1989, LEBBEUS WOODS

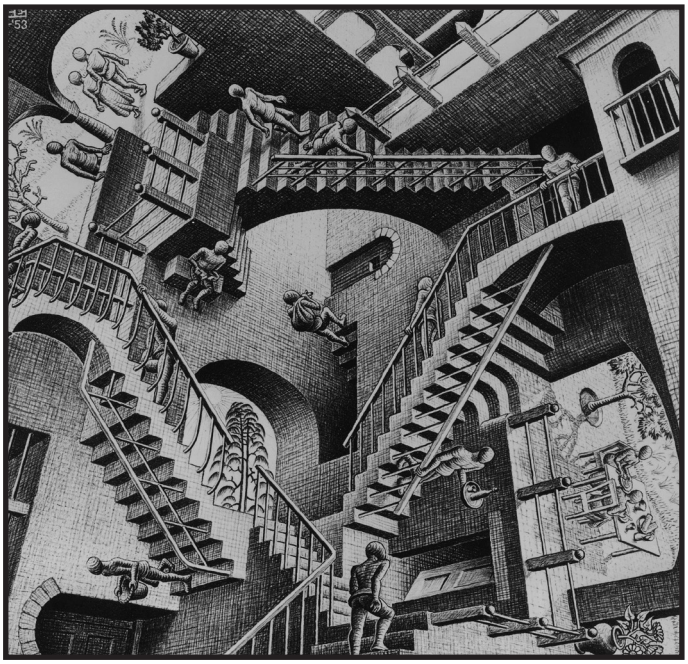


FIG. 5. RELATIVITY, M.C ESCHER, 1953

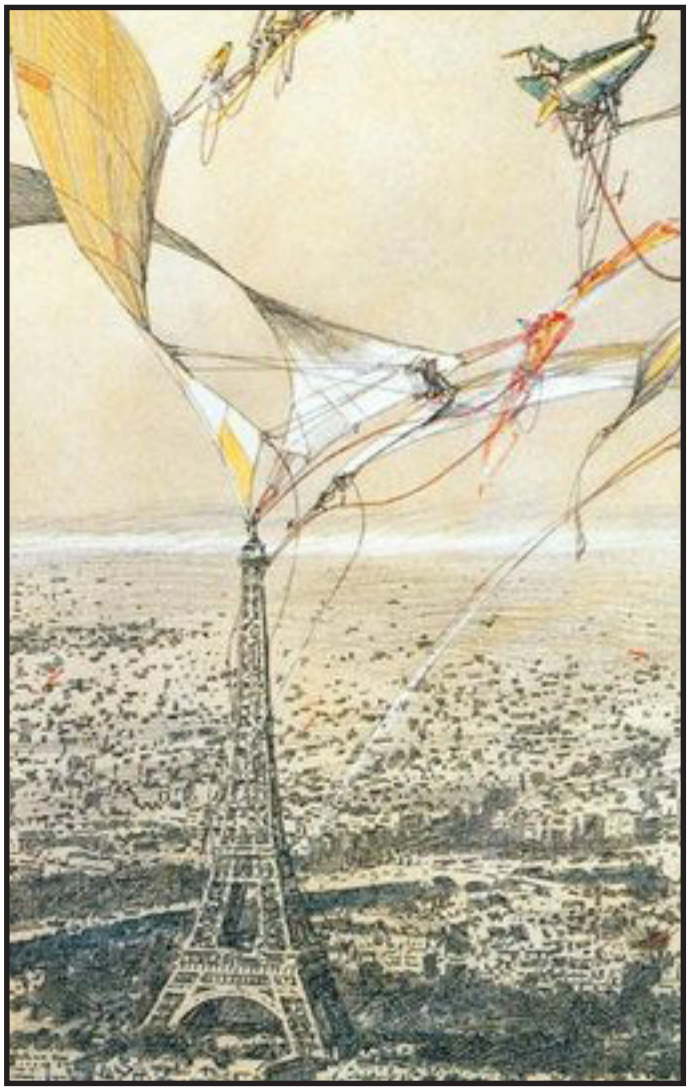


FIG. 6. AERIAL PARIS 1989, LEBBEUS WOODS

1.2 LIFE IN SPACE VS HISTORY

The forerunner of any modern space station was designed almost a century ago when the Slovenian engineer Herman Potočnik “Noordung” , or ”the father of space architecture” as he was called, first presented his rotating space station in 1929. A wheel-like structure(fig. 8.) is spinning around a solar powered engine, with a machine room and an observatory that each connected via an umbilical to the living courters. Since the observatory was dedicated to conducting special experiments it lacked gravity and to make moving around more pleasant, he cushioned all edges and hard surfaces.(Nasa, 2017) Noordung seem to have been a big inspiration to director Stanley Kubrick in 1968 when he imagined the future in his film *2001: A Space Odyssey.* Accompanied by dramatic classical music we get accentuated with a spinning wheel-like structure that uses centrifugal force to create artificial ”gravity”. Besides from the interior needing to be curved, this would allow the inhabitants of Discovery one to live in a more earth-like environment with the possibility of moving through the structure in a more familiar manner.(Kubrick, 1968)

In his book *The high frontier - human colonies in space* from 1976, the Princeton physicist Gerard O’Neill laid out his idea, in likeness with both ”Noordung” and Kubrick, of a 5 mile diameter, 20 mile in length spinning cylinder which would provide its habitants with a size of 300 square miles of livable area inside of it. Billionaire and Amazon founder Jeff Bezos seem to agree with O’Neills idea of a cylinder like structure as an alternative for future human dwellings. Through his company Blue Origin he expressed an ambition to put up to 1 trillion people in space in O’Neill-like colonies.(Ma, 2019)

The cost of launching only 1 kg into low earth orbit today cost about 20 000, which makes the idea of launching a structure of this magnitude close to financial madness. The structure would be so expensive that only the absolute financial elite would be able to able to afford living there. To reduce building costs, the artificial gravity would probably be slightly less than that on earth, and it would vary throughout the structure depending on your altitude. As you approach the rotational axis, the ”gravity” would eventually reach zero which could be a place for zero gravity sports or perhaps entertainment. (Cool Worlds, 2019)

Besides that none of these suggestions on space habitat have yet been realized, what they all have in common is that they make use of artificial ”gravity”. In theory however, it is definitely possible to create a gravity like sensation. Albert Einstein postulated that if centrifugal force is equal to the gravitational force, there would be no way to distinguish being in a gravitational field from just accelerating.(Cool Worlds, 2019) Rhett Alain, an associate professor in physics at Southeastern Louisiana University however, argues that creating an artificial gravity isn’t as easily applicable to real life. By calculating the exact amount of apparent weight needed to mimic

FIG. 7. MODEL OF "NOORDUNG"S SPACE STATION HABITAT MODULE.

FIG. 8. "NOORDUNG"S ROTATING SPACE STATION DESIGN 1929.

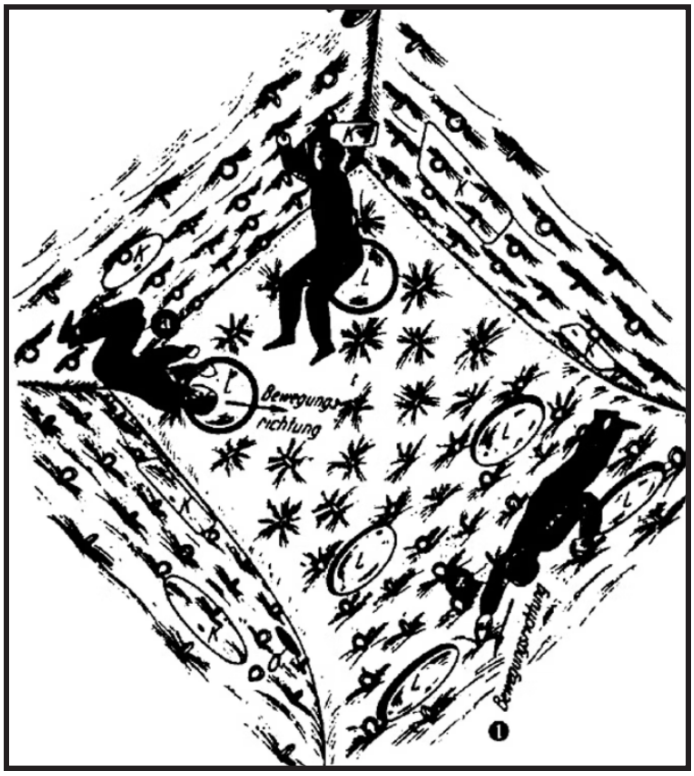


FIG. 9. IMAGE SHOWING NOORDUNGS SPACE STATION INTERIORS FURNISHED WITHOUT ANY LOOSE OBJECTS, COMPLETELY CUSHIONED AND EQUIPPED WITH STRAPS.

FIG. 10. A CREW MEMBER ABOARD THE FICTIONAL SPACE SHIP *DISCOVERY ONE* FROM *2001: A SPACE ODYSSEY* (1968) EXCERSICING BY RUNNING IN AN ENDLESS LOOP IN THE CIRCULAR CREW COMPARTMENT.

FIG. 11. THE FICTIONAL SPACE SHIP DISCOVERY ONE FROM STANLEY KUBRICK'S *2001: A SPACE ODYSSEY* (1968)

the gravitational force on earth the crew compartment in relation to its size would have to spin incredibly fast, and by making it smaller other problems would arise, such as the fact that the apparent weight, or sense of ”gravity” varies with height from the floor, and it would make docking to the station increasingly more challenging. (Condé, 2022) In addition to this, accelerating at the speed needed for months, year or even decades would require engines incredibly much more powerful than any modern space vehicle.(Cool Worlds, 2019)

This has raised the question on living in reduced gravity compared to that on earth (1g), perhaps equal to that on Mars (0.38g), or even the moon (0.17g). In anything below moon gravity, people will have problems with finding an upright position and navigating which I will return to in another chapter. However, studies show that due to a force known as the Coriolis effect, trying to move inside of a rotating cylinder or torus can have a similar effect and cause nausea. This effect is also known as canal sickness.(Cool Worlds, 2019) To conclude, before being able to creating artificial ”gravity” we have a lot of challenges to overcome.

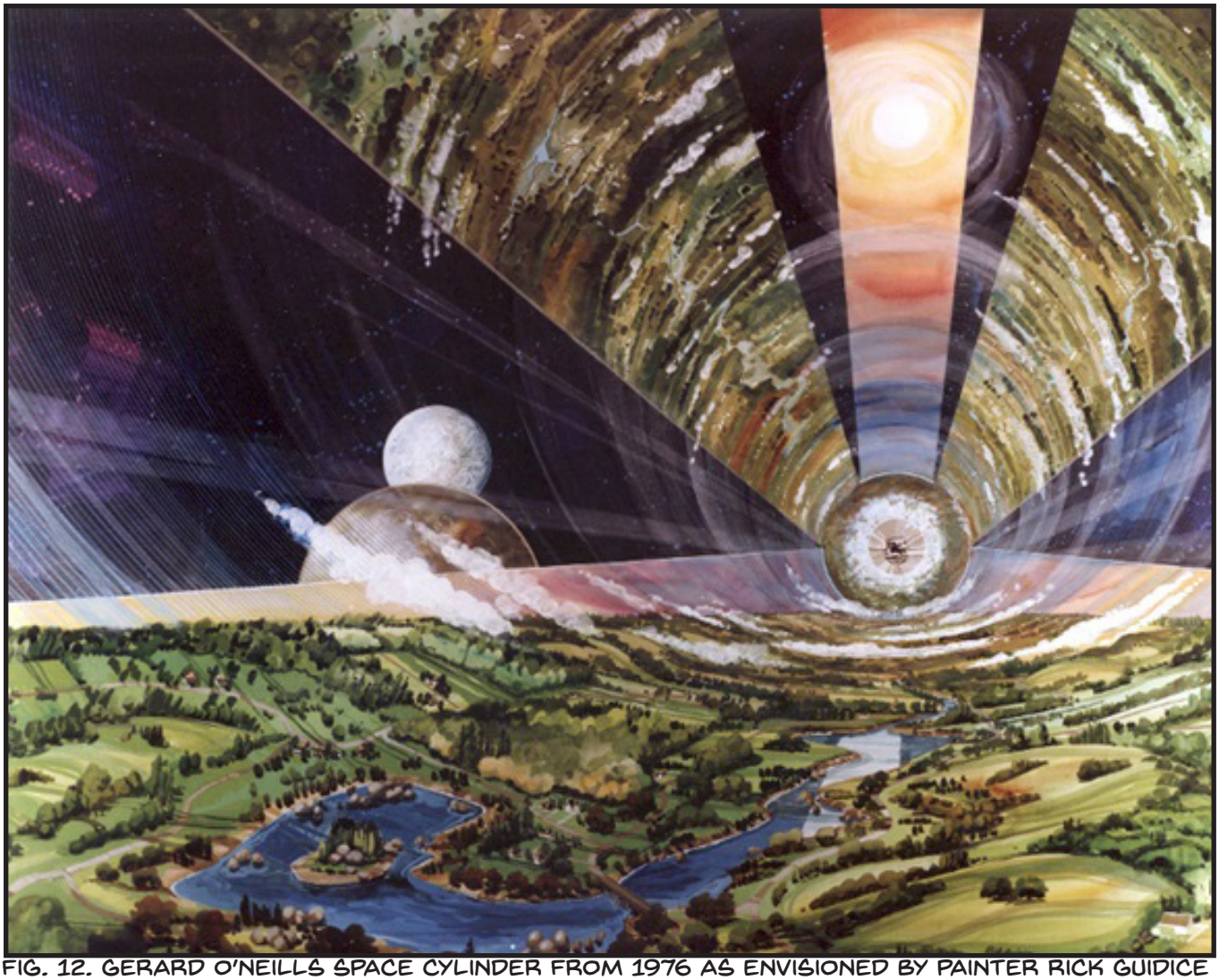


FIG. 12. GERARD O'NEILL'S SPACE CYLINDER FROM 1976 AS ENVISIONED BY PAINTER RICK GUIDICE IN 2004.

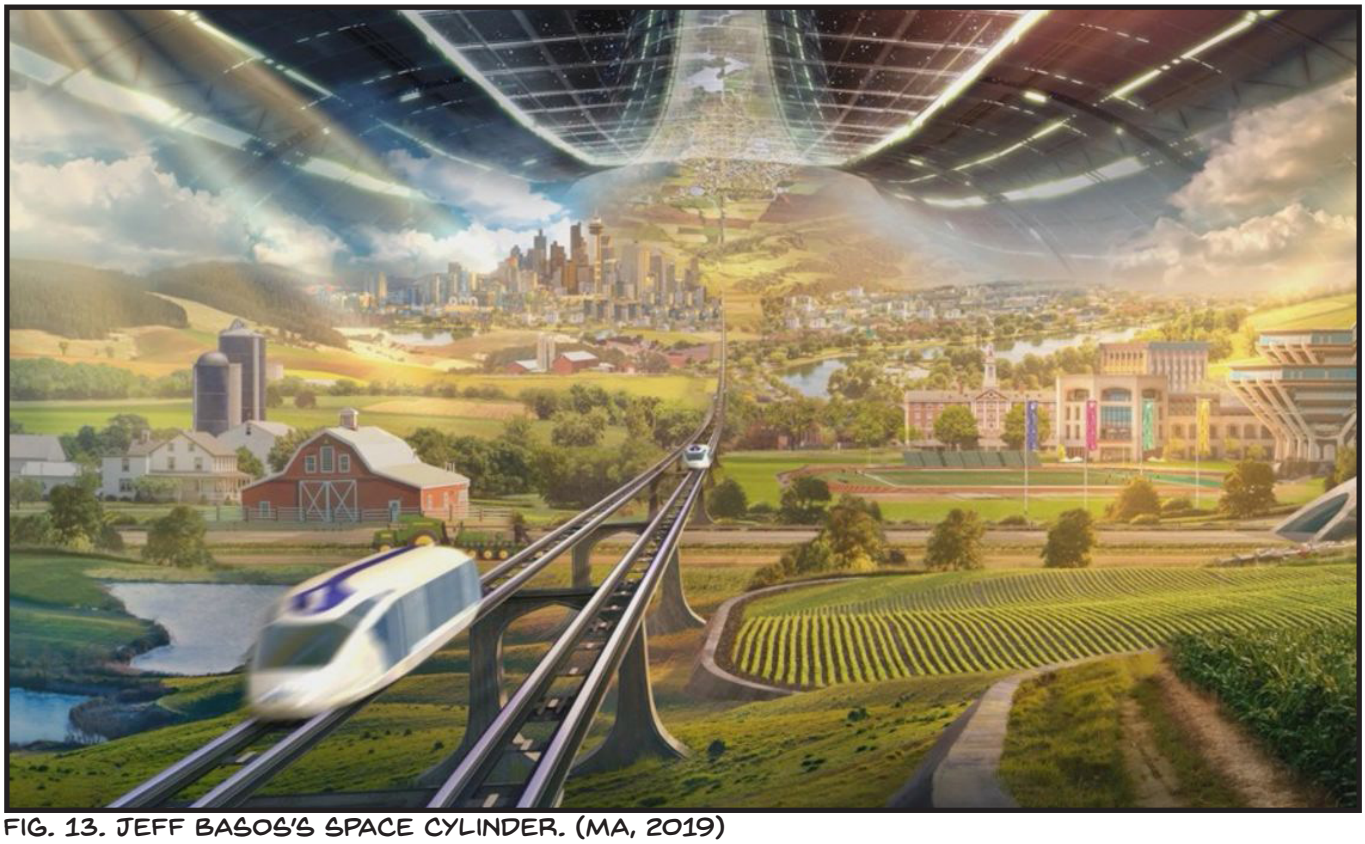


FIG. 13. JEFF BASOS'S SPACE CYLINDER. (MA, 2019)

1.3 REAL LIFE IN ZERO GRAVITY

The *International space station* (ISS) is a perfect example of engineered structures. Orbiting just outside of the earth's atmosphere, ca 400 km, it remains the largest man made structure in space since the former president Ronald Reagan first ordered the construction of an international space station in 1984. It took 10 years to build and over 30 missions to complete. 15 countries came together via 5 different space agencies to complete the ambitious structure. The first component of ISS was launched in 1998 by a Russian proton rocket into space. Just a month later, the first US module joined the Zarya module during the STS-88 mission. In the year of 2000, NASA astronaut Bill Shepherd and cosmonauts Yuri Gidzenko and Sergei Krikalev became the first crew on board the ISS and spent four months making it ready for future passengers and bringing it "to life". Up to now, the ISS has been the home for 230 astronauts, wealthy space tourists and cosmonauts for six months at a time.(ISS National Laboratory, 2022) Life in zero gravity is generally hard on our bodies that are hardwired for life on earth, and without gravity, we lose 20% of our muscle mass after just a week in space. To prevent this from happening, astronauts must exercise for at least two hours every day.(Cool Worlds, 2019)

Even though the ISS is an impressive construction, the interiors of the ISS leave a lot more to desire. The former astronaut Chris Hadfield allegedly drew parallels between the interiors of the ISS and that of hospital corridors. With all of the essential technicalities such as sockets, cables, switches, laptops etc, on display, the visual stimulus is overpowering and the space appears cluttered.(Nixon, 2022) The former astronaut Nicole Stott who has spent in total 104 days in space said when describing her time on the space station:

> *We have to do a better job of considering the human in human space flight. When you travel to space, you're not just working but living there, too. If there's one key thing to consider, it's how life without gravity affects the way you move. (Solondz, 2022)*

Initially the station was meant to have a habitation module dedicated to sleep and leisure time, but a slimmed down budget put the plans to a halt half through its construction in 2001. Instead of a sleep module, Naturally there aren't any traditional bedrooms as we know them on the ISS but individual sleeping compartments composed of a sleeping bag with restraints to make sure that nobody goes off sleep-floating. There is also storage space for personal belongings.(Documentary Tube, 2015)

The ISS has no living room or social space, the initial plans for a wardroom and a gallery for food preparations were scrapped due to scarce finances. However, crew members still sometimes manages to throw extraterrestrial

FIG. 14. EXTRATERRESTIAL DINNER PARTY BY THE FOLD OUT TABLE ON THE INTERNATIONAL SPACE STATION. (NIXON, 2022)

FIG. 15. THE *CUPOLA* WITH A PANORAMIC VIEW OF EARTH BELOW (NASA, 2022)

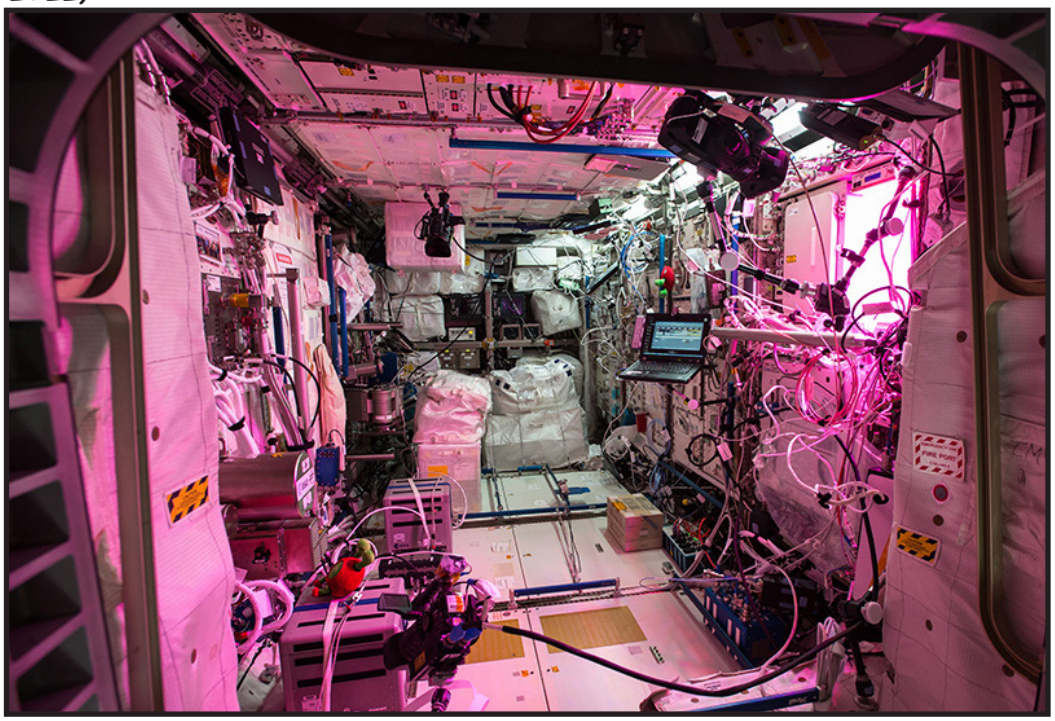


FIG. 16. CLUTTERED CORRIDORS ONBOARD THE INTERNATIONAL SPACE STATION.(NIXON, 2022)

dinner parties by the fold-down dining table in the Russian module. However they still need to be strapped down to it in order to use in it's conventional way. Because there is no possibility to cook in space in any conventional way there isn't a need for any standard kitchen either. The food is either dehydrated or has a paste-like consistency to keep it from floating away and usually comes in a tin can or a plastic pouch.(Nixon, 2022)

The *cupola,* a small room consisting of seven windows mounted on the bottom of the station, is where most astronauts claim to spend most of their free time. The cupola offers panoramic views of the earth and has become the astronauts favorite place for relaxing and to spend their leisure time in. (Nixon, 2022)

In addition to the general unhomeliness of the interiors astronauts aboard the station have reported problems with finding an upright orientation. Responsible for our sense of location is our vestibular system (sense of balance) which compare the input it receives from our surroundings with somatosensory cues such as the sensation of our own weight underneath our feet when standing upright, or visual cues to paint a complete image of our upright position.(McManus and R. Harris, 2021, p.1) Because of gravity, the somatosensory cues are exclusive for life on earth and when bodily cues are taken away from us, all we can rely on for orientation are visual ones. Luckily, more than 80% of human spatial perception is collected by vision. (Kim et al, 2021) Visual cues seem to override even a bodily sense of gravity. In a study, the body of the test persons was tilted, but the polarity of furniture indicated that they were actually upright which was how 84% of test persons said to had perceived their position. (McManus and R. Harris, 2021 p*.2)*

Thus astronauts aboard the International Space Station might orient themselves by regarding the plane beneath their feet as floor or following certain landmarks. However, when faced with an object or perhaps a colleague oriented in a polarized direction they can experience a shift in their perceived orientation or subjective "up"- plane. This psychological effect is known as the *visual reorientation illusion*.(McManus and R. Harris, 2021) The symptoms seem to stem from a lack of spacial identity. With no set walls, ceilings or floors and where up, down, left or right is highly relative and subjective, this can lead to nausea and confusion and a feeling of moving faster and further than they actually have. One astronaut reported that it felt as if the room was rotating around him one morning when he woke up and others have for brief moments during space walks not known where they were. (Universe Today, 2021)

Initially, design attempts were made to help astronauts reorient themselves by trying to create a sense of a reference plane or a floor. Still, small cues are intentionally placed to help with orientation. For example informational text is presented in the same orientation throughout the entire ship and computers

are placed to match that same direction. (Universe Today, 2021) However these small gestures doesn't seem to be enough to counteract the *VRI,* and real attempts to create reference floors were initially overruled by engineering constraints and needs. The interior therefore consists of long narrow corridors, in all directions lined with racks of equipment, dissolving any potential of defined "up"-planes. (Nixon, 2022)

1.4 FRAMING THE PROBLEM

When the International Space Station got sent into orbit it seems as if the Le Corbusian argument that "A house is a machine for living in" (Le Co., & Cohen, J.-L, 2009, p.151) got turned on it's head. A machine, is the only thing that the space station seems to be, not made at all for living. When viewing the station as the home that is actually is for the astronauts on board it seems as if environmental wellbeing and comfort is simply lost in space.

Perhaps it someday will be possible to create an "artificial gravity" in space habitations. However, we cannot know for sure that the solution to the problem would present itself before earth becomes inhabitable due to rising sea levels and environmental destruction. When this happens, we need to have the tools to create environments not only that we can survive in, but eventually we are going to crave environments in which we can thrive in. It is clear that modern space interiors aren't even close to meeting our needs.

