Beyond the Folds: Emergent Properties in Paper

By

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May, 2023

Director of Thesis: Scott Eagle

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In this body of work I explore the relationship between visual art, information science, and the geometry of paper in an attempt to create a unique visual language with which I make records; not unlike writing in a journal. Using cyanotype, origami, drawing, and digital techniques I co-opt the language of computers (binary) to represent aspects of myself in paper form, blending the analog and digital into a distinctive way of communicating. The work is informed by my understanding of Constructor Theory, Information Theory, and Quantum Mechanics with which I draw thematic comparisons between the fundamental nature of who I am with the fundamental nature of the universe.

Beyond the Folds: Emergent Properties in Paper

A Thesis

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Masters of Fine Arts

By

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DEDICATION

This document and the body of work that supports it is dedicated to my husband, Michael Pruitt Jr. Without his support, the dream of achieving a Masters of Fine Arts degree would have never been possible.

ACKNOWLEDGEMENTS

I would like to thank my parents for their unwavering support throughout my time at East Carolina University. It is thanks to them that I was able to build this body of work at all. I would also like to thank my faculty mentors and the administration of the School of Art and Design for guiding me through this process and believing in the work I make. Lastly, I'd like to thank the Art and Design graduate students for supporting me through three of the toughest years of my academic career. Thank you all for the incredible opportunity for me to find my perspective as an artist.

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MY BODY, MY MIND, MY WORK

In my thesis exhibition entitled *Beyond the Folds: Emergent Properties in Paper*, I have created a body of work that blends my obsession with science, mathematics, and the visual arts. I use paper, photography, origami, and my knowledge of both computers and physics to invent a visual code that I then use to write a diary of sorts, of myself and aspects of my personality. What follows is an explanation of the scientific framework within which I am working, followed by a description of the media used and the thematic relationships to the theoretical framework. This will contain an overview of such topics as Information Theory, Constructor Theory, Quantum Mechanics, Origami, Cyanotype and the melding of them all into one body of work. Finally I explore the work itself and provide some insight into my relationships with both the pieces and the audience.

THE THEORETICAL FRAMEWORK

It is most helpful to begin with a basic understanding of binary code when approaching my work. Binary is a system of representing information as a series of zeros and ones. When used as a language for computers each individual digit is called a bit while each series of eight bits is called a byte. These bytes are capable of representing nearly limitless kinds of information from text, to sound, to images. For example, if Alice wishes to send an email to Bob with a single letter “A” as the body of the email, her text is converted to a single byte of information and sent via cable or wireless network using an encoding system like ASCII (American Standard Code for Information Interchange). This encoding system acts as a cipher, an algorithm that assigns the correct digits to the correct positions corresponding to the text input. As long as Bob’s computer knows the ASCII cipher, it can decode Alice’s email.

From this most simple of digital languages, binary has become an integral part of many modern theories of information processing and other sciences like physics. There are many natural structures that have properties that mimic binary code. An electron, for instance, can spin in one of two directions, up or down. Since the electron can only be found in one of those two states, its spin can be mapped to the binary digits of zero and one. There are many such examples in nature, both at the large (or classical) scale and at the smallest (or quantum) scale. Additionally, any such system, be it quantum or classical, can be used to store and transmit information as each state of the system can directly correspond to one of the binary digits.

Drs. Chiara Marletto and David Deutsch of Oxford university have introduced a theory that directly addresses the quantum nature of information and how it can be transferred from one system to another. Dubbed Constructor Theory[1], the duo have created a new approach to understanding the fundamental laws of the classical and quantum worlds, relying not on laws of motion (which has been the standard assumption for millennia) but on the function and operation of constructors. Ever since humans evolved the capability for intelligence we have observed and recorded the way systems change over time, establishing rules and laws that the universe appears to follow. Even the complex equations of quantum mechanics are motion based, describing how the probabilities of a particle's motion changes from one moment to another. Instead of asking how fundamental systems like the electron or the quark behave in motion, Constructor Theory asks what actions are possible or impossible for the given system. These counterfactual properties delineating possible from the impossible are claimed to be more fundamental than the properties associated with motion.

But what are constructors? Constructors are physical entities that are capable of manipulating physical objects. The manipulations usually include building, repair, and transformation, and surprisingly do not require any intelligence in and of themselves. While the constructor can be conscious, such as a computer technician who pieces together hardware to form a functioning machine, it does not have to be. The DNA of our own cells is an excellent example of such a constructor[2]. Human DNA contains all of the information to not only create a person from scratch, but also to express that person's unique genome. This information is stored as a sequence of amino acids A, C,

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[1] Deutsch and Marletto. "Constructor Theory of Information" *Proceedings A*, vol. 471, no. 2174 (February 2015).

[2] Marletto. "Constructor Theory of Life" *Interface*, vol. 12, no. 104 (March 2015)

T or G (Adenine, Cytosine, Guanine, and Thymine) in a manner similar to binary code but with four “digits" rather than two. DNA as a constructor can replicate itself from raw materials. It can build RNA bio-machines that can further read other sections of the DNA and make the proteins necessary for nearly every biological process. When viewed in such a manner, this paramount component of our cells becomes a constructor, capable of action, manipulation, and translation. Taking this perspective into account, this could be part of the explanation for consciousness’ emergence from non-conscious components. Since the concept of a constructor is more fundamental than the laws of motion, Marletto and Deutsch propose that instead of centering our thinking around those laws, we should instead consider constructors and information-carrying systems to be the most basic “things" in nature. Then we can categorize the constructors by asking what tasks are possible or impossible for them to perform. These tasks are called translations and allow us to view information as a physical property of the system. It is the order of the zeros and ones, the ACGT bases of DNA, or another such system.

Because Constructor Theory focuses on information as a physical property, it is natural to ask how this idea interacts with Information Theory. It was physicist Claude Shannon who, in the 1940s, developed the ideas that would go on to become our modern Theory of Information. Shannon revealed a method for calculating how much information a system can hold, how much “noise” is present in a system, and what amount of confidence you can have in your transmission of information[3]. These are especially important calculations when dealing with natural information systems

[3] Lombardi, Olimpia, et al. “What Is Shannon Information?” *Synthese*, vol. 193, no. 7 (2016).

because the information limit and the amount of noise in the system can all affect how well a constructor can perform its manipulations of its system. Imagine if there was an abundance of “noise” or “static” in your DNA that caused random amino acid bases to change types. This would greatly impair the molecule’s ability to make the proteins we need to survive.

My understanding of these topics and their intersection regarding information was the catalyst that began this body of work. I began to think about how information moves from one mind to another; the physical process of translating abstract concepts into language, sound, and electricity. This led to a desire to manipulate that process, to bend the rules of communication until I had both a process and product that was unique to me as both a person and an artist. My passion for science had guided me to this point and it was time to choose my media.

FROM CREASE PATTERNS TO BLUEPRINTS

As I was pondering the implications of the physical mechanisms of information transfer, I happened to be in the process of returning to a childhood passion: origami. While looking over all of the diagrams in my collection of instructional books, I had a flash of realization; I could encode text into the paper itself simply through folding. There are only two basic folds used in origami, the mountain fold and the valley fold (fig.1 and fig. 2). The only difference between the two is the direction the paper moves during the fold.

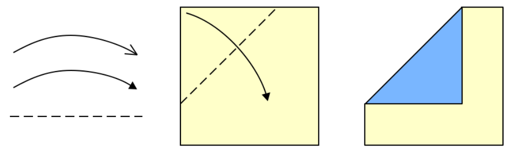


Fig. 1 Valley Fold

Coax the paper towards you as you fold and you get a valley, while moving the paper away from you and you get a mountain. The process can be seen as a kind of binary operation, in which you can assign a zero to one type of fold and a one to the other. This process of transformation and representation through a simple set of rules is similar to the way that binary code is used to represent complex data and instructions in a computer.

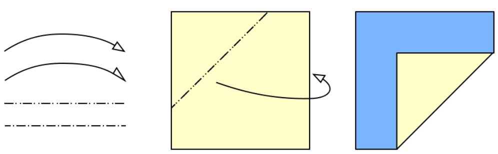


Fig. 2 Mountain Fold

In addition, many complex origami models are represented, not by a series of diagramed steps, but as a single crease pattern that shows each crease and its direction all at once (fig. 3). When represented thusly, the folded instructions become "blueprints" for how to fold the

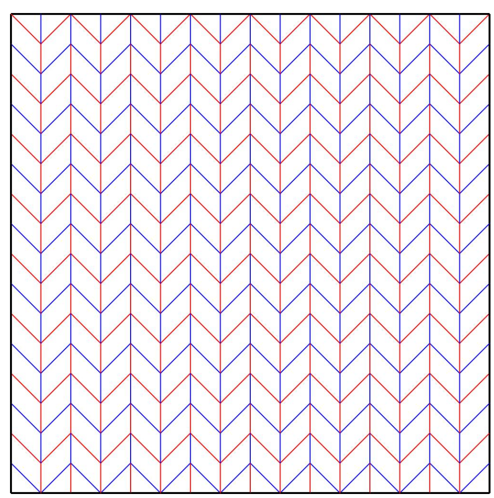


Fig. 3 Crease Pattern for Herringbone Tessellation

model, where all of the relevant information is contained in a visual diagram that corresponds to the single sheet of paper. This immediately caught my attention because it dovetailed nicely with my desire to focus on the way information was being transferred rather than creating a finished paper model. Realizing that the crease patterns themselves were of more interest to me than the actual folded structure, I had another flash of inspiration: blueprints.

