TABULA RASA

A senior project in Computing & The Arts
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*To those who wished me good weather,
happy snark-hunting, and luck in the
search for small treasures.*

CONTENTS

INTRODUCTION

The ground we stand on is a perfectly manicured lawn whose roots reach down to a layer of scorched earth beneath. It is the asphalt that paves a road that was once a river, still reeking and stinging with tear gas from a protest days ago. It is the hairpin turn of a desert switchback blown into a sacred mountain with dynamite and paved with cobbled fossils. This surface is etched with the layered afterimages of successive new beginnings: a lineage of abandonment, destruction, erasure, and starting over in the name of progress. It records the imperfect obliterations of a culture addicted to the spectacle of the total overhaul and committed to the fantasy of beginning from nothing. These are the marks of a love affair with the tabula rasa, whose illusive emptiness underpins many a vision of the human project.

Tabula rasa is a Latin term meaning “blank slate.” It means empty, razed, scorched, evacuated— but it also connotes wild, unbiased, and innocent. It means new birthplace and open opportunity, dramatizing the idea of a fresh start. It appears in various creative and scientific disciplines, each of which ascribe to it a new form and materiality but all of which rely upon the fond mythology of the completely new and innocent origin point.

This project will investigate the tabula rasa in computing and urbanism, using the mechanistic revelations of computational experiments to drive innovative observations of the tabula rasa in landscape (Fig. 1). An experimental interrogation of the computational tabula rasa through machine learning establishes a critical stance on the concept that translates from the context of artificial intelligence to that of landscape analysis, bringing a fresh perspective to the urbanist application of the term. In drawing a comparison between the related illusions of emptiness in these two fields, it intends to illuminate not only the captivating instability of the tabula rasa in each case, but also the powerful potential of computational thinking as a framework for parsing the nuances of complex urban systems.

The computational tabula rasa describes the empty structure of an artificial intelligence capable of learning without any innate knowledge. It implies the miraculous production of understanding from a totally blank and formless mechanism. To demonstrate the artifice of this notion, I construct a basic machine learning model— an autoencoder— that successfully learns to execute a simple evaluative task. By removing various parts of the model that would constitute inbuilt bias or “knowledge” and displaying the mutations these modifications introduce, I demonstrate the impossibility of the computational tabula rasa by exposing the fundamental dependence of machine learning on innately ingrained information. I then analyze the tabula rasa as a legal fiction that intervenes in the practice of computing despite its literal invalidity, questioning how the philosophy of machine learning might change if the tabula rasa were to be expunged from its technical ideology.

I translate the insights of this mechanistic exploration to the field of urbanism, where they inform an analysis of the tabula rasa defined as an empty site. Ar-

Figure 1: the neural network and the lanscape. Images: Google Earth.

chitecturally, the tabula rasa describes unbuilt environments, or wilderness, but also sites that were once built and somehow razed by human violence or natural disaster. I consider examples of each, looking for the ways in which the emptiness they supposedly represent is incomplete or flawed— and for the ways in which the tabula rasa is used to support specific narratives or cultural agendas. I pursue the traces of the erased in the reconstructed, demonstrating that cities physically obliterated exert an enduring influence through the culture of memory and the imperative of resilience. I pursue the traces of the urban in the wild, unearthing the scaffolding of civilization that props up the theater of wilderness.

My analysis of the tabula rasa in landscape is shaped by the methodology and intellectual framework I establish in the discussion of computational intelligence that precedes it. I address urban sites with attention to the layered transformations of the neural network and interpret changes in these environments as echoes of the mechanistic opacity and iterative clarity of a machine learning process. I metaphorically apply the procedures and mechanisms of machine learning to this analysis of the urbanist tabula rasa in order to propose a new model of landscape as a form of intelligent machine.

The urban case studies I address present a chronological pursuit of the tabula rasa through the second half of the twentieth century. They chase its appearance in various locations and contexts, starting with the nation-rebuilding project of postwar Japan, which I researched at its hypocenter in Hiroshima. My analysis of the Peace Memorial City that now stands on the site of the atomic bomb takes a targeted approach, mapping specific memorial sites in the city to illustrative mechanisms within the autoencoder. I deconstruct the post-atomic tabula rasa methodically and with close attention to the technical metaphor of the intelligent machine.

I then follow the tabula rasa into the overlap of colonial occupation and socialist transformation that brewed in Valdivia, Chile at the time of its catastrophic earthquake in 1960. My research in Valdivia accounts for both the environmental and social factors I observed in the course of my field work, producing an interlaced description of topographical and political upheaval. Its distributed content requires a more conceptual mapping of machine learning metaphors onto the landscape, which results in a simultaneously mathematical and sociological interrogation of a tabula rasa as political as it is seismic.

Finally, I arrive at the 1970s environmental movement and its interface with the exploding petroleum industry in far West Texas, where I explore the tabula rasa of protected wilderness in Guadalupe Mountains National Park. In this foundational and conclusive example, I return to the source of my musings on the tabula rasa in order to test their application. I follow the deep geological history of the region through to its current social and ecological incarnation, noting the importance of every era of its past to the manifestation of its present. I dismantle the tabula rasa of this environment according to the overall philosophy of learning defined by my computational experiments, using it to illustrate the utility and insight of the intelligent machine as a model for landscape analysis.

The sites I investigate are flung hemispheres apart, recalling the 19th century

scientist Alexander von Humboldt's aspiration of proving his theory of nature by demonstrating its validity in both the Andes and the Himalayas. However, despite their spatial distance, these three environments sample crucial points of inflection in the global narrative of the era at hand, creating a chorus of richly detailed object lessons that, viewed in sequence, give a point-wise representation of a global story. They sparsely represent the universality of the tabula rasa by drawing out the necessary abstraction of the concept that unites them.

It is though the analysis of these diverse urban sites according to the computational model of the intelligent machine that I access and ultimately refute the tabula rasa. My investigative style employs experimental and personal narrative observations in equal parts. As its objective demands, this mode of study intermingles the utility of output produced by scientific detachment with the emotive charge of first-person experience and participation. The textual research that supports this heterogenous mass of source material serves to establish its historical basis and fuel the rigor of its analysis.

Ultimately, this project adopts an attitude more curious than catechistic, seeking to conserve the honest observations of the wandering investigator rather than section and bind them into a linear flow. Its objective is not to logically disprove the tabula rasa once and for all, for the literal blank slate has already been abandoned in both disciplines as a practical impossibility. Instead, it looks beyond the strict absurdity of the tabula rasa to investigate the phenomena that invite and disturb its continued presence in our theoretical frameworks. Though even the briefest close look at the tabula rasa reveals it to be a total farce, the idea persists in both computing and landscape as a favored metaphor or theoretical extreme. This project fixates on the mythologies of emptiness that connect computation to urbanism and use them as a conduit for introducing computational methods to the practice of landscape analysis. In taking a fresh approach to disproving the tabula rasa, I reveal the utility of computational thinking to urban observation and demonstrate the fascinating potential of revisiting existing theories in unexpected ways.

COMPUTING

I: HISTORY

The computational tabula rasa denotes emptiness charged with potential. It is a latent intelligence, a promising void, a machine awaiting its ghost. It has made a long journey through various disciplines and movements in Western thought: it originated in philosophy, then wove through concepts of human nature to psychology, where its impact on theories of knowledge and learning brought it ultimately to computer science by way of artificial intelligence (AI). Through these transformations, it has accumulated the ornate detail of historical significance and the pervasive tint of ideology, coming to embody an emptiness that is anything but neutral. It is in this many-times-remediated form that I take up the term, evaluating its theoretical viability as well as its literal potential, which, as I will discuss, are related but distant measures.

The earliest ancestor of the computational tabula rasa appears in Aristotle's 350 BC treatise *De Anima*, where he philosophizes that "the mind is in a sense potentially whatever is thinkable, though actually it is nothing until it has thought," and compares this immaterial intelligence to the characters anticipated by a "writingtablet" upon which nothing is written yet (Fig. 2).[1] This statement, alternately used by later thinkers to signify either purity or openness in the human mind, defines the classical Greek origin of the tabula rasa: the cognitive metaphor of a promising empty vessel, awaiting the imminent but inestimable intelligence that will inhabit it and give it form and meaning. Though the term originates as a straightforward allusion to the scraped surface of a writing slate, it undergoes many connotative transformations across its history.

1 "The Internet Classics Archive | On the Soul by Aristotle."

Beyond this ancient point zero, the tabula rasa stirred in the writings of the Stoic school (circa 300 BC), the philosopher Avicenna (980-1037 AD), and St. Thomas Aquinas (1225-1274) before resurfacing in British political philosopher John Locke's (1632-1704) seminal "Essay Concerning Human Understanding" in 1689.[2] Locke's metaphor, which translates Aristotle's "writingtablet" to a "white paper" (initiating the evolution of the tabula rasa according to changes in the technology of intellectualism), equates the empty page to the human mind at birth.[3] He envisions the infant consciousness as a formless intelligence, devoid of innate knowledge, that receives information and learns to process it purely by the inscription of sensory input.

2 Duschinsky, "Tabula Rasa and Human Nature," 512.

3 Locke and Woolhouse, An Essay Concerning Human Understanding, 20.

Starting with Locke's usage, the lineage of the term becomes complex and controversial, involving a winding series of uses and misuses plagued by misinterpretation and misattribution. My simplified tracing of this genealogy primarily draws from cognitive scientist Stephen Pinker's *The Blank Slate*, which offers a traditional and effectively linear history of the cognitive tabula rasa, and sociologist Robert Duschinsky's "*Tabula Rasa* and Human Nature" (*Philosophy* 2003) which examines it with a critical philosophical perspective. The annals and detours of the tabula rasa's journey to the present are not relevant here. More important is the

Figure 2: the writingtablet.

consistent trend of the term's mobilization for various ideological projects, which still begins with Locke.

Locke's concept of human nature was a central underpinning of his social and political theory. It produced the vision of a peaceful and innocent state of nature that would support his liberal democratic ideals, a necessary basis for the rest of his philosophy. With his version of the tabula rasa, writes Pinker, "Locke was taking aim at theories of innate ideas in which people were thought to be born with mathematical ideals, eternal truths, and a notion of God," and instead enabling the assumption of a free and self-authored human mind, originally free from both sin and virtue, and universal across all humanity.[4] This idea is fundamental to his own work in advocating the idyllic state of nature and the virtues of democracy. Thus, the political ramifications of Locke's vision of human nature were not at all derived from nothingness: they were the very structure his tabula rasa was designed to support.

4 Pinker, *The Blank Slate*, 5.

Locke's democratic-empiricist concept of the cognitive tabula rasa has precursors and echoes in other philosophies of human nature— its utility was not limited to his own work. Sixteenth-century philosopher and mathematician Rene Descartes (1596-1650), who also drew upon the Aristotelian and Stoic lineage of the tabula rasa, saw the relationship of the mind to the body as that of a "ghost in the machine."[5] Descartes employed the tabula rasa in his vision of the physical body as a purely mechanical host for a phantom intelligence that possesses it at birth, pilots it in life, and separates from it to continue an independent existence in death. The convenient separation of material and immaterial being in his philosophy clearly betrays it as a notion designed to accommodate Christian ideas of an afterlife. In Descartes' philosophy, the tabula rasa appears in the form of the machine before its ghost arrives, the latent substrate of intelligence not yet animated by an immaterial mind. Thus, he co-opts the concept for ideological means, prefiguring Locke's democratic version with an example of the tabula rasa as a tool for justifying faith.

5 Ibid, 7.

The same raw material was reworked into the ideology of empire in the eighteenth century. The tabula rasa of a blank and formless human nature underpins the invention of the noble savage associated with French philosopher Jean-Jacques Rousseau (1712-1778), offering an alibi for French colonial expansion during that period.[6] This innocent character, by virtue of never having encountered the toxic alienation of modern European society, supposedly lives in an idyllic state of nature uncorrupted by the ills of civilization. Locke's precedent enables the noble savage stereotype to vindicate an imperial condescension towards indigenous peoples that rests on the implication of European superiority. This example continues the evolution of the tabula rasa's sequential reconfiguration to serve the Christian afterlife, the virtues of democracy, and eventually the conceits of colonialism.
As Duschinsky aptly summarizes, the tabula rasa has historically operated "Less as a substantive position than as a rhetorical extreme, an image of utter human malleability against which the speaker can differentiate and render more plausible their particular account of the human mind".[7] These thinkers, flung across two centuries and various political projects, demonstrate that the tabula rasa in modern cognitive philosophy describes a blank slate uninhabited by innate knowledge but riddled with tracks laid for ideological exploitation.

6 Ibid, 8.

7 Duschinsky, "*Tabula Rasa* and Human Nature," 509.

The ideas of Locke, Descartes, and Rousseau endure in intellectual culture notwithstanding the technical obsolescence of the tabula rasa in psychology, which eventually came to pass by the end of the twentieth century. The idea had always faced opposition by believers in innate knowledge. Plato (428-348 BCE) famously argued that a slave boy had an ingrained understanding of geometry regardless of his lack of formal training,[8] alluding to a system of innate knowledge that German philosopher Immanuel Kant (1724-1804) would later adapt to his idea that humans approach the world with a priori knowledge of the basic laws of modern science.[9] More recently, Noam Chomsky has deduced that the universality of language development in children indicates that they are born with an innate "language acquisition device" (1965).[10] In these three extremely influential cases and many others in between, innate knowledge is established as the binary alternative to the cognitive tabula rasa, which is discredited by arguments that reject a formless uneducated mind in favor of belief in ingrained principles or mechanisms.

8 Marcus, "Innateness, AlphaZero, and Artificial Intelligence," 2.

9 Rohlf, "Immanuel Kant."

10 Marcus, "Innateness, AlphaZero, and Artificial Intelligence," 2.

Despite this consistent criticism, the end of the psychological tabula rasa truly arrived with the Computational Theory of Mind in the 1990s (Fig. 3).[11] This cognitive framework explains how rational thought can emerge from a series of logical physical operations, connecting the machine of electrical neurons to the traceless ghost of the intelligence they produce. It hypothesizes that the combination of many instances of low-level logic, synergistically networked to create complex patterns, give rise to cognition. Pinker elaborates in computational language:

11 Pinker, *The Blank Slate*, 32.

> If a sequence of transformations of information stored in a hunk of matter (such as brain tissue or silicon) mirrors a sequence of deductions that obey the laws of logic, probability, or cause and effect in the world, they will generate correct predictions about the world. And making correct predictions in pursuit of a goal is a pretty good definition of 'intelligence.'[12]

12 Ibid, 32-33.

In his explanation, Pinker references information stored in silicon, mathematical concepts like logic and probability, and the qualification of intelligence in iterative terms: herein lies the influence of computation on late-twentieth-century cognitive theory. Ironically, it is the adjacent development of artificial intelligence by computer scientists that ultimately deconstructs the tabula rasa in psychology, even though the foundational notion of the computational tabula rasa was inherited from that very discipline.

The field of artificial intelligence has drawn upon theories from cognitive science and psychology since its inception. Although histories of the discipline cite automata and other intelligent machines as early as the first century, according to architecture and media historian Molly Wright Steenson, the modern field of artificial intelligence "developed in the 1950s out of a systems theoretical, cybernetic interest in the function of the human brain as a model for machine logic."[13] Cybernetics, a term coined by mathematician Norbert Weiner (1894-1964) as a derivation of the Greek kybernetes, for "steersman,"[14] is the science of feedback and control in organisms, technological systems, and social and political networks. Emerging from the thought processes employed by military pilots who evaluated the landscape below them to make real-time decisions about when and where to drop bombs, it encapsulates the process by which a system executes a procedure,

13 Steenson, *Architectural Intelligence*, 18.

14 Ibid, 16.

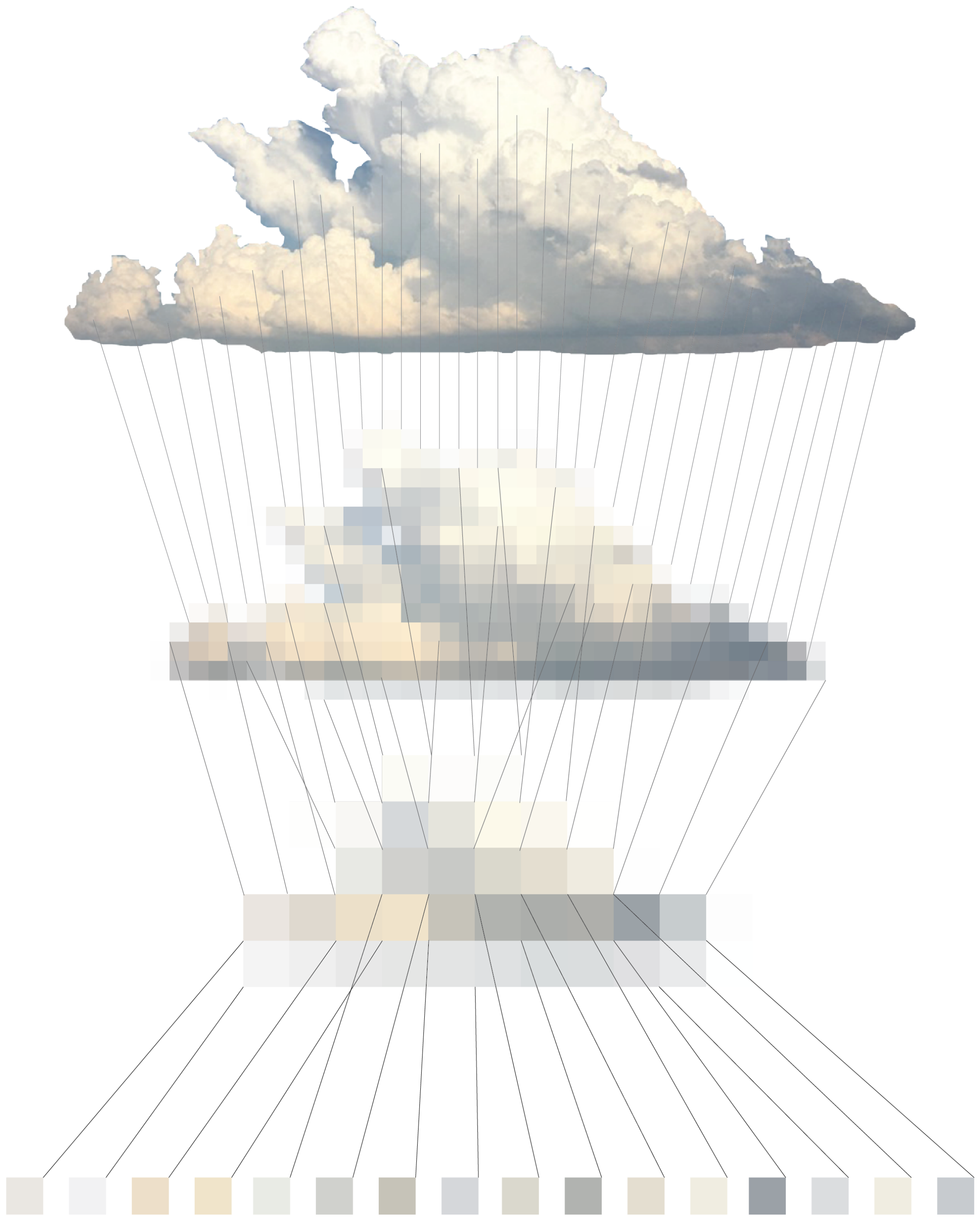

Figure 3: the Computational Theory of Mind.

receives data about its performance, and modifies its actions accordingly. Cybernetics is one of the postwar intellectual forces that shaped the modern field of artificial intelligence by defining its underlying mechanism. Another of these forces is the English cryptanalyst and mathematician Alan Turing (1912-1954), who is widely considered the father of theoretical computer science, alongside John von Neumann (1903-1957) in the United States.[15] His crucial work in the British codebreaking effort during World War II established him as a pioneer of computing intelligence and further emphasizes the military origins of this field. Turing's postwar writing on the topic of artificial intelligence begins the fundamental canon of the field's modern incarnation, and it is through his work that the tabula rasa enters the computational vocabulary:

> Instead of trying to produce a programme to simulate the adult mind, why not rather try to produce one which simulates the child's? If this were then subjected to an appropriate course of education one would obtain the adult brain. Presumably the child brain is something like a notebook as one buys it from the stationer's. Rather little mechanism, and lots of blank sheets. (Mechanism and writing are from our point of view almost synonymous.) Our hope is that there is so little mechanism in the child brain that something like it can be easily programmed. The amount of work in the education we can assume, as a first approximation, to be much the same as for the human child.[16]

Here, Turing clearly adopts the legacy of John Locke's tabula rasa, returning to the idea of the child's brain as a blank substrate—and once again updating the "white paper" to a "notebook" freshly purchased. This bookish metaphor is perhaps even more appropriate to computer programming than to the original metaphor of education, as informatics historian Nathan Ensmenger ascribes to computing a "fundamental literary nature" in reference to its basis in a series of written instructions.[17] Ensmenger's comparison of computer programming to creative writing may overlook the rigorous syntactical requirements of writing code in any language, which in reality bears much more resemblance to a negotiation of mathematical operations in sequence than to a freeform artistic medium; but it successfully invokes the overall mechanism of software production, which invariably consists of a writing exercise completely in the hands of the programmer.

This auteurist procedure of programming every mechanism of a computational agent illuminates the very rigidity that artificial intelligence intends to avoid. As reinforcement learning researcher David Silver asserts, "A long-standing ambition of artificial intelligence has been to create programs that can instead learn for themselves from first principles," implying the liberation of computing power from the prescription of comprehensive human-built programs.[18] From this aspiration, planted by Turing's original vision of programming a computer that imitates the flexible blankness of "the mind of a child," arises the ideal of *general intelligence*: a model able to learn and adapt to anything rather than being trained on and thereby bound to a specific dataset. In theory, such a model should not need to start with any innate knowledge—escaping the total control of Ensmenger's programmer— since it could learn all things with equal success, using no information-specific structures. Here emerges the profound significance of the computational tabula rasa, which underlies the most flexible and fluid extreme of artifi-

15 Jordan and Russell, "Computational Intelligence," in *The MIT Encyclopedia of the Cognitive Sciences* ed. Wilson and Keil.

16 Turing, "I.—COMPUTING MACHINERY AND INTELLIGENCE," 19.

17 Ensmenger, "Is Chess the Drosophila of Artificial Intelligence?," 25.

18 Silver et al., "A General Reinforcement Learning Algorithm That Masters Chess, Shogi, and Go through Self-Play," 1.

cial intelligence: an agent fully independent of its human engineers but as similar to them as possible in its intellectual capacity.

Though this ideal began with Turing, the history of implementation in artificial intelligence does not move nearly as quickly as the history of its theory or its aspirations. Turing had already imagined a general artificial intelligence with the cognitive capabilities of a human child in 1950, but even today the field remains far from achieving either the programmatic architecture or the training curriculum for such a network, even though Moore's Law would suggest that computing power for the same price has increased by more than thirty billion times since then. In the intermittent years, during which artificial intelligence remained primarily a military technology, the United States Defense Advanced Research Projects Agency (DARPA) identifies three waves of progress in the field that capture the types of capabilities it has successfully developed. The "AI winters" in between these waves were primarily related to ebbs in the defense funding that typically enables artificial intelligence research,[19] but the surges in interest follow a progression of both technical complexity and theoretical significance. The first wave (1956-1974) involved the production of "handcrafted knowledge"[20] and consisted of allowing a computer with extremely limited learning ability to explore a very narrow information space defined by a human. The second wave (1980-1987) invested in statistical learning, using large example datasets to train mathematical models; it relied on an ability to partition datasets and label their contents, so it focused on classification and imitation tasks.[21] It involved no contextual (semantic) information and employed a "brute-force" approach with little sophisticated reasoning. The third wave of AI is currently underway and has been since the early 1990s. It seeks to achieve "contextual adaptation"[22] that will allow it to internally explain, not just observe, real-world phenomena. This will endow it with an understanding of why things happen, enabling predictive capabilities much stronger than in previous years. It was from these third-wave theories of machine intellect and comprehension that the Computational Theory of Mind originally arose.

19 Steenson, *Architectural Intelligence*, 192.

20 Launchbury, "A DARPA Perspective on Artificial Intelligence."

21 Ibid.

22 Ibid.

In spite of this long military history, the defense department is no longer the only institution with the financial power to fund AI research: private sector businesses that fall under the category of "big tech" push the field forward at a pace academia struggles to match. Even in this new era of commercial artificial intelligence, however, the computational tabula rasa continues to influence research as a legendary goal of the discipline. The most recent lunge towards achieving a general intelligence that learns from a tabula rasa is the AlphaZero program by Google's DeepMind research group. They created an agent that can learn how to play various games— chess (the ever-present testing ground for AI models and the "drosophila" of the discipline),[23] shoji (Japanese chess), Go, and others— with no innate knowledge other than the game rules. Instead of training on thousands of examples of human games played move-by-move as a model of this type typically would, it creates its own dataset by playing the games against itself millions of times and tracking the relative success of every strategic approach. Their research has found that this model can beat world champions in the games it plays, and that it is capable of inventing totally new strategies that would not arise in human examples. The publication describing this model announces, "Our results demonstrate that a general-purpose reinforcement learning algorithm can learn, tabula rasa— without domain-specific human knowledge or data, as evidenced by the same algorithm succeeding in multiple domains— superhuman performance across multiple challenging games."[24] Here, in a monumental milestone for artificial intelligence research, is a claim to the achievement of the asymptotic aspiration of the discipline at large.

23 Ensmenger, "Is Chess the Drosophila of Artificial Intelligence?," 5.

24 Silver et al., "A General Reinforcement Learning Algorithm That Masters Chess, Shogi, and Go through Self-Play," 1.

However, the tabula rasa from which this model claims to start is questionable under scrutiny. Though the model impressively generalizes to play multiple games, it does not generalize beyond the realm of "board games of perfect information," where each player can see and evaluate the state of the board at every point in the game and where "brute-force" approaches to learning are effective.[25] Ensmenger exposes a latent critique in the artificial intelligence community that "AI's obsession with games— and not any particular game— is the more fundamental problem [than the specific failure of chess-playing as a research agenda], and that the discipline needs to shift its focus from the manipulation of symbolic systems towards interaction with the physical environment."[26] This observation perfectly frames the irony of the idea that a model could learn from a tabula rasa but only develop intelligence relevant to the narrow field of perfect-information gameplay. "Tabula rasa" means infinite possibility: if there is a constraint to the learning possible for an artificial intelligence, there must be some innate structure that makes it so.

25 Marcus, "Innateness, AlphaZero, and Artificial Intelligence," 2.

26 Ensmenger, "Is Chess the Drosophila of Artificial Intelligence?," 24

This critique of the AlphaZero algorithm, which questions whether a generalizable but exclusively game-playing intelligence qualifies as an example of learning from a tabula rasa, calls forth the more fundamental question of defining the computational tabula rasa explicitly. This impressive program claims to implement a concept that has historically only existed in theory; and even if it had been achieved previously, such a lineage would be difficult to accurately outline. At this juncture, Ensmenger's insight about the vaporous historicity of computing resurfaces: he distinguishes between the solidity of the hardware of a computing system (the tangible technology of the computational machine) and the programmed software that it runs (in this case, the intelligent agent), which "is generally invisible, ethereal, and ephemeral. In many cases, it exists only as a unique—and temporary—arrangement of digital bits buried deeply within a tiny microprocessor."[27] The abstract freedom of computer programming constrained only by syntax and mathematics produces the difficulty of tracing algorithms due to their immaterial malleability: though they so clearly encode social realities and technical aspirations, they evaporate with the temporality of the spoken word and evade the gaze of interrogation with impish secrecy. Their ephemerality matches their transparency. Perhaps software is as difficult to track as the ghost that flits in and out of Descartes' bodily machine…

27 Ibid, 7-8.

For this reason, the following evaluation of the computational tabula rasa rests upon a program created and run by the author, who can control and image her own abstract creation sufficiently to expose the function and meaning of its parts. The next section describes the form and function of a neural network created for this project, as well as a series of experiments conducted upon it to investigate the viability of the computational tabula rasa.

II: AUTOENCODER

To empirically investigate the computational tabula rasa— the basis of an intelligence that learns without innate knowledge— I conducted an experiment on my own machine learning model. Machine learning is the primary sub-discipline of artificial intelligence, and it captures the "educational" process associated with the tabula rasa in the work of thinkers from Turing to Chomsky. It follows computer scientist and machine learning theorist L. G. Valiant's definition of learning (1984) as "the process of deducing a program for performing a task, from information that does not provide an explicit description of such a program."[28] I adopt machine learning as a synecdoche for artificial intelligence at large, justified by the significance of learning as the resolution of the tabula rasa.

