Digital Rubbish: A Natural History of Electronics
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Introduction

A NATURAL HISTORY OF ELECTRONICS

To each truly new configuration of nature—and, at bottom, technology is just such a configuration—there correspond new "images."

—WALTER BENJAMIN, "Convolute K," in *The Arcades Project*

The domain of machine and non-machine non-humans (the unhuman in my terminology) joins people in the building of the artifactual collective called nature. None of these actants can be considered as simply resource, ground, matrix, object, material, instrument, frozen labor; they are all more unsettling than that.

—DONNA HARAWAY, "The Promises of Monsters"

Electronic Waste

If you dig down beneath the thin surface crust of Silicon Valley, you will find deep strata of earth and water percolating with errant chemicals. Xylene, trichloroethylene, Freon 113, and sulfuric acid saturate these subterranean landscapes undergirding Silicon Valley. Since the 1980s, 29 of these sites have registered sufficient levels of contamination to be marked by the U.S. Environmental Protection Agency (EPA) as Superfund priority locations, placing them among the worst hazardous waste sites in the country.[1] In fact, Silicon Valley has the highest concentration of Superfund sites in the United States. What is perhaps so unexpected about these sites is that the pollution is not a product of heavy industry but, rather, stems from the manufacture of those seemingly immaterial information technologies. Of the 29 Superfund sites, 20 are related to the microchip industry.[2] The manufacture of components for such technologies as computers, mobile devices, microwaves, and digital cameras has contributed to the accumulation of chemicals underground. Mutating and migrating in the air and earth, these caustic and toxic compounds will linger for decades to come.

Silicon Valley is a landscape that registers the terminal, but not yet terminated, life of digital technologies—a space where the leftover residue of electronics manufacturing accumulates. Yet this waste is not exclusive to the production of electronics. Electronic waste moves and settles in circuits that span from manufacturing sites to recycling villages, landfills, and markets. Electronics often appear only as "media," or as interfaces, apparently lacking in material substance. Yet digital media materialize in distinctive ways—not just as raw matter, but also as performances of abundance—often because they are so seemingly immaterial. The elaborate infrastructures required for the manufacture and disposal of electronics can be easily overlooked, yet these spaces reveal the unexpected debris that is a by-product of the digital. The waste from digital devices effectively reorders our understanding of these media and their ecologies.[3]

"Waste is now electronic," writes Gopal Krishna in describing the escalating number of obsolete electronic devices headed for the dump.[4] This is the other side to electronic waste—not a by-product of the manufacturing process, but the dead product headed for disposal. E-waste—trashed electronic hardware, from personal computers and monitors to mobile phones, DVD players, and television sets—is, like the electronics industry, growing at an explosive rate. Electronics consist of a broad range of devices now designed with increasingly shorter life spans, which means that every upgrade will produce its corresponding electronic debris. In the United States, it is expected that by 2010, 3 billion units of consumer electronics will have been scrapped at a rate of 400 million per year.[5] Many of these electronics have yet to enter the waste stream. Of the hundreds of millions of personal computers declared useless, at least 75 percent are stockpiled.[6] Computer owners store the outmoded model as though there might be some way to recuperate its vanishing value, but the PC is one item that does not acquire value over time. At some point, stockpiled computers and electronics enter the waste flow. Most of these consumer devices are landfilled (up to 91 percent in the United States),[7] while a small percentage are recycled or reused. Recycling, moreover, often involves the shipping of electronics for salvage to countries with cheap labor and lax environmental laws. The digital revolution, as it turns out, is littered with rubbish.

While much of the attention to electronic waste focuses on the recycling and disposal of computers, these devices comprise only a portion of the electronic waste stream. The pervasiveness of electronics—the insertion of microchips into such a wide range of systems and objects—means that the types of waste that emerge from electronics proliferate. Microchips—or "computers on a chip"—recast the extent of computing beyond the medium-sized memory machines that occupy our desktops to encompass miniature devices and distributed systems. Microchips can be found in computers and toys, microwave ovens and mobile phones, fly swatters and network architectures, all of which contribute to the stock of electronic waste.[8] While the use of these devices differs considerably, the material and technological resources that contribute to their "functionality" have a shared substrate in plastic and copper, solvents and silicon. Electronics typically are composed of more than 1,000 different materials, components that form part of a materials program that is far-reaching and spans from microchip to electronic systems.[9]

