INTRODUCTION

Environment as Experiment in Sensing Technology

THE EARTH BECAME PROGRAMMABLE, Marshall McLuhan once wrote, the moment that *Sputnik* was launched.[1] Rocketed into orbit on October 4, 1957, and circling around the earth every ninety-six minutes, *Sputnik* was a technological intervention that turned planetary relationships inside out. Inevitably, what springs to mind with McLuhan's easy statement about the transformation of the earth and our relationship to it are the familiar images of *Earthrise* and the *Blue Marble,* which are often pointed to as simultaneously signaling the rise of environmentalism as well as the distancing of the planet through a disembodied space view. And yet, *Earthrise,* an image captured by *Apollo 8,* was not to appear for another eleven years, in December 1968, and the whole-earth view of the *Blue Marble* did not appear until 1973.[2] In contrast, *Sputnik 1* generated not photographic icons of whole or fragile earths, but rather produced a series of inexplicable beeps through a radio transponder, and relayed information about the likely conditions of Earth's upper atmosphere.[3] If *Sputnik* made the earth programmable, it was in part through radio transmissions that encircled the planet and created a live auditory map of a new orbital environment.

Although the twenty-three-inch *Sputnik* did not offer up a *view* of Earth from afar, it did activate a multitude of new experiences for inhabiting the earth. While it sent a signal of Cold War triumph (and even suspected propaganda) for the Soviet Union, in the United States the orbital machine regularly pacing through the skies portended catastrophe, where GDP and money markets as well as science education were all feared to be on the brink.[4] The continual revolutions of *Sputnik* around the earth, which spurred viewing sessions of its orbits in numerous cities, recast spaces of earthly sensibility and began to reshape environments.

Launched during the International Geophysical Year 1957–1958 (IGY), *Sputnik 1* was in many ways a proof-of-concept technology, which contributed to the development of a method for putting a satellite into orbit, while also testing the propagation of radio waves through the upper atmosphere and assessing the endurance of the satellite in space.[5] The testing of *Sputnik 1* further facilitated the development of *Sputnik 2* and *3,* which were launched in 1957 and 1958. *Sputnik 2* was sent into space complete with a dog, Laika, whose heartbeats could be heard through radio transmission. These later satellites were designed to be geophysical laboratories that collected data on the earth's magnetic field, radiation belt, and ionosphere. The remote sensing that the *Sputnik* triad undertook consisted of sending telemetry signals from space to Earth and of experimenting with the conditions necessary for developing a sensing laboratory that could eventually provide data about terrestrial ecologies through further satellite development.

Subsequent to *Sputnik,* satellites such as Landsat became key technologies for undertaking environmental monitoring, whether to detect change or to identify natural resources.[6] As Andrew Horowitz details in a 1973 issue of *Radical Software,* Eastman Kodak Company launched an advertisement in the *New York Times* that promoted the environmental benefits of satellite systems and detailed the endless possibilities for aerial monitoring to aid in the management of the environment, suggesting that this could not only reveal undiscovered dynamics within nature

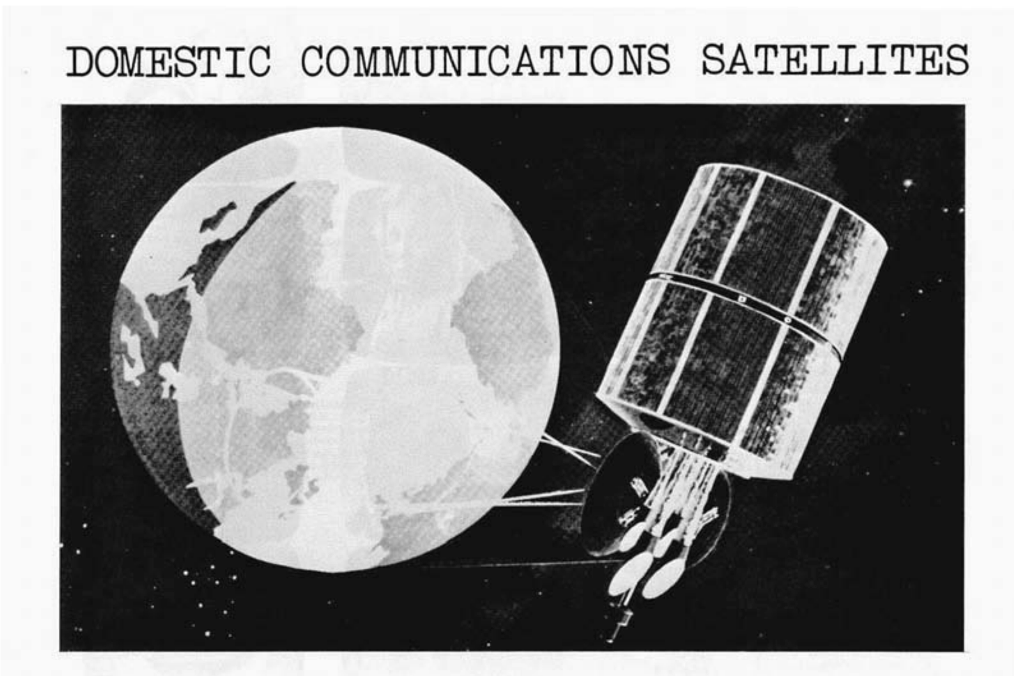

Figure I.2. Domestic communication satellites. Image from article by Andrew Horowitz, *Radical Software* 2, no. 5, chief editors Beryl Korot and Ira Schneider. Courtesy of Radical Software, copyright 1973 by the Raindance Foundation.

but also extend to identifying resources for extraction, and monitoring land use and living patterns.[7] Satellites were promoted as making an easy transition from military research and development to ecological and social applications.[8] Remote sensing developed into a critical technology and method within environmental science and became a crucial way in which to study environmental change on a global scale.[9]

Satellites now regularly monitor environmental change, tracking carbon dioxide in the atmosphere and patterns of deforestation. Satellites are referred to as "eyes in the sky" that communicate to ground stations while relaying data about and through environments, as they watch over earthly spaces and even transform the planet into a digital earth. Our understanding of environmental systems is now bound up with communication technologies that sense earthly processes. Satellites have played an important role in this development. And practices of monitoring environments have further developed from remote sensing to a more distributed array of sensing technologies.

I begin with this discussion of *Sputnik* and the programmability of the earth since this was a moment when a particular approach to sensing emerged that would inform monitoring and approaches to environments. However, what I attend to in this book is not a history of satellites or even Earth as understood from outer space. Instead, I develop an account of more recent developments in sensing technologies through distributed and networked environmental sensors within more earthly realms.

As it turns out, sensing has come down to earth since the time of *Sputnik*. Environments are now monitored not just by satellites but also increasingly by a wide range of sensors that track everything from air quality to traffic levels to microclimates and seismic activity. Such environmental monitoring is a practice that is computational, often networked, frequently automated, and increasingly ubiquitous. Many current scientific initiatives suggest that the monitoring of Earth processes remains one of the core areas of focus and development for the scientific understanding of environmental change. But sensors are also collecting data on any number of environmental processes that include managing cities and facilitating logistics, as well as providing and harvesting a range of data to and from smartphone users. The programmability of environments has expanded from the earth as enveloped in an orbital if experimental technology to a distributed and embedded range of monitoring technologies that inform how environments are sensed and managed. It is this explosion of environmental sensors and environmental sensing operations that I discuss in this book.