28 Valiant, "A Theory of the Learnable," 1184.

This exploration is formatted not as a proof of computational capacity as in Jirí Wiedermann's work on "The computational limits to the cognitive power of the neuroidal tabula rasa" (2003), which breaks down Valiant's neuronal approach to machine learning in a series of logical examinations. Neither is it an attempt to directly model an animal learning process along the lines of Lawniczak et al.'s "Simulated Naïve Creature Crossing a Highway" (2013), in which a population of artificial cognitive agents learn to strategize in the face of risk without prior knowledge of their environment (but with a strong survival instinct and a pre-established data structure for storing observations). Instead, the following experimental procedure and conclusions access the bank slate through the demonstrative structure of a traditional neural network, designed not to expose and interrogate the computational tabula rasa as in a laboratory setting, but to observe it as if stalking it in the wild.

For my experiments, I built an autoencoder, one of the simplest neural network architectures, to perform the task of reducing and reconstructing images of a handwritten zero and a handwritten one. I constructed the model properly and trained it successfully, so that it was capable of recognizing and distinguishing between each type of image correctly. Then, I interrupted this learning by modifying an aspect of the original model I would classify as "innate knowledge" and demonstrating the effects of these modifications on the network's ability to learn its task correctly. The impairments brought on by my interventions demonstrate that the model absolutely requires a certain type and amount of innate knowledge in order to function. Because the basic principle of this example is universal to the field of machine learning to date, the resultant conclusion applies broadly: that artificial intelligence without innate knowledge—from a tabula rasa—is currently impossible, due to the fundamental reliance of contemporary machine learning on innate and human-determined information.

The model I constructed and distorted for these experiments represents a variety of central concepts in machine learning. The substrate of this process is the neural network, a computing system vaguely inspired by the biological neural networks that make up the human brain. A neural net is composed of artificial neurons that build up signals and "fire" when they reach a certain value threshold, similarly to how their biological predecessors behave (Fig. 4). These neurons are connected to one another in multiple layers that apply different transformations to the data they take as input: as learning proceeds, the various "weights" that temper the outputs

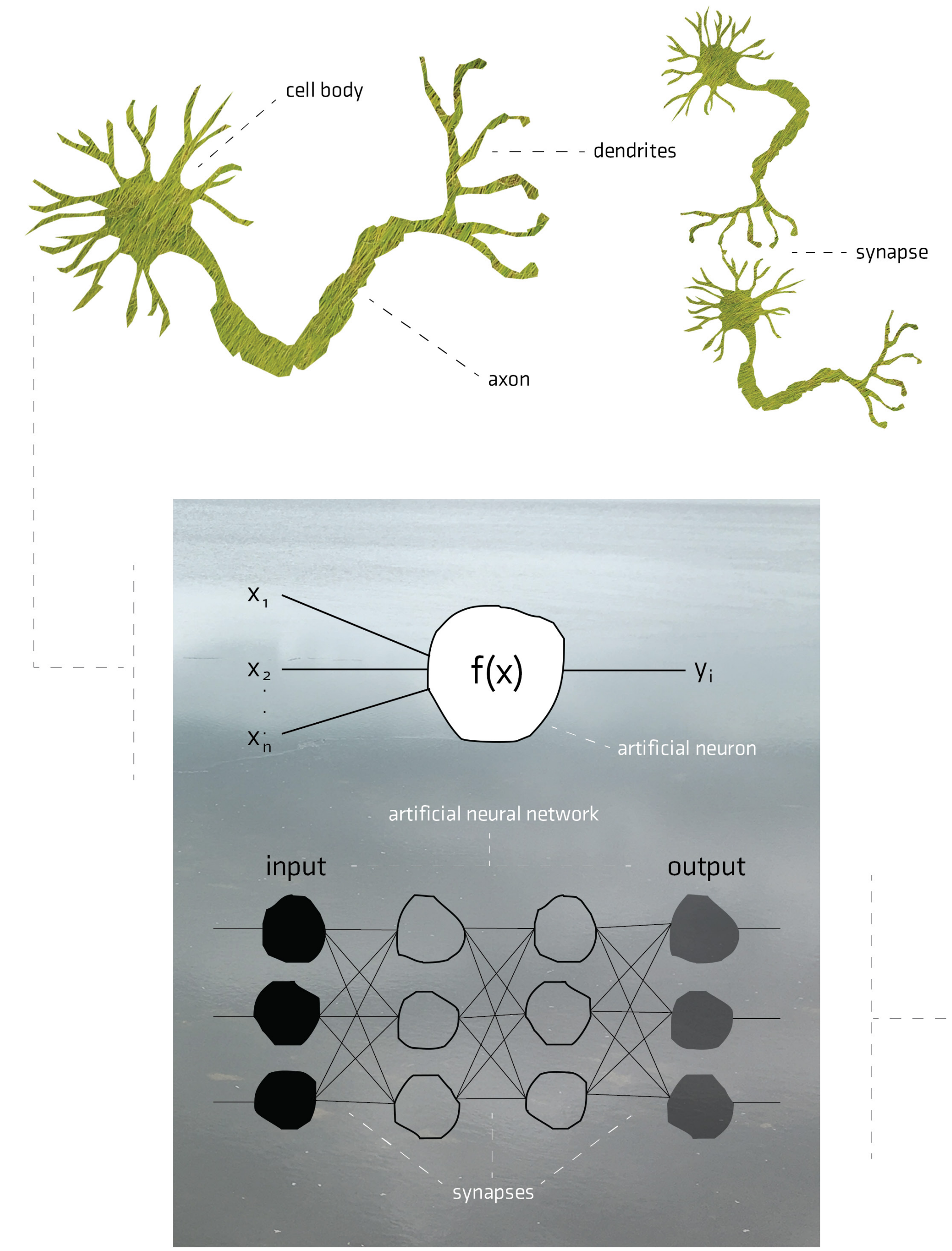

Figure 4: the artificial neural network and its biological inspiration.

of each layer are modified until a functional composition is achieved.

The learning process works by iteratively modifying and adapting this data-filtration complex to optimize its output in terms of a specific goal, which is defined by a "loss function" that defines the difference between the output the network produces with a given level of training and the output it ultimately intends to achieve. By modifying the parameters of the neural network to progressively minimize this loss, the network learns to perform its task correctly.

Unsupervised learning is a machine learning technique for finding patterns or structures in data, using inferences that a network can derive from that data without descriptive labels. It typically involves training a network to learn a system of classification without knowledge of what that classification describes. In contrast to supervised learning, where a system learns to produce correct output according to predetermined labels that define each data point, unsupervised networks learn relationships among data points based on various similarities and differences within the data set, never accessing an authorized measure of correctness.

An autoencoder (Fig. 5) is one type of neural network used for unsupervised learning. Its goal is to learn an encoding (an efficient data representation) for a given data distribution by filtering out all but the most defining features of its components that differentiate them from one another. This architecture is composed of an encoder, which compresses the input data to a dense and efficient encoding by a process of dimensionality reduction, and a decoder, which maps that encoding to a reconstruction of the original input. This reconstruction is typically a rough approximation of the original it references because the encoding forces the network to focus exclusively on the most definitive aspects of the data it represents, eliminating nuance and detail. In a basic autoencoder, the loss function typically describes the difference between the original input and the reconstructed output, and the network learns to generate accurate output by minimizing that difference.

The loss function for this network is called a "binary cross-entropy" loss, and it is commonly used for problems that involve classification into two groups. It effectively computes the uncertainty ("entropy") of a given data distribution across both categories as a way of measuring its probability. It evaluates the overall accuracy of the network's labels, in terms of whether they correctly describe the data. The formula for this loss is as follows, where N is the total number of points, y is the outputted label for a given point (1 or 0), and $p(y)$ is the probability of that point belonging to group 1:

$$Hp(q)=-1/N\sum y_i\times log(p(y_i))+(1-y_i)\times log(1-p(y_i))$$

It is derived from a sigmoid curve along the boundary between the two classification groups, combined with a logarithmic function that results in high-probability values resulting in losses close to zero (since they are likely to be correct) and low-probability values resulting in exponentially higher loss values. This same formula applies to every point in the data distribution, regardless of its predicted classification.

Autoencoders are both data-specific (once trained, they only work with the dis-

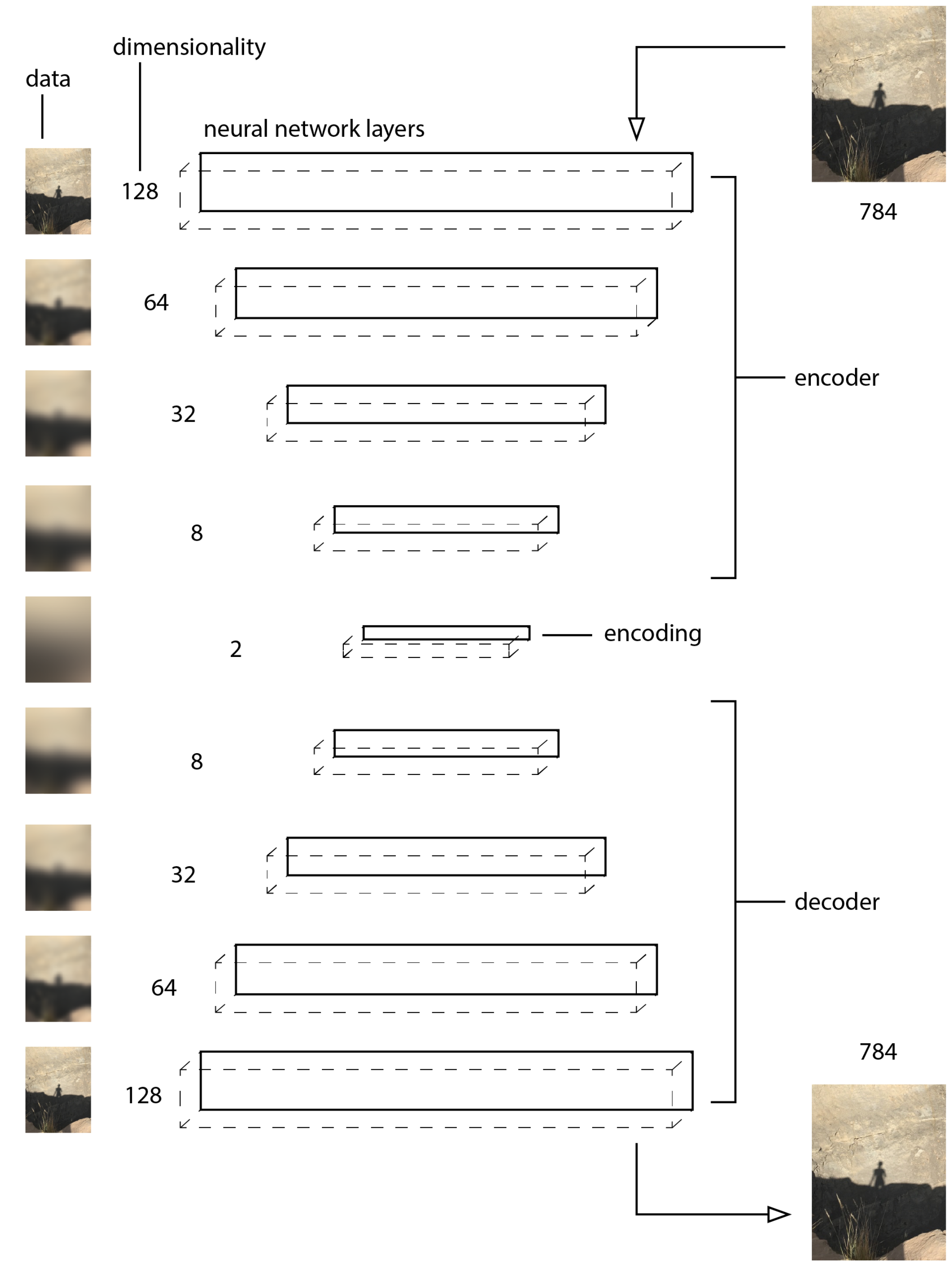

Figure 5: autoencoder architecture.

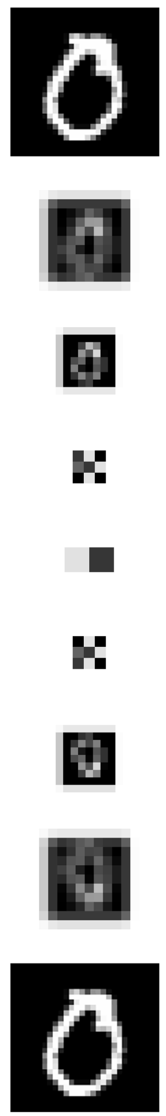

Figure 6: image reconstruction on MNIST "0."
Image: LeCun et al.

tribution of data for which they are calibrated) and lossy (their decoded representations are necessarily approximate and reductive). However, their simplicity makes them an effective case study in the basic concepts of machine learning, and the clarity of their output makes them an attractive subject for interdisciplinary work. I chose the autoencoder structure for this project because its unsupervised nature evokes the tabula rasa: in this context, it is possible to observe a network that learns without even the most basic semantic labeling of what its training data represents.

The autoencoder I implemented undertakes the straightforward task of differentiating between two types of images: those showing a handwritten numeral "1" and those showing a "0." This is a common exercise in machine learning, where the ubiquitous MNIST dataset[29] of handwritten number images offers a visually and conceptually clear object for experimentation. The input images are 28x28 pixel representations, meaning a model reads them as matrices of 784 numbers— or data points in 784 dimensions. The goal of this autoencoder is to learn an encoding that reduces a 784-digit matrix to a representation of only two numbers (two dimensions). That encoding must capture the key features in the data with sufficient accuracy that the decoder, when it reconstructs the data from two dimensions back to 784, will correctly approximate the original image (Fig. 6). Such stringent dimensionality reduction forces the autoencoder to capture exclusively the differentiating features of the data, and it also allows the learned encodings to be plotted on a cartesian plane, which offers a compact visualization of the latent space between input and output.

29 LeCun et al., "MNIST Handwritten Digit Database."

The unsupervised aspect of this example lies in the fact that, though it learns to distinguish between subgroups of a data distribution in the process of learning the primary features of that data, the autoencoder never actually accesses the labels that identify the value of the number in each image. It uses no semantic information: the algorithm simply learns to transform its input into a lower-dimensionality encoding, never validating its operations against knowledge of what they represent.

The neural network that performs this task is made up of a four-layer encoder and a four-layer decoder that create and unravel the encoding. This multi-layer structure makes it a "deep" autoencoder and allows it to develop an effective latent space by reaching the encoding gradually. The architecture I constructed formats the encoder as a series of dimensionality reductions, from 784 dimensions to 128, then 64, 32, and finally eight before reaching the two-dimensional encoding. The decoder mirrors this series of steps to slowly expand the data representation back to its original size. Once constructed properly and trained, this autoencoder is able to take in original images from the MNIST dataset, effectively encode them to two dimensions, and reconstruct them with an acceptable level of accuracy.

The image reconstructions it outputs show clear, unambiguous numerals 0 and 1, corresponding correctly with the input images they intend to reproduce. This successful output is the product of a latent space whose cluster representation shows two clearly separate clouds of points, with zero encodings (darker) fully differentiated from one encodings (lighter). This output will be visualized in comparison to experimental output, which differs significantly.

III: EXPERIMENT

In order to investigate the computational tabula rasa through this autoencoder, I performed a set of straightforward experiments that expose the relationship between innate knowledge and functionality in machine learning. I chose to focus these experiments on one specific element of the model, whose presence or absence is key to every neural network: the activation function. This mathematical entity is the gateway that determines the firing threshold for artificial neurons. It is assigned to each layer in the network. During the learning process, each layer of neurons receives a weighted sum of inputs from the previous layer and outputs the activation function's transformation of that number. At a most basic level, therefore, the activation function has the fundamental role of deciding when specific neurons will fire, which directly impacts the behavior of the neural network.

Activation functions can take various forms, but according to the general intention of neural networks, they roughly model the behavior of biological neurons (Fig. 7). In the brain, a neuron fires only when a sufficient electrical impulse builds up to provoke an action potential, which suddenly releases a charge down the neuron's axon with enough intensity to transmit a signal to the surrounding cells. The activation function in an artificial neuron acts as the gateway determining when the neuron's input is sufficient to transmit to the next layer. The function typically maps low input values to non-firing outputs until a certain threshold, at which point a slope increase indicates the transition to the range of input values forceful enough to make the neuron fire. The activation function is determined by the programmer, and it is a key feature of neural networks that cannot be modified by the neuron over the course of the learning process.[30]

30 Wiedermann, "The Computational Limits to the Cognitive Power of the Neuroidal Tabula Rasa," 271.

My experiments addressed the role of the activation function in impacting the quality of the system's overall output. I began with my working autoencoder, whose ten layers use a composition of both ReLU (Rectified Linear Unit) and Sigmoid activation functions: the network's best performance comes with the first nine layers using ReLU activations and the final decoding using a Sigmoid function. I used this composition as the base case for my experiments— it serves as a working control against which to compare alternatives.

I tested unified approaches across all layers, converting them all to the same activation function to explore a unilateral approach (Fig. 8). Using exclusively ReLU activation functions, my neural network generated a reconstruction output that recalls the proper appearance of the working system, but with a significant level of pixelation noise. Though the reconstruction offers images that blearily show the correct digit, the output data are unstable and would be considered a failure for this network. Its latent space is represented in clusters that take various shapes but never fully differentiate from one another.

Meanwhile, when I tested a version using Sigmoid activations for every layer, the outputs devolved to complete ambiguity, showing identical composite images of a blended zero and one for every test input presented. These results demonstrate the importance of activation function placement within the network, highlighting the sensitivity of the autoencoder to different neuron-level procedures even between the relatively similar pair of ReLU and Sigmoid activations. Its latent space takes

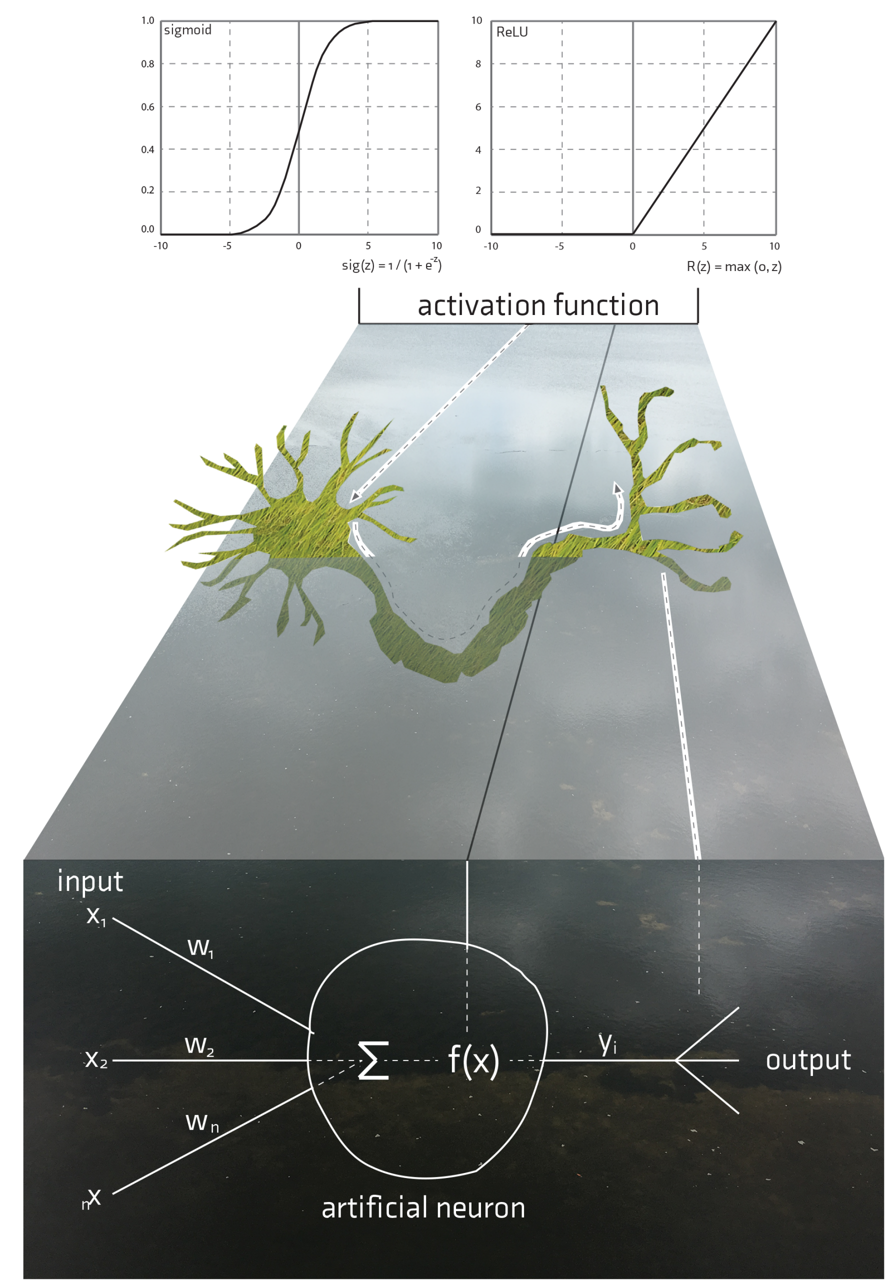

Figure 7: the activation function.

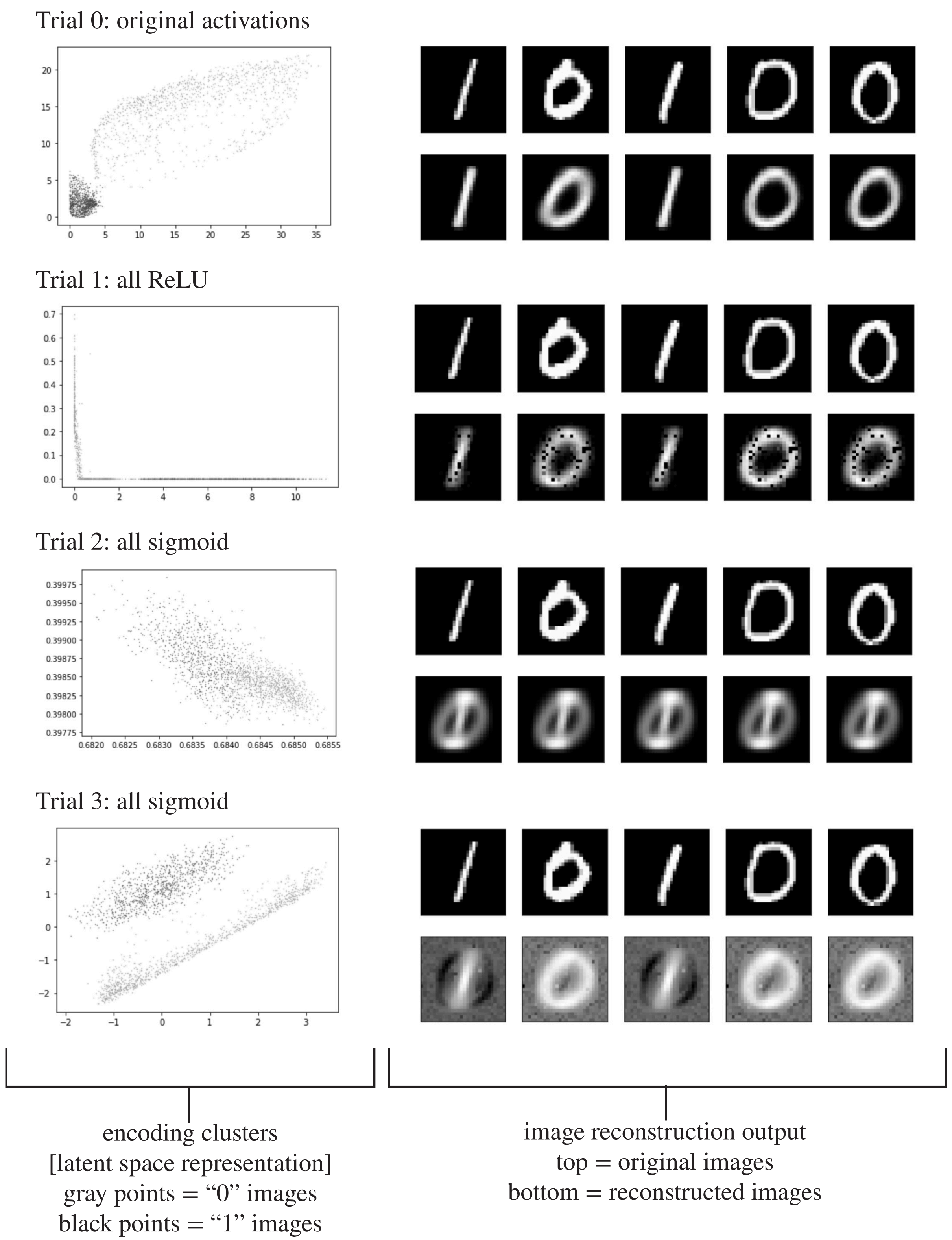

Figure 8: experimental output.

the form of a completely muddled single cloud, with no distinction between the two label classes.

But to approach the tabula rasa in this context is to remove the activation function altogether, leaving neuronal input and output as raw translations of one another without the intervention of a mediating mechanism. In order to achieve a state in which the activation function hides itself and exerts no effect, I trained the network once again, this time with the linear identity function (y=x) as the activation function for every layer. With this construction, the output of every neuron was the same as the weighted sum of its inputs, with no interloping recalculation between layers to evaluate or parse that input.

This final test demonstrated the ramifications of eliminating the activation function from this network completely, and as such it yielded very poor results. The reconstructed images from this approach show varying gray backgrounds, numerals hybridized or blurred together, and noise throughout. Though it produces a latent space with separate clusters that differentiate between the two classes of images, the overall reconstruction across both groups is by far the worst of the experimental options, lacking both numeral clarity and compositional correctness. The neural network fails with exclusively identity activation functions because that construction forces it to behave as a linear function, which prevents the bottleneck of the autoencoder from performing proper reconstruction. As the last in my series of experiments, it solidifies the importance of the activation function to the success of the neural network.

IV: TABULA RASA

The activation function is assigned at the initialization of the network, before any training data passes through it. In this way, it intervenes in the original Aristotelian “writingtablet:” a blank surface where nothing is written yet, where no learning has taken place. When the neural network’s layers are constructed and their respective activation functions assigned, the model knows nothing, not even the type of data it will receive. In fact, in a neural network, the learning algorithm and weight-adjustment mechanism are not considered strictly part of the network,[31] which exclusively comprises the layers of artificial neurons. This distinction differentiates them from L. G. Valiant’s “neuroids” (1988), which integrate the learning mechanism within the neuron.[32] In other words, the activation function in this case is embedded within the most fundamental basis of the machine learning model, established before any trace of intelligence emerges from it.

I identify the constructed neural network, before learning begins, as a computational tabula rasa. Yet the network’s functionality responds to the manipulation of activation functions within that dormant substrate, so they must account for some form of proto-knowledge defined by the programmer and innately ingrained in the network.

According to this idea, the activation function constitutes innate knowledge that disrupts the tabula rasa. This means its removal constitutes a step towards man-

31 Wiedermann, “The Computational Limits to the Cognitive Power of the Neuroidal Tabula Rasa,” 268.

32 Ibid.

ufacturing knowledge from nothing. However, as my experiments show, that modification deeply disrupts learning outcomes, indicating the mechanism's dependence on its innate structure. This logic implies the impossibility of learning without innate knowledge and demonstrates the fictive nature of the computational tabula rasa (Fig. 9). As Pinker observes of the human brain: "Something in the mind must be innate, if it is only the mechanisms that do the learning."[33]

33 Pinker, *The Blank Slate*, 34.

Perhaps this conclusion comes as no surprise: it is a commonly accepted truth that the tabula rasa in its most literal form does not exist. Long gone are the days of the formless blank slate as a valid description of the infant mind in psychology, and the notion of artificial learning without a designed mechanism is and always has been pure folly. However, according to Duschinsky, though the tabula rasa has operated as a "polemical empty-shell of a philosophical concept,"[34] it is through its extreme and absurd nature that the concept establishes a far-limit boundary and scaffolding for discourses on the true form of human nature. In this sense, the tabula rasa functions as a legal fiction for the discipline of artificial intelligence. As law and language analyst Sanford Schane observes, particular untruths can be accepted in the interest of their practical utility. He offers the foundational example of the legal fiction that construes the word "person" as inclusive of corporations: though a corporation is not literally a person, this convenient misnomer ascribes corporate organizations the capacity to own property, incur debt, take on liability, and delegate responsibilities to their consituents as legal entities independent of their members.[35] The tabula rasa in computing serves a similar role as a "legal fiction" of its discipline, operating not as a literal reality but as a practical assumption that influences its field without regard to its empirical invalidity. Rejection of this exaggerated concept, or its use as a "constitutive outside,"[36] continues to offer the basis for more complex theorization.

34 Duschinsky, "Tabula Rasa and Human Nature," 520.

35 Schane, "Corporation Is a Person: The Language of a Legal Fiction," 568.

36 Duschinsky, "Tabula Rasa and Human Nature," 528.

Thus, though the computational tabula rasa is easily refuted in the discipline of artificial intelligence, it offers insights beyond the technical. Pinker's reference to "mechanisms" provides an entry point to a broader discussion of the distinction, if any exists, between innate mechanism and innate knowledge. Pinker invokes psychological mechanisms as sufficiently concrete innate structures to disqualify the psychological tabula rasa, and I echo this stance in relation to the activation function of a neural network, given its predefined form and measurable importance. In this sense, the biological and artificial intelligences at hand may lack innate knowledge but do possess innate processes for achieving knowledge, and those processes prefigure the information they produce.