Blueprints, or cyanotypes as they are more commonly known now, are a photographic process in which the artist mixes a solution of potassium ferricyanide and ferric ammonium citrate and then brushes the solution onto the paper (fig. 4). As the paper dries, the chemicals become light sensitive which necessitates drying in a dark room. Then a negative, printed or drawn on a transparent film, can be placed on top of the paper and weighed down with glass. The paper and negative are then exposed to ultraviolet light, either via a UV exposure unit or simply the sun. The highly energetic light waves initiate a chemical reaction on any area of paper they hit, causing the chemicals saturating the paper to physically bond with the cellulose structures contained within. This bond causes the light reflected from the paper to appear as a deep blue cyan. This monochromatic nature of cyanotypes gives it a strong thematic

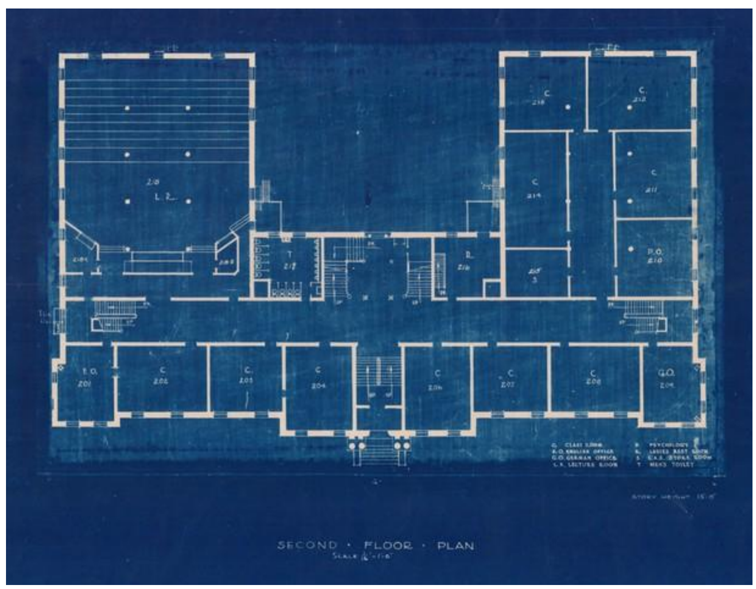


Fig.4 Blueprint Floorplan

link to the binary language of computers. Because the chemical reaction produces an insoluble blue compound when exposed to UV light, this process can be seen as a kind of chemical binary code, with the presence or absence of light determining whether the chemical reaction occurs.

Cyanotype's relational link to information can also be seen in the way that it is used to represent ideas and communicate. Cyanotype has been used historically for scientific and architectural illustration and documentation. While it was invented by John Herschel in 1842 as a photographic process, it became used as a way to quickly create multiples for engineering or architectural plans. In both cases, the simplicity of the medium allows for precise and efficient representation of information. It also works remarkably well when used to represent origami crease diagrams, as the notation for representing the two fold types are simply a solid line for mountain folds and a dotted line for valley folds.

Overall, while the relationship between origami, folding, binary, and cyanotype is more metaphorical than literal, there are similarities in the way that these processes rely on simplicity, efficiency, and a set of rules to represent complex forms and ideas. This also echoes (thematically at least) the concept of emergent properties. An emergent property is a characteristic of a system that is not shared by its individual parts. From spartan rules regarding folding comes a near infinite number of two and three-dimensional forms, as complex or as simple as you like.

THE MASTERS

In researching topics for this body of work, I found myself gravitating towards both scientists and artists, sometimes both. One of the biggest inspirations for my work is the physicist turned artist Robert J. Lang. Lang is a renowned origami artist and theorist who has made significant contributions to the field of origami. Born in Ohio in 1961, he studied physics at the California Institute of Technology and Stanford University. His textbook *Origami Design Secrets* was invaluable for learning how to read crease patterns and understanding the geometry involved in creating my own diagrams[4].

Lang's origami practice is characterized by his focus on intricate and complex designs that push the boundaries of what is possible with paper folding. He is known for his highly technical approach to origami (fig. 5), which involves using mathematical algorithms and computer programs to design and fold models with hundreds or even thousands of folds. His background in physics has been instrumental in his approach to origami, and has developed mathematical principles that govern the behavior of paper when it is folded. He uses these principles to create new folding techniques and design highly complex origami models. Lang's work in origami has also had implications for fields outside of art and design, including engineering, materials science, and robotics.

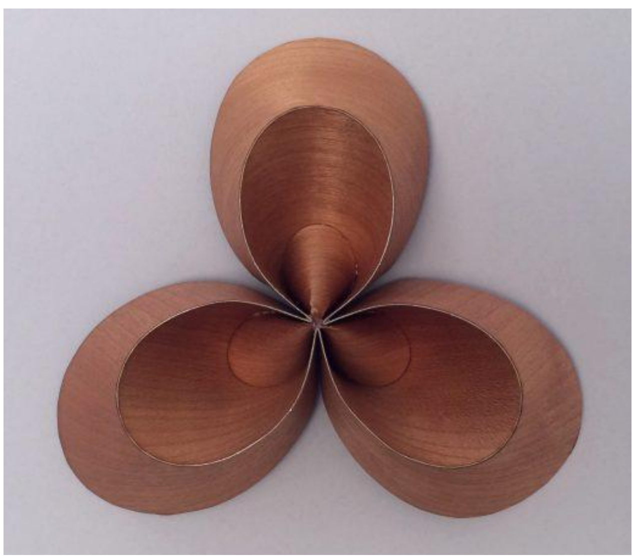


Fig. 5 Lang, Cone Three-Way, *Opus 721*, 2017

[4] Lang. *Origami Design Secrets: Mathematical Methods for an Ancient Art*, Second Edition (2017)

He has also received numerous awards for his contributions to the field, including the 2021 Kyoto Prize in Arts and Philosophy, which is one of the most prestigious international awards in the fields of science and culture.

Another incredibly influential origami artist regarding my work is Akira Yoshizawa. Yoshizawa (1911-2005) was a renowned origami artist and master who is considered to be one of the founders of modern origami. His philosophy of origami was rooted in his belief that origami is an art form that should be accessible to everyone, regardless of their cultural or economic background. He believed that origami could be used to bridge cultural divides and promote peace and understanding between different communities around the world. Yoshizawa also believed that origami was a form of self-expression that allowed artists to create beautiful and intricate works of art using only a single sheet of paper (fig. 6). He emphasized the importance of creativity and experimentation in origami, encouraging artists to push the boundaries of the medium and explore new techniques and designs. His contributions to origami have had a lasting impact on the art form, and he is still one of the most influential origami artists of the 20th and 21st centuries.

Fig. 6 Yoshizawa, *Bull*

In addition to the masters of origami, Christina Z. Anderson and her approach to cyanotypes were a major source of guidance and inspiration when making this body of work. Anderson is a contemporary photographic artist and educator who specializes in alternative photographic processes, particularly cyanotype printing. She was born in

Fig. 7 Anderson, *Death Valley*, 2018

California in 1965 and earned her MFA in Photography from the University of New Mexico. Anderson is known for her innovative use of cyanotype printing. She has developed a unique approach that incorporates other materials and techniques, such as hand-coloring, to create richly textured and expressive images (fig. 7). Her work often explores themes related to memory, identity, and place, and she frequently incorporates found objects and personal artifacts into her cyanotype prints.

Her identity work in cyanotype, coupled with Yoshizawa's philosophy and Lang's science, helped to formulate the direction my work would go in. These three titans of their respective fields were a great boon to my own research and practice.

THE WORK EMERGES

When I began this body of work, I set out to accomplish several things. I wanted a body of work in which I could encode data about myself, creating a kind of visual journal that used “rules” which echoed the process by which computers exchange binary information. Because the content of the work, the actual data, was not as important to me as the process by which the data transferred, I decided to make each message something silly. I have a great love of puns and consider the “dad” joke to be the peak form of short comedy. I imagined the surprise (and maybe chuckle) of those in the audience with the desire to translate my work. As time passed and I continued to work on the pieces, I began to understand that, while I think the messages encoded in the work are silly, they collectively represent another major aspect of myself.

I wanted the typical viewer to understand that they are being presented with a visual “language” rather than making my goal that the audience decode the work. In talking about my work, I keep likening the cyanotypes to the hieroglyphics of ancient Egyptian cultures. Those scholars who studied the symbols knew they were looking at a language because there appeared to be repeating patterns of glyphs. Additionally there was an order to the glyphs that seemed to indicate a preferred direction in which they were to be read. It was only once the Rosetta Stone was discovered and direct translations from hieroglyphics to other ancient languages were found that the true meanings of the glyphs were finally discovered. I hope to communicate similarly to the audience. Unfortunately for some, there is no equivalent to the Rosetta Stone for my work. Rather than frustration, I would like to inspire curiosity about the attempt at communication.

So I began with the crease patterns because it is the starting point for folding and that seemed as good a place to start as any other. I started by folding some simple patterns known as tessellations, repeating sets of folds that mimic the way certain shapes and polygons can tile forever without overlapping; like the hexagonal honeycomb pattern made by bees. From there I unfolded each piece and recorded the shape and direction of the folds in a digital origami planning tool called Orihime. This would give me a digital vector file of the tessellation crease pattern that I could import into another program like Adobe Illustrator (fig. 8). This crease pattern is like a blueprint but specifically for origami. Those who know how to read the crease pattern can build the folded shape from it, the way that an engineer or contractor can build a house from an architectural blueprint. Then I turned those plans into negatives, allowing me to make cyanotype schematics based on my own folded shapes. Finally I wrote and drew on those cyanotypes and encoded text in binary forms on each blueprint.

