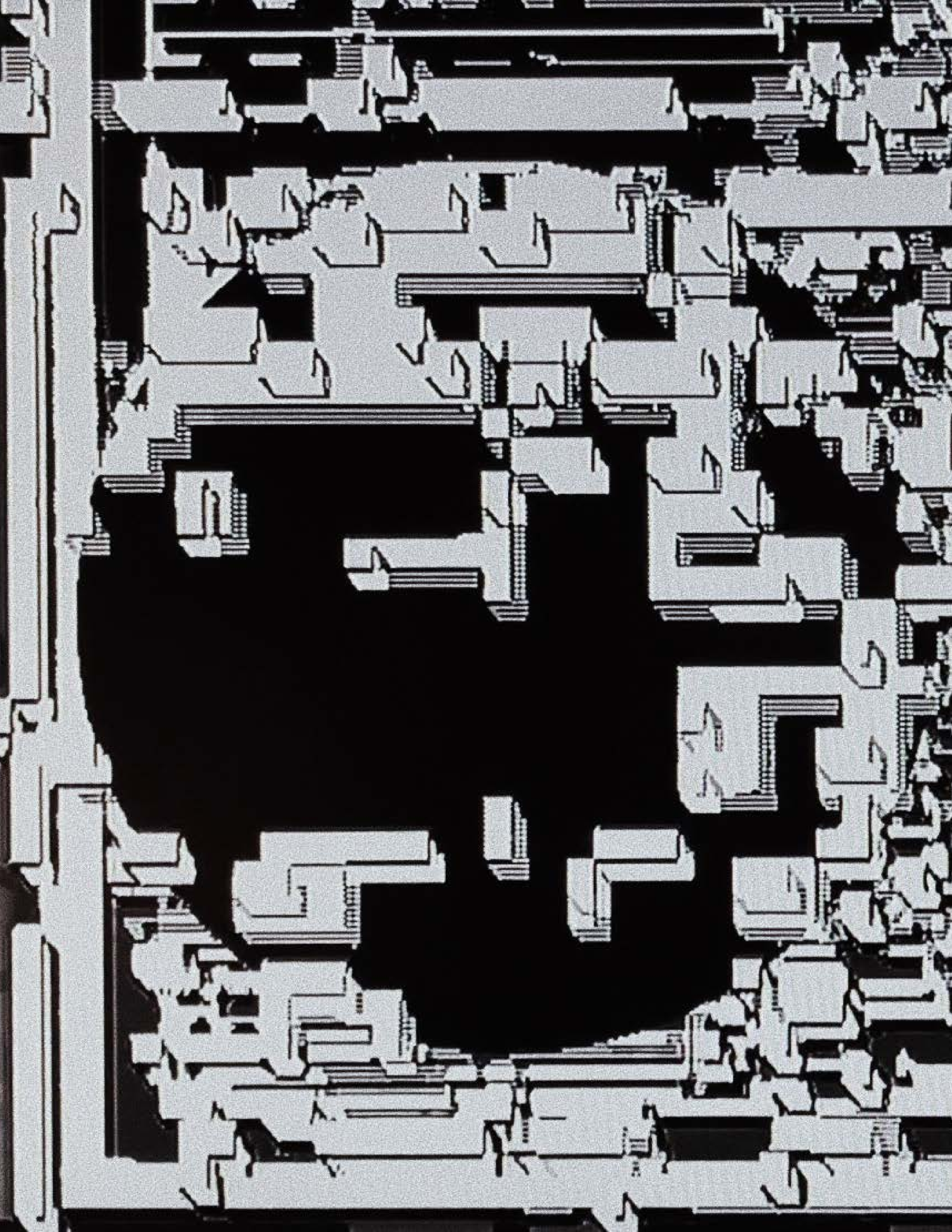
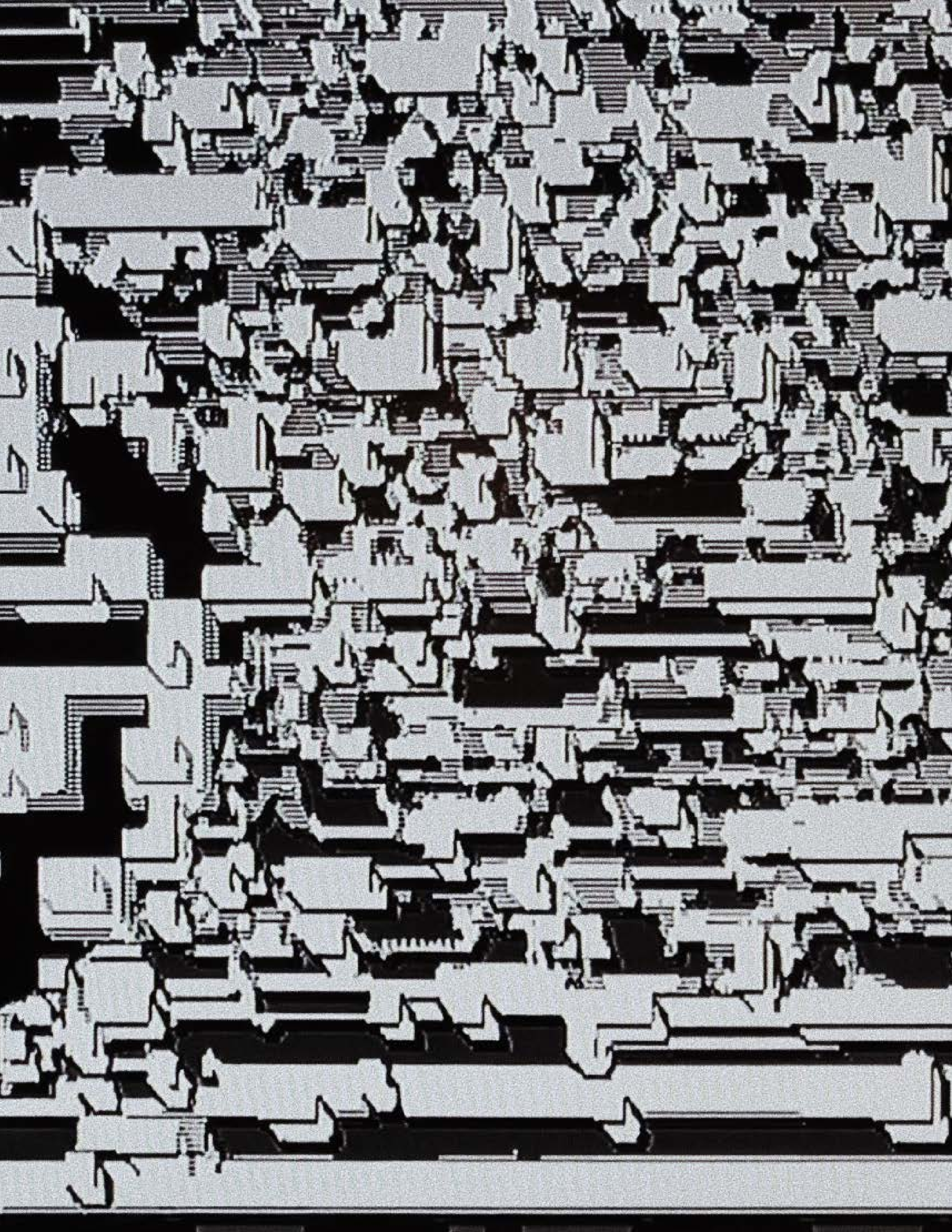
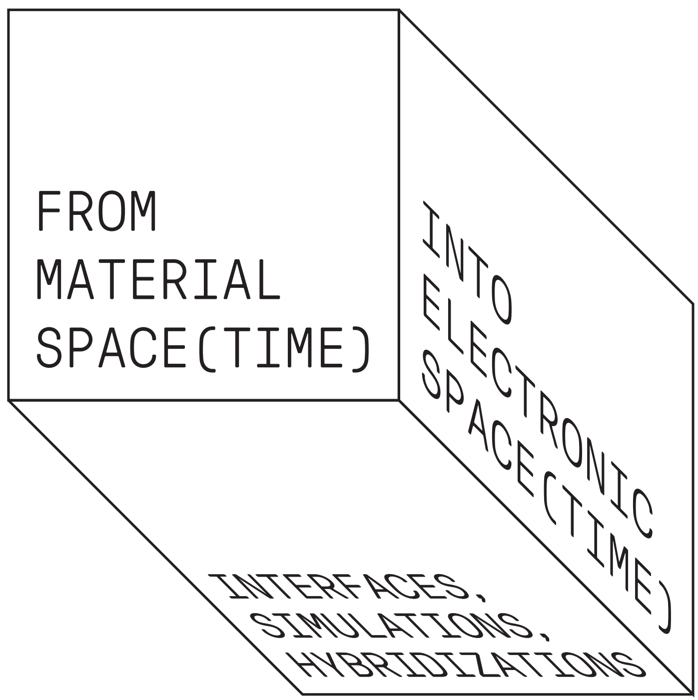
FROM MATERIAL SPACE(TIME) INTO ELECTRONIC SPACE(TIME)

INTERFACES, SIMULATIONS, HYBRIDIZATIONS

Paloma Kop



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PALOMA KOP

Expanded Media
School of Art & Design
New York State College of Ceramics
Alfred University

Thesis Book
Master of Fine Arts in Electronic Integrated Arts
Department of Expanded Media at Alfred University
Committee: Andrew Deutsch, William Contino, Eric Souther

Digital PDF edition

Paloma Kop
Alfred, NY, USA
July 2020

http://palomakop.tv/mfa

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Andrew Deutsch
William Contino
Eric Souther
Joseph Scheer
Peer Bode
Mark Klingensmith
David Toot
Joseph Kirtland
Monir Madkour
Angus Powers
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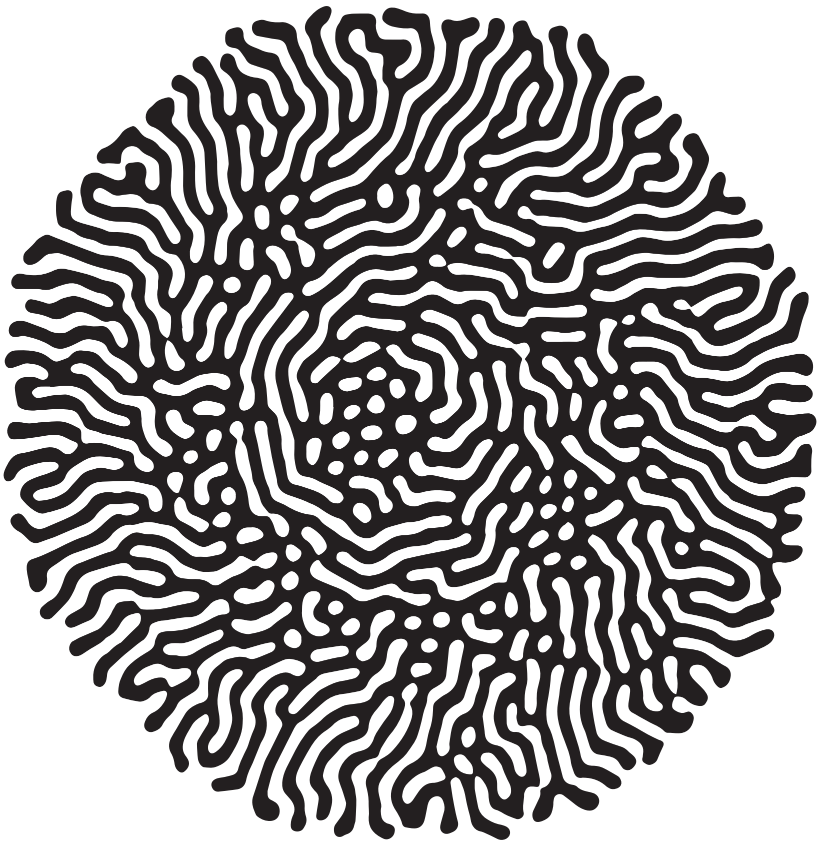
Joe McKay
Sam Horowitz
Leslie Rollins
Andrei Jay
Liaizon Wakest
Alma, James, & Leo



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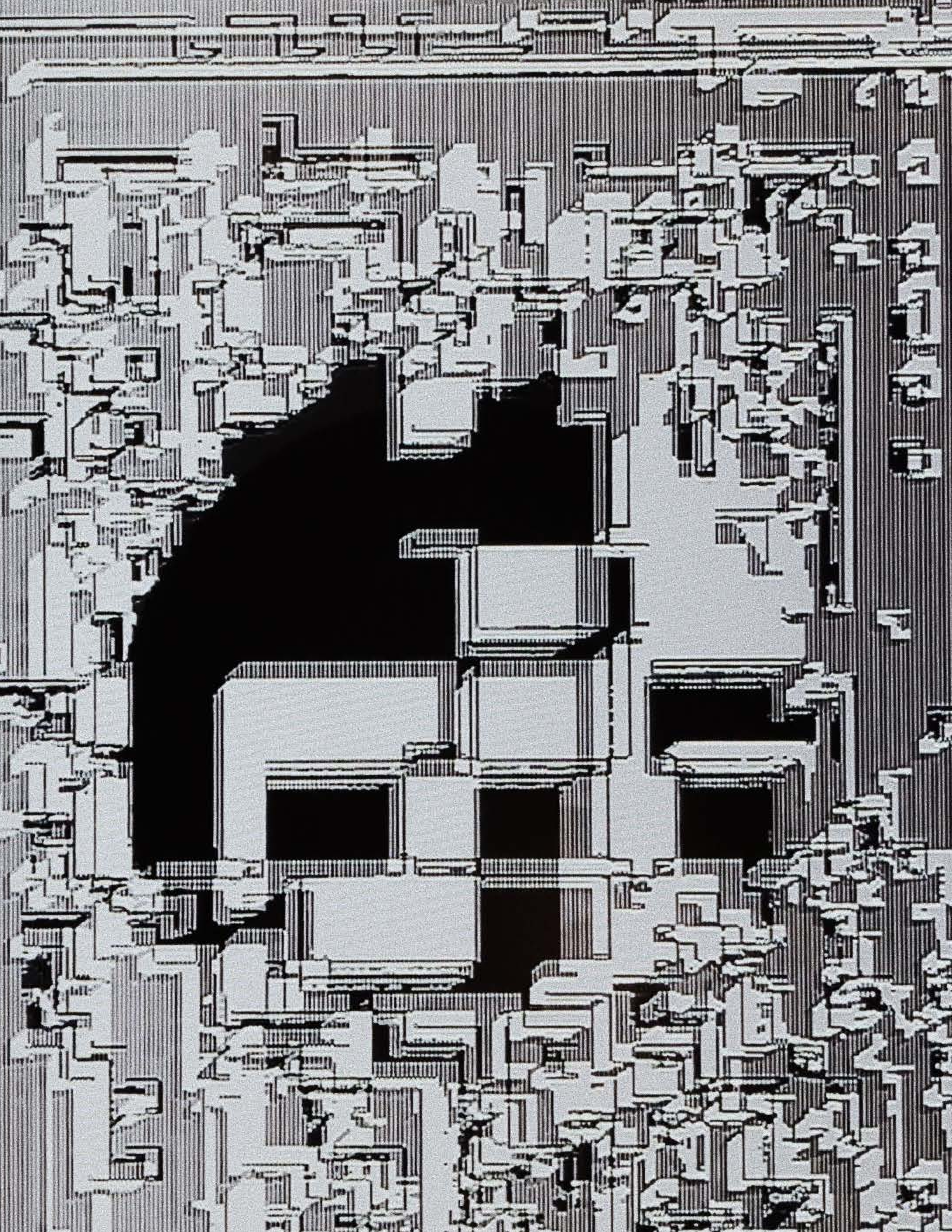


INTRODUCTION: SPACE(TIME) THRESHOLDS

The brain is an amazingly plastic organ. As human beings, our brains allow us to make observations, conduct experiments, and use the results to create a predictive map of the space-time manifold we inhabit. What we experience in the learning process (which continues throughout our lives) shapes our map of familiar concepts, and thus shapes how we perceive the world around us.

As we enter new situations and practice new skills, our minds re-shape our maps to encompass the parameters and behaviors we encounter. For example, when we learn to drive a car, our scope of self-perception expands to encompass the bounds of the vehicle. We learn just how sharply we can turn, just how small a gap we can squeeze through. We develop new techniques in maneuvering into a parallel parking spot. If we lived our whole lives in the car (and some people nearly do), our sense of our *bodies* might include the vehicle as well as our flesh and bones.

There is a concept from the mathematical field of dynamical systems theory called *phase space*, which has influenced my thinking. In phase space, the array of possible states (or *degree of freedom*) of each moving part in a system is represented as an axis of multidimensional space. So, for every specific state of the entire system, there is a single point in the system's phase space. The number of dimensional axes depends on the number of variable parameters in the system – for instance, a phase space of a really simple system, which includes 1 particle that is able to move along a line, might have two dimensions: position and velocity. Watching the path that particle traces across its two dimensional phase space (phase plane) can reveal insights about its behavior over time. In a phase portrait, we can observe all the states it occupies over time simultaneously, revealing the geometric properties of its behavior. We learn in school, in an abstract sense, that space and time are elements of the same fabric, but how often do we consider ways of translating the dimension of time into a dimension of space, and vice versa?

As babies, we develop an understanding of the world around us as a space. We humans are, first and foremost, native to material space. When we begin to acquire more abstract concepts, they can be made easier to comprehend using metaphors of space. We can apply geometric thinking to grasp abstract mathematics, or relate our lives' trajectory through time to a *journey*. The *memory palace* technique aids in memorizing information by placing it in a building visualized in the mind. We develop concept maps where each concept is organized by proximity to other concepts in a concept-space. Of course, the dimension of time is implicit in these metaphors as well – I use the term space(time) rather than simply space, to make this relationship more explicit.

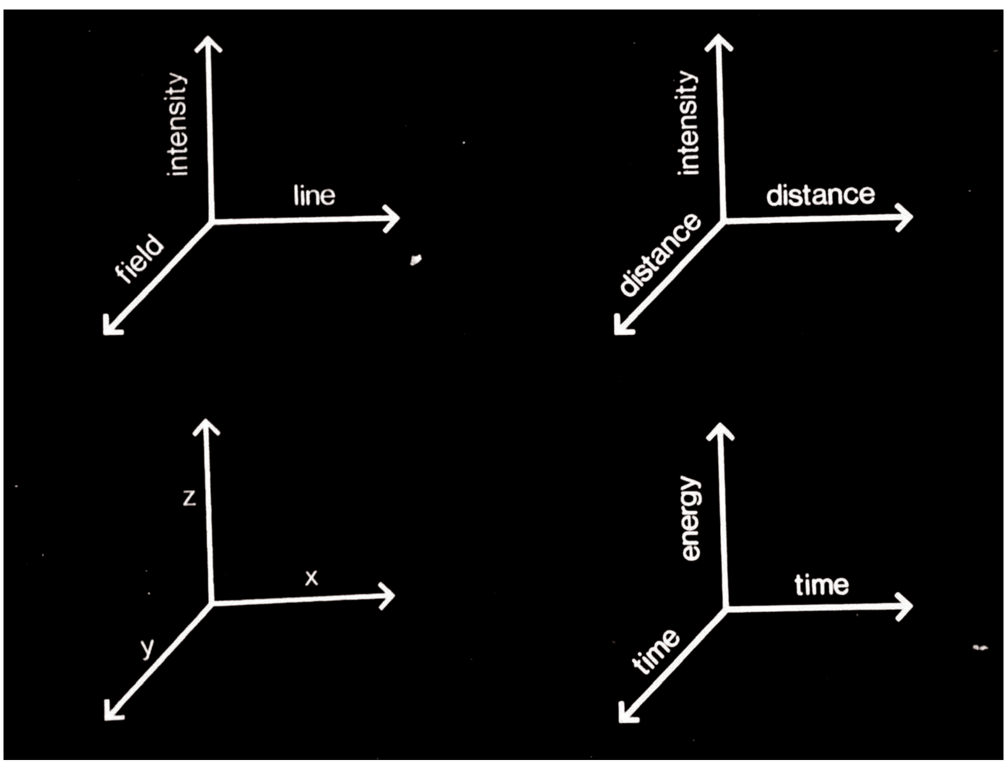


Figure 1. *Some alternate descriptions of the x-y-z grid, from* <u>*Buffalo Heads*</u> *(404)*

The development of electronic equipment and networked computer systems has led to a new conceptual type of space(time), which is here called electronic space(time). In popular culture, the concept of *cyberspace* permeates all dramatized depictions of computers and the internet. *Virtual reality* as it is portrayed in this media bears no relation to existing physical space; one must leave their existing body behind to enter it. These metaphors are not limited to sci-fi; ordinary civilians can *surf the net*, or land on someone's *homepage*. Relating interfacing with an electronic system to moving through physical space aids in bringing the experience closer to familiarity and tangibility. These concepts are separate from the existence of electronic components that form these systems in physical space, similarly to how people prefer to imagine a person's consciousness as separate from their physical bodies: their complexity and depth as systems seems to beg some conceptualization beyond these entities as the sum of their parts.

As an electronic media artist, I have grown exhausted of what I see as a false dichotomy between material space(time) and electronic space(time). One metaphor that seems to feed reductionist stereotypes of electronic arts is the term *IRL* or *in real life*, as contrasted with anything taking place on a computer or digital system. One incredulous stranger, after learning the subject of my studies, wondered aloud: *So it isn't even an object?* In fact, all computer systems are objects, even the ones marketed as the cloud. The artificial boundary between these two spaces is purely for the convenience of our understanding of how we interact with them, as we navigate trees of choices and decisions.

In my artistic practice, I assemble systems, and then I explore them. Through the process of improvising, making observations, then adjusting my own strategy based on those observations, I begin moving around the phase space of that system, mapping it, and developing intuition about what I can do within its bounds. This is not a process specific to working with electronics. For example, when learning a new musical instrument, the practice involves a feedback loop of experimenting with different techniques, seeing what produces the results you prefer, and then repeating those techniques until you can do them the way you want every time. I have experienced this recently while exploring the phase spaces of my violin and musical saw.

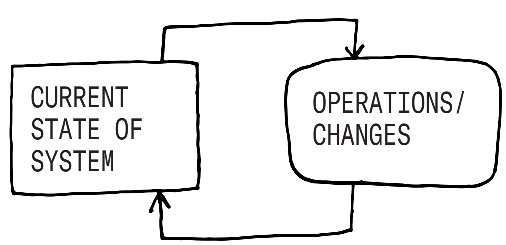


Figure 2. *Simple feedback loop*

One thing that sets electronic systems apart is the sheer number of parameters available. The exact number varies between different systems, but even in a relatively simple system, the combinatorial possibilities can be overwhelming. It takes time to explore the many-dimensional phase spaces of these systems, and find the pockets within them that resonate with me, or produce something interesting and unexpected.

Beyond manually adjusting all the parameters and settings to find singular *sweet spots*, the possibilities expand even further with the introduction of modulation sources and automations. These allow me to program one or more parameters to fluctuate over time, so that things continue to change after my hand is lifted away; the system begins to take on a life of its own, and the creative process shifts more towards setting things in motion. It is also possible to make these modulations performative, by making changes to the behavior of the modulations as they are running, resulting in a real-time hybrid performance of humans and automata. Beyond a person being *in dialogue with the machine* as described by Steina and Woody Vasulka, we can view them as a combined cyborgian entity.

Automations usually involve a series of pre-programmed changes over time, but another way to allow the electronic system to influence itself is to introduce feedback loops, by feeding outputs back into inputs. In this way, I can create systems that really seem to come alive with autonomously evolving intricate patterns, because they share operating principles with phenomena found in the natural world. Weather systems, turbulence in fluids, erosion leading to land formations, and arrhythmia in the human heart are a few examples. In a feedback system, the whole really is more than the sum of its parts, as the iterative process cascades into a fractal infinity like the illusion of two mirrors facing each other, opening the door to complexity and emergent behavior. The results can become nearly impossible to predict, due to their extremely sensitive dependence on initial conditions. The parallels between electronic and computerized systems of this kind and the natural world have been demonstrated extensively by John Horton Conway and Stephen Wolfram using cellular automata, as well as James P. Crutchfield using video feedback, in his paper, *Space-Time Dynamics in Video Feedback*.

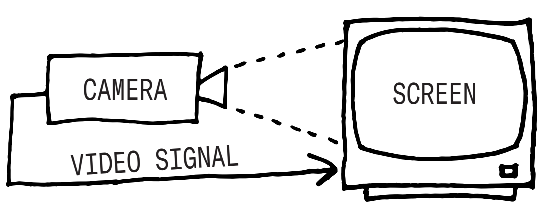


Figure 3. *Simple video feedback loop formed by plugging output of camera into screen, then pointing camera at screen*

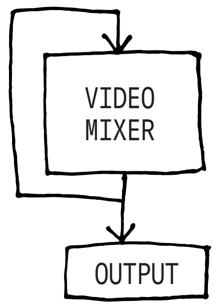


Figure 4. *Simple video feedback loop formed by plugging an output of a video mixer into an input of the same mixer*

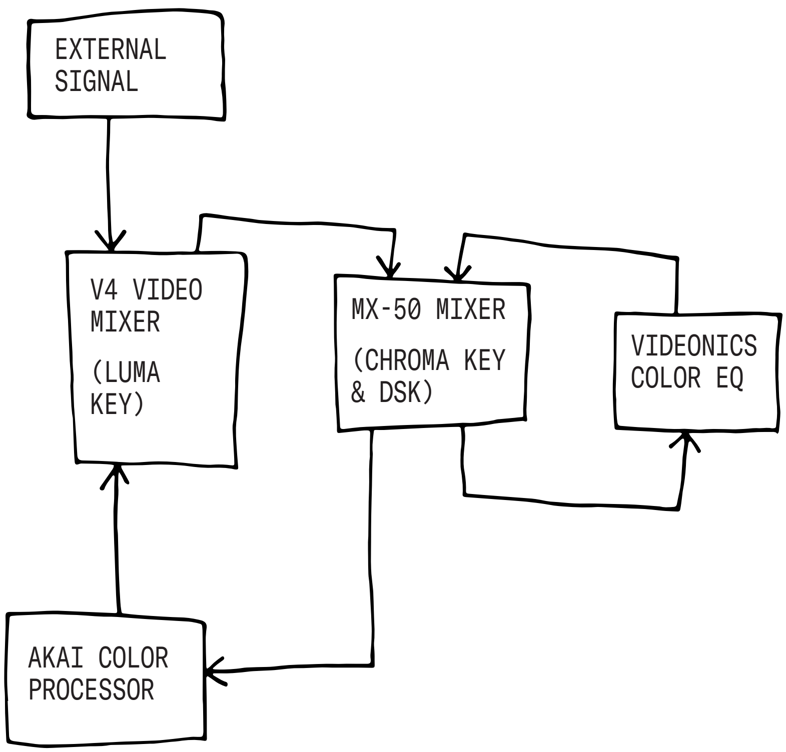


Figure 5. *"Double color feedback:" a more complex video feedback system using two mixers and two color processors.*

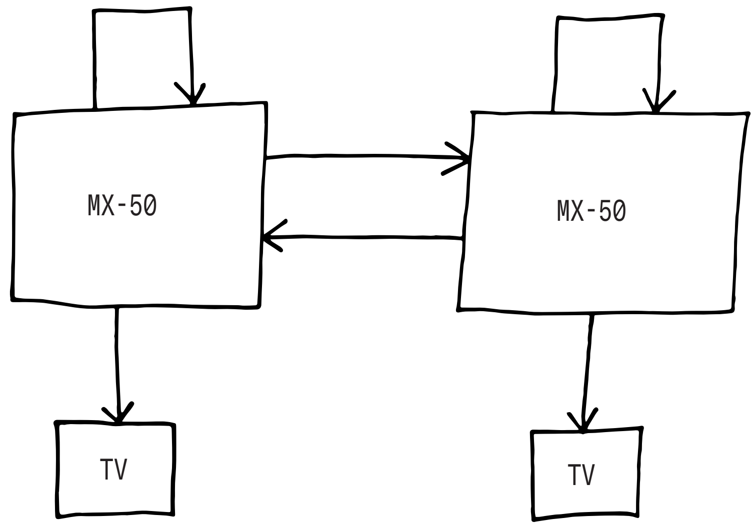


Figure 6. *"Dueling MX-50s:" a video feedback system where each mixer has its own local loop, as well as a larger loop passing through both, and the outputs of both can be viewed on a pair of television monitors.*

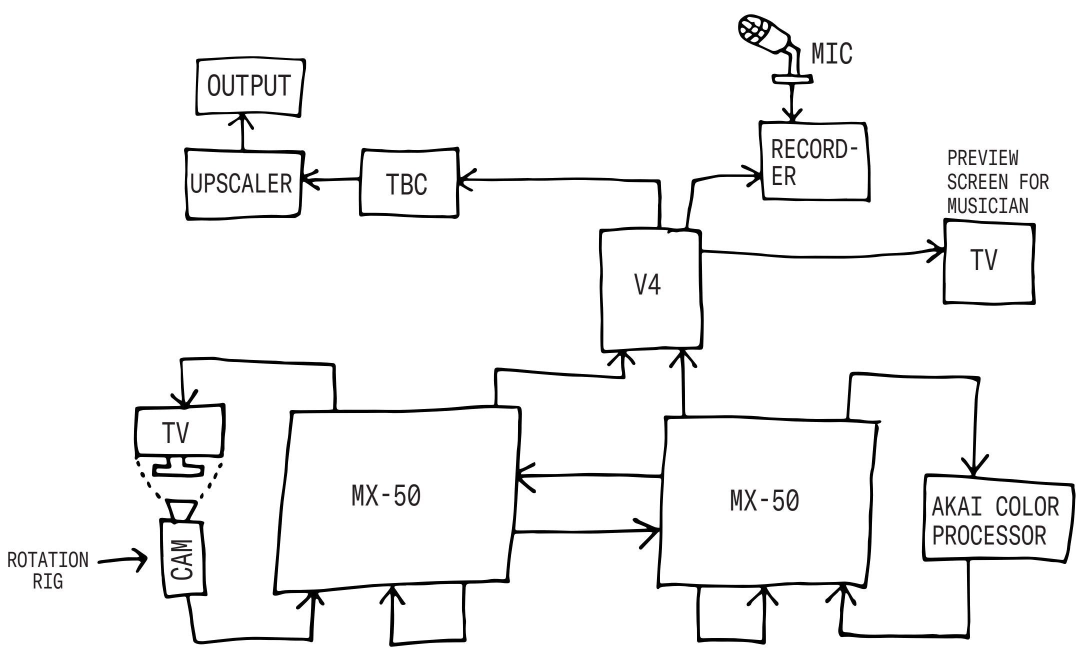


Figure 7. *A setup for an improvisational a/v performance in collaboration with musician Killick Hinds, in the Turner Gallery at Alfred University, Feb. 26, 2019*

In my practice, I think about these systems on multiple scales, since the signal flow diagrams shown are made of many smaller systems, and they are also part of a larger system in which I try out different configurations, learning each time, and finding new devices or methods to incorporate. Over the years, these systems evolve along with the materials I record from them. As various ideas are tried out, an arsenal of techniques, concepts, and aesthetic vocabularies takes shape. I have experimented with a range from material and analog processes to new media, electronic devices from different eras, and virtualized systems in code. But the systematic approach described here applies to any of these equally, as intuitions on how to interact with them are built and reinforced.