This book raises questions about how to investigate electronic waste as a specifically *electronic* form of waste. In what ways do electronics pollute, and what are the qualities and dispersions of this pollution? Electronic waste is more than just a jumble of products at end of life and encompasses new materialities and entire systems of waste making. Wastes related to electronics give rise to entirely new categories of waste classification and ways of regulating waste. While the electronics industries may not consume as many hazardous materials by volume as heavy industry, for instance, no comprehensive criteria account for the *degree* of toxicity of materials used in the manufacture of electronics.[10] But the proliferation of electronics occurs as much in the form of "hardware" as it does in programs or "software"—those seemingly more immaterial forms of digital technology, from information to networks, that still inevitably rely on material arrangements. Electronics are comprised of complex interlocking technologies, any part of which may become obsolete or fail and render the entire computing "system" inoperable.

Current reports and studies generated on electronic waste specifically contend with its increase and control, as well as the environmental dilemmas that emerge with the exportation of waste.[11] While these studies provide invaluable information about the volume, distribution, and policies surrounding electronic waste, my overriding intention is to situate electronic waste within a material and cultural discussion of electronic technologies. Waste is not just sheer matter, so, arguably, the methods for studying waste might also account for *more than empirical* processes of waste making. The sedimentary layers of waste consist not only of circuit boards and copper wires, material flows and global economies, but also of technological imaginings, progress narratives, and material temporalities. Waste and waste making include not just the actual garbage of discarded machines but also the remnant utopic discourses that describe the ascent of computing technologies—discourses that we still work with today.[12] Exhuming these layers and fragments from an already dense record requires expanded definitions of what constitutes electronic waste, as well as inventive methods for gathering together stories about that waste.

In this study, I take into account the range of delineations for what constitutes electronic waste, and I further expand the definition of electronic waste to an examination of these material and cultural processes that facilitate and contribute to technological transience. To bring these multiple layers of electronics into play, this investigation registers how and where electronics transform into waste. Through waste, we can register the effects of these devices—the "materiality effects" as well as "the unintended, 'after-the-fact' effects" or "perverse performativity."[13] Electronics continually perform in ways we have not fully anticipated. Electronic waste, chemical contamination, failure, breakdown, obsolescence, and information overload are conditions that emerge as wayward effects of electronic materiality.[14] While these aftereffects are often overlooked, such perverse performativity can provide insights into technological operations that exceed the scope of assumed intentionality or the march of progress, and it can further allow the strangely materialized, generative, or even unpredictable qualities of technologies to surface.[15] Rather than move quickly to proposals for remedying these electronic dilemmas, I look more closely at the mutable qualities of electronics and evaluate the multiple ways in which these technologies fail and stack up as toxic remainders.

The advantage of focusing on electronics through remainder is that not just the effects but also the material, cultural, and political resources that enable these technologies become more evident in the traces of these fossilized forms. Such an approach interferes with—while taking up—the specters of virtuality and dematerialization, which often ensure that the material "supports" of electronic technologies are less perceptible.[16] But materiality is more than a support, and as this study suggests, virtuality consists not just of the *appearance* of immateriality. Virtuality, I suggest, can even enable more extensive consumption and wasting. When electronic devices shrink to the scale of paper-thin and handheld devices, they appear to be lightweight and free of material resources. But this sense of immateriality also enables the proliferation of waste, from the processes of manufacture to the development of disposable and transient devices in excess. Here, I take as my point of departure this proliferation of possible types of electronic waste. These waste traces sediment into a natural history of electronics.[17]

Natural History: A Material Method

Imagine any typical electronic device broken into pieces, scattered into assorted component parts, and cast across disparate sites. Microchip and screen, plastic casing and packaging, electronic memory, peripherals and formless debris—all these sift out from the black box of electronics. Distinct fossils are generated and cast off throughout the life and death of electronics. These fossils bear the traces of electronic operations; they accumulate into a natural history record. But this natural history and these fossils are not remainders from past ice ages. Instead, they are the recently petrified forms from rapidly succeeding technological epochs. These fossils are more than inert objects to be decoded. They are indicative of places and "processes of materialization"[18] that have sedimented into and through these residual forms.