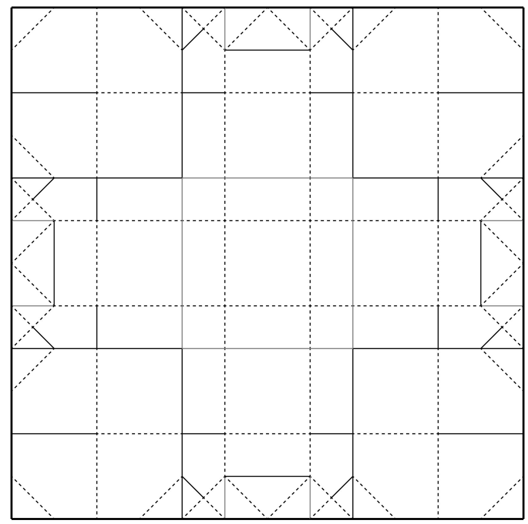
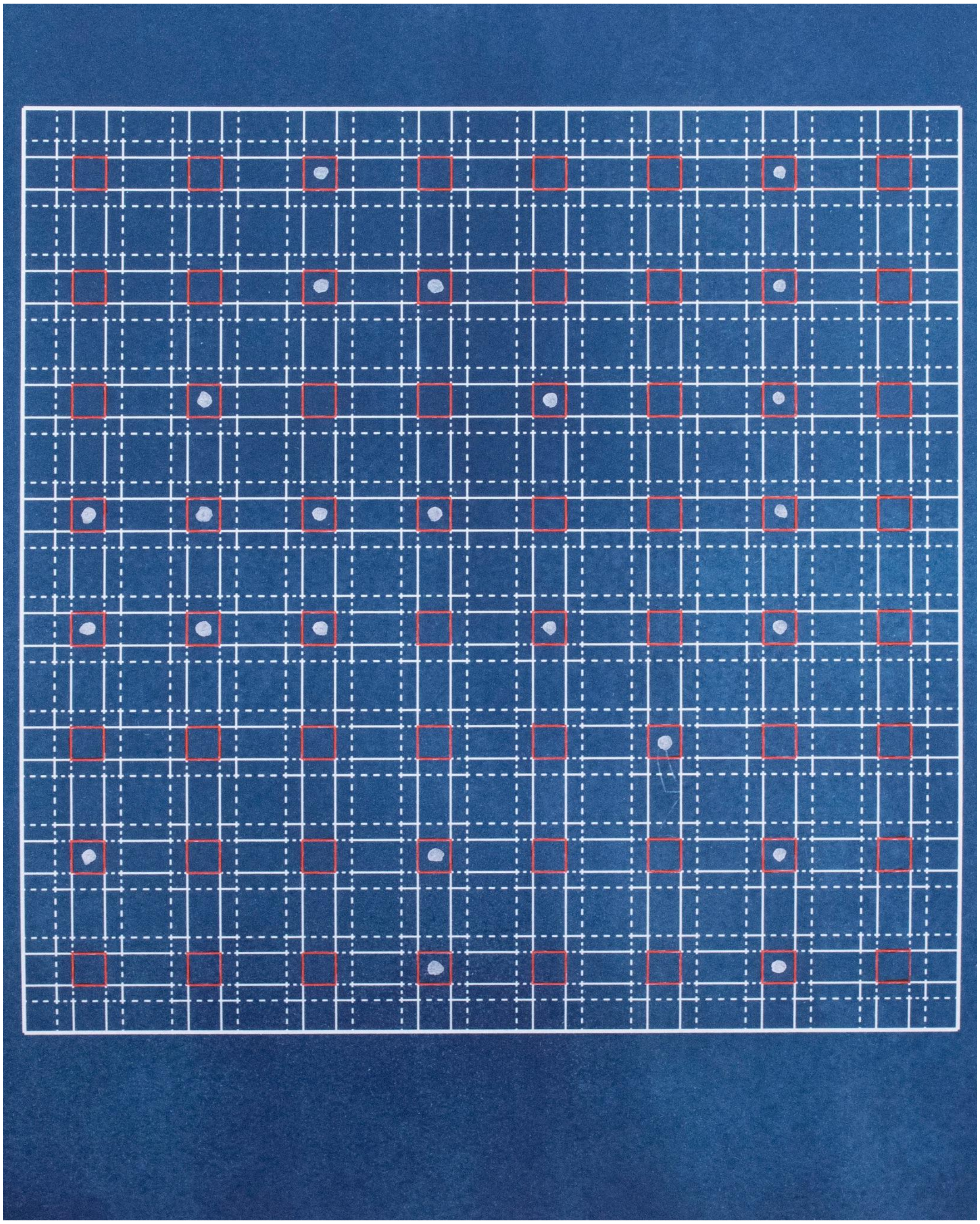
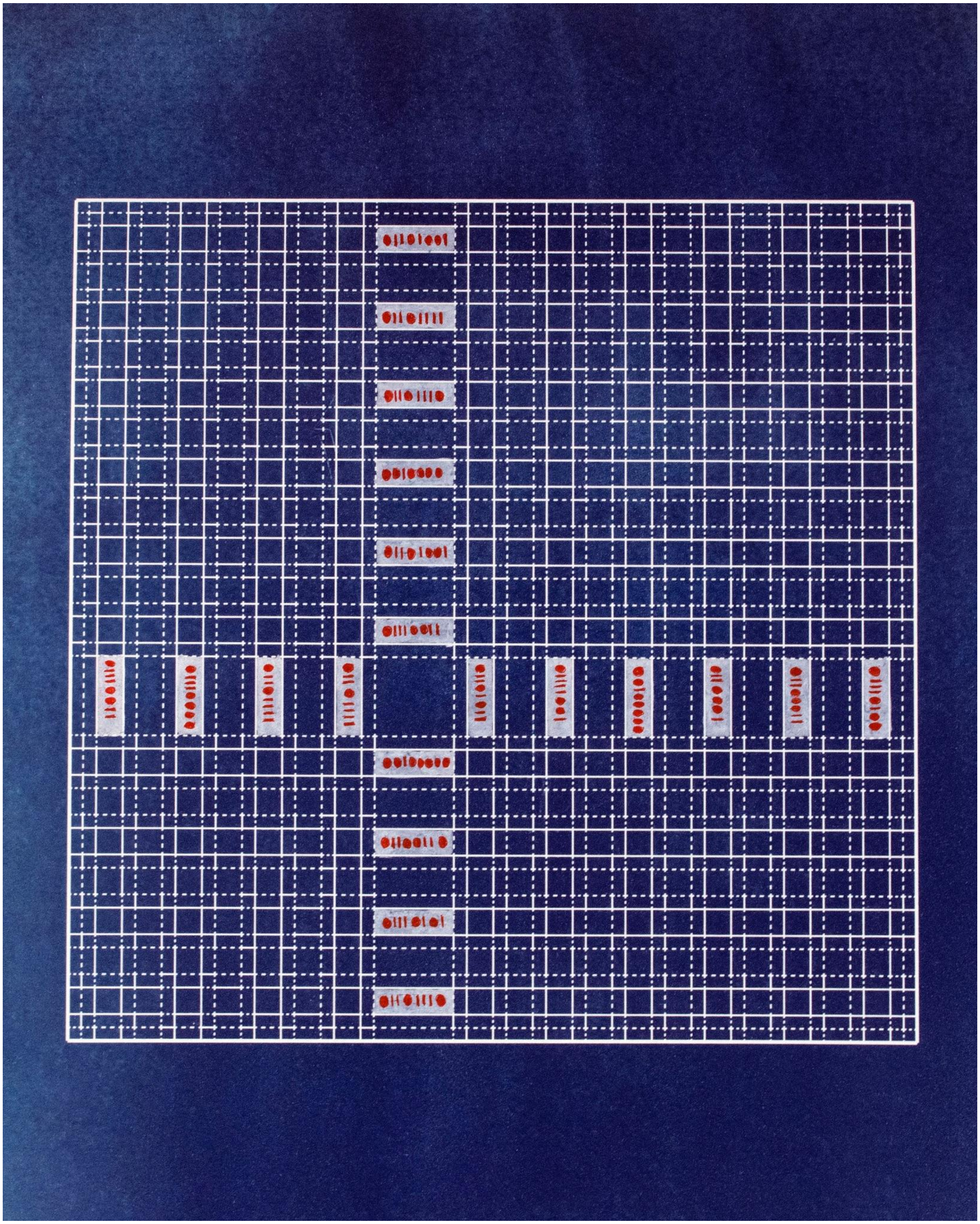


Fig. 8 Crease Pattern Vector

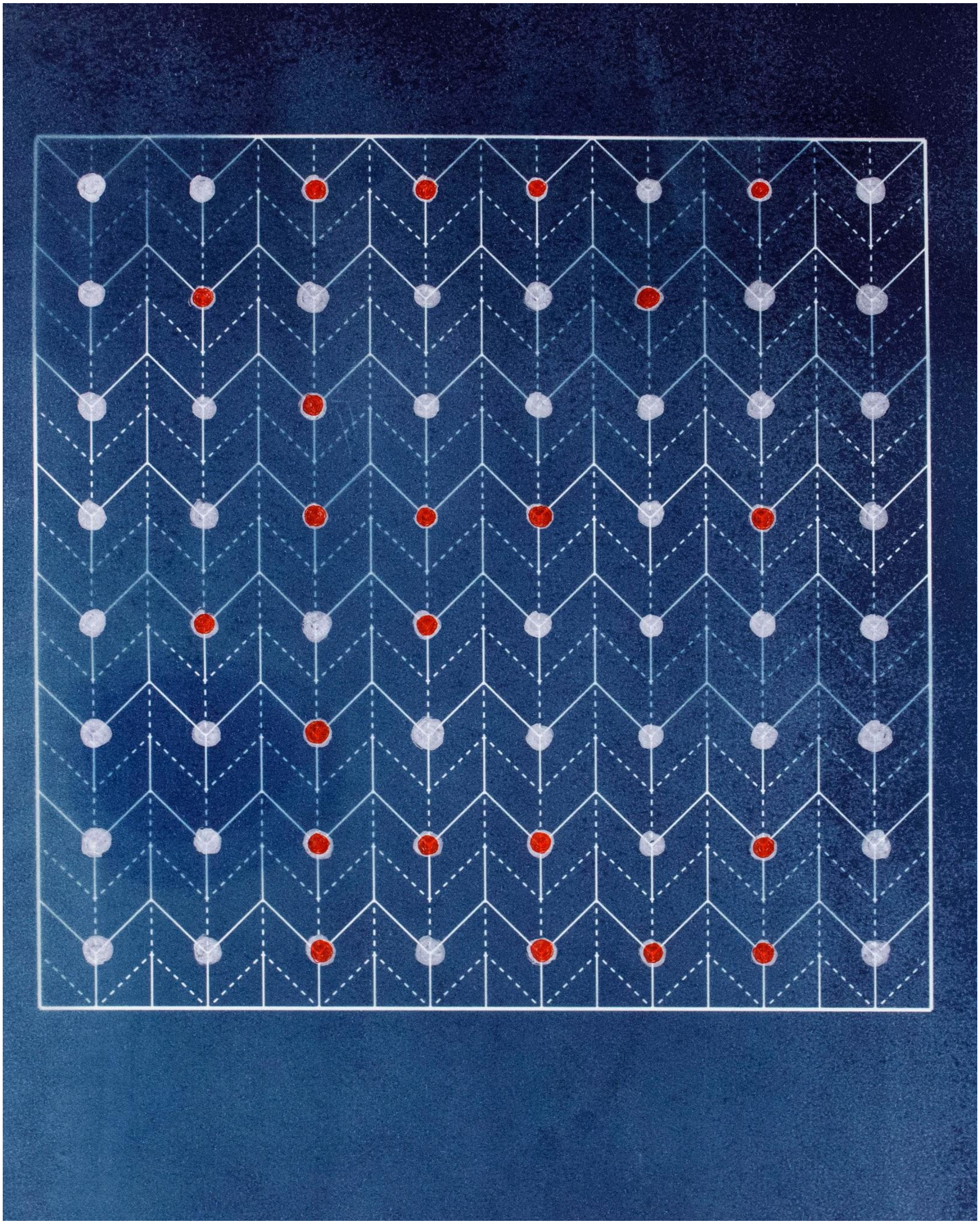
This process of seemingly arbitrary decisions produced exactly the type of “digital glyph” I was aiming for. The cyanotype itself is an actual blueprint whose instructions can be followed to recreate my initial folded form. This base cyanotype is meant to provide an anchor for the viewer by calling on the cultural familiarity of the blueprint. From there the viewer can cast their curiosity a little farther by asking questions about the drawn elements. Why is the red ink paired with the blue of the cyanotype? What does the pattern of dots (or squares, circles, etc.) say in binary? How do I even translate that information? These are all questions that of course have answers in my mind, but will never be available to the typical viewer.