When presenting my thesis during the mid-review I got a great question from one of my teachers. She asked me: "Why don't you just make a spaceship? At the time it threw me a little, because why wouldn't that be enough? I came up with some elaborate answer to why it needed to be done my way, mostly based on an intuitive feeling that I actually did have a good reason to do so. Thankfully, her question forced me to seek out better answers. The answer came from the question that would have followed hers; how would I go about designing a spaceship with when fundamental prerequisites like gravity doesn't apply? I had no idea, and not only because it is a daunting task per se, but because I found that the tools to design homely zero gravity environments were nowhere to be found. Since space travels are a relatively new undertaking when viewied in a historical context and highly complex in a technical sense, there's no wonder that the art of engineering has taken a front seat in the process. Therefore, the tools to design the shell and the technicalities are there, but are more successfully utilized by engineers. We need a tool as architects that provides us with potential answers on how to deal with radically alien prerequisites for design.

So, for this thesis I decided to try and create that tool.
To do so, we first need to define what the characteristics of a home or homely environment are. When typing in the term home, one of the many definitions on Merriam Webster online dictionary is *": a familiar or usual setting : con-*

genial environment"(2022). When looking up the word homely you will find:

> *:being something familiar with which a person is comfortable and at ease : comfortable and familiar like home", ": free from affecta tion : unaffectedly natural : SIMPLE" and ": not elaborate or complex.*(Merriam Webster, 2022)

Space and zero gravity environments are unfamiliar to those who are used to life on earth (read: everyone) and therefore, one could argue, per definition unhomely. To bring homeliness to such a place might seem like an impossible task, but in this thesis, I want to explore if it is possible by implementing tools already created for making complex environments more comprehensive and comfortable here on earth. I also want to explore if it is possible to exploit the perks of having six furnishable planes (up, down, left, right, backwards and forwards). Being able to use all six planes could reduce construction costs and help streamline interior spaces but might make wayfinding more difficult and trigger the visual reorientation illusion.

In addition to the lack of design tools, the experience of zero gravity isn't very accessible to just anyone which makes it difficult to test these things. The price tag is 55 000 000 dollars for any non-astronaut who wants to take a journey aboard the ISS and experience life in zero gravity. (Chapell, 2021) If they are willing to settle with the next best thing they could can go for a ride in the *G-Force 1,* for 75 000 dollars. The purpose of this airline by *Zero G Corporation* is mainly for astronauts who are about to board the ISS to experience weightlessness before going into space, hence the price tag. The G-Force 1 is a suborbital flight which simulate weightlessness by flying in parabolic motion to create multiple spurs of weightlessness which lasts for a couple of seconds at a time. In a video on YouTube, Rachel Crane, a CNN Innovation and and Space Correspondent, interviews the CEO of Zero-G Corporation, Matt Godh, about their Zero-G simulator:

"There is a lot of talk about these suborbital flights democratizing space, but is this experience the closest thing that, you know, a normal person will ever experience?" (CNN, 2021, min 1:30)

Matt Godh responds:

"Absolutely, yeah the price point, no one will say that 7500 dollars is cheap, but it's accessible." (CNN, 2021, min 1:43)

The G-Force 1 makes use of the same phenomenon as when you go reach the top of a hill on a roller coaster and feel weightless for a brief moment as the roller coaster goes downhill. One could therefore argue that amusement parks are the absolute cheapest and easiest way to get access to a zero gravity experience but is a restricting environment in which to test issues regard-

ing environmental psychology which in the article *The Influence of Users' Spatial Familiarity on Their Emotional Perception of Space and Wayfinding Movement Patterns* is defined as "the psychological state that people feel in a specific environment among various living environments". (Kim et al, 2021) Therefore there is clearly an increasing need for democratizing these environments in order to be able to collect data on a grater scale. Luckily, as stated in the previous chapter, vision is decisive in our perception of our body position. This indicates that we might actually not need weightlessness in order to have a zero gravity experience.

In this project, I will explore is a virtual space could function as a test bed for zero gravity environments. My hope is that a virtual space can bridge the gap between designers and future space inhabitants and democratize the conversation about the possibilities of future space design. Perhaps it could even generate new spatial configurations that are applicable to earthly architectural design and function as a springboard for further studies on the subject.

The questions I hope to answer by creating my design tool is:
- *In what way do we need to redefine architecture when we remove gravity?*
- *Is it possible to apply our knowledge of wayfinding in complex spaces to zero gravity environments?*
- *Can virtual reality encompass a generative tool for spatial innovation in architecture?*

1.5 METHOD

When starting this project, I wasn't sure of how much, and what kind of information I would find on the subject. A big part of it is about spatial psychology which is a difficult subject to derive any quantitative data of. I did however, manage to find studies that are relevant and applicable to my project, such as wayfinding research and reports about astronauts experiences of everyday life in zero gravity. In this first part of my project I will carefully study different written sources, focusing on wayfinding tools and psychological responses to environmental features. The virtual environment that constitutes the tool and which will be presented in the second part of this thesis introduces another layer of complexity due to the fact that its created to test a real environment. For this reason I have also studied virtual environments to identify possible obstacles when trying to apply findings from real environments to a virtual environment and vice versa.

In the second part my theoretical findings will be applied to a virtual environment. The virtual environment will be modeled in Rhinoceros 7 and imported into the free gaming engine *Unreal Engine* to access interactive mechanics. The interactive aspect is crucial for my project since my subject is of a relatively subjective and highly psychological character which demands empirics. The key difference between my virtual environment and a more realistic

virtual reality experience is the way in which you are able to move within the environment. It might easy to jump to the conclusion that I would, from a first person perspective, simulate and design a space in which you are floating like you would in a zero gravity space. However, this isn't how we naturally navigate on which I will go into more detail in the next chapter. Spatial experiences are formed by an up, down, left, right, forward and backward even in spaces without structural boundaries such as a ceiling or a wall. The big difference when moving and navigating in zero gravity is that the perception of these spatial identities are constantly changing. Because of this, my virtual test bed will be designed not as a spherical space but as a space with planes that can shift identity depending on how our position shift in the virtual space. In addition to this, by using 90 degree planes, we have more conventional furnishing space which would heavily reduce costs compared to if we would try to counteract the risk of the *visual reorientation illusion (VRI)* by furnishing only one perceived floor or by trying to furnish a spherical space.

A reason other than that of democracy to why I am creating a virtual space is to strip the user of any sensory input other than vision. By letting the user lone a virtual "body" the physical experience will be the same for everyone and the data collected from the tool might therefore be considered more objective. The visual nature of the tool will allow us to test if different objects are stronger triggers than others when placed in polarized positions in regards of the *VRI*.

2.0 WAYFINDING IN COMPLEX ENVIRONMENTS & HOW WE MOVE

Every time I went with my dad to the beach it ended in disappointment. I loved exploring the bottom of the sea, looking mostly for crabs and pretty stones. I always nagged him about coming along for the next expedition and each time he had to explain to me why his rare condition made the experience less enticing from his perspective. About 30 years ago he lost his sense of balance and with it his sense of what is up and what is down. Having to rely purely on his eyesight , weightless under water where his eyesight is compromised is a terrifying experience for him. Not being able to differentiate up from down under water imposes an immediate threat of drowning. Failures in navigating on dry land does not, but comes with a great discomfort and is proven in some cases to cause anger, embarrassment, resignation or fear which in turn can lead to avoidance of the, in terms of wayfinding, problematic space. (Kim et al, 2021)

The term wayfinding was first used by the urban planner named Kevin Lynch in his book The Image of the City written in 1960. In his book, he describes the city in terms of its physical form, classified into five key elements: paths, edges, districts, nodes and landmarks. He believed these five elements to dictate and facilitate all movement in the city and to allow us to navigate

successfully in complex spaces. Even though this initially was a model meant for the city, it can according to Lynch be applied to most built environments. (Lynch, 1960, p.46)

PATHS - “Paths are the channels along which the observer customarily, occasionally, or potentially moves. They may be streets, walkways, transit lines, canals, railroads. For many people, these are the predominant elements in their image. People observe the city while moving through it, and along these paths the other environmental elements are arranged and related.”(Lynch, 1960, p. 47)

EDGES – “Edges are the linear elements not used or considered as paths by the observer. They are the boundaries between two phases, linear breaks in continuity: shores, railroad cuts, edges of development, walls.””(Lynch, 1960, p. 41)

DISTRICTS - “Districts are the medium-to-large sections of the city, conceived of as having two-dimensional extent, which the observer mentally enters ’inside of,’ and which are recognizable as having some common, identifying character.” ”(Lynch, 1960, p. 47)

NODES - “Nodes are points, the strategic spots in a city into which an observer can enter and which are the intensive foci to and from which he is traveling. They may be primarily junctions, places of a break in transportation, a crossing or convergence of paths, moments of shift from one structure to another. Or the nodes may be simply concentrations, which gain their importance from being the condensation of some use or physical character, as a street-corner hangout or an enclosed square.”(Lynch, 1969, pp. 47-48)

LANDMARKS - “Landmarks are another type of point-reference, but in this case the observer does not enter within them, they are external. They are usually a rather simply defined physical object: building, sign, store, or a mountain. Their use involves the singling our [sic] of one element from a host of possibilities. Some landmarks are distant ones, typically seen from many angles and distances, over the tops of smaller elements, and used as radial reference. [...] Such are isolated towers, golden domes, great hills. Even a mobile point, like the sun, whose motion is sufficiently slow and regular, may be employed. Other landmarks are primarily local, being visible only in restricted localities and from certain approaches. These are the innumerable signs, store fronts, trees, doorknobs and other urban details, which fill in the image of most observers. They are frequently used as clues of identity and even of structure, and seem to be increasingly relied upon as a journey becomes more and more familiar.” (Lynch, 1969, p. 48)

Kevin Lynch’s theories seem to have inspired the the architecture design network UNStudios that developed a set of wayfinding design tools much

similar to those of Kevin Lynch. Some of these are in a clear way implemented in their design of the Qatar integrated railway project. The project located in the Greater Doha Area by the Arabian Gulf, was completed in 2019 and its role is to act as a complete railway system with four lines, 35 stations in phase one and 60 stations in phase 2. A toolkit containing three major tools for wayfinding was implemented in this project:(Unstudios, 2022)

1. COLORS & MATERIALS

The station was divided into three different categories or identities: User-Network, Line and Station. Each of the categories were assigned their own materials and colors so that users could easily distinguish between the three of them. Each profile is consistently presented from interiors, furniture included to exteriors.(Unstudios, 2022)

2. SPATIAL ORGANIZATION & URBAN INTERVENTION

In the Qatar integrated railway project focal points, or nodes to use a Lynchian vocabulary, are highlighted with the use of trees, tall vegetation, light poles, shading pavilions, bicycle racks, bins etc. The main attractor points in the project are completely devoid of view blocking. The use of pavement as zoning also assists to ensure wayfinding. (Unstudios, 2022)

3. SIGNAGE & SCALE

The information system in the Qatar railway system is made functional and clear through typography, contrasting colors and in its graphic design. All signage has literal meaning.(Unstudios, 2022)

However, providing a structure for - and implementing elements that hold wayfinding value in a space doesn't explain the full extent of our preferred movement patterns. If we want to be able to make use of Lynch's theories in terms of zero gravity spaces which inherently adds another layer of complexity and discomfort compared to other built structures, it is important to try and paint a complete image both on what routes we prefer and why, and what spaces we choose to dwell in. For this thesis it is important to address how the design of spaces can manipulate the way we feel about them and the way we feel about ourselves *in* them. The economist Kenneth Boulding argued that understanding the "mental image that people form about their physical and non-physical surroundings" was crucial for our understanding of their behavior. (Kim et al. 2021)

Wayfinding refers to a series of cognitive processes where understanding and being able to interpret ones environment is the foundation to being able to establish a plan and executing the plan as a behavioral activity. Therefore, recognition within your environment is crucial for wayfinding. When following a familiar path, recognition seems to be more important and efficient than recalling. For instance, one does not need to be able to explain a long decision plan to a third party in order to find their way flawlessly, but

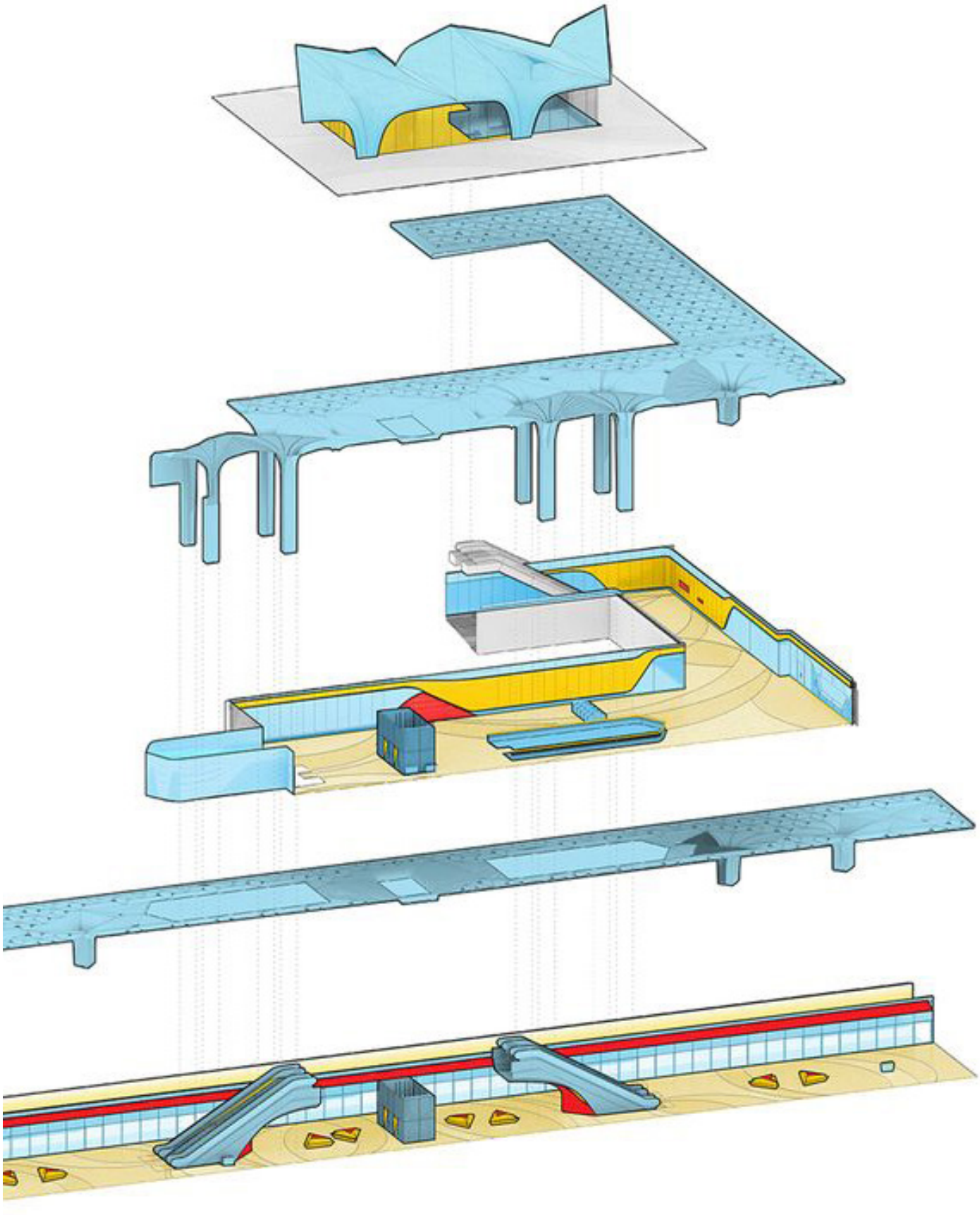


FIG. 17. DIAGRAM SHOWING THE COLOR CODING OF THE QATAR INTEGRATED RAILWAY PROJECT *(UNSTUDIOS, 2022)*

simply be able to recognize environmental features when actually faced with them.'Turn left after the tunnel', 'Get off at the next stop' or other examples of wayfinding decisions are all composed of two major units where one is a behavior (turning, getting off, stopping, looking) while one is an object or/ in a location (the after the tunnel, the next stop, by the station). This allows a person to record information by giving a certain behavior a place identity. (Kim et al. 2021)

It is thus important that environments are distinguishable from one another and contain features/objects that can be connected to a behavior in order to create decision plans. However, if there are too many distinguishable elements and/or objects the effect could be equally confusing. In addition to this, the density of events can cause distortion and confusion. This is referred to as the clutter effect. (Passini, 1984) "Clutter" or sensory input has also been shown as a factor to manipulate perceived time. Research shows that time seems to slow down with less sensory input and speed up when there is more stimulation. This could have interesting possibilities for architecture where the experience of the duration of movement through a building could potentially be manipulated to feel longer by reducing the amount of visual or auditory stimulus, or it can be made to feel shorter by increasing the amount of sensory input.(Louw, 2016) An interior space based on absencing can release us from impressions and raise awareness of greater matters such as existential questions or religion. An example is the commonly spartan interiors of prison cells and how the lack of stimuli could encourage reflection upon one's criminal actions. In the same manner, the interiors of shopping malls or casinos are designed to make sure you forget about everyday life or the world outside so that you invest as much time and money as possible.

The entrance to Tadao Ando's Chapel at Mount Rokko (1986) is another example of how architecture can manipulate our sense of time. The 40 meter long monotonous glass arcade through which you access the chapel seems to extend one's sense of time passing. The arcade is characterized by matte turquoise glass with repetitive concrete frames. The intention for the long arcade was to make whoever visits the chapel aware of the present. Studies have shown that anchoring the present moment can evoke feelings of happiness and joy and give us more energy. (Louw, 2016)

However, just before you reach the chapel, the time stretching walk through the arcade is abruptly interrupted by a short flight of steps that takes you down to the chapel. These are meant to anchor you even deeper in the present, as they force you to focus. Inducing fear by introducing a last obstacle before reaching the ultimate goal could be seen as a nod towards the Swiss-French architect Le Corbusier who allegedly used this trick in many of his projects, (Louw, 2016)

Besides from how stimulating an environment is, the amount of time we

FIG. 18. START OF THE LONG "HALLWAY" AS AN ENTRENCE TO TADAO ANDOS CHAPEL VIEWED IN THE BACKGROUND (PHOTO BY: AZEVEDO FRANCA, 2006)

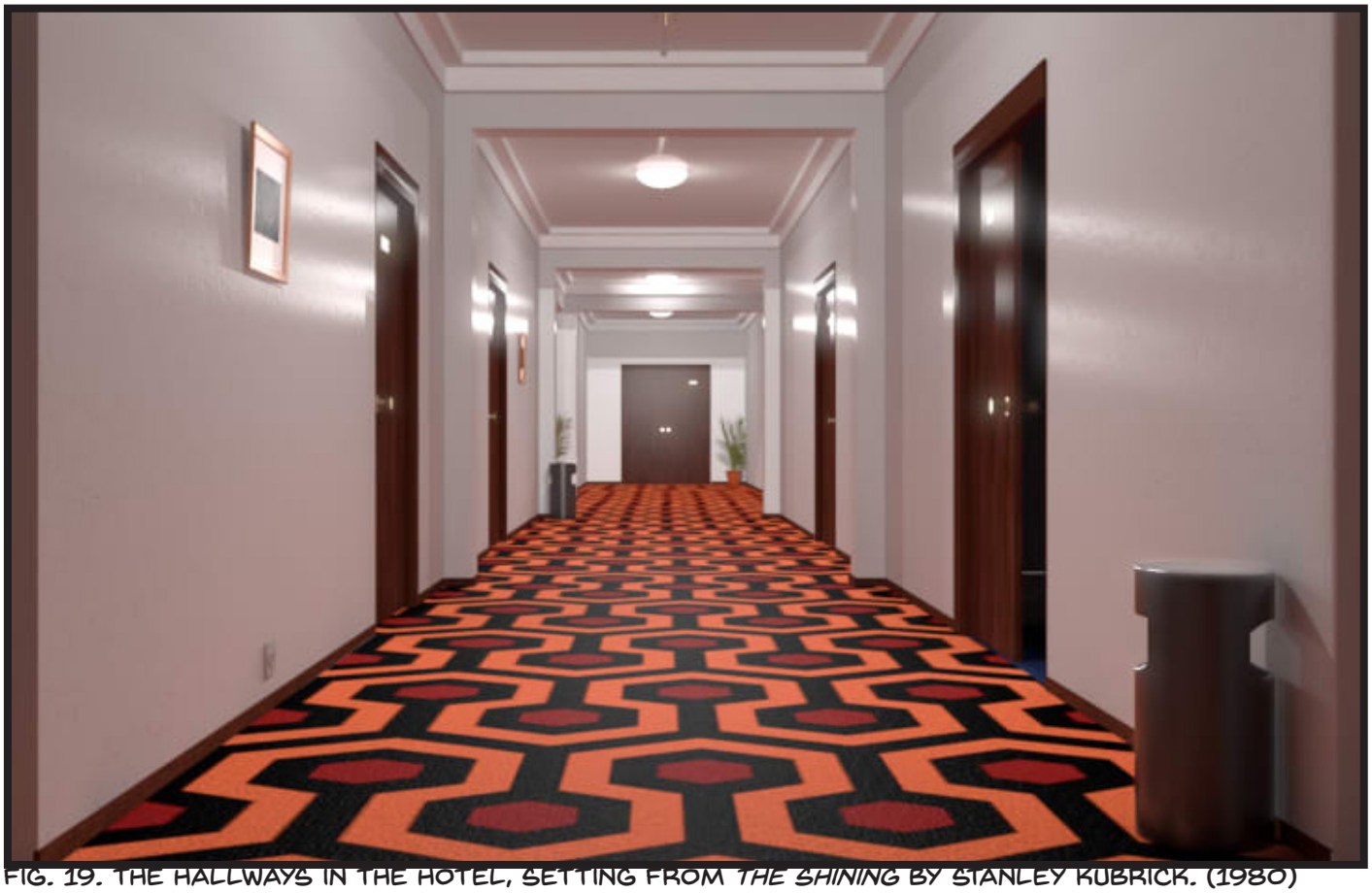


FIG. 19. THE HALLWAYS IN THE HOTEL, SETTING FROM *THE SHINING* BY STANLEY KUBRICK. (1980)

choose to spend in one place is also much influenced by scale and spaciousness. Depending on activity, the scale deemed comfortable varies. For instance, we feel insecure in a low cave or narrow corridors while we feel energized on top of a mountain. These psychological effects originate from an estimation of one's possibilities for movement in the surrounding space. (Britannica, 2022) A corridor restricts movement to the sides to encourage a constant forward or backward motion. This gives us a feeling of having limited escape routes which might be the reason for the corridor as a common feature in horror movies. For example the seemingly endless and repetitive corridors in Stanley Kubricks The Shining induce a feeling of vastness and enhances the labyrinthian feel. The intense pattern on the floor increases the sense of confusion and psychosis.

The way users feel about a space can be a factor in their route decision making. In a study published in the article *The Influence of Users' Spatial Familiarity on Their Emotional Perception of Space and Wayfinding Movement Patterns,* people were asked to choose between two routes in a large shopping mall. After walking their route of choice interviews were conducted with the participants in which they were asked to describe their emotional response to their route. (Kim et al, 2021) The results showed that it is the interest in space that determines the route and not necessarily the most efficient and fastest route.

2.1 THE ARCHITECTURAL PROMENADE AND VIRTUAL SPACE

The *promenade architecturale* is a key term frequently used when discussing modern architecture. It first appeared in the architect Le Corbusier's writings about the design of his Villa Savoye to replace the word circulation. The architectural promenade could be described as the narrative of a building where images unfold as sequences as an observer advances through the built space. (Samuel, 2010) Perhaps the *promenade architecturale* is better described through a quote from what Le Corbusier himself wrote of a documentary about the Unité in Marseilles. "The building itself is allowed to make the film" (Le Corbusier, 1995).