Bruce Sterling's proposal (quoted in the preface) to undertake a paleontological examination of dead media was, in fact, previously implemented in a much different way by the twentieth-century German cultural theorist Walter Benjamin, who developed a particular "natural history" method by reflecting on the fossilized commodities in the obsolete arcades of nineteenth-century Paris.[19] Strange, extravagant, yet mundane and ultimately broken-down objects assembled within his natural history, including "the briefcase with interior lighting, the meter-long pocket knife, or the patented umbrella handle with built-in watch and revolver."[20] For Benjamin, decaying objects and outmoded objects that were no longer fashionable revealed concrete facts about past cultural imaginings. By examining these objects, it might be possible to discern not just their former lives but also the larger contexts in which they circulated, as well as the economic and material forces that contributed to their sedimentation and decay. His natural history presents a method for exploring the transitory impulses that unfold through commodities and technologies.[21]

Such a natural history is an effective guide for thinking through the remainders of electronic waste. But this is not a conventional rendering of natural history. The emergence of natural history as a more usual practice of classification and description signals, in Michel Foucault's account, the beginning of the "modern episteme."[22] From the seventeenth century onward, natural history increasingly operated as a process of "purification," where the allegorical dimensions of naming things and of forming stories about the natural world were erased from scientific practice. In this way, it became possible to represent an animal or vegetable objectively—without the intervention of myth or fable. Such transparent descriptions depended on established and often physical criteria (e.g., color or size) by which specimens could be identified. This practice of natural history has enabled a whole set of modern scientific practices that filter out the noise between words and things and that delete the "play" of calling the world into being through language.[23] Charles Darwin's particular development of a theory of evolution is situated within this longer natural history, but his observations have often been conflated with (Victorian) notions of progress[24]—the same notions of progress within natural history that Benjamin sought to challenge in his own natural history method.

Benjamin, in his practice of natural history, at once drew on but departed from the usual, more scientific practice of natural history. While he was fascinated by nineteenth-century depictions of and obsessions with natural history and fossil hunting, he interpreted these historical records of the earth's deep time as a renewed temporal vantage point from which to assess practices of consumption. Obsolete objects returned to a kind of prehistory when they fell out of circulation, at which time they could be examined as resonant material residues—fossils—of economic practices. He reflected on the progress narratives that were woven through Victorian natural histories (and economies) and effectively inverted these progress narratives in order to demonstrate the contingency and transience of commodity worlds.

In this natural history of electronics, I take up the suggestive and unconventional natural history method developed by Benjamin and extend it—laterally—not as a model to replicate and follow but as a provocation for how to think through the material leftovers of electronics. The natural history method allows for an inquiry into electronics that does not focus on either technological progression or great inventors but, rather, considers the ways in which electronic technologies fail and decay.[25] These failures and sedimentations can be understood in part through the repetitive urge to pursue technological progress and regularly "upgrade." By focusing on the outmoded, it is further possible to resuscitate the political and imaginary registers that are so often forgotten in histories that rely on the persistent theme of progress.

Outmoded commodities are fossilized forms that may—through their inert persistence—ultimately unsettle notions of progress and thereby force a reevaluation of the material present.[26] While commodities might guide us to a space of speculative promise, the vestiges of these promises are all around us. These fossils persist in the present even as the assumed progress of history renders them obsolete. Within and through these forms, more complex narratives accumulate, which describe technologies not only as they promise to be but also as they materialize, function, and fall apart. In this Benjamin-inspired natural history method, such an approach to fossilized commodities becomes a way to circumvent "naturalized" histories, which typically assume that technological progress is automatic and inexorable or even a "natural" event, on par with evolution. Histories of technological forms are often narrated through the logic of "onward and upward," of crude early devices eventually surpassed by more sophisticated solutions. But rather than examine technology as an inevitable tale of evolution, I take up the notion that these fossil forms are instead evidence of more complex and contingent material events.