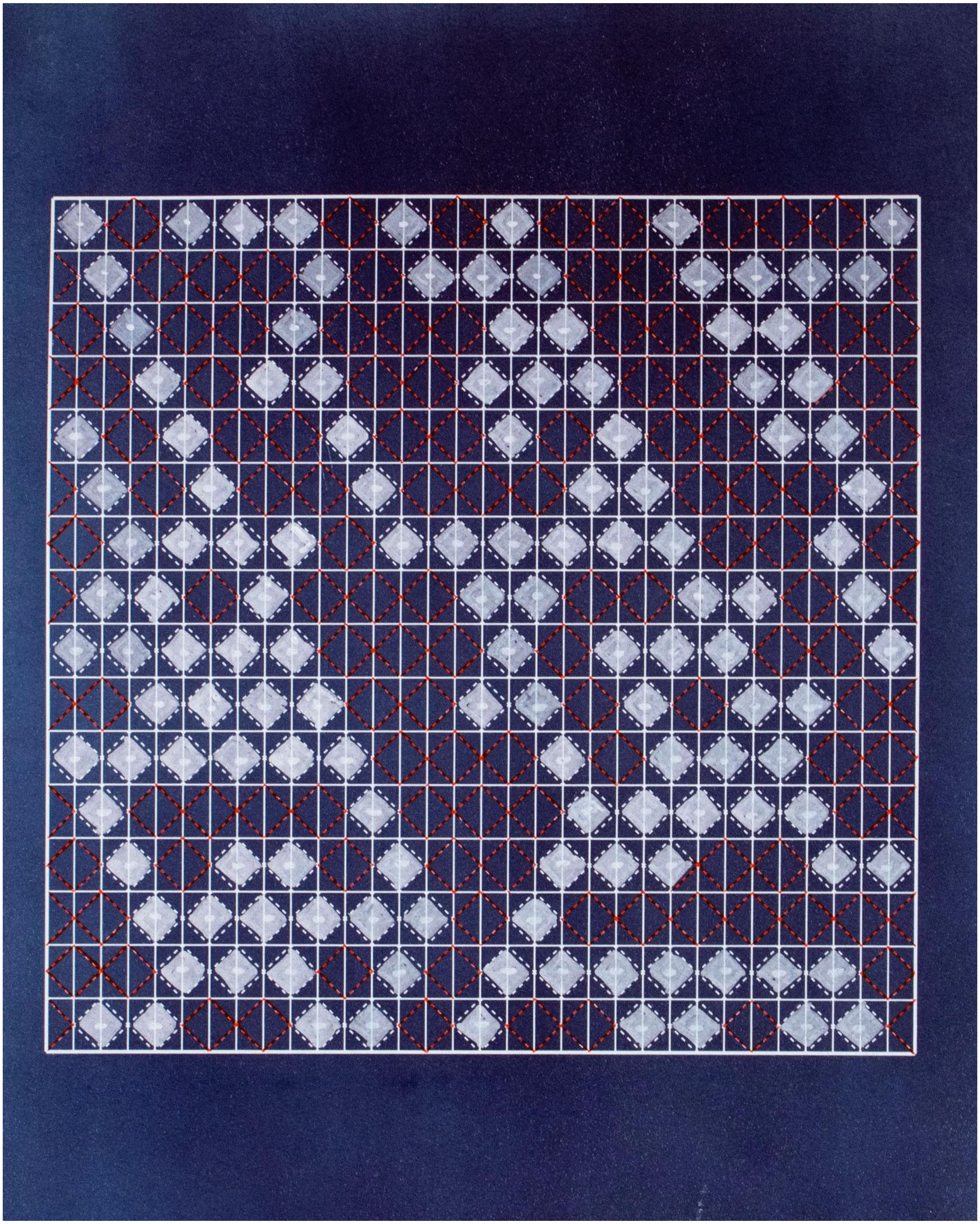
Pla. 1 *Opus 00110001*



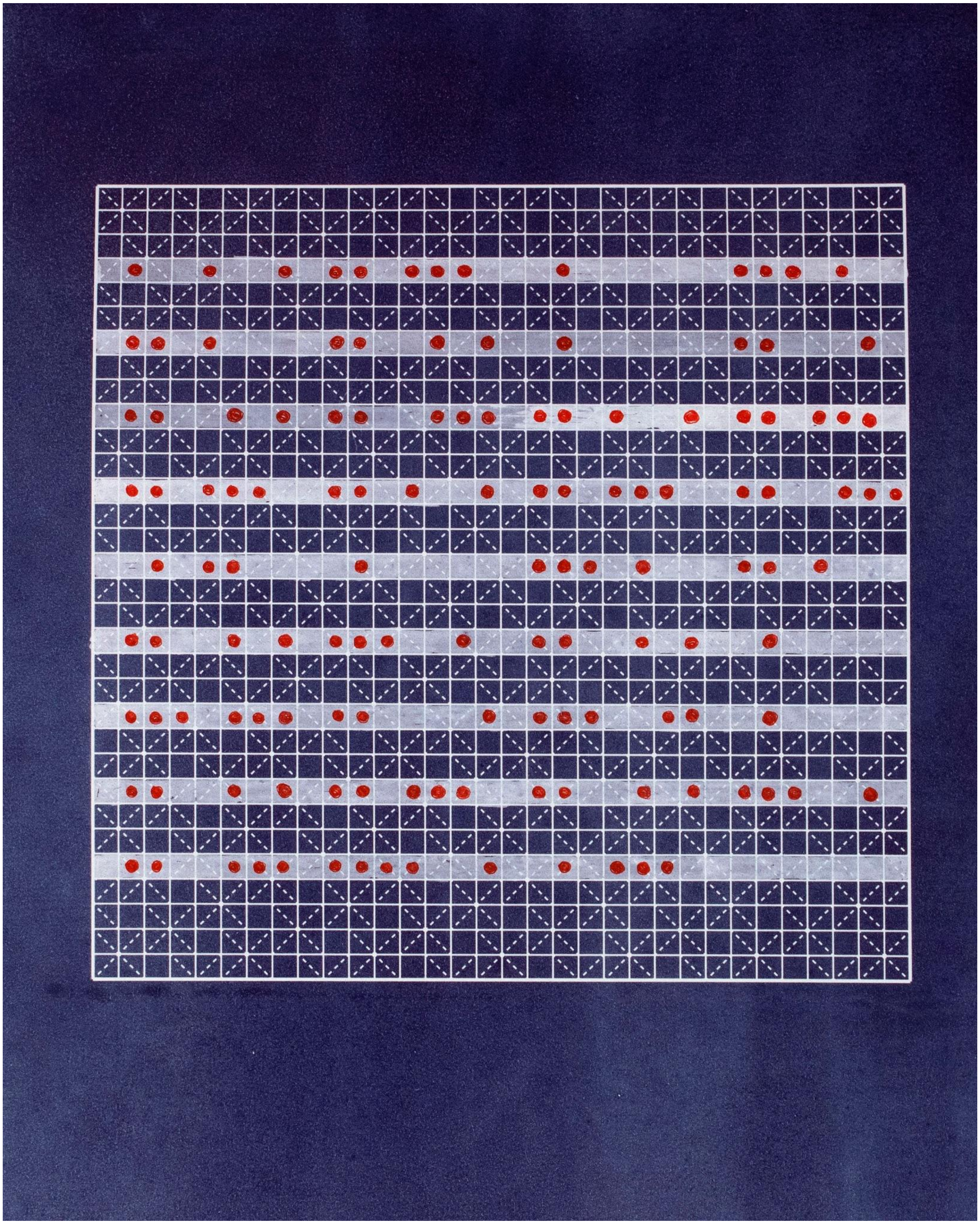
Pla. 2 *Opus 00110010*



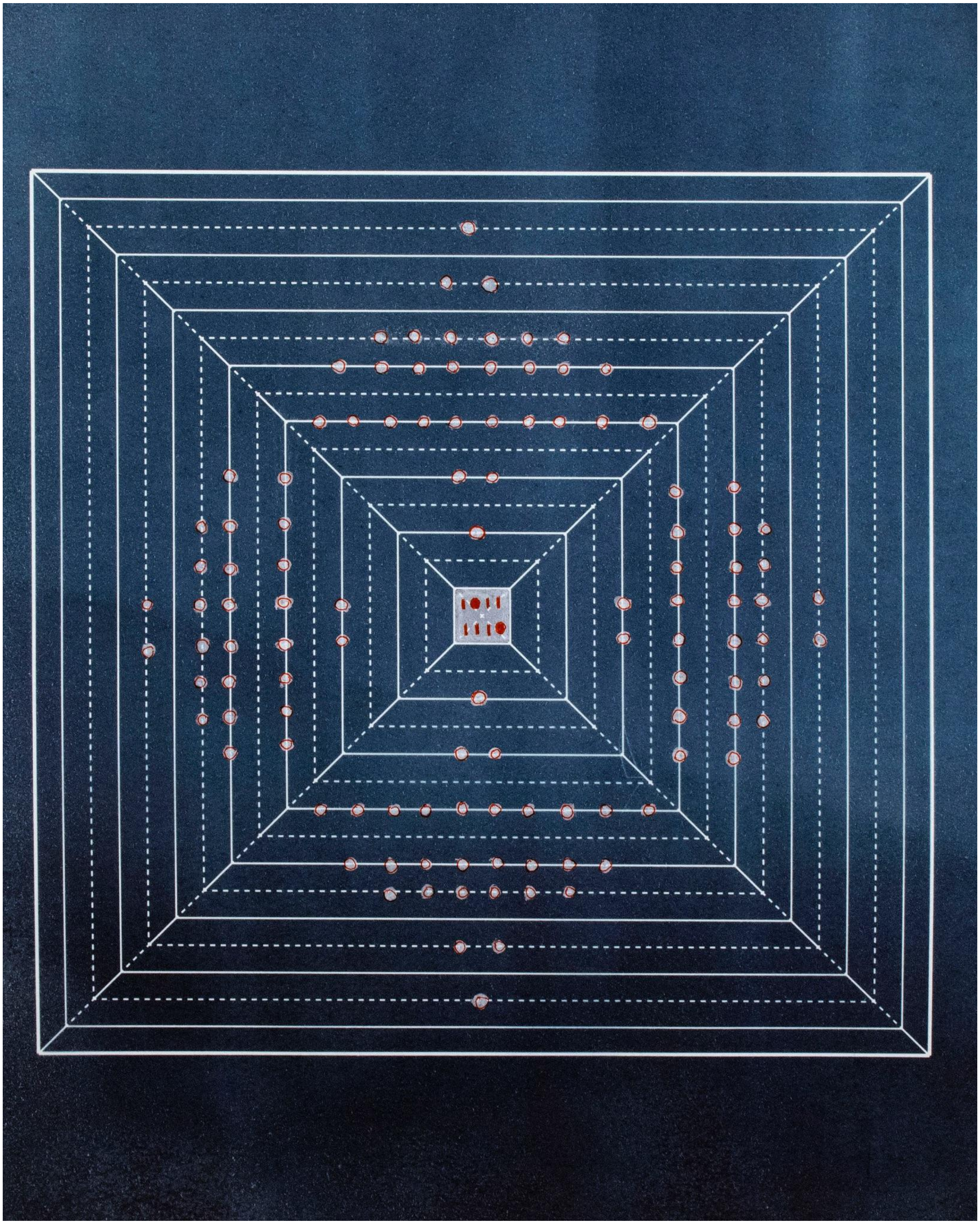
Pla. 3 *Opus 00110011*



Pla. 4 *Opus 00110100*



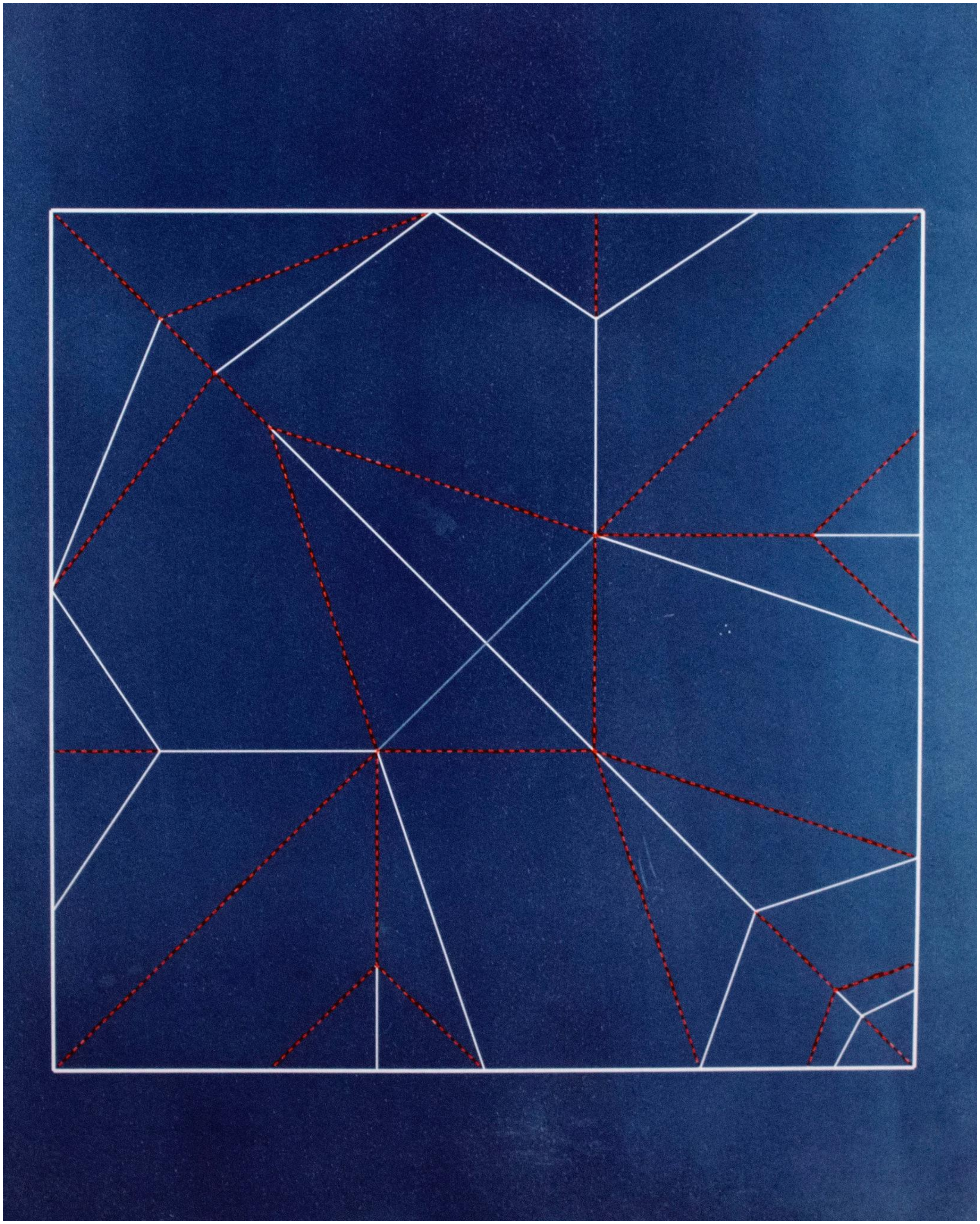
Pla. 5 *Opus 00110101*



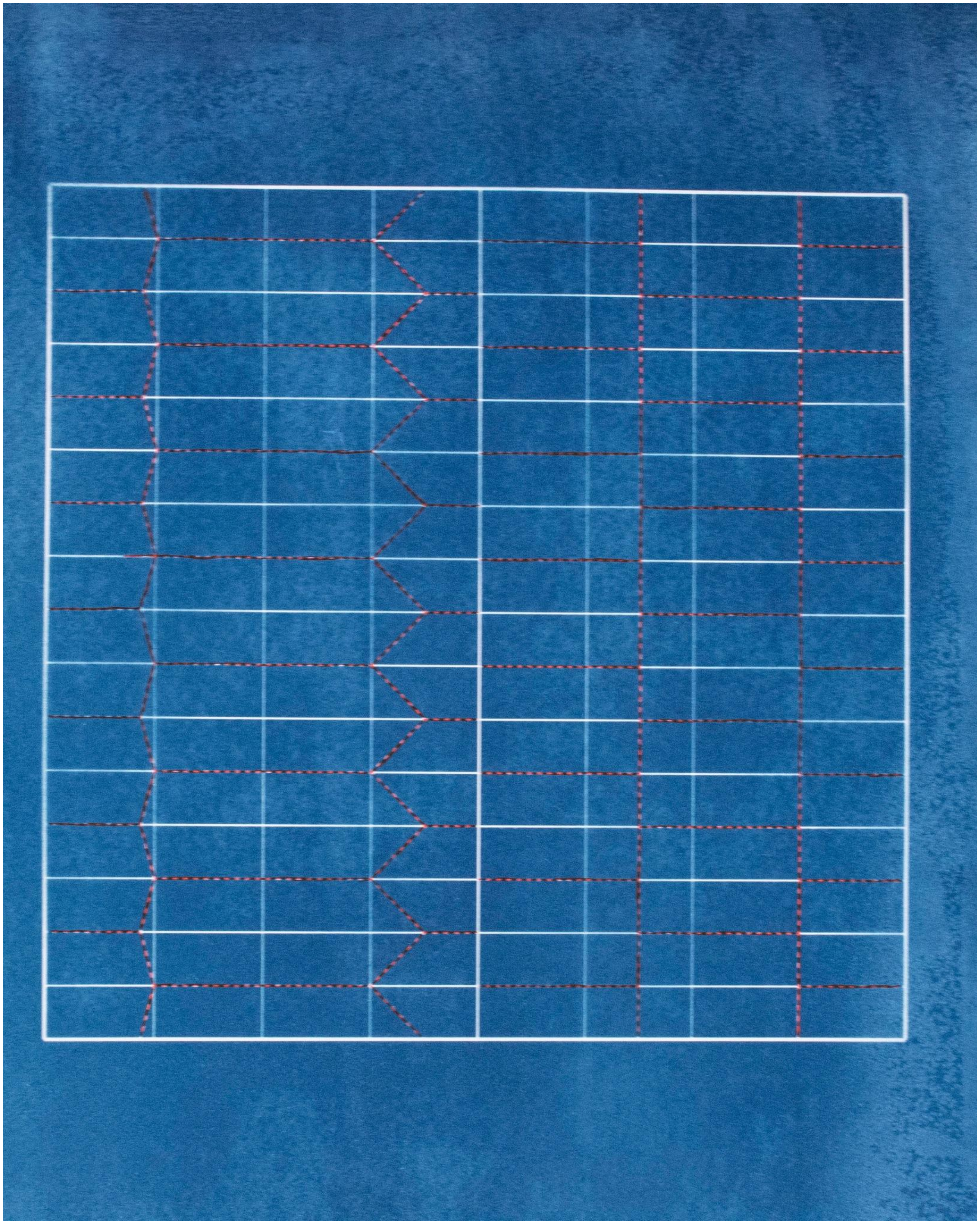
Pla. 6 *Opus 00110110*

I see this too as a thematic echo of my relationships with the people around me. Only those who are close to me and exist within my small sphere of influence are the people who can say that they “know” me. In a similar manner, only those with a like-minded curiosity will attempt to decipher the messages and jokes hidden in my work. Like in my own life, it is these people who can claim to “know” me through my work. And while I expect that to be a small number of people, I consider every person who is curious enough to even ask a question a success in communication. For these reasons, the first six pieces became the core around which I would build the rest of the work.