While there is much to debate in McLuhan's characterization of *Sputnik* and its relationship to "the natural world," I find the provocation of a planet that has become programmable a key point to take up in relation to the current proliferation of environmental sensors. In his characteristically sweeping essay on media environments, which ranges from the death of Queen Victoria to poetry and newspapers as "corporate poems," as well as Xerox as enabling everyone to become a publisher, and the immersive experiences of electronic "man," McLuhan suggests that *Sputnik* is yet another communications-based revolution that remakes people and environments.

What might he have meant by this rather elliptical discussion, written seventeen years after the launch of *Sputnik 1*? If we take him at his word, *Sputnik* seems to have given birth to a new planet and new environment. As he writes, "Perhaps the largest conceivable revolution in information occurred on October 17, 1957, [*sic*] when *Sputnik* created a new environment for the planet."[10] The usual way to read McLuhan and his sudden leaps of logic would indicate that such a statement runs the risk of technological determinism, and so it might. But I take up in a rather different way the provocation that this proto-remote-sensing device—and that our newer environmental sensing devices—are creating new environments and are programming Earth in distinct ways. I also depart from McLuhan in his understanding of the programmability of the planet, where he goes on to render *Sputnik* as yet another "extension of man," to consider instead how programmability might signal a quite different and distributed way of remaking environments. Programmability, the programming of Earth, yields processes for making new environments not necessarily as extensions of humans, but rather as new configurations or "techno-geographies" that concretize across technologies, people, practices, and nonhuman entities.[11]

Program Earth addresses the programmability of the planet by focusing on the *becoming environmental of computation*. I understand computation to include computationally enabled sensors that are distinct and yet shifting media formations that traverse hardware and software, silicon and glass, minerals and plastic, server farms and landfills, as well as the environments and entities that would be sensed. In other words, I am attending to the extended scope of computation that includes its environmental processes, materialities, and effects. Through discussing specific instances where sensors are deployed for environmental study, citizen engagement, and urban sustainability across three areas of environmental sensing, from wild sensing to pollution sensing and urban sensing, I ask how sensor technologies are generating distinct ways of programming and concretizing environments and environmental relations. I further consider how sensors inform our engagements with environmental processes and politics, and in what ways we might engage with the "*technicity*" of environmental sensors to consider the possibility for other types of relations with these technologies.[12] But before I unfold these concepts and explain how they are important for attending to the specific capacities of these machines, I first provide a bit more background on the growing sensorization of environments.

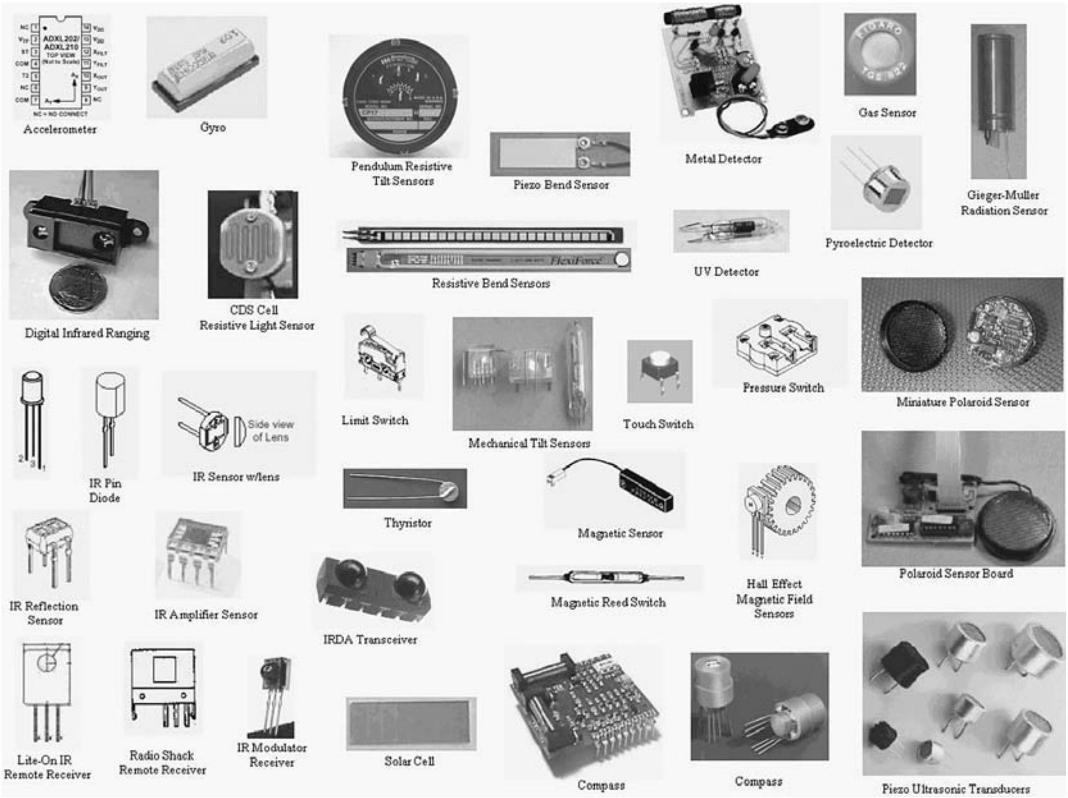

Figure I.3. Types of sensors. Sensors detect and measure stimuli through a wide range of inputs, including chemical, mechanical, and biological sources. The sensor assemblage typically involves using electronics and software to convert stimuli into electrical and digital signals. Screen capture.

GROUNDING SENSE

While satellites eventually became fully equipped with numerous sensor packages, sensors for use in environmental monitoring on the ground have also proliferated from initial military use to scientific study and commercial deployment. Nonnetworked and analog sensors have been in use in multiple applications for some time, and depending upon how one classifies sensors these could include cameras and microphones, not to mention sensors for use in applications such as radiation detection. For instance, in his work related to the Association for Computing Machinery (ACM) "Working Group on Socially Desirable Applications of Computers" and the "Citizen's Committee for Radiation Information," Edmund Berkeley proposed that radiation sensors could be put to work for political and environmental purposes to better understand radiation hazards and in aid of nuclear disarmament during the Cold War.[13] But the development of one of the first *sensor networks* has been traced to the air dropping of seismic and acoustic sensors by the U.S. military in Project Igloo, where sensors were used to detect movement along the Ho Chi Minh Trail in Vietnam.[14]

Beyond these early instances of sensors and sensor networks, however, the most usual reference for discussing the distributed and networked possibilities of sensors in the form of ubiquitous computing is Mark Weiser's 1991 text, "The Computer for the 21st-Century." Weiser makes the case for computing—and the sensors that would facilitate computational operations—to be distributed in and through environments. Identifying how computers were already present "in light switches, thermostats, stereos and ovens [that] help to activate the world,"[15] Weiser suggested these technologies might allow computing to "disappear" into the fabric of everyday life. Rather than the well-known trope of engagement that involves making the invisible visible, Weiser advocated for further invisibility, to develop computing not as a project principally of cognition and awareness, but rather as something that is integrated into environments and experience.