An example of a building that clearly is designed with the narrative in focus is the unbuilt monument designed during the fascist government of Mussolini in 1938. The monument was designed by architects Giuseppe Terragni and Pietro and was dedicated to the Italian writer Dante Alighieri, structured around his greatest work, The Divine Comedy. It has been described as one of the most elaborate architectural promenades in all of literature as an architectural allegory of Dante's journey through Hell, Purgatory and Paradise. In Terraginis own words, the building should provide a "removal from the external world". The plan is made up of two intersecting rectangles where the

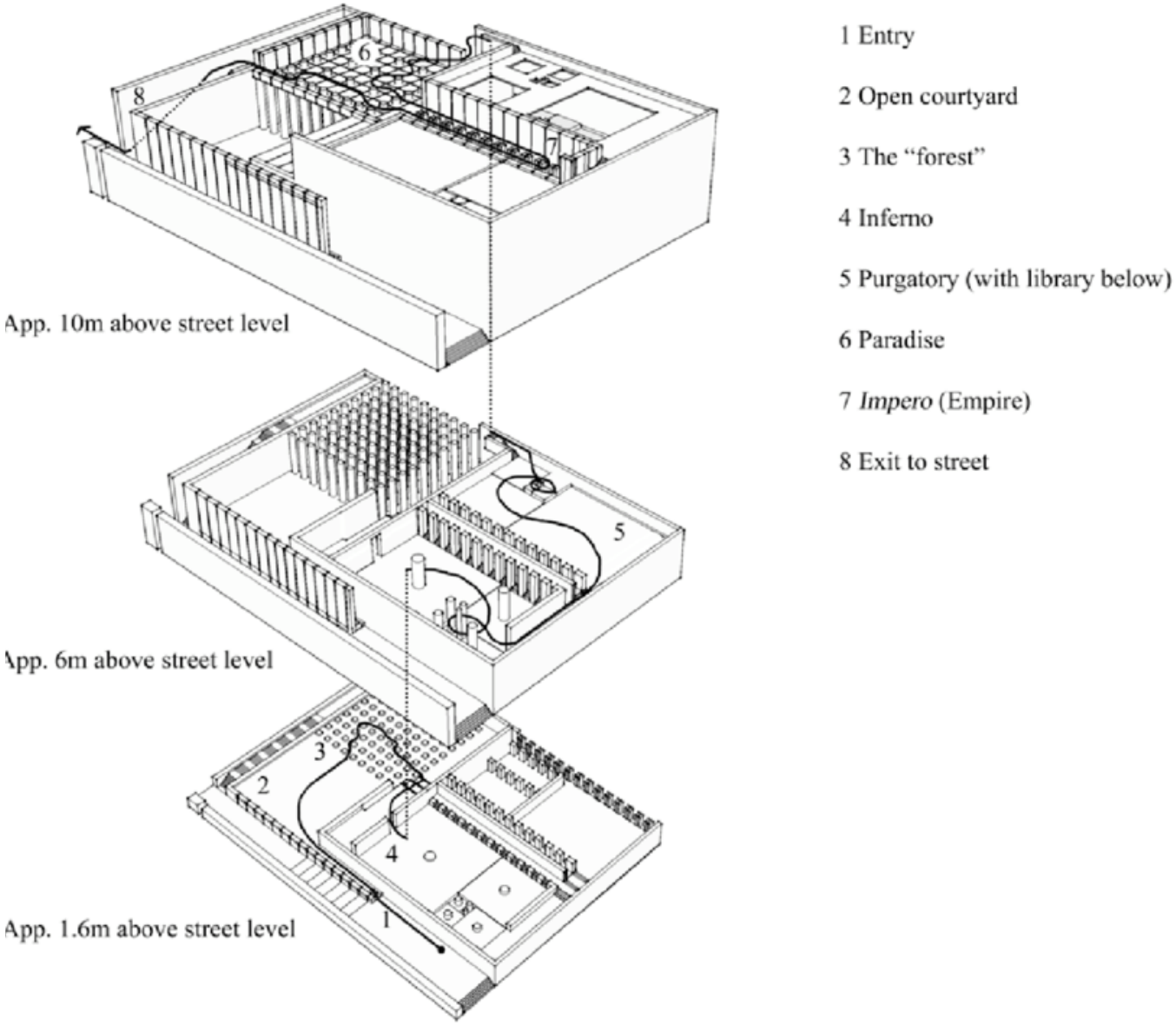


FIG. 20. AXONOMETRIC DRAWING SHOWING THE PROMENADE THROUGH THE DANTEUM (LOUW, 2016)

entrance (1) to the Danteum is hidden in the intersection. The visitor begins their promenade at Via dei Fori Imperiali through a narrow passage surrounded by tall walls and is meant to wonder how they entered in the first place. This way of entering the Danteum correlates to Canto (Section) 1, line 10 in the inferno described in the Divine Comedy. (Louw, 2016)

The visitor then reaches an open courtyard surrounded by high walls (2) in which the “Forest”(3), mentioned in section 1 of the Inferno, is represented by a hundred columns. From the forest the visitor walks up a number of stairs past five sculptures of the damned before entering the “gate of Hell”. (The architectural promenade and the perception of time). As the visitor now enters the “Inferno”(4) the space descends via a series of increasingly smaller square floor panels. The floor panels end, if followed along their spiraling composition according to the golden ratio, with the smallest one which essentially leads nowhere but downwards, to represent Dante’s spiraling journey to hell. This space is dark and lit only through the doorway and through narrow gaps in the roof. Leaving the Inferno, you continue a now ascending promenade to “Purgatory” (5) which is a lighter space lit through openings in the ceiling. Via a series of stairs in a confined passage the visitor now rises to “Paradise”(6). The long narrow passage is believed to symbolize the difficulty with which a soul enters into Paradise. The space designed to represent Paradise is made up by a forest of transparent glass columns with glazed strips between them and the glass square blocks that they support to make the roof appear as if it was floating. The glass slits in the floor, the glass roof and the glass columns would create a bright, radiant but equally confusing space with no clear focus or direction. (Louw, 2016)

A dead-end passage in connection to the “Paradise” and dedicated to the Roman Empire itself called the “Empire” is believed to be there to make the visitor reflect upon the past glory of the Roman Empire and its hopeful future. The visitor then has to go through Paradise again to try and find the hidden exit through a narrow passage back down to Via dei Fori Imperiali where the promenade ends.(Louw, 2016)

One could only speculate since the monument was never built, but the walk through the Danteum would probably be quite disorienting with the difficulty of finding entrances and exits along with the high rising walls and maze-like colonnades - just like it was designed to be. In many ways the Danteum is designed a lot in accordance with common video game level design. The architectural promenade, or a space meticulously designed with an awareness of spatial psychology in regards to movement, becomes especially important in a digital environment since the user is not necessarily restricted by any worldly physical barriers or where the laws of nature are completely different. The difference between the digital realm and the real is that the promenade in reality is too simplified in the sense that the real world spurs beyond boundaries of the building site onto the roads that lead up to it and further into the

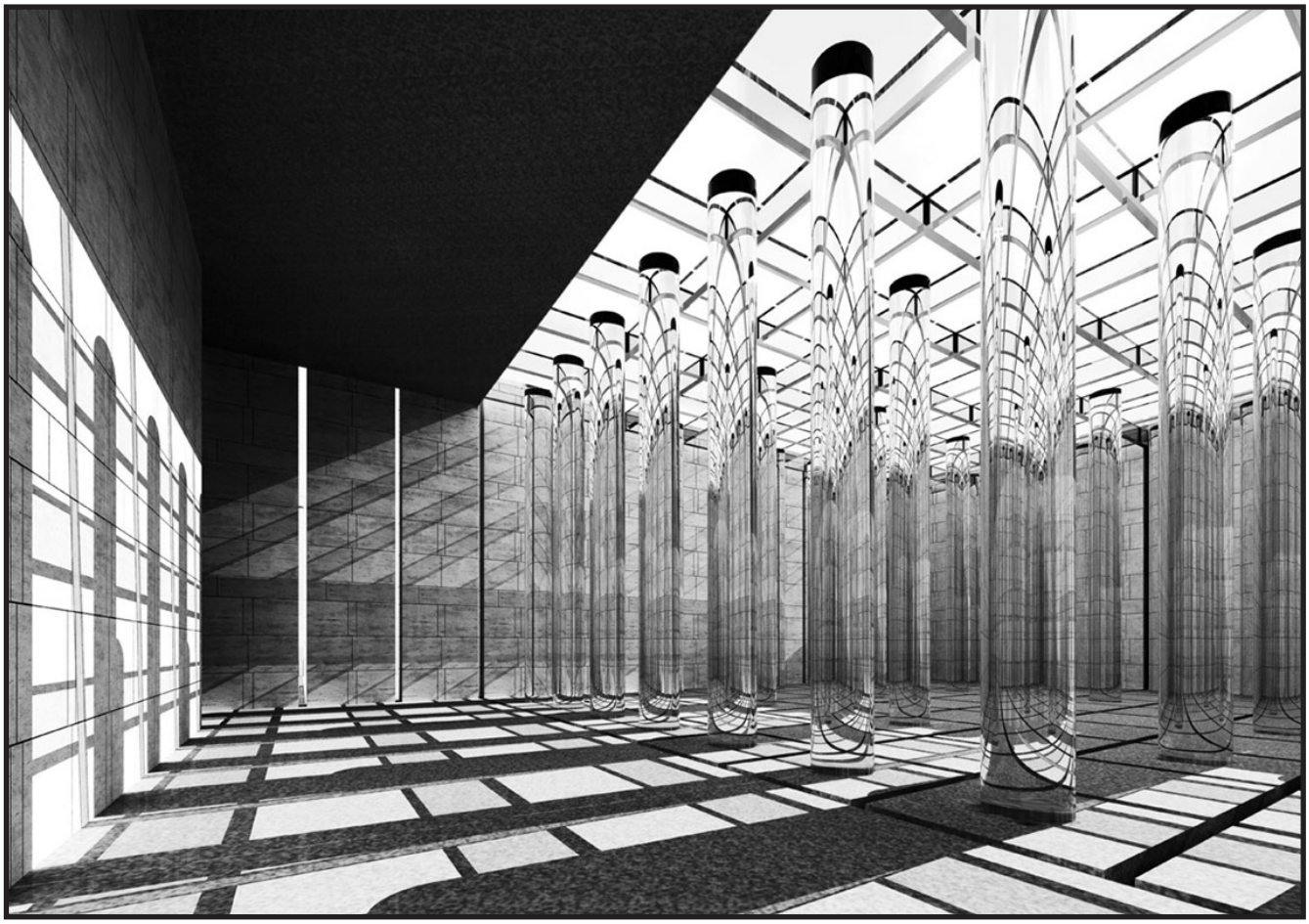


FIG. 21. THE GLASS COLONNADE IN "PARADISE". (TERRAGNI, 1938)

city and even beyond that.

In virtual environments, architecture and architectural elements are sometime interpreted differently than if sat in a real environment due to the fact that our depth perception generally is altered. The result of this is that shadows and and distances become more difficult to read which requires overly articulated cues. According to Brendon Chung, the creator of the Blendo Games company, hallways for example can be read as dead ends if not designed properly. (fig. 22.) This can be solved by using either suggesting elements, like a staircase that both indicates a fortward motion but also shifts the view in elevation. Another way to tackle this problem with virtual hallways is to add a 45 degree bend which suggest continuation. Placement of elements like cleverly placed windows can create a node for the hallway ends and thereby create a suggested continuation. It can also make the transit through the hallway feel faster, according to William Chyr, the creator of the video game Manifold Garden.(GDC, 2016)

In a video on Youtube from 2016 Chyr goes on to explain the importance of clear structures and intentional architectural elements in virtual environments. In his level designs, it is important that the architecture communicates a clear path so that the puzzles of the levels are solvable. For instance he talks about that at one point in his levels, he wants the player to understand that in order to get to the next level they would have to switch gravity and fall onto the level below. Therefore he placed a block onto which the player would walk onto, switch gravity and fall off. However letting people test play the game, he realized that the simple block failed to communicate its intentions. He therefore replaced it with a set of stairs and a platform which better managed to communicate its intentions.(fig. 23.)(GDC, 2016)

To conclude, it seems as if familiar architectural elements in digital environments (as well as in zero gravity environments) for natural reasons have been stripped of their structurally functional value, but are still relevant as symbols for navigation and spatial comfort.

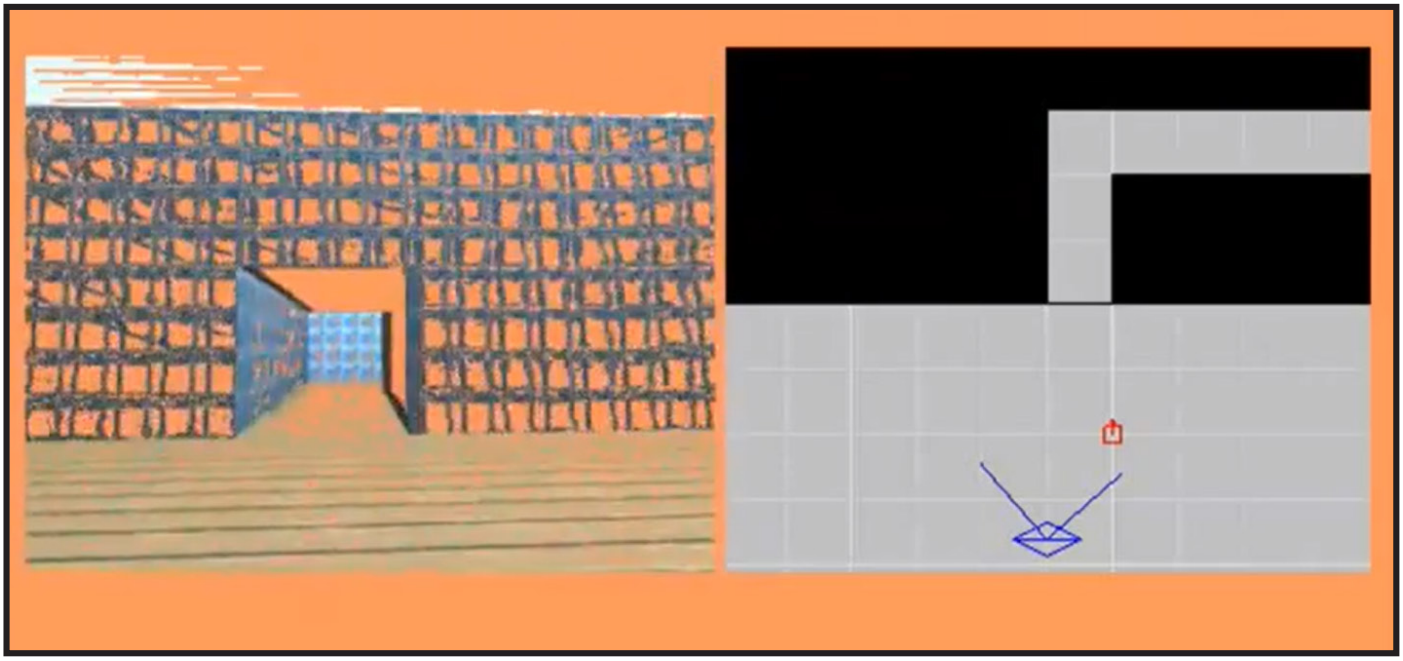


FIG. 22. A SCREENSHOT FROM BRENDON CHUNGS LECTURE ABOUT WAYFINDING IN VIDEO GAMES (GDC, 2016)

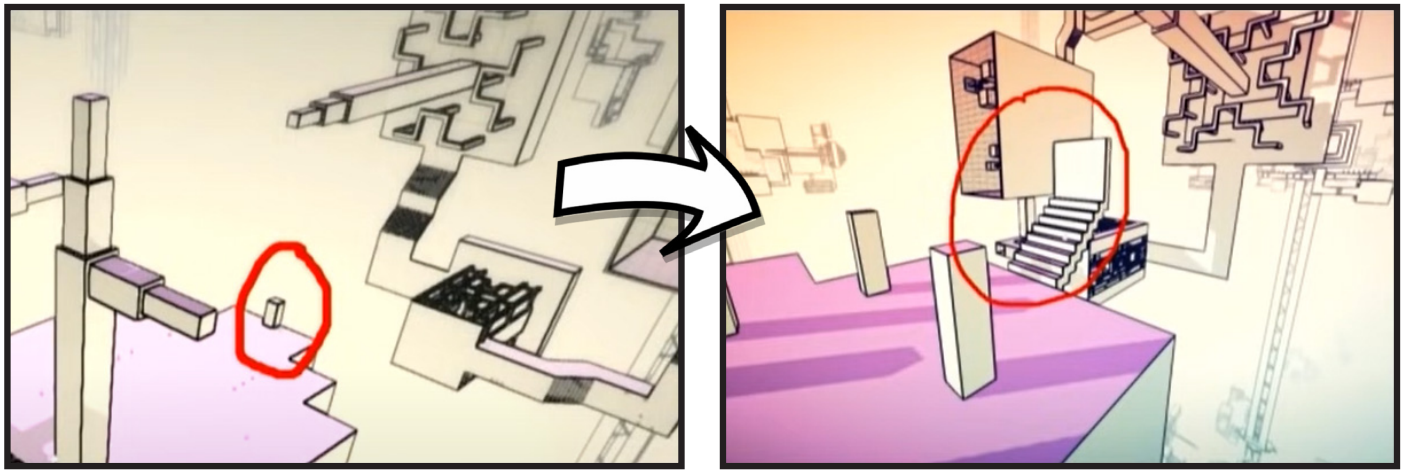


FIG. 23. A SCREENSHOT FROM THE LECTURE BY WILLIAM CHYR, SHOWCASING THE INITIAL BLOCK AND THE STAIRCASE THAT REPLACED IT. (GDC, 2016)

2.2 ARCHITECTURE AS SYMBOLS

Architectural elements seem at first glance quite easy to define, but depending on our position in relation to them they could gain a completely new identity. For example, a floor simultaneously becomes a roof when units are stacked, depending on if your position is under or above it. I asked my friends a question: Imagine moving up a freestanding staircase running from one floor to another, at what point will the former roof become the new floor? Some of them said that a roof becomes a floor when their eyes are leveled with it so that the surface of the new floor is visible. Some claimed that simply the knowledge of a second floor, that was provided by the staircase, made them aware of the roof as a floor the second they started climbing the stairs.

Le Corbusier spoke of a “radiant” architecture. Radiance as a concept was developed in his book La Ville Radieuse in 1933 and inspired by his visit to Parthenon. He described how the ancient piece of architecture generated “lines spurting, radiating out as if produced by an explosion”.(Le Corbusier, 1955, p.26) He searched for ways to create this kind of accomplished “radiant architecture” that created a sense of community by imposing its influence upon the world around it. He found his answer in letting his architecture be shaped by a universal language - mathematics. By measuring and mapping mainly the human body in regards both to its own proportions and in relation to domestic objects but by also measuring vehicles, nature, and basically everything around him he created his “radiant architecture guide” called the *Modulor* (Le Corbusier, 1955). This search for a universal answer to creating accomplished architecture was not an unique idea. The German architect Gottfried Semper thought that if we could recall, or in his case find the origin of architecture or the first “image” of a house, we might find the essence of what architecture is. He believed, unlike Corbusier, to have found it in the Caribbean hut. In this much more modest example of architecture he described how one could find “all the elements of antique architecture in their pure and most original form: the hearth as the center point, raised earth as a terrace surrounded by posts, the column-supported roof, and the textile enclosure as a spatial termination or wall”. By removing it from its original context he transformed the Caribbean hut from a house into a diagram of architecture in its purest form.

Le Corbusiers and Semper both looked to history to pan for pure form, and what the elements that they found in antique architecture all have in common is they have withstood the test of time. They have looked more or less the same throughout history. For example, the Art Nouveau movement, an ornament-based style, survived for only twenty years between the 1800’s and the 1900’s, perhaps because it derived neither from a structural system or a tradition(Britannica, 2022)

In 1914 Le Corbusier designed his modular system Maison Dom-Ino, meant

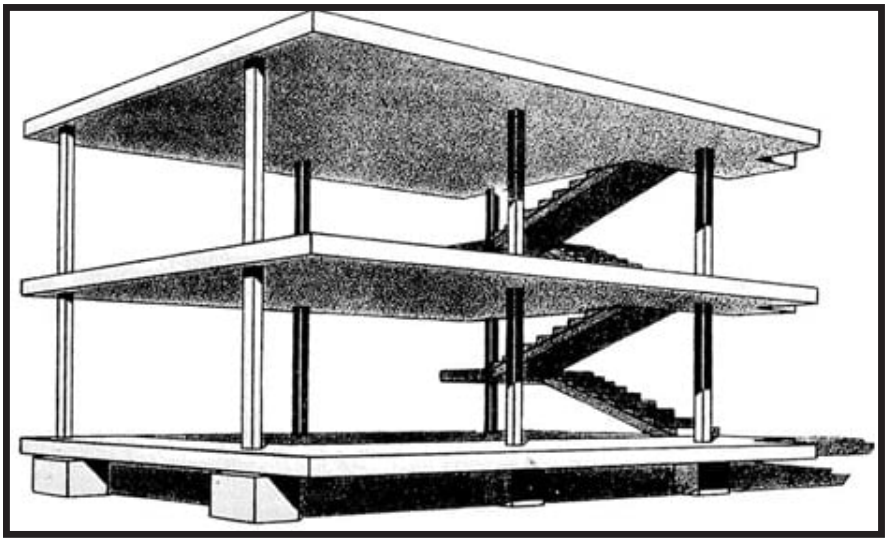


FIG. 24. PERSPECTIVE VIEW OF THE *MAISON DOM-INO* SYSTEM, 1914.*(CHING, 2007)*

FIG. 25. PARTHENON, ATHENS (VAFEIADAKIS, 2022)

FIG. 27. ONE OF BABYLON CITY GATES, THE ISHTAR GATE, 6TH CENTURY BCE

FIG. 26. ENTRANCE TO SKOGS-KYRKOGARDEN'S CHAPEL, PROVIDING SIGHTLINES TO THE CHAPEL'S ENTRANCE STOCK-HOLM. (PERSONAL PHOTO, 2021)

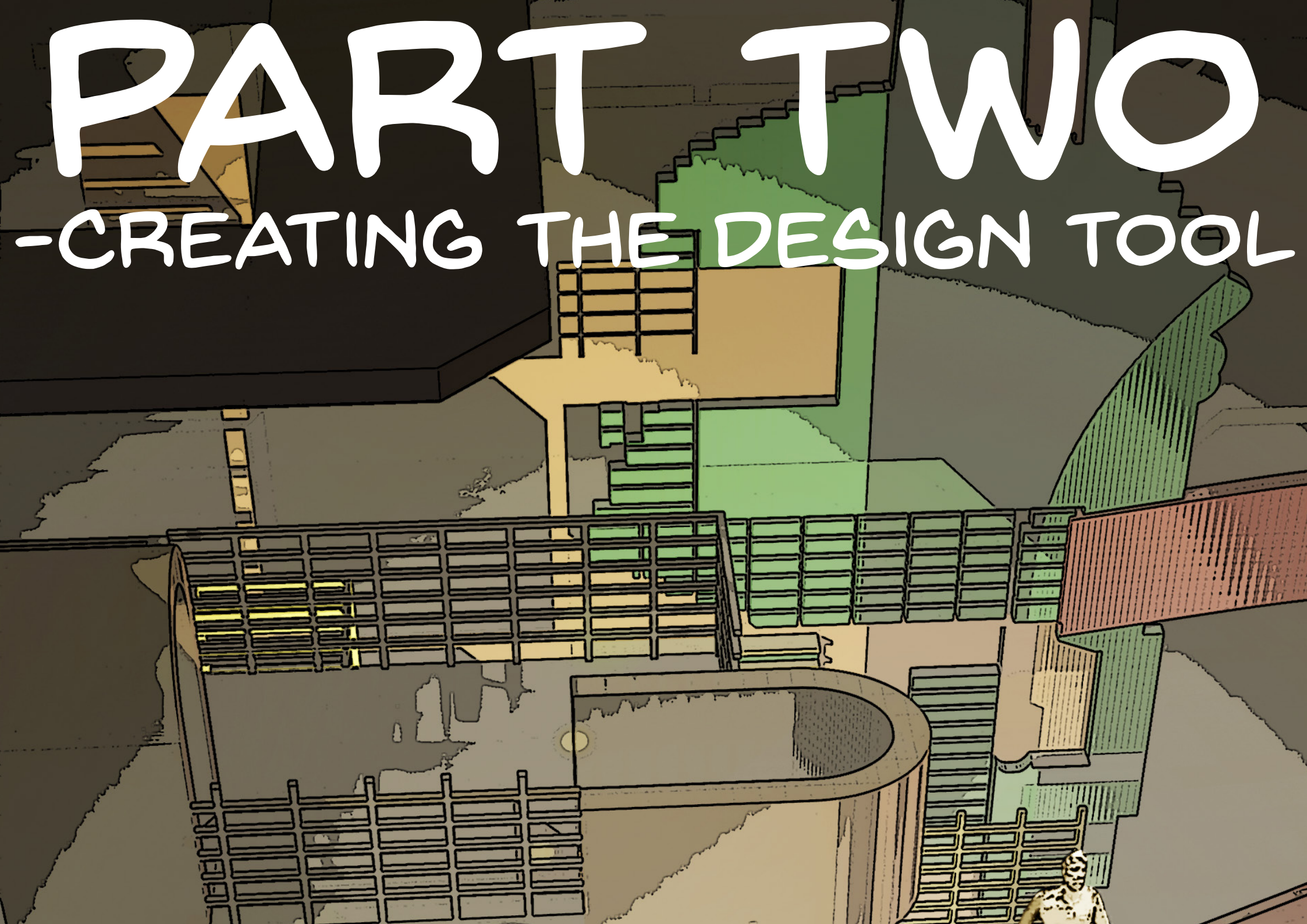
FIG. 28. SUSPENDED COLUMN *IN THE WEX-NER CENTER FOR THE VISUAL ARTS AND FINE ARTS LIBRARY BY EISENMAN ARCHI-TECTS 1983-1989*

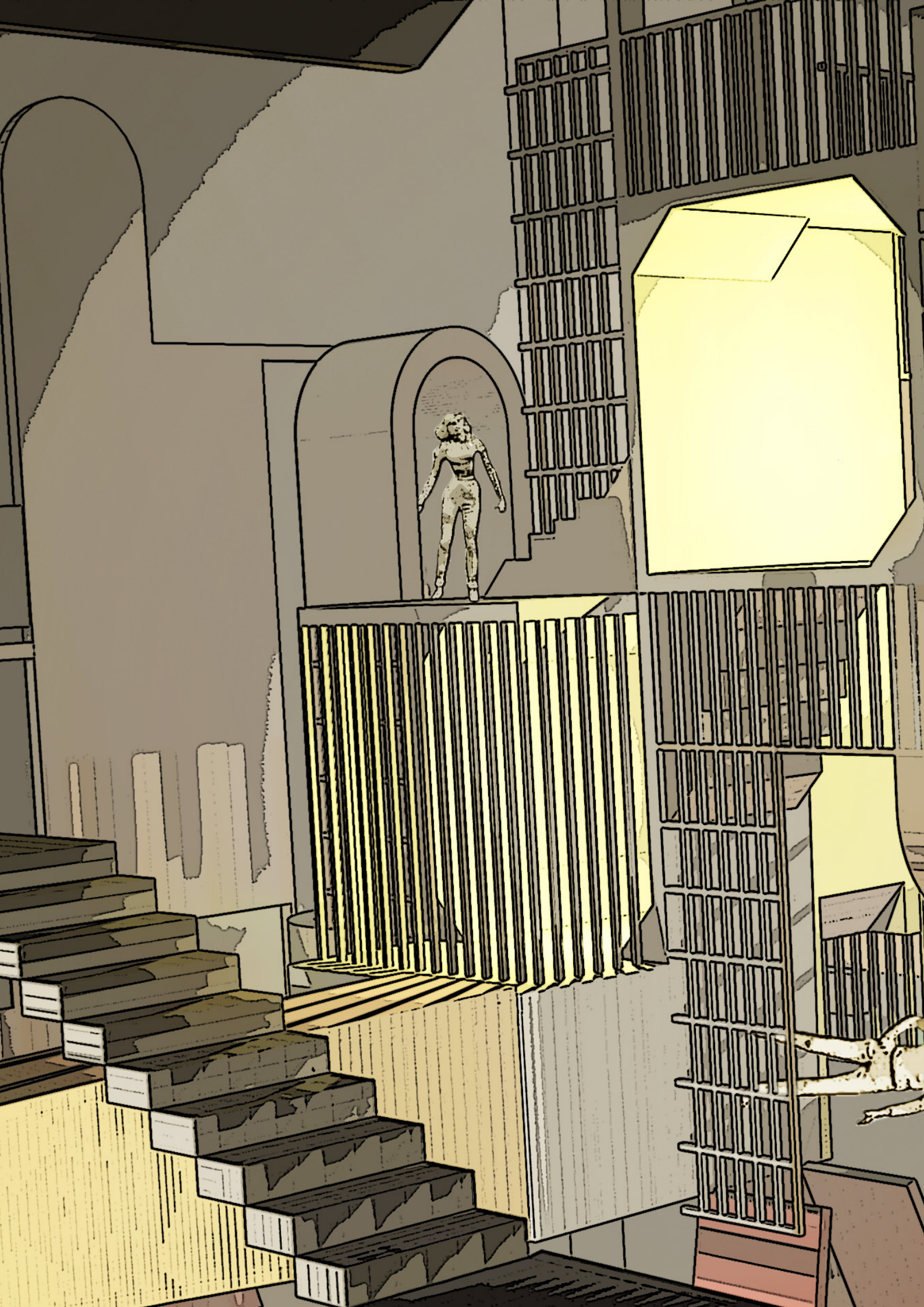
to solve the forthcoming housing crisis after world war one. Consisting only of slabs (living space), columns (structural support) which allows for free design on the facade, and staircases (vertical circulation) it creates a sort of modernistic diagram in a Semperian manner. The purpose for this radical simplicity, except for its modular qualities, was to allow the inhibitor to be the architect/designer of their own home. (McGuirk, 2014) All of the elements of Parthenon seem to echo in Maison Dom-Ino and perhaps the column especially is the poster child for both antique and modernist architecture. In Parthenon we find the Greek column, whose narrower summit compared to its base almost gives it an effect of muscular power to withstand loads.(Ching, 2007, p.13) This is even more articulated in the human shaped columns, the caryatids. In Maison Dom-Ino they remain purely structural.