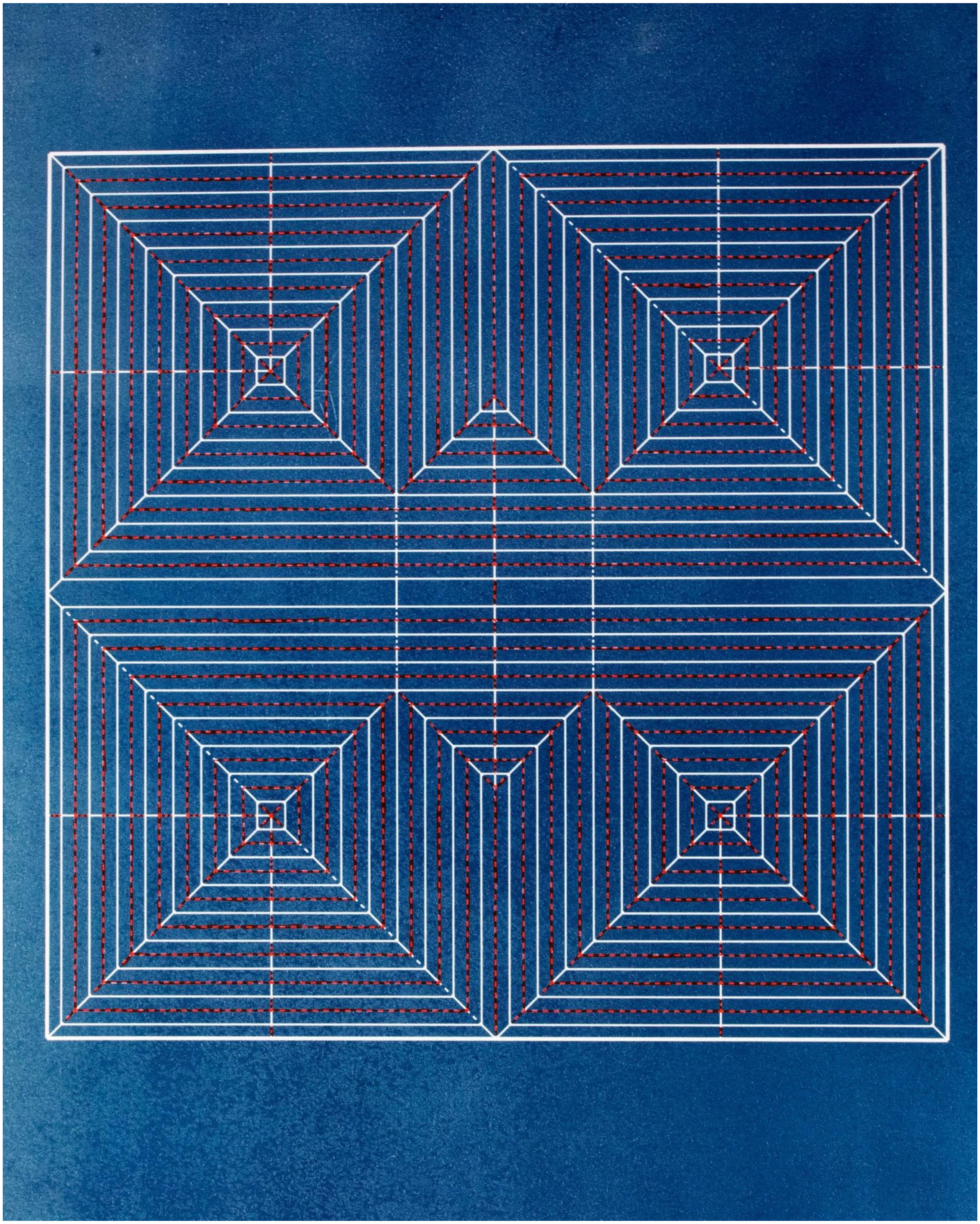
I also wanted to give the audience a visual representation of the pure fold information contained in a crease pattern. The next set of cyanotypes would address that desire. For these, I started with some of my favorite objects to fold from my childhood. From there I created more crease patterns, but these would not have information encoded in them further. Instead I would draw attention to the two folds by altering the dotted lines of the valley folds to be red. This highlights the binary information that is already encoded within a crease pattern and also echoes the standard color coding of folds, with blue usually representing valley folds and red, mountain folds. Some of these cyanotypes were developed with accompanying companion pieces in mind. These origami objects are the folded versions of this second set of crease patterns, but they appear in varying stages of completeness; again showing the process of converting information from one form (the lines of the crease pattern) to another (the three-dimensional paper forms).