This body of work combines media and phenomena from both material and electronic space(time), in order to investigate and deconstruct the boundary between them. The works take place in a single, multifaceted space(time) manifold, which encompasses the dimensions of both, and reveals the many ways in which they overlap, interact, or enter into dialogue.

Electronic space(time) is an abstraction used to make sense of the less familiar experience of interaction with electronic systems. For individuals and humans as a whole, material space(time) comes first and becomes the default, and then electronic space(time) is encountered and annexed. Long before the emergence of digital computers, scientists developed mathematical models to help them predict and understand the world around them. But once they were able to translate their mathematical models into computational models, there was a sudden shift. The number of calculations they could run in a given amount of time exploded, allowing them to view macroscopic behaviors that contradicted their previous intuition. This led to the emergence of chaos theory and nonlinear dynamics, which proposed a new view of the universe as unpredictable and erratic, with tiny changes in initial conditions leading to huge shifts in the final outcome of a system. So, even early on, the expansion of human consciousness into electronic space(time) irrevocably altered people's view of their original home, material space(time).

When models of the natural world are entered into a computer system and set to run, a virtual environment is created. The programs evolve according to algorithms that represent our understanding of the mathematical behaviors of the natural world. By translating these models into electronic space(time), we may lose some detail in favor of abstraction, but we gain a godlike power over these virtual domains. We can slow things down or speed them up (within the limits of our computing power) in order to perceive greater detail or run many different possible scenarios in a short amount of time. We can freeze time, or sometimes even reverse it. We can view objects from the inside-out, create visualizations of data on as high or low a level as we please, or alter the fundamental laws of physics as we know them. We can set a system in motion and watch things evolve, and test whether the rules we propose fit with our experience of the material world, or create generative simulacra that exist only in our electronic world.

There may be phenomena from material space(time) which cannot be modeled in this way. The possibilities for our electronic universes are limited according to computability theory, and throttled by the capabilities of our current hardware. However, the scope of what we can perceive and control is transformed so significantly that there is an incredible potential for gaining new insights into familiar things, and expanding the scope of our imagination. As humans gain fluency at navigating electronic space(time) and translating things back and forth across space(time) thresholds, we become increasingly able to make ourselves at home in a unified space(time) encompassing matter, information, computation, and mathematics. Letting go of the stigmatized view of electronic space(time) as a feeble imitation of the *real world*, we can appreciate it as an expansion of possibilities, with very real effects on the world.

There are already areas in which physics and the study of computing overlap. Information theory, a field introduced by Claude Shannon to mathematically quantify the phenomena of signal processing and data compression, has become important in theoretical physics and string theory. The concept of information entropy has been applied in physics to reveal paradoxes inherent in quantum mechanics that string theory is attempting to resolve. A central question is whether matter — or the information it contains — can truly be destroyed when passing the event horizon of a black hole. In areas such as the holographic principle, physicists have developed methods of analyzing matter in regards to the information it contains; all the details about the positions and states of every particle in the universe can be viewed as data.

For some, this further provokes the question of whether life as we know it may be taking place in a computer simulation. I prefer the interpretation that there are universalities which transcend whether a system is physical or virtualized on a digital computer. This means that humans, in developing systems of computing, have stumbled upon a process of world-creation.

PART I

VIDEO

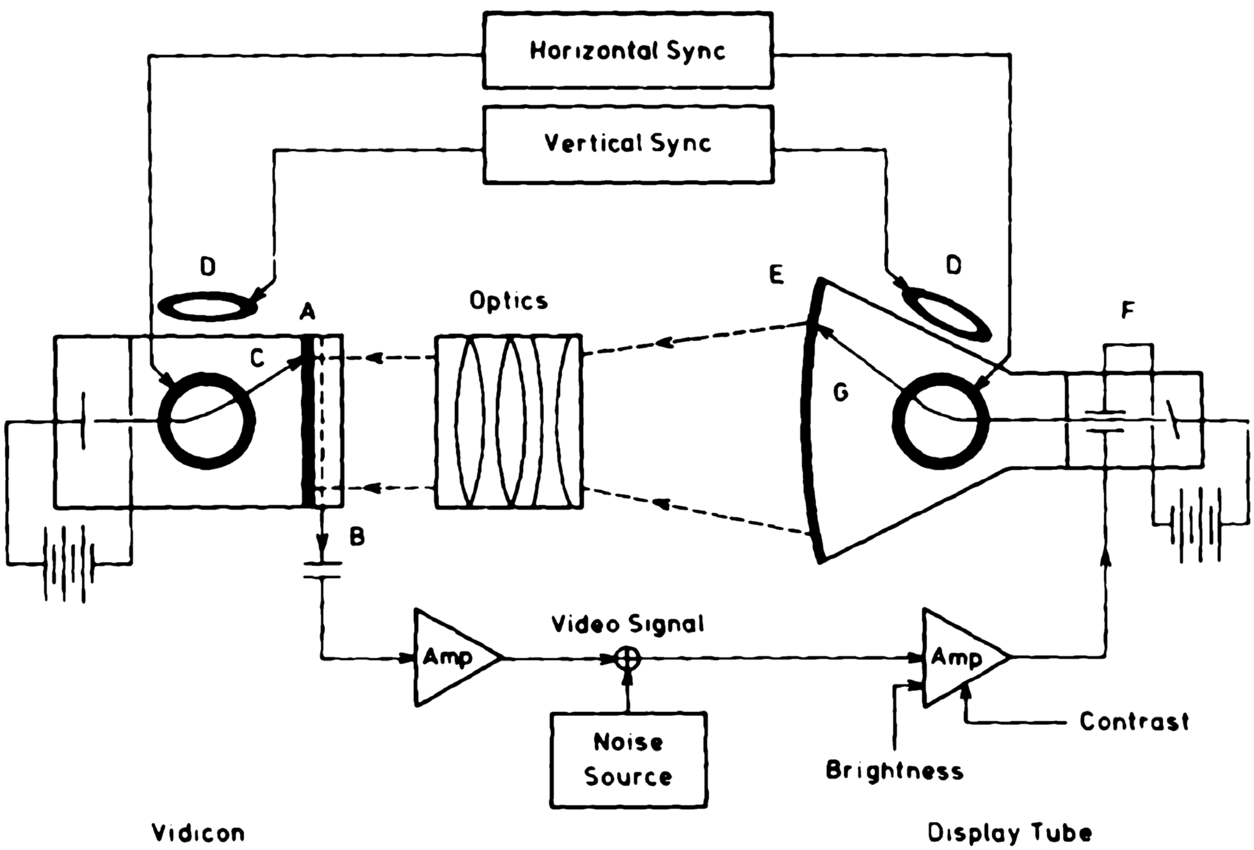
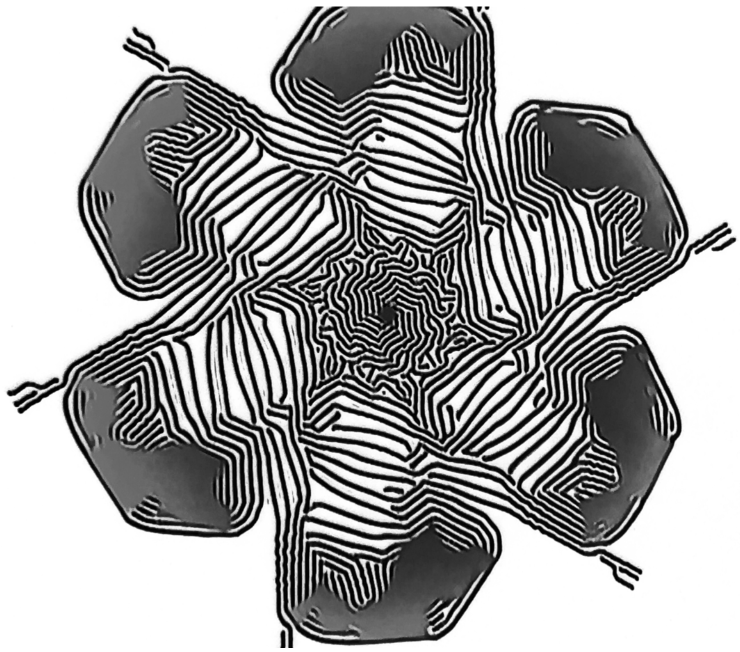


Figure 8. *Idealized monochrome video feedback, from Space-Time Dynamics in Video Feedback (234)*

A question that frequently arises in using electronic systems to investigate theoretical problems of complexity is whether the process involved is a simulation or an experiment. The distinction is somewhat moot as long as science is served. Nonetheless, it should be said that once the functional elements are well characterized, video feedback as an experiment becomes video feedback as simulation. This is simply a change in the experimenter's attitude rather than in the apparatus or the phenomena observed. Speaking broadly, as a simulator video feedback allows one to study the class of systems, called reaction-diffusion partial differential equations introduced by Alan Turing. It can do much more than this, though, such as simulate spin glasses, neutral networks, delay-partial-differential equations, multi-species chemical reactions, and so on…

-James P. Crutchfield, Spatio-Temporal Complexity in Nonlinear Image Processing (771)

EXPERIMENTS IN PUBLIC



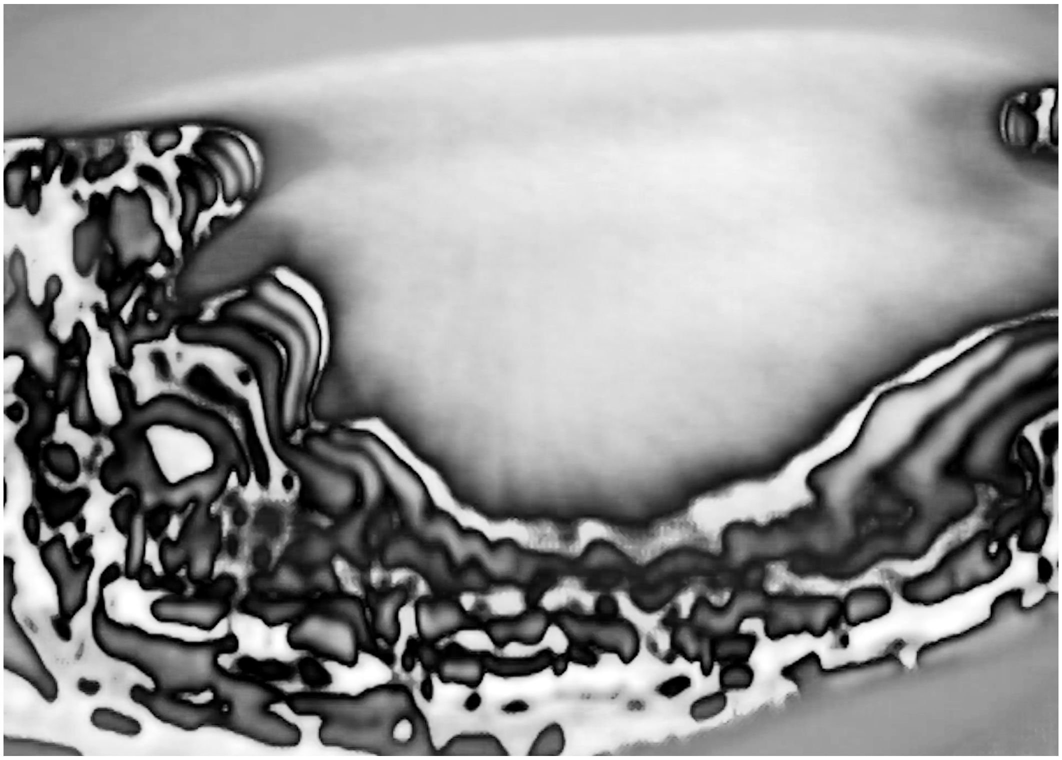
Experiments in Public is a series of short audiovisual works I created at the beginning of my program at Alfred. My intention was to produce a variety of *video sketches*, for the purpose of exploring many ideas without spending more than a few hours on each one. I published them immediately online throughout the project (regardless of my feelings about the results) with descriptions of my techniques and processes.

This was a way for me to counteract my tendency to overanalyze things and sit on pieces for too long. It is also in the spirit of *experimenting in public*, a community practice of sharing knowledge and learning from each other's mistakes as well as successes.

The pieces and explanations from this series are a good illustration of my approach to exploring the phase-spaces of my video systems. They exemplify my ongoing practice in analog video feedback, out of which this larger body of work in expanded media has evolved.

1. PLASMAPLEX

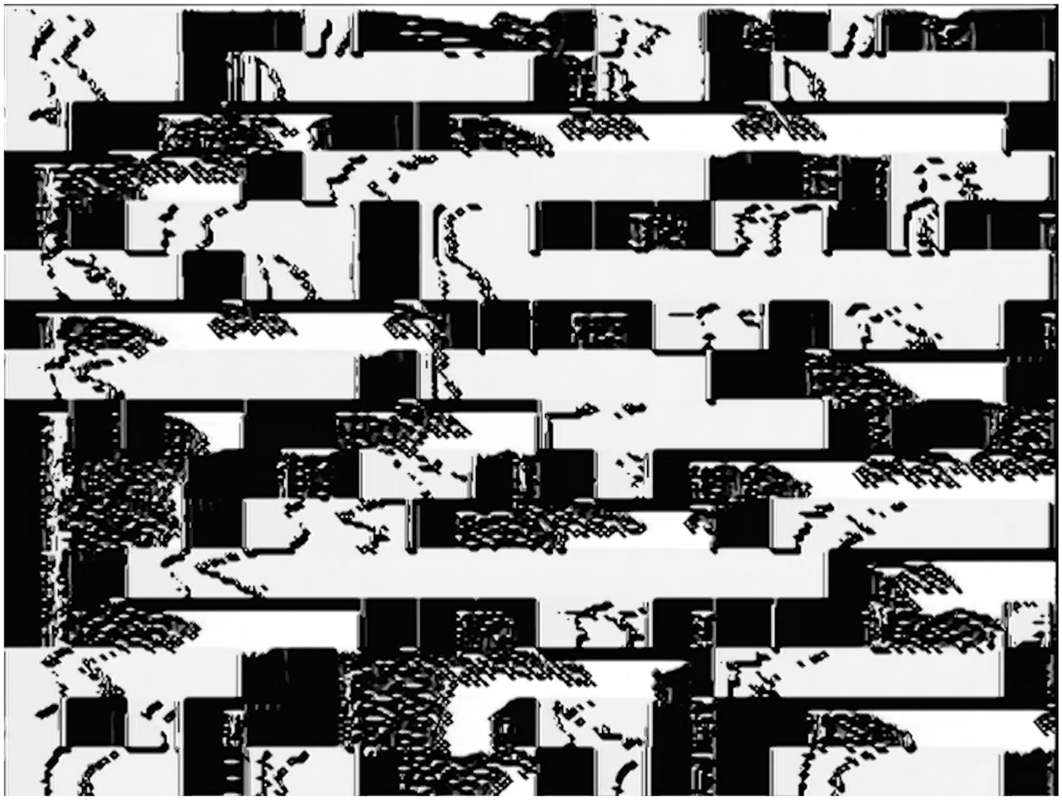
This piece was created using camera/LCD screen feedback, interrupted by a Cokin Multi-Image filter which I held in my hand and rotated. The camera was deliberately out of focus, and I was moving it slightly with my other hand. I changed the focus slightly over the course of the recording, and at about 1:04 you can see it go into much sharper focus, creating a detailed pattern of fine lines. The footage came out very green, so I did color-correction in Premiere using RGB curves. There are three layers of sound; two were created using VST synths, and one was created using a sampler loaded with a recording I made of water running through a storm drain in the sidewalk. I manually triggered slices of this recording using a midi controller.



2. PSYCHOCHROMATIC

This piece was created using a camera feedback loop running through two video mixers. The camera first passed through the MX-50a, which was doing a simple, subtle colorization. The feed then passed into the Edirol V4, which black-luma-keyed the feed over a negative version of itself. This causes the black areas of the image to become light again, creating an increasingly turbulent perturbation of the feedback, depending on the key clip level. (I call this *psychokinesis mode*, because it is the characteristic effect from my *Psychokinesis* series; this is a chromatic version of the same patch, hence the title *Psychochromatic*.) The output is then passed into the LCD screen at which the camera is pointed, completing the loop.

During the course of this recording, I slowly increased the key clip on the V4, allowing more and more of the negative image to pass through. I also continuously moved the camera very slightly, and changed the focus as well. The sound was created using software VSTs – I built up the sound loops at the same time as I was working on the video patch, letting each one go on its own as I actively worked on the other.

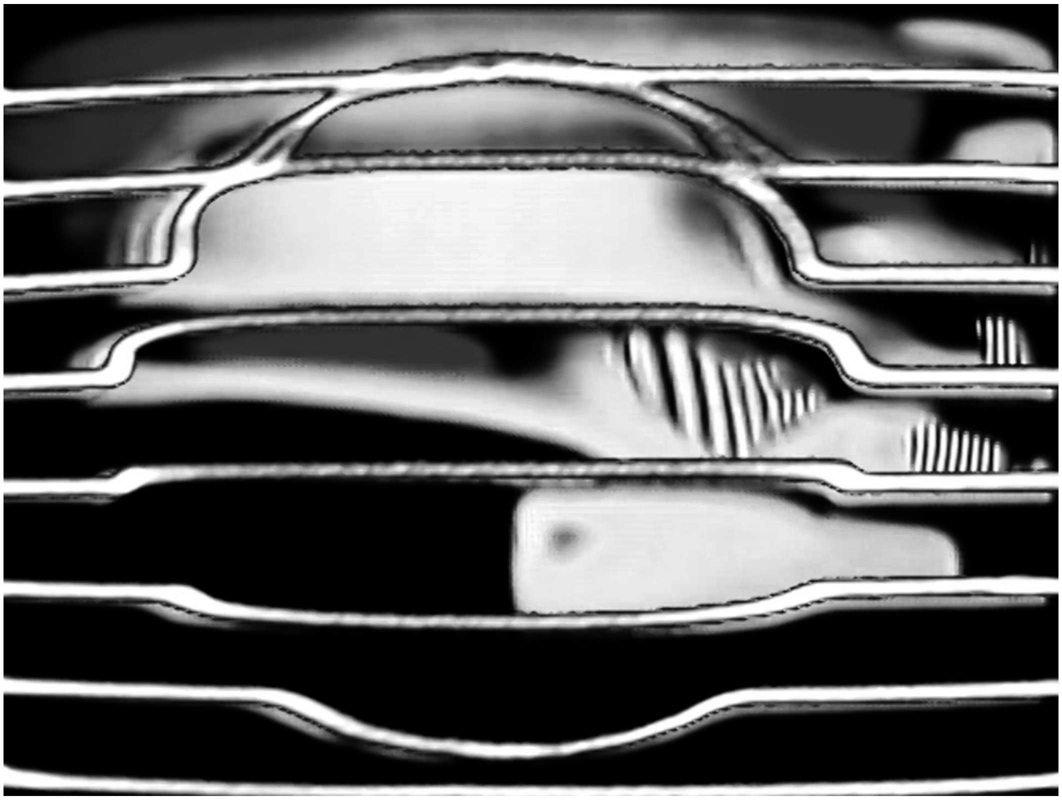


3. ZERO OPERATIONS

For this piece, I used two MX-50 video mixers patched together in a double feedback loop as seen in *Figure 6* of this book. (This is a patch we often use in *Fugitive Dream Recovery*, my a/v duo with Bobby Pharaoh.) The larger squares are created by *mosaic* mode on the first mixer, with *negative* and *strobe* modes in use as well, and *downstream key* creating the solid white shapes. The second mixer combined the output from the first with its own internal feedback, as well as the *downstream key* effect. While making the recording, I slowly changed the *mosaic* size.

The goal was to create multiple self propagating, cellular automata-like systems, happening on different scales of time and space within a single video and influencing each other.

The audio was created using VST instruments and drum machines. In Premiere, I added edits so that the video channel was inverted during a specific part of the song, and then reverses its speed.



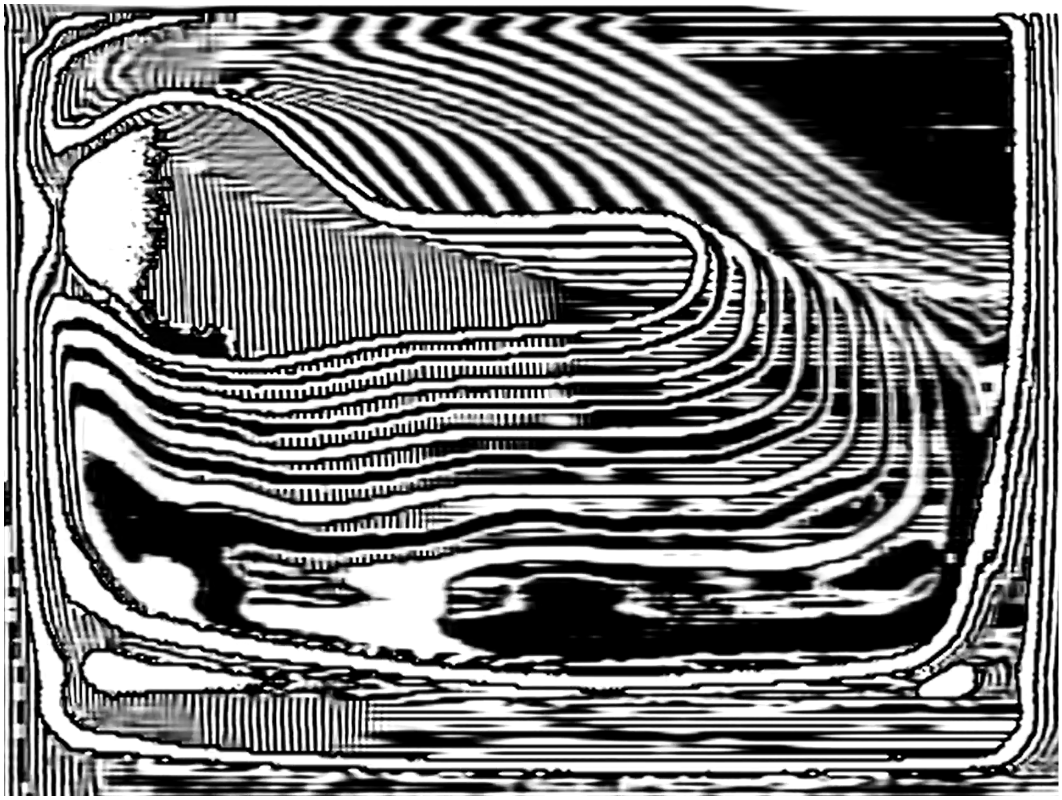
4. FLOATING POINT

I created this piece using a combination of camera feedback and vector synthesis footage that I recorded previously. I used an LCD monitor and a color security camera to create an optical feedback loop, which I keyed under the vector footage, sending the combined output back into the loop. The properties of the cameras I use have very distinct effects on the quality of the feedback. The color security camera is somewhat broken — the cord that powers a focusing element within the lens is missing, so the only way of controlling the focus is by partially unscrewing the lens. The focus is very soft and some of the bokeh seems to create color effects which are amplified by the feedback. It has an auto-exposure function that you can control with a tiny screw-pot, which I exploited to create this self-correcting system that cycles through different colors on its own. The sounds were, again, created with VSTs, with automations on the parameters modulating them over time.

5. IMAGINARY TOPOGRAPHY

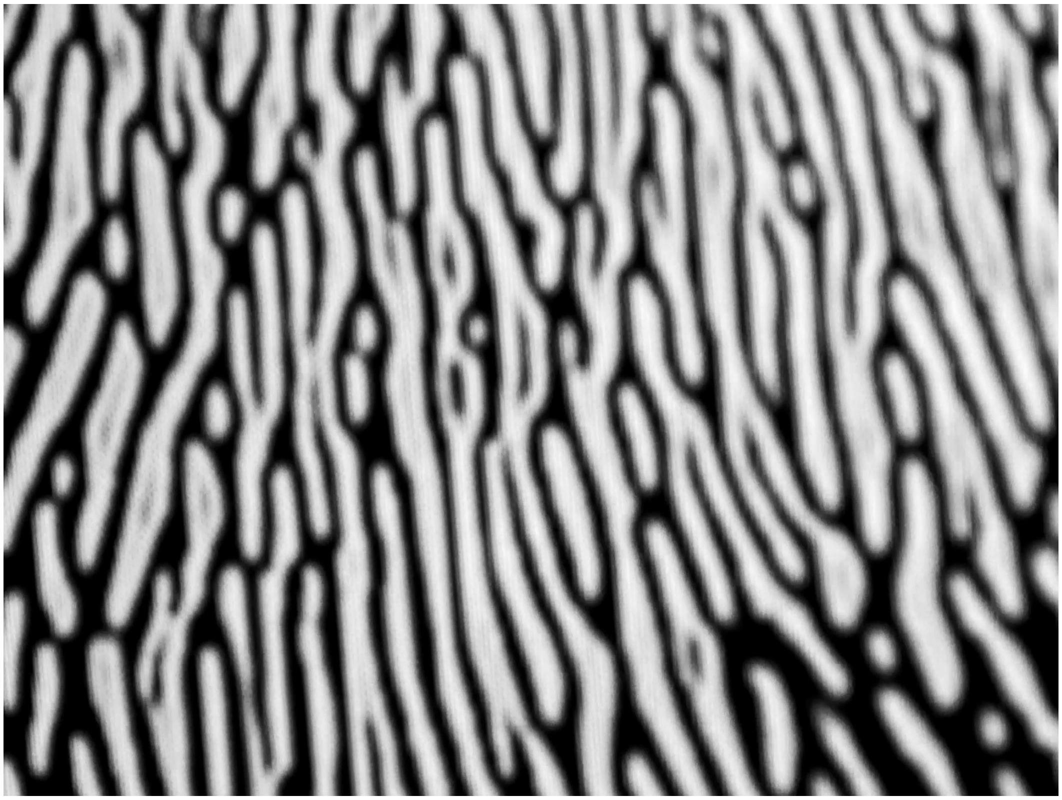
This piece was created using a camera feedback loop and the internal feedback and functions of an MX-50 video mixer.

The camera loop ran between the same color security camera as my last experiment, and a 7” LCD monitor designed as a backup screen for cars. The signal passed through a V4 video mixer, which then sent it onwards to the MX-50. The MX-50 was displaying the internal feedback loop as its output, and the downstream key was on, set to the camera feedback as its source. As the camera feedback ebbed and flowed, the downstream key picked up its contours, and the internal feedback caused them to echo and color shift as they faded away into the background. In Premiere, I reversed the speed so the forms are emerging, rather than receding. I created the sound using u-he Bazille, a modular synth VST.