To this end, Weiser stressed that ubiquitous computing was not simply a project of populating far-flung places with computers. As he writes, "'Ubiquitous computing' in this context does not mean just computers that can be carried to the beach, jungle or airport." Such a strategy would still be focused on the self-contained box-like quality of computing, which would remain a discrete object demanding attention. Weiser emphasizes that ubiquitous computing is not "virtual reality, which attempts to make a world inside the computer." Rather than simulating worlds, he was interested to enhance the world already in existence by making computing an invisible force that runs through the background of everyday life.[16] And he imagined this would take place through networked and computationally enabled sensors.

A growing wave of interest in sensors and ubiquitous computing has occurred on either side of Weiser's proposal, from the 1984 launch of *Sensor Magazine,* to the proposal for technologies such as "smart dust" in 1998 (ambitiously micro-scaled sensors that were imagined to drift in clouds or swarms and monitor environments), to the coining of the term "Internet of Things" in 1999.[17] "Earth Donning an Electronic Skin," a 1999 article in *Business Week,* made predictions for the imminent encircling of the planet in electronic sensors that would measure and transmit data from millions of points:

> In the next century, planet earth will don an electronic skin. It will use the Internet as a scaffold to support and transmit its sensations. This skin is already being stitched together. It consists of millions of embedded electronic measuring devices: thermostats, pressure gauges, pollution detectors, cameras, microphones, glucose sensors, EKGs, electroencephalographs. These will probe and monitor cities and endangered species, the atmosphere, our ships, highways and fleets of trucks, our conversations, our bodies—even our dreams.[18]

Moving well beyond the singular object of *Sputnik* in space, this article presents a much different vision for a programmable earth, composed of the implementation of "trillions of such telemetric systems, each with a microprocessor brain and a radio,"[19] which would gather and transmit data on the ground by monitoring people, infrastructures, and events. No realm fell outside the reach of these sensor systems, where even dream activity could be surveyed.

A planetary brain, working through parallel and distributed computing, these electronic devices were envisioned to eventually form "a whole ecology, an information environment that's massively connected."[20] Imagined as a "huge digital creature," this ecosystem of electronic sensors, software, and communication networks was intended to be designed to "help human beings, not harm them."[21] With the planetary sensing fabric in place, scientists and technologists could then also turn their attention back to outer space, where this sensory network could spread to Mars and beyond.

While this vision for an electronic sensory network spanning the planet is now nearly two decades past, it continues to influence developments in environmental sensing and the Internet of Things. Today, sensors can be found in traffic infrastructure and ocean buoys, as well as in trees in forests and planted in soil underground. Sensors are used to manage urban traffic flows and to aid in the movement of freight, to signal flooding alerts, and to enable rapid responses in disaster situations. Sensors are located in environments, attached to infrastructure, fixed to vehicles, ported around as wearables, and embedded in smartphones, of which there are now one billion sold every year.[22] As an IBM video pitch for a "Smarter Planet" explains, the increasing instrumentation of the planet is meant to give rise to a "system of systems" that will facilitate heightened levels of observation, responsiveness, and efficiency.[23] "New insights, new activity, new forms of social relations" are meant to come together through an instrumented planet, which as "an information creation and transmission system" becomes newly intelligible. In the aspirations of the Smarter Planet vision, networked environmental sensors make it possible to listen in on a planet that has always been "talking to us," but which we can only now begin to hear.[24]

The drive to instrument the planet, to make the earth programmable not primarily from outer space but from within the contours of earthly space, has translated into a situation where there are now more "things" connected to the Internet than there are people. Some commentators suggest that the defining moment for implementing the Internet of Things was in 2008, when machinic connectivity to the Internet outnumbered human connectivity.[25] Sensing occurs across things and people, through environments and within infrastructures. People-to-people communication is becoming a smaller proportion of Internet and networked traffic in the complex array of machine-to-machine (M2M), machine-to-people (M2P), and people-to-people (P2P) circuits of communication. Cisco has projected, somewhat fantastically, that there could be fifty billion connected objects in circulation by 2020.[26] Many more objects than this could be eventually interconnected, since the IPv6 address system creates 10^{30} Internet addresses per person.[27] Intel ultimately envisions a future where sensors will be monitoring and reacting to us at every second, which would involve "altering reality as we know it."[28]

The basic diagrammatic flow of how sensors are meant to improve environmental understanding and responsiveness goes something like this: Distributed computational sensors monitor real-time events while collecting data on environmental conditions. Data on phenomena such as air quality and temperature, as well as location and speed of bodies and objects, are processed and trigger responses that may be human- or machine-based. These responses are often oriented toward making systems and processes more efficient or "balanced." The real-time "intelligence" provided by sensors is meant to translate into smart systems that continually enable corrective actions. The ambition is that environments and infrastructure can be managed intelligently and cohesively with networked sensor data. Preventative decisions can be taken. And major events such as floods can be instantly reported to ensure intelligent and immediate environmental management.[29]

Sensors are devices that typically translate chemical and mechanical stimuli such as light, temperature, gas concentration, speed, and vibration across analogue and digital sensors into electrical resistors and voltage signals. Voltage signals further trigger digital circuits to output a series of conversions into zeros and ones, which are processed to form readable measurements and data.[30] Data points are captured from a distributed multiplicity of sensors that are often measuring simple variables. By sensing environmental conditions as well as detecting changes in environmental patterns, sensors are generating stores of data that, through algorithmic parsing and processing, are meant to activate responses, whether automated or human-based, so that a more seamless, intelligent, efficient, and potentially profitable set of processes may unfold. Yet what are the implications for wiring up environments in these ways, and how does the sensor-actuator logic implicit in these technologies not only program environments but also program the sorts of citizens and collectives that might concretize through these processes? *Program Earth* takes up these questions and examines the distinct environments, exchanges, and individuals that take hold through these sensorized projects.

THE BECOMING ENVIRONMENTAL OF COMPUTATION

When Weiser made the case that computing should recede into the background, he signaled toward the ways in which environments would become the experiential envelope through which computing would unfold. Computation was to become environmental, or to become even more environmental than it already was. However, at the time of his writing he notes, "Silicon-based technology . . . is far from having become part of the environment," since although "more than

50 million personal computers have been sold," nevertheless, "the computer nonetheless remains largely in a world of its own."[31] The environment that Weiser would have computing disappear into was a very particular type of milieu, one of inattention and everyday activity, an automated surround that did not require reflection or focus. But the ways in which computation becomes environmental are not necessarily always a project of disappearing as such, and Weiser articulated a distinct way of understanding what the environment is or would be as computing became more pervasive.

While Weiser suggested that ubiquitous computing would be a way to enhance reality, and Intel goes so far as to propose that sensor networks will create new versions of the real, I take up the work of writers such as Gilbert Simondon and Albert North Whitehead to consider how these technologies are involved in individuating and concrescing environments, entities, and relations. Simondon uses the term "individuate" to describe the processes whereby individuals and collectives take form as they concretize from a "preindividual reserve." For Simondon, not only are individuals not automatically given but also the process of becoming individual is always incomplete and continues to provoke new modes of becoming and individuation.[32] Whitehead uses the term "concresce" to capture ways in which actual entities and actual occasions are realized and joined up as distinct and immanent creatures.[33] In not dissimilar ways, these writers and philosophers are searching for and establishing a set of concepts that help us approach entities not as detached objects for our subjective sensing and contemplation, but rather as processes in and through which experience, environments, and subjects individuate, relate, and gain consistency.