This natural history method, then, signals a distinct approach to materiality—not just as raw stuff, but, rather, as materiality effects.[27] Electronic fossils are in many ways indicative of the economies and ecologies of transience that course through these technologies. Electronics are not only "matter," unfolding through minerals, chemicals, bodies, soil, water, environments, and temporalities. They also provide traces of the economic, cultural, and political contexts in which they circulate. To begin to develop a more material account of these dematerialized technologies requires accounting for the multiple registers of what constitutes materiality—not as the raw matter of unproductive nature made productive, nor even as "second nature,"[28] but as a complex set of material processes and relations.

What would it then mean to do a natural history of electronics, if the sense of natural history encompassed these complex conjugations of materiality, nature, and history and also accounted for the telling of histories not as progress narratives but as more embedded, deeply material, spatial, temporal, and political effects? In this way, the microchip, as one of the fossilized forms discussed here, can be conceived of as a site where materials, environments, bodies, politics, technologies, ecologies, and economies accumulate. The microchip appears to be a thing in itself, similar to the way in which Haraway describes the gene. This is the way in which commodities are fetishized; they seem to be free-floating and without consequence. Yet the microchip, like the gene, requires "all the natural-social articulations and agentic relationships," from "researchers" to "machines" and "financial instruments," in order to circulate in the world.[29] Discussing these "things" involves being able to register the complex forces that bring them "into material-semiotic being."[30] This study does not advocate an approach that attempts to de-fetishize the chip or electronics. Instead I seek to develop a method that can encompass the apparent singularity of the chip together with the things it powers and the disparate fields it affects.

In this material method, I attempt to develop a practice of thought that works through cast-off objects in order to take up the density and "scatter" of electronic materialities.[31] This is a method that, following Benjamin, focuses on the "micrological and fragmentary," in order to "relate them directly, in their isolated singularity, to material tendencies and social struggles."[32] Such a method of natural history is not prescriptive but, rather, works across fragments and fossils to material processes and social conditions. By encountering fragments as traces of material processes, it is possible, as Benjamin notes, "to approach, in this way, 'what has been' . . . not historiographically, as heretofore, but politically, in political categories."[33] By not accepting naturalized histories, it is possible to engage with the political and situated character of materialities, progress narratives, and definitions of history and nature.

Taking up this more fragmentary approach, I work with the notion of the machine in pieces—of the fossilized forms of microchips, screens and plastic, memory and peripherals—in order to examine how these fossil forms are not just material remainders and effects but also indicative of the changing relations and definitions of technology, culture, nature, and history. "Nature," as Judith Butler notes, "has a history."[34] This natural history does not describe a commodity world operating alongside a more essential nature (where commodities, histories, and economies become naturalized); instead, it transforms nature and culture, staging their collision and revealing their shared conditions of transience.[35] Shifting definitions of "nature" can be identified through the different ways in which fossils have been interpreted throughout time. Fossils operate as indicators of changes in the "interrelated conception of nature, culture and history."[36] At one time, these encrusted forms might be read for proof of the Deluge; at another, they were evidence of the progress of life. From these readings, it is possible to develop an understanding of nature not as an essential or original reference point but as historical matter. Nature is no longer a stable ground against which it is possible to describe the progressions of culture. Benjamin put forward a neat summation of this approach in *The Arcades Project:* "No historical category without its natural substance, no natural category without its historical filtration."[37]

Why is it important—in a study of electronic waste—to think through the history of nature and the nature of history? Distributions and definitions of nature are never static, and through their shifting registers and relations to "culture" and "history," these definitions also inevitably inform the politics of matter and processes of materialization. Nature, while historical, cannot be reduced to either sheer process of social construction or inert matter. Because it is historical, it is emergent, contingent, embodied, and political. It is not absolute, which is important to articulate when anything cultural comes to seem to be an absolute condition. Technologies, economies, and commodities may appear to be natural or naturalized. But this is because they operate through a whole set of what Butler calls "sedimented effects."[38] Material appears to be given—as matter—because it has stabilized or sedimented, as Butler writes, "over time to produce the effect of boundary, fixity, and surface we call matter." This is the "process of materialization."[39] The fossils I investigate are not just congealed electronics but also a contaminated mixture of nature, history, and technology. Fossils effectively work to *denaturalize* technology and its effects. In this way, it is possible to engage with materiality not just as materialization but also as ultimately prone to instability and breakdown.