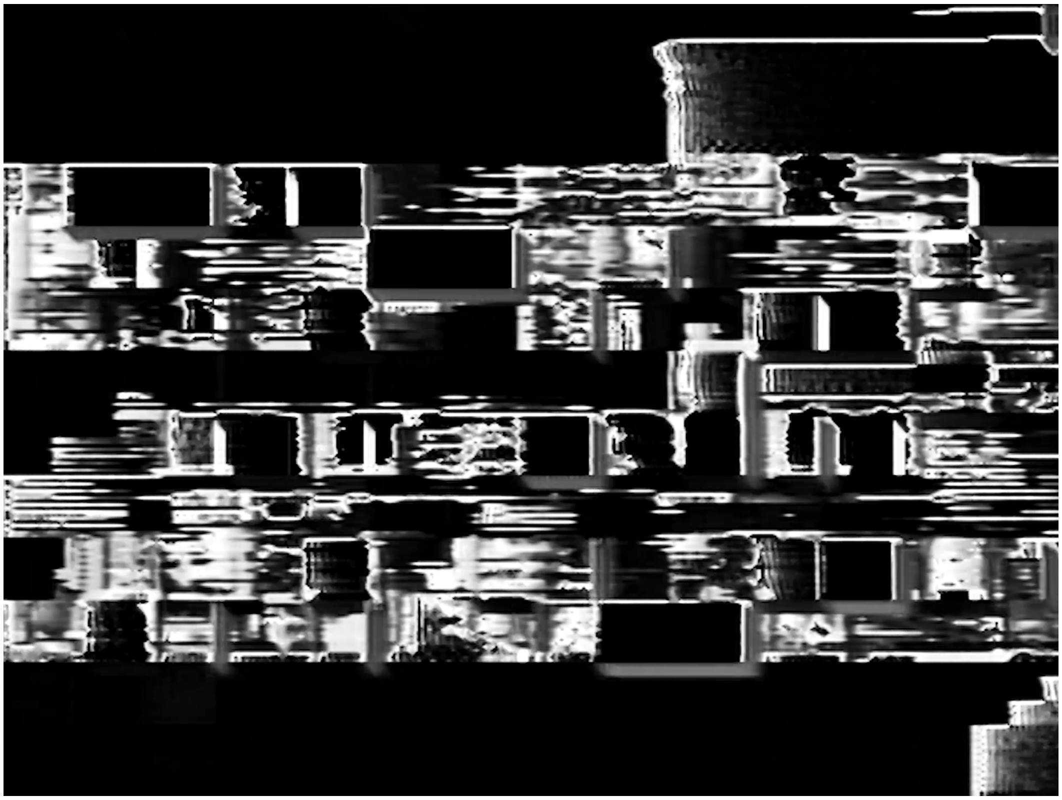
6. IMAGINARY TOPOGRAPHY II

This piece was created using the same patch as the last one, but this time, the internal feedback on the MX-50 was inverted (or *negative*). As the camera feedback undulated, I scrubbed the down-stream key back and forth as I recorded. In Premiere, I doubled the speed of the footage with *frame sampling* interpolation, so that it dropped every other frame, making the negative feedback less strobey and seizure-inducing. The sound for this piece was also created with Bazille.



7. REACTION DIFFUSION

This experiment emerged from some thoughts I had about reaction-diffusion systems, initially around a comment from Joost Rekveld which mentioned how Turing patterns can be generated using an iterative blur-sharpen process. I decided to try setting up a feedback loop that passed through two pairs of cameras and LCD screens – one set to blur the image by defocusing the lens, and another with the maximum possible sharpness in the focus and camera settings. The resulting video feed did not look like the kind of Turing patterns I had in mind, but it definitely formed some sort of intriguingly goopy reaction-diffusion. I recorded the output by re-scanning one of the LCD screens with an HD camcorder. I paired it with a processed field recording as the sound component. The original sound was captured from a set of pentatonic windchimes on Leslie Rollins's porch in Michigan. I then sent the recording through a series of granular and spectral processing using a set of plugins called GRM Tools.



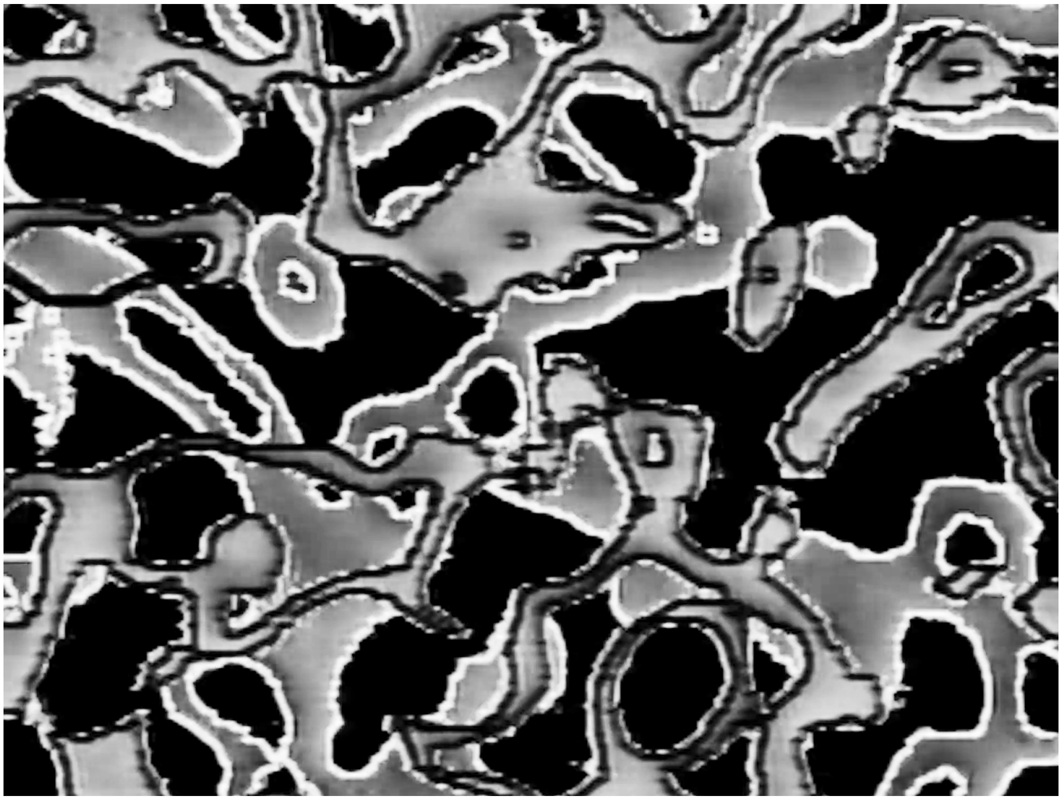
8. METASOMATISM

This video is an excerpt from some collaborative experiments by me and my friend Andrei Jay during his recent visit to my studio. Our explorations began with a goal to plug in a single feedback loop using all of ten of the video mixers I currently own. Because the setup quickly grew more complex than we could keep track of, it is difficult to give a specific explanation of what is occurring here. The squares and oblique shadows are definitely created using the *mosaic* and *downstream key* effects from two MX-50 video mixers. The greenish background is being generated by the feedback between all of the mixers combined (hence why it appears to be moving in multiple directions at once). As the piece progresses, parameters are changed which affect the colors, patterns, and behaviors. During this recording, I was influencing the video, while Andrei influenced the sound, which was created using a software synth and granular filter. I decided to title this excerpt *metasomatism* after the name of a process in which the composition of rocks is altered by fluids.

9. MORPHOGENESIS I

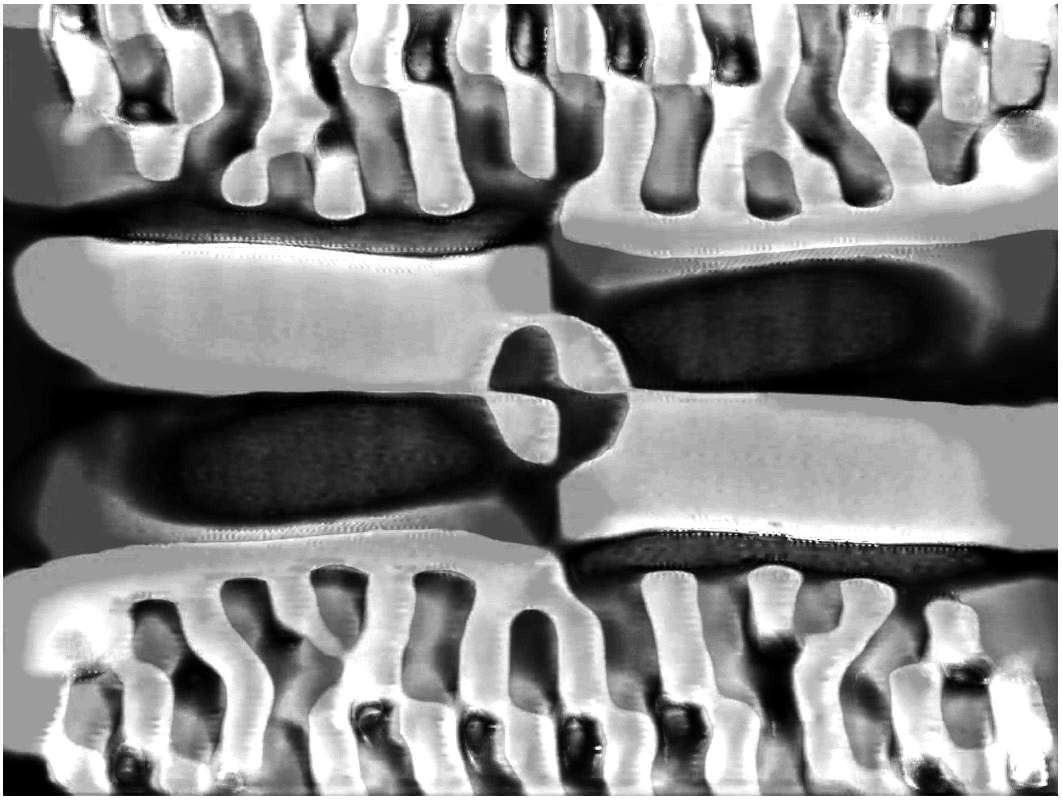
This piece was created during the same session with all of my video mixers. During this piece, a camcorder became part of the loop, and the signal path branched off at another point in the loop. Two different speed *strobe* effects were applied before they re-merged through luma-keying. The patch also made use of the *luma invert* function on the Videonics MX-pro mixer, as well as *horizontal-flip* which created the quasi-symmetry. The keying edges, plus the *down-stream key* effect from one of the MX-50s, created the shimmering contours around the bright areas.

The forms emerging from the top left and right corners were from on-screen text from the camcorder, which I cropped out in Premiere. These *seeds* caused the feedback to take on an unusual shape, and the contoured edges, combined with a defocused lens, caused the shape to chaotically morph and form strange cavities and hollows. The sound was created from another music session with Andrei, which I then applied some processing to in Ableton.



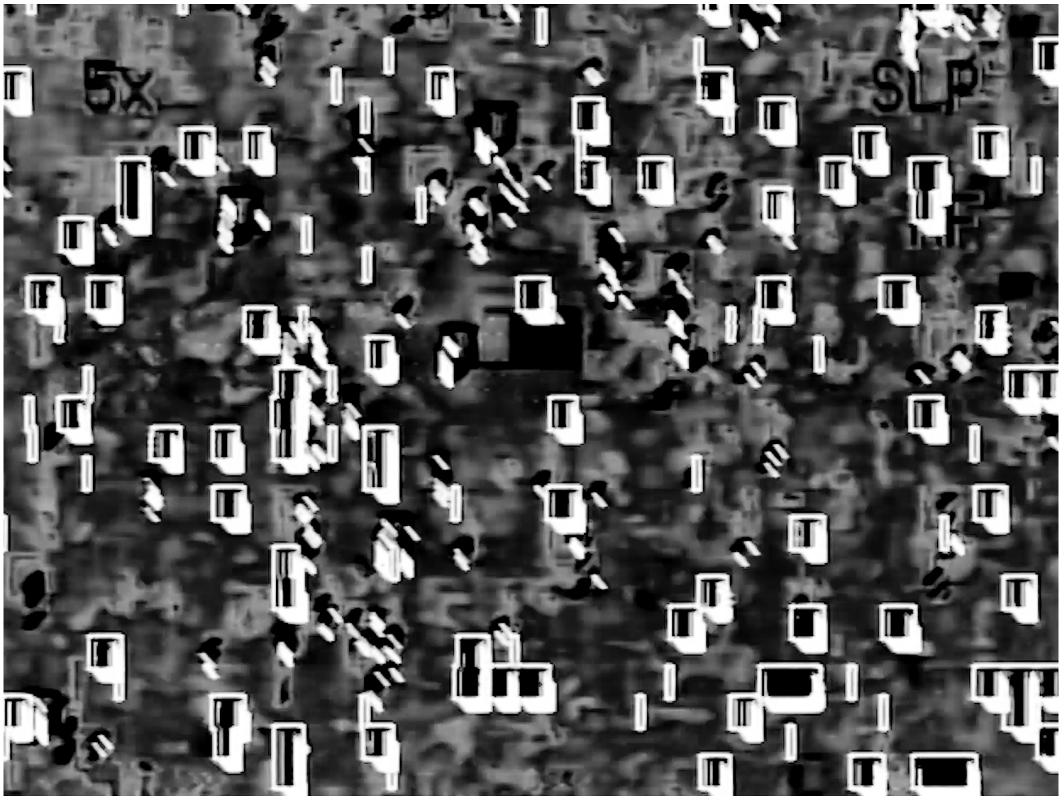
10. MORPHOGENESIS II

This video is a continuation of the last one, *Morphogenesis I*. It uses the same patch described previously. The camcorder has zoomed in, bringing us inside the emergent structures. By manually shifting the clip level of one of the keys, I was able to transform these structures from lines to forms that appear to have volume, then back again. At the very end, the lens zooms back out, bringing us back to a skeletal version of the shape that appears in the last piece.



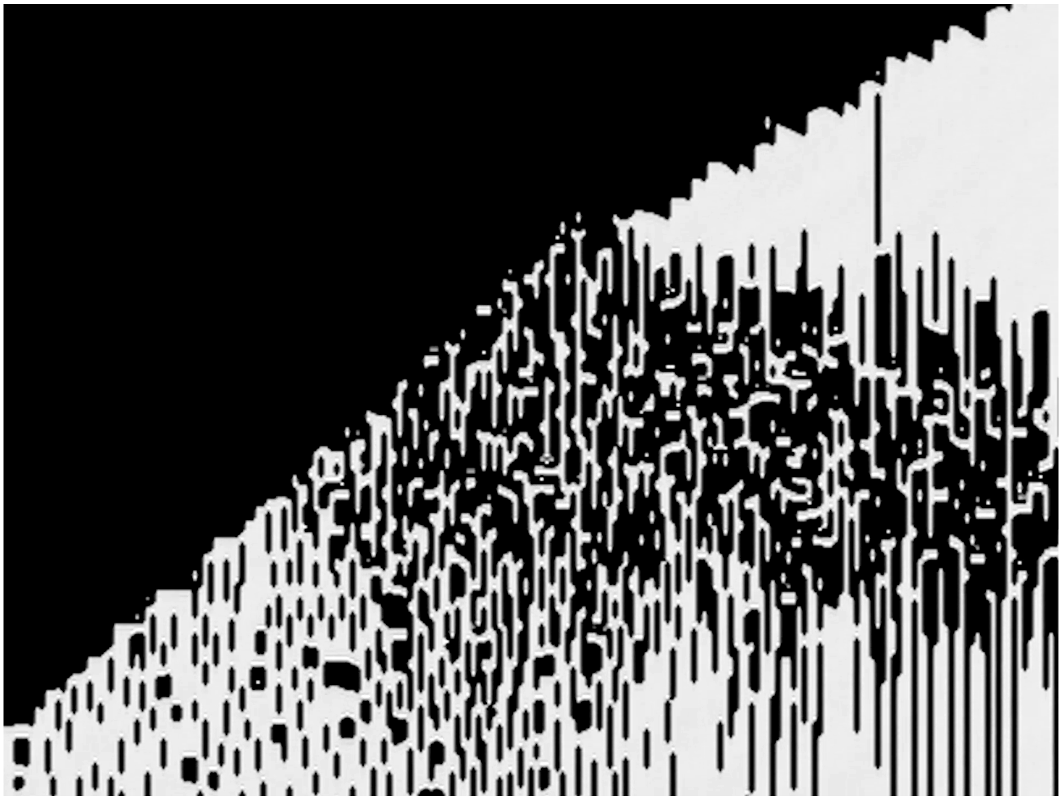
11. PORIFERA

This piece was recorded using the same feedback chain through many mixers. The main structure of the video patch at this point was a loop passing through three MX-50s, an AVE-5, two V4s, two Simas, and two Videonics mixers. The red and blue liquid parts are formed by the feedback loop passing through relatively little processing – it is possible to see the jittery instability and noise caused by the extremely long chain. I believe that a processed version of the feed, including horizontal and vertical flips, was being faded into the loop by one the Videonics, to create the tropical coral-reef formations that emerge. There were too many moving parts to keep track of all of the settings, so there was probably more occurring that I was not aware of; some shapes suggest a wipe pattern. I did some color processing to the video in Premiere as well.



12. DANCE OF THE AUTOMATA (CELLULAR STORM)

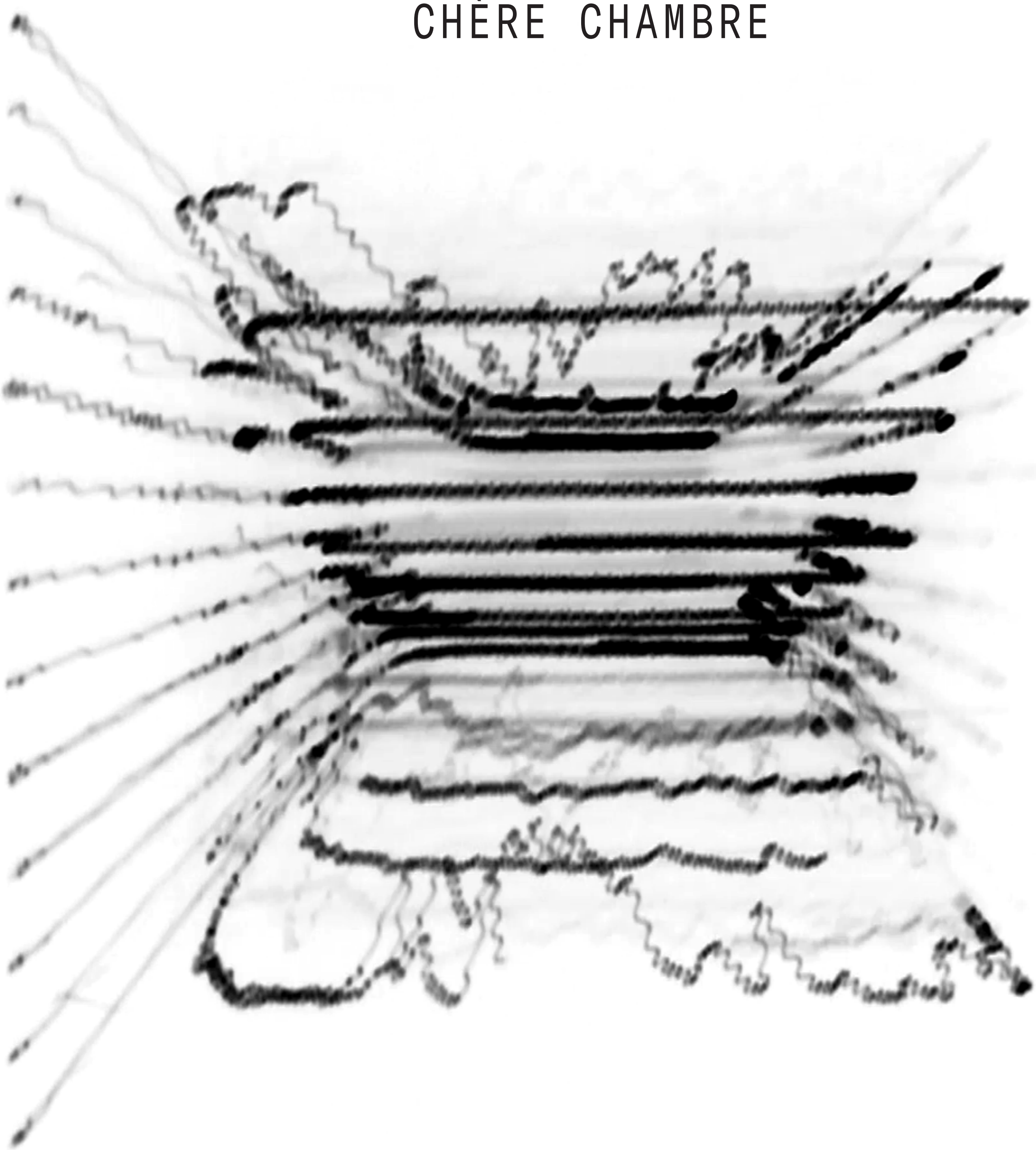
This video continues the exploration of the giant chain of video mixers. In this video, multiple MX-50s are used to generate the oblique outlined squares and cubes. Their colors and shapes, and the scape in which they reside, are degraded along their infinite journey through the loop. An additional, unseen inverted channel of feedback guides their semi-random, flickering passage through the environment. Stochastic choreography and noise patterns emerge as they execute frantic procedures according to invisible rules. At times, near the end, as their numbers increase, they merge to form a single textural mass. The sound was recorded in a separate, earlier session, involving an arpeggiator, a VST synth, and granular processing. I applied further processing and granular stretching to the audio during the editing process, resulting in a 20 minute sound piece, part of which was excerpted as the soundtrack for this piece.



13. GLYPH CITY

This piece emerged unexpectedly as I was testing out the effects of an Archer enhancer on a feedback loop running through an MX-50. The MX-50 was set to *posterize* and *monochrome*, limiting the image to a stepped array of gray values; I controlled the posterize effect during the process of recording, changing the number of gray levels in the palette. I was also changing the settings on the enhancer, which is a high-pass filter used to enhance fine details in the image. This piece is a good example of how complex emergent phenomena can arise in relatively simple feedback setups. Noise inherent in the analog circuitry is amplified by the enhancer, which takes small differences in brightness and increases them, resulting in areas of light and dark reinforcing themselves through each iteration of the loop. This is a reaction-difusion process at play, producing a pattern that I imagined to resemble some kind of alien writing system.

CHÈRE CHAMBRE



SCAN PROCESSING

Chère Chambre is a video piece that uses scan processing to reshape the rectangular grid of an analog video signal into a morphing wireframe form which appears to have dimension and depth.

I recorded the video track for this piece using the Jones Raster Scan at Signal Culture, which was designed and built by Dave Jones. It operates similarly to the Rutt/Etra and the Scanimate. Historically, these devices were used to create animated titles and graphics for television and movies, but were also explored by Steina and Woody Vasulka and other artists to produce works that investigated the properties and possibilities of the medium.

> *An energy/space relationship is herein described: light by means of a time-energy code can become building material for an architectural space.*
>
> -Woody Vasulka, Buffalo Heads (404)

In a typical television monitor, the deflection system is hard-wired into the circuitry, forcing the video raster into a fixed set of spatial coordinates. Scan processing removes that constraint by providing its own programmable deflection system that allows signals to be injected. These signals interact with the video raster based on their relationship in time.

Scan processing is a form of analog computing that can transform and reshape a video raster in space. Though the image produced is still two dimensional, the scan processor can create the illusion of three dimensional space by transforming it according to conventions of graphical projection.

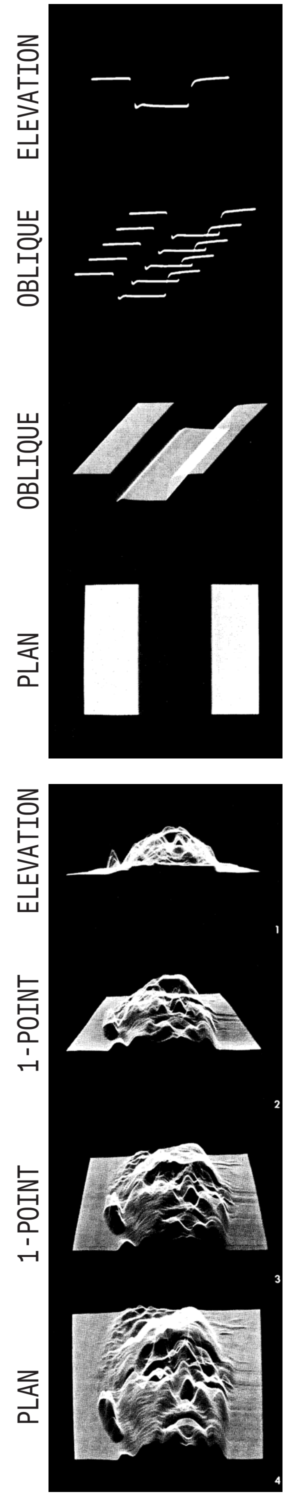


Figure 9. *Woody Vasulka, Tableau I-C & Tableau IV-C, from Buffalo Heads (406-408) with added labels*

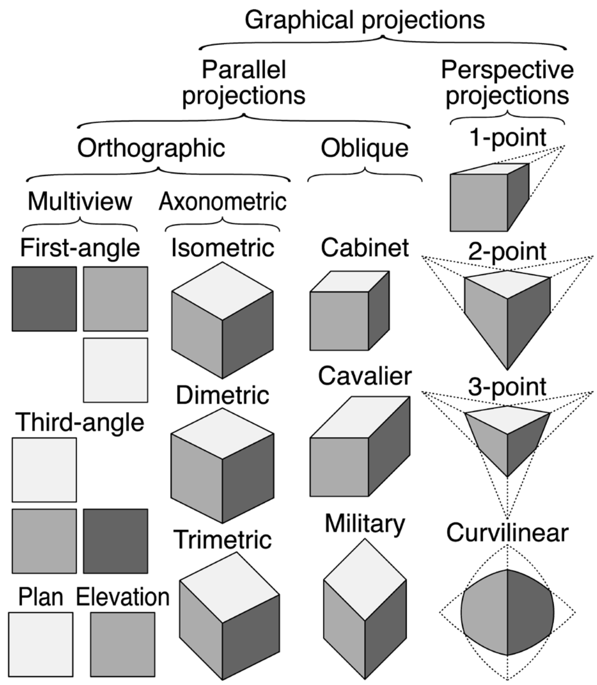


Figure 10. *Diagram showing relationships between some types of 3D to 2D projections by CMG Lee from Wikimedia Commons*

Projections are methods for mapping points in three dimensions onto a flat surface. They are inherent in the processes of drawing, photography, and 3d rendering in computer grapics. When cameras are used, the projection is created by an optical process, usually producing perspective similar to human vision. But in diagrams and electonically synthesized images, each dimensional axis is often mapped to a fixed angle, so that objects do not decrease in size as they get farther away. Or in other projections, straight lines in three dimensional space might become steeply curving lines in their two dimensional counterparts. Space and proportion can manifest in a wide variety of ways. The farther we are willing to venture from the perspectives we expect from our biological eyes, the more ways of seeing we can explore.

During my session with the Jones Raster Scan for *Chère Chambre*, I used brightness information from a video mixer wipe pattern to control the overall size of the raster, creating a 1-point perspective projection. Using a solid black rectangle in the center and grayscale gradients around the edges, I created the interior of a rectangular room.

I controlled the brightness of the raster with a narrow pulse wave in the vertical frequency range, so that the raster is filtered through a series of horizontal stripes, creating a hollow wireframe. The pulse wave was slightly out of sync with the frame rate, so that the stripes slowly drift over the raster.

As the stripes scroll past different parts of the video image, they appear to morph as they are displaced in z-space by variations in the video signal controlling depth, which now has additional oscillators and imagery keyed over the gradient wipe pattern that forms the structure of the room.

Using this series of interacting modulations, I found myself in a space with an entirely different set of properties than the room where my physical body was turning knobs. I named the patch *my room*, after the intimate electronic space I created and inhabited in that moment.

I created the accompanying audio later, in the sound lab at Alfred, using the Doepfer modular synthesizer. As the video recording played on a monitor, a photo resistor taped to the screen transformed the variations in brightness to voltage, to modulate an audio filter. Because the stripes of brightness scroll by as their phase shifts relative to the video frame rate, this phase relationship became the primary rhythmic element in the sound.
I repeated this process several times with variations in the patch to create several layered drones.

When this piece is installed as a wall projection, the electronic space of *my room* is annexed onto the material space of the physical room. An illusionary window is created, through which the perspective lines of the architecture are extended. This invites the viewer into an experience, similar to the one I had when making the recording, of being on the threshold between two forms of space(time).