"Environment" as a term has multiple resonances and genealogies. Within this space of examining ubiquitous computing and sensor networks, I consider specifically how environments inform the development of sensor technologies and how these technologies also contribute to new environmental conditions. Not only do computational technologies become environmental in distinct ways, the environments they populate are also in process. The *becoming environmental of computation* then signals that environments are not fixed backdrops for the implementation of sensor devices, but rather are involved in processes of becoming along with these technologies. Environment is not the ground or fundamental condition against which sensor technologies form, but rather develops with and through sensor technologies as they take hold and concresce in these contexts. Distinct environmental conditions settle and sediment along with these technologies as they gain a foothold.[34] These processes involve not just the creation of the entities and environments that are mutually informed but also the generation of the *relations* that join up entities and environments.

As much as computation becoming environmental, this discussion also attends to the ways in which environments become computational, or programmable.

Following Whitehead, this would be a way of saying that environments and entities concresce through processes of relating (as well as excluding) and as units of relatedness and modes of prehension that involve each other.[35] From this perspective, it is possible to see that Whitehead's notion of concrescence does not entail a simple adding together of preformed subjects and objects into an assemblage, but rather articulates the very processes by which entities are parsed, are able to conjoin (or not), and persist in environments. Relations, furthermore, do not precede the acts of relating and are specific to the entities and environments that concresce. Following Simondon and his notion of concretization, this would be another way of saying that how individuals and collectives are individuated gives rise not just to individuals and the environments in which they form but also the relations and potential—especially collective potential—expressed across those entities.

Far from being passive matter upon which human or nonhuman "sense" operates, environments in this way are an active part of how actual entities come to concresce and relate, how organisms endure, and how values—including those values implicit in technology—are expressed.[36] These distinctions and approaches are important since, in discussing the ways in which environments are sensed and monitored by sensor networks, I am bypassing an automatic understanding of sensors as merely detecting preformed environmental data as though there is a world of substantialist phenomena to be processed by a cognizing device. Instead, I consider how distinct environments and environmental relations emerge, take hold, and are programmed with and through these technologies.

Programming Environments, Programming Sense

Sensing is in fact a key part of the way in which computation works, as described in early diagrams outlining the basic components of a computing machine.[37] From input to logic, memory, control, and output, the five basic components of the von Neumann–influenced computer architecture depend upon sensing as part of the process by which computation works in the world. While the modes of input might consist of everything from keyboards to scanners to microphones, the point is that each of these "peripherals" is engaged in a transformation and conversion process. Sensing (broadly understood) in this arrangement has to do with all the ways in which computers input data into internal calculative processes in order to output data in another form. Sensors (as more specific input devices) emerged within this computational arrangement as just one of many possible devices for inputting data into the machine. With this system of input-output, it would seem that you simply need to get a bit of the environment into the machine, process that input, and output the results for onward action.

Environmental monitoring and sensing are inevitably situated within this computational diagram. On one level, environmental sensors are input devices that facilitate monitoring, measuring, and computing. Yet on another level, environmental sensors can be described as engaged in processes of individuating by creating resonances within a milieu, where individual units or variables of temperature and light levels, for instance, are also operationalizing environments in order to become computable. Simondon uses the term "in-forming" as a way to indicate exactly how information-related processes are also ways of giving form, above and beyond an epistemological project, since for Simondon in-forming involves registers of affect and experience as much as cognition and rationality. Sensing is then not just a process of generating information but also a way of in-forming experience.

The title of this introduction, "environment as *experiment in sensing* technology," speaks to the ways in which programming and programmability are approached in this book as experimental engagements in individuating—through sensing—environments. This is not an experimentalism that requires a control subject in order to understand results against a stable indicator. Rather, it is a more speculative way of asking what new entities and environments concresce through computational and distributed sensors. Programmability, in this way, is approached less as an ontology and more as an ontogenesis,[38] where processes of operationalizing environments put dynamic attributes into play rather than simply writing a script against which a workflow is executed.

In her discussion of the "regime of computation," Hayles suggests a salient characteristic of computation is that it is more than a practice of observing and simulating—it is also a process of *generating* new conditions.[39] While one could argue that multiple practices of scientific instrumentation are also generative, Hayles calls attention to the ways in which—within its own inherent logic—computation undertakes generative, rather than merely descriptive, engagements. Computing computes. It processes data to arrive at another point of synthesis. Programming is a way of making operative. In some ways, it attempts to enable processes of self-replication and automaticity. In other ways, it unfurls processes that are potentially open-ended and even speculative.[40] Throughout *Program Earth,* I address these varying ways of understanding programmability in relation to the becoming environmental of computation to consider how environments become programmable and are made to be operational through sensor technologies, as well as the ways in which they might open into speculative engagements and inhabitations.

"Programmability," as I employ the term, has a somewhat wider use than just software or code. Instead, this expanded engagement with programmability considers how code is not a discursive structure or rule that acts on things, but rather is an embodied and embedded set of operations that are articulated across devices, environments, practices, and imaginations.[41] Programmability then exceeds software (and even computation) to encompass the formation of events, spaces, and things. In this study, I open the concept and practice of programmability out into a question of how environments are generated and made operational through sensors and to the ways in which programmability often yields unpredictable (or unscripted) results.

The Multiple Milieus of Environmental Computation

In developing this analysis of the processual environments of sensor technologies, I work across discussions of environments, milieus, technologies, and sensing practices as found in Simondon, Whitehead, Isabelle Stengers, Michel Foucault, and Georges Canguilhem to consider the implications of how computation becomes environmental, and to what a/effects. I start from a point of understanding environments as made up of multiple milieus. "Milieu" is a term with a rich and long history within the history of science and technology, and as Canguilhem draws out in his arresting analysis of milieus, the term has moved from connoting a mechanical-fluid space, to something like the ether, a seemingly necessary binding agent or surround that would bring entities into communication even if not directly connected, an environment influencing genetic adaptation and evolution, and to the contrary, even an environment to which living entities are indifferent.[42]

Both Simondon and Foucault were students of Canguilhem's, and both use milieu as a way to variously describe spaces of transfer, influence, and environmental inhabitation. Foucault's use of milieu often signals the material-spatial conditions in and through which modes of governance may be experienced and lived.[43] Milieus in this respect have relevance for discussions of power and politics. Simondon used multiple terms in his discussion of milieu, including inner milieu, exterior milieu, and associated milieu. These concepts describe the processes whereby environments and entities are formed across individuals (inner) and environments (exterior) through energetic and material exchanges that occur through the transversal field of the associated milieu.[44]

I take up these discussions of milieus to consider how they become situated and multiple zones of transfer and inhabitation within environments. My use of the term "environment" is perhaps closest to Simondon's exterior milieu, which is one milieu of several that designate spaces in communication. I also draw connections across these discussions of milieu to engage with Whitehead's designation of environment as the processual condition and datum influencing the formation of feeling subjects. Environment and milieu are concepts that are threaded throughout Whitehead's and Simondon's approaches to the processual formation of subjects. In varying but not dissimilar ways, for both Whitehead and Simondon there is no such thing as a founding or original subject that cognizes discrete objects. Instead, subjects concresce together with environments to form subject-superjects, where everything—even a stone, as Whitehead would say—counts as an experiencing subject;[45] or where everything is individuated from a shared preindividual reserve, which includes a preformed collective of nonhumans both natural and technical, as Simondon has noted.[46]