The staircase seem to be another timeless element. The staircase connect different levels, in Parthenon it elevates the slab as a continuation of the mountain Parthenon rests upon. The staircase as a concept, is not only a documentation of human presence and creation, but also of human movement, which provide reminiscence of human proportions and scale. Historically the stairway was employed to give monumentality to buildings and therefore perhaps give monumentality to the human race itself. This is especially evident in Baroque architecture.(Britannica, 2022)

The portal, is another element that seem to have become a monument in itself as they often are designed to heighten or communicate the significance of whatever lies behind them. The time of ancient Egyptian temple pylons and Babylonian city gates are examples of monumental portals. The views through its openings become part of the spatial experience by providing sight lines.

The importance of recognition is especially evident in popular symbolism of domestic environments. The atmosphere of the home is not seldom expressed by the use of saddle roofs, trellises, shutters, paned windows, picket fences and other recalling to a more peaceful past. The international Space Station, that is consisting solely of hallways and that is lacking completely of familiar elements and objects paints a diptych portraying the interiors of the International Space Station as inherently unhomely. However, if we presume that we can, as Le Corbusier and Gottfried Semper did, distill architecture into its basic elements they would naturally be elements that everyone can recognize as symbols for their functional value. As familiar objects they might be able to assist in wayfinding and help create a more homely environment.

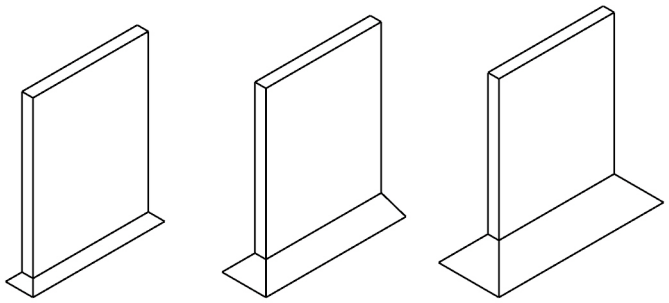

PART TWO
-CREATING THE DESIGN TOOL



CREATING THE DESIGN TOOL

The tool consist of a virtual environment in which the test subject is being encouraged to explore different architectural typologies via an architectural promenade carefully curated using wayfinding design tools and theory about architectural symbolism.

The tool applies multiple gravity fields rather than zero gravity which means that rather than floating in the tool, the test subject are able to walk on all surfaces. The reason for this is to be able to restrict the number of reference planes in order to create a more controlled test environment. I wanted the environment to be minimalistic in a sense, in order to shift focus onto the elements and objects in the environment. Another reason for this is due to the way that we naturally navigate and how we usually construct our environment which most likely would be more cost effective in a real zero gravity environment. It is also a more familiar arrangement of space, and therefore also more homely. However I was forced, due to restrictions in the script in the plugin that I used to make all surfaces walkable, to chamfer all edges in order to get a smooth transition between different ”gravity fields”. I had to test a few before realizing that a 45 cm chamfer worked best.



The tool will test three different architectural typologies in zero gravity, the gallery, the garden and the home which will be described in more detail later in this thesis. The typologies were chosen to represent a variety of architectural characteristics. The reason for this variety is both to test the potential importance of familiar elements in architecture in terms of mental wellbeing and wayfinding while having to navigate within and between different zero gravity spaces. I also wanted to provide a variety of typologies to understand what life in space would actually mean and to try and pin point problems we could encounter when designing different types of spaces for a life in zero gravity.

When designing my different typologies and spaces I tried making the separate volumes equal in length and height to not suggest spatial identities such

as roofs, floors or walls.

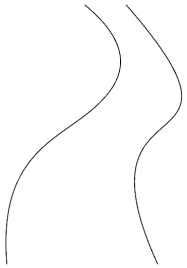
The issue of lighting the promenade inside of the tool has been another challenging issue. I realize that by having a single, large light source, it would imply a sun and therefore a specific orientation. Best would be to have flat shading and even light, unfortunately I was restricted by my Unreal Engine skills. Instead, I tried placing light sources in the middle of my structures to not imply a roof (up) where a light source would normally be placed in a gravity space.

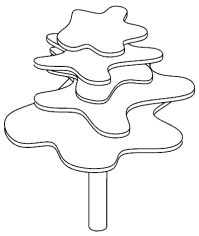
The biggest challenge with creating the tool has been to create complex multiple gravity structures that are alien in the way that you move inside of them, but familiar enough, after the implementation of wayfinding tools, so that a test subject can navigate within them. I quite simply had to first create highly complex structures and then simplify them. It has also been a challenge to let go of my own concept of direction and orientation while creating the tool which could make it flawed. To avoid a set sense of direction within my designs I continuously made sure to rotate them while modeling to see them from a new perspective.

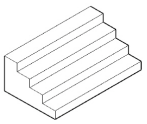
The goal of the tool is to test if wayfinding tools utilized in complex familiar environments and theories about environmental psychology in part one could be utilized to make zero gravity environments more homely. The test subjects task is to find their way from the first sequence in the promenade Möbius Gallery to the last sequence that is Home. My hopes for the tool are that it will open up a discussion of how we can think of, and arrange space in new ways.

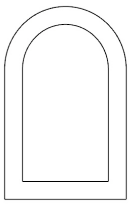
INDEX OF ELEMENTS

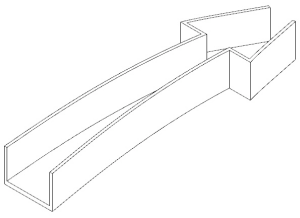
To create my tool, I have choose a set of elements based on my research that I believe carries a high symbolic value in relation to wayfinding and positive emotional responses to use as tools in my virtual environment.











THE PATH
The path, as mentioned by Kevin Lynch, is a crucial wayfinding tool.

THE TREE
The tree functions as a landmark or node on paths, according to Lynchian wayfinding theory.

THE COLUMN
The column carries strong associations to ancient architecture, and high structural value.

THE STAIRCASE
The staircase introduces a sense of human scale and suggest a vertical direction.

THE PORTAL
The portal provides sightlines and suggests a heightens the significance of whatever lies behind it. Its shape encourages you to walk through it, thus it aids in wayfinding.

THE BRIDGE
The bridge, as a variation of a path spanning between one space and antóther encourages you to cross over. To add literal signage qualities that communicate a forward motion, I shaped my bridge as an arrow.

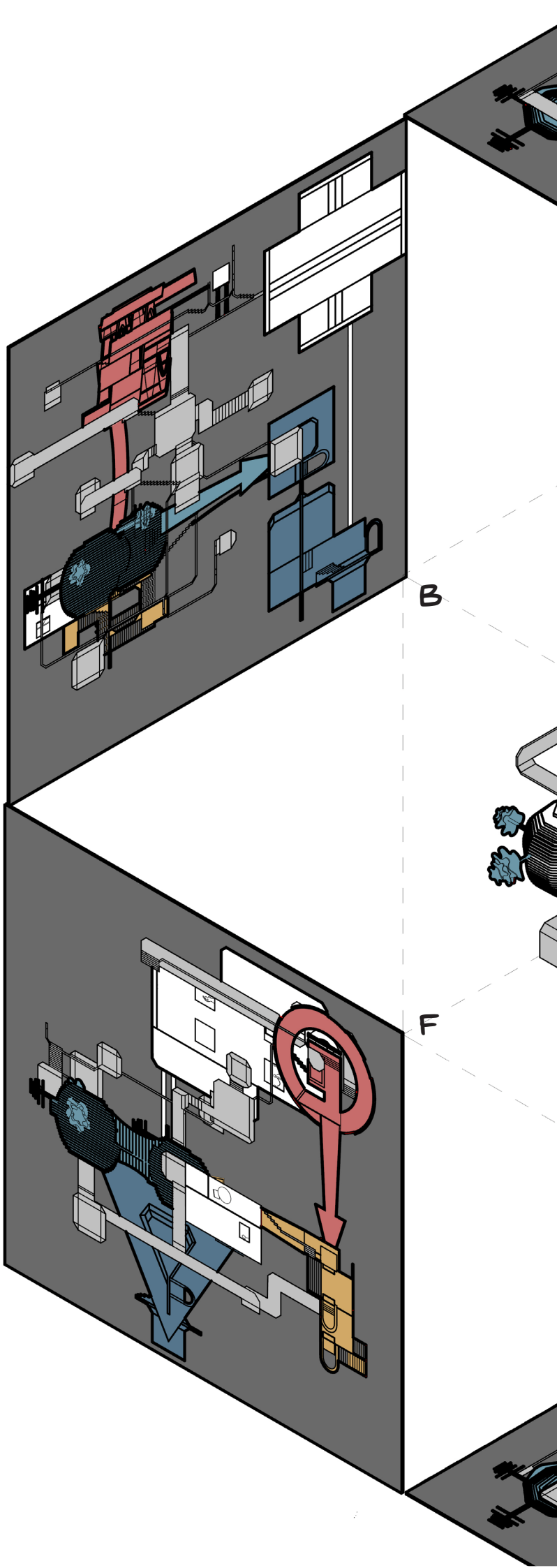
THE PROMENADE:

1. MOBIUS GALLERY

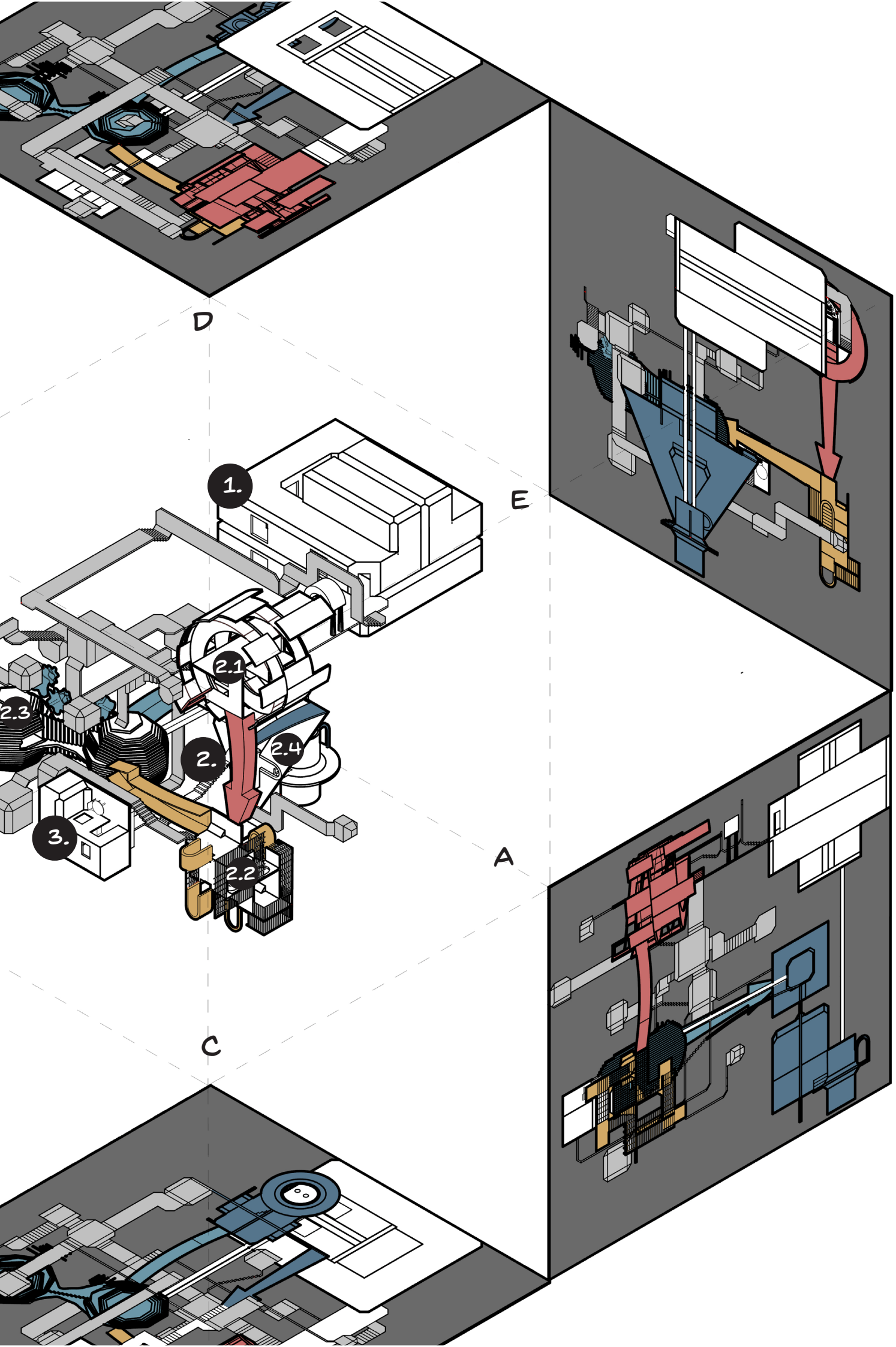
2. CARTESIAN GARDEN
2.1 TCHUMIS TURBINE
2.2 GAGARINS GATES
2.3 MEIERS METABALL

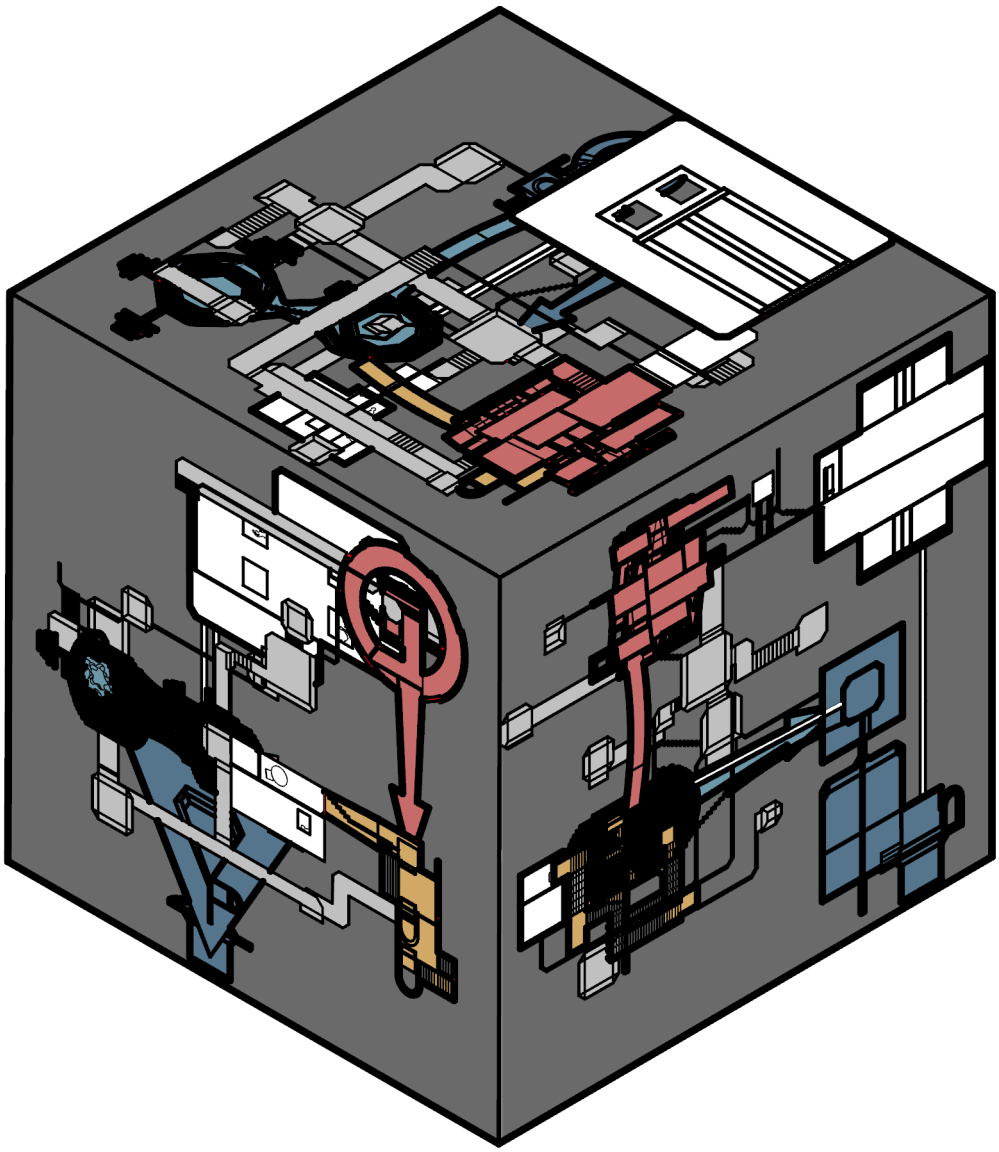
2.4 KAZIMIRS CASTLE

3.HOME



EXPLODED
AXONOMETRIC VIEW
1:400

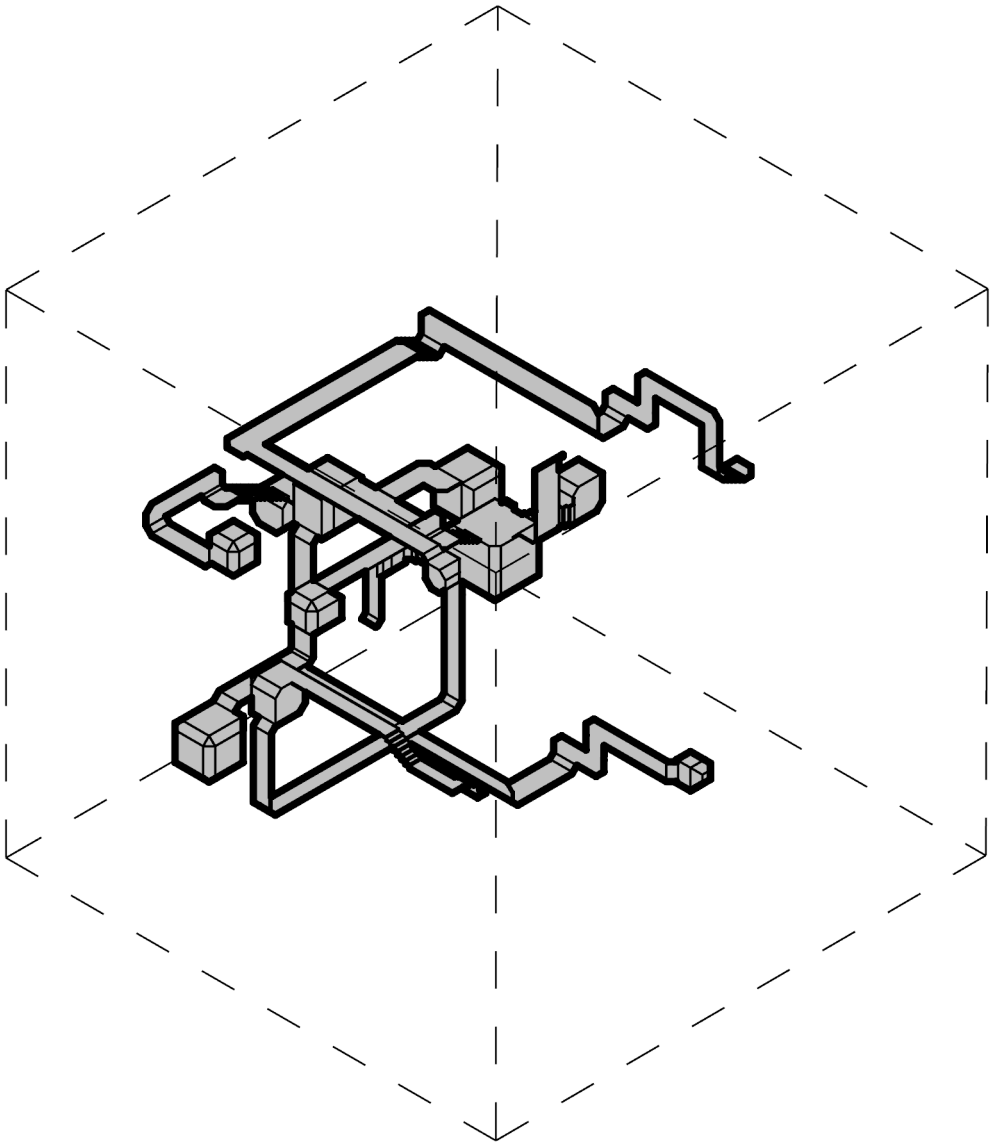

D
E
A
C
1.
2.
2.1
2.2
2.3
2.4
3.



ENCLOSURE 1:400

For my tool I wanted to create an enclosed environment for multiple reasons. I wanted to be able to control all aspects of the environment which is easier in a restricted environment. I also wanted to avoid a situation where the test subject would fall off the course completely and would need to be respawned, instead I aimed to create a continous environment in which the test subject is given the possibility to find their way back on the right path.

The color coded structure inside of the envelope is projected on its sides to make wayfinding easier. If the test subject falls off the main structure, they can find their way back onto it by positioning themselves on the right color projected on the envelope and jump back and land onto their previous position.