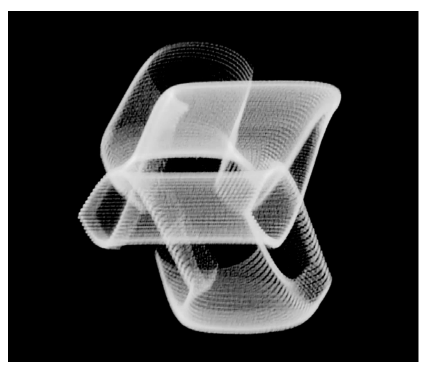


Figure 11. *A still from Raster Scan Forms, another piece I created that explored projection and space through scan processing, inspired by Steina and Woody Vasulka's Objects.*

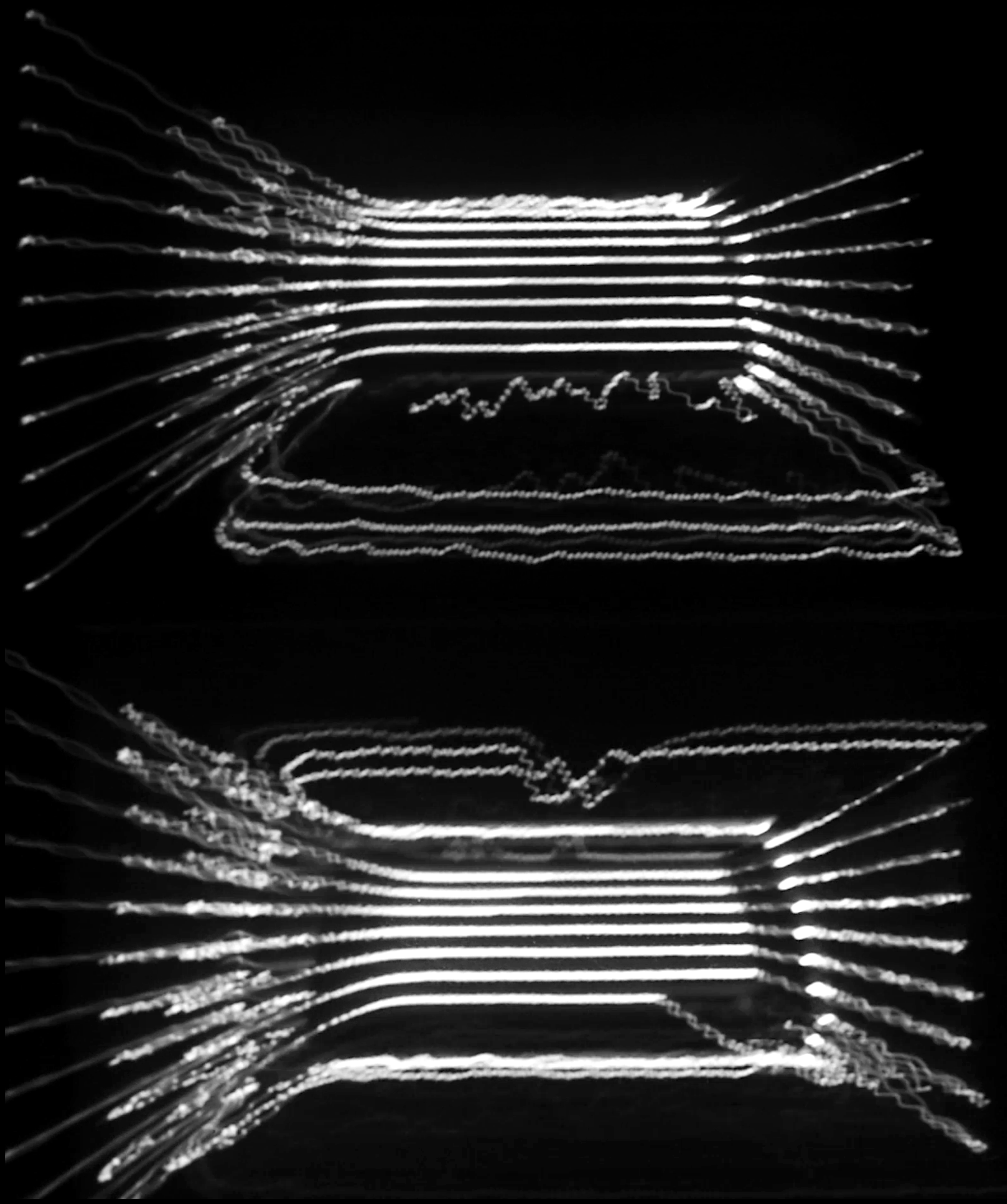


Figure 12. *Stills from* <u>*Chère Chambre*</u>

PART II

OPTICS

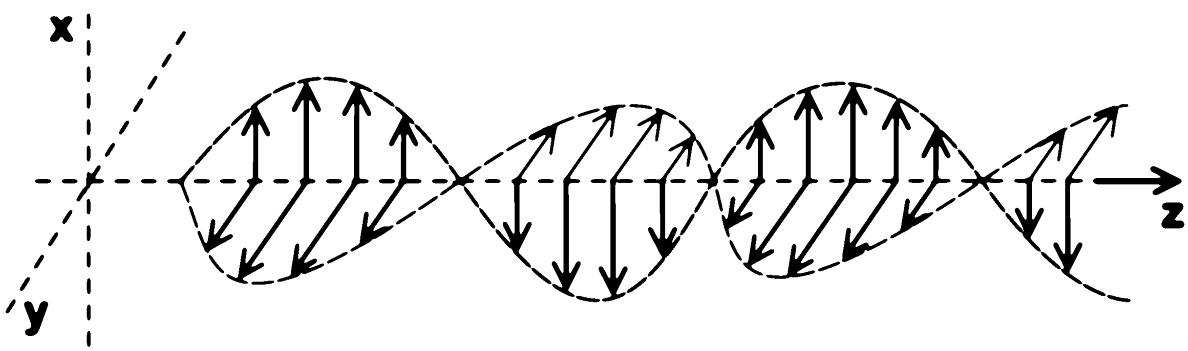


Figure 13. An electromagnetic wave

GLASS OBJECTS

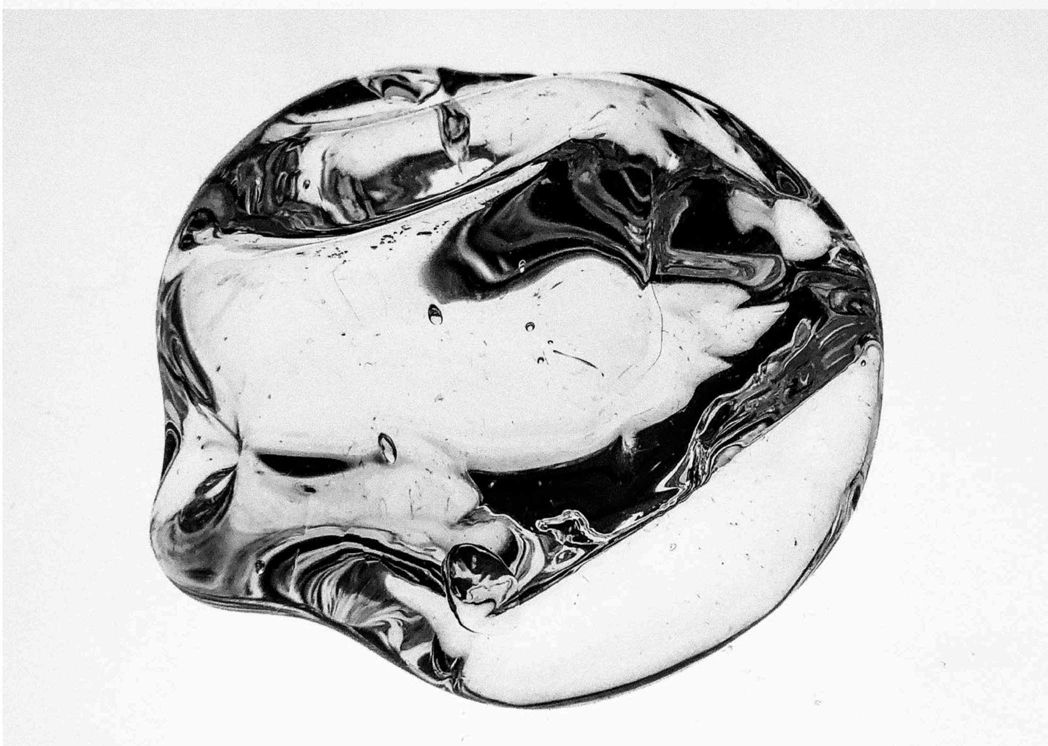
Through my exploration of projection and distortion of imagery, I became interested in manipulating light waves directly through optical processes such as reflection and refraction. In cameras, telescopes, and other optical devices, these processes are used to produce as *faithful* an image as possible; faithful, that is, to the ideal of human vision. I wanted to explore the potential for the disruption and reconfiguration of image-making.

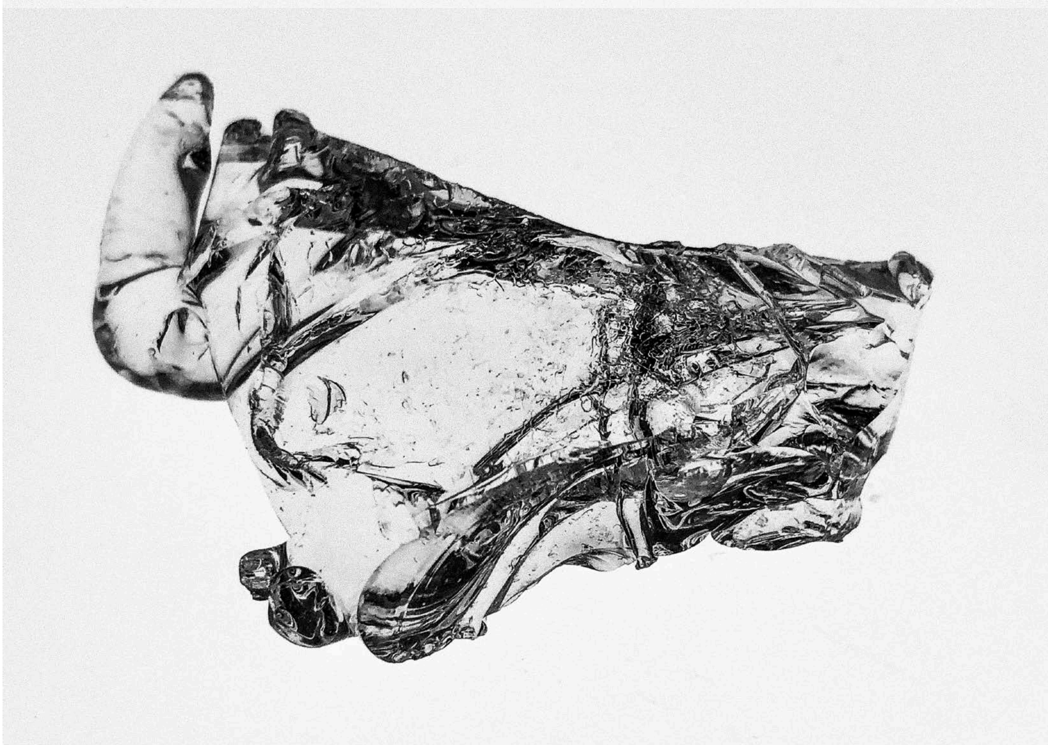
During fall 2019, I worked in the glass studio at Alfred to create a series of irregular, fluid forms to supplement my collection of prefabricated lenses and prisms, for experiments with light in my studio.

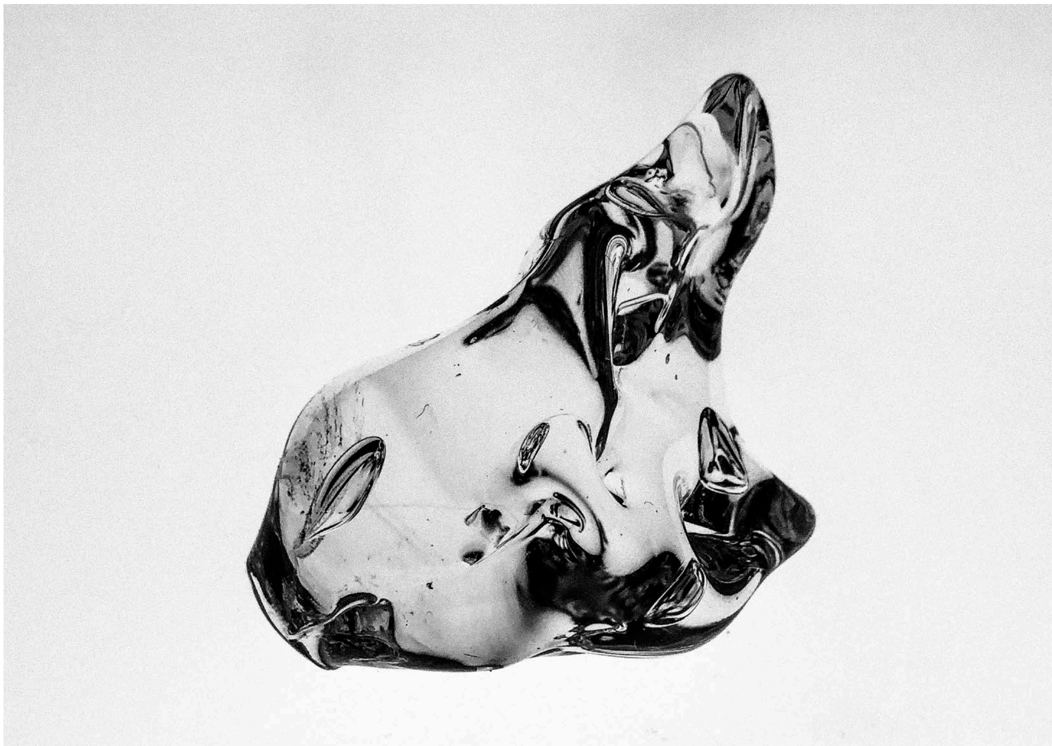
Monir Madkour and the rest of the Sculpture/Dimensional Studies division gave me a lot of kind assistance. At the same time, Dr. Joe Kirtland of the Physics department let me sit in as an observer in Optics. As my understanding of the interactions between light waves, reflective and transparent materials, and curved surfaces deepened, it informed the way I approached the medium of glass, and changed the way I looked at liquids, plastic, and metal surfaces in daily life. Through working with glass, a material process, it is possible redirect the path of electromagnetic radiation (including visible light). Considering light in this way breaks down the artificial barriers between material and electronic media and concepts of space(time).

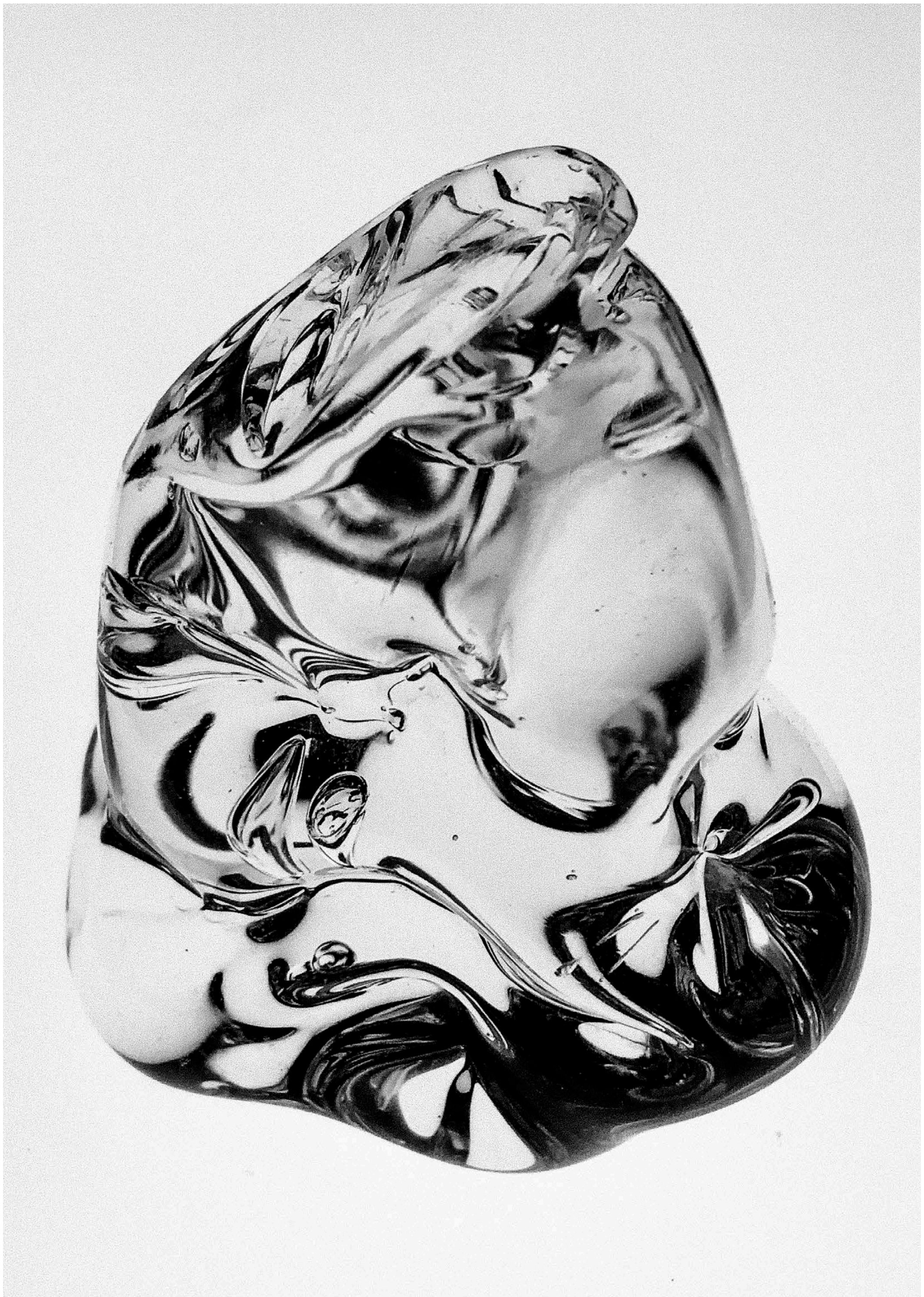
While my glass forms might look messy and random, especially to someone with any skill in glasswork, they led to many interesting experiments in the studio. My goal was not to try to force the material into a particular shape, but to let its properties inform what emerged. I created shapes of many sizes and thicknesses, hollow and solid, jagged and smooth. In the studio, I used them to manipulate light and imagery from various sources, such as lasers, LEDs, light boxes, and projectors. I shot stills and footage through them, and used them to disrupt video feedback loops.

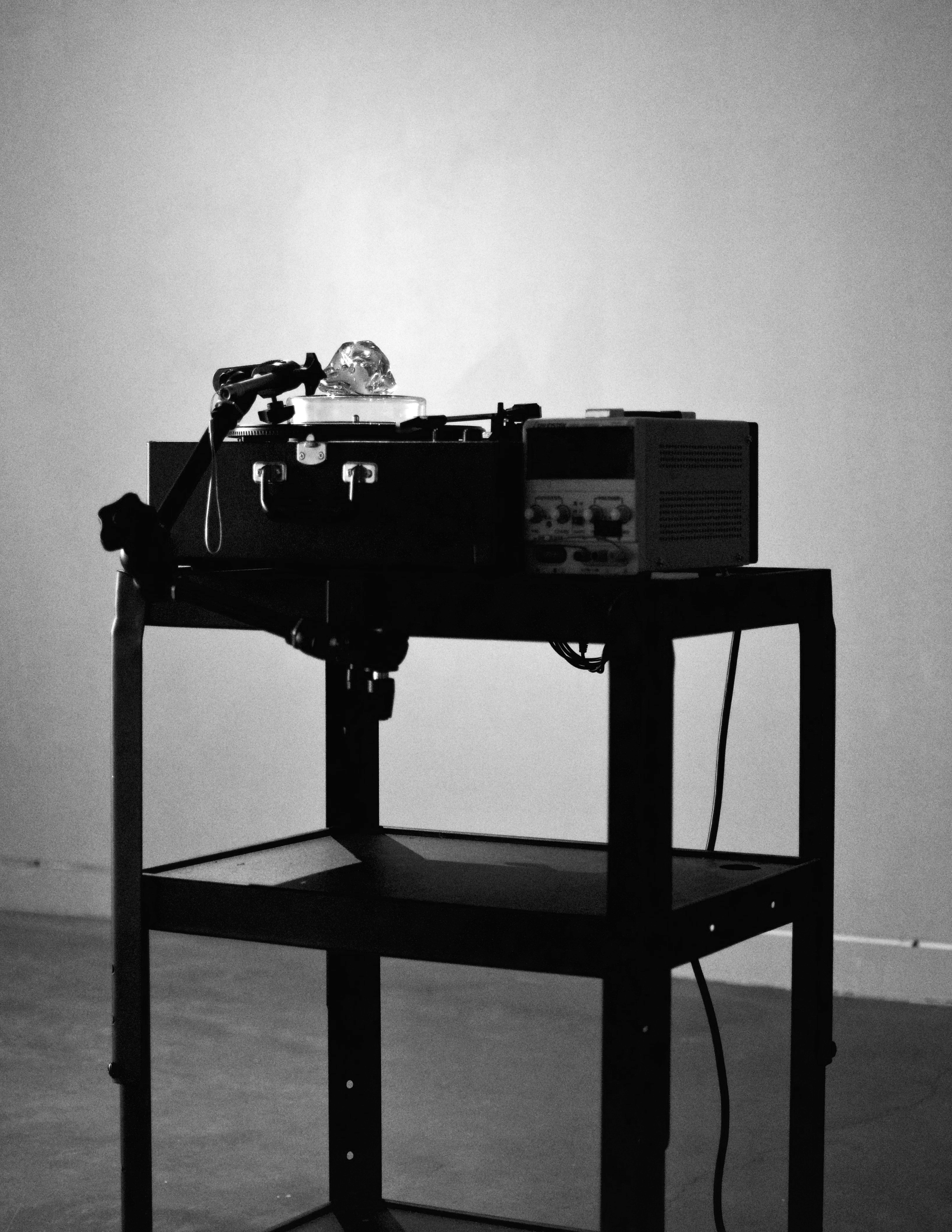
This is a series of photos I took to document some of my glass objects. These forms were used in the making of the following two projects in this book, *Lumiagraph* and *Refraction/Projection*.











LUMIAGRAPH

Lumiagraph is an installation that uses a red laser pointer and a hot-formed glass object to produce an analog projection. The title is a combination of *Lumia*, a term for light-based art coined by Thomas Wilfred in the early 1900s, and *-graph* as in phonograph.

The apparatus consists of a modified phonograph, a variable DC power supply, a laser held by an articulating arm, and a raised platter on which the glass object is placed. The motor for the turntable was disconnected from its circuit and instead was powered by the DC supply, allowing its speed to be controlled by adjusting the voltage. The glass object sits at the center of the rotating platter, with the laser pointing directly at it. As the laser beam passes through the glass, it creates a series of patterns which are spread across the walls and ceiling of the room, and morph as the object rotates. The support is a wheeled a/v cart. The room is completely blacked out and free of any light sources except the laser.

The idea for this piece emerged from considering information storage in vinyl records, and optical discs such as CDs. In vinyl, the information is encoded into the object's physical form, and read mechanically in a process that transforms it into sound waves. In CDs, the information is stored optically, in a series of reflective and non-reflective bits which are read using a laser. Vinyl is a continuous, analog medium with theoretically infinite resolution; CDs are a quantized, digital medium, storing discrete bits of data.

I wanted to consider the glass object as an analog, optical information storage medium. The information it stores is simply its own shape and interior optical properties. Through the process of projection and rotation, the information is read and transformed into a time-based image, displayed on the surrounding walls.

People collect vinyl records for the storage and recall of abstract patterns of sound. What if we did the same thing for visuals? We could get home from work, and kick back with a favorite abstract light show in the living room.

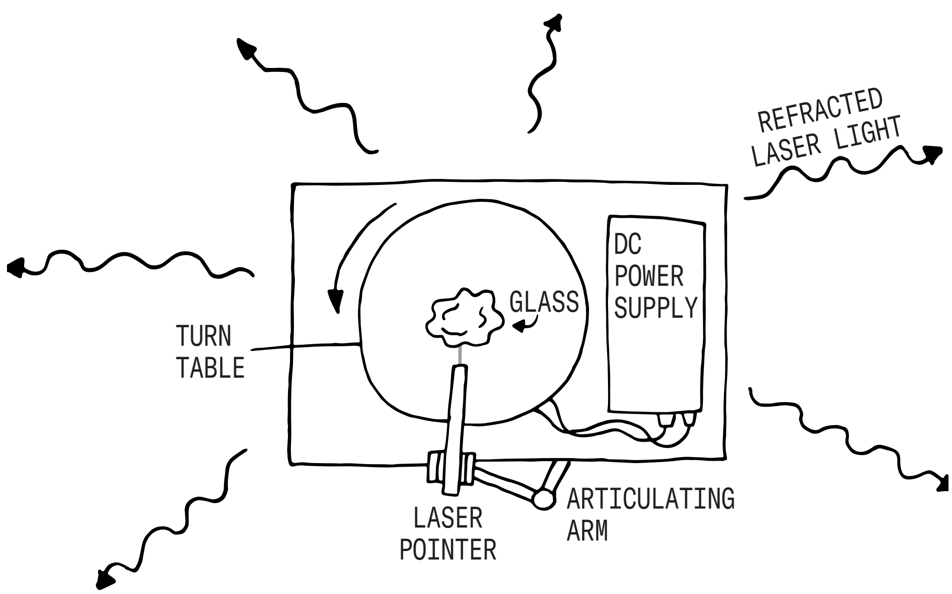
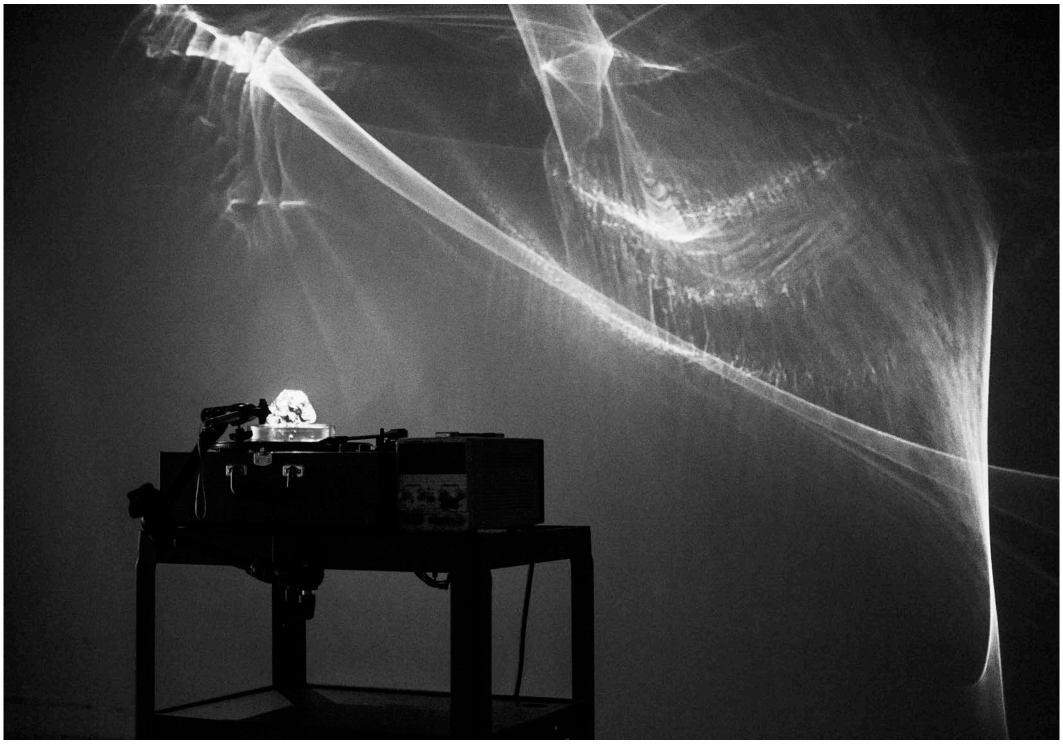


Figure 14. *The apparatus for Lumiagraph*



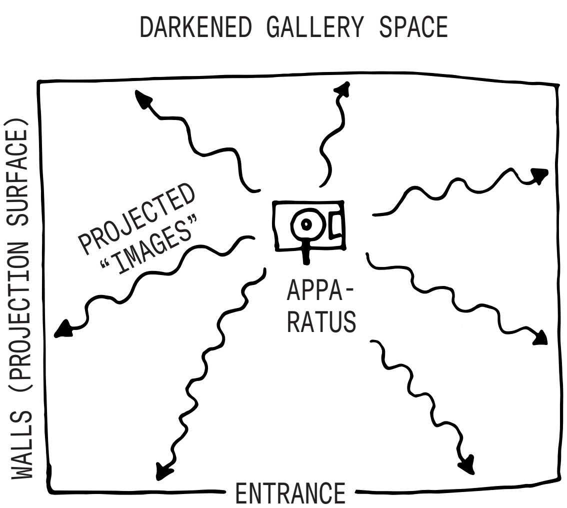


Figure 15. *The gallery view for* *Lumiagraph*

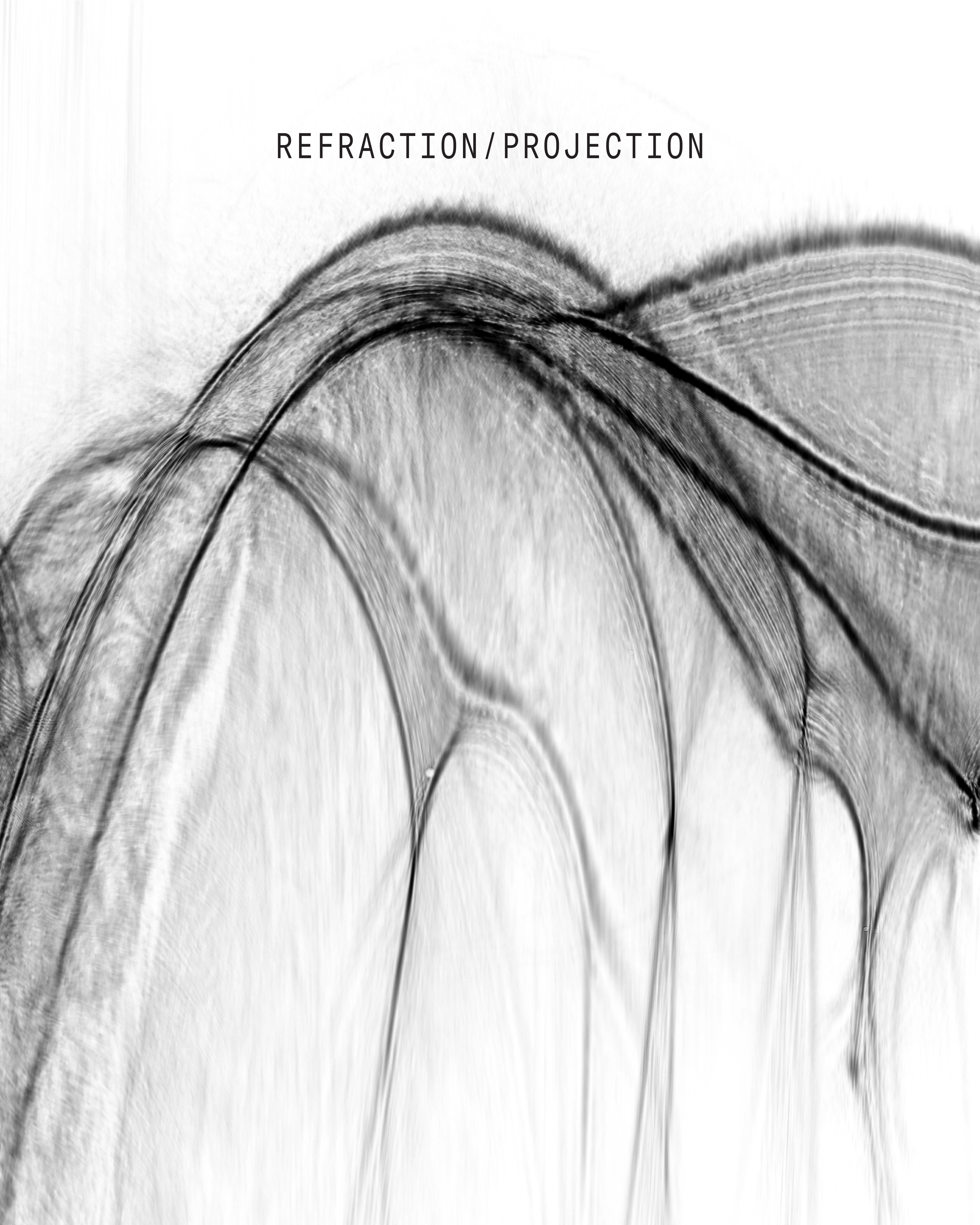
The specific patterns created using *Lumiagraph* are dependent on the properties of the glass object chosen, and the particular angle and positions of the laser and glass. A tiny shift will change the pattern completely, so it is very difficult to obtain a repeat result (the calling card of a chaotic process). It is also impossible to predict what the projected images will look like by looking directly at the glass object itself. While all the same information is present, it can not be *decoded* with the naked eye. The process of projection is transformative, providing a new way to see the material properties of the glass and twist it inside out, and as its information dances across the surrounding walls, the sensation arises of being on the inside.