Fossils—the remainders and residues of technology and media—are, then, potent forms that bear the imprint of events (both actual and imagined); they are traces of prior lives, events, and ecologies. Residual matter and the unintended consequences of technology have emerged as a topic of interest within contemporary media studies, as well as studies of science and technology. In the edited collection *Residual Media,* media theorist Charles Acland suggests that residuals allow expanded ways of engaging with media beyond the obligatory narratives of media revolutions.[40] Similarly, in his media-archaeological investigations into the "deep time" of media, Siegfried Zielinski begins with the "rubbish heaps" of media, to suggest that bundled into media are more complex temporalities and imaginings that exceed the simple or assumed progression toward advanced devices.[41] By decoupling histories of media and technology from progress, it is possible to examine the more complex temporalities and materialities that accompany distinct media technologies. Such extended terrains further resonate with what media theorists, from Marshall McLuhan to Friedrich Kittler, have called the "media environment"[42]—understood as the material conditions and discursive "networks" that constitute media[43] or as the set of processes and effects that even suggest that "there are no media."[44] Rather than isolated media objects, there are institutions, practices, and devices that—assembled together—enable media operations.

The fossils studied here do not assemble into a network, however, nor are they "actors" in a planar field of influence.[45] Rather than circumscribing systems, these figures open into spaces of relation and resonance.[46] Fossils are not abstract distributions but, rather, temporal sedimentations and transformations; they are mutable and contingent forms. From this perspective, users—as well as electronics waste workers—are also part of the materiality effects of electronic technology. However, the focus in this book is less on how users engage with a vast array of computing devices—particularly since waste workers, among others, often play a much different role as "agents" in their engagement with electronic technologies.[47] The material culture of electronics discussed here is not centered on users as manipulators of media content but, instead, focuses on how materialized workers, technologists, and consumers all emerge in relation to processes of electronic obsolescence and decay.

Materiality is a topic and focus that is now pervasive across multiple disciplines, from media studies to geography and science and technology studies. Given its concern with drawing out the complex material processes of digital media, this study is primarily located within media studies, but it also draws on writings within cultural geography and science and technology studies to analyze these technologies.[48] What becomes evident in these writings is a shared interest in describing how matter matters, and in this way multiple terms emerge that are used both similarly and dissimilarly. Material may rematerialize or dematerialize, it may be performative or transformative, or it may circulate in or as a network, system, or circuit. While this study does deploy these terms, it calls out the ways in which many of these terms have specific histories within computing and information theory. The histories of these terms are material histories as much as intellectual histories, and where relevant I discuss the ways in which these often apparently abstract terms work in quite specific ways in the digital realm.

It may be tempting to chart a sort of life-cycle analysis of electronics in order to track the comprehensive movement from raw material to waste product.[49] But I intentionally do not seek to understand the circuits of electronic waste through a life-cycle analysis, which would run the risk of appearing to be a tidy analysis of inputs and outputs to the neglect of both the material and imaginative residues that accompany electronics. Instead, the circuits I pursue are spatial and material instantiations of how electronics generate waste, whether in the form of chemical contamination or information overload. But there is more to expiration than just the guilt of discards. As Benjamin demonstrates, outmoded commodities "release" the imaginary and wishful dimensions that made them so compelling when first distributed as novel objects. Natural history, as a study of expiration, also engages with this mythic aspect of innovation. Any investigation into electronics would be incomplete if it did not account for this more fantastic register of technologies, as well as the ways in which technology does not constitute an orderly narrative.[50]

Electronic waste is a topic that challenges the methods and delineations used to describe it. Benjamin's natural history method suggests ways to mobilize the possible play of relations within material culture, economies, consumers, dreams, and politics. This is a natural history method that is simultaneously political and poetic, concrete and literary. Data is never devoid of dreaming. What registers as empirical matter bears an inevitable relationship to theories that would identify and describe that matter. Deciding what counts as empirical matter is also a process of materialization.[51] As much as it draws attention to the complex material effects of electronics and electronic wastes, this natural history method is ultimately a strategy for *rematerializing* electronics.[52] Electronics can be rematerialized both in the way their pasts accumulate—as fragmentary and the outmoded—and in the way ecologies, politics, and imaginings emerge from the rubble. Natural history—as a theory, practice, and method—brings together questions of materialities, time, politics, environments, technology, commodities, and imaginings; it also reorients the relations between nature, history, culture, matter, and time. This is a method for collecting material residues and for reorienting the histories and temporalities that emerge with technologies. It moves across scales, from the fossilized fragment to the temporal landscape. It tells material histories not as fixed, abstract, or essential but as dynamic, concrete, and entangled.