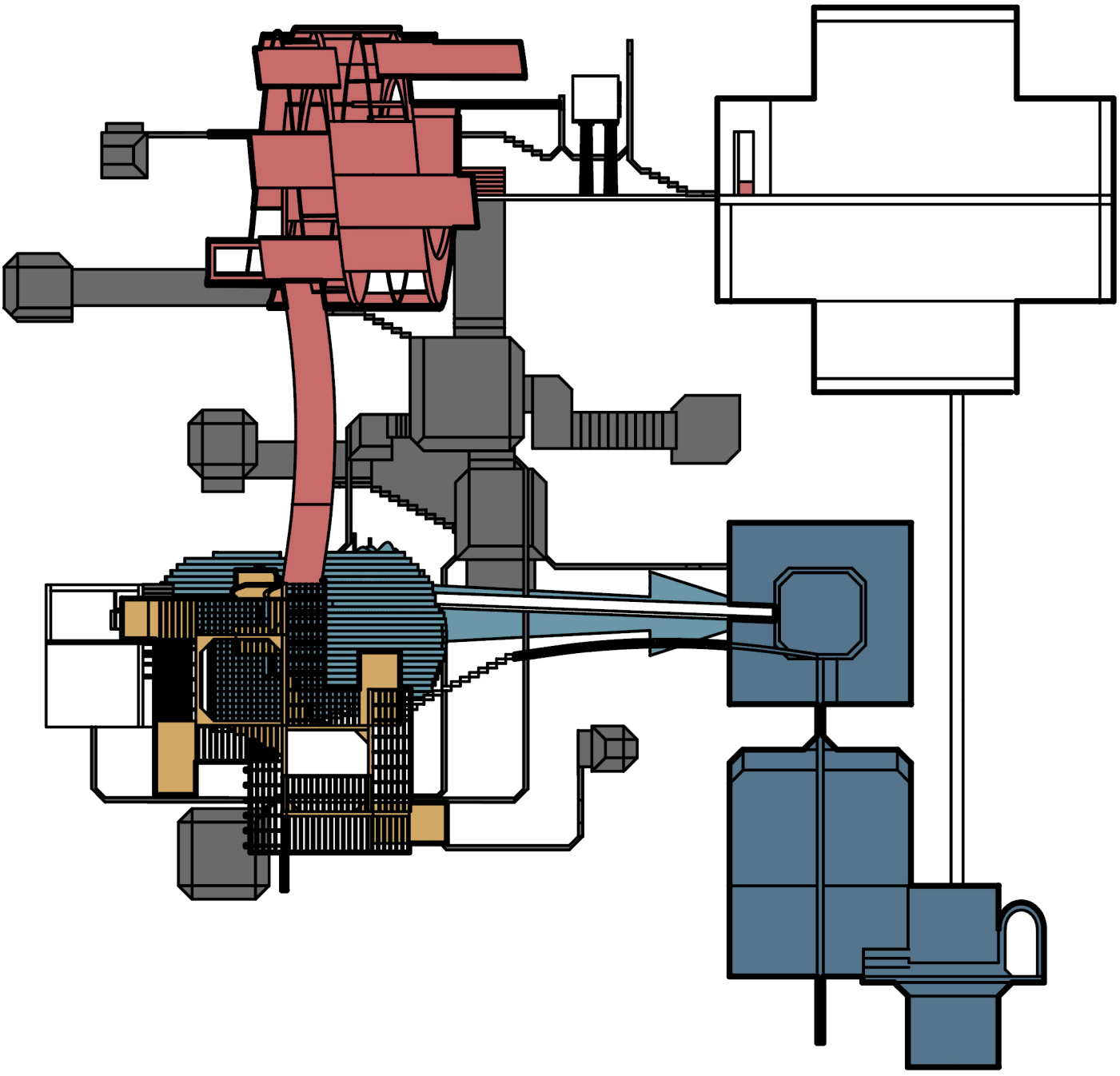


SAFETYNET 1:400

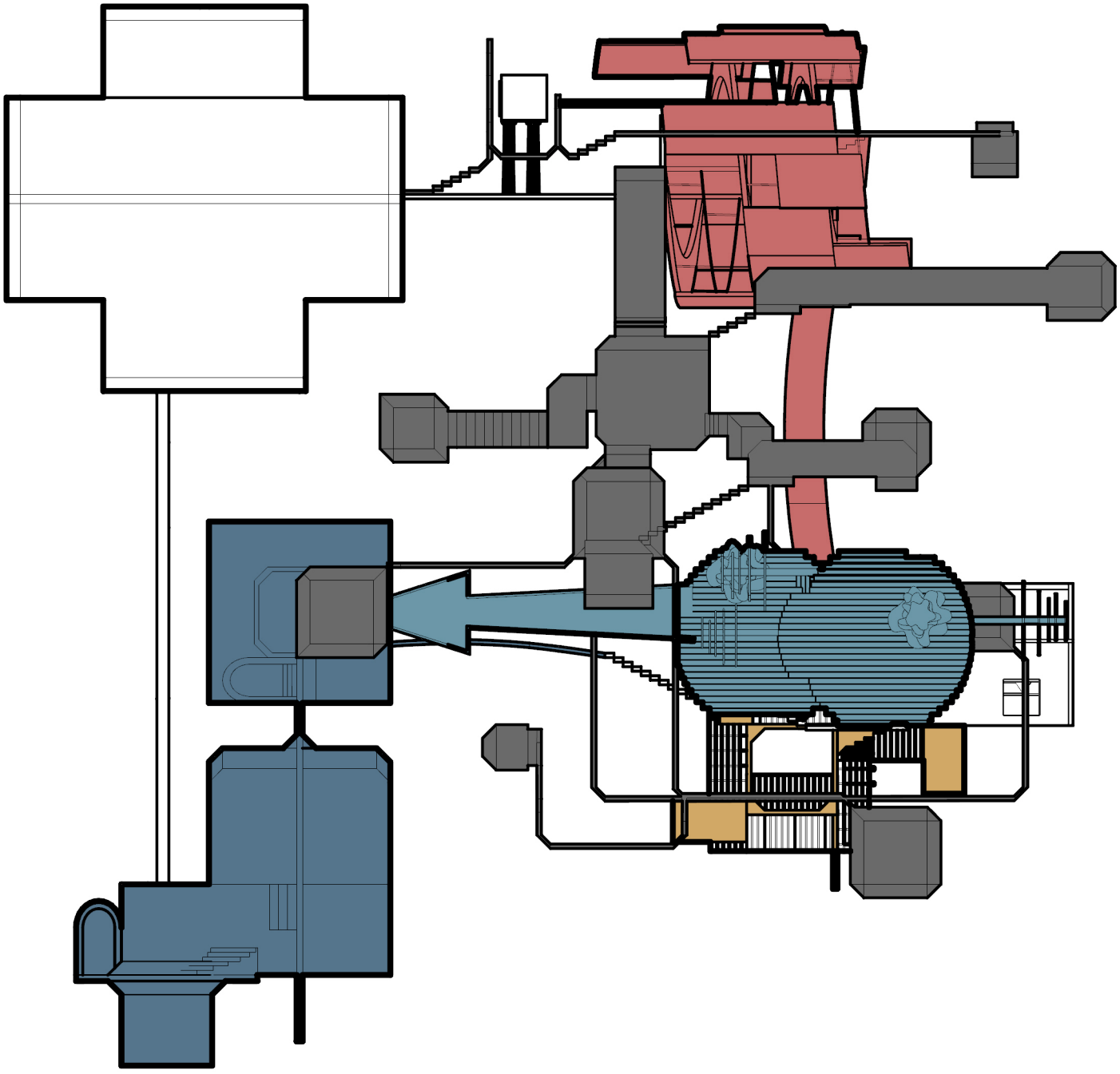
This light gray clusters purpose is to function as a first ”safety net”. Before the test subject falls onto the
sides of the enclosure they might first fall off onto the wrong path, marked by the light gray color. Following these paths will enventually lead the test

subject back to the right course where they can continue their promenade.

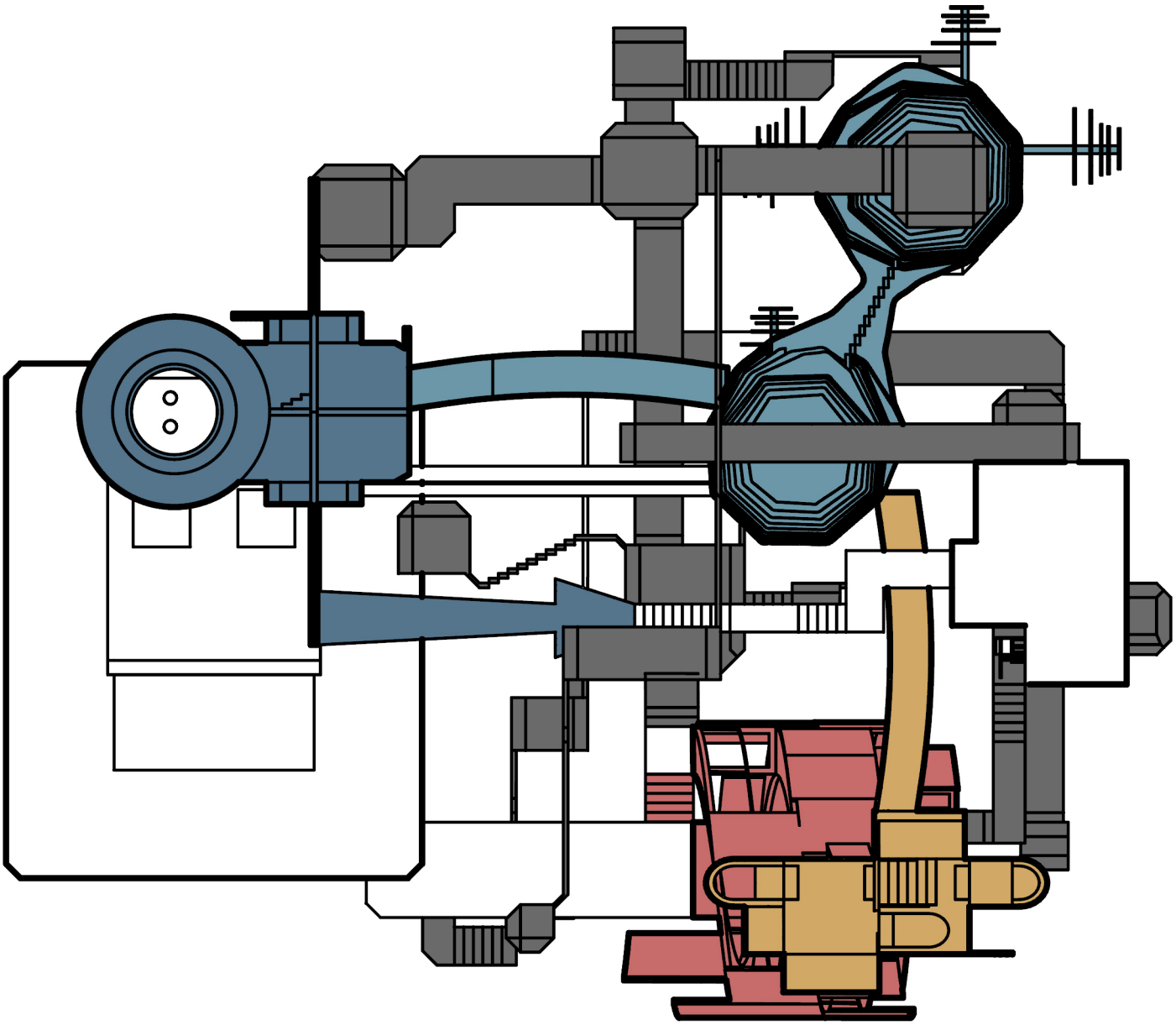
ELEVATION A, 1:200



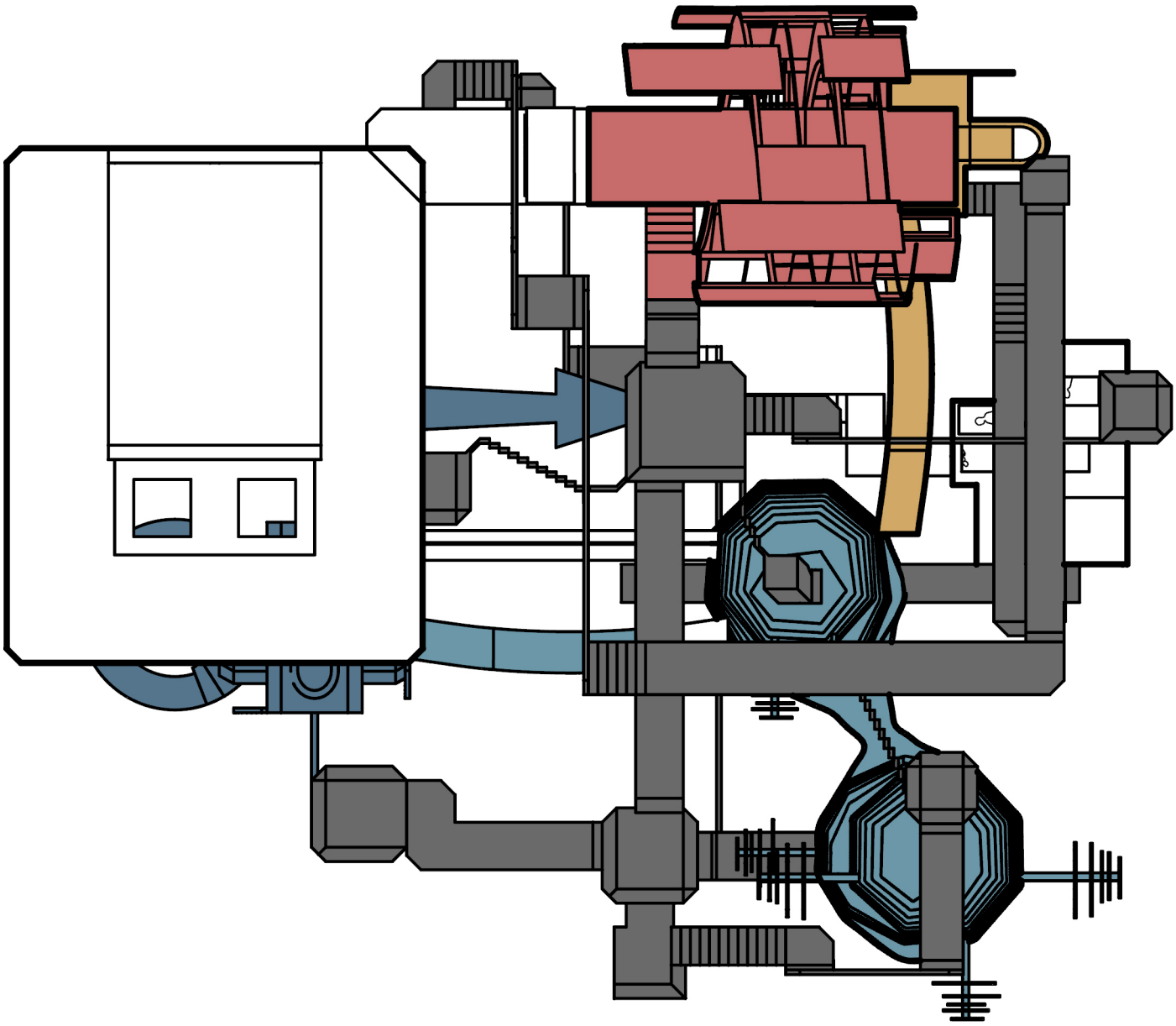
ELEVATION B, 1:200



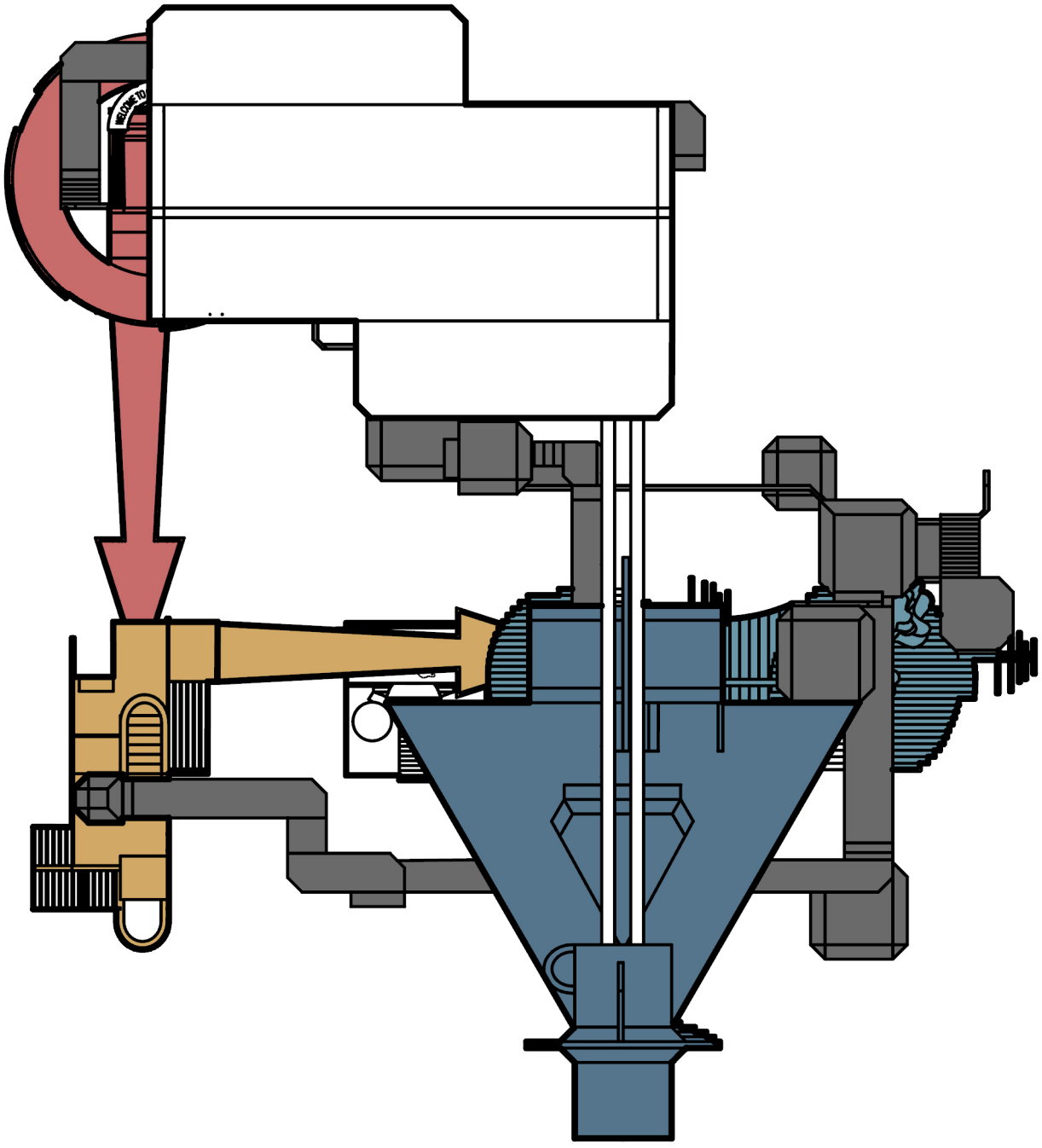
ELEVATION C, 1:200



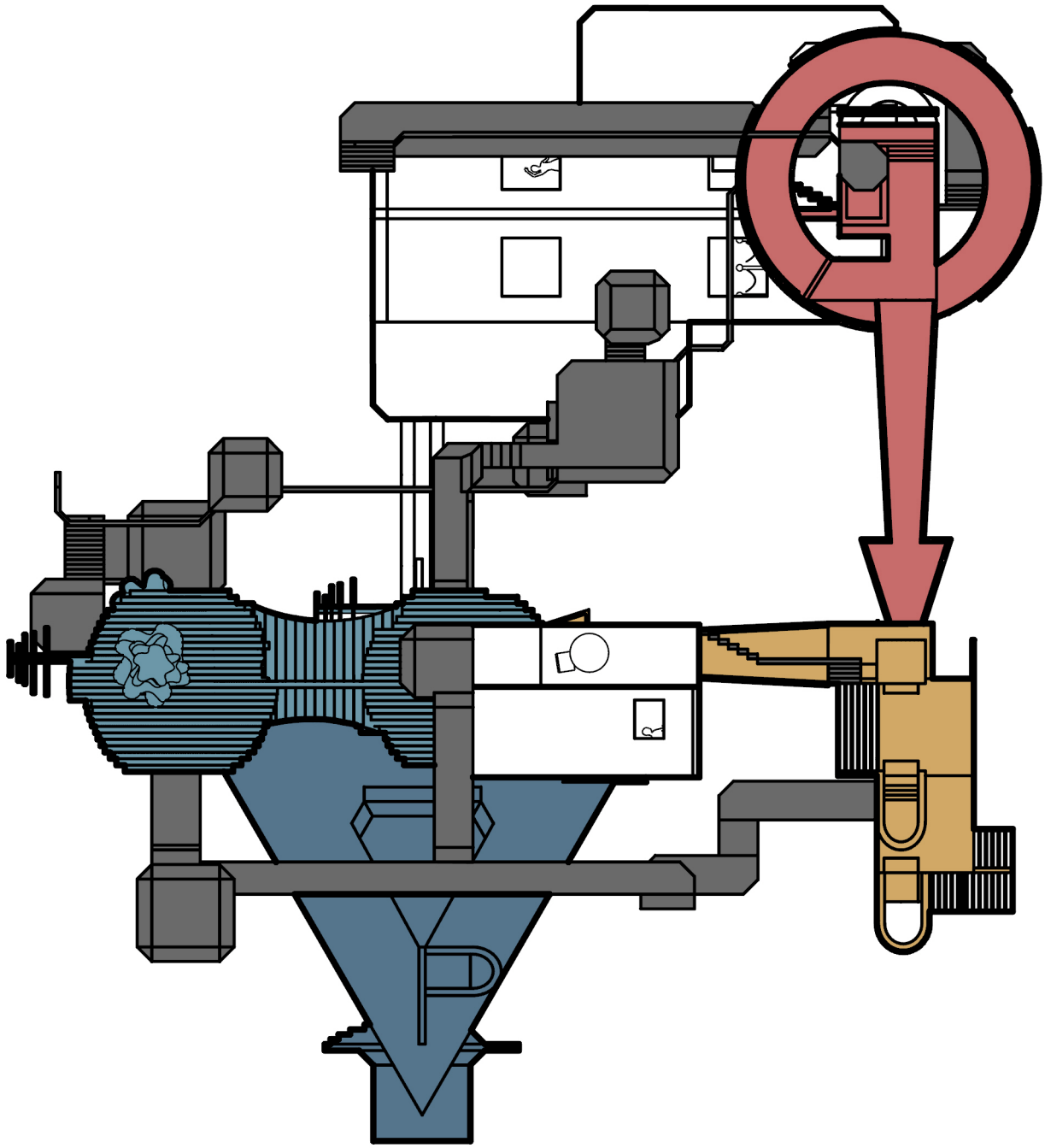
ELEVATION D, 1:200



ELEVATION E, 1:200



ELEVATION F, 1:200



3.1 MOBIUS GALLERY

Your architectural space promenade starts in Möbius Gallery. This structure is perfectly symmetrical, based on the möbius strip, which allows you to walk in an endless loop. From your starting point you will eventually end up on the same place but on the polarized side of the plane and if you continue following the path you will end up back at your starting point.

As you start your journey within Möbius Gallery you are greeted with a message: ”Welcome to Möbius Gallery. What is up? What is down?” to encourage the player to reflect on their current reference plane throughout the promenade. The purpose of this level is to test what and when the *visual reorientation illusion* (VRI) happens. Due to the many bends in the unit you get visually restricted to one space at a time and we can thereby test how elements in the unit either break or enhance the perception of standing upright. I will vary the strength of visual orientation cues to test what impact different cues have.

To assist in wayfinding the corners are chamfered and windows are placed intentionally to make sure that the bends are not perceived as dead ends and to make the space more pleasant.

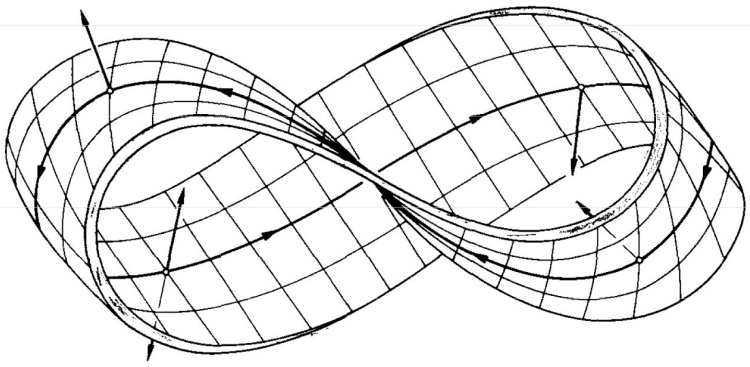


FIG. 29. IMAGE SHOWING THE PRINCIPLE OF THE MOBIUS STRIP.

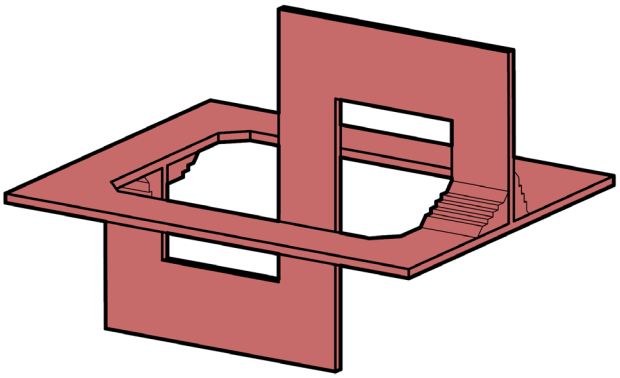
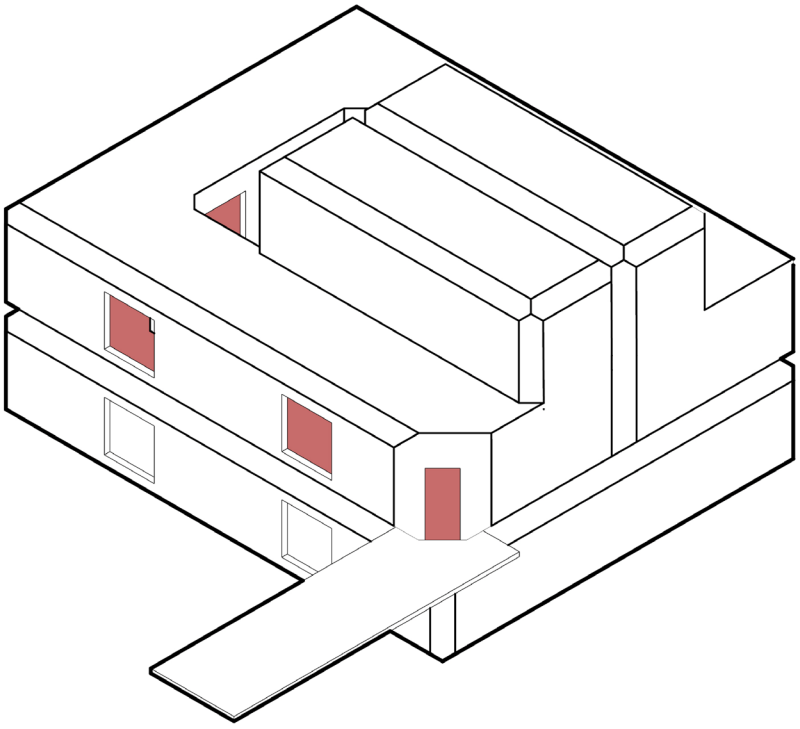
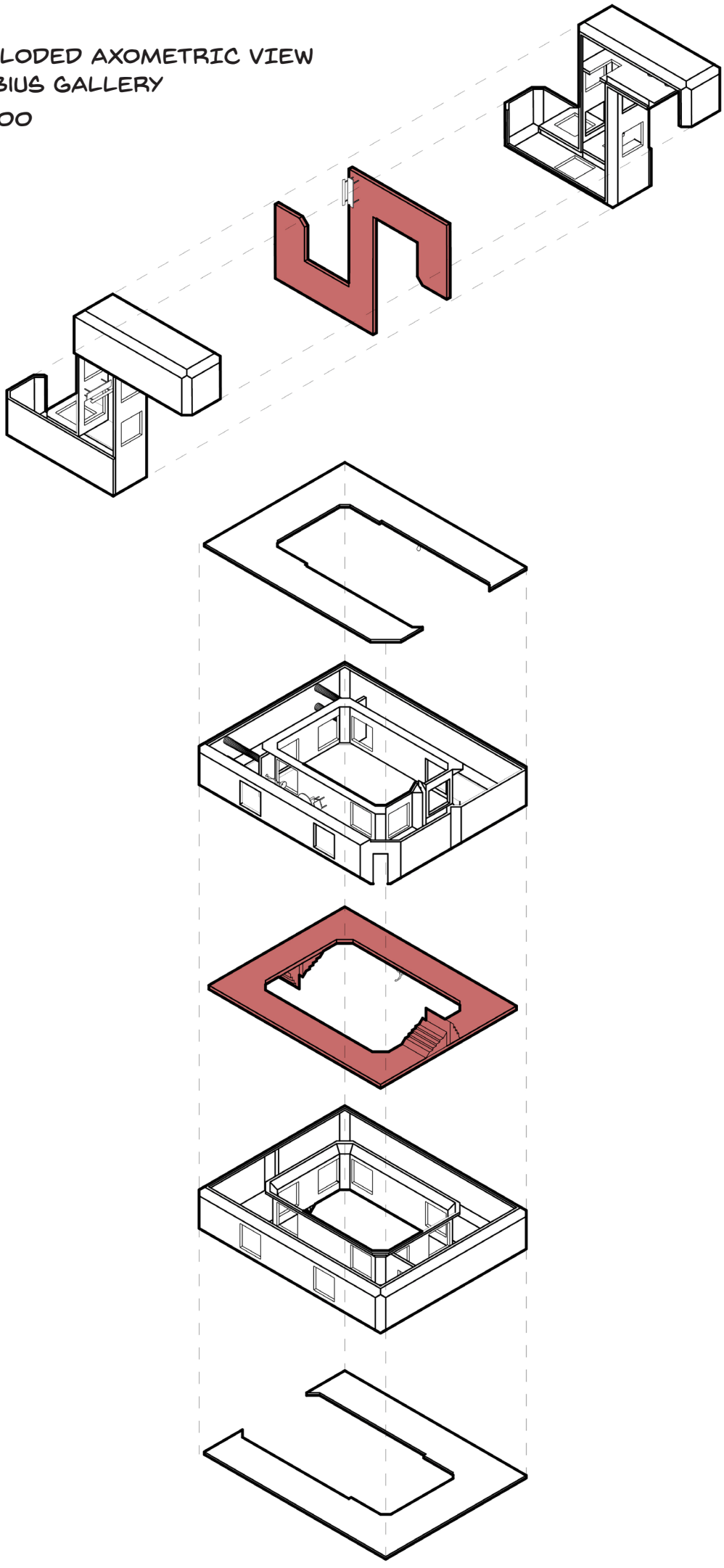