With the rotation continuing at a constant speed in a single direction, one might expect the movement of the projected patterns to share the same overall appearance of motion. But the beam of the laser was so distorted as it passed through the thick glass that the patterns actually seemed to move in many different directions at once. The quality of the movement sometimes had a parallax quality, creating a sense of foreground and background, while other times the shapes morphed in ways that seemed to defy any familiar sense of perspective. In a completely darkened room lit only by constantly shifting patterns of light, the best visual anchor for one's sense of balance becomes the rotating, glowing glass object itself, positioned at the center of the room.

This installation piece presented some challenges. The room had to be completely blacked out because the projections were quite dim, since all the light originated from a single laser pointer. I preferred the handheld laser over higher powered laser sources because it was too weak to pose a danger of injury, so viewers could safely enter and roam the area of its throw, becoming part of the projection surface and exploring it from any angle they chose. However, there was a drastic period of adjustment when entering from a well-lit room. Even the tiniest light sources, such as an indicator LED on a light switch, could disrupt the piece. I began exploring ways of recording the patterns of refracted light, which led to the piece *Refraction/Projection*.

Figure 16. *One of the glass forms held in front of an overhead projector beam to demonstrate its refractive properties.*

REFRACTION/PROJECTION



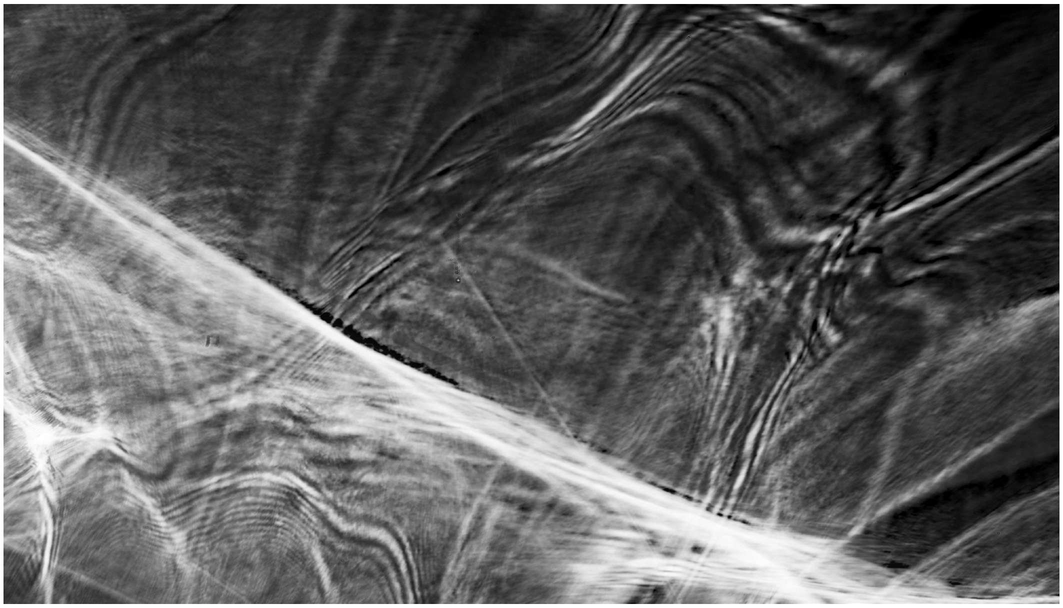


Figure 17a. *Channel 1 of <u>Refraction/Projection</u>: stop-motion recording of refracted light from rotating glass object, captured by image sensor with no lens*

Figure 17b. *Channel 2 of <u>Refraction/Projection</u>: realtime recording of refracted light from rotating glass object, top-down view, captured by camera with lens*

Refraction/Projection is a 2 channel video piece which uses a camera sensor to record the patterns of refracted light created by a hot-formed glass object. It evolved out of ideas from the *Lumiagraph* installation and uses a similar process, but the final result is a video recording rather than an installation. Therefore, it can more easily be shown on standard video displays; however, the room in which the original recording process takes place must be completely dark.

Instead of a laser pointer, which can damage camera sensors, a bright LED flashlight serves as the light source. A piece of board with a pinhole is used to block all the light outside of a highly focused beam, which is pointed directly at the glass object. As the light passes through the irregular glass form, the waves are bent and deformed, resulting in the patterns of refracted light. While these patterns are cast in many directions, the camera sensor is only able to record the portion of the image that falls within its area.

Because the patterns of light created by this method are very dim, I needed to capture them as individual long-exposure photos. However, I wanted to generate a video with the same rotational movement as *Lumagraph*, so for each individual frame, I rotated the turntable about 0.5 degrees, then joined all of the frames together into a video sequence. Channel 1 of *Refraction/Projection* was shot as several hundred photographs.

Channel 2 of *Refraction/Projection* uses the same setup, but viewed from the top-down, and shot on a video camera with a normal lens. This is the view of the glass object in the darkened room, with light coming from the flashlight, captured in a way that looks similar to the view through a human eye. I wanted to include this view in addition to the abstract landscape of light in Channel 1, similar to how multiple perspectives are presented in an architectural blueprint or other forms of technical illustration to add context.

In the *Lumiagraph* installation, a common response from viewers was, *I'm not sure whether to look at the patterns of light or at the glass object itself*. In translating from an installation to a video recording process, I wanted to preserve both options.

In practice, the imagery in Channel 2 is almost equally abstract; in the darkness, different parts of the glass object become activated by the light as the angle of rotation changes. The object appears to shift and even transform; this is a different manifestation the same processes of reflection and refraction. Channel 2 shows the glass as a contained object; Channel 1 shows it from the inside out.

The setup for capturing the refracted light directly onto the sensor can be seen as a large camera occupying the entire space of the darkened room, with the glass form acting as a strange lens. The image created is the result of the manipulation of the beam of light in space and time; in a sense, it is a camera that creates an image of itself.

The white light is split into different colors as the different wavelengths are refracted at slightly different angles, and interference patterns are created, resulting in intricate stripes and shimmers. The texture of the glass appears in sharp focus, due to the pinhole at the light source.

The 2 channel video that emerged from these experiments is the artifact of a single piece of glass performing a complete rotation, but any transparent object can be placed on the turntable for its light patterns to be recorded. The main limitation for me was the time consuming process of manually shooting hundreds of photographs for the stop-motion sequence while sitting in complete darkness. This recording was the first full, seamlessly looping rotation that I had time to capture before the setup had to be disassembled due to the pandemic. Additionally, the sensor of my DSLR was exposed to the air with no lens for long periods of time, and collected a significant amount of dust in the process. I hope to continue exploring and refining methods of capturing these landscapes of light...

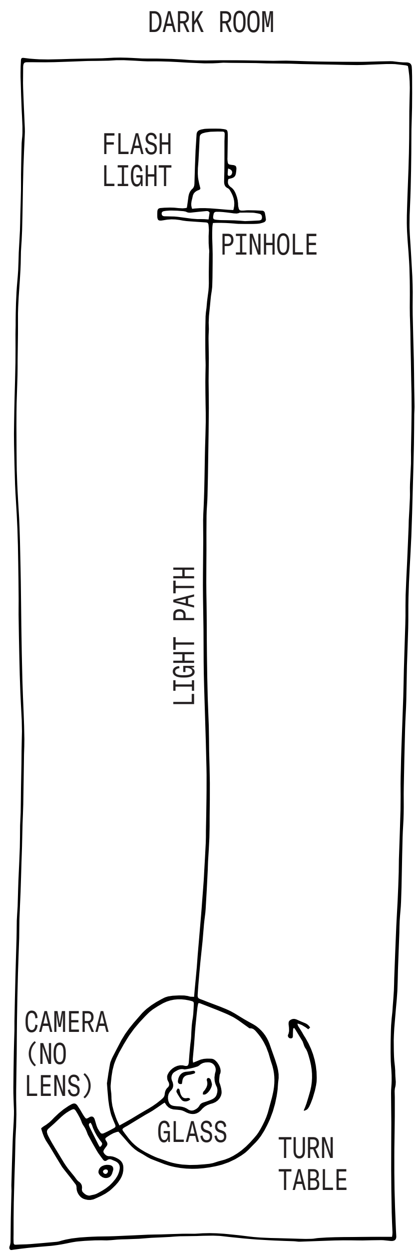
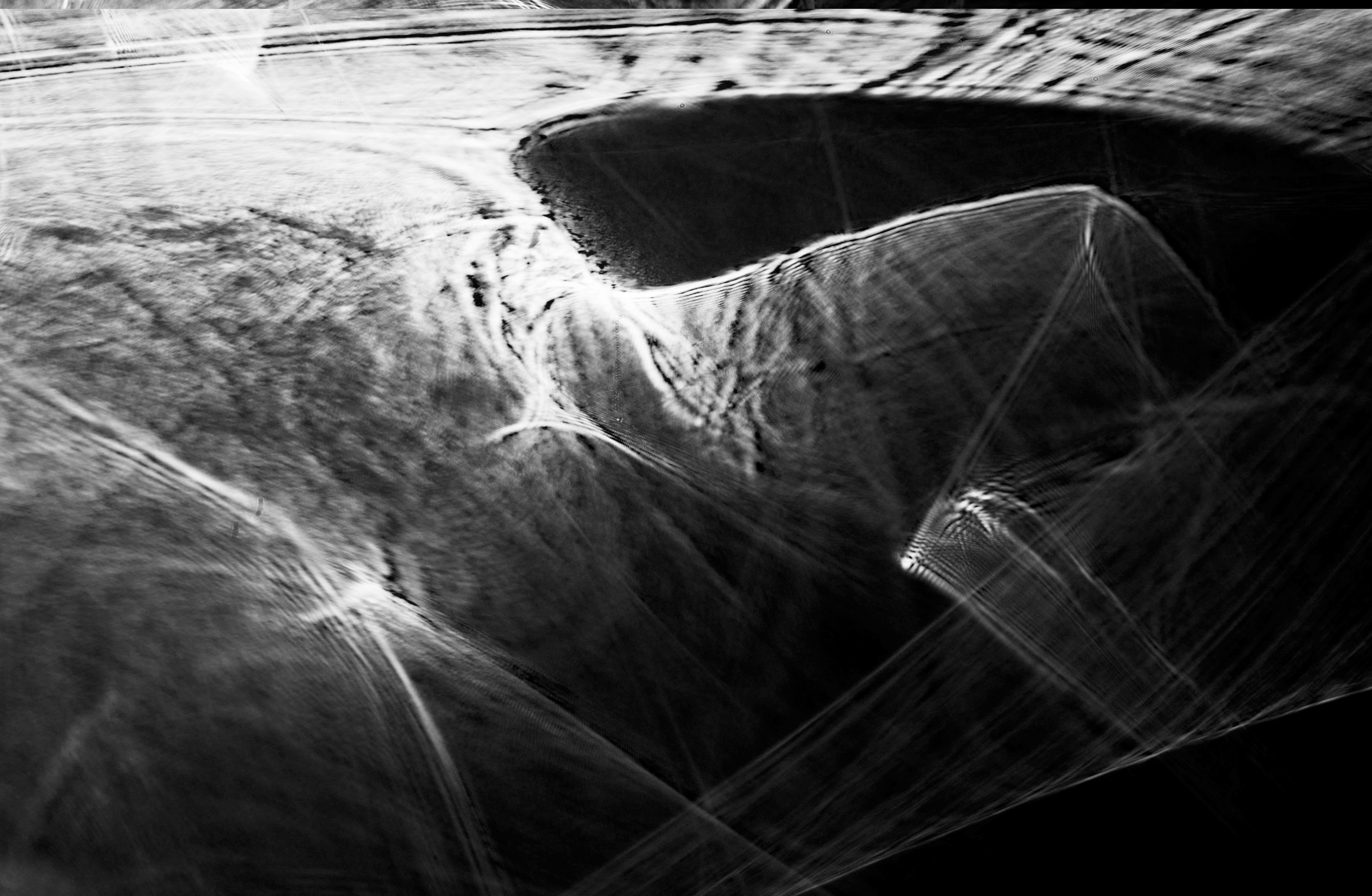
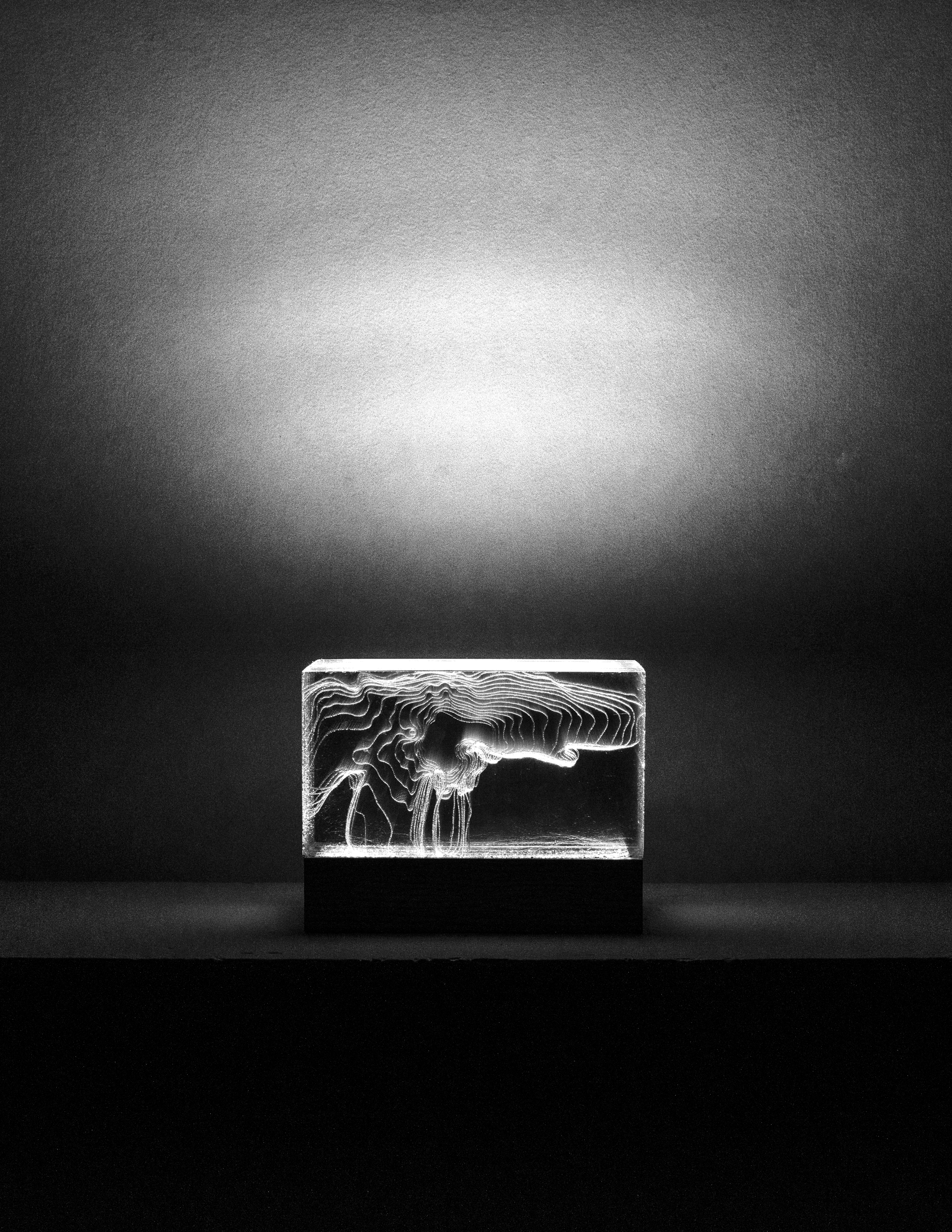


Figure 18. *Shooting setup for channel 1 of* *<u>Refraction/Projection</u>*

VIDEO TOPOGRAPHY

Video Topography is a small sculptural piece consisting of layers of laser-etched glass, placed on a lighted wooden base. The forms etched into the glass are from video feedback, where each frame from a 1 second sequence was traced to a vector path. Viewed from the front, the shape of the piece is a 16:9 rectangle, a standard aspect ratio for video signals; the light used in the base is a backlight extracted from a 7 inch LCD monitor.

In this re-interpreted *screen*, the dimension of time is translated into depth. All frames in the sequence are seen at once, to create a new three-dimensional form from a sequence of two-dimensional images in time. As the video feedback system evolves in time, the shapes shrink in size, to form a sort of crater or well. Each layer resembles a land formation like an island or continent; together, they resemble a topographic map in three dimensions, composed of glowing, suspended lines. Imagery generated from a flowing dynamical system is frozen in time and preserved for examination; it becomes an artifact of the system and process.

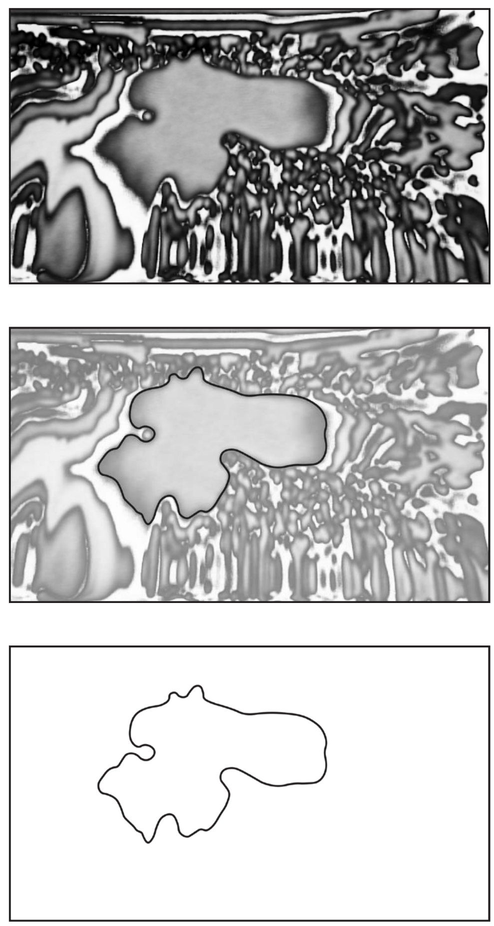


Figure 19. *A still frame of the source video, the traced vector overlaid on the source image, and the traced vector on its own, which was output to the laser etching machine.*

As in *Lumiagraph* and *Refraction/ Projection*, the process for this piece involve glass, lasers, and light, but the methods are quite different. The glass was sourced as a flat sheet, which I cut down into many smaller pieces of the same size and layered together. Each layer was individually placed inside the laser cutting machine to be etched; the high powered laser beam was focused on the glass surface, and as it traced the vector line, it heated the surface of the glass, causing it to crackle on a microscopic scale. From afar, this results in a white line on an otherwise clear surface. When the lines are lit from below, they scatter the light, which makes them appear to glow.

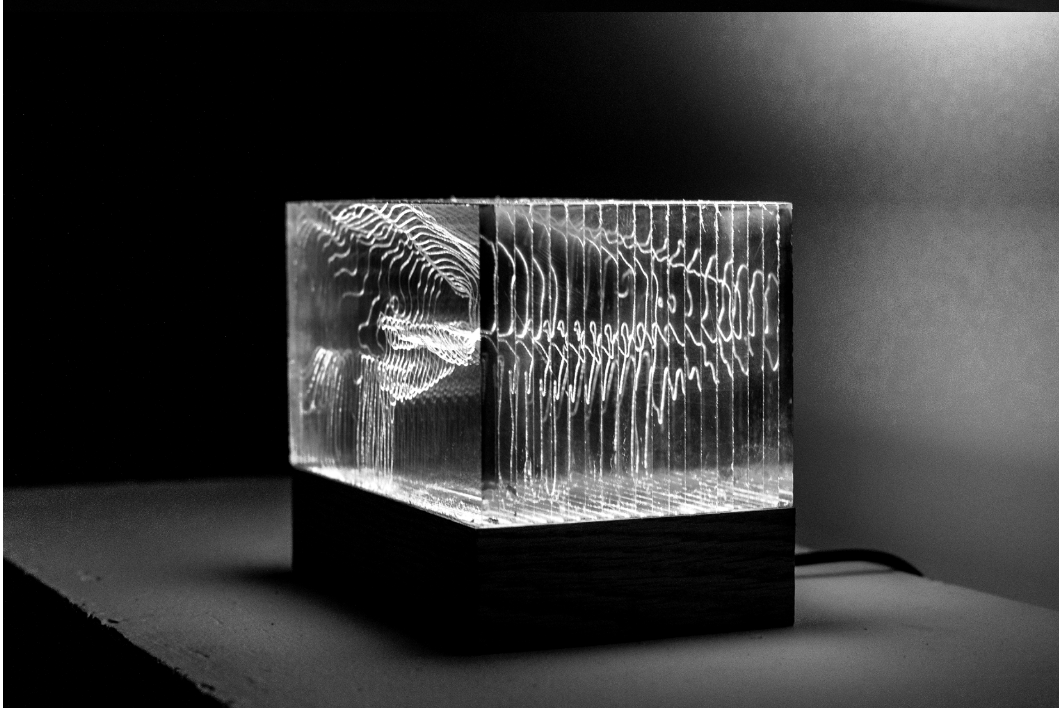
I stacked up all of the layers, and used UV glue to adhere them together, then ground the outside edges down to flat. The individual layers of glass are still distingushable, especially when illuminated; each sheet has a certain amount of interior reflectance, resulting in a subtle *infinity mirror* effect which gives the lines an increased sense of depth and visual echo. The piece rests on the wooden base, which is fitted with the LCD backlight. The screen which I extracted the backlight from is the same model used in the original camera feedback loop.

The floating lines inside of the transparent medium are reminiscent of the wireframe view of a digital 3D model, but the shape they take is decidedly organic. There are many parallels between video feedback and the formation of geological features. Both can be viewed as a iterative processes, where the current state is used as the input for the next iteration. In the natural world, stone and soil are layered, eroded, and transformed on an ongoing basis, though mostly on a much larger time scale than humans can observe; in video feedback, changes can occur very rapidly, and time is quantized, with each frame being a snapshot of the process. In both, tiny imperfections or irregularities are amplified in the loop, so similar systems can produce a vast variety of different results depending on the initial conditions.

In camera feedback, noise in the signal and slight variations in brightness, the interplay between the rasters of the camera sensor and screen, overall brightness and exposure levels, and optical convolutions and diplacements all play a role in transforming the image between each new video frame. A small bright speck can become a seed for a much larger blob of light; when it grows too large, the camera may automatically decrease exposure, causing the border of the shape to recede as the edges are eroded. In geological processes, the action takes place in three dimensions; water and wind remove material from some areas and add it to others; the border between positive and negative space parallels the threshold between light and dark in the video signal. This sculpture shows one way to bring video feedback into the third dimension.

Figure 20. *Video Topography, detail view*

Figure 21. *Rock strata in a gorge carved by water at Watkins Glen State Park*



PART III

PROGRAMMING MATERIAL

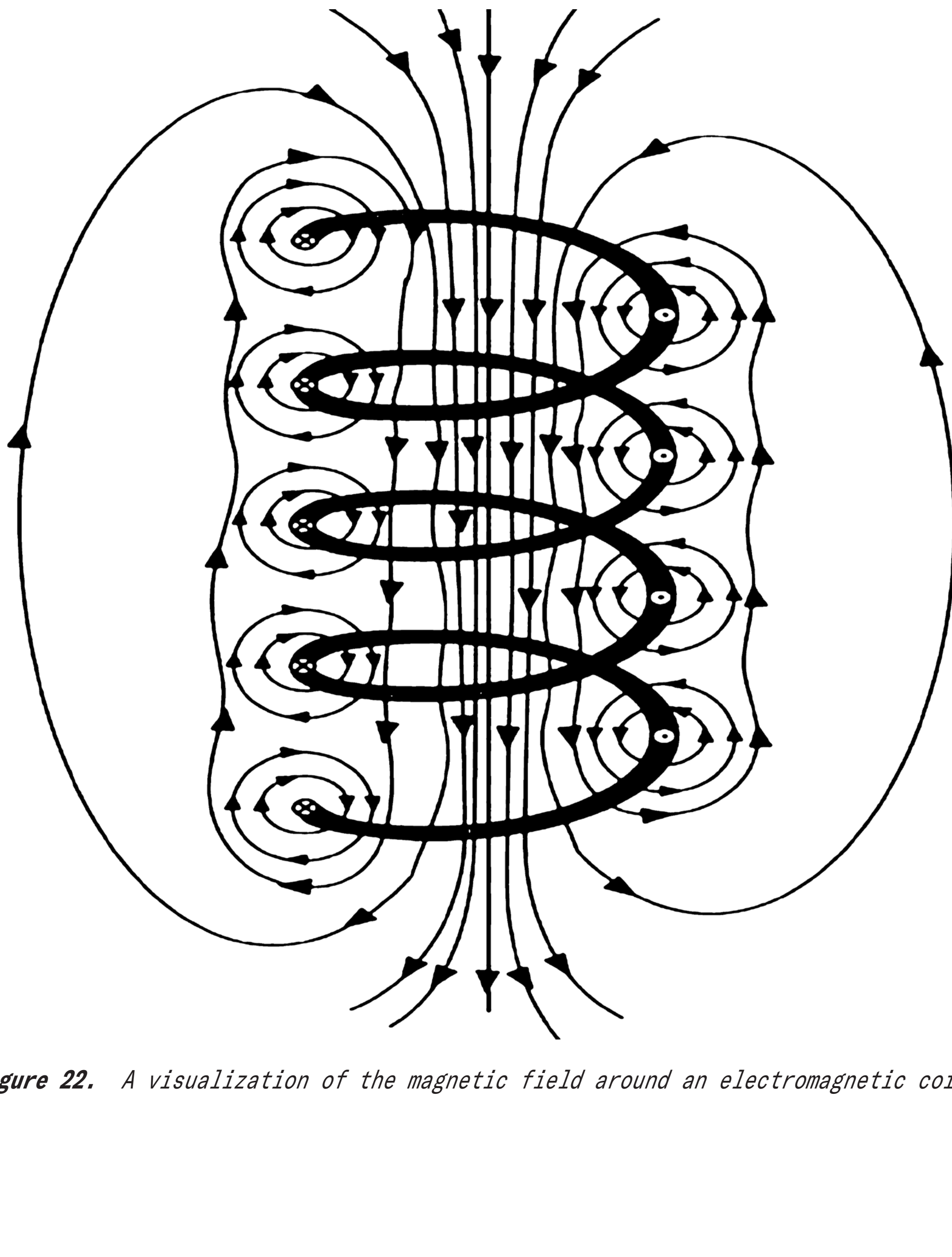


Figure 22. *A visualization of the magnetic field around an electromagnetic coil.*

DECOHERENCE

DECOHERENCE

DECOHERENCE

DECOHERENCE

DECOHERENCE

DECOHERENCE

Decoherence is a single channel video piece created using cymatics. It explores the dynamics of wave interference patterns.