This natural history is grounded in the time of electronics, situated within a historical framework that primarily coincides with the development of the microchip, although it also draws on the longer postwar history of computing and automation. The material, references, and sites assembled in the following chapters draw on diverse sources relevant to electronics and the material economies and ecologies of which they are a part. While this method is rooted in fieldwork and draws on theoretical literature in technology, media, and material studies, it also engages with primary sources, including archived objects and documents, Web pages and online interviews with electronic "pioneers," reports by governmental and nongovernmental organizations, annual reports, newspaper articles, and popular commentaries, which together capture not just the material textures of electronic waste but also the material textures of language relating to electronics.

I explore the material-semiotic aspects of electronics by writing alongside these texts, in a further attempt to work with—and even transform—the "technophilic" and "technophobic" approaches that can emerge, at turns, in relation to electronics.[53] This project is neither utopic nor dystopic in its discussion of electronics, but it does draw on both the hyperbolic promises and informational and material excesses through which electronics are described. My intention is to move beyond a utopic/dystopic "e-mail address," as Haraway suggests when describing her attempts to forge another position in relation to cultural salvation-or-catastrophe discourses.[54] Similarly seeking to find another route around the steady oscillations between positive and negative renderings of cultural history, Benjamin suggests, "Overcoming the concept of 'progress' and overcoming the concept of 'period of decline' are two sides of one and the same thing."[55] Benjamin then makes a "modest methodological proposal" to find a new "positive element," where failure is not just the flip side to progress but, rather, offers an opening or rupture into other material relations and imaginings.[56]

When Benjamin undertook his investigations into the natural history of commodities, he did so in urban landscapes that emerged through accreted registers of consumption. He focused on the "dying arcades" of Paris, where "the early industrial commodities have created an antediluvian landscape, an 'ur-landscape of consumption.'"[57] In the arcades, "a past become space,"[58] he was able to imagine how commodities and technologies transformed into residues that contained traces of the resources, labor, and imaginations that went into these transformations. Similarly, electronic waste calls attention to the spatial and material infrastructures that support the transformations of these technologies. In addition to the texts, documents, and objects already discussed, I here focus on a number of key sites in which the remains of electronics can be studied. Fieldwork conducted in the gathering of these spatial stories has ranged from Silicon Valley to Singapore and from the Bronx to London. Superfund sites and museums of the electronics industry, shipping yards and electronics recycling facilities, computing archives, and electronics superstores and repair shops inform the content, texture, and structure of this study, which takes up natural history as much as a method as a theoretical point of inquiry.

To chart the multilayered spatial and material infrastructure of electronic waste, I have organized the chapters in this book around five sites in which distinct electronic fossils can be located. I unearth these fossils found throughout the life and death of electronics, in order to register the diverse resources, materials, and imaginaries that undergird this technology.[59] These sites and fossils are microchips in Silicon Valley; screens used in market transactions of the National Association of Securities Dealers Automated Quotations system (NASDAQ); plastics—in the form of housing, packaging, and more—as they move through the spaces of shipping and receiving, consumption and disposability; memory devices stored and at work in the electronic archive; and all the peripherals and scrap, from printed circuit boards to copper wires, which can finally be found in the landfill and salvage sites. These fossils and spaces of remainder each embody specific processes of electronic materialities and electronic waste. These are not just "waste sites" but also temporal zones that register the speed and volume of production, consumption, and disposal of digital technologies.

The aging electronics that occupy dumpsters and landfills register not just as fossils from successive upgrades but also as objects that circulate through a number of spaces in the process of their making and unmaking. Circulation, as described throughout this study, is a method both for mapping electronic waste as it congeals in and moves through diverse spaces and, at the same time, for registering the often amorphous or mutable arrangements of electronics and electronic residues.[60] This research describes not a "society of flows" but, rather, sites of unexpected accumulation. I take up these scraps and fossils in the sites where they are found, in order to think through the disparate effects, sedimentations, and imaginaries that inform the making and breaking of electronics.