In his rather distinct understanding of "mediation," Simondon develops a use of this term that addresses phases of being and becoming that occur through communication. As an example, he describes a plant communicating and mediating between the cosmic and the mineral, the sky and the ground, taking up and transforming energies and materials through its processes. The *associated milieu* operates as this mediatory space, a transversal ground through which transformations play out and new phases of being emerge. Mediation is not, however, a negotiation between two preformed units, but rather is a process in and through which entities transindividuate through communicative exchange. And it is not simply the entities that are individuated but also a milieu with which these entities interact. As Muriel Combes writes in relation to Simondon, "No individual would be able to exist without a milieu that is its complement, arising simultaneously from the operation of individuation: for this reason, the individual should be seen as but a partial result of the operation bringing it forth."[47]

I take up a parallel approach to how sensors harness energies and materials, transforming their own configurations and the environments they would tap into in the process.[48] Sensors are exchangers between earthly processes, modified electric cosmos, human and nonhuman individuals. The environmental computation that materializes here could be described as individual-milieu dyads that become as they communicate, subject-superjects that concresce as entities, and thereby enable particular environments to materialize and sediment. In this way, I am extending an understanding of communication-as-exchange to address the programmability of environments, the conversions across electronics and environments, and the material redistributions of environments and electronics through distinct phases and processes of individuation.

Planetary Computerization and Media Ecologies

The programmability of the earth and its environments as operation-spaces activates distinct ways of approaching the planet as a modifiable object. However, the earth of *Program Earth* is not a stable object undergoing a certain modification. Instead, one could say that, from *Sputnik* to the multiplicity of networked sensors that have since developed, sensing technologies are involved in parsing and making present certain entities and capacities that are bound up in the relational project of programmability. The "earth," as this discussion so far has suggested, is an entity that might be approached as both an antecedent object or datum as well as an entity in process and formed through modes of individuation and concrescence that enable this entity to stabilize and have consistency—as a unit of relatedness, concern, observation, and experience. The planetary then describes processes of individuation and concrescence that in-form the potential of this entity, Earth, to take hold and be experienced in particular ways. Programmability is one way of characterizing a particular process of individuation and concrescence that activates the planet and its entities as an operation space.

Earthly observations can be generative of distinct engagements and relationships. As discussed earlier, *Earthrise* is typically discussed as sparking international environmental initiatives through a "Spaceship Earth" photographic perspective and a counterculture ethos that was simultaneously a sort of neoliberalism in the making.[49] A planetary perspective can at once prove to be limiting and enabling for environmental practices.[50] It can also be the basis for an "infrastructural globalism," as Paul Edwards argues, that binds certain types of scientific practice together in the interest of understanding the planet as a discrete system.[51]

If the satellite view has largely been narrated as a project of making a global observation system and of seeing the earth as a whole object, then the more distributed monitoring performed by environmental sensors points to the ways in which the earth might be rendered not as one world, but as many. Here are multiple earths, in process, programmed and in operation, unfolding through distinct environmental conditions, sites of study, and responsive inhabitations. Where global observation systems might be working toward a planetary-scale project of knowing the earth as an entire system through (ideally) linked-up data sets,[52] in contrast multiple earths are articulated through numerous distributed sensors that as currently implemented rarely form a "system of systems," and more likely produce discrete and localized data sets for particular purposes. What "counts" as an environment—and Earth—then concresces in different ways in relation to the sensors sensing within distinct conditions.

The multiple "views" or "senses" that environmental sensors concretize might be approached through the machinic polyphony described by Félix Guattari in his discussion of "the age of planetary computerization."[53] At the time of his writing, Guattari suggested there was an emerging age characterized by a "polyphony of machine voices along with human voices, with databanks, artificial intelligence, etc." In addition, "New materials made to order by chemistry (plastic matters, new alloys, semi-conductors, etc.)" would take the place of previous materials. In this age, where time and experience were shifting, "the temporality put to work by microprocessors, enormous quantities of data and problems can be processed in miniscule periods of time." With the new machinic subjectivities that he anticipated would arise, as well as the "indefinite remodeling of living forms" that would occur through "biological engineering," he imagined there would be "a radical modification of the conditions of life on the planet, and as a consequence, all the ethological and imaginary references relating to it."[54]

Guattari captures a sense of how the earth and its inhabitants are remade through planetary computerization. In resonance with Simondon, Guattari identifies how the material, energetic, and machinic conditions that take hold and gain consistency become the basis both for remaking environments and remaking the human-machinic subjectivities that unfold in those environments.[55] In this sense, environments are not merely antecedent objects to be translated through informational devices, but rather are entities that concretize along with technologies. Computerization, in Guattari's view, becomes at once planetary and polyphonous, generating new living conditions, subjectivities, and imaginaries.

As the planet becomes a space of newly modified connections and relations, it also joins up and gives rise to new ecologies. McLuhan described *Sputnik* as a machine for generating ecologies.[56] The programmability that he identified as being key to this proto-remote-sensing technology was bound up with notions of what environments are and what it means to monitor and understand them. Contemporaneous with *Sputnik* and the rise of remote sensing, ecology shifted from an embedded field practice to an informational and even cybernetic undertaking, where the earth materialized as an object of management and programmability.

"Ecology" is a term that has multiple resonances and, as discussed throughout this study, also refers to informational or cybernetic management of environments as much as a philosophy of interconnectedness. Moreover, our post–World War II understanding of ecology is predominantly articulated through communication technologies, systems theories, and information science.[57] Donna Haraway has described how ecosystems, similar to immune systems or organisms, materialize through specific technoscientific practices that are in-formed by cybernetic logics. She therefore suggests a project of "probing the history and utility of the concept of the ecosystem."[58] Numerous texts—many of them referring to Haraway's early insights—engage with the question of how information theory and cybernetics have influenced the understanding and practice of ecology.[59] I draw on these informational and cybernetic approaches to ecology to consider how environmental processes and relations are not only increasingly studied through computational technology but also seen to be analogous to computational processes. Read through devices such as sensors and satellites, and assembled into networks and code, ecology is now a shifting entity that typically becomes visible—and manageable—as information. In this way, such ecologies in-form our lived material, political, and ethical engagements, and they contribute to the scope of our environmental practices.

Clearly, in developing these articulations of environment and ecology, I am also situating this work in relation to research on *media* ecologies. "Media ecologies" as a term and area of media research has expanded from its former associations, where ecologies and environments might have been used rather interchangeably to discuss the at-times deterministic effects that media spaces were assumed to have on subjects.[60] Newer work on media ecologies focuses on discussing the material-spatial conditions of media as part of an extended way of understanding what media are and the effects they have—encompassing but also extending beyond devices.[61] More recent approaches to media ecologies also draw extensively on Guattari's notion of the "three ecologies," which makes the case for approaching ecologies across mental, socio-cultural and environmental realms.[62] Within this space, some work on media ecologies goes so far as to even disavow the use of the term "environment" as a problematic term leaning toward unquestioned environmentalisms.[63]

An important point of clarification that is stressed throughout *Program Earth* is that a practice of attending to the milieus of media technology does not automatically translate into an environmental*ist* encounter with media. While these are often discussed in the same space in relation to sensors for environmental monitoring, I make a point of understanding "environment" as not always already environmentalist in order to consider the distinct ways in which environmentalist practices and politics concresce in and through computation technologies as they become environmental. Environmentalism might then be articulated as a response to having monitored environments, for example, in relation to declining habitat or increasing temperatures. Or it might provide the impetus to monitor in the first place, where sensors are tuned to looking for patterns of change or disturbance, and where data is seen as the necessary resource for motivating political action.