The procedural nature of machine learning that inspired the Computational Theory of Mind is worth revisiting here. That theory connects intelligence to apparatus with the idea that a coordinated combination of many small calculations can give way to an intelligent rationality much greater than the simple logic machines that make it up. Perhaps in the mind these small calculations have an agility that makes them sufficiently malleable to learn any type of information, but not so in artificial intelligence where the field stands today. The primary task of machine learning is to specifically construct and calibrate the agents that perform the component calculations in such a way that they produce the desired learning framework: in other words, the network (whether as simple as my autoencoder intended to reconstruct images or as complex as the AlphaZero model designed to play

Figure 9: locating the computational tabula rasa.

multiple complex games) bespeaks its task. Accordingly, knowledge achieved by these systems is not an effect of their independent creative genius but instead the end product they were designed to synthesize and trained to manufacture based on clear metrics of success and failure. In this way, a given model's desired output is as innate to its construction as that construction is to the output it ultimately produces.

The intentional predilection of the autoencoder towards the knowledge I designed it to achieve appears in outputs from various trainings with the same parameters, in which the neural network's weights begin with random initial values but always eventually converge to a system that can achieve correct reconstructions despite the latent space variations these random initial weights create. Effectively, each training of the network begins at some random initial location on the loss function but always moves to diminish that value, eventually stabilizing at a local minimum every time. If the network's initial parameters ae within the range of successful training outcomes, the overall mechanism will always advance in the same direction.

These observations mark a transition away from the shallow vision of intelligence as an entity that begins with nothing, performs some procedure of learning, and produces knowledge. Instead, it clarifies that the foundation of a network's capability to learn arises from design choices oriented towards a specific learning outcome. But even the composition of a neural network descends from precedent, from libraries of code that expedite the construction process, from the computing power available through a cloud-hosted coding platform, and from factors representing technological realities all the way down to the nature of manipulating the binary logic units of a machine that runs on electricity transmitted through physical mechanisms made out of the metals available on this planet. These influences, no less fundamental to the autoencoder's operation than the activation function that immediately determines its neurons' firing pattern, dissolve the possibility of a tabula rasa at any point in the formation or behavior of intelligence by creating an image of learning as a process that extends infinitely from its agent, encompassing a massive context of contributing systems (Fig. 10).

As Ensmenger observes, "The degree to which software is embedded in larger socio-technical systems makes starting from scratch almost impossible. To the degree that writing software does resemble literary production, the product is less an original poem than a palimpsest,"[37] whose every layer depends on those below.

37 Ensmenger, "Is Chess the Drosophila of Artificial Intelligence?," 25.

Thus, I arrive at a concept of knowledge as merely a snapshot representation of an ongoing mechanical learning process: not the outcome of a linear procedure with beginning and end, but simply the informatic inventory of a learning process at a given point in time. Therefore, a computational investigation reveals the impossibility of the tabula rasa not simply by the rote observation that learning fails without innate knowledge, but through the revelation that all knowledge is nothing but a measure of learning. The flaw in the computational tabula rasa is not its notion of innate emptiness, but its separation of learning from knowledge.

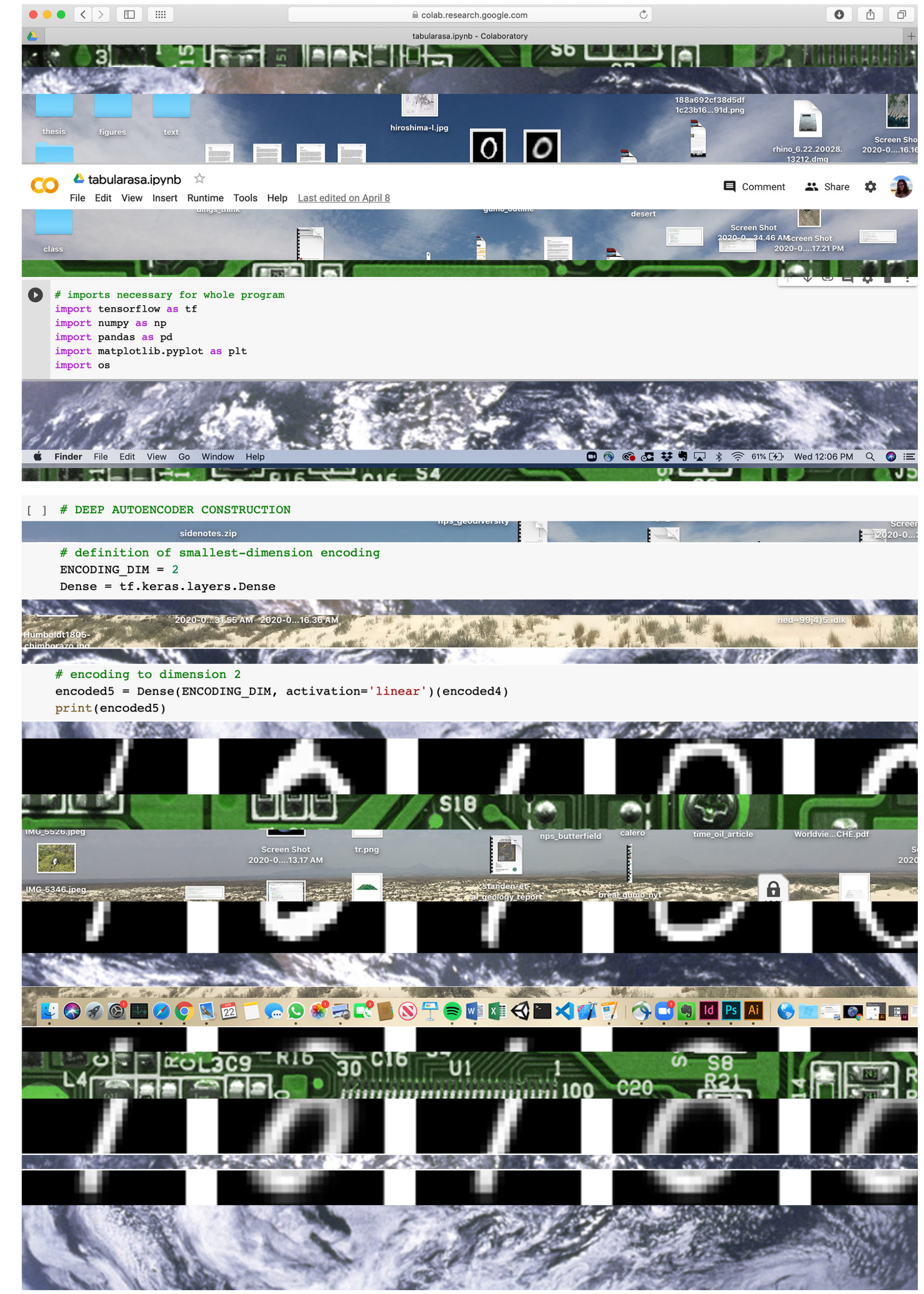

Figure 10: core sample of machine learning stratigraphy.

IV: INTELLIGENT MACHINE

A historical-experimental investigation into the legal fiction of the computational tabula rasa yielded a view of machine learning as a process built of processes, whose compound impacts and designs prohibit a blank slate of any form. Just as the tabula rasa reflects philosophical motives when invoked by thinkers from Locke to Turing, the desertion of that concept according to empirical observations represents an alternative theoretical mindset with its own socio-technical products. Ensmenger acknowledges the broad significance of algorithms to nontechnical systems, in that "Like all technological inventions, they are fundamentally human (and social) constructions, and as such embody and enable specific values, agendas, and possibilities."[38] These social implications of technology situate algorithms as both representatives of existing ideological conditions but also as agents of future development beyond their technological substrates. It is towards these extra-disciplinary effects that I now turn my focus.

38 Ensmenger, "Is Chess the Drosophila of Artificial Intelligence?," 26.

As the Computational Theory of Mind demonstrated in 1990s psychology, developments in artificial intelligence technology can spell revolution for other fields. In the remaining sections of this project, I will follow the tabula rasa into the discipline of urbanism—the architectural discipline that studies built form, the lives of cities, and human marks on the landscape— where it describes the empty architectural site, razed earth, or wilderness. I propose a "Computational Theory of Urbanism," so to speak, that draws on the myth of the computational tabula rasa and applies the framework of mechanized learning to structure an analysis of various representative landscapes. The concept of the tabula rasa creates a channel between the disciplines of computer science and architecture, offering a conduit for a new metaphorical reading of the city as an intelligent machine.

At an abstract level, the same concepts that have driven advances in artificial intelligence research have had similarly profound effects on urbanism, specifically in the United States during the postwar years. Historian of science and technology Jennifer Light discusses widespread fear in that era that the cybernetic military mindset had infiltrated society at the level of the city and the individual:

> The most extreme depictions suggested cities were helping to achieve the darkest consequences of cybernetics— government by computer. This was not a case of human-like computers taking over the world, but rather humans coming to think more like their machines, limited in their beliefs of what it might be possible to accomplish in cities.[39]

39 Light, *From Warfare to Welfare*, 88.

While the crossover of personnel between military research and city governments[40] and widespread applications of defense-oriented organizational strategies, such as dispersal and decentralization,[41] certainly produced widespread effects on American urbanism during the 1950s and '60s, this approach to computational urbanism relies heavily on the narrow rigor of policy analysis. I pursue a totalizing but more metaphorical interpretation of the city as an intelligent machine, acknowledging the cybernetic origins of artificial intelligence but conceptualizing urban intelligence as a means of framing the city as a learning entity.

40 Ibid, 59.

41 Ibid, 63.

The idea of the computational city or computational world is not new. For instance, Mark Weiser, a computer pioneer and Silicon Valley paragon of the 1980s and '90s, coined the term "ubiquitous computing" in 1998. This concept imagines a world in which computing is integrated everywhere, into every device, location, interaction, and format, creating a society totally pervaded by ambient computational intelligence. In addressing this vision, Weiser famously claimed, "The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it."[42] Perhaps the world we inhabit at the opening of this second decade of the twenty-first century, with its connected devices, internet of things, and aspirations towards smart classrooms, smart homes, and smart cities, approaches that reality. Halpern et al.'s seminal 2017 essay "The Smartness Mandate" describes this phenomenon, which involves the integration of human populations and sensing devices to enable a world of data-driven organization and automated governance in the name of optimization and resilience.[43] The present spotlight on embedding computational intelligence in urban networks illuminates a metastasizing system of devices and exchanges of information across them, an astral projection of the grounded physical systems it describes and governs. This literal description of our pervasively technological environment informs but stops short of my imagination of the intelligent landscape, which is at once more abstract and more universal. I use machine learning as a model or framework for the analysis of urban environments, envisioning landscapes as hosts of the many small, networked computations that give rise to artificial intelligence. I view landscapes themselves as complex learning technologies, without pinning that analogy to the literal electronic devices operating within them.

42 Weiser, "The Computer for the 21st Century," 94.

43 Halpern, Mitchell, and Geoghegan, "The Smartness Mandate."

Thus, my investigation of the computational tabula rasa will inform a metaphorical mapping of machine learning concepts onto cultural landscapes and their histories, according to Pinker's observation that "the sister field of artificial intelligence is confirming that ordinary matter can perform feats that were supposedly performable by mental stuff alone."[44] I use the tabula rasa as a point of linkage between computation and urbanism, traveling across this disciplinary continuum laden with insights from the neural network that will act as my instruments of urban observation. The following sections detail analytical adventures in the concept of the empty landscape, viewing such environments through an afterimage of the layered transformation, the transcendent procedure, and the mechanistic intelligence of machine learning.

44 Pinker, *The Blank Slate*, 33.

URBANISM 0

INTRODUCTION

My landscape analysis draws on the history of the urbanist tabula rasa as well as a long lineage of architects likening cities to intelligent organisms or mechanical automata, of which my metaphoric use of machine learning is both. In order to frame my imaginative methodology of urban analysis, I will briefly sketch these intellectual histories and thereby establish the language and boundaries of the subsequent architectural investigation. This orientation begins with a discussion of the urbanist tabula rasa, and the particular image of it upon which my research will focus.

The computational tabula rasa primarily refers to an originary state of emptiness, encapsulated in a blank slate yet unwritten upon, a child's brain yet uneducated, or a neural network before its training. However, another version of the concept exists. According to Duschinsky, the original Latin tabula rasa referred to a writing tablet after the inscriptions in its wax surface had been removed. He claims that "a more precise translation would be 'a slate that has been blanked', the effect of the erasure of text,"[45] indicating that the more accurate usage is not Locke's "white paper" but nineteenth century German philosopher Friedrich Nietzsche's "to make room for something new."[46] It is towards this aspect of the tabula rasa, which emphasizes erasure rather than emergence, that I direct my architectural exploration.

45 Duschinsky, "*Tabula Rasa* and Human Nature," 510.

46 Ibid.

Though the history of the urbanist tabula rasa is riddled with utopian greenfield settlements like Ebenezer Howard's idyllic Garden City (1898), Tony Garnier's Cité Industrielle (1917), and Frank Lloyd Wright's Broadacre City (1935)— all designed for construction on free and open land— the erasure I pursue is preceded by examples of violence and demolition in the name of progress. These precursors include Nero's alleged burning of Rome in AD 64 to rebuild it according to his own vision, as well as the radically new plan for Chicago proposed by architects Daniel Burnham and Edward H. Bennett in response to the city's great fire of 1871. Perhaps the most famous proponent of this post-demolition urbanist tabula rasa, however, is the architect and theorist Le Corbusier (1887-1965), who famously advocated a total destruction of preexisting conditions in order to make way for the ideals of modernism. His 1925 *Plan Voisin* demanded the demolition of central Paris to restructure the city into a network of identical cruciform glass skyscrapers with pedestrian promenades and spacious motor-roads in between.[47] This extremely ambitious plan would have involved erasing two square miles of central Paris, including some of the city's most architecturally rich urban fabric. It should be noted that the tabula rasa advocated by the *Plan Voisin* aligns with the unbroken tradition of the blank slate underwritten by an ulterior motive: the proposal's emphasis on the integration of an airport and gleaming network of highways reveal the influence of Gabriel Voisin, the avant-garde aircraft and automobile manufacturer who sponsored the project.[48]

47 Le Corbusier, "Plan Voisin, Paris, France, 1925: Extract from Le Corbusier and Pierre Jeanneret, Oeuvre Complète, Volume1, 1910-1929."

48 Ibid.

Corbusier's insistence on the empty site as the birthplace of urban progress evokes the sterile character of a laboratory study, where the entropy of unsupervised development and the richness of the urban wild are excluded so that the goals of his modernist program may play out uninterrupted. The scientific character of this attitude recalls visions of the city as a machine or medical subject: the tabula rasa in these cases represents a controlled environment for testing urban theories, a blank page rendered as a clean petri dish. Already the scientific framing of the tabula rasa invites investigation through intelligent-mechanistic metaphor.

Various architectural thinkers appear in the precedent for envisioning the city as an organism or machine, and their ideas tend to bleed together. As French architectural historian Francoise Choay describes in her book *The Rule and the Model*, planner Ildefons Cerdá (1815-1876), who designed the extension of Barcelona in 1959, approaches urban history and theory as a scientific dissection of the "urban body."[49] In a rhetorical strategy that can be traced to the writings of Italian Renaissance architect Leon Battista Alberti (1404-1472),[50] Cerdá appropriates the phenomenon of homeostasis to describe urban functions as analogs to circulation and digestion, invoking anatomy as a conduit for bringing life-scientific thought to urbanism.[51] Later, architect Frank Lloyd Wright (1867-1959) would combine the idea of the city as a biological system with specific attention to the mechanical nature of its organs and processes. His description of the city of Chicago as a sprawling industrial nervous system, in his seminal essay "The Art and Craft of the Machine," betrays both fear and awe of the magnitude of its mechanized life force:

49 Choay and Bratton, *The Rule and the Model*, 240.

50 Ibid, 241.

51 Ibid, 242.

> There you may see how in the image of material man, at once his glory and his menace, is this thing we call a city. Beneath you is the monster stretching out into the far distance. High overhead hangs a stagnant pall, its fetid breath reddened with light from myriad eyes endlessly, every- where blinking. Thousands of acres of cellular tissue outspread, enmeshed by an intricate network of veins and arteries radiating into the gloom. Circulating there with muffled ominous roar is the ceaseless activity to whose necessities it all conforms. This wondrous tissue is knit and knit again and interknit with a nervous system, marvelously effective and complete, with delicate filaments for hearing and knowing the pulse of its own organism, acting intelligently upon the ligaments and tendons of motive impulse, and in it all is flowing the impelling electric fluid of man's own life. And the labored breathing, murmur, clangor, and the roar—how the voice of this monstrous force rises to proclaim the marvel of its structure![52]

52 Wright, "The Art and Craft of the Machine," 369.

This comparison also recurs in the work of Le Corbusier, whose work merits a second reference for its tendency to "casually and without explanation treat the city alternately as organism and artifact;" most evocatively creating an image of the urban system as a "concrete biology."[53] These descriptions of cities as both mechanical and biotic connect the theory of urban analysis to the parallel synthetic biology of the neural networks used for machine learning: through the metaphor of the living machine, the city can be read as a sibling to the machine learning model, an alternative substrate for the biomimicry of artificial intelligence. The computational and urbanist concepts of the intelligent machine offer the analytical framework necessary for this interdisciplinary investigation. While the tabula rasa locates a quilting point between the two fields that offers an interface for theoretical transfer, the model of the intelligent machine provides the analytical framework

53 Choay and Bratton, *The Rule and the Model*, 242.

to fully integrate the principles of computing with the practice of urban analysis.

It is from this entry point that I pursue the architectural tabula rasa through the methodology of machine learning. As I pursue this second blank slate, chasing it to its sources and sifting through its flaws and fabrications in each case, I develop analogies to the elements of network and knowledge in artificial intelligence. In an essay about the entropic potential of overgrown sites of urban neglect, artist Flower Marie Lunn muses, “The spatial experience of a city is composed of multiple grids and cordoned areas, each with its abstracted boundaries. Striated space extraordinaire, a city is layers upon layers of structures and meaning—epistemological bureaucracies in concrete, if you will,”[54] evoking the interlaced layers of a neural net as well as the methodical choreography of their interactions. She describes the city as, to borrow phrasing from Choay, a model governed by rules.

54 Lunn, “Patterns of Growth and Perception,” 156.

My urban analysis takes a similar view of the city and pushes this concept even further, explicitly drawing on the idea of a programmed computational system that produces and manipulates information according to logical procedures. However, the information, or “knowledge” that I ascribe to the city diverges from the mathematical data analysis of machine learning. I conceptualize it more as a collective or distributed version of the “tacit knowledge” originally formulated by Hungarian-British polymath and philosopher Michael Polanyi (1891-1976). This type of information is acquired through practice and cannot be articulated clearly, having more in common with mental muscle memory or instinct than with explicit knowledge.[55] I approach the city as a network of the woven quality Lunn describes, that produces a set of spatially-expressed habits akin to Polanyi’s tacit knowledge. This urban paradigm is an analog to the neural network, which inspired it and informs its analysis.

55 Nye, *Michael Polanyi and His Generation*, xv.

I apply this framework to my analyses of various examples of the urban tabula rasa, mimicking the process of exposing its computational relative, but now replacing experimentation with field work. The examples I have chosen represent a chronology of empty-site prototypes originating in the second half of the twentieth century. I start with the nation-rebuilding project of postwar Japan at its hypocenter in Hiroshima, investigating the archetypal tabula rasa of the post-atomic landscape. I then resurface in the milieu of colonial occupation and socialist transformation in 1960s Chile, where political upheaval imitates the tectonic shifts that produced the most powerful earthquake humanity has ever seen. I ultimately arrive at the 1970s wilderness movement and its interface with the advancing petroleum industry in far West Texas, excavating the many human traces on seemingly empty land. The wide geographical and cultural distances among these examples seek to evoke a diversity of experimental groups, though none of them constitutes a control (Fig. 11). Each presents its own variables and parameters, but their collective relevance to a global enviro-political narrative in the time period at hand, as well as their respective encapsulations of the urbanist tabula rasa, makes them a harmonic combination of test cases. They sparsely represent the universality of the tabula rasa, and their sweeping variation foregrounds the abstract nature of the concept that unites them.

In computing, my experiments revealed the function of the tabula rasa not as an attainable ideal but as a legal fiction, accepted as true in the service of a philosophy that treats learning as a process of creating knowledge from nothing. My experiments illustrating the technical fallacy of the computational tabula rasa gave rise to an alternative image of knowledge as purely a measure of the product of an indefinite process of learning, taken at a given point in time. In urbanism, I will follow a similar path, applying insights from machine learning to my analysis of landscapes emblematic of the architectural tabula rasa, with the hypothesis that a refutation of this other blank slate— carried out according to my interdisciplinary method— will reveal new insights about the philosophy and practice of urbanism. If the computational tabula rasa is a legal fiction, the urbanist tabula rasa is a myth: a romanticized and allegorical phantom associated with landscapes of virgin purity or complete destruction, coded with narratives of renewal and progress.

Here I transition from the disciplined exercise of investigating a logical peculiarity to the unruly, meandering, and profoundly human process of exploring an imagined environmental condition. In the following sections, historic research intermingles with photographs, diagrams, testimonies, and tales of the tabulae rasae I dismantled in search of the narratives and ideals beneath each supposed blank slate. I carry with me the framework of artificial intelligence as a research apparatus, traversing its mechanism as I wander across territories descended from razed earth and no-man’s land.

Figure 11: sites of urban tabula rasa.
Images: Google Earth.

URBANISM 1

Hiroshima, Japan

"Ladies and Gentlemen,
Welcome to the Shinkansen."

The soothing voice of a British-accented woman wafted coolly through the train compartment, in coordination with her announcement's text scrolling along a dot matrix screen overhead. I looked out the window of the brightly sterile high-speed train as it peeled out of Tokyo's Shinagawa station and shot through a blur of glowing green rice fields and dense, tile-roofed towns slung between the steep foothills of distant mountains. Several hours later, I emerged into late afternoon sun shining onto the matrix of flat concrete and glass surfaces that is Hiroshima, Japan (Fig. 12). I crossed a six-lane city road and stared up at gleaming office towers. This was not the urban fabric suggested by the landscape I had observed on my journey.

The strikingly spacious modernism of Hiroshima differentiated it, even at this very first glance, from cities like Osaka and Nagoya that I had glimpsed on the way there. Its simple, wide-set cadence of streets and buildings sets it decidedly apart from the patina and density of other Japanese cities, of which Kyoto, with its tight, irregular weave of tiny buildings crammed into lively narrow streets, is the archetype. Though Hiroshima's built form once aligned with these classic elements of Japanese urbanism, today its resemblance to them lies in details and abstractions visible only at a closer look. Its divergence from this architectural norm can be traced to a single moment in history.

At 8:15 AM on August 6th, 1945, Hiroshima was illuminated by a noiseless flash from above. Following that momentary flare, the city would make history as the first witness to the horrors of atomic warfare, suffering some of the most complete physical destruction ever experienced by an urban landscape. Its reconstruction process after this devastating event represents not only an instance of total erasure and recovery, but also an opportunistic effort to revise the ethos of the urban environment. Hiroshima emerged from the blank slate of its post-atomic landscape having shed its military past to become an International Peace Memorial City, as decreed by the Japanese government in 1949. It is this self-reinvention that drew me to Hiroshima and that produced the striking scene that greeted me upon my arrival.

The connotation of tabula rasa as "razed earth" makes Hiroshima the iconic example of the twentieth century empty site, and perhaps the most extreme case study possible given the unprecedented completeness of its physical obliteration. Anthropologist Anna Lowenhaupt-Tsing describes its impact: "Hiroshima changed things. Suddenly, we became aware that humans could destroy the livability of the planet— whether intentionally or otherwise. This awareness only increased as we learned about pollution, mass extinction, and climate change."[56] Hiroshima's

56 Tsing, *The Mushroom at the End of the World*, 3.

Figure 12: shinkansen platform, rectilinear city.

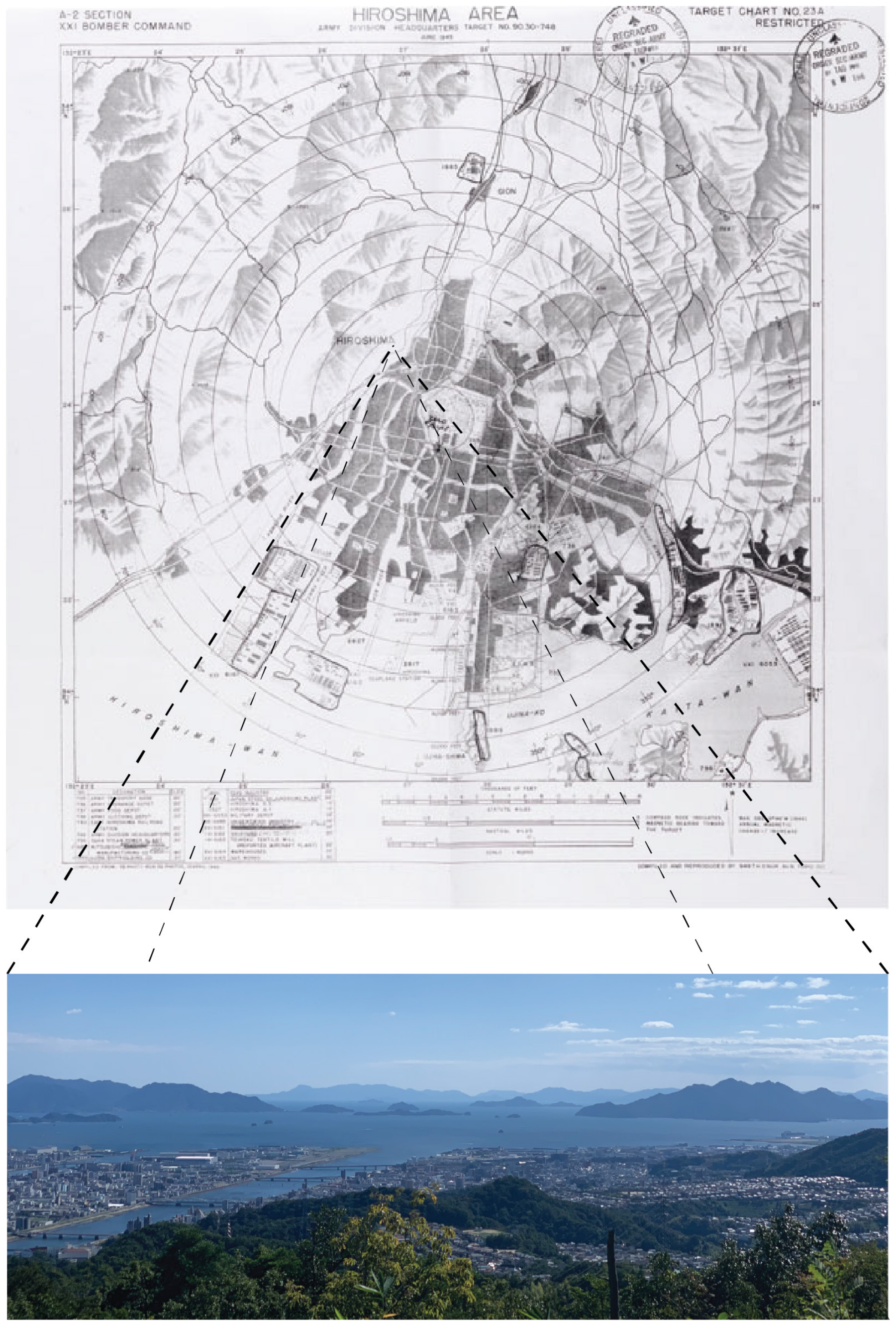

Figure 13: Hiroshima plan and topography.
Map: US National Archives.

example detonated a paradigm shift in the human relationship to the earth, symbolizing a new techno-political era characterized by precarity and fear related to the scale of human disturbance on this planet. However, Hiroshima also calls upon the aspirational history of tabula rasa planning, given the strategic intention of its reconstruction to ingrain the culture of an International Peace Memorial City into what was once a military-industrial stronghold. This total overhaul of Hiroshima's international brand required a nationally legislated reconstruction strategy, which brought about the overt representation of the city's new identity through law. In this case study, the mythology of the tabula rasa and its mobilization in support of ideology-driven urban transformation— in the vein of Corbusier's *Plan Voisin*— is particularly salient, and the programmatic aspect of this development procedure opens an entry point for its interpretation in terms of artificial intelligence.