This book begins with the perception that digital technology is light, postindustrial, or dematerialized. Worldwide, discarded electronics account for an average 35 million tons of trash per year.[61] Such a mass of discards has been compared to an equivalent disposal of 1,000 elephants every hour.[62] A colossal parade of elephants—silicon elephants—marches to the dump and beyond; suddenly, the immaterial abundance of digital technology appears deeply material. A considerable amount of waste is also generated at the point of electronics manufacture. Chapter 1 traces these economies of abundance and focuses specifically on the waste that emerges in the interrelated production of microchips, information, and environments. Through a study of these material relations, it is possible to examine how "overload" is a condition that describes information and contaminated environments alike.

Before it becomes trash, however, digital technology drives another type of abundance, this time in the dematerialized space of electronic trading. NASDAQ is the electronic trading market that specializes in technology companies, and it is also the world's first electronic stock market. Established in 1971, NASDAQ was described in its 2004 annual report "Built for Business" as the world's largest "electronic screen-based equity securities market." NASDAQ is an index of the volume and value of technologies, but it is also a digital technology of its own. As an automated system programmed to deliver financial data across a scattering of sites, its telecommunication networks enable market activity to take place across a vast and decentralized geographic terrain. In this sense, the NASDAQ network is located in multiple locations, from individual screens, to stories-high display screens in Times Square, to the massive server farms that collect and disperse data. Chapter 2 turns to the screen as a fossil figure, to examine the electronic market interface and to track the processes of dematerialization and automation that characterize electronic exchanges.

Chapter 3 investigates the locations and processes of electronic disposal and focuses on plastics as a fossil form and critical material that facilitates disposability. Electronics primarily consist of a complex composite of plastics, and plastics are the emblematic material of the "throwaway society." In this sense, plastics are both disposable and mobile, because once they are discarded, they also inevitably circulate through extended geographies. In the end, transportable electronic waste follows the path of the most undesirable forms of trash—from economically privileged country to poorer one. The primary exporter of electronic waste is the United States, a country that does not consider the export of waste to be illegal. But electronic wastes from the United Kingdom to Singapore turn up in places as distant as the rural districts and urban slums of China, India, and Nigeria. Recycling methods in these regions are typically toxic for both workers and the environment.[63] Chapter 3 trawls through these circuits in order to examine the material exchanges and geographies of disposal.

Chapter 4 considers electronic archives and memory as a site and fossil in which the accelerated temporalities of electronics become evident in sedimented form. The electronic archive operates as a kind of extended memory for the select electronic devices that are relegated not to the bin but, rather, to the archive and the museum. For every ton of electronic material cast out, a select portion ends up preserved in the halls of history. Much of the technology in the museum or archive of electronic history is inaccessible, however: ancient computers do not function, software manuals are unreadable to all but a few, spools of punch tape separate from decoding devices, keyboards and printers and peripherals have no point of attachment, and training films cannot be viewed. Artifacts meant to connect to systems now exist as hollow forms covered with dust. In this sense, the electronic archive can be seen as a "museum of failure."[64] It is a record of failed and outdated technologies. If it collects anything, it collects a record of obsolescence. The idleness of these electronic artifacts ultimately raises questions about how technology demarcates duration. How does one preserve media that have a built-in tendency toward their own termination?

Most electronics do not advance to preservation, however. Instead, idle machines, at end of life and end of utility, stack up in landfills, are burned, or are buried. More formally known in the Western world as the "sanitary landfill," the dump is the terminal site of decay, where electronics of all shapes and sizes commingle with banana peels and phone books. Plastic, lead, mercury, and cadmium break down and begin their terrestrial migrations. Electronics—media in the dump—require geological time spans to decompose. Chapter 5 begins and ends in the dump. Extending the discussions made in previous chapters, chapter 5 draws on the disposal practices developed in chapter 3 and the notions of time and preservation discussed in chapter 4. It dwells on the masses of scrap and peripherals, as fossil forms that are stripped, salvaged, burned, and finally dumped, often far from the sites of their initial consumption.