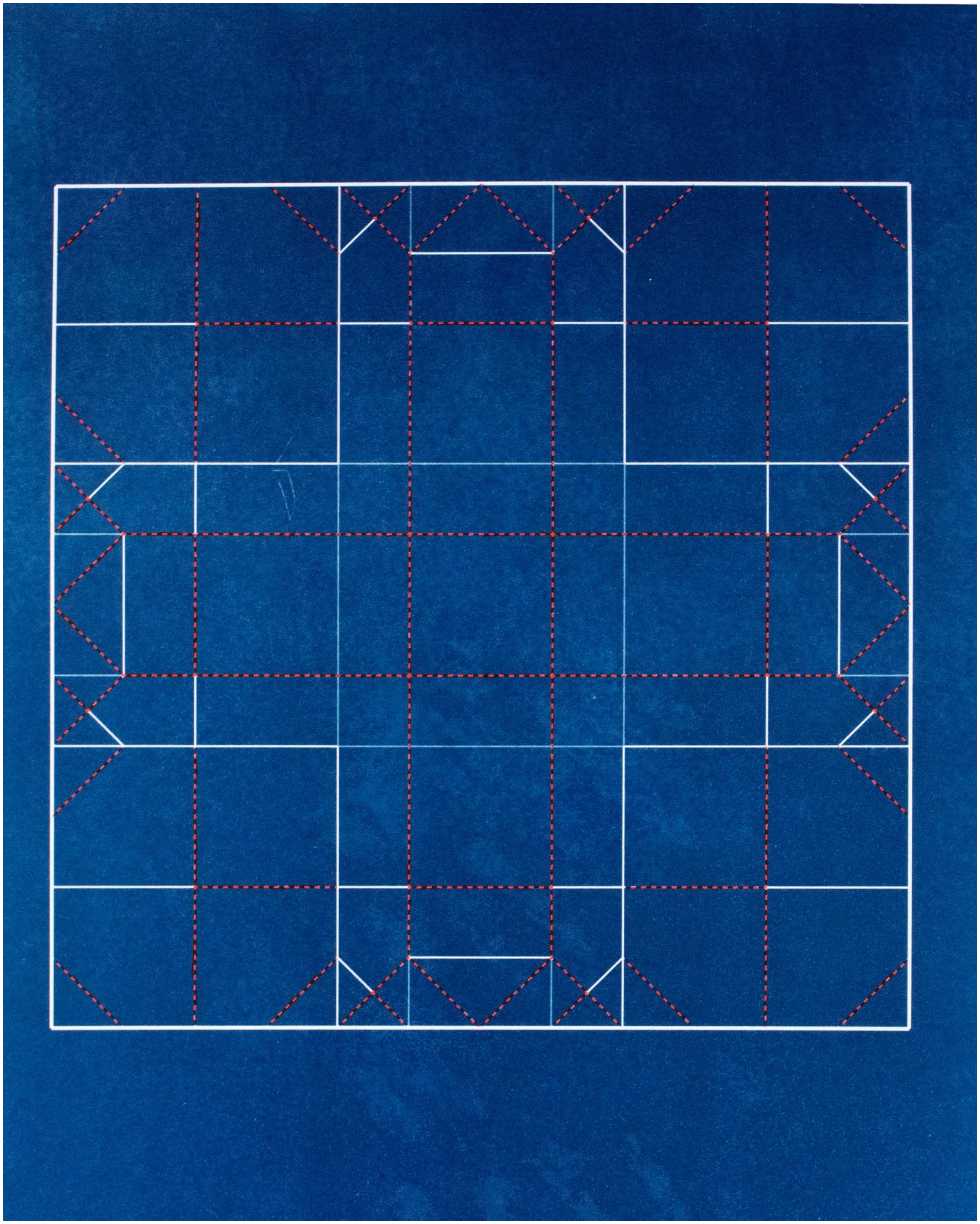
Pla. 7 *Opus 00110111*



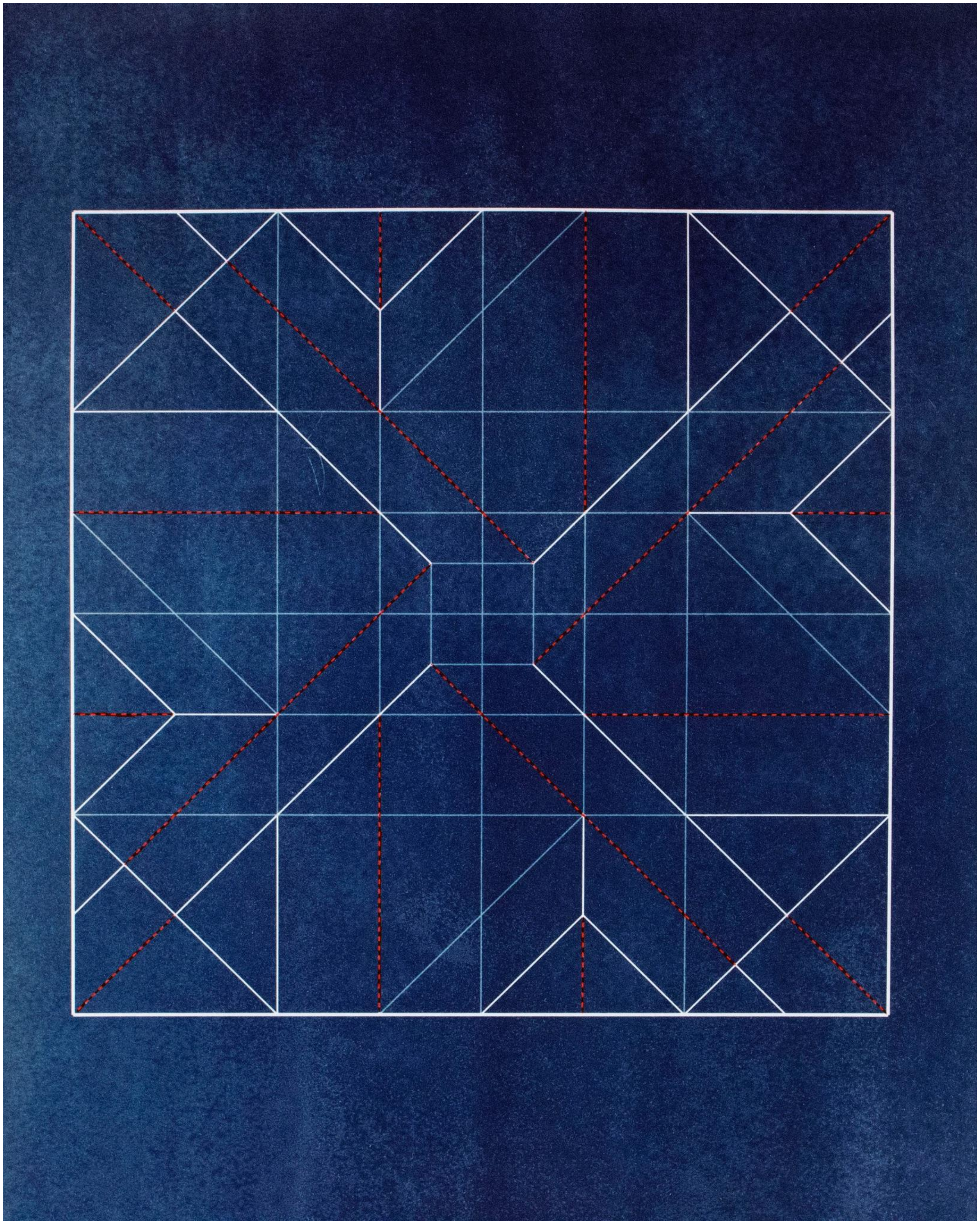
Pla. 8 *Opus 00111000*



Pla. 9 *Opus 00111001*

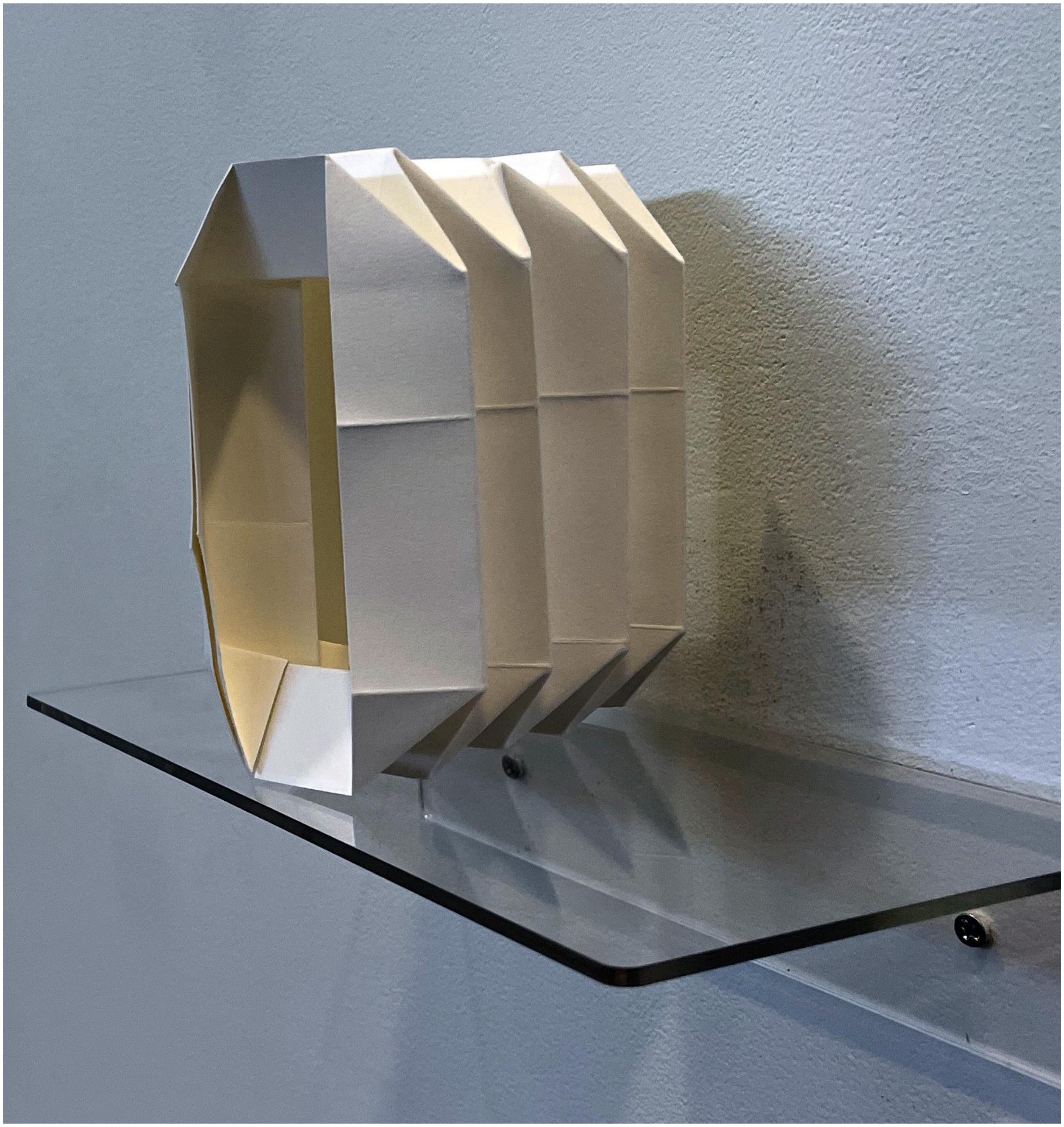


Pla. 10 *Opus 00110001 00110000*

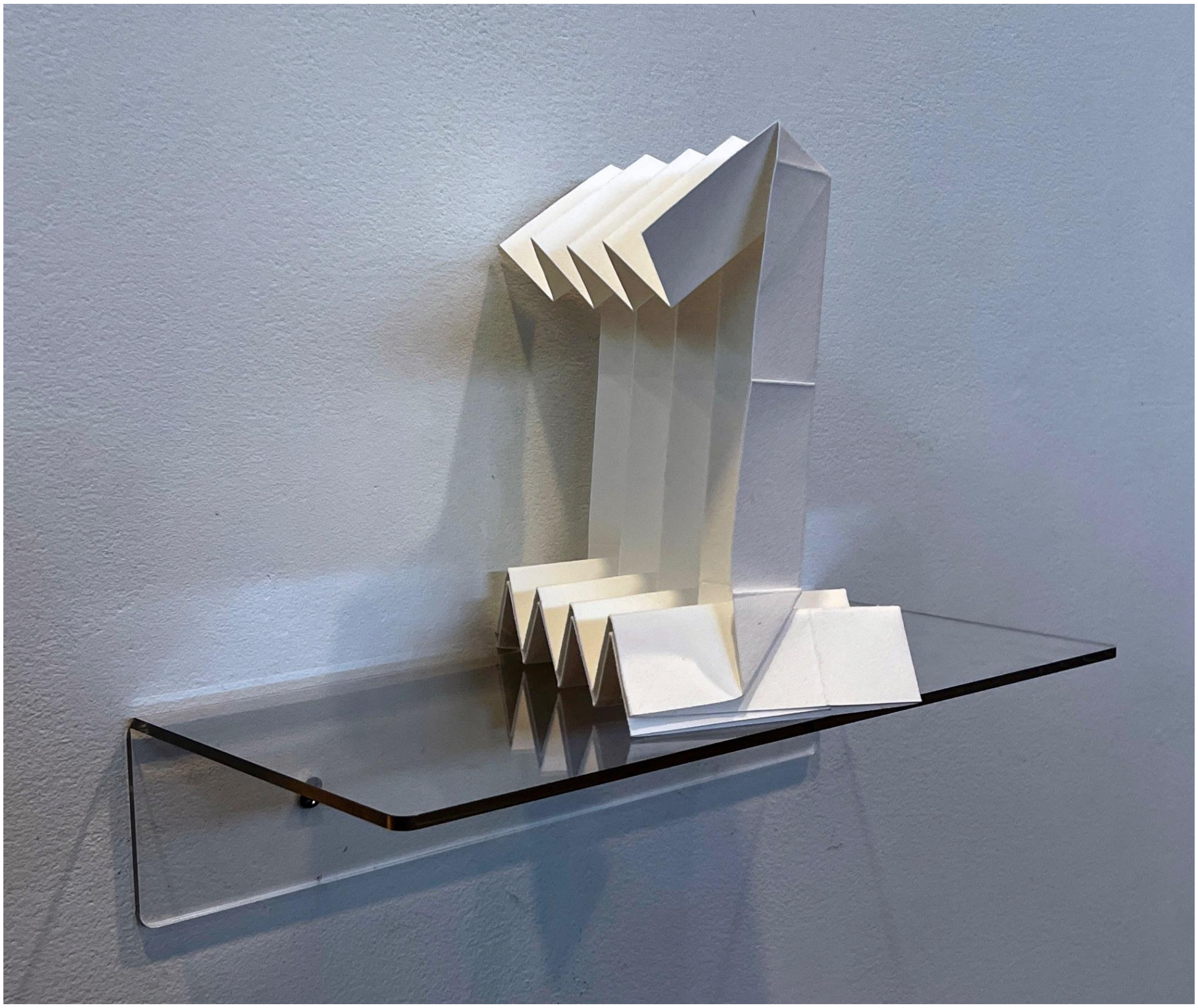


Pla. 11 *Opus 00110001 00110001*

Pla. 12 *Opus 00110001 00110111*



Pla. 13 *Movement 0. Opus 00110001 00110101*



Pla. 14 *Movement 1. Opus 00110001 00110101*

Pla. 15 *Opus 00110001 00110011*

Pla. 16 *Opus 00110001 00110010*

In addition to the cyanotypes, I created pieces that use individual units, known as sonobe units, that can fit together in a myriad of ways to produce complex shapes and structures (fig. 9). For *Opus 00110001 00110100* (pla. 17) these same units come together to create a field of geometric shapes that also contain binary hidden within the structure of the piece. Some of the units are made of cyanotype coated paper and are thus much darker in value than the rest of the stark white units. In this way, a pattern of binary again builds to encode information across the surface of the paper. This piece is also meant to represent the great emptiness of space and how matter, the “stuff” that makes up all things in the universe is but a small fraction of the whole. The dark blue units amongst the field of white echoes that disparity between empty space and space that is filled.