The layers of tradition and mandate that influence Hiroshima's urban form create a mesh of interlaced cultural factors ripe for analogy to the neural network and studded with sites that encapsulate the tension between the city's past and present. The following investigation unites form with content, structuring an analysis of the tabula rasa and its repopulation in terms of various examples radiating from an epicenter. They start with the city's central void, the Peace Memorial Park, where the tabula rasa and its memorialization are most prominent and extend in layers of increasing spatial distance and conceptual abstraction from that point. The interpretation of each example recalls the fictive computational tabula rasa and uses the precedent of its underlying machinations to metaphorically model the lingering intelligence of a razed landscape. Critical analysis of these nodes begins with an orientation to the city.

Hiroshima, according to its famous description by John Hersey in The New Yorker (1946), is a "fan-shaped" city.[57] It spreads across the estuarial delta of the Ota River as it meets the Seto Inland Sea in seven branches, making it a city of islands and bridges. It takes a form not unlike the veined flare of a gingko leaf, bounded by steep verdant hills that pinch its northern sides and flowing out towards the island-choked sea to the south. Looking South from the summit of nearby Mount Mitaki (Fig. 13), it is clear that Hiroshima's sprawl obeys topography, creating a densely urbanized surface on the flat valley floor that quickly dissipates with the sharp elevation change of the hills that surround it. The importance of the memorial sites addressed here is legible in as fundamental terms as the flat open green space they lay bare, which occurs nowhere else in this close-set concrete web.

57 Hersey, "Hiroshima."

Hiroshima was originally a feudal town. Its history begins with the construction of a castle in 1589 by Terumoto Mori, whose family ruled there from the Edo period (1603-1868) until the Meiji restoration (1868), at which point Hiroshima became the seat of the regional headquarters for the Imperial Japanese Army, retaining its importance as a political and military center from the fall of the shogunate to the reinstitution of the Emperor.[58] Over the course of rapid national industrialization during the Meiji period (1868-1912), the construction of a working port, railroad and streetcar networks, and new bridges and roads connecting the branches of the Ota River Delta enabled Hiroshima's economic development, and the city became a center for cotton-spinning and later heavy and chemical industries.[59] These infrastructures of production and connectivity emphasized its importance to Japanese war strategy.

58 "Hiroshima for Global Peace" Plan Joint Project Executive Committee, "Hiroshima's Path to Reconstruction (Hiroshima Reconstruction and Peacebuilding Project)," 8.

59 Ibid.

Approaching the year 1945, the main commercial and residential districts in the center of Hiroshima housed three quarters of its population, which had been reduced to about 245,000 by several waves of wartime evacuation.[60] Most of their homes, according to the style typical of the region and time period, were constructed with wooden frames and walls that supported a tile roof. The fabric of these structures was so crowded and lush that some houses extended beyond the footprint of the city's available ground, standing half-suspended over its rivers on stilts planted in the tidal clay. Imagining the reduction of this abundant environment to the nothingness that followed is a harrowing task.

60 Hersey, "Hiroshima."

The uranium bomb sliced through the sky like a sheet of sun and made no sound. It dropped on a warm day in Hiroshima, detonating midair in a nuclear eruption almost directly above the center of the city marked by its target, the Aioi bridge. The explosion created a colossal fireball, emitting intense heat rays and inducing roaring winds that swept the urban valley in a matter of seconds. This initial cataclysmic demolition was followed by an overwhelming firestorm that flared up from the resulting heat rays and burned every wooden structure in its path, incinerating the vast majority of the built environment. Radiation beamed into the landscape from the blast and washed over it in black radioactive rain. Between 120,000 and 160,000 lives were lost.[61]

61 "Hiroshima for Global Peace," "Hiroshima's Path to Reconstruction," 8.

This apocalypse laid waste to Hiroshima and left the rest of Japan reeling: three days later, on August 9, a plutonium bomb rained equivalent doom upon Nagasaki, and on August 15, 1945, all of Japan absorbed the even greater shock of the imperial surrender, announced over national radio by the Emperor Hirohito— the first time the public had ever heard his voice. The surrender dealt a tremendous blow to the collective Japanese morale, which was characterized at the time by an incredible tenacity that drove the public to accept any sacrifice required to continue the honorable national service of war.

The psychological element of Japanese urban challenges following the war is described within its political history in architect Rem Koolhaas' *Project Japan* (2011), which details the rise and fall of the Metabolist movement in Japanese postwar architecture. The story begins with massive ambition and ends with profound trauma. In the mid-1930s, Japan invaded China with the goal of instituting a "Greater East Asia Prosperity Sphere," which would unite parts of Manchuria, Mongolia, Thailand, Vietnam, Laos, Burma, the Philippines, and Indonesia in a new geopolitical alliance. For Japanese architects, this endeavor represented the fabulous prospect of building on vacant land appropriated from a new continent: the extremely dense habitation of their island never offered such an opportunity for unfettered construction, so the imperial project was a magnificent thrill. However, this mirage was violently ripped away with the atomic destruction of their own cities, by which the tabula rasa they had imagined in foreign territories was imposed instead upon their homeland. As Koolhaas sympathetically describes, "The same architects and planners who had, in the '30s, projected vast new settlements on wide open spaces abroad were now confronted with their own cities transformed into radioactive rubble. From utopia to apocalypse in less than half a generation…"[62] Thus, the wasteland left behind by the atomic bomb became a spatial representation for the dramatic collapse of the Japanese expansion initiative, capturing the particularly architectural heartache implicit in that defeat.

62 Koolhaas et al., *Project Japan*, 12.

It was in this environment that Hiroshima's reconstruction began, under the crushing and humiliating weight of American occupation and with the imperative to memorialize the tragedies of the war while developing an ethos for moving forward. In order to support this effort in the city most deeply associated with the nation's wounds, the National Diet enacted the Hiroshima Peace Memorial City Construction Law in 1949.[63] Its first article asserts that "Hiroshima is to be a Peace Memorial City symbolizing the human ideal of the sincere pursuit of genuine and lasting peace."[64] The law goes on to detail specific strategies for constructing public peace memorial facilities on the same timeline as the basic infrastructure necessary to revive and inhabit Hiroshima, designating land for "Memorial Places" with the same urgency applied to roads and sewage systems. These commemorative structures still stand today as the primary landmarks of the city, which literally rebuilt itself around them as its defining features, selecting a specific public-facing message to program the resurrection of its livelihood.

63 Alkazei and Matsubara, "The Role of Post-War Reconstruction Planning in Hiroshima's Image-Shift to a Peace Memorial City," 3.

64 "Hiroshima for Global Peace," "Hiroshima's Path to Reconstruction," 12.

I learned at the Peace Museum that a scar of scorched earth, carbonized and encrusted with small debris, still forms a continuous layer at a depth of 70 centimeters beneath Hiroshima's repopulated surface.

At the core of Hiroshima and directly below the hypocenter of the atomic bomb's explosion lies the Peace Memorial Park (1949) designed by architect Kenzo Tange (1913-2005). This central void, around which all other sites magnetically orbit, is Hiroshima's cartesian origin point both geographically and philosophically. It occupies the upriver tip of Hiroshima's smallest and most central island, creating a pointed green beacon around which the rest of the city flows and from which its peacemaking manifesto radiates. The park's primary compositional elements include the Peace Memorial Museum (designed by Kenzo Tange), the Cenotaph for A-Bomb Victims (designed by Kenzo Tange with the inspiration of an original concept by Japanese-American sculptor Isamu Noguchi), and the A-Bomb Dome, the preserved ruin of Hiroshima's Industrial Promotion Hall, whose brick and concrete patchwork still stands, crowned by the metal skeleton of its domed roof. Their linear arrangement forms a central vector pointing north, creating a common sightline that acts as the primary vertical axis of the city.

Of the structures in this transect, the A-Bomb Dome is the only one that stood before the bomb was dropped. In its prime, the site now occupied by the Peace Memorial Park was home to Hiroshima's Nakajima district, a bustling commercial and residential neighborhood densely built with wooden structures that were immediately and absolutely destroyed with the explosion.[65] With the exception of the Dome, this total obliteration left the center of the city completely reduced to a flat crust of radioactive rubble.

65 Ibid.

Tange's Peace Memorial Museum was the first monument to emerge from the wreckage, creating a dramatic tableau in which commemoration appeared to precede emergency shelter. The spare modern structure reverently captures the scorched plane it memorializes in the unbroken horizontal mass of its primary volume. However, it recoils from the traumatized ground of its site: the building hovers above the razed earth on pilotis, touching the tragic surface it stands on only with its shadow. In Yasuhiro Ishimoto's iconic photograph of the Peace Park in its early stages (1949-1955), the floor of the building levitates above the horizon line.[66]

66 Cho, "Hiroshima Peace Memorial Park and the Making of Japanese Postwar Architecture," 72.

When I visited the Peace Memorial Park in September 2019, I found that this vista no longer exists (Fig. 14). The facade of the museum is interrupted by an enormous fountain immediately to the south, and the striking purity of the building's form is interrupted by wings on either side. These additions were also designed by Tange Associates but only completed in 1994. They play a supporting role to the main building, housing artifacts and images beyond the museum's primary collections, as well as meeting rooms, a large lobby, and a coffee shop. Due to these distracting additions, today's view of the Peace Park emphasizes not the museum, which once stood imposing and stark over its ravaged site but now blends into the prismatic gray composite of the city rebuilt around it. Instead, in the now thriving and dense concrete matrix of contemporary Hiroshima, the figure-ground relationship of the park's postwar composition is reversed. Today, it is the empty space of the ground plane that stands out.

The lawn on the north side of the museum delivers the shock of a wide-open space carpeted in grass so green it nearly glows, completely untrodden and unoccupied. Its perfectly level expanse flanks the walkway between the museum and the cenotaph, creating a phenomenal sensation of non-enclosure that lasts the duration of this walk. And the walk is a long one, stretching out farther than the distance enclosed by the Peace Memorial Museum's horizontal extent. Signs and ropes close the pathway off from the lawn, forbidding visitors to set foot on the perfect grass.

In contemporary Japan, such a sprawling plane of perfectly uniform but fallow vegetation is almost astonishing. The density of Japanese urbanism requires most parks to fit within a fraction of a city block, and most of the public outdoor spaces I observed in my field work were paved plazas, gravel playing fields, or the constructed synthetic landscapes of corporate office parks. Meanwhile, traditional Japanese gardens take shelter in secluded enclaves, cherishing secret worlds of carefully composed synecdochic nature, coded with complex webs of meaning and intricate perceptive choreographies… they are anything but open space. In this cultural and physical environment, the preservation of emptiness— of flatness, of volumetric vacancy and non-use— is monumental in itself.

I interpreted this untouchable verdant surface as a preservation of the tabula rasa created by the atomic bomb: a softened reference to the razed earth of Nakajima. However, even the traumatic emptiness it memorializes has its cultural roots in an earlier dream of fallow territories on the Asian mainland. The atomic tabula rasa was far from a blank slate or a formless intelligence. Instead, it was encoded with the attitude towards open space that preceded it, which implied the projection of an East Asian Co-Prosperity Sphere onto the empty lands of the continent. In accordance with the lineage of the very phenomenon of open space in Japanese urbanism and national advancement, the architecture atop this former tabula rasa

Figure 14: Peace Memorial Museum past and present
Photograph: Yasuhiro Ishimoto, undated, from Cho.

recalls its expansionist precedent.

Despite its message of peaceful remembrance, Tange's Peace Memorial Park design has clear roots in his earlier competition entry for the Greater East Asia Co-Prosperity Sphere Commemorative Building (1942), dragging Japan's prewar ambitions into the limelight of its post-atomic nation building project (Fig. 15). The two projects share an extremely similar plan characterized by a central axis connecting a primary entrance structure and a commemorative monument. This continuity in Tange's work on either side of the war reflects the architect's smooth transformation from an imperial propagandist to a virtuous symbol of peace-building, which critics described as a "Symptom of the society's collective amnesia about its enduring imperial legacy."[67] However, I would argue that this continuity represents the opposite of amnesia.

67 Cho, "Hiroshima Peace Memorial Park," 76–77.

A reading of this architectural history through the lens of a neural network offers an alternate interpretation. The design culture of the Japanese elite as captured in Tange's work could be modeled as an intelligent machine that takes the inputs of site and national project, processes them in some way, and outputs an appropriate commemorative building. Under this framework, the inputs of an empty site on the Asian mainland and the imperialist Greater East Asian Co-Prosperity Sphere project produce the output of Tange's Greater East Asia Co-Prosperity Sphere Commemorative Building design. Accordingly, the inputs of Hiroshima's post-atomic tabula rasa and the national project of peace-building and recovery result in the output of the Peace Memorial Museum. This metaphorical model evokes the dimensionality reduction performed by the "encoding" element of an autoencoder: just as my neural network reduces a 784-pixel image to a two-dimensional representation, this hypothetical machine takes a national development initiative and captures it in a single architectural project.

In an autoencoder, this process relies on the specificity of its input data: a model trained to compress and reconstruct images of one type cannot successfully do so for inputs outside of its narrow range. I believe the same is true of my architectural translation of this model. A view of Tange's designs as the outputs of an encoding procedure displaces the similarity of the Peace Memorial Museum and the Commemorative Building from the architect's own methods to the tonal parallels in the national initiatives they represent. This analogy implies that Japan's extreme prewar ambition and its intense postwar commitment to peace are sufficiently analogous information sets to feed the same intelligent machine, and I think this reflection is accurate. What was once an ideology of total takeover became a complete dedication to peace, captured in the Flame of Peace that burns in the Peace Memorial Park and will never be extinguished until all nuclear weapons have disappeared from the earth. The uncompromising vehemence of both ideologies explains the kinship of prewar nationalism and postwar resilience in Japan, and it supports a reading of them as input datasets sufficiently similar to accommodate the specific training of an intelligent machine.

With this perspective, the building that once seemed a miraculous monument to reconstruction from nothingness, as well as the grassy plane that memorialized that nothingness, grows roots much deeper than the scorched nuclear crust beneath Hiroshima. An analysis through the machine learning framework of an

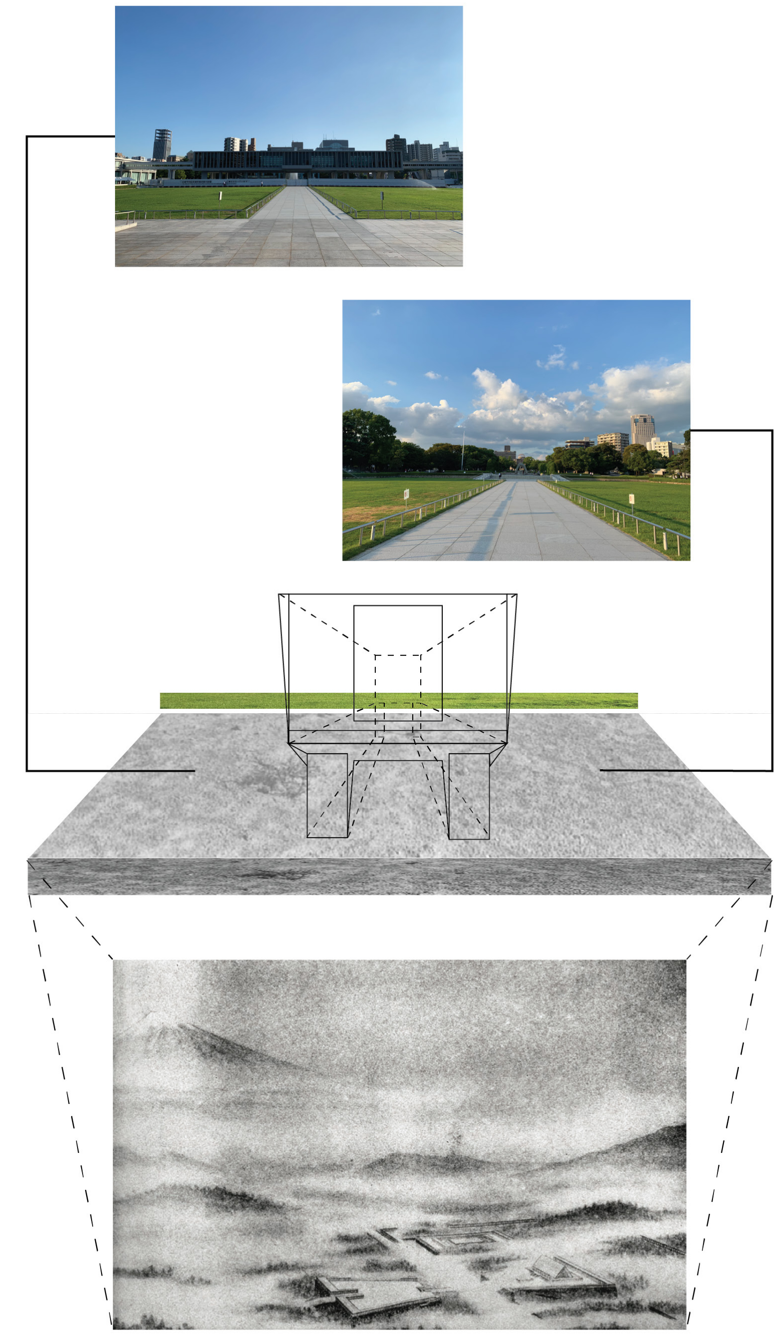

Figure 15: Tange and the tabula rasa.
Bottom image: East Asian Co-Prosperity Sphere Commemorative Building, Tange Associates, from Cho.

autoencoder explains the aesthetic continuity between imperialism and peace, locating their linkage within the tone of those national projects rather than in the design strategy of a single architect. This ironic mesh of interlaced ideas about the tabula rasa, the project of nation building, and the effects of the war give rise to a reading of the Peace Memorial City as an intelligent machine that will recur in the analyses that follow. It imagines Hiroshima not as a brand new urban intelligence born of an archetypal tabula rasa, but as a reframing of existing cultural attitudes according to revised priorities. This image of the city implies the incompleteness of the tabula rasa from which it was reconstructed, denying the totality of its self-reinvention to consider a more nuanced narrative of transformation.

I learned from a gaijin friend that the Japanese idea of "mu," meaning "nothing," is a fundamental element of the wabi-sabi traditional design ethic. It is conceptualized as a finite emptiness whose utility lies in its vacancy, like the hollow space inside of a bamboo branch.

The coded design of the Peace Memorial Park creates a vertical axis for Hiroshima, pointing north from the Peace Memorial Museum to the A-Bomb Dome. The cartesian counterpart to this line is the Peace Memorial Boulevard: a 100-meter-wide transect of linear parkland and several lanes of traffic cutting a horizontal swath through the city. This wide arterial corridor, flanked with rectangular stands of shade trees and memorial sculptures, gives the city its equator. It is a latitudinal landmark and distinct urban boundary that transcends the natural interruptions inscribed by the Ota River's numerous branches, skipping through the city over narrow bridges as if its green medians were beads strung along an asphalt string.

It functions as a wide social promenade, studded with park benches, ornamental sculptures, and informational plaques thanking benefactors who donated the trees that shade them. The outer single lanes of traffic offer an ecotone interface with either side of the city, shielded by the landscaped tracts of park and path that preserve their sense of narrow shelter. Meanwhile, the middle of the boulevard stages a complex choreography among five lanes of traffic organized and funneled through a network of alternating turn lanes and diamond intersections. Crossing this artery involves passage across a single lane of traffic, then perhaps the shaded respite of a moment in the shoulder garden before traversing the long, exposed crosswalk to repeat this sequence in reverse on the other side before reentering the city. Longitudinally, the Peace Memorial Boulevard is an arterial transect of central Hiroshima, giving a diametric cross-section of the city's densest commercial and memorial district. Latitudinally, it interrupts the gridded concrete fabric of the city with brief moments of urban forest and open sky, marking a transition between upriver and downriver Hiroshima. This broad channel through the city offers a conductive and dynamic memorial counterpart to the Peace Memorial Park's spacious stillness, injecting everyday navigation of the city with awareness of its tragic history and optimistic aspirations for the future. One might expect that this version of monumentality through empty space, like the Peace Park, arose

from the preservation of the atomic tabula rasa. But in this case, the wide swath of unbuilt space was already in progress before the bomb dropped.

This 100-meter-wide gap in Hiroshima's otherwise dense urban fabric actually began as a wartime technology. The space it created between the two halves of the city was planned as a firebreak, intended to protect each side from bomb-seeded fires on the other by imposing a gap in combustible material wide enough that flames could not reach across.[68] This project was urgent and ongoing: at the time of the atomic bombing, there were crews of civilians, including young students, at work demolishing buildings in the path of the firebreak.[69]

The Peace Boulevard creates an idyllic frontage for Hiroshima's Peace Memorial City messaging, but the revelation that it actually predates the atomic tabula rasa, and that it was originally a defense apparatus instead of a peacemaking one, invites a closer look at its embodiment of that message. This urban form was initialized as a war technology and still under construction for that purpose when its entire context was destroyed by the atomic bomb. When the city was reconstructed, the same form reemerged and retained its importance but took on a new meaning as a representation of peace. If the Peace Memorial Park embodied the machine learning concept of an encoding, the Peace Memorial Boulevard acts as its counterpart not only spatially but conceptually: I propose to analyze it with the function of the decoder in mind.

In an autoencoder, the encoder reduces the dimensionality of the input data until it reaches the fully-reduced representation of the encoding; the decoder then receives this encoding and attempts to gradually expand it into an approximate reconstruction of the original input. In less specific terms, the decoder receives a very basic and condensed version of an idea and tries to imagine the full-scale original from which it was derived. The strange, forced translation of the Peace Memorial Boulevard from a defense strategy to a nonviolent monument evokes the imprecise reconstructions of a decoder working from a very small encoding. The lower the dimensionality of the encoding— literally, the less information it conveys— the less definite the decoder's reconstruction of it will be. In my autoencoder, the input images were reduced all the way from 784 dimensions to two, which resulted in reconstructed output images that only very roughly captured the content of the originals. Envisioning the post-atomic wasteland as an encoding, in which almost every detail of the original city had been erased and only the barest suggestions of its former structure remained, enables the literal translation of machine learning image reconstruction to the process of post-war urban reconstruction.

Under this metaphorical concept transfer, the Peace Memorial Boulevard's present form and messaging are a reconstruction of its original concept according to the extremely reductive encoding of its post-atomic state. In other words, the reconstructed Boulevard is an alternative approximation of its military predecessor, distorted through the transformative gauntlet of the war. This translation is effective: the Boulevard continues to perform its most basic role as a firebreak despite the layers of new messaging applied to its public appearance, and though the manicured promenade of the present day creates a very different atmosphere from the panicked civilian demolition project of wartime, the actual form that carries out

68 Alkazei and Matsubara, "Hiroshima's Image-Shift to a Peace Memorial City," 4.

69 Takezaki, "Volunteer Citizen Corps Building Demolition."

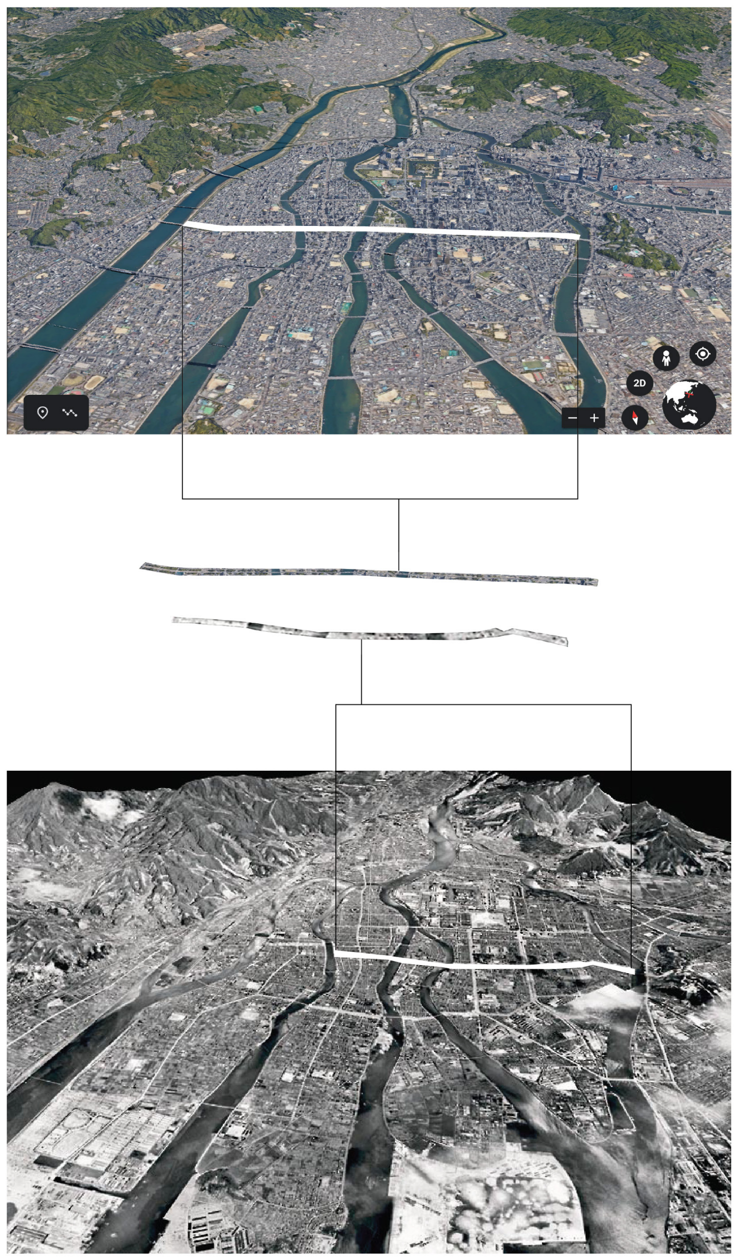

Figure 16: tabula rasa as encoding.
Top image: Google Earth.
Bottom image: Hiroshima with firebreaks, July 25, 1945, taken by US military aircraft, from Takezaki.

this function remains the same. The drastic dimensionality reduction of the war distorted the details of aesthetic and political messaging, but the Peace Memorial Boulevard remains an accurate reconstruction of its wartime predecessor in that the most basic elements of its form and function remain in place (Fig. 16).

A reading of the Peace Memorial boulevard as a skewed mathematical reconstruction of its former self reflects the inertia of the city through the metaphor of the intelligent machine. It frames Hiroshima's rebranding not as a total self-reinvention but as a pivot, in which the same urban patterns were repurposed to represent new messaging without undergoing any fundamental structural changes.

A treasured object I brought home from the shore of the Seto Inland Sea: the outline of an oyster shell, whose intact edges enclosed a vacant center worn or eaten away.

The Peace Memorial Boulevard was not the only conspicuous void left over from Hiroshima's war effort. Beyond the civilian firebreak project, the city was home to various military bases and fabrication facilities that had been crucial during wartime but became not only obsolete, but problematic, in the postwar reconstruction period. Hiroshima's transition from military-industrial stronghold to international symbol of peace require the very literal conversion of its defense resources, suddenly transformed from assets to blemishes, for alternative uses. The Peace Memorial City Construction Law transferred ownership of these lands from the national government to the city, with the mandate that they be repurposed for more appropriate activities.[70]

Immediately following the atomic bomb, the Motomachi district became the primary site of this redevelopment. The area formerly contained a military complex including barracks and a hospital, but in the post-atomic chaos it was quickly adapted for emergency housing both official and unauthorized. In 1946, the city constructed row houses for survivors on this land, but the number of units available could not hope to shelter all of the displaced citizens who needed it, many of whom had lost homes in Nakajima when that land was designated as the Peace Memorial Park.[71] The large homeless population left out of the official emergency housing project resorted to building a settlement of shacks and makeshift illegal houses along the 1.5-kilometer bank of the Ota River that forms the Eastern boundary of the Motomachi district. This unofficial neighborhood grew to comprise over 900 shacks by 1960,[72] which continued to pose a challenge for the city due to their flammable construction and immobile residents until the late 1970s.[73] Today, the redevelopment project is complete, and Motomachi includes public parkland, civic and recreational facilities, and a massive public housing complex, whose cluster of large apartment buildings rendered in graphic dark brown siding and white concrete is visible far and wide. I found my way home by it more than once.

70 Alkazei and Matsubara, "Hiroshima's Image-Shift to a Peace Memorial City," 5.

71 Hayashi, "The Motomachi District, 65 Years After the Atomic Bombing."

72 Ibid.

73 Alkazei and Matsubara, "Hiroshima's Image-Shift to a Peace Memorial City," 5.

Motomachi's visual drama arises from its unique scale and position in Hiroshima, making the buildings themselves a monument to the land readjustment endeavor. Nowhere else did I see a pack of identical buildings clumped together as a single development; instead, my journal comments at length on the astonishing density and diversity of Japanese urbanism, noting with wonder that I could walk the same compact street every morning and each time notice something that had escaped me before. In contrast, the Motomachi housing complex reads as hulking and monotonous, a zigzag of enormous buildings whose facade appears continuous when viewed from the waterfront and whose floors and corridors of homogenous units are so uniform as to retain a militaristic aspect. Perhaps these are simply the design tragedies of public housing in general, but a form that would evoke quotidian utility in the United States startles an observer attentive to the distinctive compact richness of typical Japanese urban environments.