Furthermore, "environmental media" as a term often signals a media-based focus on environmentalist topics and environmentalist modes of representation, or alternately points to the "greenness of media." However, I discuss the becoming environmental of computation through the technoscientific processes that environmental sensors enable, rather than assume that this is automatically a project in sustainability.[64] Computational media unfolds not only through the capacities of devices but also through their environmental entanglements and effects, where material conditions such as soil and air together with circuits and screens generate concrete sensor-entities and experiences. With this focus, I am also building on my previous work that has attempted to draw out the environmental aspects of media by, on the one hand, attending to the atmospheric modalities and milieus of media and,[65] on the other hand, by considering the environmental effects of media in the form of electronic waste, which includes disposed gadgets as well as the extended spaces of mining, manufacturing, use, storage, recycling, and decay in and through which electronics circulate.[66] Computational technologies are constitutive of environments, have environmental effects, and also in-form environmentalist practices.

Program Earth then builds on research into media ecologies while making a distinction between environment as referring to *conditions* that form through multiple milieus, in the first instance, and to ecology as articulating the *connections* that take shape within a milieu and across environments, in the second instance, as a way to develop sufficient analytical clarity to be able to discuss both the connections and the conditions whereby the environmental media of sensors take hold. By making this distinction, I am also working in relation to the descriptions of ecology made within scientific literature, which this study draws on in considering how computational sensors are used to study environmental change and advance engagements in citizen sensing.

As mentioned above, the earth in *Program Earth* is not a whole or singular figure. Instead, the earth articulated here is multiple in the ways in which it is put to work, and in the ways it is drawn into experiences of environmental change, practices of environmental citizenship, and optimizations of urban systems. In this sense, I look at this multiplicity not to celebrate the more-than-singular ways in which earth-ness is animated, but instead to consider how a multiplication and accumulation of programming-earth projects shifts the ways in which the practices and effects of digital media unfold. And one of the primary ways in which I take up these environmental sensing practices is by examining the modes of

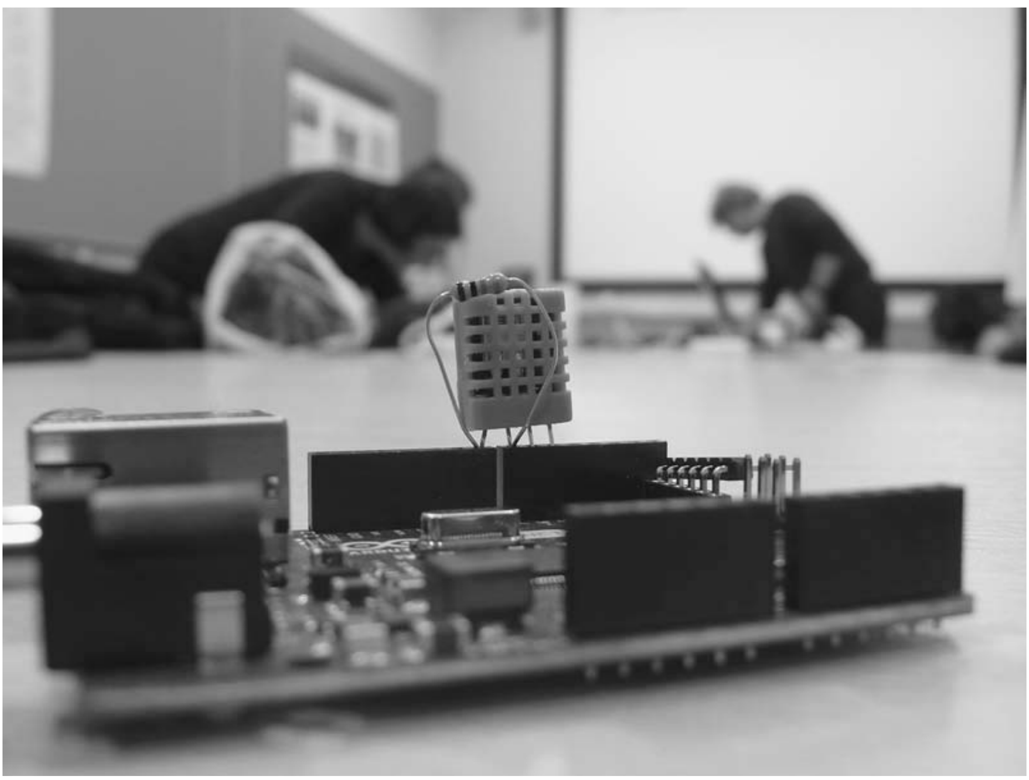

Figure I.4. One basic example of a "DIY" sensor in the form of Arduino open-source electronics with a carbon monoxide (CO) sensor that would typically be found in a smoke detector. Assembled at a citizen-science workshop in London. Photograph by author.

citizen sensing that are expressed in and through the use of sensors. Since many environmental sensor applications are oriented toward understanding environmental change or managing environments, so too do the ways in which environments come to be articulated through sensing technologies have relevance for the types of environmental politics and citizenship that take hold along with these technologies.

FROM ENVIRONMENTAL SENSING TO CITIZEN SENSING

A key tool within ubiquitous computing, sensors are the technologies that make possible the distribution of computational logics beyond the screen and interface to spatial and environmental applications. While sensors have become embedded in everyday spaces and infrastructures, practices of monitoring and sensing environments have also migrated to participatory applications such as citizen sensing, where users of smart phones and networked devices are able to engage with DIY modes of environmental observation and data collection. Beyond monitoring ecological processes, sensors have then become key apparatuses within citizen-sensing projects that monitor air quality, radiation concentrations, noise levels, and more.

Yet how did the ostensibly technoscientific technology of environmental sensors migrate from computational and scientific uses to more everyday applications? And how effective are practices of citizen sensing in monitoring and addressing environmental issues and in giving rise to new modes of environmental awareness and practice? *Program Earth* examines the migration of environmental sensors from ecological research and commercial applications to a wider array of environmental and "citizen" engagements. By analyzing informational ways of understanding environments, I map the trajectory of the computational and informational approach to environments from ecological sensing applications to more citizen-focused undertakings, and to urban and infrastructural developments that join the objectives of sustainability, intelligent cities, and engaged citizens. I further identify the material, political, and spatial relationships that environmental sensor practices enable; and I ask how a particular version of the "environmental citizen" has become entangled within these relationships and practices. The becoming environmental of computation includes processes of making citizens *and* milieus.

From citizen science to participatory sensing, crowdsourcing, civic science, street science, DIY media, and citizen sensing, a number of widespread practices of environmental monitoring and data gathering are emerging that variously work through ways of democratizing the technoscientific tools and understandings of environments.[67] While these terms are used in different ways to stress the scientific, big data, or civic aspects of these practices, I work with the term "citizen sensing" in order to draw explicit attention to the ways in which computational and mobile practices of environmental monitoring might be discussed as modes of citizen *sensing,* specifically.