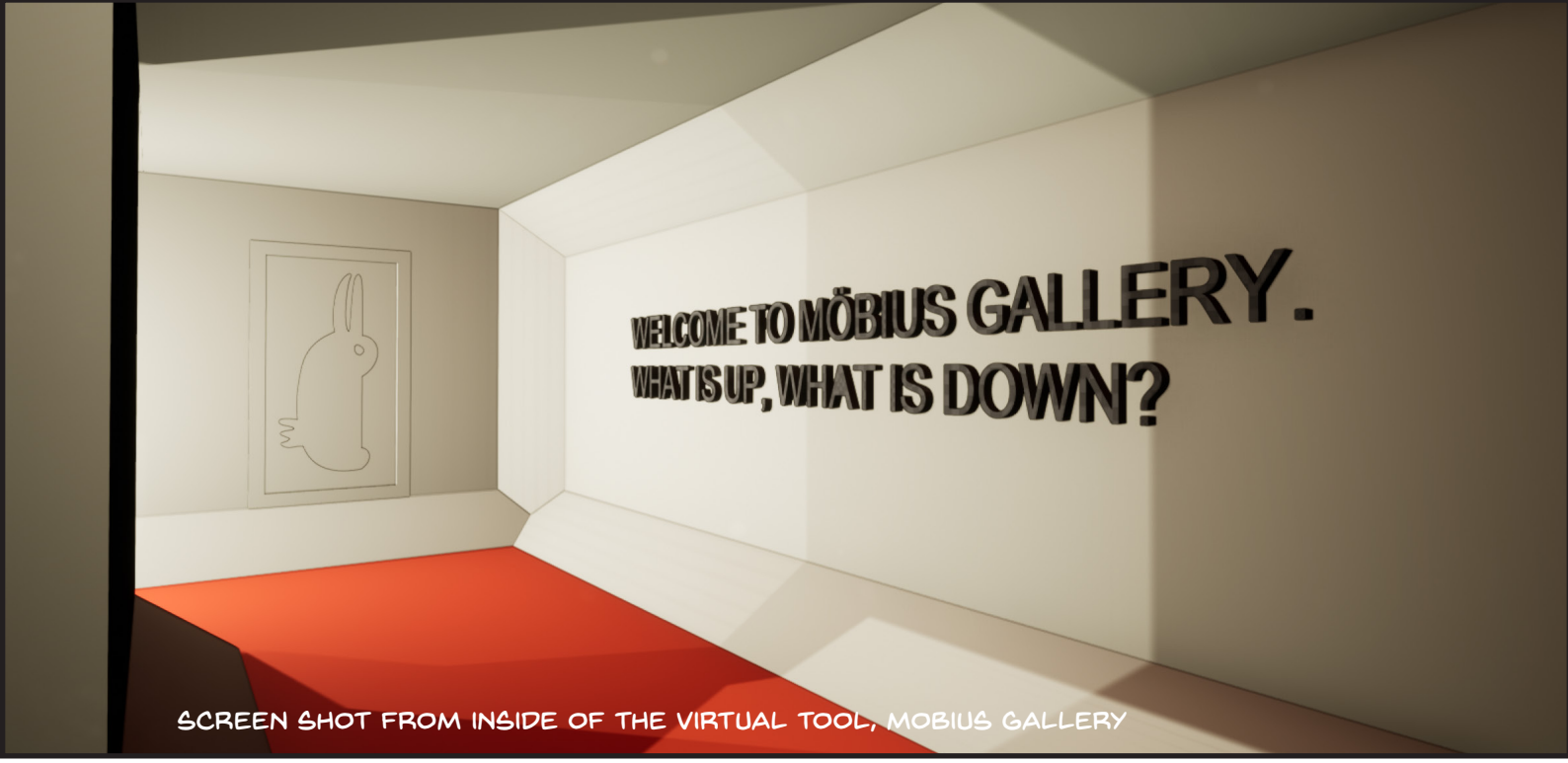
IMAGE SHOWING THE PRINCIPLE OF MOBIUS GALLERY.



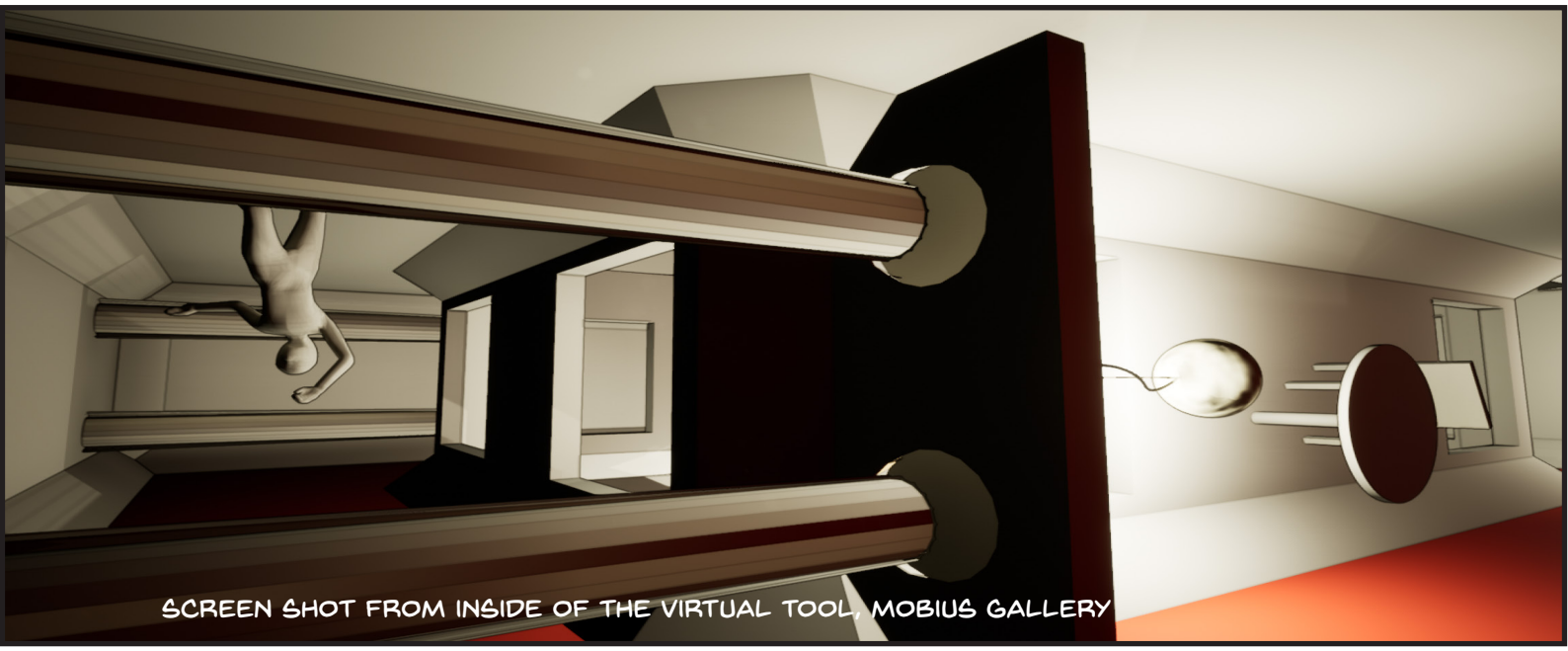
AXOMETRIC VIEW OF EXTERIOR, MOBIUS GALLERY

EXPLODED AXOMETRIC VIEW
MOBIUS GALLERY
1:400

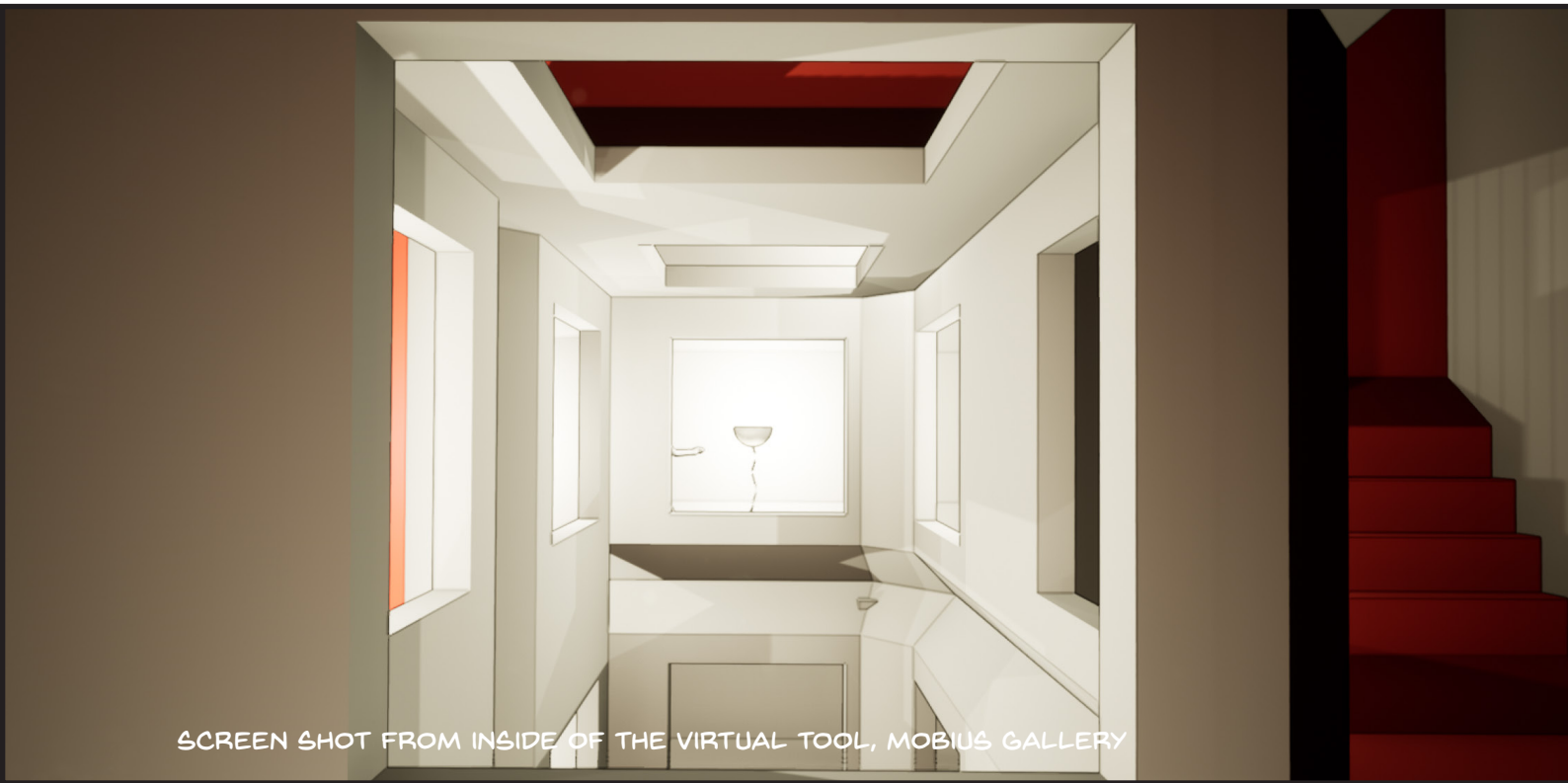




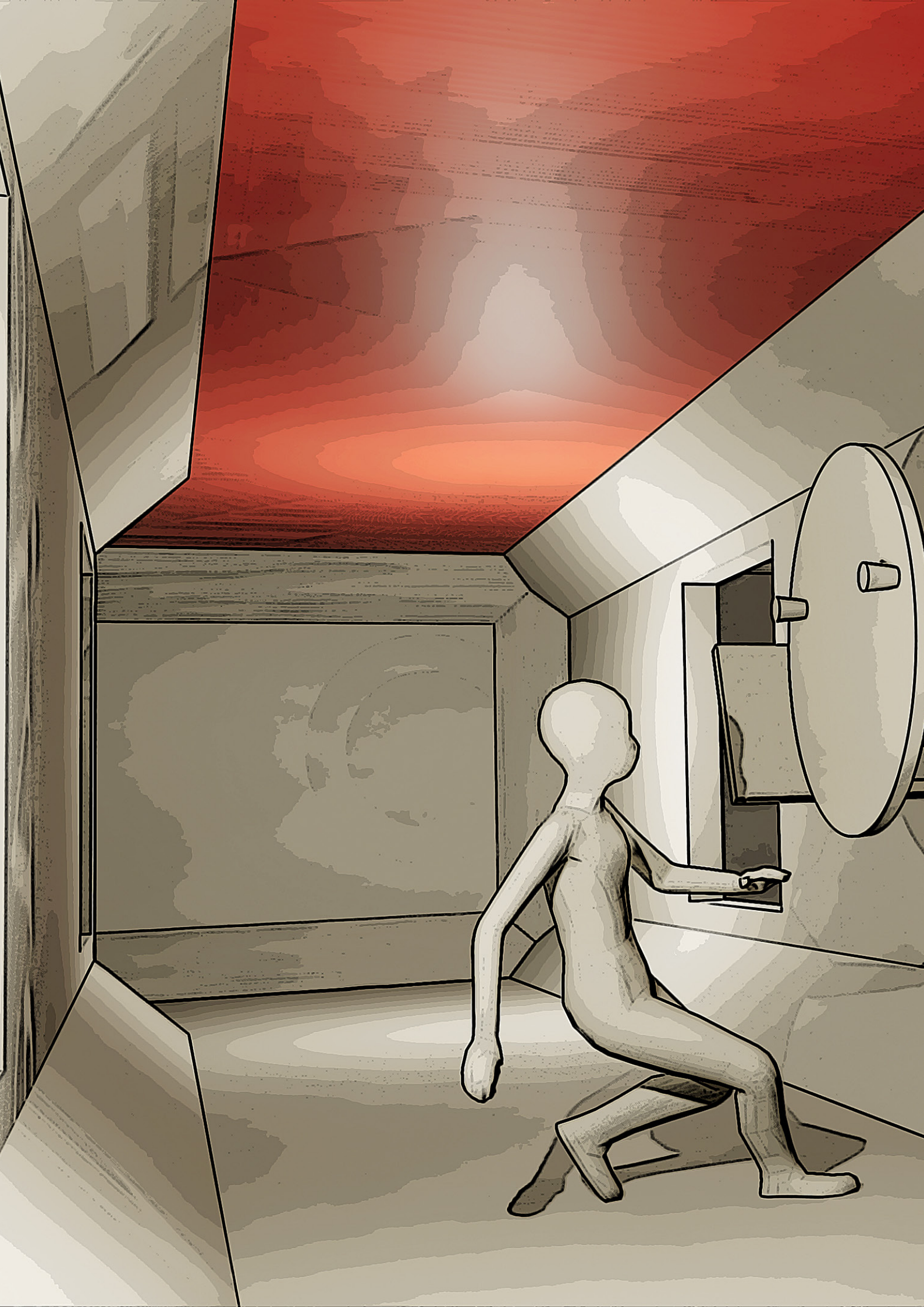
SCREEN SHOT FROM INSIDE OF THE VIRTUAL TOOL, MOBIUS GALLERY

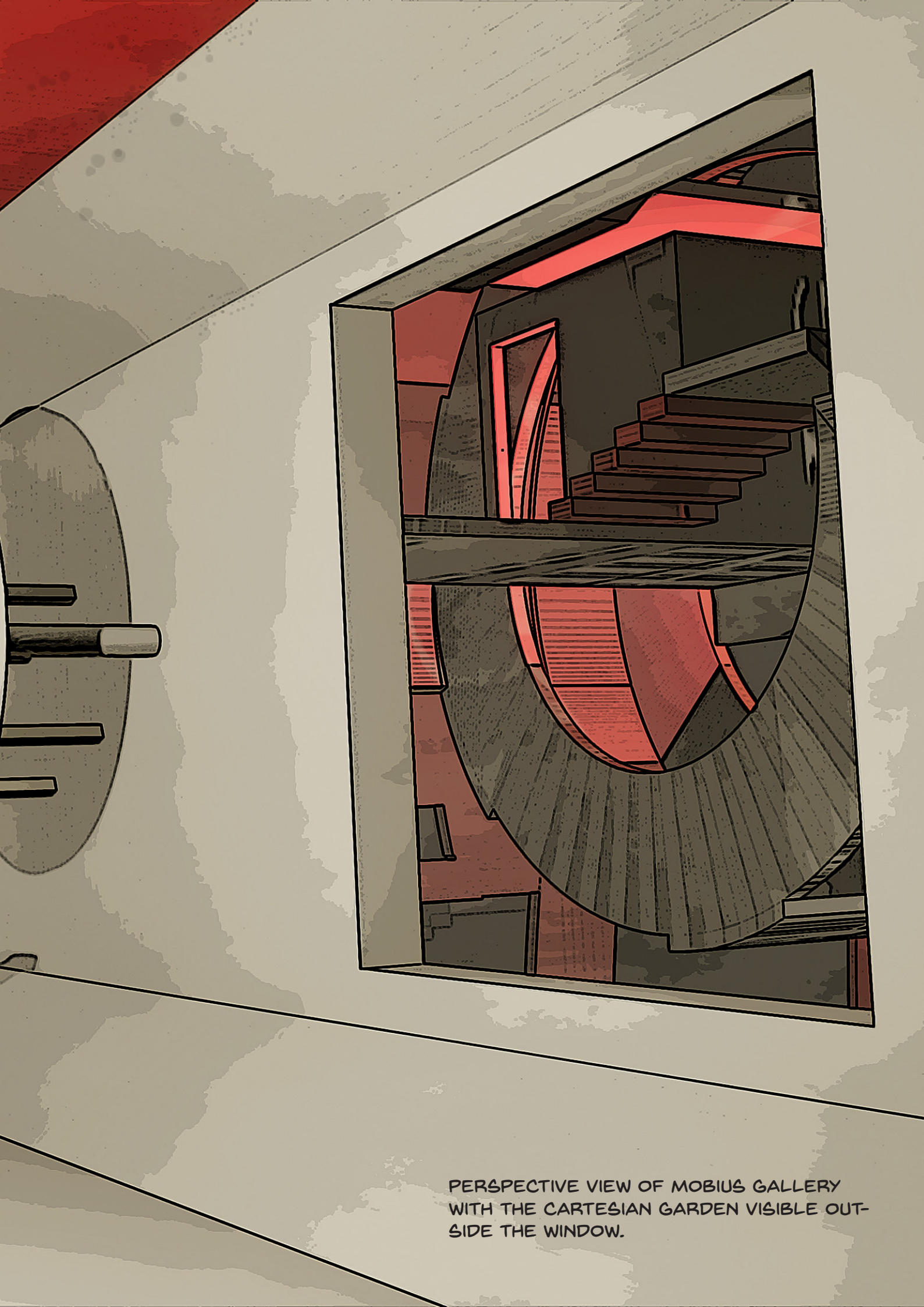


SCREEN SHOT FROM INSIDE OF THE VIRTUAL TOOL, MOBIUS GALLERY



SCREEN SHOT FROM INSIDE OF THE VIRTUAL TOOL, MOBIUS GALLERY



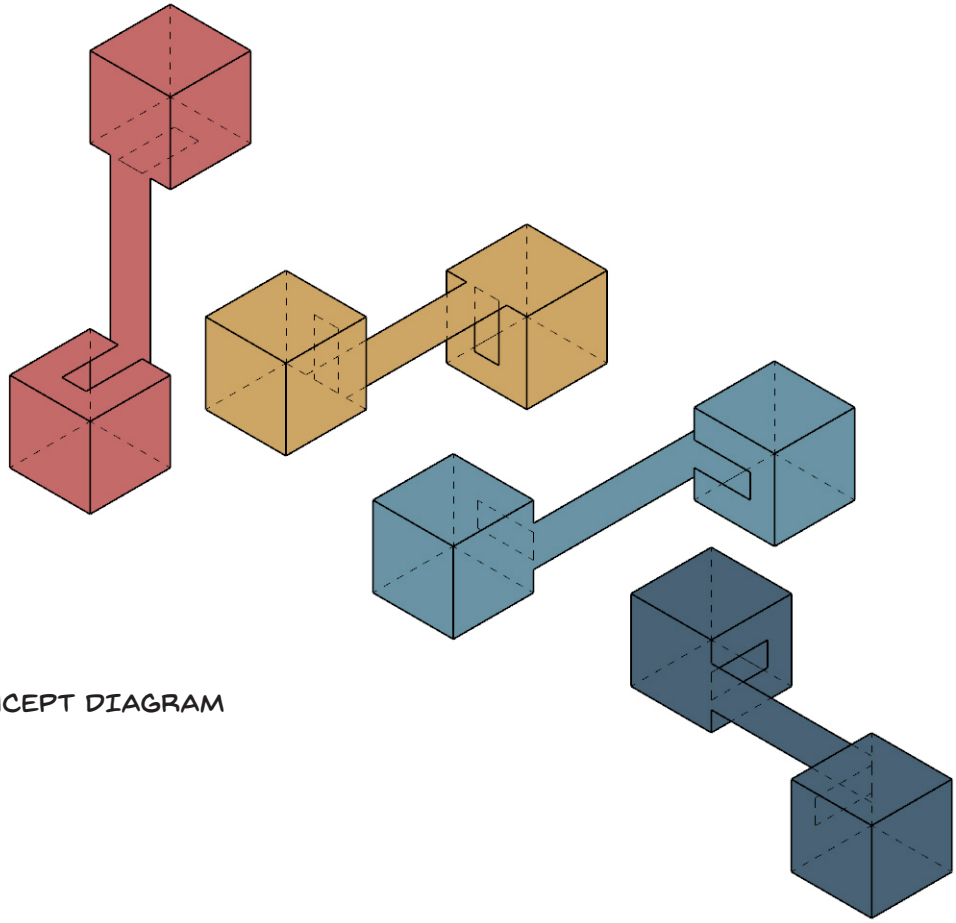


PERSPECTIVE VIEW OF MOBIUS GALLERY WITH THE CARTESIAN GARDEN VISIBLE OUTSIDE THE WINDOW.

3.2 CARTESIAN GARDEN

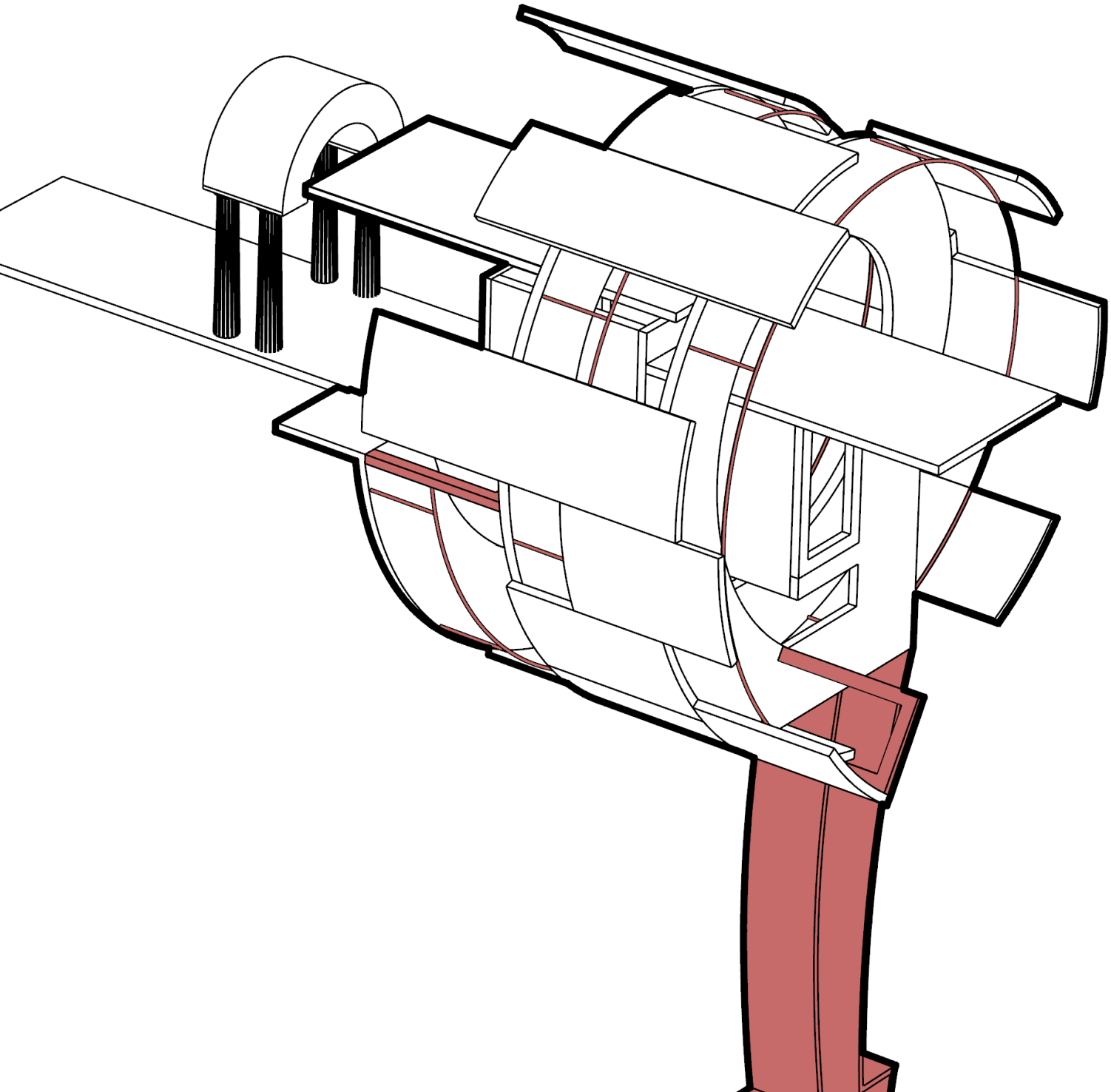
This structure mainly tests wayfinding. When creating this part of the tool I wanted to make sure that you had to move in every gravity direction in order to properly be able to test wayfinding in zero gravity spaces. With this in mind I created simple box like ”houses” to cover all of the eight unique opening directions. I paired each polar direction to create four pavilions and added a path between them to force you to move up and around the opposite ”house” to access the next opening.