I found Motomachi impenetrable. I struggled to photograph the massive facades despite finding them leeringly visible from everywhere. I failed to approach it close enough to sense daily life there but could never distance myself adequately to see the whole development at once. I perceived subtle formal differences between the buildings though I failed to grasp any one of them sufficiently to differentiate it from the others. The removed perspective of viewing this district in plan, however, reveals its driving narrative (Fig. 17). Maps comparing prewar and postwar Hiroshima tend to focus on Motomachi as a primary zone of land use readjustment, highlighting the transformation from military compound to civilian community and public recreational area as a representation of the city's self-reinvention after the war. This planning maneuver captures the image shift to Peace Memorial City at its most fundamental.

The clarity of comparison between the prewar plan of Hiroshima and its reconstructed progeny relies on a formal continuity that merits further investigation. Motomachi provides an attractive case study of urban transformation not only because of the value shift evident in its modified land use but also because its unchanged shape is easily identifiable in both prewar and postwar maps: while the content and function of Motomachi changed completely in Hiroshima's reconstruction, the historic boundaries of the district remain in place. This phenomenon recalls a mechanistic approach to image processing, as if city blocks contained values like the pixel numbers in an image. In my autoencoder, images are fed into a program that simplifies them to the most basic representation possible and reconstructs them according that encoding, capturing only the most crucial information necessary to reproduce the correct overall shape. Though the reconstructed image may appear blurry or imprecise, the composition of the original image in terms of zones and boundaries remains intact. This process as a metaphoric lens for studying Hiroshima's reconstruction illuminates the longevity of contours and patterns in information (in this case, the city plan) beyond the low-level data points that create them. Though Motomachi's content as a military base was obsolete in postwar Hiroshima, its shape remained almost unchanged in the city plan.

In line with the implications of this mechanistic analysis, urban patterns surrounding this district survive despite the transformation of its program. Alkazei describes the difficulty of rehabilitating Motomachi, beyond the obvious challenges facing a traumatized and housing-insecure community, as a struggle to reintegrate

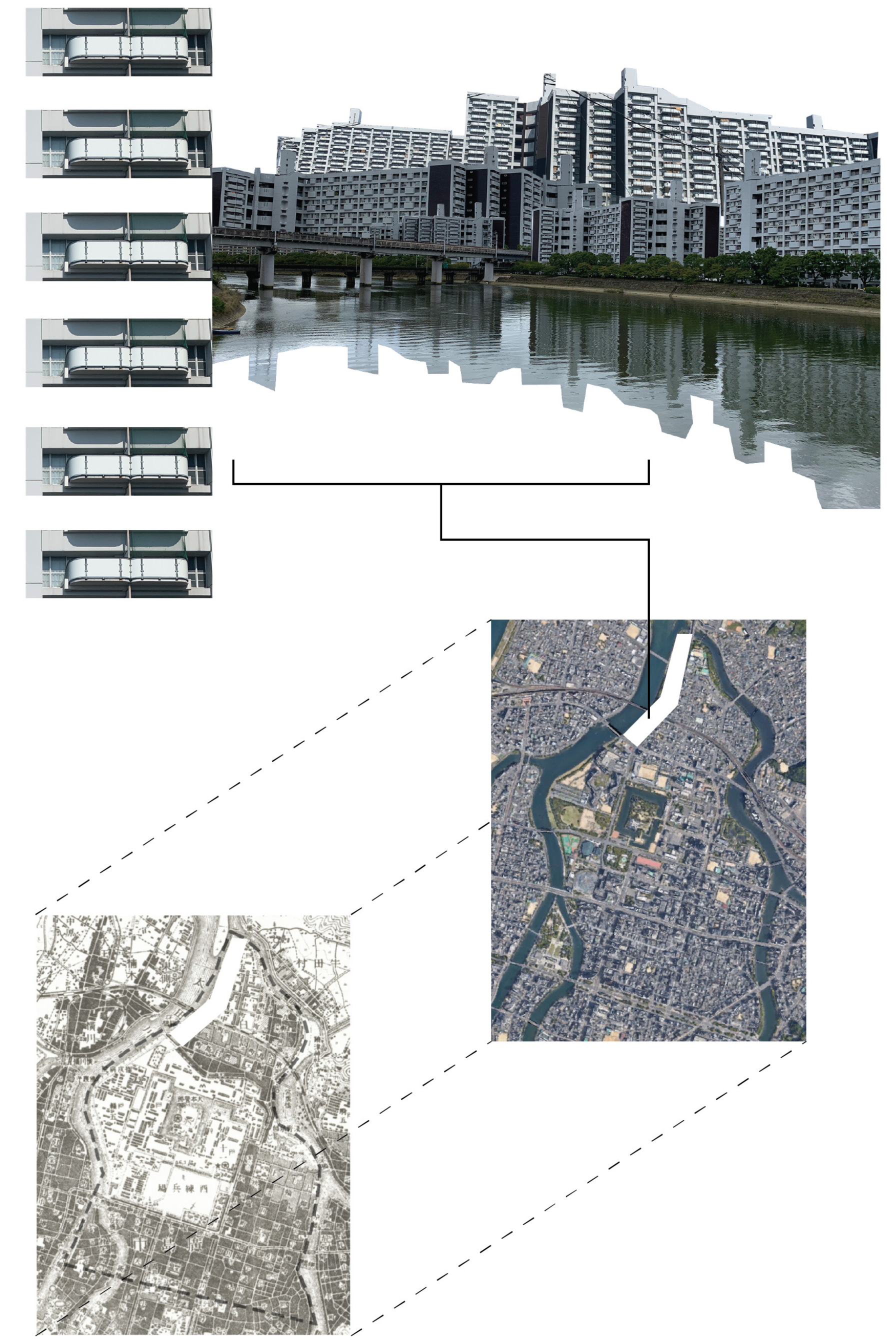

Figure 17: Motomachi in person and in plan.
Middle image: Google Earth.
Bottom image: plan of Motomachi district, 1930, from Alkazei.

74 Alkazei and Matsubara, "Hiroshima's Image-Shift to a Peace Memorial City," 5.

the formerly sealed and separated military district with the rest of the city once it had been converted to civilian housing.[74] This social disconnection appears to arise from factors beyond the stylistic abnormality I observed of Motomachi in comparison to the rest of Hiroshima, including the lasting structure of land use boundaries that enclose the district as well as the afterlife of government control that remains in place in the public housing development, albeit at a municipal rather than national level. In this sense, the nonmilitary Motomachi of today retains the most permanent contours of its historical urban presence, evoking the fundamental shapes in data that can penetrate through processes of computational or physical reconstruction.

A common and charming sight in Hiroshima: traditional "sudare," horizontal slats of decorative wood or bamboo strung together to make hanging blinds, shading the balconies of spare modern apartment buildings

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Within the Motomachi government administration zone stands Hiroshima Castle, perhaps the only vestige of its prewar identity that the city celebrates. This feudal-period tower is situated on a square plot of land surrounded by a moat that echoes the river-island nature of the surrounding city, seemingly creating a scalar barrier that shelters a context in which the castle appears imposing and majestic despite its diminutive size in comparison to the skyscrapers of modern Hiroshima. Crossing the footbridge over the moat indicates an atmospheric transition from postwar progress to historic preservation.

The notion of preservation in this case operates in a purely aesthetic sense; the tower that stands on this venerated site today is actually a replica. The original castle, like the majority of Japanese architecture in its time, was primarily built of wood; but because it stood less than a kilometer from the atomic bomb's hypocenter, it was completely destroyed by the blast. Its rubble was carried away in the aftermath for the construction of salvaged emergency shelters.[75] The structure that currently represents it was built in the 1950s and occupies a footprint about a hundred feet from its original location. The foundation stones of the original castle still lie quietly in the grass next to those of a historic military facility from the Meiji era, which was never reconstructed. The matrices of foundation stones, which retain the occasional detail of a staircase or gutter, offer quilting points for the imagination of these structures in space. They, like the lawn of the Peace Memorial Museum, symbolize a previous condition by preserving its footprint on the ground and bounding the open space above.

75 "Hiroshima for Global Peace," "Hiroshima's Path to Reconstruction," 8.

However, the reconstruction of the castle is a much more literal representation of the historic structure (Fig. 18). I approached it along a shaded path that led up to an elevated corner of the artificial island. The castle's facade towered gracefully, with curved eaves at every floor and the brilliant white of painted trim standing out against the dark patina of wooden siding. I stopped briefly to appreciate this elegant artifact before eagerly proceeding towards its shaded entrance, grateful to

Figure 18: Hiroshima Castle and its concrete core.

briefly escape the ambient humidity and curious about the ornament and artifacts that awaited me inside. Instead, to my surprise, when my eyes had adjusted to the dim interior of the castle, I found myself in a concrete box that bore no resemblance to the luxurious craftsmanship of the building's exterior. I realized quickly that this reconstruction did not replicate the entire original castle but instead simply displayed the shell of the historic building on a concrete armature, whose unadorned interior housed artifacts and educational exhibits but made no attempt at capturing the atmosphere of the original space. The concrete galleries had no windows, and photography was not allowed.

As I climbed a series of staircases towards the building's upper balcony, I reflected on the castle as an interpretive device. Perhaps this building offers a synecdoche for the overall reconstruction of Hiroshima, where the traditional patina and detail of Japanese life adorn and surround a core whose construction is sturdy and new. The modern city offers a reinforced and durable scaffolding for the activity and adornment of a cultural lifestyle that has remained largely unchanged despite major upheaval in its built context since the war.

The aesthetic layering I describe could be attributed to the wabi-sabi design ethic, a value system integral to the Japanese concept of beauty that lauds the rustic over the glossy and the organic over the standardized. Leonard Koren, in his seminal *Wabi-Sabi for Artists, Designers, Poets, & Philosophers* (1994), positions this framework in opposition to the ethos of modernism. Wabi-sabi celebrates the vague, accommodates the contradictory, and views damage or degradation as a rich and wonderful development in the life of an object. Koren contrasts the earthy warmth of this philosophy with the cool geometric objectivity of modernism, citing the modern movement's emphasis on permanence, universality, and control as direct conflicts between it and traditional Japanese design.[76] In Hiroshima at large, as in the representative case of Hiroshima Castle, wabi-sabi and modernism collide: just as the weathered wood of a traditional facade adorns the spare concrete prism inside the castle, elements of traditional Japanese patina cling to the walls, waft over the balconies, and germinate in the fertile corners of Hiroshima's modern concrete armature. The classical Japanese-ness of the city— evident in traditions that range from the ubiquity of house slippers, to the occasional noren curtain shading a cinderblock entryway, to a rare shrine at the foot of a late-modern office tower— demonstrates that a city is more than its built environment. These patterns persisted through the destruction of Hiroshima's traditional architecture and its reemergence as a city built primarily in the efficient and straightforward midcentury modern style.

76 Koren, *Wabi-Sabi for Artists, Designers, Poets & Philosophers*, 26.

This observation gives way to a fundamental insight about Hiroshima through the reading of its landscape as an intelligent machine. The artificial neural network, upon which this notion of computational urbanism is based, intends to imitate biological cognition through the substrate of computer code. It takes an intelligent network of interacting cells and models them with computational representations that function in similar ways. Perhaps Hiroshima's reconstruction can be thought of similarly, as a replacement of the organic original city with a synthetic alternative that hosts its layers of intelligence in a synthetic structure. If the city before the war evolved like a biological brain, Hiroshima's reconstruction is the artificial neural network that simulates that original intelligence. This metaphor casts the

tabula rasa not as a complete erasure of precedent but as the impetus to recapture the same intelligent network in a manufactured substrate.

And just as an artificial neural network retains the precise calibration and mysterious complex interplays of its biological inspiration, Hiroshima's reconstructed built environment retains the design ethic and aesthetic quality native to Japanese cities. Though cultural touchpoints as fundamental as Hiroshima's political identity emerged from the tabula rasa transformed, the network of cultural reference points, philosophical habits, and patterns of inhabitation long ingrained in the city's intelligent patterns could not be destroyed by an atomic bomb. These factors create a mesh of interwoven signals that operate continuously and invisibly on the landscape. The Japanese cultural sensibility and aesthetic tradition transcend the materiality or date of the structures that host them, and the vigor of their expression continues despite the tabula rasa that once erased their substrate.

"The heavens are split asunder,
The city has disappeared,
The river
Is flowing"
– Tamiki Hara, "Give Me Water" (excerpt)[77]

77 Treat, *Writing Ground Zero: Japanese Literature and the Atomic Bomb*, 171.

On one of my final days in Hiroshima, I took a walk towards the uppermost fork in the Ota river. I wanted to find the origin point of the city, where the river began the series of branches and splits that create Hiroshima's deltaic landscape. I navigated by simply walking upstream, in an attempt to access the machinations of the hydrological ecosystem constantly underway beside the human bustle of city traffic. It certainly was a water machine that I discovered: at the northernmost joint of the Ota, where the retaining walls of downtown Hiroshima dropped off and the river flowed wide and lazy between its grassy banks, I found not a fertile crescent but a roaring spillway (Fig. 19). A dam studded with towers funneled foaming jets of water into the eastern and primary vein of the river, diverting the rest of its flow into the subsidiary western branch. This engineered intervention was necessary to maintain what I learned was not a native waterway, but a constructed canal designed to mitigate flooding in the city's river network, whose water levels breathe up and down with tidal fluctuations every day.

The spillway's construction began in 1934, but the project was suspended to release labor for the war effort and slowed by Hiroshima's extraordinary reconstruction process. It was not finished until 1968. The spillway now runs for nine kilometers, straight to Hiroshima Bay. Though it appears as riverlike as the natural branches of the Ota, the canal's artificial aspect reveals itself through its relatively straight path as well as in the wide grassy floodplains on either side of it, which create an absorbent buffer within its retaining walls.

As I watched a large plastic canister float down the river, disappear into the spillway, and tumble into the froth of its wake, I contemplated the terra firma of

Figure 19: scenes from the spillway.

Hiroshima. I considered the Ota and its many fractures as the motive force of the city; I thought of the many times I had observed people fishing, wading, and exercising in the margins of these arteries; I came to wonder if they were the true master strokes of the city plan. It occurred to me that even an atomic bomb cannot un-divert a river.

This brought me to view Hiroshima's ground plane, its water and soil, as a final and conclusive site of the city's tabula rasa. It is the tablet upon which the inscription of the city was written over hundreds of years and then obliterated in an instant, yet its palimpsestic layers capture so many of the deeply ingrained urban factors that never disappeared from Hiroshima even with the destruction of its built environment. When its physical components were scraped from this surface, the elements of Hiroshima that operated under the ground, through the air, or in the intangible complex networks of human distributed computing survived. They quickly reemerged, much like the vegetation John Hersey describes in the following passage on the atomic bomb's ecological aftermath:

> Over everything—up through the wreckage of the city, in gutters, along the riverbanks, tangled among tiles and tin roofing, climbing on charred tree trunks—was a blanket of fresh, vivid, lush, optimistic green; the verdancy rose even from the foundations of ruined houses. Weeds already hid the ashes, and wild flowers were in bloom among the city's bones. The bomb had not only left the underground organs of plants intact; it had stimulated them.[78]

That stimulation also affected Hiroshima's intelligent urbanism: in the city's reconstruction, its prewar and wartime social structures remain, regrown in new configurations. The container technologies of war now carry messages of peace, the aquatic and terrestrial city plan mutates within its traditional sections, and the old vines of cultural tradition send new shoots creeping up the walls of modernism. The postwar Hiroshima I observed was ethically reborn and conceptually rebranded, but its form and function were close kin to those of the original city before its atomic demolition. The two incarnations of this built environment compare as if outputs of the same program, whose parameters had changed slightly but whose ultimate convergence was directed towards the same result.

78 Hersey, "Hiroshima."

Valdivia, Chile

I woke up to a cold drizzling morning and a gray sky outside the windows of my rented room on Isla Teja, across the Calle-Calle river from Valdivia, Chile. I looked out over the quaint slanted roofs of barely-variant alpine cottages in picturesque rows, softened with mist and emitting silent clouds of smoke from wood burning stoves. I drank coffee and dressed in wool: early springtime in the far-Southern Hemisphere had not yet shed the chill of winter. It was hard to believe any instability could shake the peaceful atmosphere of this environment (Fig. 20).

But instability was exactly the phenomenon I had come there to study, and it abounded in my observations beyond that quiet morning. It originated beneath the very ground I stood on. I chose Valdivia as a companion to Hiroshima in representing the urban tabula rasa because it had been the site of the most powerful earthquake ever recorded, on May 22, 1960. This tremendous tectonic shift and the devastating destruction it caused seemed an appropriate sequel to my investigation of the post-atomic landscape, though in fact the earthquake represented an energetic outburst more than a million times more powerful than the atomic bomb.[79]

79 Benedetti, *El terremoto más grande de la historia*, 33.

This kinetic delta gives way to a world of fundamental differences in context and method that make Valdivia much more a counterpoint than a complement to Hiroshima as a case study in the urban tabula rasa. In Valdivia, the razed landscape emerged not from synthetic doom rained down from the sky but from the stirring of natural forces under the ground. And in line with this bottom-up framework, the city's reconstruction by its own residents rather than national law represents the accommodation of permanent changes in the natural landscape more than it does any memorialization or future-facing social project. Nowhere in Valdivia did I find this phenomenally destructive event interpreted textually or monumentally. Instead, its effects were accessible only through a social-topographical reading of the city— resolving its socioeconomic landscape with its physical one— informed by local politics and lore. In Valdivia, I read graffiti rather than polished plaques and traced ecological boundaries more attentively than I did the urban plan. The trails of my research follow allegory and anecdote more hungrily than cross-referenced detail.

I approach my exegesis of Valdivia's tabula rasa with an eye to this new mesh of form and content, abandoning the radial logic of Hiroshima's structure to parse this alternate environment as if describing a voyage along the city's looping rivers or through its dense, humming forests. I will narrate this ecosystem of people and land as it was narrated to me, using the sensitive black box of the machine learning model to interpret the observations I made from the ground. Perhaps dragging the sterile and finicky technology of an artificial neural network into the vibrant upheaval of Valdivia calls to mind the absurd technicality of the scientific

Figure 20: a morning on Isla Teja. Bottom image: Google Earth.

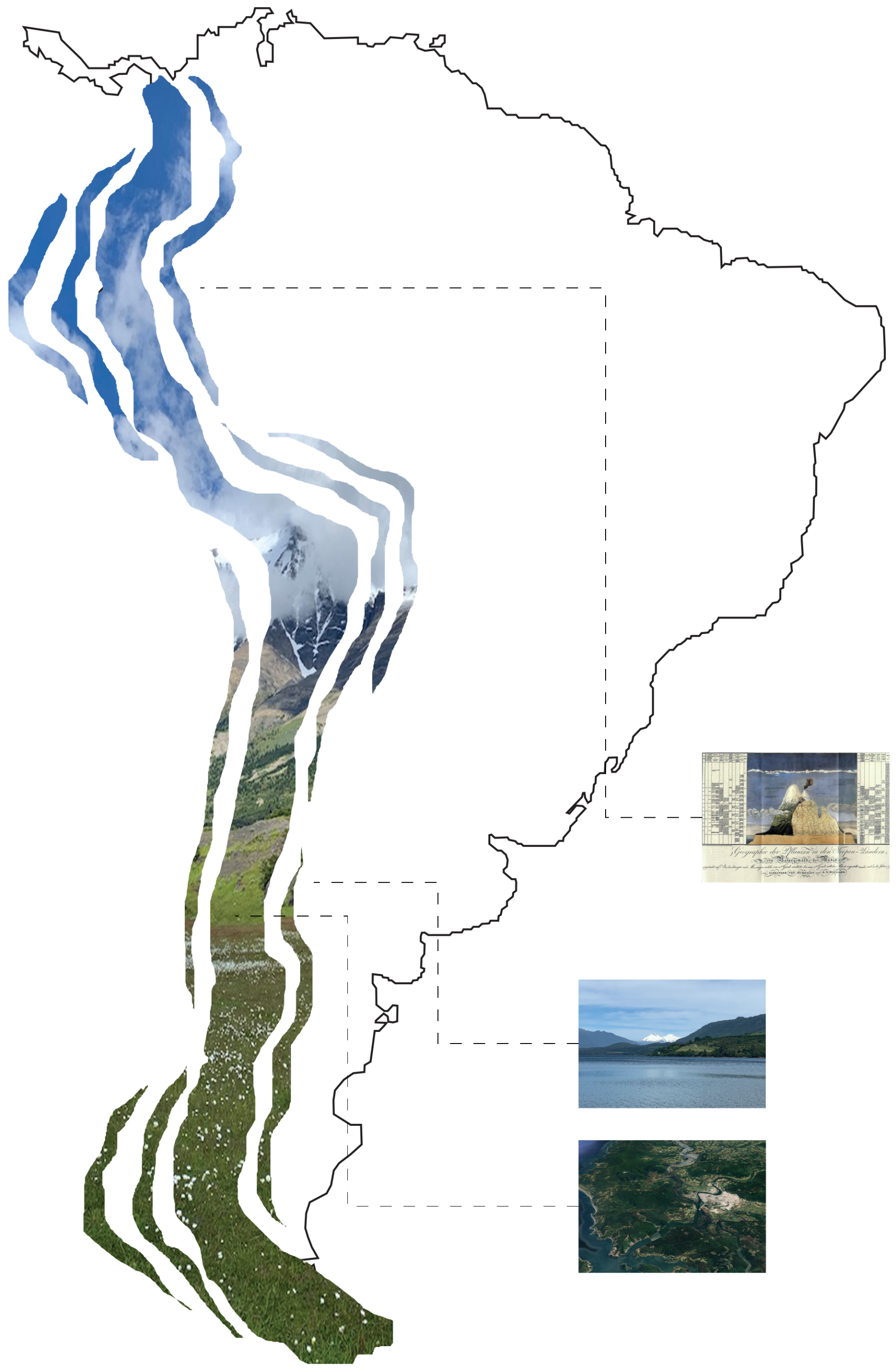

Figure 21: seismic network.
Top image: Natürgemalde, Alexander von Humboldt, 1805, from Buttimer.
Bottom image: Google Earth.

tradition, most notably upheld by naturalists Alexander von Humboldt (1769-1859) and Charles Darwin (1809-1882), of hauling extensive arsenals of fragile scientific instruments through South America on European research voyages. I embrace this association and draw on their linked legacy of field work— Darwin's observations were frequently derivative of von Humboldt's— for both information and inspiration in this project. I hope my neural network will function like von Humboldt's ever-present barometer, giving readings across the tabulae rasae of the late twentieth century as incisive as those von Humboldt took on the slopes of the Ecuadorian volcano Chimborazo, giving way to a new urban model like a *Naturgemälde* for the city.

Chimborazo is a distant peak far to the north of Valdivia, but, as Humboldt and later Darwin observed, the two are connected by a massive geological system that incorporates the seismic and volcanic activity in South America's portion of the Pacific Ring of Fire (Fig. 21). This turbulent zone emerges from the unstable interface between the South American tectonic plate and the Nazca plate subducting beneath it. The incremental movements of this translation produce frequent tremors and volcanic events at the surface, which have consistently jostled and rearranged Chile's topography over the entirety of its history.[80] This territory's characteristic volatility, however, is not limited to its unstable ground. The political history of Chile, from various indigenous uprisings by its several sophisticated precolonial societies (most notably the Mapuche, whose historic home is the territory where Valdivia now sprawls, and who continue to resist colonial occupation into the present day), to multiple waves of colonization by different European powers and later a series of revolutionary social movements that reconfigured Chilean society in different ways. The environmental determinism implicit in these paired observations cannot be overlooked, and I will readily admit my captivation with the idea that Chilean psychology incorporates the acceptance of a reality in which the most fundamental earthly order can be upended at any moment. Perhaps the prevalence of such a worldview in the indigenous, rather than colonial, community supports this impression: according to researcher Steven Bendetti, "Despite the reoccurrence of seismic events, Chileans resist interpreting earthquakes as an integral part of their lives. On the contrary, the Mapuche incorporate these events into their essential beliefs, giving them a transcendent meaning."[81]

80 Villagra Islas and Felsenhardt Rosen, "Emergency Urban Landscape in Valdivia, Chile," 3.

81 Benedetti, *El terremoto más grande de la historia*, 42.

Bendetti also notes that in the Mapuche belief system, seismic catastrophes are "symptoms of cosmic disequilibrium," or retaliation by mother nature for human wrongdoing.[82] In this case, a profound degeneracy must have corrupted the Valdivia of May 1960, when the city suffered the largest earthquake in recorded history. On that sunny Sunday afternoon, an initial shaking flushed residents out of their houses and primed them to witness the earthquake's most intense tremor, which lasted for five full minutes.[83] The earth surged, rippled, and frayed, destroying 70% of the buildings in the city[84] and flooding lowlands with river water as the soil settled into a new topography.[85] This new terrain so differed from the previous configuration of the earth that whole islands disappeared, complete with sheep and the families that farmed them, as they sank below sea level, and new islands emerged from the ocean and rivers bare, streaming water, and hemmed with banks of mollusks.[86] A tsunami that spanned both sides of the Pacific brought seawater crashing into the city and inundated its rivers,[87] creating a disaster as much hy-

82 Ibid, 40.

83 Ibid, 68.

84 Ibid, 95.

85 Ibid, 68.

86 Ibid, 168.

87 Ibid.

drological as it was terrestrial. This massive rearrangement of the earth, reaching to even the most fundamental level of boundaries between water and land, recalls Charles Darwin's reaction, also almost directly quoted from Humboldt's earlier sentiment, to a much smaller earthquake he felt near Valdivia in 1835:

> A bad earthquake at once destroys our oldest associations: the earth, the very emblem of solidity, has moved beneath our feet like a thin crust over a fluid;—one second of time has created in the mind a strange idea of insecurity, which hours of reflection would not have produced.[88]

88 Darwin, *The Voyage of the Beagle*, 322.

Despite this profound disruption, the societal imbalances to which the earthquake may have been a punitive natural response unfortunately did not end with it. Through the 1950s, Chile had struggled economically with a lag in agriculture connected to the worsening of its chronic inflation, which had posed a problem since the 1880s.[89] These issues resulted in a heavily regulated but still struggling economy that failed to improve despite the efforts of three presidents from 1927-1970.[90] Implicated in this economic plight was the continued influence of the longstanding and exploitative hacienda agricultural system, a holdover of the early colonial period that left workers on large privately-owned estates (*latifundios*) relegated to diminutive satellite plots (*minifundios*) for their own subsistence.[91] Under this antiquated framework, 80% of Chile's agricultural lands were concentrated in 7.5% of its properties, leaving the majority of the peasant laborers without viable land holdings, acceptable housing, or basic educational opportunities.[92] The pressure to dismantle this program grew leading up to 1960, and in 1962, while Valdivianos still labored to rebuild their community on a new landscape, the conservative government of president President Jorge Alessandri Rodríguez finally implemented an agrarian reform law.[93]

89 Hudson, *Chile: A Country Study*, chap. Economic Policies, 1950-70.

90 Ibid.

91 Winn and Kay, "Agrarian Reform and Rural Revolution in Allende's Chile," 135.

92 Ibid.

93 Ibid, 136.

That administration largely failed to enforce this new law, but the Christian Democrat government headed by President Eduardo Frei starting in 1964 committed to peasant liberty and inclusion through the expropriation of large and poorly managed latifundios, incentives for efficient production, and the government-sponsored organization of peasants for fair wages and job security.[94] The aspirations of this reform represented a "rural revolution" that could be considered the first step towards communitarian society in Chile, but conflicting interests and political checks on the Christian Democrat Party stopped it short of achieving the total overhaul it intended. Ultimately, very few of the original latifundios were expropriated, and these cases all too often resulted in fractal reproductions of the original system, where the co-operative asentamientos were monopolized by the subset of peasants eligible to administer them, who turned them into miniature versions of their parentage.[95] Though the Frei administration succeeded in introducing agrarian reform to Chilean society, it left numerous still-underserved peasant groups hungry for more sweeping changes and open to the radical ideas of Salvador Allende's socialist government, which took over in 1970.

94 Ibid, 137.

95 Ibid.

The increased dedication to agrarian reform under Allende was represented both in further expropriations of large estates by the government as well as by unauthorized stirrings from below. Especially in the Mapuche region of Southern Chile, native uprisings to take back land occupied by colonial communities inspired

peasants to seize farms, using informal militancy to put tremendous pressure on the government to speed up its land reform regimen.[96] The consequently accelerated land redistribution, which sometimes resulted in the "entire land tenure structure of a region changed in an afternoon,"[97] left the whole configuration of the Chilean landscape reorganized suddenly and vigorously. In this instance as in Chile's constant seismic events, tension in the ground erupts in shifting that transforms the terrain and its topography.