In physics, the word *decoherence* refers to a phenomenon in quantum systems. Decoherence occurs because it is impossible to completely isolate a quantum system from its surroundings. It is the reason that macroscopic systems (such as things at the human scale) do not exhibit the same strange, paradoxical behaviors as the quantum realm. Macroscopic systems are modeled classically; quantum systems are modeled using wave functions of probability, and these wave functions can interfere with each other. Coherence refers to a quantum object's wave-like nature and ability to interfere with itself, resulting in superposition: the ability to be in mutliple states at the same time.

In a universe containing only this object, it could exist in this way forever... In our universe, when an inevitable disturbance occurs, the wave function collapses and the object is found to be in a single state.

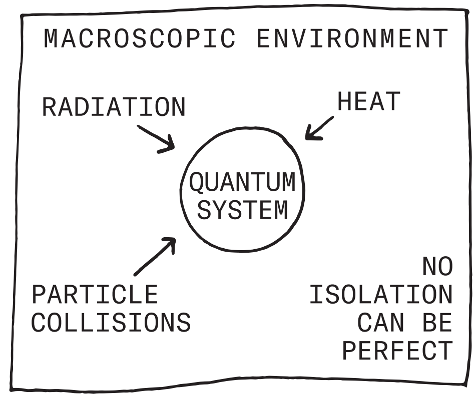


Figure 23. *A quantum system whose coherence is threatened by outside forces.*

Decoherence is currently the biggest obstacle in quantum computing. This is why quantum computers can only operate at extremely low temperatures. To the question of whether the human mind may be a quantum computer, some argue this is impossible... because it is too warm.

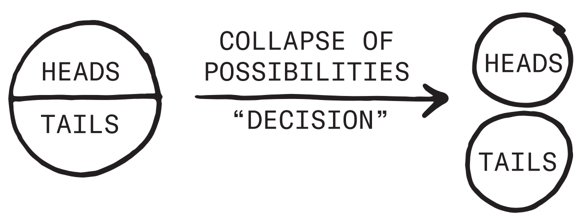


Figure 24. *After a collapse of possibilities, a system is found to be in a single state.*

CYMATICS

Cymatics is a way of translating sound waves (pressure waves) into visual patterns, usually by vibrating a container of liquid or small grains of material (such as sand). The frequencies and harmonic content of the sounds influence the patterns produced.

In a Chladni plate (Figure 25), the particles on the surface of the metal plate are scattered by the vibrations. Eventually they arrange themselves into different patterns depending on the sounds used, and how the waveforms resonate with the shape of the plate.

In Figure 26, as the speaker vibrates, the container of liquid moves up and down. Ripples appear on the surface of the water and reflect back in on themselves at the edges, causing self-interference and forming symmetrical, nonlinear standing waves called Faraday waves. This process was the basis for my own cymatics setup, which I used to record *Decoherence*.

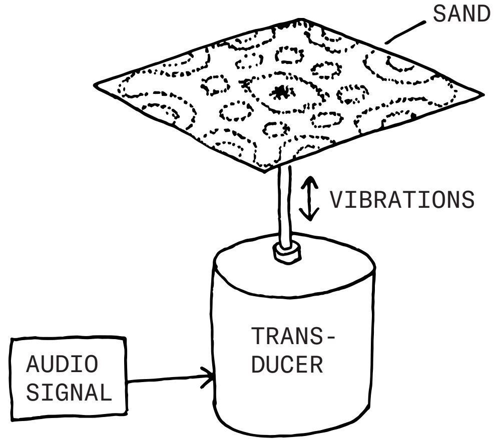


Figure 25. *A Chladni plate driven by an electromagnetic transducer. The original version, invented by physicist & musician Ernst Chladni in the 1700s, used a violin bow to vibrate the plate.*

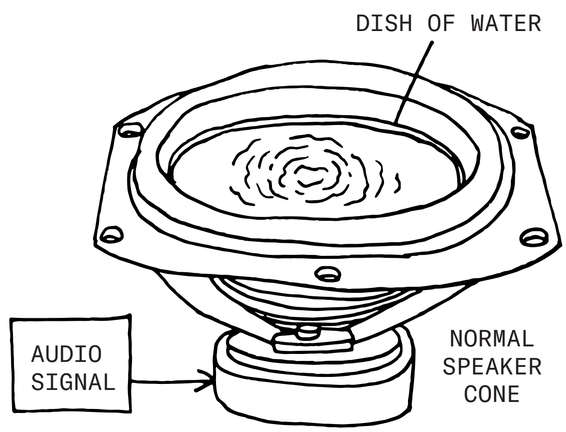
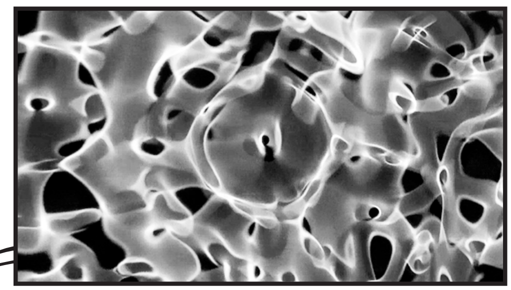


Figure 26. *A speaker cone being used as a transducer for liquid cymatics.*

MY EXPERIMENTS

I decided to experiment with cymatics as part of my exploration of the space between physical materials and electronic media.



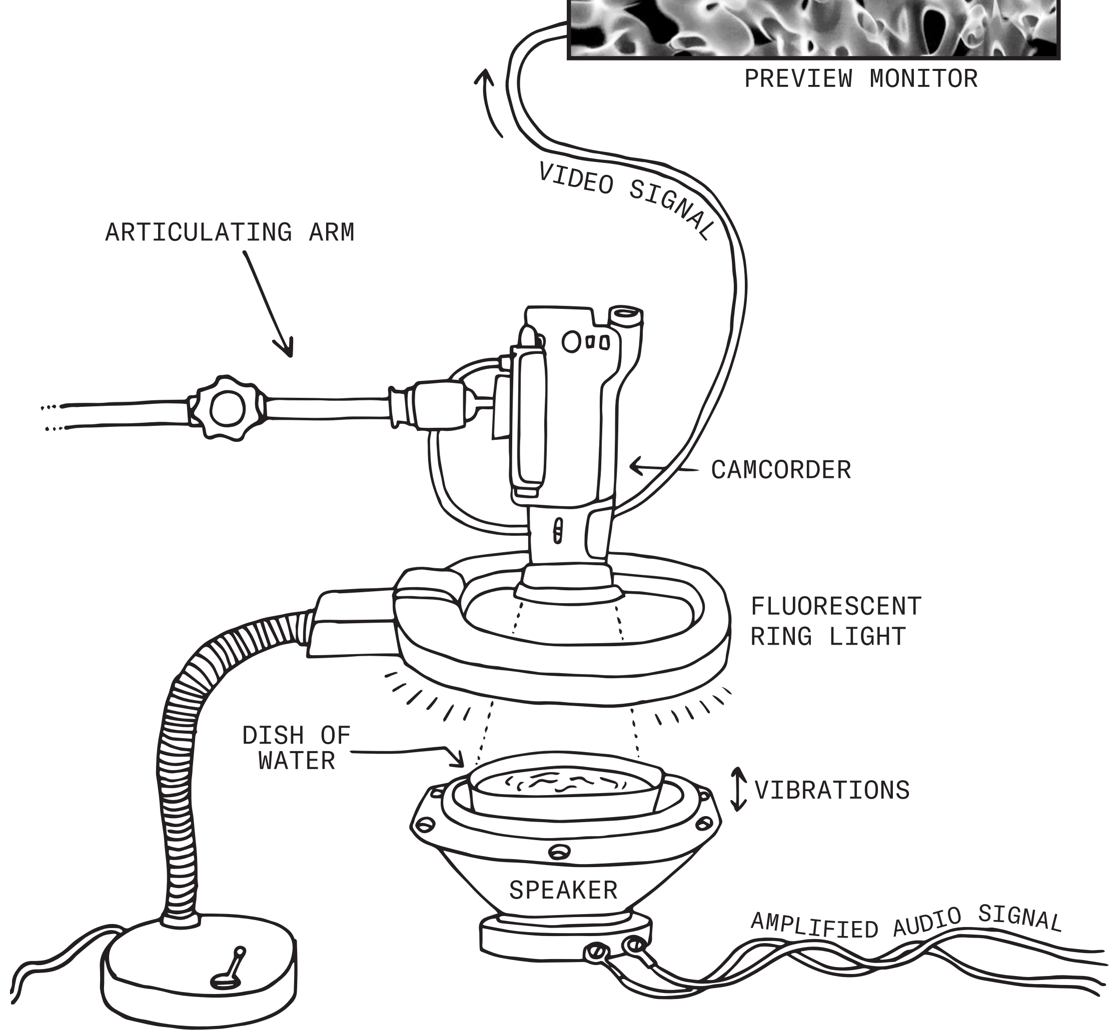


Figure 27. *Illustration of my cymatics rig for <u>Decoherence</u>.*

I developed a setup that allowed me to control the frequency and amplitude of a sine wave which vibrated a dish of water. The vibrations created ripples, and the ripples distorted the reflection of the ring light which pointed down at the water. The camera recorded the distorted reflection at 30 frames per second. The preview monitor allowed me to see as the camera did while I explored the system I had created.

The patterns in the water looked jumpy, because they were moving faster than the camera could capture. But when I oscillated the speaker at 60 Hertz (twice the frame rate), they seemed to sync up and the movement became smooth.

As I increased the amplitude, the smooth patterns became increasingly unstable; they began to fluctuate erratically, as though pushing and shoving against each other. Eventually, the smooth harmonic forms fully disappeared and droplets of water broke the surface, flying towards the camera lens.

I later read that Faraday waves tend to oscillate at half the driving frequency, which is why the results were smoother using a frequency of 60 Hertz rather than 30 Hertz.

Figure 28. *The image that the camera showed when no sound was played through the speaker; it's just a cropped reflection of the circular fluorescent light bulb.*

I painted the water dish black so that it would be mostly invisible behind the bright reflection.

Throughout the process, dust from my studio ceiling fell into the dish. I eventually accepted it as part of my image.

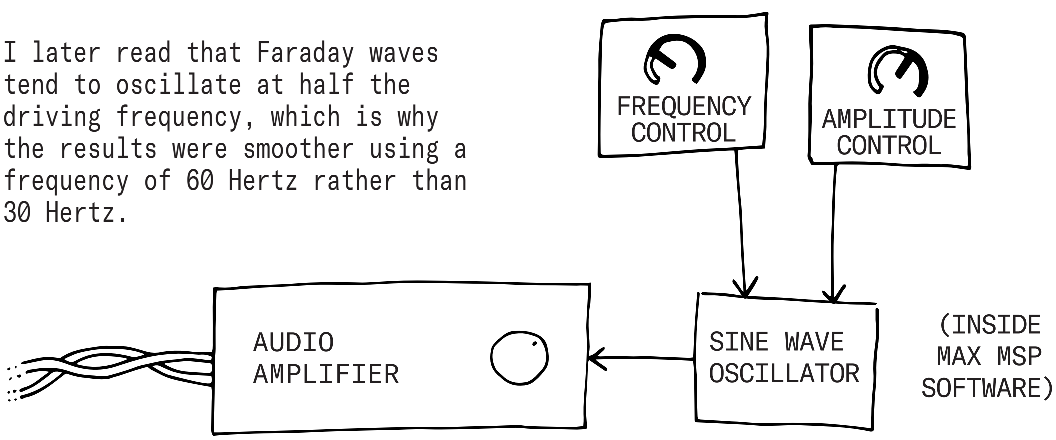


Figure 27. *Cont'd.*

In the video recording which became the piece, *Decoherence*, I kept the frequency of the oscillator locked in at 60 Hertz to maintain the smooth motion. The main gesture in the piece is the transition from the slow undulations of the standing waves, toward transient, spasmodic randomness when the amplitude is pushed to its peak, and then back.

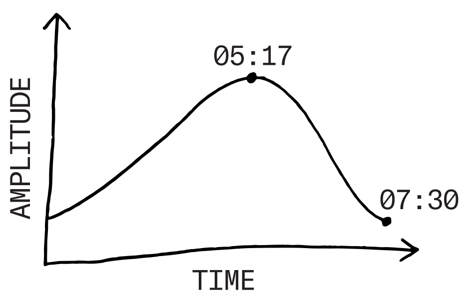


Figure 29. *A graph showing the amplitude of the sound waves during the recording of* <u>*Decoherence*</u>*.*

The transition between these states is a gradient. It is impossible to pinpoint an exact moment as the turning point. When the movement is slow, the patterns seem almost organized, though they are still unstable. The frame appears to be filled with clusters of overlapping toroidal forms, which fluidly snap together or separate from each other. When viewing the footage frame by frame, the morphing of each shape can be tracked as each frame differs only slightly from the last. By contrast, at the peak amplitude, the movement is too fast and hectic to be seen at 30 frames per second; while each frame may contain similar patterns to the last, they appear to rearrange themselves completely between the time of each frame, with a frenetic cadence like a rapidly boiling pot on the stove.

The gradual change from smooth to turbulent was mesmerizing to me. As the energy of the waves grew, their height increased, causing the toroidal forms to turn *inside out* and form what looked like small nodes connected by tubes. As these tubes shuddered, twitched, and grew faster, I observed macroscopic patterns that emerged from the movements of large numbers of these nodes, which seemed to form a network of energy exchange.

The recording of the 60Hz sine wave became the underlying sound in the piece. In the beginning and end, where the movements of the wave patterns morph slowly, the ripples spreading across the surface reach the edge of the container and are reflected back in, where they interfere with the original waves. To parallel this in the sound, I duplicated the original sine wave and modulated its frequency slightly to create sonic beating, which also grew in speed and intensity.

For the climax in intensity of the visual patterns, more layers of the sound through spectral and granular processing are slowly introduced. These sounds are higher pitched, and composed of tiny snippets of sound which flit in and out of existence rapidly as the water droplets spew forth.

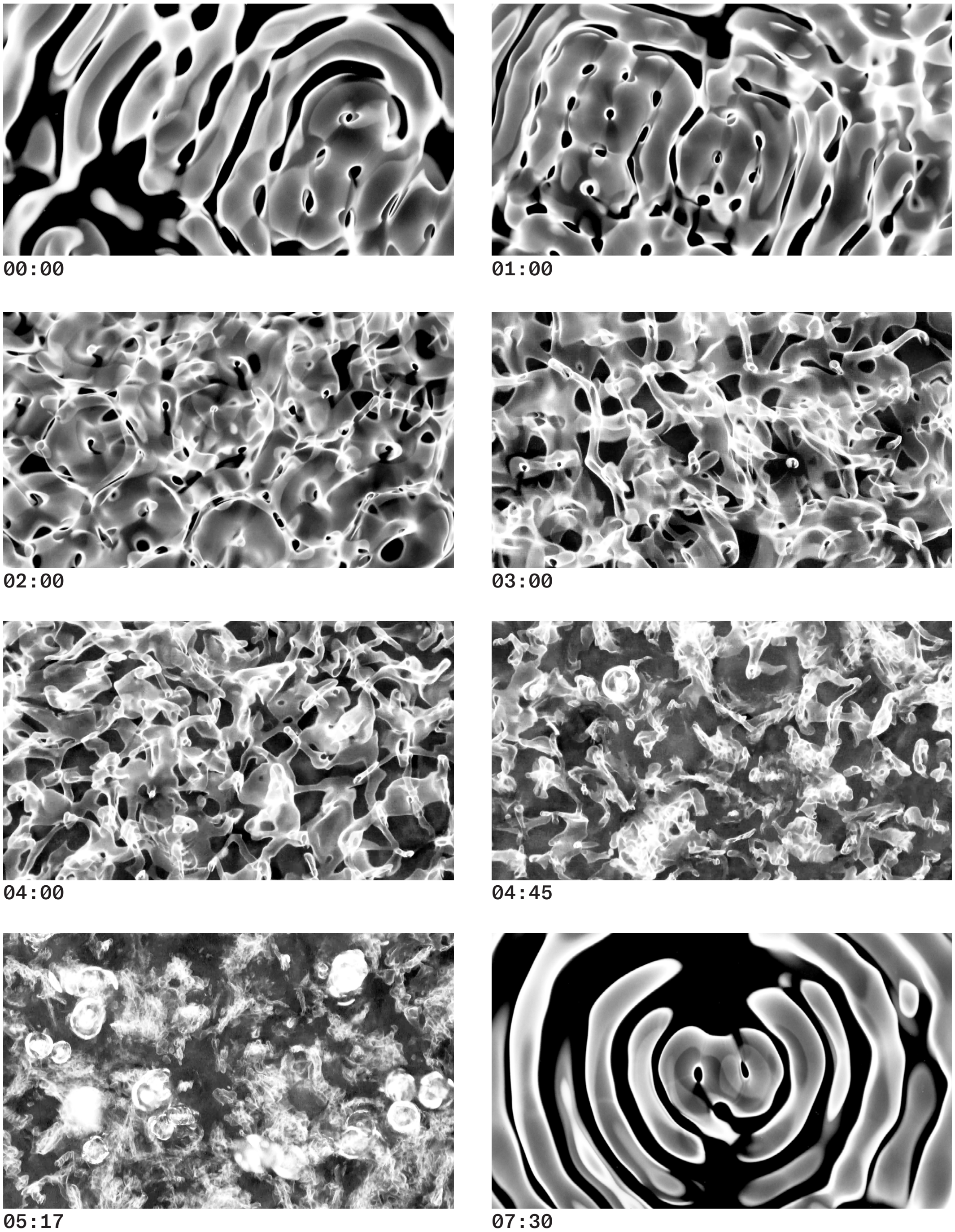
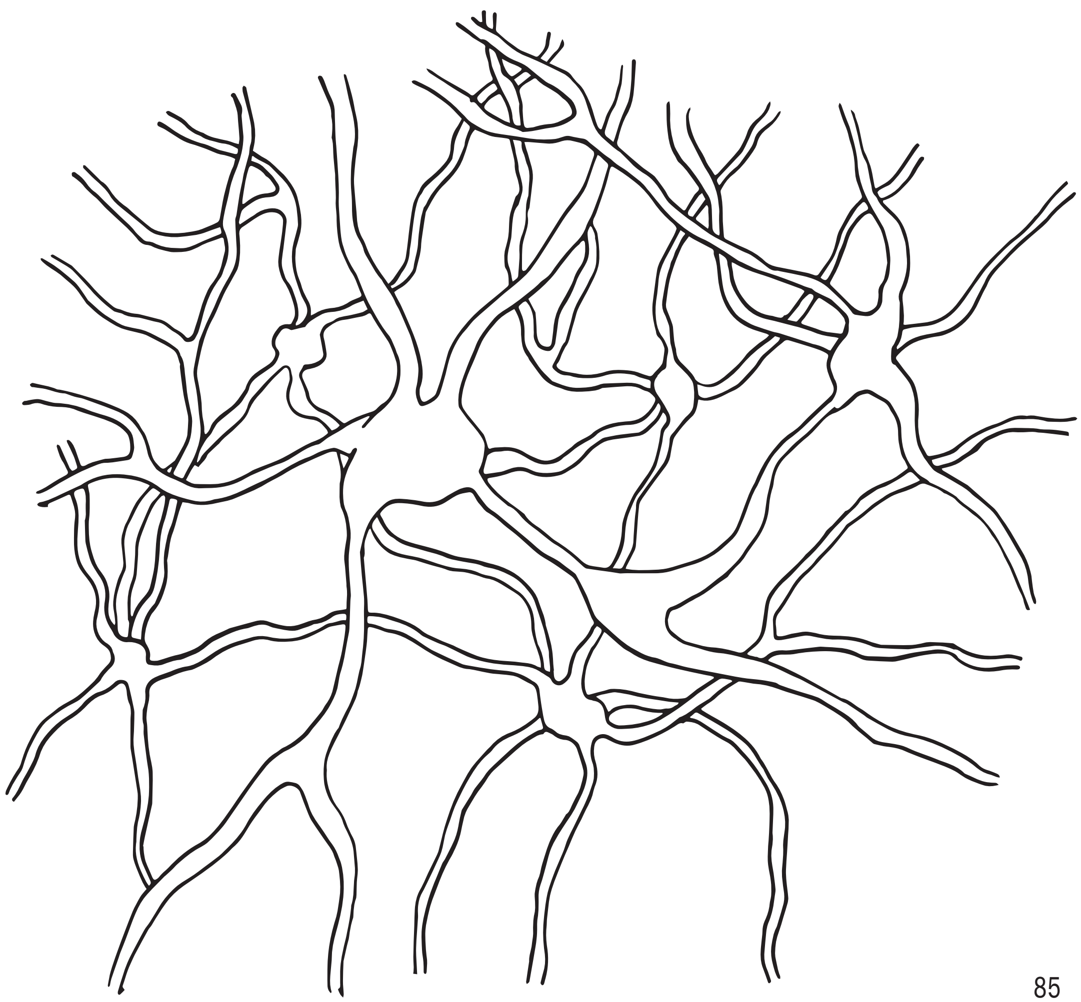


Figure 30. *A chronological series of stills from Decoherence, showing the transition from smooth standing waves to noisy randomness and back.*

THOUGHTS

While working on this piece, I was also doing some reading about brain science and philosophy of mind, particularly influenced by Douglas Hofstadter's *I am a Strange Loop*. I was especially struck by the difficulties in reconciling our understanding of the human brain on the microscopic scale versus the macroscopic.

Each neuron transmits electrochemical signals on a time scale much faster than we can perceive. Meanwhile at the scale of the entire organ, all these tiny interactions coalesce into patterns of conscious and subconscious thought, experience, memory... As I worked with the footage for *Decoherence*, I began to see parallels between the visual patterns at play and these ideas about the brain, as the individual forms seen in the video combined together to create larger, macroscopic patterns which seemed to take on their own emergent set of behaviors.



LABYRINTHINE

Labyrinthine is a single channel video piece that resulted from my experiments with ferrofluid. Ferrofluid is a viscous, oily liquid infused with iron particles that allow it to react to magnetism. I became interested in working with it because of its potential to bridge the perceptual gap between electronic space(time) and the physical world in a very visual way. Magnetism in general, especially electromagnets, provide a tangible and tactile way to interact with the invisible forces of electricity, but here was a substance which literally reshapes itself into the forms of magnetic field lines, creating a distinctive footprint of the phenomenon.

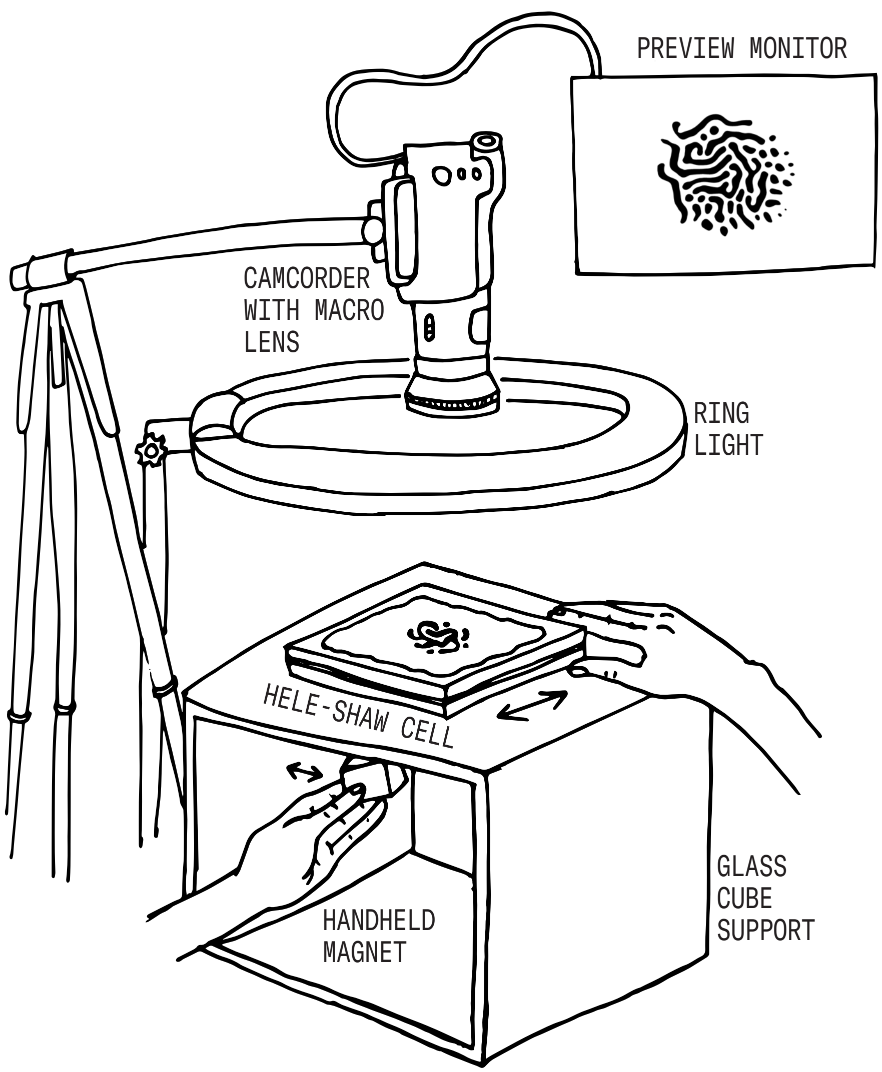


Figure 31. *Illustration of my rig for shooting Labyrinthine.*

Due to its fluid nature, it has a very organic movement to it, which gives the impression that it is a creature with its own affects and goals. I also found it a temperamental medium to work with, and I spent a long time developing ways to suspend and contain it.

In *Labyrinthine*, the ferrofluid is suspended in a saline brine, inside a narrow gap between two sheets of glass. This thin slice of space limits its freedom of movement, and changes the way it responds the the magnetic fields manipulating it. Instead of a spiky orb, the most common form it takes when magnetized, it arranges itself into intricate, mazelike patterns: a two-dimensional slice of the field lines attracting it. The narrow container is called a Hele-Shaw cell, and is used to study the dynamics between fluids of different viscosities.

I used a neodymium permanent magnet which I held in my hand to create the movement, and I also moved the entire cell around underneath the statically positioned, downward facing camera above, much like a wet slide can be moved around beneath a microscope. I used a macro lens to allow the camera to focus in and magnify the tiny phenomena within the cell.

I was able to influence the ferrofluid by moving the magnet around beneath it along the x and y plane, and varying the distance along the z axis by moving it up and down. Moving the magnet away made the field lines farther apart and the force weaker, creating a sparser pattern, while bringing it in close made it tighter and more distinct. For my shooting rig, I built a hollow 10 inch cube out of glass, leaving one face open for my hand to enter, then placed a fluid cell at the top (see Figure 31). A layer of white paper attached to the top face served as a backdrop.

The biggest challenge was creating the Hele-Shaw cells such that they would not leak, and the ferrofluid would not stick to the glass. Many months of trial and error eventually resulted in several cells which performed well enough to shoot with.

Each cell was comprised of two sheets of glass, with spacers around the edges to hold the 1 millimeter gap between them. I experimented with thin glass and weather sealing tape for the spacers, and with silicone sealant and UV glass glue to adhere them together and seal in the fluids. I left a small gap in the spacers, through which I could inject the saline and ferrofluid.

In order to minimize the sticking of the ferrofluid, I treated the glass with heat and cleaned it thoroughly with ammonia before using it to construct the cells. I also allowed 1 week intervals between the cell construction, injection of the saline, and injection of the ferrofluid in order to allow it all to set. I let the finished cells sit for several weeks before attempting to move the ferrofluid around inside.