Digital Rubbish Theory

The dump is a site where objects typically absent of utility or value collect. Except through the work of invisible salvagers, from mice to treasure seekers, the material here is unrecoverable. Yet garbologist William Rathje suggests that the best way to investigate contemporary material culture is through this apparently useless garbage.[65] Much as archaeologists study the relics of the distant past, Rathje unearths the refuse of the recent past to measure human consumption. Garbology examines cultural phenomena by linking discarded artifacts with consumption patterns. Garbage Project crew members set out to landfills to draw core samples, tabulate and catalog discrete waste objects, and thereby chart significant patterns of consumption. In this sense, a dump is not just about waste, it is also about understanding our cultural and material metabolism. A dump registers the speed and voracity of consumption, the transience of objects and our relation with them, and the enduring materiality of those objects.

Electronics linger in the dump, where they stack up as a concrete register of consumption. The garbology of electronic waste may have an obvious reference point in landfills, but from Silicon Valley Superfund sites to recycling villages in China, there emerges an even more expansive array of waste sites where electronic debris expands, sifts, and settles. Electronics, media, landscapes, and waste are all linked and in constant transformation. From the virtual to the chemical and from the ephemeral to the disposable, the accumulation of these electronic wastes creates new residual ecologies and requires expanded practices of garbology. With electronic waste, it is possible to expand the thin surface of digital interfaces to encompass those material processes that work to support the appearance of immateriality. In the dump, our digital media and technologies turn out to be deeply material.

As the Garbage Project demonstrates, sorting trash into categories can become a habitual and absorbing project. A liminal zone, the in-between, the fringe, the outside of the inside, a site of expenditure and revitalization—the demarcations for waste are potentially endless. The ambiguity of determining when waste definitively becomes waste points to its role as a dynamic category. Waste oscillates in relation to ordering systems and structures of value. It is a variable within what Michael Thompson calls an "economy of values." As Thompson states in his authoritative *Rubbish Theory,* rubbish is a way of understanding the relative position of value relations.[66] Waste is, in this sense, what cultural theorist Walter Moser calls a "category of transition, a limit category."[67] Waste reveals the economies of value within digital technology that render valueless, for instance, a computer that is more than three years old. This collapse in value demonstrates assumptions within electronics—based on duration, novelty, and consistent consumption—that might otherwise go unnoticed, if it were not for the now-looming rubbish pile.

The interdisciplinary method of natural history developed in this book not only draws on studies of media, materiality, and technology, as already discussed, but also works through rubbish theories and waste studies, which critically inform this examination of the decay of electronics. The processes of materialization discussed here focus on "what was wasted"[68] in the manufacture, imagining, consumption, and disposal of electronics. The natural history method that emerges in this study is informed by these transformations and migrations to waste. Benjamin's method was, in fact, an early form of rubbish theory, where ruins, transience, fragments, and fossils served as key figures for thinking through exactly what is wasted in processes of materialization. The digital rubbish theory developed here weaves together these theories of waste and materiality in order to examine the material cultures and geographies of electronics through their dissolution.

Michel Serres asks, "Where do we put the dirt?"[69] Dirt, he suggests, may present another way for considering systems and relations through perceived imperfections. Where is the dirt of electronics? How does dirt inform the making of electronic materials and spaces? Electronic waste presents a crucial case study of dirt, of both how it is generated and where it is distributed. The nature of electronic waste suggests that it may be necessary to sort through the trash at an even finer scale to understand the implications of electronic modes of waste. Electronic waste, moreover, presents a critical subject for reevaluating our relationship with "new media." Digital technologies are disposable, and data is transient. Yet the rapidity of technological progress leads to enduring and toxic electronic materials. Electronic waste gives rise to a distinctly electronic version of garbology, a digital rubbish theory. Organized into chapters that focus on the previously described fossils and sites, the research that follows considers how remainders—and dirt—may be the most compelling devices for registering the transience of electronic technologies.

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Silicon Valley Superfund site, hazardous waste log, 2005. (Photograph by author.)

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Fry's Electronics Superstore, Silicon Valley, 2005. (Photograph by author.)