96 Ibid, 142.

97 Winn and Kay, "Agrarian Reform and Rural Revolution in Allende's Chile," 142.

This tectonic social adjustment seemed a tremendous victory for the Chilean peasant class, and perhaps individuals benefitted, but the collective eventually began to struggle. Small farmers concentrated on their new private land plots rather than contributing labor to communal fields, resulting in a decline in agricultural productivity overall. This slowdown led to a diminished food supply that floundered in response to the increased demand permitted by Allende's income redistribution and the enduring problem of inflation.[98]

98 Hudson, *Chile: A Country Study*, chap. Economic Policies, 1950-70.

The turbulence of Chile's socialist years came to an abrupt end with the violent seizure of power by Augusto Pinochet's reactionary military junta in 1973. The military mutineers acted not in favor of an alternative social reformation but in a rejection of Allende's policies, backed by the United States' interest in ousting socialist leadership from Chile. By 1979, Pinochet's new military dictatorship had instigated land reforms according to a strategy of "regularization," returning almost a third of the lands that had been expropriated during Allende's administration to their original owners and reallocating the rest such that peasants lost about 60% of the land they had received during the previous agrarian reforms.[99] Perhaps this single aspect of Pinochet's reign of terror constituted a course correction towards a more stable past, but other projects of the dictatorship would traumatize Chilean society in ways that changed it forever and continue to affect its future. From 1973 to 1990, the Pinochet government killed, tortured, and otherwise "disappeared" thousands of people, sending political dissidents to concentration or internment camps and creating an enormous void in Chilean society where los desaparecidos left holes in families and communities. Beyond these crimes against humanity, Pinochet also dissolved the Chilean legislature, suspended the country's constitution, and sent thousands of people into exile in the process of implementing sweeping policies of decentralization aided by the American CIA and advised by economists from the University of Chicago, called the "Chicago Boys."[100] In 1980, Pinochet established a new dictatorial constitution, which lasted past the end of his reign in 1990 and has stayed in place through several subsequent presidents to the present day.

99 Heit, "Rural Development and the Agrarian Reform Process in Chile," 75.

100 Hudson, *Chile: A Country Study*, chap. Neoliberal Economics.

Pinochet's neoliberal economic policies also continue to endure in Chile, where the tensions of lingering inequality and corruption have recently erupted in yet another seismic reckoning in Chilean society. The combination of trade issues related to Chile's crucial copper industry with the regressive tax policies of billionaire President Sebastián Piñera have left Chile's lower class feeling abandoned and frustrated. When subway fares in the capitol city of Santiago increased marginally in October 2019, these tensions reached an untenable strain and snapped, sending Chile into a chaotic milieu of protests that started with widespread subway fare evasion and devolved into scenes of looting, vandalism, and arson in several cities.[101] The scale of these protests brought the military police, *los carabineros*, out

101 Londoño, "What You Need to Know About the Unrest in Chile."

Figure 22: a single march.
Top image: march for Allende reforms, 1964, from Titelman.
Middle image: march against Pinochet abuses, undated, from Titelman.

onto the street to enforce order for the first time since Pinochet's regime. However, protesters were undeterred: the nationwide uprising continued with demonstrations every day for months, at one point culminating in a million protesters on the street in Santiago[102] marching for reforms to issues as varied as indigenous rights, women's liberation, and environmental protections, beyond the core outcry against economic inequality. This animus pervaded the whole country and left its imprint on the urban environment in the closed businesses of strikers, the ubiquitous graffiti of protesters, and the constant insidious lurking of the carabineros (Fig. 22).

102 Editor, "A Million Chileans March in Santiago to Protest Inequality."

This was the environment I encountered when the spring rain let up, the mist cleared, and I walked into the center of Valdivia looking for earthquake evidence and wondering where I might find the Chilean tabula rasa. Unlike in Hiroshima, no informative plaques pointed me toward it, and no dedicated museums offered to explain the lay of the land. Even if this information did exist in a tourist information kiosk or local library, it was shut inside boarded windows and locked doors, unavailable to me: almost every public building in Valdivia had closed due to protests and strikes by the time I arrived there in late November 2019. I discovered as much on that first day in Valdivia, when I had hoped to orient myself with the help of a local history and tourism center but instead ended up wandering the streets and plazas, wondering how to develop an image of this city whose official messaging was inaccessible. The silencing of the authorized voices to which I first gravitated, however, did not leave the city mute: graffiti on the walls of every public building, in pasted posters and furious streaks of paint, spoke more forcefully than any resource I could have found inside, though it conveyed different information from what I had originally been seeking. Nonetheless, I realized I could not study the buildings while ignoring the writing on their walls.

Eventually, my method in Valdivia evolved from an expectation of straightforward history research and cultural landscape analysis to a reality of immersion in an immediate milieu of social upheaval: it became a simultaneous study of layered political and ecological landscapes. I learned about popular frustrations and protest objectives from slogans spray-painted on walls and about the patchwork of aquatic and terrestrial ecology from hours spent walking the city. Most valuable of all, I came to understand the subliminal currents of local lore and protest slang from my friend and informant Vicente, who traced many kilometers of the city and region by my side, narrating its stories as we went. I recorded a great deal of my information from conversations with Vicente, with his architect-activist friends, and with my landlady, Sonia. Some of their accounts I can corroborate, and some I cannot: they waver among local knowledge, politicized belief, and untraceable legend, but I include them for their vividness and for their tremendous impact on my understanding of this landscape. Such is appropriate: the tabula rasa itself is nothing more than a belief about a place.

From so many walks and talks in Valdivia, I came to understand its tabula rasa as a phenomenon both geological and social, whose aftershocks continued to appear in the landscape as well as in the political unrest taking place upon it. I parse these sedimentary layers through two interpretive core samples derived from the destructive forces involved in the 1960 earthquake disaster: Valdivia's unstable ground and its propensity to flood.

“Somos la raíz rompiendo el cemento” — Gobierno Regional de Los Ríos, Intendencia Regional

“We are the root breaking the cement” — Los Ríos Regional Government Building (graffiti)

The history of Valdivia’s spongy, shifting foundation begins long before the earthquake that brought it infamy. The city sits at the intersection of the Calle-Calle, Cau-Cau, and Cruces rivers, where they flow together to create the Valdivia River that flows in a swirling delta towards the Pacific. The tremendous breadth of these waterways betrays the scale and distance of their origin points in the Andes Mountain Range, where springs and snow from so many massive peaks flush together into a wide aquatic artery. Valdivia once blended into this hydrology: before it was colonized and named after conquistador Pedro de Valdivia, the town was a Mapuche trading center called Ainíl, where the built environment meshed with canals and wetlands filled with river water. This amphibious urbanism inspired European explorers to describe it as “a kind of little Venice.”[103]

Valdivia’s foundation changed in accordance with its political history, however. After a long and conflictual era of colonization characterized by fierce indigenous resistance, the establishment of a Spanish fort solidified the European presence in Valdivia— and its stone towers still stand there today. The city adopted a significant German population through an organized immigration program that began in the early nineteenth century and attracted visitors including Charles Darwin. The earthquake Darwin witnessed in Valdivia may have intensified the urban transformation associated with its industrial development, a process by which most of the state-owned lakes in the area were filled in and built up to house the city’s growing population by 1885.[102] In 1909, a fire destroyed part of the city and prompted the reconstruction of houses, whose new arrangement required the extension of streets to the hills and wetlands of rural zones.[105] Thus, as the colonial settlers built the machine of their city atop this uneven substrate, they created a mottled ground of soggy infill, stone reinforcement, and scattered ashes (Fig. 23).

The devastating earthquake of 1960 exaggerated these inconsistencies in the ground. Much of the city occupies sediments composed of sand, lime, and clay deposited by the rivers, and the seismic waves of the earthquake caused greater transformations in these materials than in rockier areas. This range of stability was clearly evident in the distribution of building damage, the extent of which was highly dependent on the soil below.[106] Some of the more porous subterranean geologies liquefied entirely, causing the earth to open up or cave in at the surface and creating new wetlands studded with ghostly tree trunks and half-submerged fenceposts.[107] At the time, these sunken bruises lay outside the city limits, but today the collapsed farmlands occupy swaths of more recently urbanized land, interrupting the constructed fabric of Valdivia and foregrounding its collapsible base. In an extreme case, a newly aquatic zone adjacent to the river looped back to its source, creating a new riverine loop and enclosing Islote Haverbeck, a tract once part of the mainland but now completely separate from it and only reachable seasonally, by boat.

103 Villarreal, *The Adventure Chronicles of Conquistador Pedro De Mérida: Valdivia*, Volume 2:50.

104 Villagra Islas and Felsenhardt Rosen, “Emergency Urban Landscape in Valdivia, Chile,” 3.

105 Ibid.

106 Benedetti, *El terremoto más grande de la historia*, 194.

107 Ibid, 168.

Figure 23: ground composition.

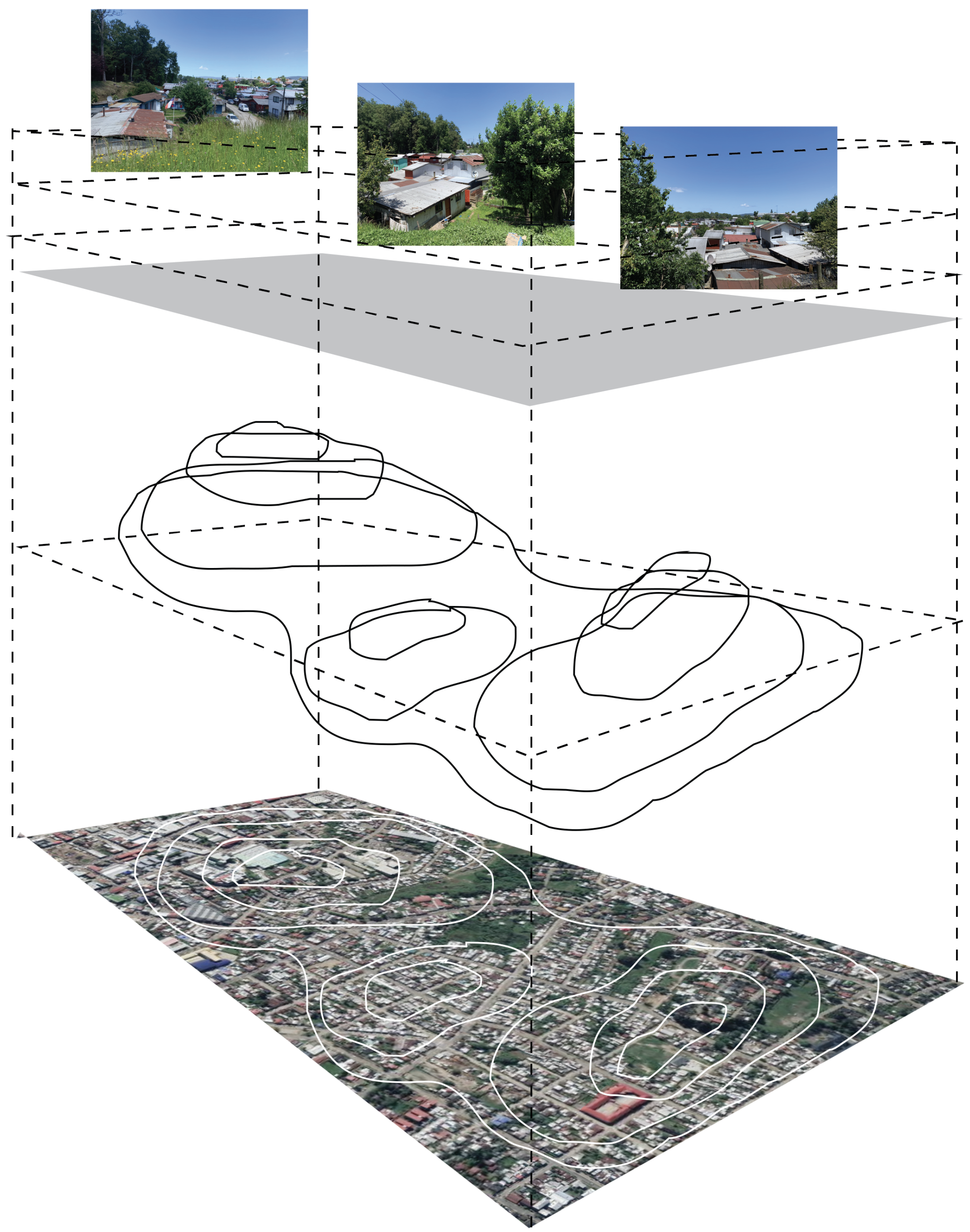

Figure 24: urban topography.
Bottom image: Google Earth.

Islote Haverbeck is one of various new islands that emerged through the earthquake's topographical overhaul, which lifted some outcroppings out of the water and submerged others. This terrestrial mutation was not limited to islands and reefs. It also disrupted the ground plane of the city's dry land, creating an uneven surface whose streets and neighborhoods, Vicente pointed out, now follow its hilly contours more than a uniform grid. These elevation changes also map to social class. During one of many walks through the city, Vicente and I found ourselves on a road suddenly fifteen feet above the corrugated steel roofs of a neighborhood below (Fig. 24), which he explained to me was one of several *barrios bajos* (low neighborhoods) in the city, where disadvantaged communities literally live at a lower elevation than their more privileged neighbors. These tracts of substandard housing demonstrate social stratification topographically as well as hydrologically: hardly any building in Valdivia has a basement because the water table of the saturated land is so high. Barrios bajos are closer to the lurking volatility of this liquid soil and at a much greater risk of flooding than elevated regions. Perhaps it comes as no surprise that the economically frustrated inhabitants of these neighborhoods would rise up in protest, surging out of the social-sedimentary depressions that represent and enforce their economic oppression.

These linked geologies of people and land share the turbulence of uneven and unpredictable foundations, whose mottled effects project through layers of urban fabric. The murky mesh of their interface becomes clearer with a return to the metaphor of the city as an intelligent machine: Valdivia's geology and social stratification arise from subterranean logic gates and political programs that create an uneven output in terms of literal and socioeconomic topography. The loss function of a neural network, which serves as the system's feedback measure of correctness, offers an interpretive lens. One can imagine a loss function as an uneven surface, riddled with peaks and valleys representing high and low values in a multidimensional space. This topography of highs and lows represents the levels of similarity between the system's given output and its desired output. When the neural network begins training, its randomized parameters generate responses that map to a random location on this surface, and the learning process involves iteratively calibrating these parameters to minimize the value of the loss function. This procedure can be visualized as a point-sized agent falling onto an uneven surface and logically traveling downward along that surface in short increments, until it reaches the lowest point of the closest valley— a local minimum. At this point, the program's loss has been minimized, meaning the output it provides is as close to the intended output as it can get within the local topology of the loss landscape.

Because the network always starts with random values for certain parameters, it will land at a different starting point on the loss function every time it is trained, and it may not always settle at the same local minimum. That randomness enables the loss function's topography to project through various trainings of a single network, such that the model does not predictably arrive at the same solution even when it consistently functions correctly. In this way, the complexity of the loss landscape and the many potential paths through it give rise to an intelligence that is mutable rather than static: its impact lies in its capacity to solve the same problem in different ways.

Clearly, the ground of machine learning is not a featureless plane, and neither is it a tabula rasa: even its fundamental starting point is a surface full of hills and valleys that impact the entire learning process. Valdivia's porous and unstable ground evokes the loss function in this way, demonstrating that though the city was once reduced to almost nothing, that razed earth was both artificial and naturally animate. Even its new and unbuilt post-earthquake topography was encoded with features that would influence the city's reconstruction both physically and sociopolitically.

"Cuando la tiranía es ley, la revolución es orden" — Ilustre Municipalidad de Valdivia

"When tyranny is law, revolution is order" — Valdivia City Hall (graffiti)

Intensifying the effects of Valdivia's unstable ground is the water that seeps into its foundations from the river and oozes out of its water table from under wetlands. This flowing, flooding medium, though not the direct implement of the 1960 disaster, exacerbated its challenges and threatened to finish the almost-total destruction brought about by the earthquake. Roughly 65 kilometers upriver of Valdivia lies the enormous lake Riñihue, a basin in the foothills of the Andes that collects water streaming down from the mountains before it flows past Valdivia to the ocean. In 1960, the earthquake caused three major landslides that clogged the outflow of this lake, plugging its drainage with sand, dirt, and rock for more than two kilometers and causing its water level to climb rapidly with no outlet (Fig. 25).[108] The menacing rise of this lake and expansion of its shoreline forced the evacuation of various nearby communities as the water swelled beyond its boundaries[109] and threatened to break through the unstable barriers of the landslides to overflow completely. Such a catastrophic rupture would have sent a thundering cascade of water downriver to Valdivia, wiping out the shaken city entirely and spelling permanent doom for its built environment, likely leaving its site submerged forever. The city narrowly escaped this fate.

108 Hernández de Padilla, *La Respuesta*.

109 Benedetti, *El terremoto más grande de la historia*, 162.

The Chilean government sent 450 workers from its national electricity company and its national development agency to lead locals in the effort to control the threat of the Riñihuazo, as this crisis is called.[110] That work, illustrated in the documentary film *La Respuesta* (*The Response*) released by the Austral University of Chile in 1961, was extremely arduous. The landslides that choked the lake's outlet were made of mud and unstable rock, which clogged automobile wheels and gripped boot-clad feet. The workers and locals, determined to release the water before it destroyed Valdivia, had to labor by hand, shoveling nearly-liquid mud out of massive trenches day and night for weeks.[111] Eventually, they succeeded in digging a narrow canal sufficiently open to release the extra water from the lake and began a drainage process that would save Valdivia from the threat of total erasure. Riñihue's shoreline would eventually recede again, and the water flow from snowcapped Andes peaks to the South Pacific would regain its continuity.

110 Ibid.

111 Hernández de Padilla, *La Respuesta*.

Water in Chile, especially the Andean fresh water concerned in this case, is a contentious and threatening topic in Chile beyond the issue of its literal blockage.

Figure 25: Riñihuazo.
Top image: Google Earth.
Drawings: Riñihuazo plan (top) and section (bottom), from Hernández de Padilla.

Just as Pinochet's neoliberal dictatorship involved land reforms, it addressed the country's water as another commodity to harness for profit through big business. In 1981, the military government established a new Water Code, unleashing the forces of free market domination and private monopoly to manage Chile's extraordinary freshwater resources, which include alpine glaciers in the Andes and the enormous lake and river systems they feed. This structure, under which the majority of fresh water in Chile is privately owned, creates several issues despite its arguable success and routine invocation to exemplify the advantages of neoliberalism.[112] Water is a vital resource and a fugitive substance: it cycles in ways that transcend the bounds of private property and flows in complex networks such that interventions in a single location trickle down to affect the whole system. This makes it extremely difficult to regulate piecewise if it is not under unified control, and Chile's looming water crisis demonstrates that reality: millions of people in Santiago live without running water, and the rest buy it from foreign enterprises that own the resource and sell it back to Chileans at prices inflated by tariffs.[113] Climate change and its effects on the hydrological system supporting Santiago threaten this water model and leave poor communities exposed to drought,[114] facing the exact opposite existential threat to Valdivia's in 1960.

112 Bauer, "In the Image of the Market: The Chilean Model of Water Resources Management," 147.

113 Gallagher, "The Heavy Price of Santiago's Privatised Water."

114 Ibid.

115 Ibid.

This fundamental insecurity, class-determined risk, and antiquated policy represent some of the frustrations with Chile's lingering neoliberal organization that prompted the protests of October 2019 and onward.[115] Though the protests erupted in response to a small incremental increase in subway fares, people took to the streets out of overwhelming general frustration with their personal socioeconomic precarity due to the lingering effects of Pinochet-era social structures, which subsequent leaders have failed to unravel despite the traumas and failures of the dictatorship. The riots inundated many cities in Chile, including Valdivia, where the most powerful uprising took place on the single night of October 19, 2019: Santiago lay silent under a military-enforced curfew, but Valdivia did not. Students and lay people stormed public spaces, leaving government buildings, churches, and banks covered in graffiti and surrounded by broken glass from their own windows. They left a watermark of damage at about two meters above the ground on every building they touched, as if a flood of public fury had rushed into the city overnight and left a stain where it crashed and tumbled into the concrete walls of its government. The natural tension and potentially uncontrollable release of Riñihue foreshadowed its social analog in the October protests, which no national effort succeeded in preventing.

Though this level of violence had subsided in Valdivia, the protesters' conviction remained clear and heated when I visited the city a month later: I participated in one of the demonstrations that continued to take place every night in the Plaza de la República, Valdivia's main central square. People banged pots and pans, sang songs, and chanted slogans about the strength of the Chilean *pueblo* and the inadequacies of Piñera's government. A man sold barbecue from a grill cart, a fire started in the street, and young women donned masks and bandanas in preparation for tear gas, *la crimogena*, knowing the carabineros waited just around the corner. Vicente speculated that some shadowy figures on the other side of the intersection might be preparing to loot a supermarket, as a form of protest and also as a desperate grab for basic commodities they could not afford. By late November, this scene was routine.

I wrote in my field notes that night about the simultaneous fragility and violence of the social and environmental forces at work in Valdiva, and I now return to my idea of the cultural landscape as an intelligent machine in order to parse that observation from a mechanistic point of view. The cases of Riñihue's threat of catastrophic flooding and the street protests' persistent disruption present extremely sensitive systems whose blockage interrupts their operation in unstable and chaotic ways: an isolated landslide dangerously clogs a massive riparian network, and a minor subway fare hike sends an entire nation into rebel chaos. These breakages demonstrate the precarious calibrations of such intelligent networks, which malfunction when sensitive points fail to behave according to the norm. In my experimentation, the analog to this phenomenon is represented in the activation function that determines how neuron layer inputs map to firing or non-firing outputs. This crucial parameter slots unassumingly into the neural network generation command, and the differences between its possible formations seem minute, but the incorrect application of this mathematical procedure can introduce extremely disruptive errors into the network. The confused, noisy, and poorly approximated images my network produced when trained with the wrong activation function demonstrate the depth of the problems even such a minor adjustment can cause.

Even if every other aspect of a neural network is perfectly in order, a problem with the activation function will cause a road block, a bottleneck, that derails the whole training process with cascading effects that lead to failure outputs. This small disruption to the complex system of machine learning causes a disproportionate response, revealing not only how sensitive the system is to its calibration but also how rigid it is in following its hard-coded procedure. The neural network as a metaphorical model for Riñihue's blockage and Chile's social unrest offers a systems approach to interpreting these challenges, but the likeness stops at the element of rigidity. A neural network at the level of my autoencoder imitates intelligence, reproducing its effects without any genuine consciousness or capability to interrupt its own process in response to a problem. In contrast, the society that managed to mitigate Riñihue's existential threat and erupt in mass protest against failing economic policies is intervening in its own mechanism. The aversion of one flood and the continuous waves of the other illustrate a cultural landscape that is more intelligent than it is machine, and whose history of upheaval has enabled it to learn the practice of existential conflict response. A city, in this case the Chilean pueblo at large, learns procedures over time that manifest in its ecological and political instincts.

"No somos nietos de la dictadura, somos hijos de la rebelión!!" — Universidad Santo Tomás

"We are not grandchildren of the dictatorship, we are children of the rebellion!" — Saint Thomas University (graffiti)

One of the most striking visualizations of Chile's political moment that I witnessed in Valdivia was the site of what Vicente called "*la casa socialista*," the socialist house. It once served as the base for the socialist party in Valdivia, an important political node given the significance of socialism in Chile as the goal

Figure 26: the socialist house
Drawing: traced from Google Street View.

of Allende's aborted presidency and the primary ideology of political dissidents since then. When we arrived, the site captured a striking negative space (Fig. 26). Its pink concrete retaining wall still stood, with stenciled socialist emblems still visible beneath new graffiti. Within that boundary, the house had been reduced to a straight-sided basin filled with charred rubble and punctuated by the unattached brick columns that once supported its ground floor. The building had burned to the ground almost completely inside of its own footprint, leaving only the dark smudge of smoke on its neighbors. Vicente said the whole city knew its socialist base had been destroyed, but no one could say who was responsible: there was equal likelihood that protesters dissatisfied with the party's failure to protect the people had ignited the building as that the corrupt neoliberal carabineros had set it alight.

On the walk to the socialist house, I had stopped at a street side newsstand when its offerings caught my eye. Beside tabloids and packs of gum, the stand sold booklets on the controversial trade treaty TPP-11, pamphlets about Chilean rights to free speech, and copies of the national constitution. I bought a constitution book and perused it over the next several days, sitting in the Plaza de la República trying to understand how this nation would rewrite itself. Protesters' political demands commonly included the resignation of President Piñera and the convocation of a legislative committee to draft a new constitution, arguing that the present document's formation during the Pinochet dictatorship could not fail to infect its character overall. At first, I understood the protests as an effort to expunge every stain of the dictatorship from Chilean society and start again, from a political tabula rasa. Perhaps one can believe in the possibility of separating contemporary Chile and its political uproar from the traumas of the dictatorship, but anger towards the socialist party as manifested in the burning of the socialist house reaches back to the years before Pinochet came to power. The series of revolutionary initiatives in Chile build on one another, each time starting anew from a ground as complex, layered, and artificial as the unstable substrate of Valdivia's geology—and similarly volatile as well.

In Chile, the political landscape is as much an experiment in tabula rasa as the devastating earthquake I traveled there to study, and the two interface with one another to create a social-geological environment legible as an intelligent machine. Just as in a neural network, whose every layer takes the previous layer's weighted output as its input, the tectonic shifts in Chilean history represent responses whose outcomes are ghostwritten by their predecessors. Valdivia's 1960 earthquake destroyed the city but did not flatten or fully erase it: instead, it left a complex new topography of land and water derived from the geological formations that preceded it and still legible in the socioeconomic urban landscape today. Similarly, the narrowly avoided overflow of Riñihue represents a hydrological precedent to a flood of public outrage derived not from a desire to level the common ground but to mitigate the flaws in a system rooted in layers of political overhaul in the late twentieth century. In this sense, it is impossible to be a child of the rebellion without also being a grandchild of the dictatorship to which that rebellion is a response. On one of my last days in Chile, I crossed a street and felt my eyes stinging and my throat burning, at which moment I learned a poignant fact: even after a conflict has ended and the canisters roll away, tear gas clings to asphalt for days.

URBANISM 3

Texas, USA

Though I found myself captivated by the Guadalupe Mountains long before I conducted my field work in Japan or Chile, they provide a fitting final case study for this wild and wandering project. In summer 2019, I spent a few months working as an intern at Guadalupe Mountains National Park, where I hiked harsh, empty trails, played dirt-court volleyball with park rangers, researched a historic mountain cave system, and roved around the West-Texas high desert in a rented Jeep. It was in this environment that my first thoughts about the tabula rasa began to solidify, where its mythological meaning in landscape became clear and then unraveled (Fig. 27). I end with this example because its present identity as a protected wilderness area evokes the Lockian and computational tabula rasa of an Edenic original innocence, a landscape uncorrupted by the blemishes of human habitation. However, as the following analysis will demonstrate, the reality of the Guadalupes actually falls directly in line with the notion of erasure I have investigated in the previous examples, and its conceit of total regression to pre-human purity concludes the sequence perfectly.

I experienced the Guadalupe Mountains as a vertiginous rapture of fast driving and sunburn, punctuated by conversations with park staff that revealed pieces of historical and environmental knowledge I would file away mentally or scrawl in my journal. Though I had not arrived there planning to research the region for this project, I found myself marveling at these tidbits of information and trying to interpret their relationships. I had stumbled into a mesh of Apache artifacts and Permian-era fossils illuminated by the nighttime glow of distant oil flares, where search-and-rescue missions were as commonplace as off-road journeys to swim in abandoned cattle tanks. The vivid and dissonant images of this place became formative to my practice of reading landscapes, and when I finally resolved them into an intelligible system, its relevance to my investigation of the tabula rasa became not only glaringly obvious but foundational to the project overall.

This final section will act as the bright conclusive note of this composition, new and unlike its predecessors but effective in encapsulating the ideas they convey. My closing analysis of the Guadalupe Mountains wilderness will seal and clarify the notion of landscape as an intelligent machine that arises from this dual-disciplinary interrogation of the tabula rasa. While my investigation in Japan followed the staccato structure of several brief examples radiating spatially and conceptually from a concentrated hypocenter, its Chilean counterpart echoed the mottled pattern of a winding or flowing narrative that incorporated terrestrial, aquatic, and social dimensions. This ultimate exploration will forgo the experimental parsing of its predecessors in favor of a wholistic historical analysis that will map to the overall structure of the machine learning model. It will imitate the stratified and encrusted formations of the geology that characterizes the Guadalupes, which influences every band of their history.

Figure 27: wilderness projections.

Figure 28: oil in the Permian Basin.