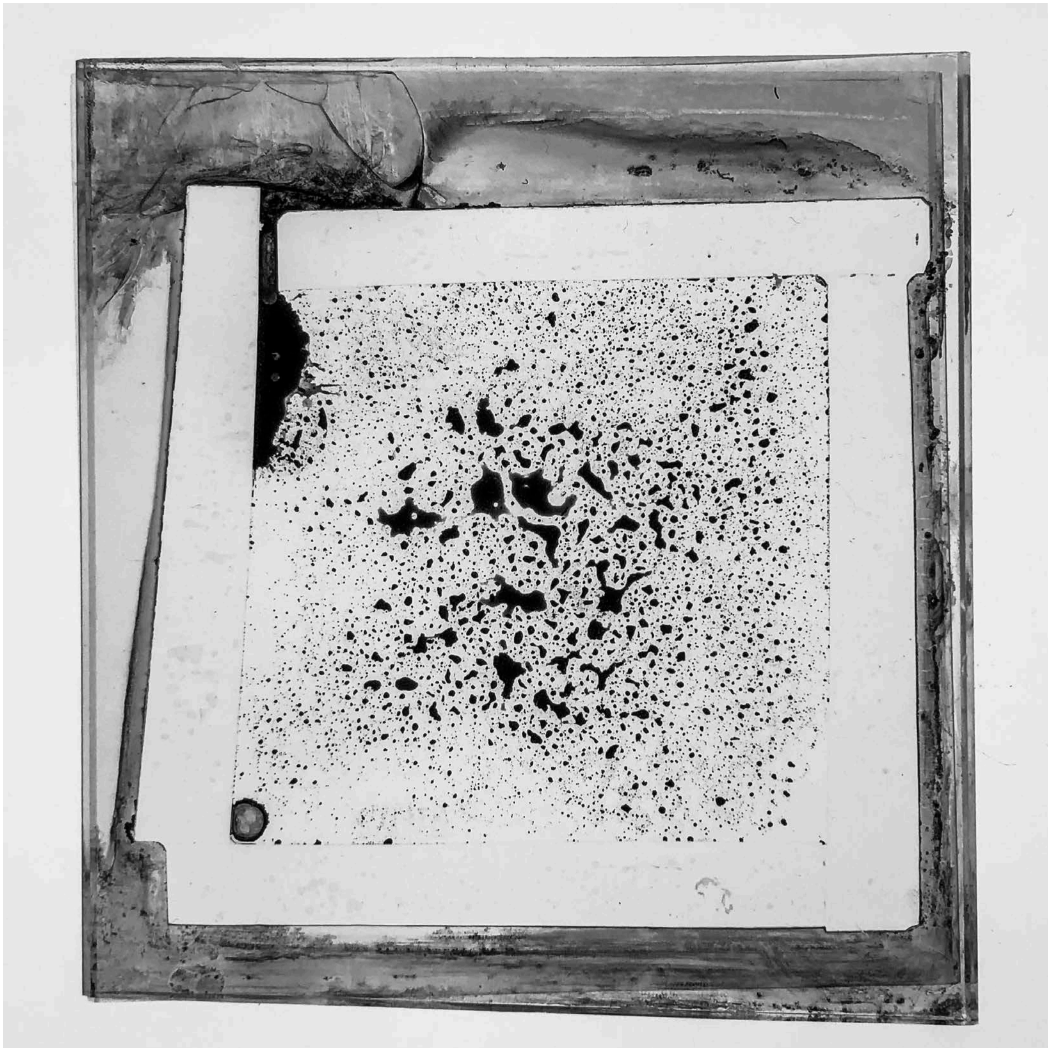


Figure 32. *Ferrofluid cell attempt #1: proof of concept. Glass spacers and UV glue. This was constructed all in one day, whereas the rest were built as a batch over the course of months. The ferrofluid stuck to the glass quite badly, but I was able to use it for testing of my magnets, shooting rig, and macro lens.*

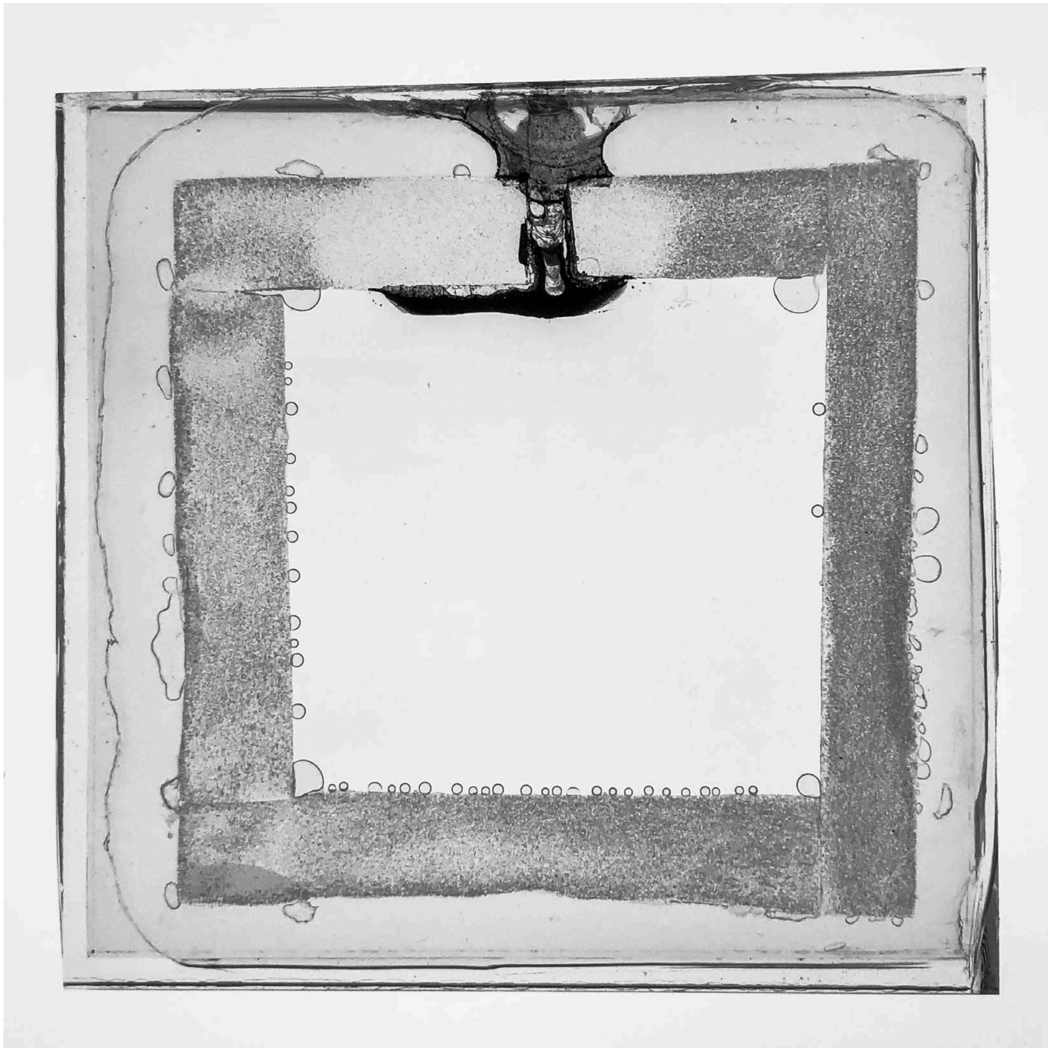


Figure 33. *Ferrofluid cell attempt #2. Weather tape spacers and silicone sealant. This cell did not have a good seal, so it dried out completely and was unusable.*

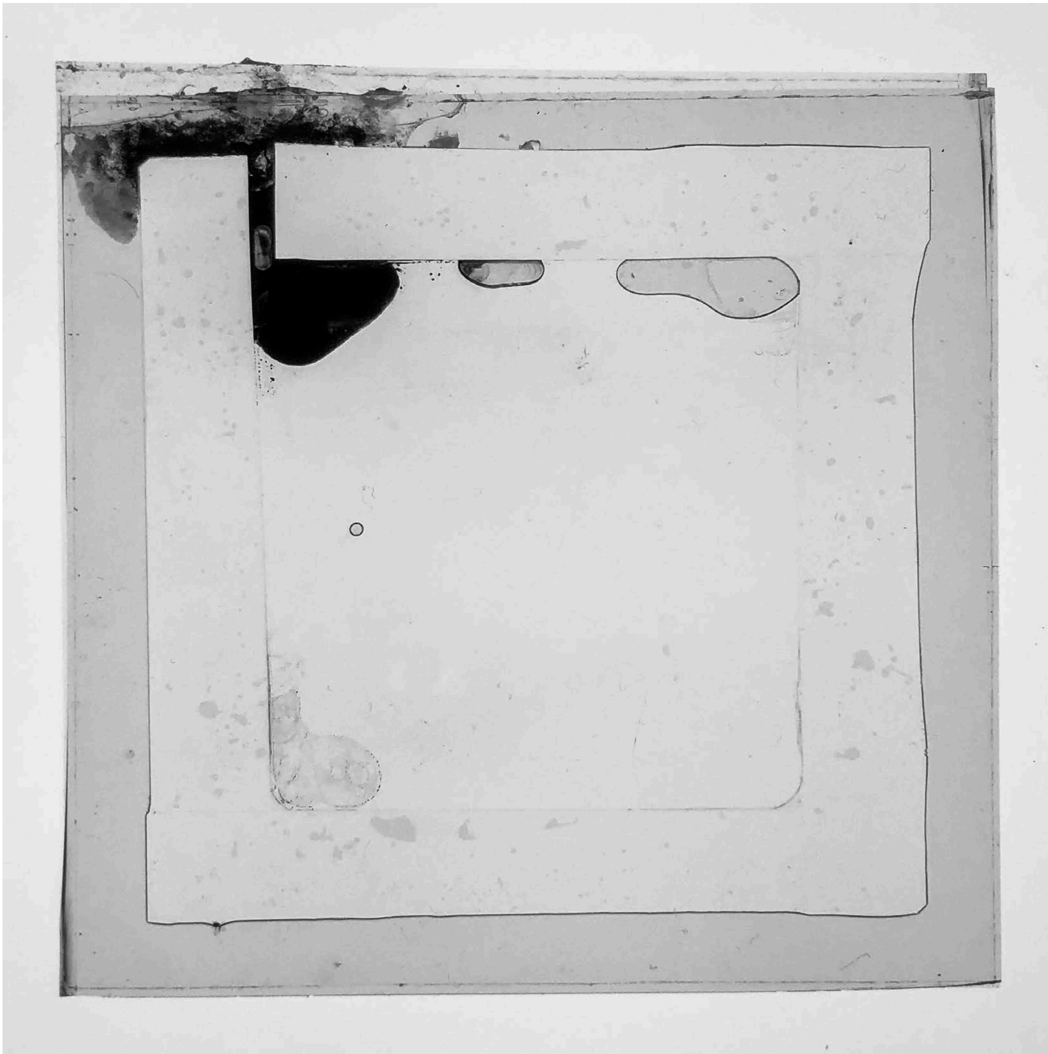


Figure 34. *Ferrofluid cell attempt #3. Glass spacers and UV glue. This cell had a good seal, however there was some debris and pockets of air that found their way inside which would have interfered with shooting.*

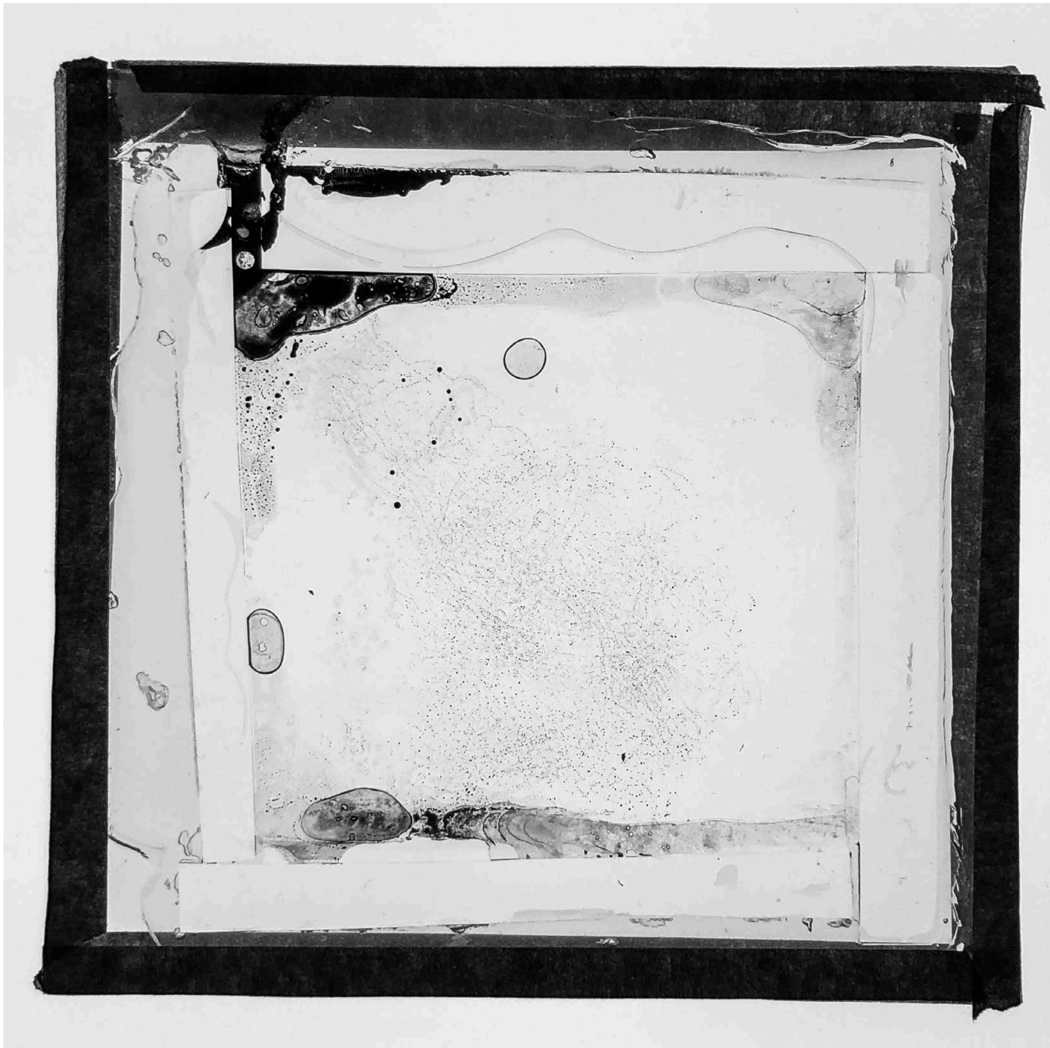


Figure 35. *Ferrofluid cell attempt #4. Glass spacers and UV glue, with additional silicone sealant applied around the outside edges. This cell was reasonably successful, and I used it to shoot my "rehearsals" of the final piece. The ferrofluid left behind a trail of very small dots, but it had the least sticking of any cell.*

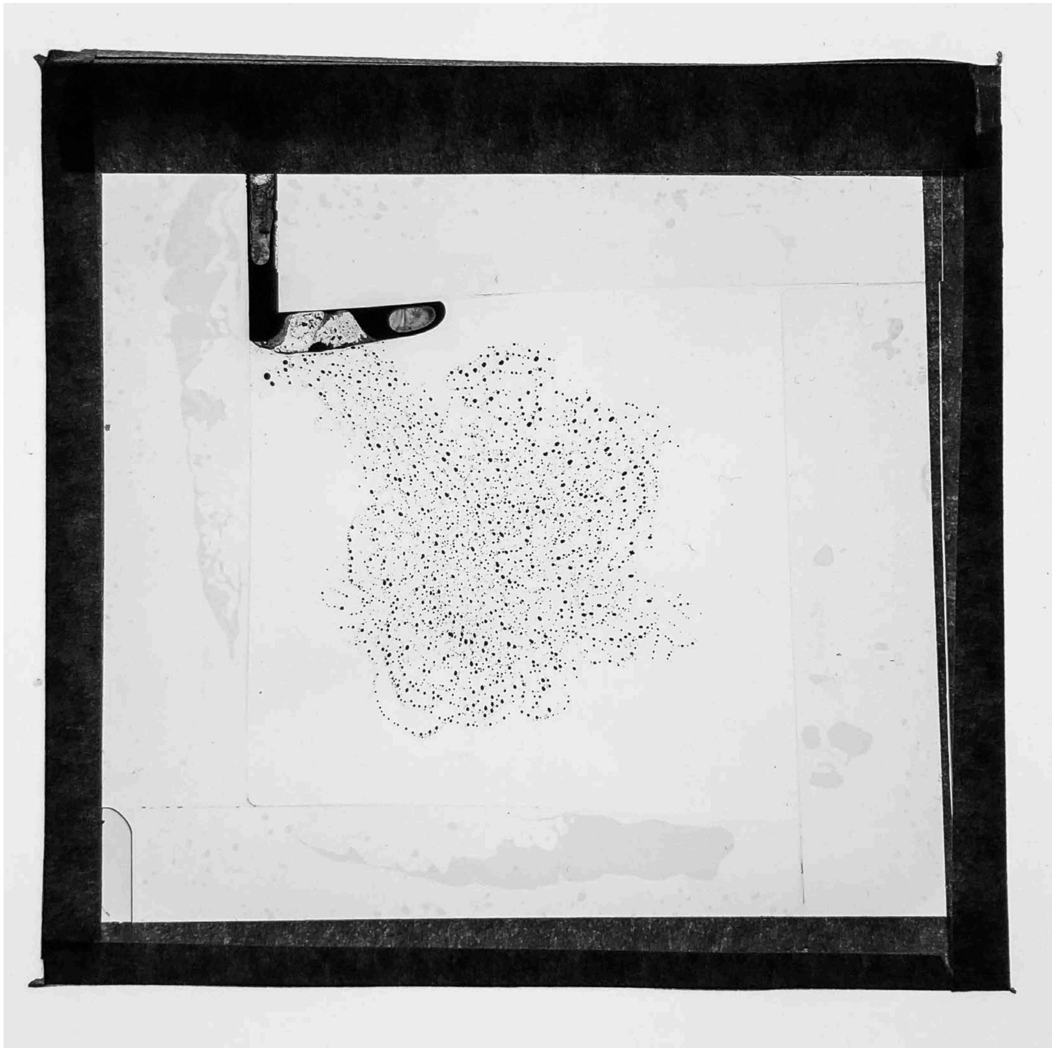


Figure 36. *Ferrofluid cell attempt #5. Glass spacers and UV glue. This cell was the most effective of the batch, with very little staining and air bubbles. The trail left behind from the ferrofluid consisted of larger dots than attempt #4, but it did not interfere too much with my shooting. This cell was used to shoot the final recording for Labyrinthine.*

Figure 37. *My shooting setup for Labyrinthine in my studio at Alfred University, before I had to move out due to COVID-19 and finish the project in my home.*

The final composition of *Labyrinthine* can be seen as a performance. The choreography was determined both by the system where it took place, and by my influence within its phase space. Although the movements I performed with my hands were simple, the system produced complex patterns and behaviors, which were different each time, no matter how hard I might have tried to repeat them.In this way, it felt as though I was collaborating with the ferrofluid system, rather than controlling it.

The sound was also produced through a collaboration, though this time with another human being. I invited Andrei Jay to record a soundtrack on the guzheng by improvising while watching the video recording. I then combined this with layers of granular processing and spectral drones, to create a layering of textures crossing between acoustic and electronic spaces.

In addition to the video piece, I experimented with taking stills from the footage and vectorizing them. The forms that emerged resembled glyphs of an alien language, so I wanted to work with them as a set of typographic elements. After gathering a number of vector forms, I broke them apart and used them to compose an asemic poem — a type of visual poem with no known semantic meaning.

In both the video and graphic works, the ferrofluid system becomes a generative visual language, reminiscent of Turing patterns often found in video feedback using a sharply focused camera pointed at a screen, and reaction diffusion patterns seen in chemical oscillators, and the skins and shells of many living creatures.

When I set out to build this fluid system, I intended to manipulate it using programmatically controlled electromagnets in addition to my handheld permanent magnet. However, after testing with the cells, I found that the electromagnets were not strong enough to significantly influence the ferrofluid inside the Hele-Shaw cells, since its movement was so restricted. Instead, I created another ferrofluid suspension inside a deeper glass vessel, which the electromagnets were able to move successfully. These subsequent experiments resulted in another ferrofluid video piece, titled *Morphogenentic Fields*.

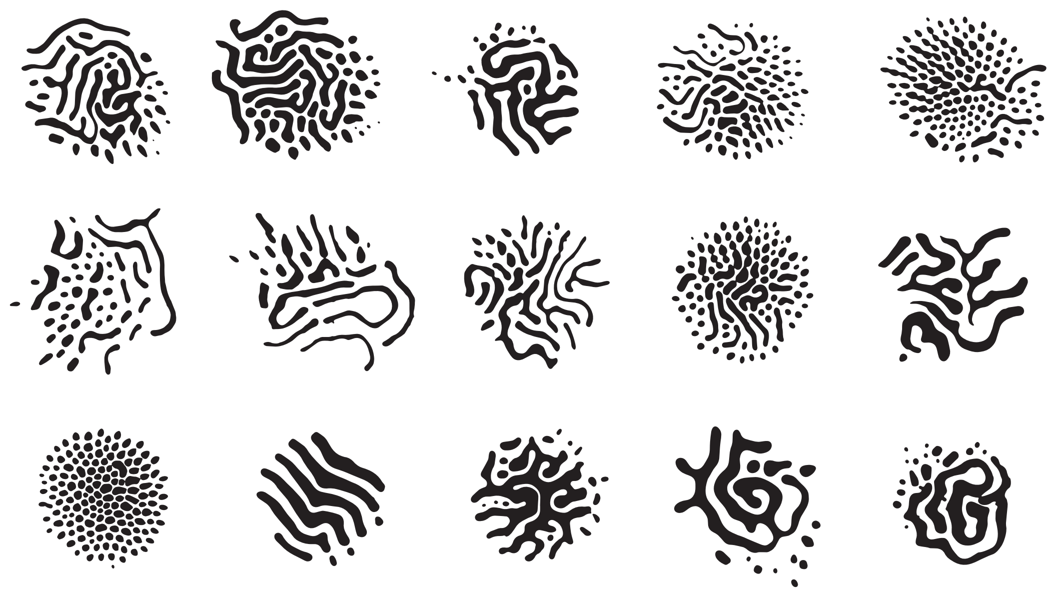


Figure 38. *A series of vectorized ferrofluid forms.*

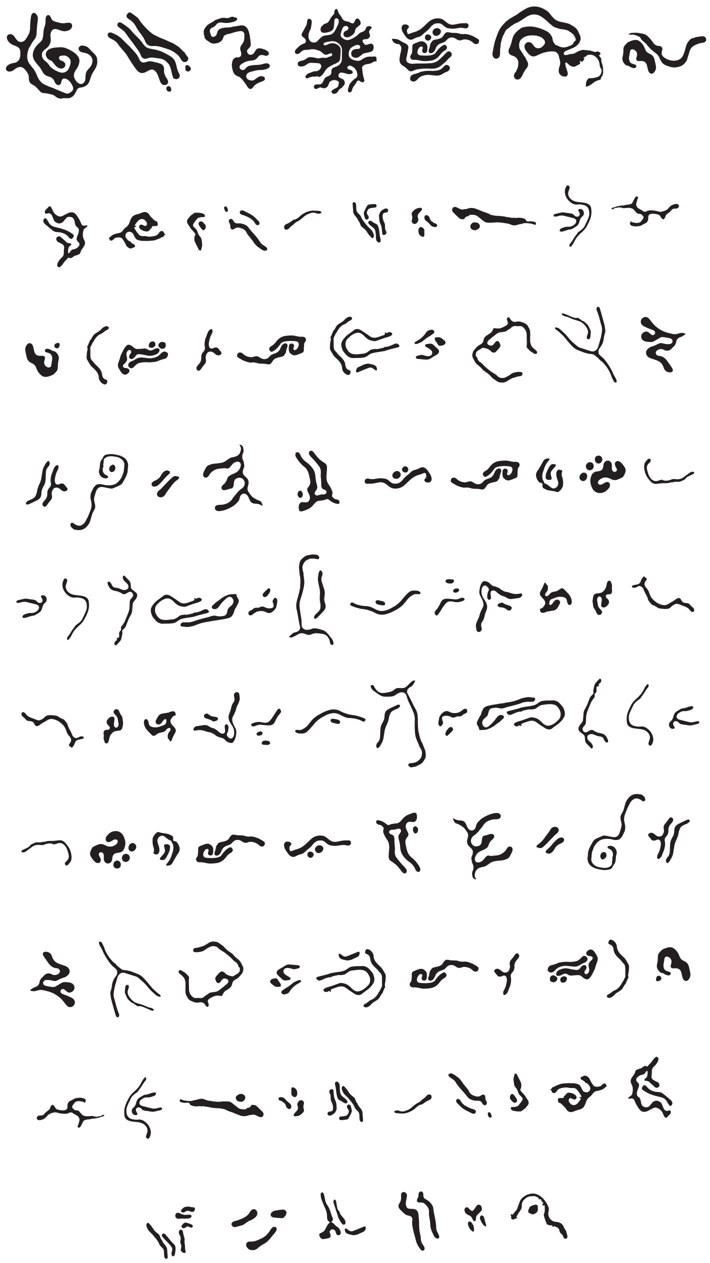


Figure 39. *Ferrofluid asemic poem.*

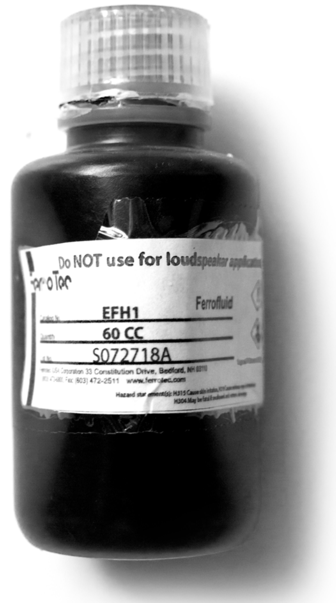


Figure 40. *A container of Ferrotec brand ferrofluid used in my projects.*

MORPHOGENETIC FIELDS

Morphogenetic Fields is my second video piece created using ferrofluid. The process was similar to *Labyrinthine*, but in place of my hand holding a magnet beneath the fluid cell, there were four electromagnetic coils. I used the same hollow glass cube as the structure to hold these coils in place, and built supports for them out of moldable plastic. Three of the coils were controlled by low frequency oscillators, generated using Max/MSP on my computer. The remaining coil, positioned vertically in the center of the others, was powered by a laboratory grade DC power supply.

The ferrofluid was again suspended in saline, but it was contained in a small, rectangular glass bottle. The depth of the vessel was around 25 millimeters – 25 times the depth of the Hele-Shaw cells in *Labyrinthine*, allowing for much more freedom of movement.