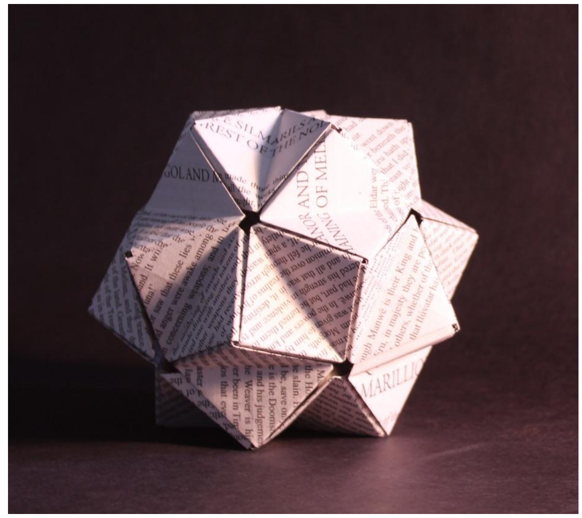
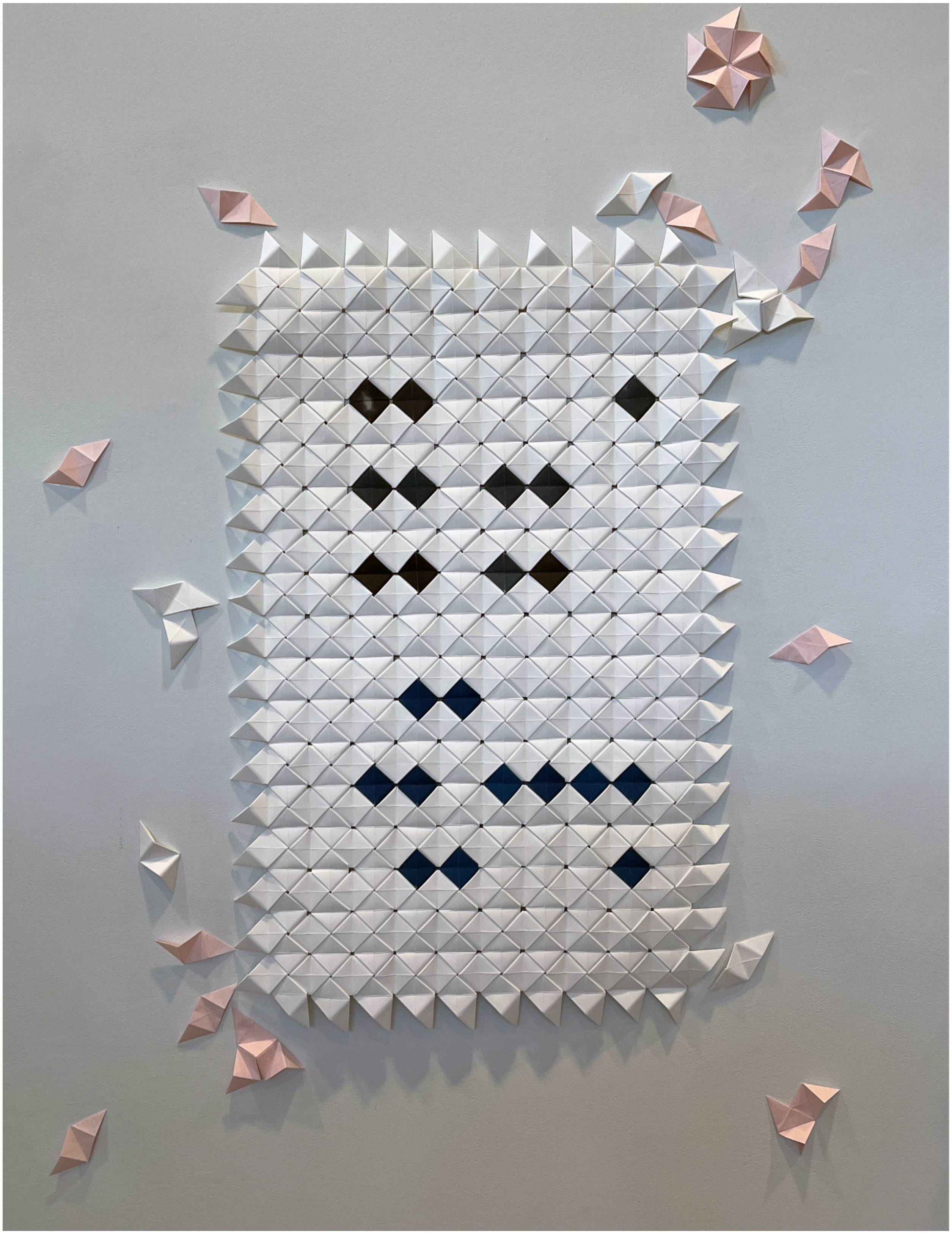


Fig. 9 Sonobe unit sphere

Of all of the pieces in this body of work, this is the one that strayed away from my original vision. I had intended for the piece to be more sculptural with undulations and bulges. Many factors, including concerns about the space in which it was to be hung and the need to work on a grid, ended up limiting my options regarding the piece being less three-dimensional. I did succeed in creating a modular piece that included a binary message, but the large scale and sculptural elements that were sacrificed might have allowed the piece to be more of a focal point.



Pla. 17 *Opus 00110001 00110100*

CHOOSING POST-POSTMODERNISM

The emerging artistic and cultural movement known as post-postmodernism is one that seeks to go beyond the skepticism and irony of postmodernism, and reassert the importance of values, such as morality, spirituality, and community. It is characterized by a renewed interest in the sacred, a rejection of the relativism of postmodernism, and a focus on the human subject and its relationship with the world[5]. In many ways post-postmodernism is a response to the failures of postmodernism and a way to move forward in a more constructive and positive way.

It can be difficult to discuss post-postmodernism because the movement is only in its infancy. Rather, much of the discussion of critics and philosophers tends to focus on the problems with postmodernism. Many critics like David Holt hold that postmodernism has failed as a movement[6]. In particular it has failed in two ways that my work tries to address. First, postmodernism's emphasis on differences has led to a breakdown in communication. Postmodern art tends to have a call to action but because little care or thought is put towards the way in which that call is communicated, many audiences feel as if they are being yelled at. In this way postmodernism is like a PETA (People for the Ethical Treatment of Animals) ad; you might abhor fur farms but seeing a fox skinned alive might only sicken you. Eventually people turn themselves off to such communication. Post-postmodernism is more concerned with the way ideas are communicated. Much of the art emerging currently is a return to methods of communication that fosters a sense of positivism while also potentially calling to action.

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[5] Hassan, Ihab. "The Question of Postmodernism." Performing Arts Journal 6, no. 1 (1981): 30–37

[6] Holt. "Postmodernism: Anomaly in Art-Critical Theory." *Journal of Aesthetic Education* vol. 29, no. 1 (1995): 85–93

Also many postmodern artists express a distrust of science and a rejection of evidence-based knowledge. I hope to prompt a curiosity in the audience that leads to a greater awareness of and openness to new ways of talking to each other. In that respect my work is explicitly using science as the basis for a game of rules that only I know. In doing so I am following centuries of tradition as artists have hidden messages in their work for a very long time. Using modern forensic techniques scholars have discovered music encoded in Da Vinci's "The Last Supper"[7] or what is guessed to be Van Eyck's portrait in the mirror of his "Arnolfini Portrait." But instead of hiding a message in a larger work, my pieces turn the written message itself into art that hides the subject. Instead I focus on trying to prompt curiosity about the way the message is being communicated rather than what the message says. The work seeks to provoke new inquiries in the minds of the audience that are more fundamental and recognizable than anything that is overtly personal about me or my life. For this reason I feel that my work sits comfortably within the new movement of post-postmodernism.

[7] Shaw. "You probably had no idea that there are secret images hidden in these 14 famous works of art." *Insider*, (Sep 19, 2019) https://www.insider.com/hidden-images-in-art-2018-1

END

For most of my life and during my undergraduate degree, I made work based on my interests, but also work that played to my strong eye for drawing and my sense of color. There was only one problem; I never felt truly invested and interested in my own drawings. This body of work, while still incorporating aspects of my personality and humor, feels very different. I feel as if I have unified several areas of interest that have been partitioned within my brain for a very long time.

I have not met many artists who are also passionate about science and mathematics, though I am beginning to find them as I talk about this body of work. Those artists that I am finding who share these interests often tell me that they feel like they need to keep those two aspects of themselves separate. I felt much the same when I began attending ECU in the fall of 2020. This work has freed me from that particular self-imposed constraint. The more surprising aspect of the work is the fact that it (quite unintentionally) became a self portrait. As I worked on the pieces, communication was always the most important aspect of the work, not the message itself. So I chose dad jokes and puns as the information that I would hide. Over time, however, I came to understand that these humorous inclusions, coupled with my desire to fold paper and my fascination with the cosmos on all scales, culminated in a near complete picture of who I am.This body of work represents an excavation of my own personality and desires, especially surrounding topics that I find utterly fascinating. I finally feel as if I have produced pieces that are truly and thoroughly “me.”

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APPENDIX: INSTALL PHOTOS