The topography and materiality of the Guadalupe Mountains originate in the Permian era of geological time, which spanned a period from 251 to 299 million years ago. In those days, the world consisted of the supercontinent Pangaea and the vast ocean that surrounded it. Life on this planet had diversified from simple forms of algae and fungi to include amphibians, fishes, and insects that occupied the unstable surface of steadily shifting tectonic plates.[116] On the western edge of Pangaea, near the equator, a narrow inlet connected the ocean to a depression called the Permian Basin, where a shallow inland sea covered the area that is now northern Mexico and the southwestern United States.[117]

About halfway through the Permian era, a reef began to form along the margin of this sea.[118] For several million years, it grew and thrived there, expanding as the invertebrate skeletons of algae, sponges, and bryozoans accumulated on its surface and were cemented there by a limey mud that captured them in the reef rock.[119] This composite carbonate structure eventually formed a living behemoth 1,300 feet high.[120] The reef was primarily inhabited by algae and sponges, while creatures like sea urchins and bivalve clams slowly roved the rocky sea bottom and ancient relatives of squid and octopi swam in open water, where the basin sloped downward to depths of nearly half a mile.[121] The remains of dead plants and animals sank to the seafloor and embedded in layers of black limestone. Over millions of years, intense subterranean heat and pressure would transform this organic composite into oil and gas (Fig. 28).[122]

From my porch, I could see the combustion of these oozing ancient substances in the fiery flares of oil wells out on the flatlands. While the mountains were protected from drilling, the wide, flat expanse of the former seafloor was riddled with an ever-expanding grid of fracking and extraction that was invisible in the bright sun of daytime but illuminated like a sprawling distant city at night. Once I drove through the oil fields on my way to the WIPP (Waste Isolation Pilot Plant) Site, where radioactive waste is stored in subterranean salt caves and where I was sent to get my fingerprints taken in an office, so that I could receive a government ID. I was impressed by what felt like a strangely inverted worm's-eye view of the landscape, where only the dipping noses of oil wells and the flaming pipes of flare stacks betrayed an invisible underground network of insatiable extraction and toxic storage.

As the Permian era came to an end, the outlet connecting this basin to the single planetary ocean became restricted, and the sea began to evaporate. Minerals left behind by the vanishing water formed alternating bands of mineral salts and mud, which filled the basin and covered the reef,[123] keeping it buried for millions of years. It was not until 80 million years ago, coincident with the Cretaceous period and the emergence of modern mammals, that tectonic compression along the western edge of North America began to lift the area that is now West Texas and New Mexico.[124] Eventually, 50-60 million years later, steep faults formed along the western side of the basin and caused a long-buried segment of the reef to rise several thousand feet above its original position.[125] The exposure of this block to wind and rain caused its soft exterior sediments to erode, uncovering the hardened core of the fossilized reef and forming the sharp ridges now known as the Guadalupe Mountains.[126] Their most prominent feature, the thousand-foot-high El Capitan formation, now towers above the desert floor.

116 "Geologic Formations - Guadalupe Mountains National Park."

117 Standen et al., "Capitan Reef Complex Structure and Stratigraphy," 13.

118 KellerLynn, "Guadalupe Mountains National Park Geologic Resource Evaluation Report," 25.

119 Standen et al., "Capitan Reef," 14.

120 KellerLynn, "Geological Resource Report," 19.

121 Ibid, 4.

122 Ibid, 15

123 Standen et al., "Capitan Reef," 14.

124 KellerLynn, "Geological Resource Report," 26.

125 Ibid.

126 Standen et al., "Capitan Reef," 14.

By the end of the Pleistocene epoch (about 11,000 years ago), animals like enormous ground sloths, saber-toothed tigers, North American rhinoceros, and mammoths roamed the Guadalupe Mountains.[127] The first humans to inhabit the area shared it with these creatures. The earliest human artifact found in the Guadalupes is a 12,000-year-old stone projectile point associated with the Folsom Paleo-Indian archaeological culture of New Mexico, but other hunter-gatherer tribes also left petroglyphs and objects in the area.[128] These stone-age nomads disappeared from the high desert after a lengthy drought about 6,000 years ago, which marked the turnover from the Paleo-Indian Period (12,000-6,000 BC) to the Archaic Period (6,000 BC-1 AD): an era characterized by the presence of other hunter-gatherer groups who introduced the bow and arrow to the region and shifted their diet towards smaller game.[129] The subsequent Transitional Period (1-800 AD) saw the emergence of low, circular stone ovens called midden rings, and the Ceramic Period (800-1500 AD) witnessed the brief presence of Puebloan and Great Plains Indian groups and their decorated pottery. These nations disappeared and a new era began with the invasion of a people known to themselves as the *N'de* and to others as the Mescalero Apache.[130]

One of them left behind a blade, a semicircular stone tool that lay in an unmarked archaeological site less than fifty feet from the edge of a public trail. It was casually dropped into my hand during a fieldwork-planning outing on my first day of work.

The creation story of the Mescalero begins with White Painted Woman floating on a primordial sea, where she gives birth to the world.[131] White Painted Woman, the sacred mother and source of life in the Mescalero belief system, appears throughout their mythology as both the deity that watches over her people and the embodiment of the land they inhabit and steward: she is the key figure in a mythic fabric in which the Mescalero care for the Earth, and the Earth watches over them in turn. The center of this sacred geography is "*tse 'ichi*," or "nose rock," the southernmost peak of the Guadalupe escarpment, whose sheer drop on one side (the El Capitan formation), resembles a face in profile when contemplated from the proper viewpoint.[132] The surrounding mountains are the sacred territory of both the Mescalero and the central characters of their mythology, and the gaze of nose rock watches over this richly storied homeland.

The Spanish had arrived in the land of the Apache with the expedition of Coronado around the year 1540.[133] They found the nomadic inhabitants of *Apachería*, as they called the territory of the larger Apache nation, extremely difficult to monetize, so they tended to recognize the autonomy of the tribe's land and culture.[134] For this reason, when Mexico won its freedom from Spain in 1824, the Apache remained unconquered in their homeland, known as the people the Conquistadors could not subdue.[135] However, the nascent Mexican Republic was threatened by the bankruptcy of its treasury and its inability to protect its northern regions from Apache raids, and when the nascent government instituted a bounty for the murder and enslavement of the Apache people, a genocide ensued that substantially reduced their population in the area.[136] Despite this bloodshed, the Mescalero remained relatively undisturbed in their enclave in the Guadalupe Mountains, which presented a sufficiently harsh and inhospitable barrier to remain free of white exploration for hundreds of years.[137] However, this safety would not last. In

127 Kohout, "GUADALUPE MOUNTAINS."

128 Ibid.

129 Hood, "Discursive Horizons of Human Identity and Wilderness in Postmodern Environmental Ethics: A Case Study of the Guadalupe Mountains of Texas," 66.

130 Ibid.

131 Ibid, 45.

132 Ibid, 44.

133 Ibid, 78.

134 Ibid, 10.

135 Ibid, 83.

136 Ibid.

137 Kohout, "GUADALUPE MOUNTAINS."

1848, though the Apache never recognized the legitimacy of any colonial government on their land, the United States took most of their territory from Mexico in the Treaty of Guadalupe Hidalgo.[138] That transfer, combined with the discovery of gold in California, brought a rush of Anglo-American settlers right through the heart of the Mescalero world.

The gold rush increased traffic on the San Antonio-El Paso road, where stagecoach and Federal Mail Service routes were established in the 1850s.[139] This mail and migration artery passed directly through the Guadalupe Mountains, where the Pinery stagecoach stop allowed travelers on the Butterfield trail (the stagecoach route from Fort Smith, Arkansas to San Francisco awarded to John Butterfield in 1857) to stop for rest and water.[140] Stagecoaches navigated with the help of El Capitan, which guided and vexed them, visible from an arduous fifty miles away.[141] The same formation continued to watch over the Mescalero, who remained in the area and regularly raided stagecoaches filled with travelers, supplies, and federal mail,[142] eventually forcing the Butterfield stage route to move south in 1859 to an area where military forts would protect them.[143] After the Civil War, these forts served as bases for troops known as the "Buffalo Soldiers," who were deployed to place the Apache on reservations and hunt down and kill those that did not comply.[144] This second genocide commenced in the 1870s and eventually brought Texas Rangers into the Guadalupes, where valiant Mescalero holdouts remained sheltered by their rugged homeland for roughly another decade.[145] The last surviving band of free Mescalero Apache were killed by Texas Rangers in 1881.[146]

The scattered debris of this era proliferates around the park today, some pieces of it forming landmarks and others remaining concealed. The ruins of the Pinery stagecoach station still stand a short gravel drive off of Highway 62, their masonry walls crumbling but clarified by nearby informational plaques. The route of the Butterfield stage remains identifiable also: on a solo journey along an abandoned service road facing El Capitan, I noticed the winding scar of the old trail cut into a hillside high above. I heard later that the wreckage of a 1920s station wagon still lies where it landed after careening off of this precarious ledge, but that tourist tragedy came later. Further evidence of violence in the late nineteenth century can be found with a trained eye or with friends who know the territory. Park Service archaeologists can identify the former campsites of Mescalero on the run, which remain scattered with the the rolled metal "tinklers" that adorned their clothing and the bullet casings of the Buffalo Soldiers that hunted them. Several Apache burial sites also exist in the park, nestled into secluded mountain caves and rocky niches; many of these are not tracked officially by the Park Service and are only known to tribal authorities, who protect the knowledge of their location from disruption by outsiders. Looting is a perennial problem on public lands.

The assassins of the Mescalero were not the only Anglo-Americans encroaching upon the Guadalupe Mountains during this era: towards the end of the extended struggle between the Mescalero and the United States government, white ranchers and prospectors arrived in the region. In 1869, Felix McKittrick acquired a parcel of land at the mouth of the canyon that now bears his name,[147] and in 1876, two brothers built a house near Frijole Spring that would later belong to the Smith family, who operated an orchard there for forty years.[148] Around 1908, the Belcher

138 Hood, "Human Identity and Wilderness in Postmodern Environmental Ethics," 84.

139 Ibid, 85.

140 Kohout, "GUADALUPE MOUNTAINS."

141 Ibid.

142 Hood, "Human Identity and Wilderness in Postmodern Environmental Ethics," 85.

143 Kohout, "GUADALUPE MOUNTAINS."

144 Hood, "Human Identity and Wilderness in Postmodern Environmental Ethics," 87.

145 Kohout, "GUADALUPE MOUNTAINS."

146 Ibid.

147 "Ranching in Guadalupe Mountains."

148 Ibid.

family established an aqueduct and house at the base of the Western Escarpment.[149] James Adolpus Williams later bought the property, and it is now known as Williams Ranch. In the 1940s, both Frijole Ranch and Williams Ranch changed hands again when they were purchased by Judge J.C. Hunter, Jr., whose father was the leading rancher in the area by the 1920s.[150] The Hunters were both ranchers and environmentalists, and they were one of the two families that would have the greatest influence on the Guadalupe Mountains territory in the twentieth century. The other was the family of Wallace E. Pratt.

Pratt was a petroleum geologist who arrived in Texas in 1916 when he began working for the Texas Company (Texaco) in Houston.[151] Two years later, he became the first geologist hired by the Humble Oil and Refining Company (also known as Exxon Company), where he made himself famous for his pioneering use of geophysical methods to predict the presence of large amounts of oil in specific locations. Pratt directed the establishment of oil exploration in the Mexia field in East Texas (1920) and inspired the scientific methods that would drive oil exploration on the Texas Gulf Coast (1922), both of which would become extremely productive locations for the American petroleum industry in subsequent years.[152] In 1944, he wrote an article predicting the presence of massive oil reserves in the Prudhoe Bay area of Alaska, which was resoundingly proven correct in 1968 with the first major discovery of oil under the Alaskan North Slope.[153] However, despite Pratt's foundational influence on the fossil fuel industry, he considered himself an environmentalist and advocated ecological protection measures for oil extraction projects. He argued for wide spacing between oil and gas wells, against the flaring of natural gas, and in favor of water pollution controls on oil tankers and refineries.[154] He also loved the natural scenery of the Guadalupe Mountains and began buying land in McKittrick Canyon after his first visit there in 1920.[155] In 1930, he built a stone cabin on that land for use as a vacation home, and in 1945 he moved into a new and less flood-prone house on the property for his retirement. This second building, designed by New York architect Newton Bevin in 1941[156] was called "Ship-on-the-desert" and took on the form of a masonry oil tanker sailing on the fossilized Permian Sea, complete with a deck and captain's bridge. Pratt and his wife lived there from 1945 until 1963.[157]

Both of Pratt's homes on his McKittrick Canyon property, as well as Hunter Jr.'s Frijole and Williams Ranches, still stand in the national park today. The three cabins serve as historical interpretive devices describing the area's ranching era for visitors, and Ship-on-the-desert remains in limbo between preservation-oriented repairs and government usage: I once accompanied a very irate park geologist on an outing to reprimand the group of State Troopers staying at the house for starting a bonfire on protected land. The movement of new settlers into this land also continues in the present day. The Permian Basin oil boom is on the cusp of its most productive years, and it draws more oil field workers (known as "roughnecks") to the nearby town of Carlsbad, New Mexico than its economy or housing stock are able to sustain. The workers are attracted by the six-figure salaries associated with this explosion of investment, and the inflated cost of living manifests itself in eighteen-dollar salads and hundred-dollar motel rooms. The overdrawn housing market has turned into an economy of trailers and prefabricated homes with sparse furnishings and soaring price tags. I watched the wreckage of one of them, an entire furnished house that had blown off of its truck bed in the high flat-

149 Kohout, "GUADALUPE MOUNTAINS."

150 Ibid.

151 Kohout, "PRATT, WALLACE EVERETTE."

152 "Wallace E. Pratt."

153 Kohout, "PRATT, WALLACE EVERETTE."

154 Ibid.

155 Ibid.

156 "Ship-On-The-Desert."

157 Ibid.

land winds, as it was gradually dismantled, looted, and eventually burned to the ground on the side of the highway.

The historic houses in the mountains are architectural artifacts and monuments to their owners, who played crucial roles in the foundation of the park. As early as 1925, Hunter Sr. had petitioned the federal government to make the Guadalupe Mountains area a national park, and in 1969, his son sold the family's 72,000 acres of ranch land and hunting preserve to the National Park Service at $22 per acre.[158] In 1961, Wallace Pratt deeded his land to the National Park Service, donating over 5,000 acres that would become the heart of the park.[159] The Pratt donation and the Hunter purchase comprise the vast majority of the land now included in the national park, which was officially established in 1972.[160] This transition from private ranching land to public parkland marked the final turnover of land administration philosophy that the Guadalupe Mountains would witness. While the Mescalero and their mutual caring relationship with White Painted Woman had encouraged a sustainable and respectful habitation of the landscape based on hunting and gathering, white settlers had carried with them notions of conquest through improvement, seeking to order the land into agricultural productivity in ways that ultimately brought about permanent ecological damage.[161] The Park Service imposed a third management protocol on the Guadalupes: a master planning strategy characterized by the tension between wilderness protection and tourist enjoyment.

As a park established very recently in the history of the National Park Service, Guadalupe Mountains National Park (GUMO) represents a different management philosophy from those of its more famous predecessors. The earliest of the national parks, including Yellowstone (created in 1872) and Yosemite (1880), represent a "scenic wonders" approach to landscape preservation, involving a notion of national parks as natural monuments or museum collections meant to be frozen in time in order to solidify the American national identity through recognizable natural wonders.[162] Later parks such as Great Smoky Mountains (1934) and Everglades (1947) incorporated more ecologically tolerant management regimes and privileged tourist recreation. The "Mission 66" era of renovation and restoration in the National Park Service revolutionized the experience of park visitation, responding to floods of visitors with massive building projects such as the construction of scenic highways that enabled the emergence of motor recreation and resulted in the much-despised "windshield tourist,"[163] raising questions regarding the appropriate extent of accessibility as a park priority that continue to plague the Park Service today. Though in its early years GUMO entertained possibilities of a scenic highway through the park and a mechanical tramway to shuttle visitors from the desert floor to the top of Guadalupe Peak, these tourist infrastructures were eventually abandoned in favor of a wilderness-forward strategy under which the majority of the park land was legally designated under the Wilderness Act of 1964.[164] This policy leaves the scenic upper highlands of the park comparatively untouched to this day, protected by trails too challenging for most visitors to traverse on foot and devoid of roads completely.[165]

During my tenure at GUMO, the wilderness character of the land was at once constantly foregrounded and constantly undermined. The park is among the least visited properties administered by the National Park Service, so at some level

158 Fabry, "Guadalupe Mountains National Park: An Administrative History," chap. III.

159 Kohout, "PRATT, WALLACE EVERETTE."

160 Fabry, "Administrative History," chap. II.

161 Hood, "Human Identity and Wilderness in Postmodern Environmental Ethics," 88.

162 Ibid, 110.

163 Ibid, 116.

164 Ibid, 117.

165 Ibid.

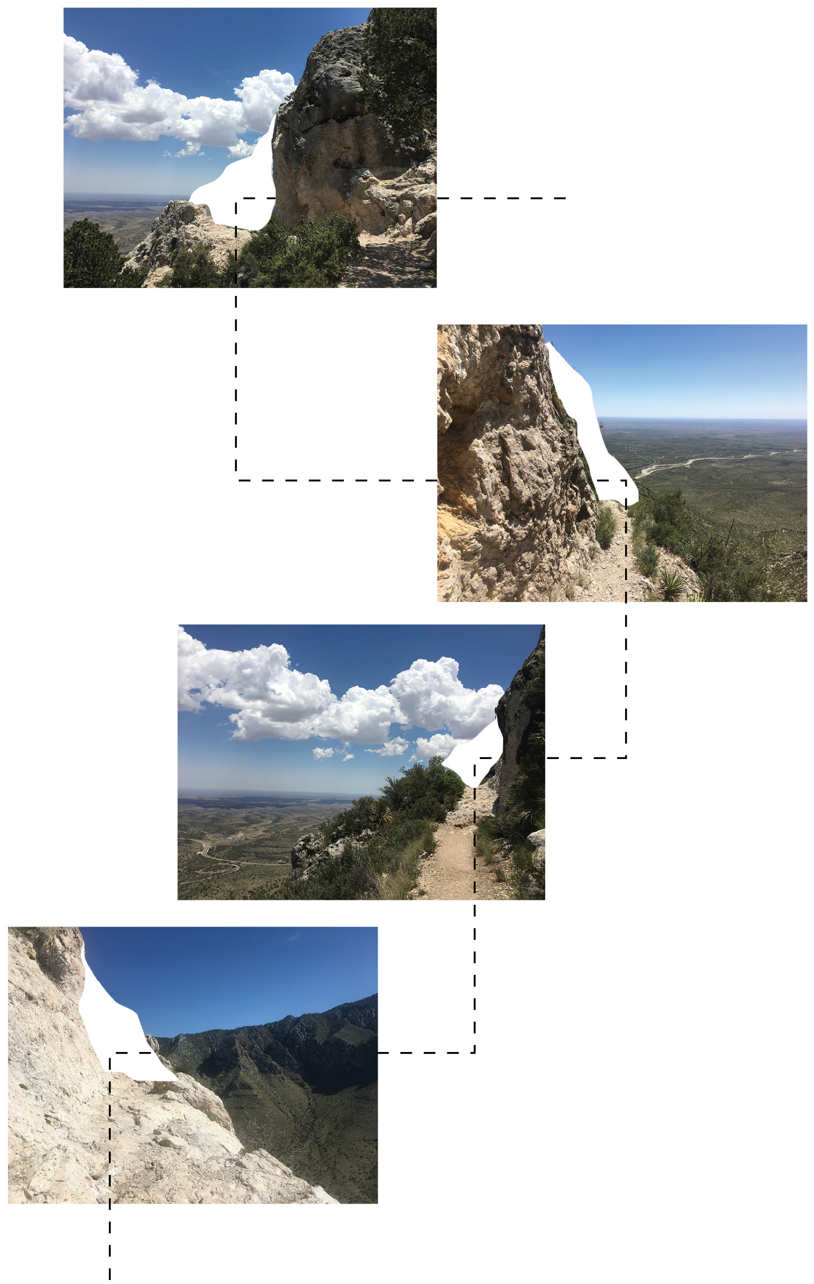

Figure 29: a mountain with a trail is a mountain missing certain parts.

its natural grit is preserved by the minimal human traffic it receives. The tourists that do visit the park tend to come for hikes up the Guadalupe Peak trail, which culminates in the highest point in Texas; and those that stay the night occupy the handful of campsites and RV tethers clustered just outside the wilderness boundary, within which no asphalt exists to bring them or their vehicles inside. It is the tension between the needs of these tourists and the implications of the wilderness designation that form the defining conflict in the park today. This tension emerges on the specific dimensions of terrain and hydration, which pose the greatest challenges to visitor safety in the park.

The first day I set out to explore a hiking trail in the Guadalupes, the park geologist stopped me before I left to make sure I was prepared for what I would find. She said to watch out for rattlesnakes and the sharp spines of the lechuguilla plant, and she strongly advised me to bring hiking poles even though I had never needed them before. She said that even after several decades working in the Park Service, GUMO was by far the most rugged terrain she had ever seen in the park system, citing rocky ground that could break your ankle even on the best-groomed stretches of trail. I understood this rough going as a function of the land management practices associated with designated wilderness, which intended to minimize the effects of human activity in the landscape, especially through limitations on the technologies of trail maintenance. For example, my park ranger roommate had recently told me that if a tree fell across a trail in the wilderness, the maintenance team could not drive an ATV up the mountain with a chainsaw to take care of it; instead, they had to hike to the tree on foot, accompanied by a mule carrying their water and hand saw.

Understandably, the rocky trails, sharp vegetation, and blazing heat make the Guadalupe Mountains an inhospitable environment for many visitors, and these challenges are compounded by the fact that the only access to many of the park's great attractions (given the abandonment of the gondola proposal) is by material hikes on foot. I observed many a family in sneakers painstakingly picking their way among the loose white cobbles of a dry river wash, whose trail route was only faintly marked with rows of stones pointing in the right direction. In fact, I nearly found myself lost and completely alone on a ridgeline whose trail was marked by nothing more than knee-high rock cairns spaced five hundred feet apart in the exposed desert scrub. However, I also climbed mountains that still bore the scars of dynamite, where the trails were little more than ledges blown into a cliffside (Fig. 29) still marked with the evenly-distributed linear divots of strategically placed explosives. And I would eventually learn that dynamite was not the most modern technology that made its way into these wilderness mountains: the illusion of traditional trail management totally disintegrated when I heard the story of a search and rescue effort that involved a Department of Transportation helicopter landing on top of Guadalupe Peak, three weeks before I arrived.

Perhaps an even greater threat to visitor safety— and to the mirage of the untouched and unsupervised landscape— is the issue of water in the high desert. There is no potable water in the backcountry, so the typical hiker must carry provisions of at least a gallon per person, per day. The few backpackers who set out for more than a day's stint in the wilderness cannot carry enough water to sustain themselves for a longer excursion, so they have to arrange for the park's packer to haul water up the mountain on a mule and store it in a cache along their route. Unsurprisingly, many of the park's casual visitors underestimate the importance of responsible hydration in the wilderness, and the combination of high elevation, dry, hot weather, and exposed terrain reduce many a confident day-tripper to a 911 call for dehydration very quickly.

I participated in one such search and rescue mission on a sweltering Sunday afternoon during my first few weeks in the park. A ranger approached me and a friend on the maintenance staff as we lounged in the shade of a covered porch, asking if we wanted overtime (search and rescue missions— "SARs"— were conducted by whatever park staff were available, not by any special unit), and we agreed to retrieve a visitor stranded at Williams Ranch. The tourist in question had set out on the El Capitan hiking trail without a map and missed the turnoff where he should have taken the Salt Basin Overlook loop to return to the parking area where he had begun, instead hiking eleven miles straight into the desert and eventually finding himself lost with no water, very far away from his car. My colleague and I packed a radio and a case of plastic water bottles into a maintenance pickup truck and set out towards Williams Ranch Road, a seven-mile journey over potholes and boulders, at the end of which stood the original Williams Ranch house where the visitor had been told to wait for us. The seven-mile drive took us an hour. The sun setting on the Western side of El Capitan presented the most strikingly beautiful view of the park I had seen until that day, a vista uninterrupted by any sign of human intervention besides the rearview mirrors of the pickup truck from which I admired it (Fig. 30). When we arrived, the visitor met us perfectly alert and physically unscathed despite the several additional panicked 911 calls he had made while his rescue was underway. As we laboriously drove back to the visitor center, he thanked us profusely and gulped water in the back of the truck, regaling us with his account of relying on his army fitness training to survive the afternoon and having resorted to drinking his own urine while he was lost for a period of no more than four hours.

During the summer I spent in the Guadalupes, search and rescue missions became a regular nuisance and eventually a contentious issue for park staff, who occasionally returned from long days off doing their own recreational hiking to be faced with an extra eight miles in the dark, as yet another visitor failed to sufficiently prepare for a day in the unforgiving mountains. The topic of visitor safety brought out inharmonious musings and rantings on wilderness recreation from my colleagues, most of whom were accomplished outdoors-people running out of patience for the disastrous mistakes of inexperienced tourists. They valued the rugged intensity of the wilderness area, but they were frustrated by the situations it created for unprepared explorers; and though they didn't wish to leave the unfortunate amateurs to fend for themselves, they resented bearing the unpredictable and unwelcome responsibility for preventable emergencies. They conceded that the supervised nature of the national park made it more akin to a theme park whose theme was "wilderness" than to a truly wild and untrammeled no-man's land. But how realistic a simulation of the brutal high-desert outdoors was appropriate for a tourist population, however small, whose competence could not be vetted?

These questions and concerns are central to the concept of designated wilderness and represent some of the many ironies it implies. Environmental historian

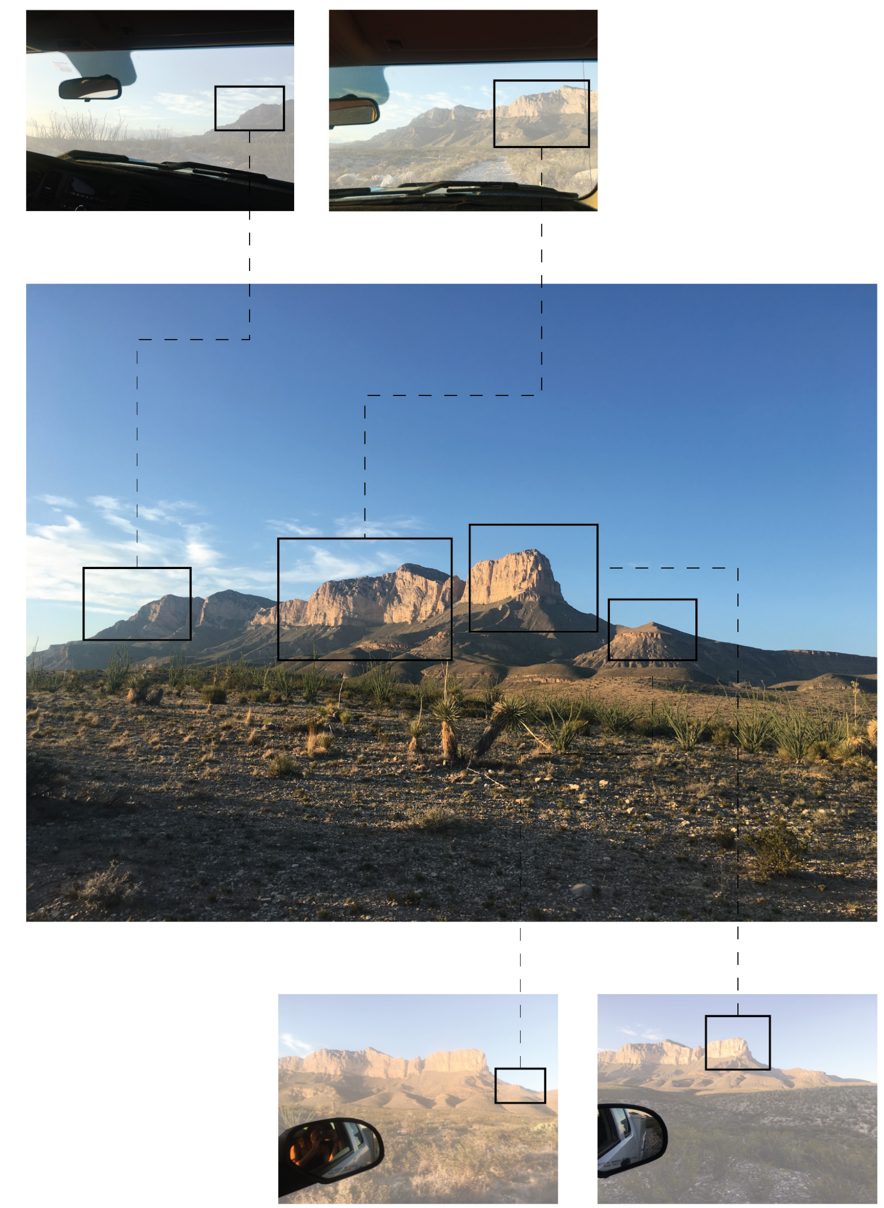

Figure 30: views from a search and rescue.