Next step was to implement wayfinding design tools such as nodes, sightlines, familiar architectural elements and signage to help navigate within and between the pavillions. For instance, every pavilion has its own color and the bridges spanning between them are shaped like arrows to clarify its direction. I have also strived to assign certain characteristics to each pavilion to both vary the impressions of the environment, to assist in wayfinding and to manipulate the perceived time it takes to move through the level.

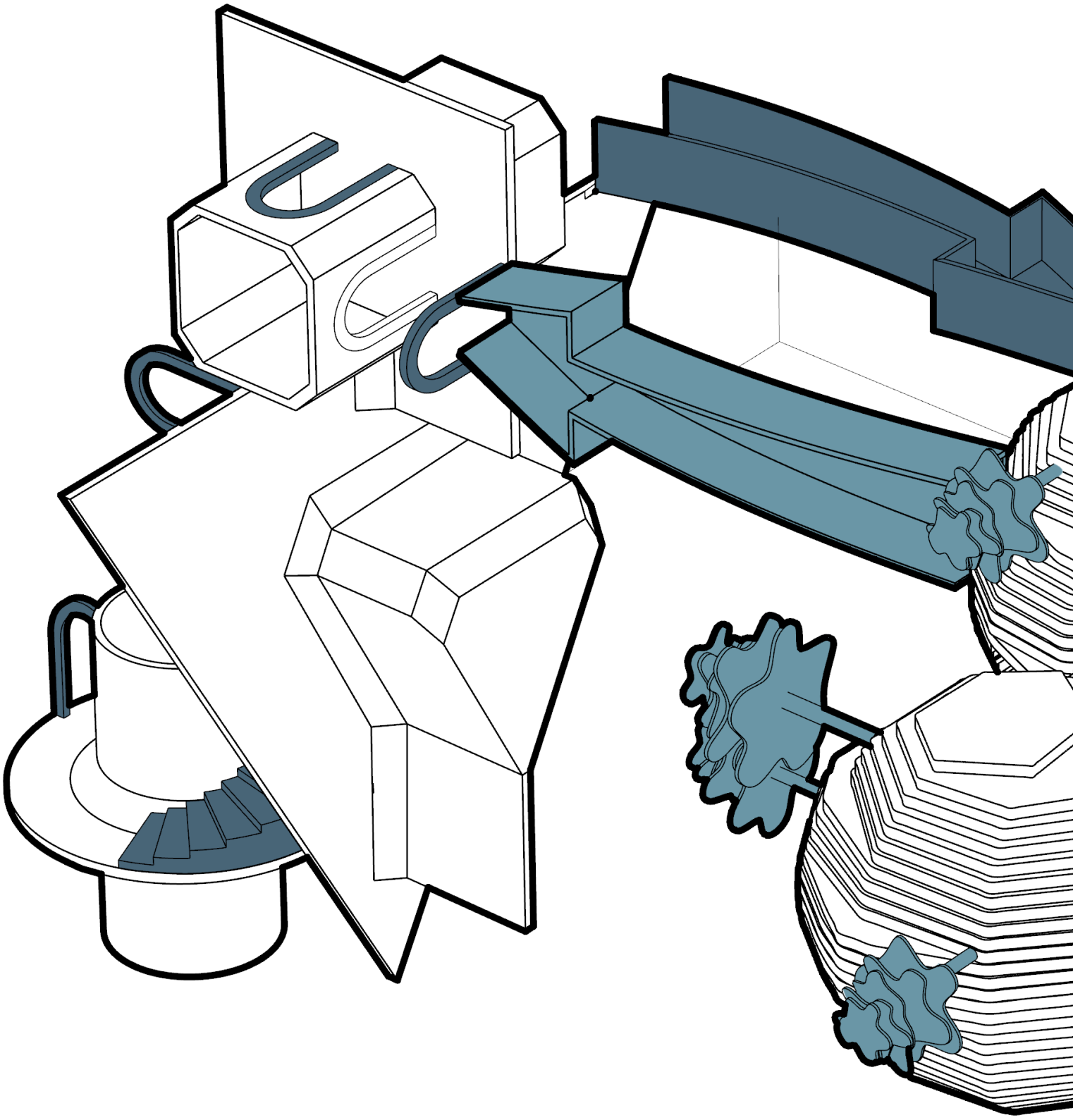


CONCEPT DIAGRAM

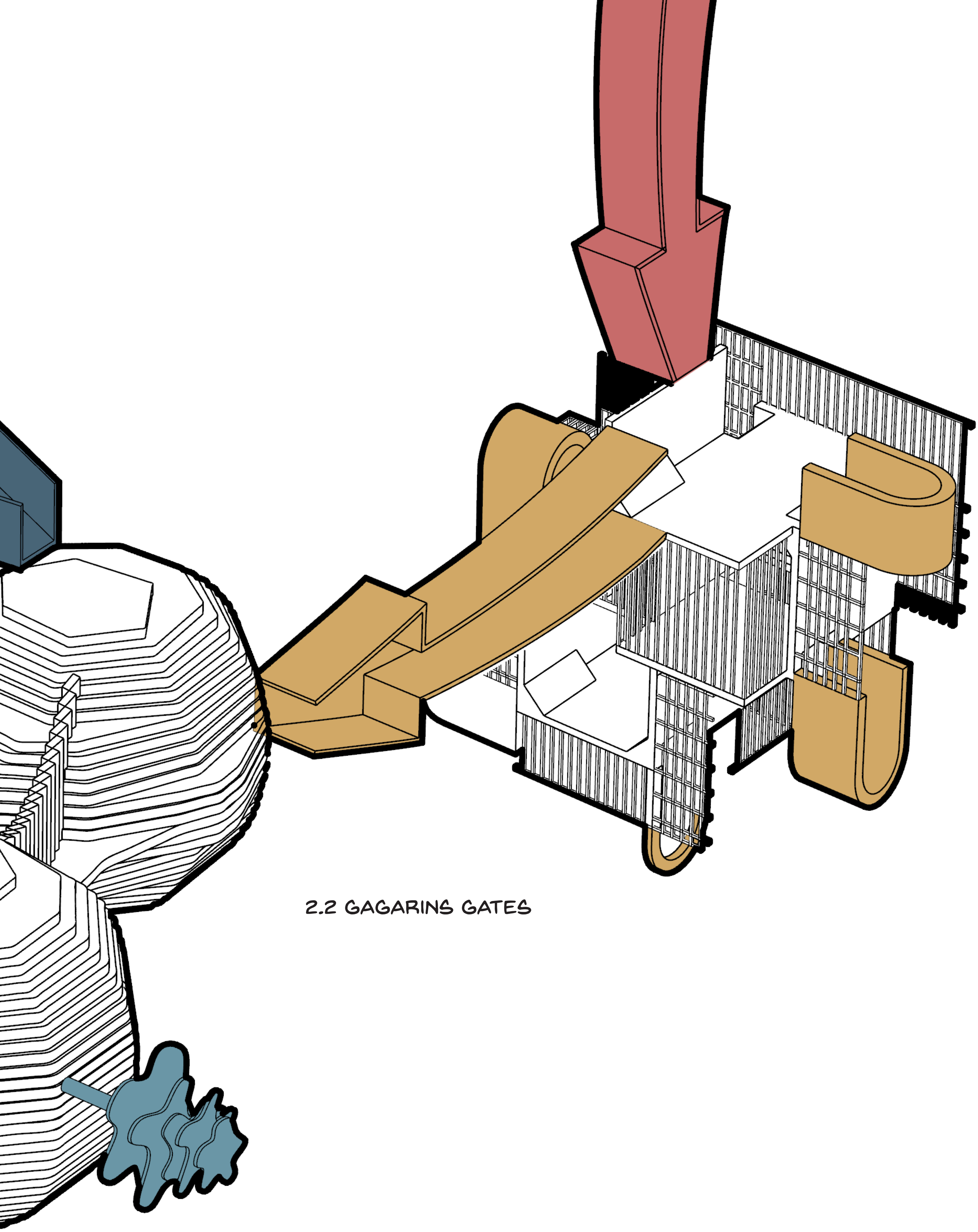
2.1 TSCHUMIS TURBINE



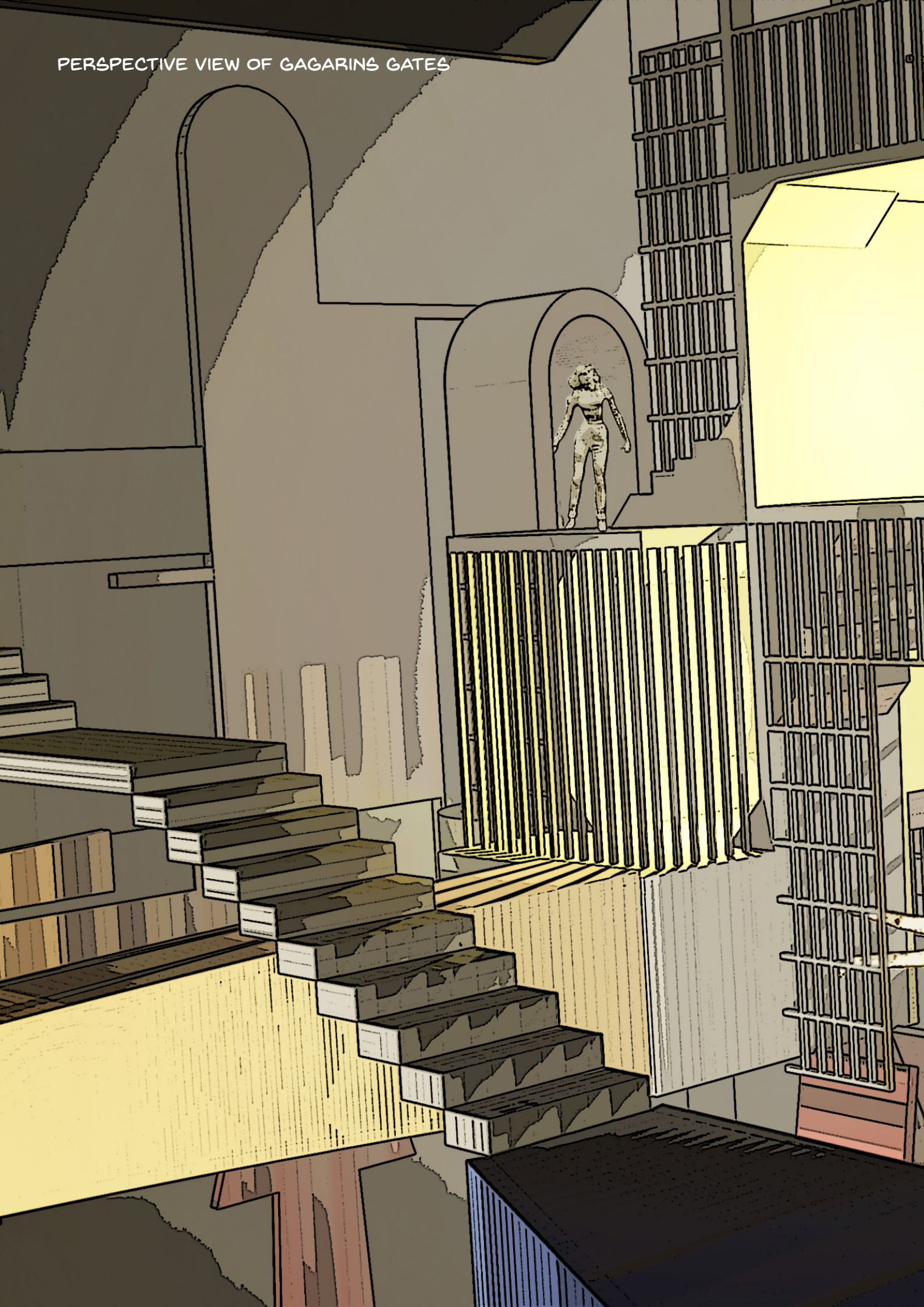
2.4 KAZIMIRS CASTLE

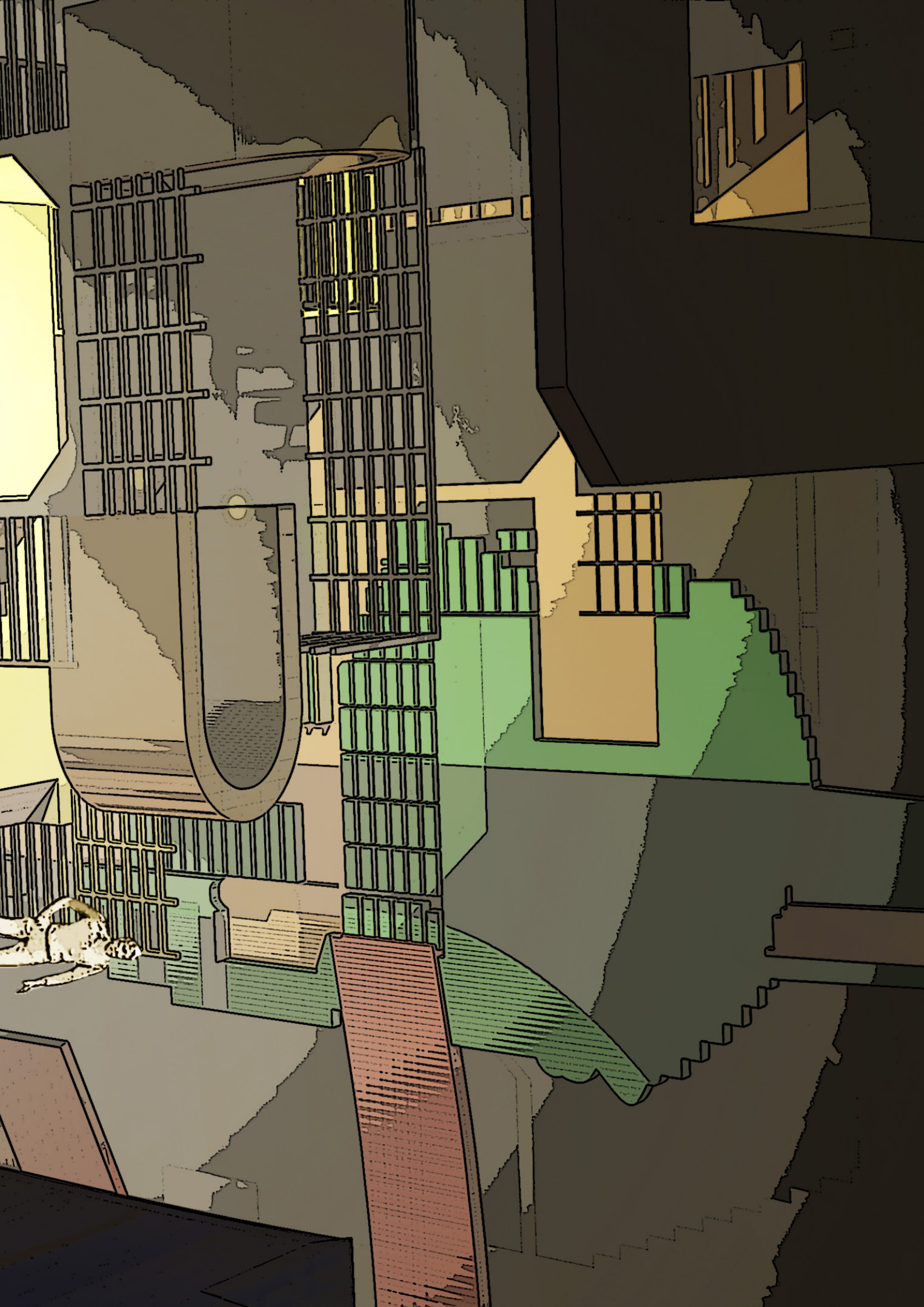


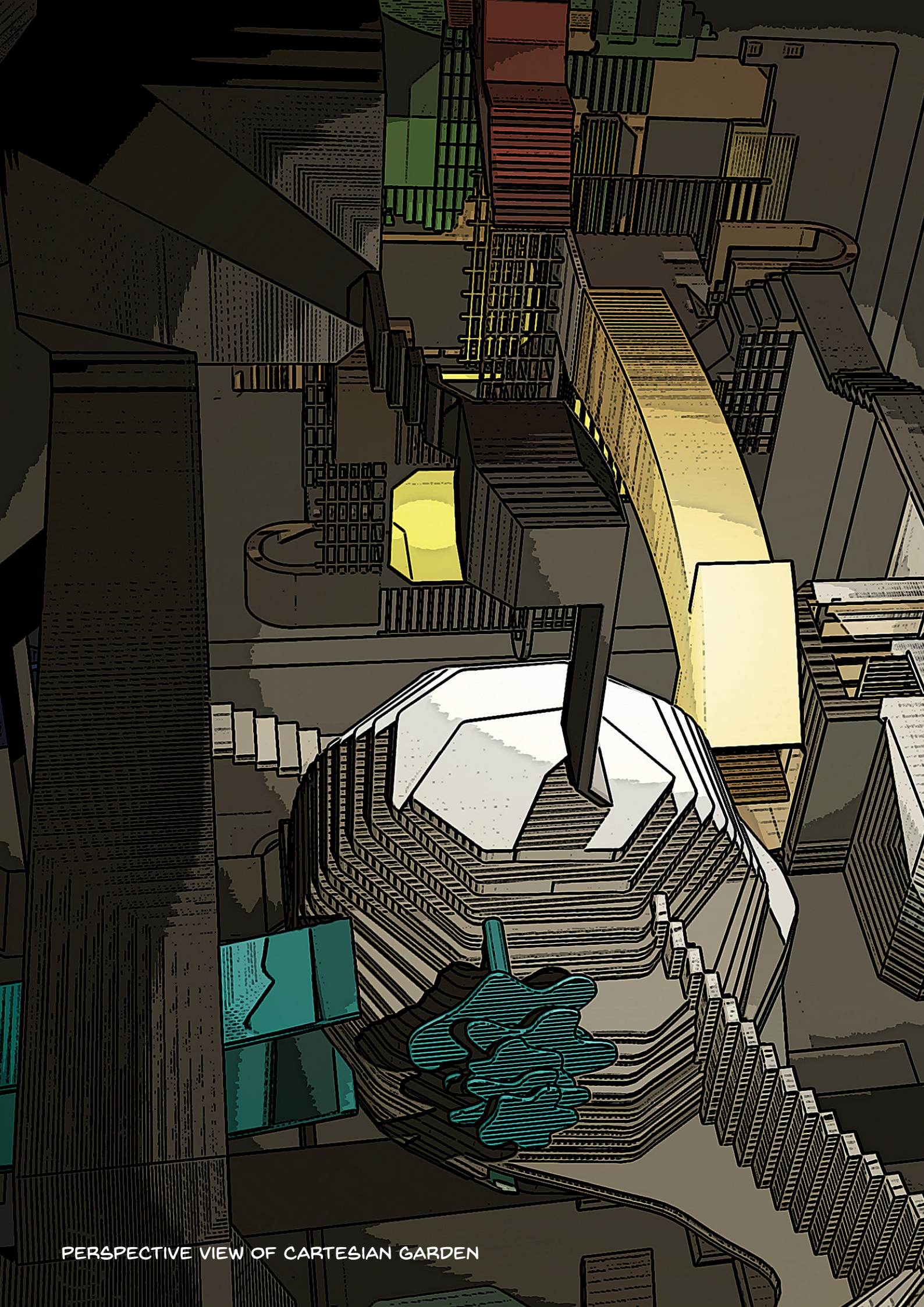
2.3 MEIRS META



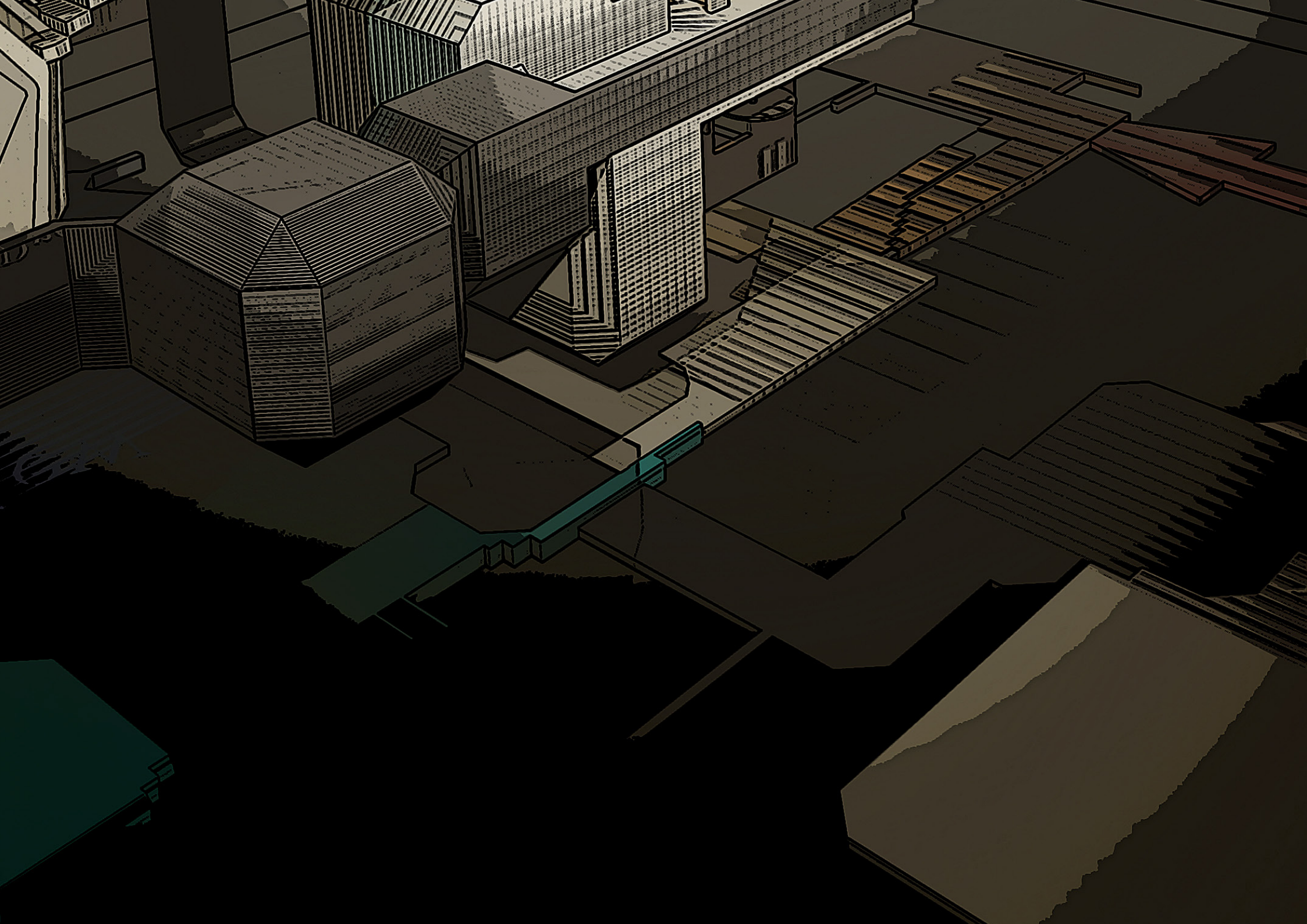
BALL


PERSPECTIVE VIEW OF GAGARINS GATES





PERSPECTIVE VIEW OF CARTESIAN GARDEN

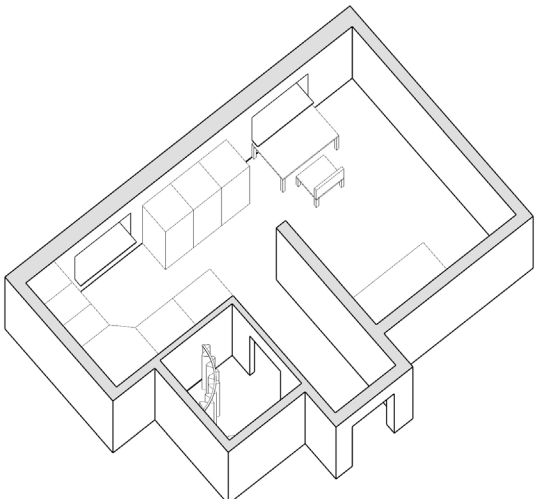


SCREEN SHOT FROM INSIDE OF THE VIRTUAL TOOL, CARTESIAN GARDEN

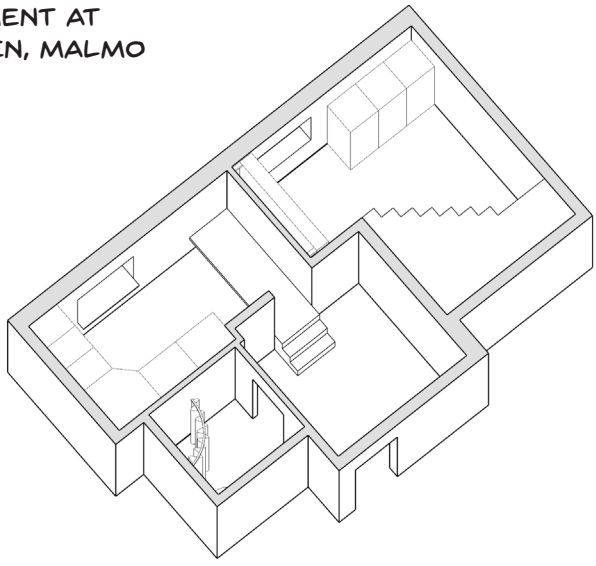
SCREEN SHOT FROM INSIDE OF THE VIRTUAL TOOL, CARTESIAN GARDEN

3.3 HOME

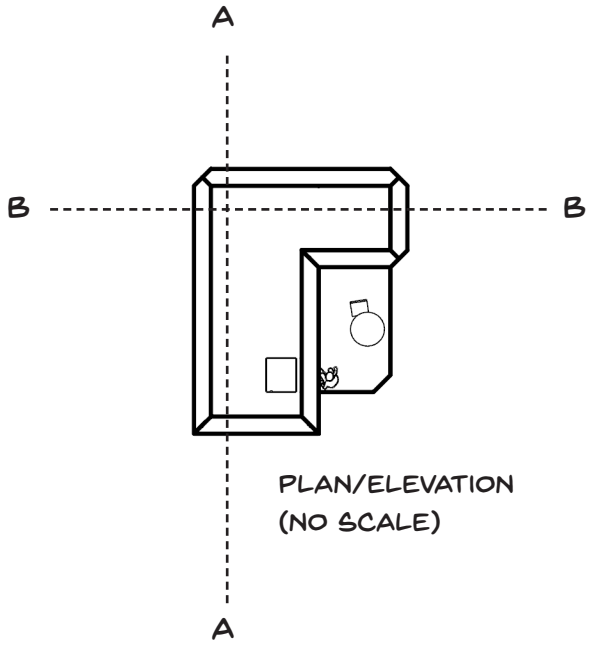
The starting point when designing the last structure was my own apartment. I started to think about how it might look if all six planes were furnishable and how it might feel to move around in it. Would it still feel like home? Would I recognize it from another angle? How can furniture be used when tipped on their sides or turned on their heads. ”Home” is mostly a play with these thoughts.