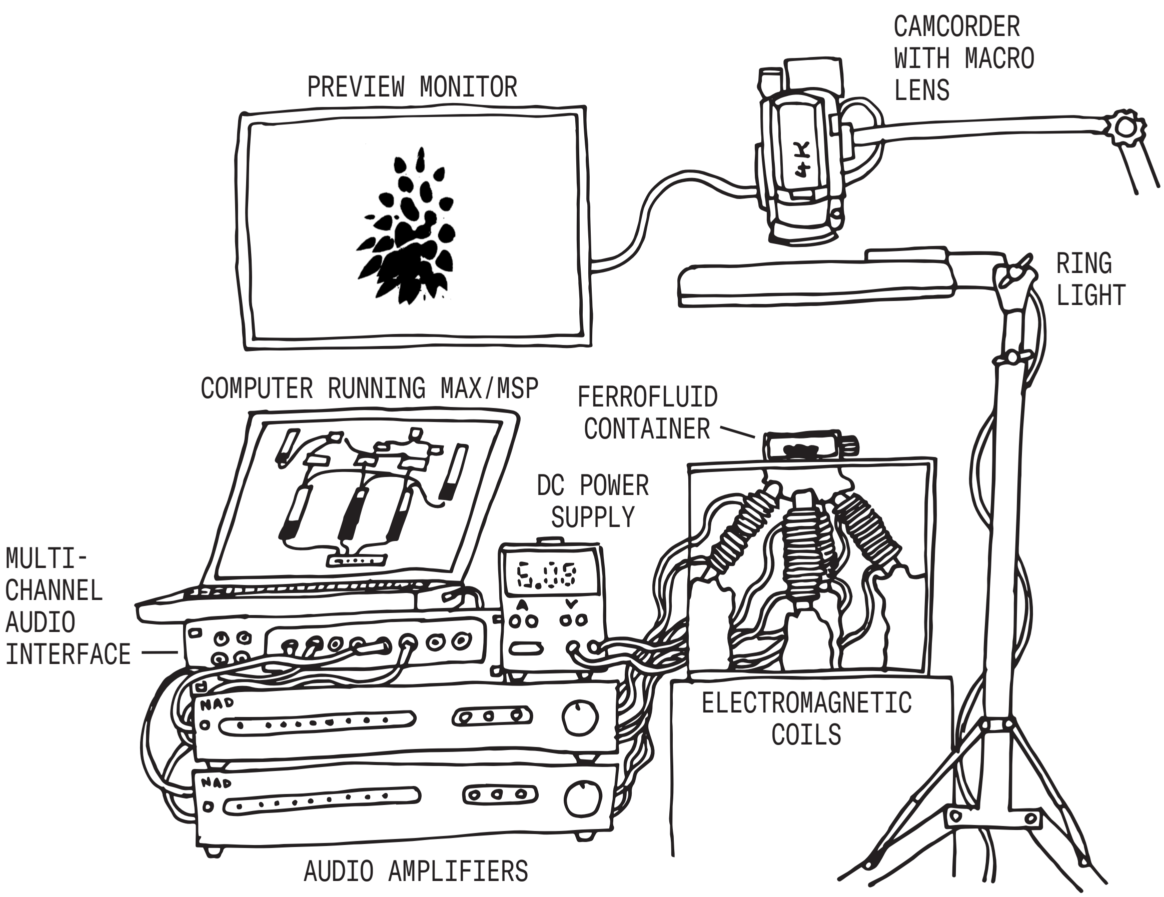


Figure 41. *Illustration of my rig for shooting Morphogenetic Fields.*

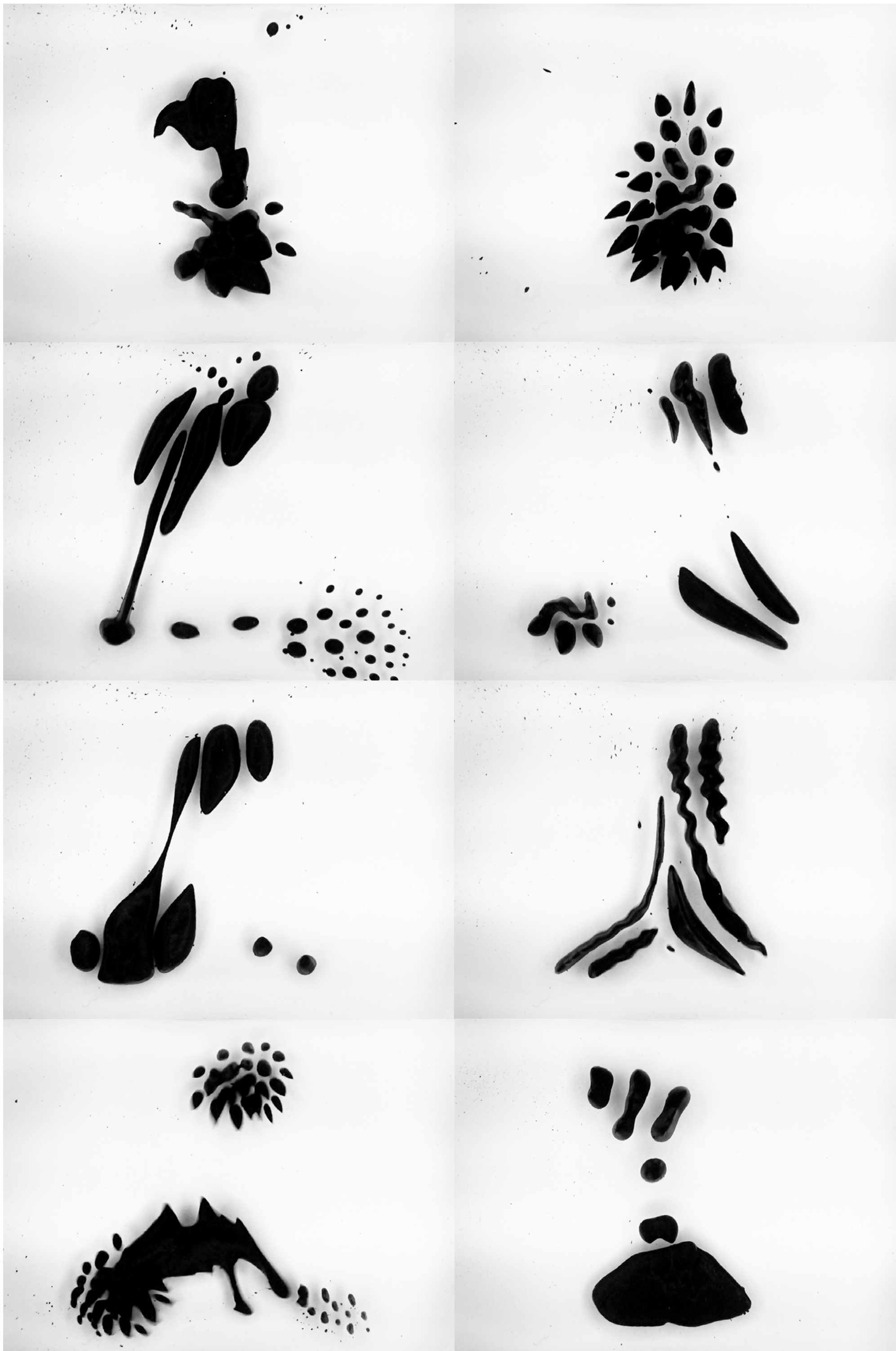


Figure 42. *A series of stills from Morphogenetic Fields.*

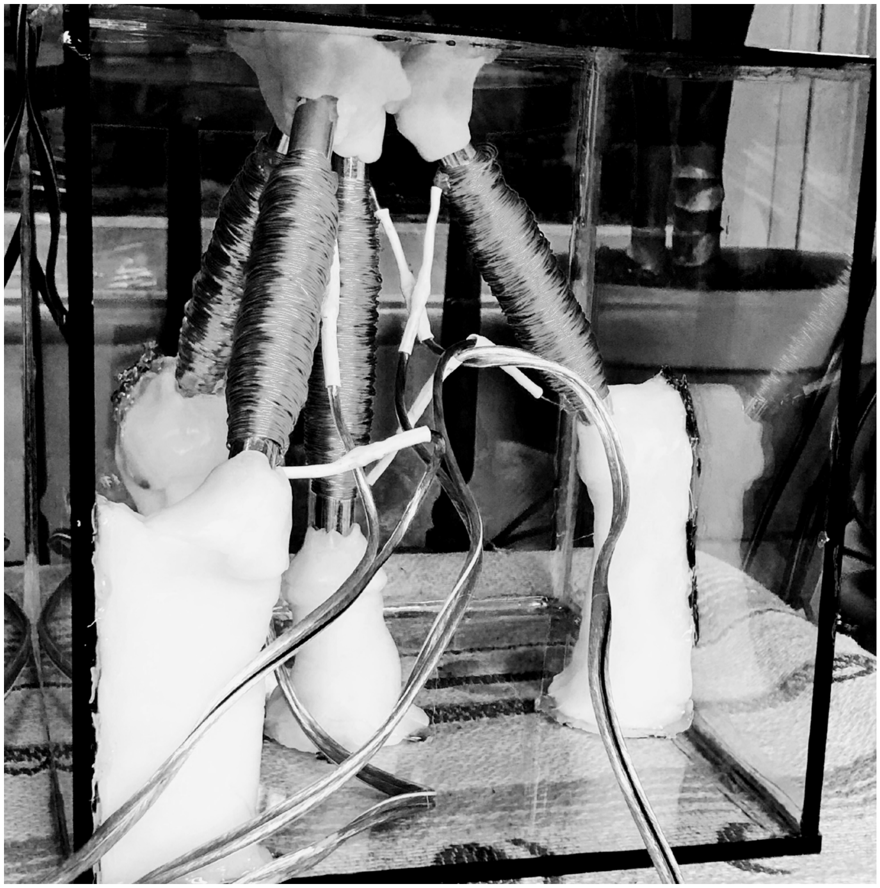


Figure 43. *The electromagnetic coils mounted inside the glass cube.*

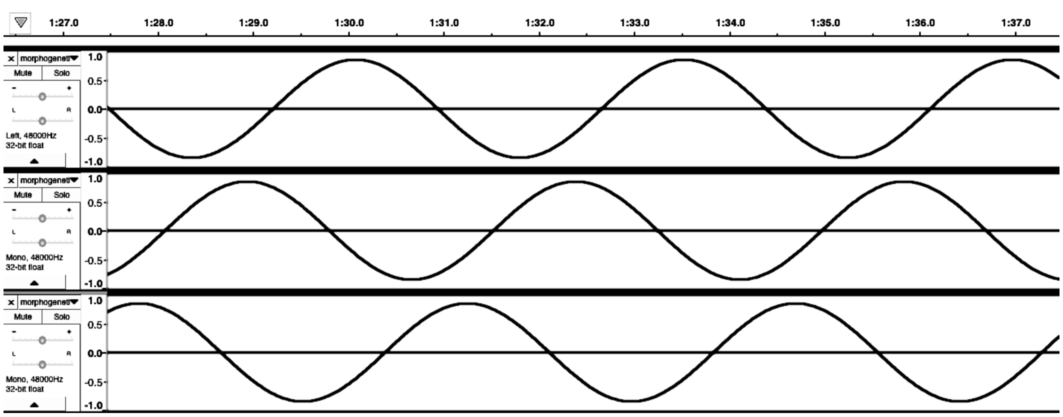


Figure 44. *These three-phase sine waves were amplified and sent through the three exterior coils, while the central coil was powered by a constant direct current.*

My goal in developing the setup was to be able to control the fluid movement as dynamically as possible, given the resources available to me. I was inspired by research from MIT such as *Ferrofluid Dynamics in a Hele-Shaw Cell Simultaneously Stressed by DC and Rotating Magnetic Fields* by Uzoma A. Orji, in which the author publishes details of their experiment setup. However, these researchers typically have access to specialized equipment such as laboratory grade signal generators and amplifiers, for which I substituted consumer grade audio equipment. My version provided much less power and precision, but still was able to achieve similar phenomena and affect the ferrofluid suspension in interesting ways, while on a much smaller budget.

The placement of the electromagnetic coils beneath the ferrofluid came together through trial and error. The central, DC powered coil was needed to hold the magnetic fluid in the center of the image, and generate a steady magnetic field orthogonal to the plane of view. I could control its level of power using the knobs on the power supply.

The three remaining electromagnets were placed around the center and angled inward, forming a triangular-based pyramid (see Figure 45). The signals driving these coils were sine waves with the phase offset by 120° (or 2*pi/3 radians) from one another (see Figure 44), so that the magnetic field generated would rotate or wobble at the frequency of the waves.

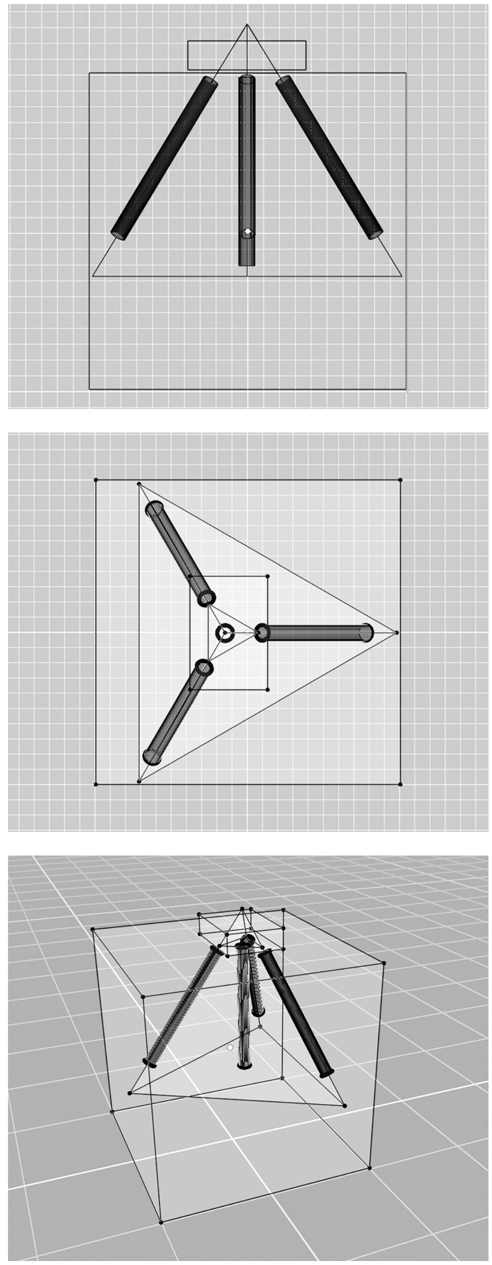


Figure 45. *The four electromagnetic coils are shown relative to the cube from the side, top, and perspective views. I had trouble illustrating the geometry of the coil placement using pen and paper, so I modeled them in 3D using Blender.*

The three sine wave signals were generated and controlled by my Max/MSP patch, passed out through a multichannel audio interface, and amplified by stereo audio amps designed for home speaker systems. The amps were not designed to handle frequencies below audible range, so sine waves below about 20 Hertz were distorted into something more like a pulse wave, though the overall frequency was preserved.

In the Max/MSP patch, I placed sliders to allow me to control the frequency and amplitude of the sine waves as they were being generated. I was able to control the overall power to the coils, or adjust the level for each coil individually. This allowed me to perform with the setup in real-time during the recording. When I decreased the power to the central DC coil, the separation between the three remaining coils became more visible, as seen by the triangular formations in the video and Figure 42. Higher frequencies and higher amplitude resulted in turbulent, spasmodic movements of the fluid, while lower frequencies and amplitude could create smooth, subtle undulations.

When I created the video recording that became *Morphogenetic Fields*, I also recorded the signals output to the coils as an audio file. Although most of it was sub-audio, I could see from the waveform viewer that the data had been recorded. Though some modulations were not captured through this process, such as adjustments on the DC power supply, it was a good starting point to preserve some of the control signals.

Later, in order to bring these signals into an audible soundtrack for the piece, I used them as modulation sources for software audio instruments and effects processors. I used each of the three phases of sine waves to control a different parameter or sound source, and added in more layers to recreate the movements of the DC adjustments. The result was a morphing drone which paralleled the visible motion of the ferrofluid. When watching and listening to them together, it feels as though the ferrofluid is either emitting the drone, or being controlled by it.

While running the electromagnetic coil setup for testing, practice, and recording sessions, I noticed that the coils generated a lot of heat. After each session, the plastic I used to mount the coils inside their glass enclosure would melt slightly and then solidify, causing the coils to slowly sag downwards, away from the ferrofluid. It seemed that this plastic material was not the best choice for constructing this rig, but I continued using it, with the addition of a fan to try to keep things cool.

The longest session of running the coils was during the recording of the final piece. Luckily, I was able to get a good take before the structure collapsed entirely. If I rebuild it, I will use a material with a higher melting point.

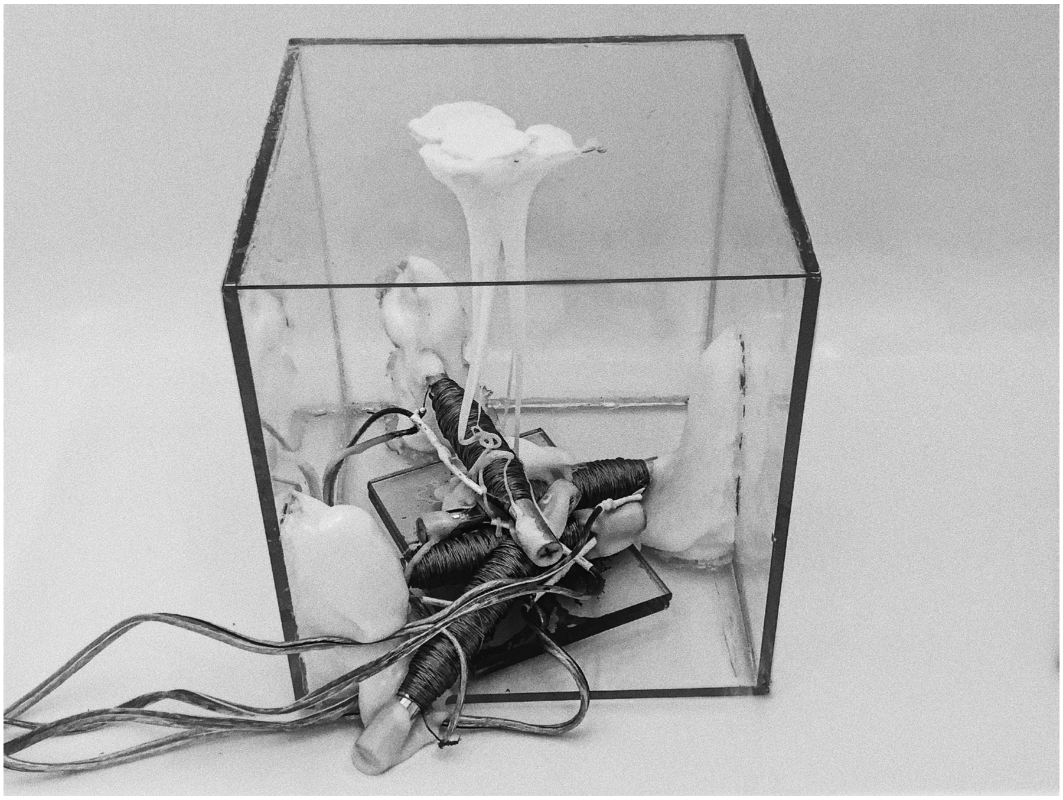


Figure 46. *The aftermath of my final recording session, when my electromagnet rig collapsed due to the plastic support melting.*

The swimming ferrofluids in *Morphogenetic Fields* resemble their *Labryinthine* predecessors in some ways, like when they extend tendrils while moving around, and take on an eerily lifelike quality. But their behavior has a distinct character, and my role in influencing their movements felt very different.

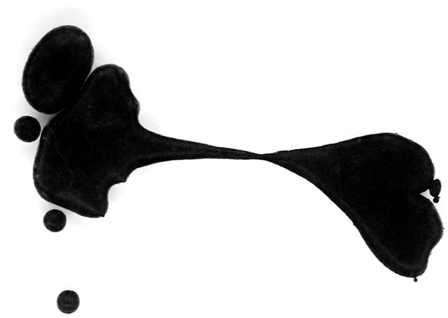
These creatures no longer stood still until my hands moved to activated them; the automation of the spinning magnetic field caused them to sway and squirm about. The forces causing their motion were invisible, and though I constructed the apparatus, the sense that they were autonomous beings was inescapable. I could change the parameters of their behavior, but unless I cut power to the whole thing, the ferrofluids would continue some form of wobbling, spinning, twitching, or breathing. They exhibited a diverse range of patterns and behaviors. In the recording, I tried to move through as many different gestures as possible in the choreography of the oscillating magnetic fields, the fluids, and me.

I set out to work with ferrofluids as a way to bridge the imaginary boundary between electronic space(time), with its invisible highways of electrons shooting through conductive materials at the speed of light, and material space(time), with its three-dimensional, tactile structure. The psychedelic performance tradition of the liquid light show, related to painting techniques, uses phenomena of fluid dynamics to generate fascinating patterns. Video synthesisizers such as the Sandin Image Processor (designed in 1969-1973 by Dan Sandin) use oscillators in conjunction with the analog video raster to produce dynamic, modulated abstract imagery and forms, which only become visible through an electronic display. I see this ferrofluid process as existing somewhere in between these practices, as it combines liquid materials with electronic oscillators.

I became interested in why the forms that emerged bear so much resemblance to biological organisms. The complex, three dimensional nature of the magnetic field lines led to the intricate forms, while their goopy mannerisms are due to the fluid nature of the material...

Their methods of locomotion sometimes resemble those of swimming microorganisms, or time-lapse footage of slime molds. How these creatures get from A to B is a combination of forces exerted by the organisms themselves, and the properties of the liquids inside and around their bodies.

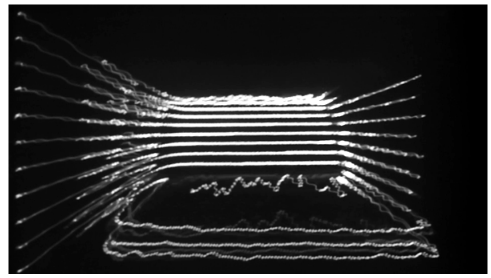
The ferrofluid forms have a way of separating into pieces, and then re-joining into a single *object*. So when comparing them with living creatures, we might ask: how can the boundaries of their bodies be defined? It can be just as difficult to answer for actual organisms, including humans. Since we are constantly taking in and excreting material, it can be more useful to describe our existence in terms of a dynamical process than as a collection of matter with sharply defined boundaries. The same concept can be applied to colonial organisms, where each one is part of a larger whole, or to the ferrofluid creatures, which can be described as a set of recognizable patterns and behaviors.



In biology, morphogenetic fields describe a series of invisible bio-chemical signals which cause groups of cells to arrange themselves into certain structures. In this piece, electromagnetic fields take on this role. They become an invisible force behind a constantly evolving series of morphologies in artificial life forms...

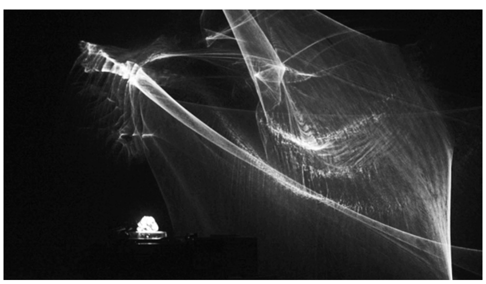
Experiments in Public, 2018.

Series of one channel HD 4:3 video recordings. Captured and upscaled from NTSC analog video source. Stereo sound.



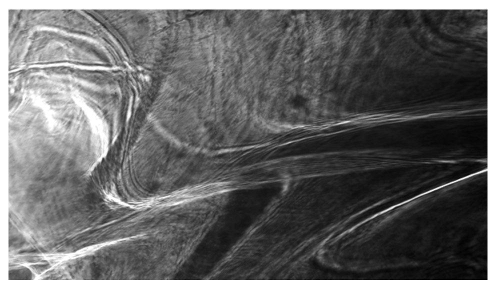
Chère Chambre, 2019.

One channel HD video recording from rescanned oscilloscope display of Jones Raster Scan. Stereo sound.



Lumiagraph, 2019.

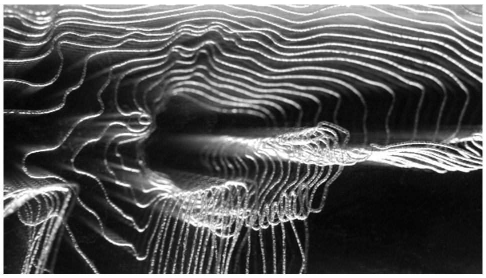
Video documentation of installation piece. Modified phonograph, variable DC power supply, red laser pointer, articulating arm, raised platter, hot-formed glass object, wheeled a/v cart. To be installed in a completely dark space with white walls. Stereo sound.



Refraction/Projection, 2020.

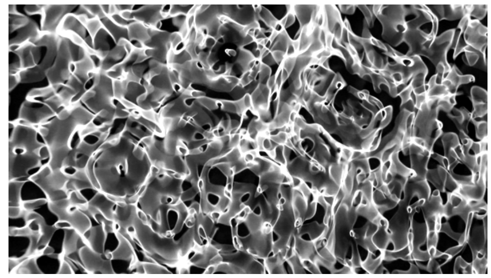
Two channel 4K looping video. First channel recorded using stop motion on lensless DSLR. Second channel recorded using 4K camcorder. Silent.

CATALOG OF WORKS



Video Topography, 2019.

Sculpture. Laser etched glass block, LCD backlight, wooden base.



Decoherence, 2019.

One channel 4k video. Recording of water surface as it is vibrated by a speaker using custom camera rig. Stereo sound.

Labyrinthine, 2020.

One channel 4k video. Recording of ferrofluid suspended in saline as it is manipulated with a handheld magnet using custom camera rig. 2 channel sound.

Sound includes a guzheng performance by Andrei Jay.

Morphogenetic Fields, 2020.

One channel HD 4:3 video. Recording of ferrofluid suspended in saline as it is manipulated by computer-controlled magnet using custom camera rig. 2 channel sound.

LIST OF TOOLS

HARDWARE

1000 lumen flashlight

Analog video mixers and processors:

- Akai Color Processor
- Archer Video Enhancers
- Edirol V4
- Edirol V4-EX
- Korg Kaoss Pad Entrancer
- Panasonic AVE-5
- Panasonic MX-50
- Panasonic MX-70
- Sima SFX-9
- Videonics MX-1
- Videonics MX-PRO
- Videonics Video EQ

Audio amplifiers

- Dayton Audio DTA-120
- NAD Electronics C 316BEE

BenQ W1080ST projector

BlackMagic Intensity Shuttle

Composite video & security cameras:

- Diebold ICD-509
- Panasonic GP-KR222
- Santex SA-01-1009A
- Sony HDR-HC1

Doepfer Modular Synthesizer

GW Instek GPS 1850D Laboratory DC power supply

Jones Raster Scan & Jones Video Oscillators

Korg midi controllers

Laser cutter

Laser pointers

Light table

Mac Pro desktop computer

Macbook Pro laptop computer

Materials and components:

- Ferrotec ferrofluid
- Glass
- Ink
- Iron rods

LIST OF TOOLS

- Lenses
- Magnet wire
- Moldable thermoplastic
- Neodymium magnets
- Prisms
- Scrap electronic components
- Speaker cones
- Water
- Wood

Nikon DSLR

Overhead projector

Presonus FP10 multichannel audio interface

Raspberry Pi Zero

Raspberry Pi B+

Ring light

Soldering iron

Sony 4K camcoder

Sony trinitron CRT monitor

Tethertools articulating arm

Timebase corrector

Tripods

Turntable

Various LCD screens

Elmo EV-500F Visual Presenter

XYZ vector display

SOFTWARE

Ableton Live 9

Adobe After Effects

Adobe Premiere Pro

Blender

Cycling74 Max/MSP

FabFilter VST Plugins

GRM Tools Plugins

Michael Norris Spectral/Granular AU Plugins

Melda Suite VST Plugins

Reaper

u-he VST Plugins

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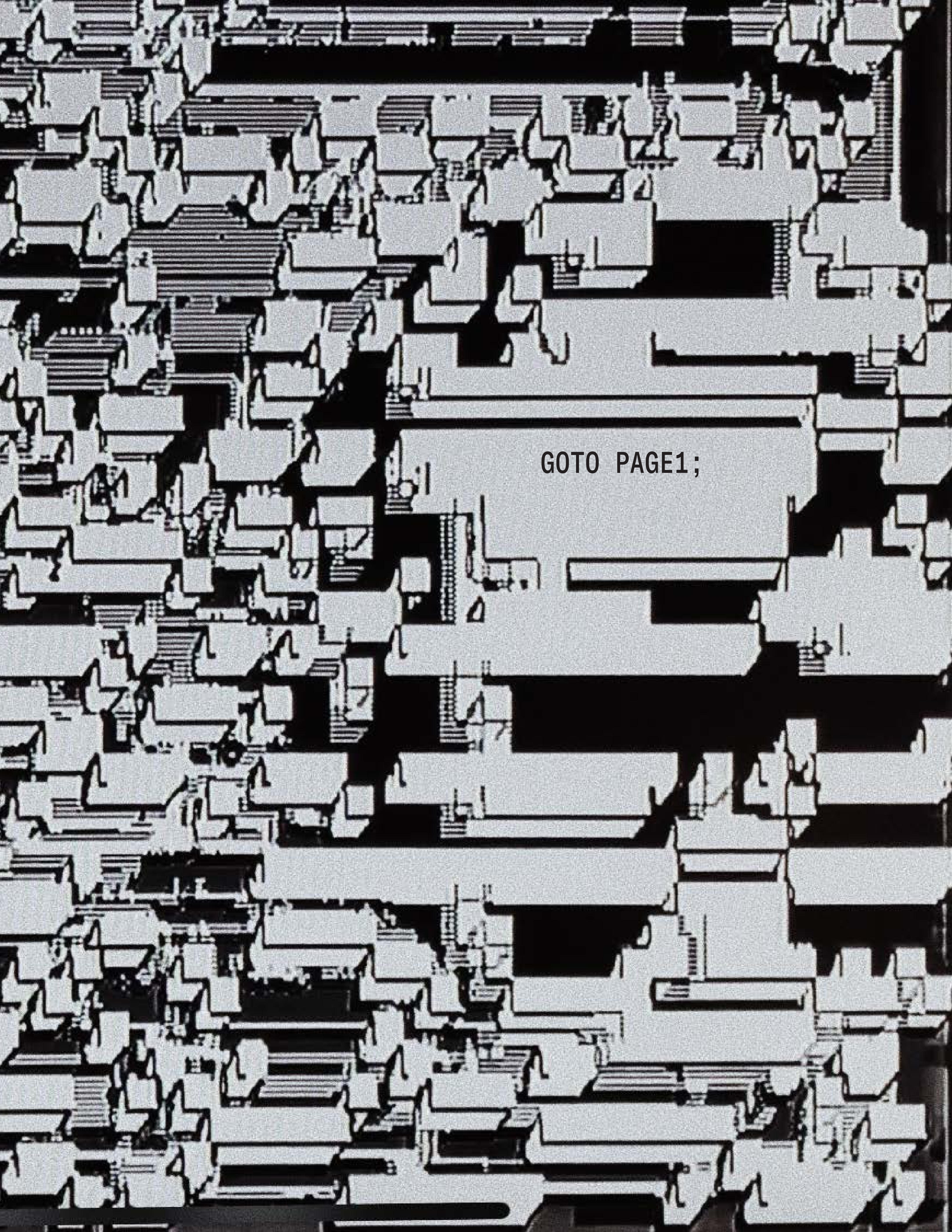

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