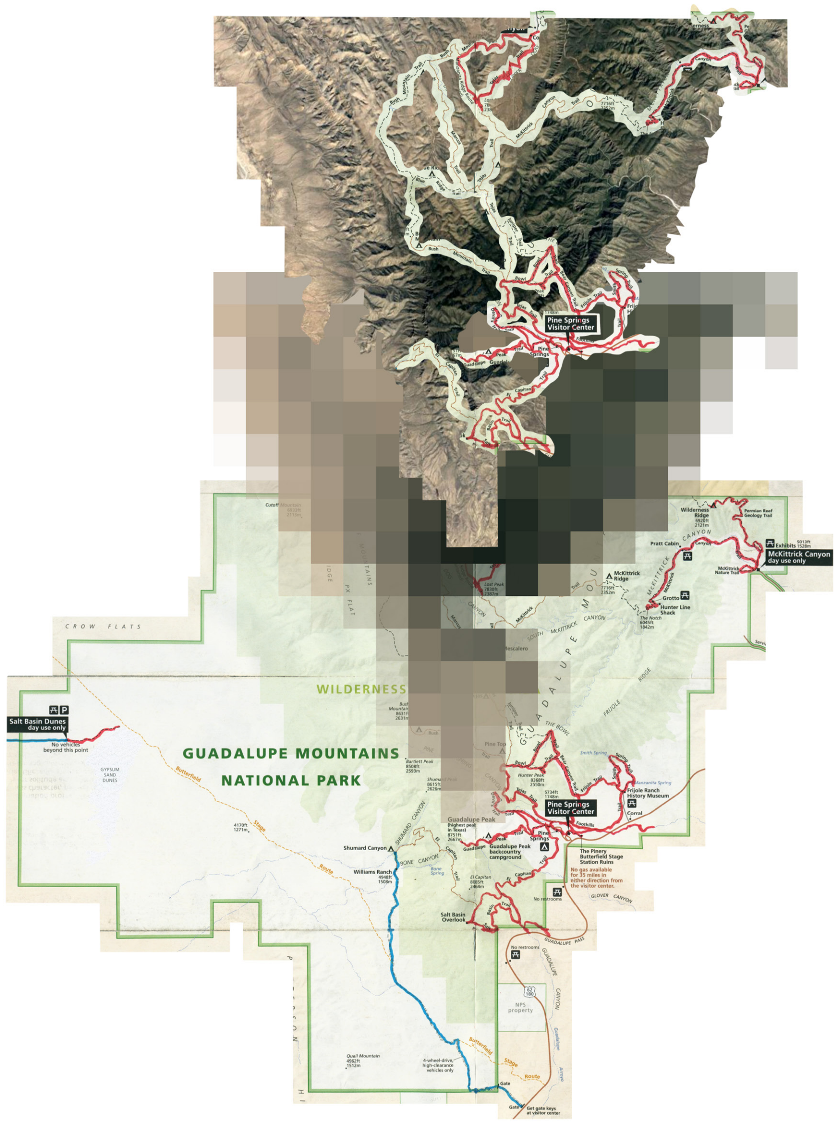

Figure 31: the trouble with wilderness boundaries.

William Cronon's seminal 1996 essay "The Trouble with Wilderness" exposes a selection of these issues and demonstrates their roots in American identity and nationalism.[166] He locates the appeal of wilderness in American culture with a romantic idea of the frontier, not unrelated to the "noble savage" of Rousseau's primitivist tabula rasa or the idyllic state of nature supported by Locke's. Cronon argues that the roots of wilderness preservation in this country lie in nostalgia for the "vanishing frontier" of American expansion[167] and the resulting national imperative to preserve the "wild" land that had been formative to the nation's development and representative of the freedom and individualism upon which it rested. In the key claim of the essay, he acknowledges: "The irony, of course, was that in the process wilderness came to reflect the very civilization its devotees sought to escape."[168] As a diversion from the artificial machinations of modern society, wilderness was necessarily defined by its opposition to the urban, making it as much a tool of civilization as an alternative to it.

This is certainly the case in the Guadalupe Mountains, where the notion of wilderness as a pristine landscape where "The earth and its community of life are untrammeled by humans, where humans are visitors do not remain," as it is described by the mission of the National Park Service,[169] could not be more obviously imaginary (Fig. 31). As Hood aptly observes:

> The park service has at the same time organized a more extensive surveillance system for the environment than any other people of the Guadalupes. Under the park service 'wilderness' is legitimated and maintained only insofar as it is able to be measured, named, and fenced in by that most domesticated and technologized of modern entities, the bureaucratic state.[170]

The search-and-rescue missions that I witnessed in the Guadalupes give a perfect case study for the "domestication" of this landscape through the imperative of supervising and sheltering its frequently-unprepared visitors, which so often outweighs the ideal of minimizing human impact on the landscape: when a tourist is in trouble, all manner of machinery can be deployed and philosophies suspended to get them out. That said, the clearest way in which GUMO protects its untrammeled and uninhabited status is in its fencing-off of native lands. The Mescalero continue to perform certain ceremonies in their sacred homeland with permission from the Park Service,[171] but otherwise they have been relegated to life outside of their spiritual birthplace. As Cronon observes, the mythological purity of the wilderness as "virgin" land primarily serves to limit its use by native peoples, who knew it as their ancestral home but were "Forced to move elsewhere, with the result that tourists could safely enjoy the illusion that they were seeing their nation in its pristine, original state, in the new morning of God's own creation."[172] In the case of the Guadalupes, this presumed return to an Edenic original state required the fabrication of "uninhabited wilderness" from a land that had been inhabited for more than ten thousand years (and still is: I lived there). The prejudiced exclusion implicit in the very notion of wilderness also plagues the contemporary environmental movement, where anthropologist Jake Kosek's analysis of forestry activism exposes a culture "haunted by exclusionary rhetorics of purity and entrenched fears of racial pollution."[173]

166 Cronon, "The Trouble with Wilderness."

167 Ibid, 13.

168 Ibid, 15.

169 Fabry, "Administrative History," chap. VI.

170 Hood, "Human Identity and Wilderness in Postmodern Environmental Ethics," 11.

171 Hedden, "Voices on the Mountain."

172 Cronon, "The Trouble with Wilderness," 13.

173 Kosek, *Understories: The Political Life of Forests in Northern New Mexico*, 2006, 145.

The erasure of indigenous and other cultural land use practices in the name of wilderness preservation does not leave the land totally void of interpretation: the tabula rasa imposed by wilderness designation is a "white" paper indeed, drawing on distinctly Anglo-American ideas about sublimity and innocence as its inspiration. Kosek notes that when John Muir, one of the legendary fathers of American environmentalism, went into the Sierra Nevada Mountains in search of enlightenment, he brought with him texts including the New Testament, Milton's Paradise Lost, and writings from Charles Darwin, Ralph Waldo Emerson, and Henry David Thoreau.[174] This literal cultural baggage was not coincidental but explicitly intended to inform his reading of that landscape, and its influence shows in his later writings. Muir explicitly places the Sierra Nevada's existing inhabitants (Hispanic, Chinese, and Native American people) in opposition to the purity of the "nature" he exalts, acknowledging with approval that its vacancy was made possible through their elimination by the US cavalry under Manifest Destiny.[175] The Guadalupe Mountains engage the imperial aspect of wilderness with their spiritual appropriation from the sacred homeland of the people watched over by White Painted Woman to a physical landmark named for a different holy mother, the Catholic Virgin Mary, who was brought to the area by Spanish colonial missionaries and kept there by the white settlers that succeeded them (Fig. 32). It is possible in the park today to observe the profile of "nose rock" from the foot of a shrine to the Virgin.

174 Kosek, *Understories*, 155.

175 Ibid, 156.

Here, with the present evaluation of wilderness and its cultural politics, I return to the original idea of the tabula rasa. Like the blank slate in its formulations by thinkers from Locke to Turing, wilderness incompletely models the fresh blankness of an original innocence. And like the tabula rasa through its entire psychological, computational, and architectural history; wilderness is a concept of emptiness that encodes the ideologies and aspirations of its inventors. However, a crucial distinction differentiates the tabula rasa of the Guadalupe Mountains wilderness from the previous case studies of Hiroshima and Valdivia, making it a suitable conclusive example to this investigation: while the urban tabulae rasae theoretically represented freshly razed blank slates upon which to build a new and better future, wilderness intends to produce a profound regression into a mythological prehuman past.

The originary connotation of wilderness makes it all the more productive an analog to the neural network, where the tabula rasa describes a formless potential intelligence, yet-untrained and lacking in knowledge. In both cases, the return to an innocent and unbiased blank slate represents an ascendant escape from the bounds and shortcomings of human instruction. The computational tabula rasa represents the pinnacle of artificial intelligence because its theoretical lack of pre-programmed knowledge makes it cognitively independent of its constructor, able to achieve intellectual maneuvers impossible with the limitations of human algorithmic design. The innovative gameplay of the storied AlphaZero model demonstrates the prospective revelations of this approach. Meanwhile, wilderness performs sublimity with its theater of complete freshness and freedom, enabling its visitors to enjoy the exhilaration of exploring a landscape that appears untouched—just as the untrained neural network appears to navigate a boundless statistical topography. In wilderness as in machine learning, the simulation of untrodden ground intends to produce a landscape ripe for enlightenment and wonder.

Figure 32: one territory, two divine gazes.

I will admit that the theater of wilderness in the Guadalupe Mountains affected me profoundly; the exploration of rugged empty land, if only a fabricated mirage, is psychologically restorative and personally delightful to me. But, as the preceding historical analysis of the Guadalupes demonstrates, with its temporal switching between historic events and my observations of their remnants or ramifications, equally exciting in that landscape are the lingering artifacts and mutations of its history and surroundings. It is these glimmers of the landscape's previous lives— the flash of an oil flare in the distance, the vertical scar of a dynamite hole pounded into a mountainside, the quietly rusting shrapnel of car crashes, Apache showdowns, and ranching projects— that undo the manufactured emptiness of the land's present wilderness designation. As Cronon, Kosek, and Hood all acknowledge, the American wilderness is a constructed blank slate that requires a collective amnesia towards everything that came before it, whose simulated return to prehuman purity requires the glossing-over of legitimate human histories in the interim.

In the Guadalupe Mountains, the mythology of wilderness is aesthetically effective, but the fiction of its return to prehuman sublimity is twofold. As I have thoroughly expressed, the designation of this land as uninhabited wilderness failed to expunge the many marks of the region's previous lives. They linger, undermining the facade of the environment as an ahistorical virgin landscape. The failure of this wilderness to achieve a flawless regression to prehuman purity, however, extends even more deeply than the obvious remnants of its history of inhabitation. The years before humans arrived in the Guadalupes were the end of the Pleistocene era, about 10,000-15,000 BC. At that time, the entire region was considerably cooler and wetter than it is today: game, fuel, and water were plentiful, and the coniferous forest that now only remains in the highest elevations of the mountains blanketed a much larger area.[176] The landscape looked nothing like the inhospitable desert it is today. Thus, the entire performance of prehuman wilderness in the Guadalupe Mountains reveals itself as a fable. There is no possibility of returning this landscape to its uncivilized origins: by the time it underwent the Paleo-Indian mega-drought and became the spectacular desert tableau it is today, humans were already there.

176 Hood, "Human Identity and Wilderness in Postmodern Environmental Ethics," 55.

This palimpsestic reading of the cultural landscape of the Guadalupes echoes no single part of the autoencoder I constructed but instead serves to model the vision of deep learning that it encapsulates overall. I rejected the computational tabula rasa after my experiments proved it impossible to locate among the layers of the neural network, whose basis extends beyond untrained artificial neurons to the libraries of TensorFlow and the python language, all the way down to the fundamental starting point of binary logic carried out by an electronic device. Just as in the case of the neural network, I argue that the Guadalupe Mountains wilderness has "learned" to be what it is in a process whose historical depth extends infinitely. The wilderness that occupies the region today relies on factors as distant as the deep geological history that made its topography, and as recent as the petroleum economy that brought it into the hands of individuals who wanted it to be a national park. In this way, the tabula rasa of wilderness in the Guadalupes is as impossible to locate as the tabula rasa of the untrained artificial intelligence: both are blank slates imposed on a layered network of active spatial, temporal, or technological components, within which no foundation of traceless emptiness exists.

It was in the non-blank slate of wilderness that I originally grasped the fiction of the tabula rasa: nowhere is the mythology of emptiness more overt, and nowhere is the fact of its inaccuracy more fascinating to expose. On the seemingly barren desert expanses and brutal mountain trails of the Guadalupes, I discovered a notion of the cultural landscape that foregrounds the palimpsestic nature of physical space occupied by humans. I began to recognize the mesh of social and environmental factors that extends continuously from the most compressed urban density to the wildest expanses of uninhabited land. The tabula rasa of the Guadalupe Mountains was formative to my notion of the intelligent landscape, and it concludes my investigation as vividly as it began.

CONCLUSION

I established the methodology of this project with my analysis of the computational tabula rasa. My experiments on the autoencoder I constructed myself evaluated the blankness of the untrained network and revealed the computational tabula rasa as a legal fiction of the discipline, intervening in its philosophy and practice despite lacking empirical validity. The mechanistic analytical method and critical conclusions of my computational experimentation ground the subsequent exploration of the urbanist tabula rasa.

I first applied the insights gained from this literal intelligent machine to the case study of the post-atomic landscape of Hiroshima, Japan. That investigation focused on urban planning projects guided by the national policy to create an International Peace Memorial City in Hiroshima, an objective whose effects I evaluated in a selection of key sites by comparing each one to a specific element of the autoencoder. My mechanistic and structuralist approach revealed a landscape whose cultural transformation was traceable to a specific set of urban devices, each of which create the effect of rebirth from nothing. However, a closer look—informed by my experiments on the computational tabula rasa—reveals a city that simply pivoted its prewar messaging towards the needs of postwar Japan, actually retaining a great deal of its original urban patterning despite the erasure of its built environment by the atomic bomb.

I adapted this same analytical strategy to the urban tabula rasa of Valdivia, Chile after its devastating earthquake in 1960. In Chile, I found an ecological and social milieu of limicole upheaval, where land and water mottled together to create the unstable ground upon which a political revolution built up and burst forth. I referred to some central concepts of machine learning— the layering of the deep neural network and the activation function in each artificial neuron— to articulate my abstracted observations about this interlaced system of topographical and social instability, clarifying my theories about the Valdivian landscape by situating them in computational mechanisms I could describe in logical terms.

In both Valdivia and Hiroshima, I tested my hypothesis that the urban tabula rasa could be refuted through the metaphor of the intelligent machine. I had already disproven the computational tabula rasa through measurable experimentation, so I mapped the mechanisms of the neural network onto the landscape in order to inductively apply my experimental conclusions to my urban observations. With this method, I succeeded in developing a new route into the invisible networks of urban habits and environmental idiosyncrasies that transcend the urban tabula rasa, making them observable by mapping them onto a logical machine that can be technically dissected and structurally parsed.

I ended this sequence with a case study that differs from its predecessors, moving beyond the training data of Hiroshima and Valdivia to test my model's efficacy in a new context. My analysis of the Guadalupe Mountains wilderness critiques this presumably empty land, whose flawed tabula rasa is the product of an effort to emulate and maintain a version of the landscape before humans had discovered and modified it. I found that, like the tabula rasa in general, the concept of wilderness is deeply tinted with ideology—in this case, Anglo-American narratives of national identity and progress— and that its expression is riddled with the tracks of that philosophical project and the previous histories it intends to erase. Just as a machine learning model learns to perform its task according to a guided logic structure, today's wilderness explorer treks through the mountains on trails defined by the National Park Service. And just as the present formulation of artificial intelligence relies on algorithms, libraries, and architectures derived from a long history of mechanical attempts to model biology, the supposedly untrammeled wilds of the Guadalupes still bear the many scars and markings of groups of animals and people that inhabited them before the notion of wilderness arrived in the region. This computational evaluation of a new tabula rasa, and its successful interpretation as a different permutation of the same basic myth, solidifies the value of the intelligent machine as an analytical device.

The conclusion to this investigation warrants a return to its conceptual point of departure, which is the Computational Theory of Mind. While the tabula rasa provides a site and conduit for interdisciplinary conversation between computing and urbanism, it is the notion of the intelligent machine that truly drives this project and contextualizes it within the broader history of the two fields. The concept of learning that emerged from my experiments in artificial intelligence, a vision of it as a process that spans the spectrum from molecular and electrical logic to high-level conceptual thinking, is a direct descendant of the Computational Theory of Mind, which originally formulated a link between the physical and the mental by formulating cognition as a form of information processing. That theory arose from advances in artificial intelligence in the 1990s and is the intellectual agent that finally expunged the tabula rasa— and its offspring, the "ghost in the machine"—from the field of psychology by connecting the fundamental molecular and electrical mechanisms of cognition to the intelligence they produce. I originally framed my analytical method as its sister, a "Computational Theory of Urbanism" in generous terms. This method, which transposes the notion of emergent intelligence from computational logic to the embedded functions of landscape, relies on the observation that the small, fundamental logic machines that underpin intelligence are not unique to biological or artificial cognition but ubiquitous across complex systems. I broaden the implications of the Computational Theory of Mind by carrying them into a new discipline, following Stephen Pinker's observation that "the sister field of artificial intelligence is confirming that ordinary matter can perform feats that were supposedly performable by mental stuff alone."[177] It is through this logical choreography that I arrive at a notion of the intelligent machine that encompasses both the autoencoder I constructed and the landscapes I analyzed according to its mechanisms.

177 Pinker, *The Blank Slate*, 33.

My investigations of sites in Japan, Chile, and Texas employ this framework of the intelligent machine to demonstrate that landscapes and the populations of people manipulating them form complex networks that develop in ways that are mysterious and subtle but incredibly important. Just like the layered black box of the neural network, the intermingled historical, environmental, and social factors operating on a landscape form invisible logical connections that produce a transcendent vitality akin to intelligence. The utility of the intelligent machine as a framework for analyzing these landscapes presents a commentary on the applicability of computational models as intellectual devices as well as direct analytical tools— the transplanting of methods and thought processes across disciplines cannot fail to produce exciting mutations of their typical outcomes. In the case of this project, those mutations resulted in uniquely rich and detailed descriptions of landscapes, ultimately developing an innovative route to the accepted destination of the tabula rasa as a fallacy.

The preceding urban investigations offer several compelling examples of the collateral progress the tabula rasa can invite—the unwavering commitment to peace memorialization in Hiroshima, the hope for a better collective future in Chile, and the public gift of spectacular mountains protected from development in the Guadalupes—but my analyses of these sites uniformly undermine the blank slate. Ultimately, they reflect that the tabula rasa cannot be supported computationally or spatially. Though a theoretical rejection of the tabula rasa breaks no new conceptual ground, my unorthodox and interdisciplinary approach demonstrates this position through mechanistic rather than philosophical means.

My structuralist methods interrogate the tabula rasa beyond the binary of truth or falsehood, revealing a legal fiction and a myth, which is never touted as a literal reality but still forms the basis of the computational and urban design ethics revealed in my research. I discovered that just as the law incorporates useful untruths that enable practical legal maneuvers, the fields of computing and urbanism rely on a notion of the tabula rasa that is easily disproven in theory but still implicit in the projects and programs of both disciplines. Through the analytical device of the intelligent machine, I was able to critique the tabula rasa not only according to its theoretical viability but according to its demonstrable agency in both computing and urbanism today, synthesizing techniques of mechanism-oriented experimentation and in situ observation to organize a robust and multivalent argument against the blank slate. In this way, I looked beyond the literal impossibility and theoretical obsolescence of the tabula rasa to understand its actual operation as a legal fiction and favored mythology that remains influential in the fields I studied. My argument against the tabula rasa, therefore, is not only a pronouncement of the blank slate as a flawed concept, but a call for the applied abandonment of a notion that continues to ghostwrite computational and urban projects.

I posit my rejection of the tabula rasa as an optimistic observation. If the blank slate represents an erasure of the past, it becomes problematic when it obscures important but difficult histories. In computing, that unglamorous truth might require the acknowledgement of general artificial intelligence as the product of far-reaching technological networks and massive human effort, rather than the hailing of such an achievement as a disembodied god trick.[178] In urbanism, it includes such stories as the military-industrial origin of Hiroshima, the dictatorship whose ramifications underlie the rebellion in Chile, and the tragic story of the Mescalero Apache's forceful removal from the Guadalupe Mountains. A rejection of this tendency to ignore the challenging or traumatic aspects of the past constitutes a call for a collective acknowledgement of those histories, which will enable the construction of a more sustainable and inclusive future—as well as the recognition of the people and circumstances that produced the extraordinary conditions currently erased by the imposition of the tabula rasa. This point of view is effectively summarized in Cronon, who rebuffs the blank slate of wilderness:

178 Haraway, "Situated Knowledges," 581.

> The flight from history that is very nearly the core of wilderness represents the false hope of an escape from responsibility, the illusion that we can somehow wipe clean the slate of our past and return to the tabula rasa that supposedly existed before we began to leave our marks on the world.[179]

179 Cronon, "The Trouble with Wilderness," 16.

My message is the converse of Cronon's. If any actionable item can be taken away from the mad science and global romp that is this project, it is that technologies and landscapes capture a matrix of human traces more complex than we can imagine and more important to the future than we know. It is a crucial project of self-preservation to develop creative and effective methods of reading the messages we imprint onto the earth, which learns from our patterns of inhabitation and responds intelligently to their effects. As I contemplate the uplifting expressions of the tabula rasa in Japan, Chile, and Texas, I respect the intentions behind the urban projects I studied, and my denunciation of the blank slate alines wholly with that admiration. This project represents the position that the message of a Peace Memorial City is more powerful when its militaristic past is acknowledged; the thrust of a revolution is stronger when it recognizes its roots in earlier movements; and the beauty of rugged land is thrown into relief when the stories of its previous inhabitants are told.

Beyond the sweeping social and political implications of finally deserting the tabula rasa, I think there is solace to be taken in the permanence this viewpoint ascribes to human traditions and interventions. As I conclude the wild journey of this project from the confines of my childhood bedroom, in a world undergoing a trauma unlike any it has experienced before, the tabula rasa I have followed for so long continues to offer a grounding in personal allegory, like a mantra, or a patron saint. It says: if you are willing to use creative methods and revisit existing theories in unexpected ways, it becomes possible to find something where there is supposed to be nothing. It says: when all seems to be lost, there is always something left.

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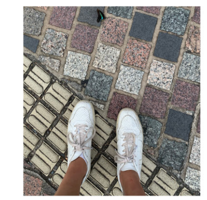
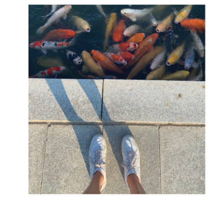
(These groups heavily overlap).

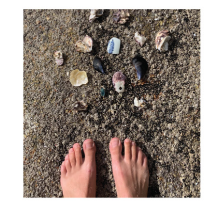
To my family, who trusted me to take on the greatest adventure of my life and helped me along the way.

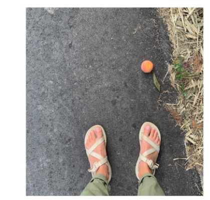
To Rudolph Hall, to the streets of Hiroshima, to the dunes and rivers of Chile, to the trails of the Guadalupes, to the comfort of home (Fig. 33). Thank you.


Peace Boulevard, Hiroshima


tatami mat, Kyoto


Shukkeien garden, Hiroshima

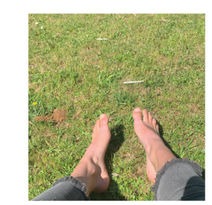

margins of Hiroshima Bay

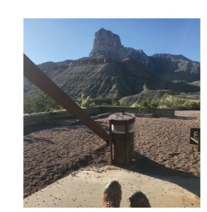

a long walk home, Kyoto


dinner by the riverside, Valdivia


cultura del cuerpo, Ciudad Abierta, Chile


Cubicula del Poeta, Ciudad Abierta, Chile


botanical garden, Valdivia


Highway 62, Guadalupe Mountains, Texas


volleyball court, GUMO


Bush Mountain trail, GUMO

Figure 33: boots (and sandals, sneakers, and bare feet on the ground.

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APPENDIX: AUTOENCODER

Python code generated for autoencoder experiments using MNIST dataset by LeCunn et al.
Hosted at: https://colab.research.google.com/drive/16J5kbhkttdf3ItHkR5euzQP3zdvheVnh

```
# -*- coding: utf-8 -*-
“””tabularasa.ipynb

Automatically generated by Colaboratory.

Original file is located at
    https://colab.research.google.com/drive/16J5kbhkttdf3ItHkR5euzQP3zd-
vheVnh

Claire Gorman
Computing & the Arts senior project, 2020
Deep Autoencoder for Image Reconstruction (TABULA RASA)
“””

# imports necessary for whole program
import tensorflow as tf
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import os

# DEEP AUTOENCODER CONSTRUCTION

# definition of smallest-dimension encoding
ENCODING_DIM = 2
Dense = tf.keras.layers.Dense

# input placeholder
input_img = tf.keras.layers.Input(shape=(784,))

# layers of encoder (dimensionality reduction)
encoded1 = Dense(128, activation='relu')(input_img)
encoded2 = Dense(64, activation='relu')(encoded1)
encoded3 = Dense(32, activation='relu')(encoded2)
encoded4 = Dense(8, activation='relu')(encoded3)

# encoding to dimension 2
encoded5 = Dense(ENCODING_DIM, activation='relu')(encoded4)
print(encoded5)
```



```
# layers of decoder (image reconstruction)
decoded1 = Dense(8, activation='relu')(encoded5)
decoded2 = Dense(32, activation='relu')(decoded1)
decoded3 = Dense(64, activation='relu')(decoded2)
decoded4 = Dense(128, activation='relu')(decoded3)
decoded5 = Dense(784, activation='sigmoid')(decoded4)

# model maps an input to its reconstruction
autoencoder = tf.keras.models.Model(inputs=input_img, outputs=decoded5)

# function to load MNIST data set and organize it
def load_data(path):
    with np.load(path) as f:
        x_train, y_train = f['x_train'], f['y_train']
        x_test, y_test = f['x_test'], f['y_test']
        return (x_train, y_train), (x_test, y_test)

# separate encoder model for prediction
encoder = tf.keras.models.Model(input_img, encoded5)

# placeholder for encoded input
encoded_input = tf.keras.layers.Input(shape=(ENCODING_DIM,))
print(encoded_input)

# last layer of the autoencoder model
decoder_layer = autoencoder.layers[-5]

# separate decoder model
decoder = tf.keras.models.Model(encoded_input, decoder_layer(encoded_in-
put))

# train autoencoder to reconstruct MNIST digits
# uses per-pixel binary crossentropy loss and Adadelta optimizer
opt = tf.keras.optimizers.Adadelta(learning_rate=2.0, rho=0.95)
autoencoder.compile(optimizer=opt, loss='binary_crossentropy')

# prepare MNIST input data, disregard labels

# load the data
mnist = tf.keras.datasets.mnist
(x_train, y_train), (x_test, y_test) = mnist.load_data()

# get only 0 and 1 images
train_filter = np.where((y_train == 0 ) | (y_train == 1))
test_filter = np.where((y_test == 0) | (y_test == 1))

x_train, y_train = x_train[train_filter], y_train[train_filter]
x_test, y_test = x_test[test_filter], y_test[test_filter]
```

```
# organize and reshape
x_train = x_train.astype('float32') / 255
x_test = x_test.astype('float32') / 255
x_train = x_train.reshape((len(x_train), np.prod(x_train.shape[1:])))
x_test = x_test.reshape((len(x_test), np.prod(x_test.shape[1:])))
print(x_train.shape)
print(x_test.shape)

# train autoencoder for 50 epochs
autoencoder.fit(x_train, x_train, epochs=50, batch_size=256, shuffle=True,
validation_data=(x_test, x_test))

# show image reconstruction output

# encode and decode some digits from test set
encoded_imgs = encoder.predict(x_test)
decoded_imgs = decoder.predict(encoded_imgs)

# plot the images
decoded_imgs = autoencoder.predict(x_test)
n = 10
plt.figure(figsize=(20, 4))
for i in range(n):

    # display original
    ax = plt.subplot(2, n, i + 1)
    plt.imshow(x_test[i].reshape(28, 28))
    plt.gray()
    ax.get_xaxis().set_visible(False)
    ax.get_yaxis().set_visible(False)

    # display reconstruction
    ax = plt.subplot(2, n, i + 1 + n)
    plt.imshow(decoded_imgs[i].reshape(28, 28))
    plt.gray()
    ax.get_xaxis().set_visible(False)
    ax.get_yaxis().set_visible(False)

plt.show()

# graph latent space as scatter plot

# separate 0 from 1 images
zerofilter = np.where(y_test == 0 )
onefilter = np.where(y_test == 1 )
x_test_zeros = x_test[zerofilter], y_test[zerofilter]
x_test_ones, y_test_ones = x_test[onefilter], y_test[onefilter]

# get encodings for each group of images
a = encoder.predict(x_test_zeros)
```



```
b = encoder.predict(x_test_ones)

                                               # plot encodings as clusters
plt.scatter(a[:,0], a[:,1], marker='o', s=0.1, c='#4a4a4a')
plt.scatter(b[:,0], b[:,1], marker='o', s=0.1, c='#9e9e9e')
figure = plt.gcf()
plt.show()

figure.savefig('plot.png', dpi=300)

# Sources:
# https://blog.keras.io/building-autoencoders-in-keras.html
# https://keras.io/optimizers/
```