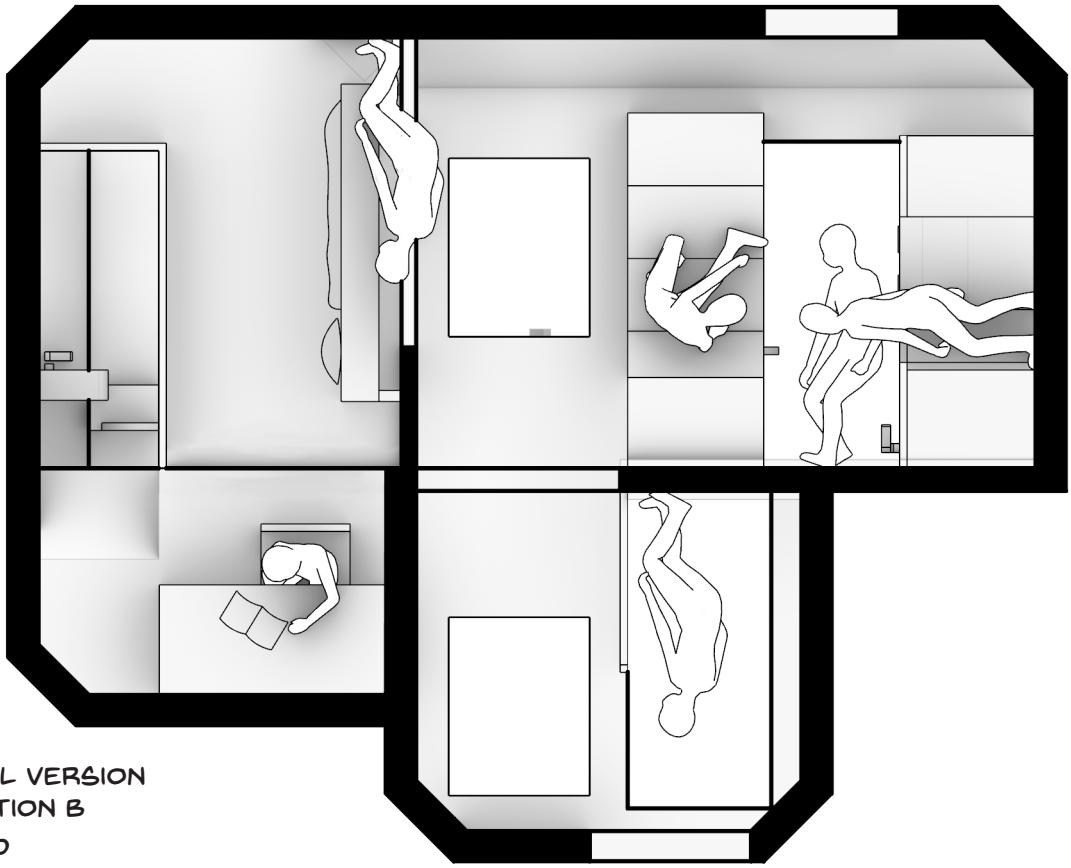
MY APARTMENT AT NOBELVAGEN, MALMO



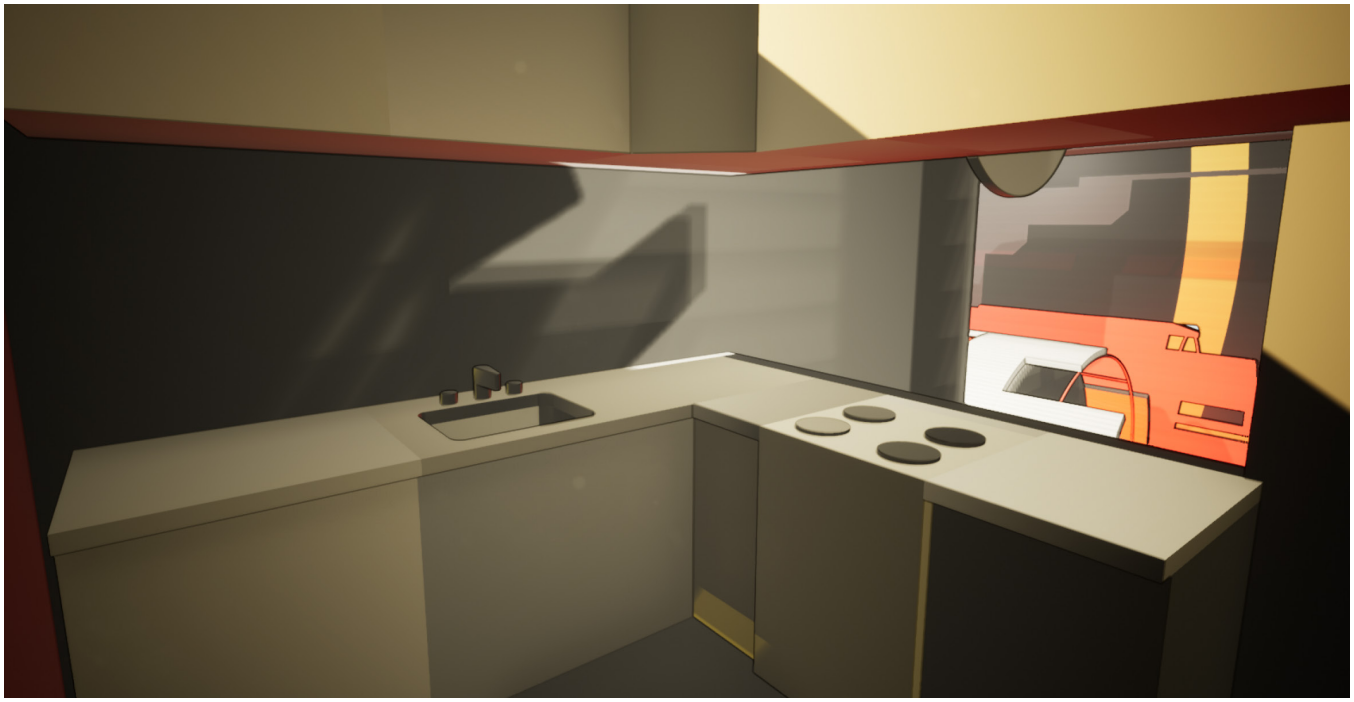
FIRST VERION OF MY APARTMENT REDESIGNED ACCORDING TO MULTIPLE PLANE GRAVITY.



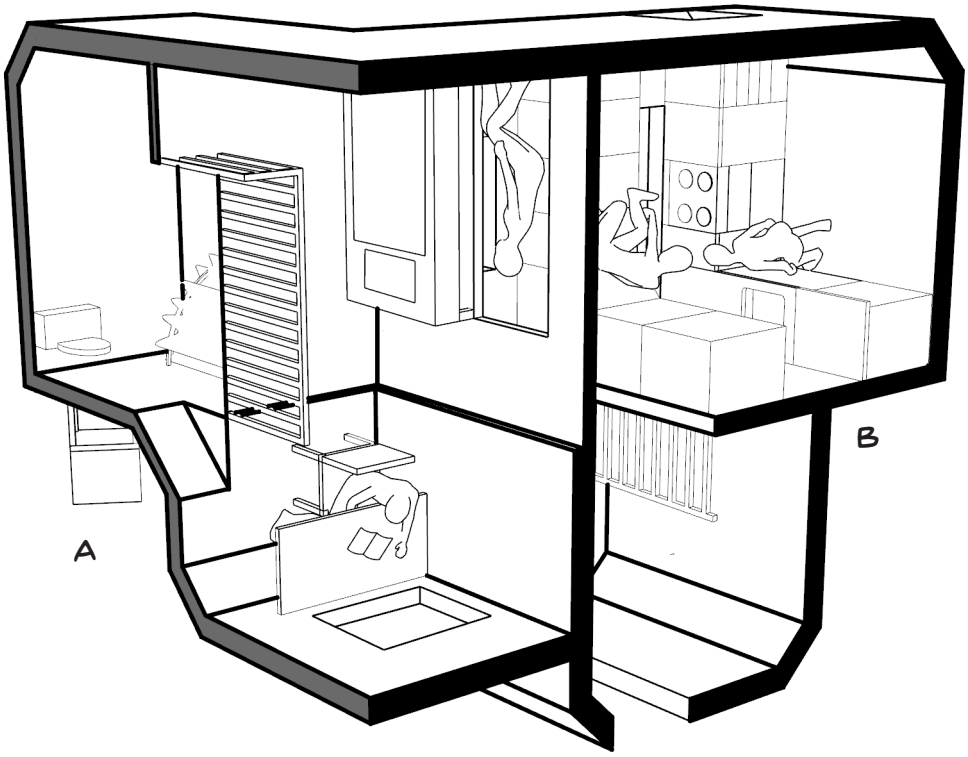
PLAN/ELEVATION
(NO SCALE)



FINAL VERSION
SECTION B
1:50



SCREENSHOT FROM THE VIRTUAL TOOL SHOWING THE KITCHEN IN *HOME.*



SECTION A & B

4.0 DISCUSSION

Throughout my years in architecture school we have presented our designs in the same manner, through static, two-dimensional images. My experience is that the way that we present architectural designs has started to change and that moving images is becoming increasingly more common. Perhaps this is because presenting a 3D-space that is in some way programmed for human activity in 2D, is bound to miss some marks.With this thesis project I wanted to explore the possibilities of presenting and discussing architecture in a new and expanded manner. During the presentation of my project I could tell that it indeed was succesful in that way.

My critics and I spoke about what this project could mean for the way that we think and talk about architecture and the subjects that we touched upon was about how our architectural elements are symbols for the world that we know and how they tell a story about it. We then discussed what happens to their inherent qualities when we remove them from this world and place them in another where laws of nature might be different. For instance, we as architects at Lund University have always been taught that a door and a window is just openings and should be treated as the same object. However, what I noticed while making my virtual space and reading about wayfinding is that this notion only is applicable to our world. The image, or symbol of a door for example, as in an arched portal that thus indicate an up or down, might play a part in our spatial perception and our perceived orientation which extends to affecting wayfinding as well.

The realm of the virtual is within itself a world where completely different rules apply, and in that sense it is similar to zero gravity space. Even if a video game level designer is trying to mimic a familiar environment, perhaps even a real historical place as in the game Assasins Creed, the structural elements present in the game are not structurally important. Their sole purpose is to induce a sense of familarity and with that instructions on how to move in that specific virtual world.

This project is much an exploration of how we can arrange new spaces which comes with an immense amount of challenges. By arranging new spaces in the manner I have suggested in this thesis there are a few pitfalls that we need to try and avoid by adressing them. One of them, that I haven't adressed due to a an attempt to limit the theoretical extent of this project is of course the risk of the project falling into what Freud and Ernst Jentsch in 1904 called *Das Unheimlich* which is the opposite of *heimlich*, or the homely. Nils Pettersson Sandmark, one of my former techer assistants tackled the challenge of summarizing the term in his master thesis. He descirbed it as a term used to describe the certain feelings of discomfort or unpleasentness that arises when what is familiar suddenly seem to contain unfamiliar objects or elements or vice versa.(Pettersson Sandmark, 2018) The familiar elements that I present-

ed in the section about creating the tool might be at risk of triggering *Das Unheimlich* since they are now placed in such an alien environment. It is probably unavoidable however to fully be comfortable right away in unfamiliar environments and as time passes even a zero gravity environment will become familiar. From it, new arrangements of space and new interiors will arise. Since architecture is shaped by human movement, as we know from Le Corbusiers *Modulor* for example, it will change along with new zero gravity movement patterns. As these new movement patterns become more familiar, so will the architecture shaped by them.

In regards to the virtual character of my project I believe it to be a good space through which one can experience complex and interchangeable structures as well as a way of experiencing the subtle feelings awoken by a real or potential space. Spending time in a virtual space is to empirically investigate what impact the architecture in it have on its users. In addition to this, it could for architects work as a subversive or critical commentary or as a socio-analytical tool. Even though this tool is meant mainly for architects and interior designers its format allows for anyone to democratically part take in imagining what architecture could be, just like Lebbeus Woods did.

5.0 BIBLIOGRAPHY

2001: A Space Odyssey (1968) Stanley Kubrick [feature film], Metro-Goldwyn-Mayer

Britannica, 2022, *Space and Mass,* https://www.britannica.com/topic/architecture/Space-and-mass, accessed: 2022-05-01

Britannica, 2022, *Symbols of function,* https://www.britannica.com/topic/architecture/Symbols-of-function, accessed: 2022-05-20

Chapell Bill, 2021, *1st Private Crew Will Visit Space Station. The Price Tag: $55 Million Each,* https://www.npr.org/2021/01/27/961169001/1st-paying-customers-will-visit-space-station-the-price-tag-55-million?t=1647506171367, accessed: 2022-05-01

Ching, Francis D. K, 2007, *Architecture: form, space, and order,* ,3rd edition, New Jersey: John Wiley & Sons, Inc. http://rsd2-alert-durden-reading-room.weebly.com/uploads/6/7/1/6/6716949/ching-architecture_form_space_order.pdf, accessed: 2022-03-03

CNN (2021), *Here's how you can experience zero gravity without going to space* [video] https://www.youtube.com/watch?v=9t_cB7FFYVI, accessed: 2022-03-27

Condé, Nast, 2022, *Artificial Gravity in the Spinning Discovery One* https://www.wired.com/2013/06/artificial-gravity-in-the-spinning-discovery-one/, accessed: 2022-04-19

Cool worlds (2019), *Artificial Gravity* [online video], Available at: https://www.youtube.com/watch?v=b3D7QlMVa5s [Accessed date: 2022-03-31]

Documentary Tube (2015), *HOW IT WORKS: The international Space Station* [Online video], https://www.youtube.com/watch?v=SGP6Y0Pnhe4, accessed:2022-06-10

Escher in het paleis, 2022, *Relativity* https://www.escherinhetpaleis.nl/showpiece/relativity/?lang=en,, accessed: 2022-04-25

GDC (2016), *How to Tell Stories and Guide Players Through Level Desig*, https://www.youtube.com/watch?v=9RbXTv7iNbw, accessed: 2022-06-19

GDC (2016) *Manifold Garden: Level Design in Impossible Geometry* [Online video] https://www.youtube.com/watch?v=ed2zmmcEryw, accessed: 2022-02-01

ISS National Laboratory, 2022, *History and timeline of the ISS,* https://www.issnationallab.org/about/iss-timeline/, accessed: 2022-05-12

Ju Yeon Kim, Jin Kyung Choi, Won Hee Han, Jong Ha Kim, National Library of Medicine (2021)*, The Influence of Users' Spatial Familarity on Their Emotional Perception of Space and Wayfinding Movement Patterns, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8067681/,* accessed: 2022-03-02

Le Co., & Cohen, J.-L. (2009)*. Toward an Architecture,* Los Angeles: Getty Research Institute

Le Corbusier, 1995, *Oeuvre Complète Volume 5, 1945-1952, French Edition, Birkhäuser*

Le Corbusier, *Modulor 2,* London, Faber, 1955

Louw Michael (2016), *The architectural promenade and the perception of time,* ResearchGate, *https://www.researchgate.net/publication/342657325_The_architectural_promenade_and_the_perception_of_time,* accessed: 2022-03-03

Lynch Kevin, 1960, *The Image of the City,* Cambridge Massachusetts, The M.I.T Press

Ma, Alexandra, 2019, *Jeff Bezos wants floating colonies in space with weather like Maui all year long — here's what he thinks they'll look like* https://www.businessinsider.com/jeff-bezos-proposes-floating-colonies-with-weather-as-good-as-maui-2019-5?r=US&IR=T, accessed: 2022-04-23

Manaugh, Geoff [blog], 2022, *Without Walls: An Interview with Lebbeus* Woods, https://bldgblog.com/2007/10/without-walls-an-interview-with-lebbeus-woods/, accessed: 2022-05-17

McGuirk Justin, 2014, *The perfect architectural symbol for an era obsessed with customisation and participation,* https://www.dezeen.com/2014/03/20/opinon-justin-mcguirk-le-corbusier-symbol-for-era-obsessed-with-customisation/, accessed: 2022-06-19

McManus, Meaghan, R. Harris, Laurence (2021) *When gravity is not where it should be: How perceived orientation affects visual self-motion processing,* https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0243381 [2022-02-28]

Merriam Webster, 2022, *Home,* https://www.merriam-webster.com/dictionary/home, accessed: 2022-04-02

Merriam Webster, 2022, *Homely,* https://www.merriam-webster.com/dictionary/home, accessed: 2022-04-02

Moravánszky Ákos, 2018, title of chapter: *4. THE FOUR ELEMENTS OF ARCHITECTURE,* from the book: Metamorphism, Berlin: Birkhäuser, pp. 93-131

Nasa, 2017, *Noordung's Space Station*, https://www.nasa.gov/multimedia/imagegallery/image_feature_1217.html, accessed: 2022-04-23

Nixon, David, 2022, Here's *How You Design for Living and Working in Outer Space,* https://metropolismag.com/viewpoints/international-space-station-workplace-design/, accessed: 2022-03-24

Noever, Peter, 1997, *Architecture In Transition,* second edition, London: Prestel Publishing

Passini, Romedi (1984) *Spatial Representations, a Wayfinding Perspective,* Science Direct, https://www.sciencedirect.com/science/article/abs/pii/S0272494484800316, accessed: 2022-03-01

Pettersson Sandmark, Niels, 2018, *Det Unheimliche och hemmet*, LTH School of Architecture, accessed: 2022-06-03

Rymdstyrelsen - Swedish National Space Agency, 2022, *60 år sedan första människan i rymden,* https://www.rymdstyrelsen.se/upptack-rymden/bloggen/2021/4/60-ar-sedan-forsta-manniskan-i-rymden/, accessed: 2022-04-20

Samuel, Flora, 2010, Le Corbusier and the architectural Promenade, Birkhäuser,

Solondz, Simone, 2022, *What to wear on Orion,* https://www.risd.edu/news/stories/students-design-apparel-for-space-travel*,* accessed: 2022-05-12

Universe Today, 2021, *Since There's no Up or Down in Space, How do our Brains Deal With This?* https://www.universetoday.com/149559/since-theres-no-up-or-down-in-space-how-do-our-brains-deal-with-this/, accessed: 2022-06-01

Unstudios, 2022, *Wayfinding as a Design Tool,* https://www.unstudio.com/en/page/9462/wayfinding-as-a-design-tool, accessed: 2022-04-02

5.1 TABLE OF FIGURES

1. Zettel, Reiner, 2005, *Lebbeus Woods with Christoph a. Kumpusch in Vienna, Austria in 2005,* JPEG, Hypeallergic, accessed: 2022-04-11, https://hyperallergic.com/59590/remembering-radical-theoretical-architect-lebbeus-woods/, modified by me.

2. Woods, Lebbeus, 1988, *Underground Berlin,* Pastel, Graphite, Colored Pencil 16" x 11.5", https://www.pinterest.se/pin/209487820136842537/, Pinterest, accessed: 2022-02-09

3. Woods, Lebbeus, 1988, *Underground Berlin 19, Elevation View, 1988,* Pastel, graphite and colored pencil on Strathmore, Artsy.net, https://www.artsy.net/artwork/lebbeus-woods-underground-berlin-19-elevation-view-1, accessed: 2022-02-28

4. Woods, Lebbeus, 1989, *Aerial Paris*, https://hiddenarchitecture.tumblr.com/post/144559265230/aerial-paris-1989-lebbeus-woods, accessed: 2022-02-28

5. MC Escher, 1953, Brigham Young University Museum of Art, *Relativity* (https://moa.byu.edu/m-c-eschers-relativity/), accessed: 2022-05-07

6. Woods, Lebbeus, 1989, *Aerial Paris*, https://hiddenarchitecture.tumblr.com/post/144559265230/aerial-paris-1989-lebbeus-woods, accessed: 2022-02-28

7. Inverse (2022), *The Forgotten Father of Space Station Design*, https://www.inverse.com/innovation/herman-potocnik-noordung-father-of-space-station-design, accessed: 2022-03-30

8. Nasa, 2017, *Noordung's Space Station*, https://www.nasa.gov/multimedia/imagegallery/image_feature_1217.html, accessed: 2022-04-23

9. Inverse (2022), *The Forgotten Father of Space Station Design*, https://www.inverse.com/innovation/herman-potocnik-noordung-father-of-space-station-design, accessed: 2022-03-30

10. *2001: A Space Odyssey (1968) Stanley Kubrick [feature film], Metro-Goldwyn-Mayer*

11. *2001: A Space Odyssey* (1968) *Stanley Kubrick [feature film], Metro-Goldwyn-Mayer*

12.NASA/ Guidice, Rick (2004), *Interior view, showing alternating land and window stripes,* https://en.wikipedia.org/wiki/O%27Neill_cylinder#/media/

File:Spacecolony3edit.jpeg, accessed: 2022-06-19

13. Ma, Alexandra, 2019, *Jeff Bezos wants floating colonies in space with weather like Maui all year long — here's what he thinks they'll look like* https://www.businessinsider.com/jeff-bezos-proposes-floating-colonies-with-weather-as-good-as-maui-2019-5?r=US&IR=T, accessed: 2022-04-23

14. Nixon, David, 2022, Here's *How You Design for Living and Working in Outer Space,* https://metropolismag.com/viewpoints/international-space-station-workplace-design/, accessed: 2022-03-24

15. NASA,, 2022, *International Space Station Cupola,* https://virtualbackgrounds.site/background/international-space-station-cupola/, accessed: 2022-06-19

16. Nixon, David, 2022, Here's *How You Design for Living and Working in Outer Space,* https://metropolismag.com/viewpoints/international-space-station-workplace-design/, accessed: 2022-03-24

17. Unstudios, 2022, *Wayfinding as a Design Tool,* https://www.unstudio.com/en/page/9462/wayfinding-as-a-design-tool, accessed: 2022-04-02

18. Mount Rokko Chapel, 1986, by Tadao Ando. (photograph by Raphael Azevedo Franca, 2006, https://commons.wikimedia.org/wiki/File:Rokko_Mount_Chapel_Tadao_Ando.jpg).

19. Kubrick, S., King, S., & Johnson, D. (1980). The shining. [Los Angeles, CA], Warner Bros.

20.Louw Michael (2016), *The architectural promenade and the perception of time,* ResearchGate, *https://www.researchgate.net/publication/342657325_The_architectural_promenade_and_the_perception_of_time,* accessed: 2022-03-03

21. Terragni, Giuseppe (1938) *Paradiso,* https://archeyes.com/the-danteum-giuseppe-terragni/, accessed: 2022-06-19

22. GDC (2016), *How to Tell Stories and Guide Players Through Level Desig* [Online video], https://www.youtube.com/watch?v=9RbXTv7iNbw, accessed: 2022-06-19

23. GDC (2016) *Manifold Garden: Level Design in Impossible Geometry* [Online video] https://www.youtube.com/watch?v=ed2zmmcEryw, accessed: 2022-02-01

24. Le Corbusier & Pierre Jeanneret*, OEuvre Complète Volume 1, 1910–1929,* Les Editions d'Architecture Artemis, Zürich, 1964), accessed: 2022-06-19

25. Photo by: Vafeiadakis, Aristidis (2022) *Anders Cullhed: Därför är Parthenon en kultplats i den svenska litteraturen*, https://www.dn.se/kultur/anders-cullhed-darfor-ar-parthenon-en-kultplats-i-den-svenska-litteraturen/, accessed: 2022-06-19

26. Private photo, Skogskyrkogården, Stockholm, 2021

27. Ancient Origins (2014), *The magnificent Ishtar Gate of Babylon*, ancient-origins.net/ancient-places-asia/magnificent-ishtar-gate-babylon-001866, accessed: 2022-06-03

28. Eisenman Architects, 2022, *Wexner Center for the Visual Arts and Fine Arts Library,* https://eisenmanarchitects.com/Wexner-Center-for-the-Visual-Arts-and-Fine-Arts-Library-1989, accessed: 2022-06-19

29. Xichen, Cheng, (2017), *1963*, https://medium.com/@shengmorni/1963-88a359d2f68b, accessed: 2022-06-02