Citizen-sensing practices have been described as making inventive contributions to both the research and development of technological tools, as well as to modes of environmental monitoring.[68] These practices range from the use of sensor data to complement other environmental observations, including remote-sensing; ubiquitous-computing approaches that often focus on the capacities and practices of sensor technologies to achieve efficiencies; and engagement with social or civic media projects that emphasize the ways in which social networking can mobilize collected data to influence policy and political action.[69] Citizen sensing as I am defining the practice for the purposes of this study encompasses or refers to those sensing activities that use computational sensing technologies in the form of smartphones, as well as mobile and low-cost electronic devices such as Arduino and Raspberry Pi, and online platforms to monitor and potentially act on environmental events through the collection of environmental data.[70] Such distribution of sensing capabilities across sensor networks and multiple mobile and individualized platforms has become a focused site for environmental and technological engagement.

Citizen-sensing projects are often closely related to citizen-science studies, but differ in the ways in which they seek to enable environmental practice through direct engagement with environmental monitoring technologies. Such citizen-sensing applications, similar to citizen-science, are frequently based on practices of individuals voluntarily tracking and monitoring everything from pollution levels to biodiversity counts.[71] Citizen-science projects are even increasingly transforming into citizen-sensing projects, where digital devices equipped with sensors are used to monitor environments and gather data.

In some cases, sensor technologies have enabled more thorough practices of environmental monitoring and observation that have already been underway through citizen-science initiatives, as in counting and tagging biological activities. In other cases, the capacities of sensor technologies have facilitated more distributed and potentially more accurate collection of data, such as urban air or noise pollution. Some applications extend the scope of citizen sensing not only to encompass sensor data and use of smart phones but also to draw on remote sensing and mapping to enable the tracking of deforestation or animal movements. In still other instances, these mobile sensor applications have sparked new forms of democratic organization and communication about environmental issues by effectively crowdsourcing environmental observations in order to influence environmental policy and action.

Another reason for engaging with these practices as *sensing* practices is then to draw out the ways in which computational devices are at once sensing and actuating technologies, as well as modes for sensing and experiencing environments.

Citizen- or participatory-sensing projects often propose to create "shorter circuits" between environmental information and the observers of that information, and in this way technologists and environmental practitioners have suggested that a more direct line of environmental action may be possible.[72] *Program Earth* specifically charts the ways in which citizen-sensing projects configure environmental practice through data gathering and sensing in order to offer a more in-depth understanding of how environmental practices and politics materialize in relation to observing technologies and communication networks.[73] I consider how environmental monitoring and citizen sensing consist not just of observations of environmental change but also of technical, political, and affective practices that are part of a complex ecology of sensing for environmental action.

What is typically activated in this diverse set of practices is a set of proposals for democratizing environmental engagement and developing other ways of doing environmental science and politics. Yet just as many new questions arise about the ways in which citizen engagement with environments and environmental concerns are in-formed with and through sensing technologies. By using the term "concern," I am here specifically drawing on Whitehead's discussion of concern as an "affective tone" drawn from objects and placed in the experiences of subjects.[74] The becoming environmental of computation includes these ways in which distinct monitoring practices and modes of reporting are enabled—and delimited—through environmental sensors, as well as the citizens and publics that would be activated and affected by these technologies and sensing practices.

Working across citizen-sensing projects that take the form of proposals, experiments, and established practices, *Program Earth* examines the ways in which the distributed and accessible capacities of computational sensors are meant to enable greater engagement with environmental issues. It asks: In what ways do computationally based citizen-sensing engagements influence modes of environmental participation? Citizen-sensing initiatives often depend upon forms of monitoring, reporting, managing, and even self-managing in order to establish environmental engagement. How might the practices of environmental citizens as data gatherers be advanced through a more intensive understanding of these modes of environmental and political practice?

SITUATING THE FIELD

From the Internet of Things to the "quantified self," there is a new set of terms circulating that engage with the ubiquitous aspects of digital media. Within this overarching area there are specific studies that focus on the imagined futures of ubiquitous computing, the distributed and spatial qualities of wireless or pervasive digital technologies,[75] and the ways in which sensor hardware and software move computation out of the black box and into the environment.[76] New texts are also emerging that provide an overview or wide-ranging survey of ubiquitous computing,[77] yet these collections often do not focus intensively on issues of environmental sensing and practice.[78] Other texts engage with the use of ubiquitous computing for social activism, for instance, but the focus on environmental topics is also less intensive.[79] These existing ubiquitous computing texts are useful in establishing context for this emerging area of computing, as well as participatory approaches to digital technology. However, I address sensors explicitly as *environmental sensor* technologies, a function that becomes more evident when devices are used for monitoring environments and collecting environmental data. And although the speculative aspects of computational sensors do influence this study, I especially focus on the ways in which sensors are actually being used and deployed.

Program Earth considers environmental sensing as a technological practice that spans environmental studies, digital culture and computation, the arts, and science and technology studies. As discussed above, the becoming environmental of computation includes considering not just how environments concresce along with individuals and objects but also how distributions of experience might be recast in and through environmental processes. Environmental sensing technologies open up new ways of approaching digital technology as material, processual, and more-than-human arrangements of experience and participation.

While there is comparatively less research within digital media studies that focuses specifically on the environmental articulations and capacities of sensors, there is a significant body of literature dealing with social media and the participatory aspects of digital devices, typically in the form of the mobile and online platforms.[80] Research into social and participatory media is a rapidly burgeoning field, where social media are often analyzed through considerations of alternative content generation, community formation, or social change,[81] as well as the politics and practices of observation, control, and tactical intervention.[82] This work forms an important reference point for understanding the rise in participatory engagements with digital media. However, *Program Earth* is situated somewhat obliquely to studies of participatory and social media, in that while it is focused on the political and participatory enablement of environmental sensing, it is primarily oriented toward more-than-human, environmental, and distributed analyses of how citizens and citizen-based engagements are expressed through this distinct set of technologies. At the same time, this research focuses on the ways in which computing has not only moved beyond screens to environments but also given rise to new imaginaries for how to program environments for digital functionality and participation.

Rather than focusing primarily on individual use or content generation for human-led manipulation of Internet- or screen-based media, I consider how environmental sensors variously articulate practices constitutive of citizenship in and through sensed environments that come into formation through an extended array of technologies and practices. Participation, as I engage with the concept and practice, is also a more-than-human undertaking.[83] I investigate how machines, organisms, energy, networks, code, and atmospheres in-form how distributed and environmental computing materializes and operates. Taking up the more-than-human, machine-to-machine, and algorithmic operations of wireless sensor networks, *Program Earth* addresses the proliferation of environmental and computational entities that concretize and participate in wireless sensor networks.

While this research synthesizes and draws on emerging media theories that deal with ubiquitous and participatory computing applications, it also seeks to develop a new terrain for thinking through distributed sensing technologies as articulating distinct modalities of environmental politics and practices. This book makes the case for different approaches to "sensing" within digital media studies, arguing that distributions and processes of sensation might be more effectively understood by not simply collapsing sensation into fixed sensing categories such as sight or hearing. Environmental sensing technologies entail a transformation of the "objects" that are turned into information; to produce information is a technological intervention that generates distinct types of realities, rather than simply mirroring them. With these insights in mind, it is possible to move beyond the notion that environments are something "out there" to be studied and acted upon by citizen sensors with their sensing devices and instead to look specifically at how the spread of informational techniques co-constitute monitored environments and informed environmental citizens. I draw on the work of Stengers specifically as she discusses the philosophy of Whitehead to develop a constructivist approach to environmental sensors to suggest not that environments are "constructed" (in the sense of being concocted) through sensing technologies, but rather that distinct capacities for *feeling the real* are articulated through these monitoring practices.[84]

It is important to note that in focusing on environmental sensing, *Program Earth* is working in a register that is not a phenomenological treatment of sense and sensation. In existing literature, sensemaking aspects of media technologies are often discussed through theories of mediation or individual attention and embodiment.[85] In related approaches, "sensing" is focused on a human subject and often rendered through theories of phenomenological or prosthetic engagement. The difference in this approach pertains to how environmental sensors are not simply providing access to new registers of information for established subjects but are changing the *subjects of experience* as well as the sensing relationships in which subjects are entangled and through which they act. Hence, vis-à-vis Whitehead's notion of the superject, we could say that the *superjects of experience* are also changing. *Program Earth* works to develop new theories of sensing that do not rely on an a priori human-centric subject or mediated subject–object relationship. Sensing here is not primarily or exclusively about human modalities of sensing, but rather has to do with distributed formations and conjunctions of experience across human and nonhuman sensing subjects, in and through environments. Sensing, in this respect, is understood as a multifaceted process of participating, individuating, and concrescing.

Methods and Chapters

Program Earth examines the monitoring and sensing of environments to question how sensing technologies give rise not just to new modes of environmental data gathering but also to new configurations of citizen engagement, environmental relationality, sensing, and action. Along the way, this work raises questions about the politics and practices of sensing that concresce at the intersection of sensor technologies, citizen participation, and environmental change.

Methods used in developing this material include fieldwork at sites of environmental sensing and testing, interviews with scientists and creative practitioners who have developed environmental sensing applications and devices, residencies and fieldwork at scientific field stations and sensing laboratories, ethnography at creative and scientific conferences and events where sensors for environmental monitoring have been exhibited or under active development (e.g., urban prototyping festivals), a visit to a sensor factory, attending and developing events for using sensing equipment to monitor environments, inventories of sensors and tests with sensor toolkits, virtual ethnography of online sensing communities, and an extensive review of environmental sensing literature, media, and practices.

This book works across this research material while developing a theoretical account of how sense, environmental participation, and politics shift through ubiquitous computing and environmental sensing technologies. Working within a radical empiricism modality, I do not "apply" theory to empirical material, but rather attend to the emergent intersections across theory and practice in order to create openings to inventive encounters with environmental sensing, as well as to enable propositions for practice.

In order to undertake this study of environmental sensing and its migration to more participatory applications, I have divided this text into three main sections that address key aspects of environmental sensing, including "Wild Sensing," "Pollution Sensing," and "Urban Sensing." The first section, "Wild Sensing," discusses the development of sensor networks within ecological applications to track flora and fauna activity and habitats and the ways in which these technologies have moved "out of the woods" to be deployed in more urban and citizen-focused applications. Within this section, chapter 1 focuses on fieldwork conducted at one sensor test site, the James Reserve in California. This chapter suggests that these experimental environmental sensor arrangements mobilize distinct sensing practices that are generative of new environmental abstractions and entities, which further influence practices such as citizen sensing. In chapter 2, I discuss two webcams, a Moss Cam and a Spillcam, to consider how images now operate as sensor data, even more than as stand-alone "pictures." Often located as one mode of input within sensor networks, images are generated from webcams and translated into data that can be parsed through image analytics while also drawing citizens into distinct practices of watching and reporting. Chapter 3 examines how the movement of organisms has become a key site of study facilitated through sensors. Migration-tracking sensors provide new data about the movement of organisms while also indicating the distinct environments and environmental relations in and through which organisms are living.

The second section, "Pollution Sensing," addresses the use and adaptation of environmental sensing technologies to monitor pollution, specifically focusing on the use of sensors as tools within creative practice and citizen-sensing projects. This is an area of sensor development that continues to trigger new proposals for citizen engagement in environmental issues. Yet how do these applications influence the becoming environmental of computation, as well as the concrescence of distinct environmental practices and politics? Beginning this section with chapter 4, I discuss fieldwork and observations gathered from my time spent at the Kilpisjärvi Biological Station while participating in an art-science residency. This field station is located within observation networks focused on studying the Arctic and environmental changes that are primarily influenced by climate change. I relate this site to a discussion of carbon and other environmental monitoring projects underway to consider how climate change is sensed and expressed across arts, sciences, and community monitoring practices. Chapter 5 shifts from carbon sensing to garbage sensing, more specifically in the form of plastic debris in the oceans in the form of "garbage patches." In this chapter, I look at the different ways that forms of marine debris that are relatively amorphous and invisible are brought to sense (or not) across Google Earth platforms, iPhone apps, and drifting ocean sensor floats. Moving from carbon sensing to ocean debris sensing, chapter 6 considers the numerous projects and sensors engaged with sensing air pollution. I develop a discussion of how air pollution is distributed across an array of devices and environments and how the data that are generated through pollution monitoring technologies and practices operate as distinct "creatures" of sense.

The third section, "Urban Sensing," looks at the ways in which citizen-sensing applications have become central to the development of the latest wave of smart city proposals that focus on urban sustainability. Smart cities proposals are developing apace, from IBM to HP and Cisco, and new projects are spun out that address not just the development of new intelligent infrastructures but also the compatible inhabitations of smart and connected citizens. How do these imaginings and deployments of environmental sensing technologies across infrastructures and citizens influence urban environmental politics? And in what ways do new versions of digital technopolitics take hold that potentially limit democratic urban ways of life? Chapter 7 takes up these questions by focusing specifically on governance and power as they are distributed through the new milieus and environments of smart cities. Using the notion of "environmentality" to describe these spatial power dynamics, the chapter asks how visions for an efficient and sustainable city might restrict urban practices and modes of citizenship. Chapter 8 considers the versions of participation that are enabled within DIY digital urbanism projects and platforms and explores the ways in which the "idiot" operates as a noncompliant digital operator and figure that does not participate as intended. Chapter 9 takes up the speculative aspects of smart cities and digital infrastructures as they are built to ask how sensor networks enable distinct types of withness in these new urban environments. I conclude *Program Earth* with a reconsideration of how planetary computerization might point toward expanded ways of engaging with sensor networks as generative of experimental worlds and speculative practices.

Each of the chapters within these sections deals with distinct deployments of and participations within sensing systems while engaging with these technologies as actual concrescences of computation and distributed arrangements of environmental sensing, practice, and politics. Across the chapters, there are multiple grounded instances of sensor technologies used in environmental projects that organize monitoring, facilitate participation, and manage urban processes. In each of these examples, the political implications of how sensing systems inform environmental practice and participation, as well as become enrolled in distinct ways of life, are articulated and addressed. While I have emphasized the becoming environmental of computation, the aspects of citizen sensing as they are expressed within environmental sensing projects are no less important, as they are intimately connected to the ways in which environments and environmentalisms materialize. Moreover, citizen engagement is a recurring lure and organizing device for enfolding people into sensing projects.

Ultimately, this book sets out to advance the conceptual understandings of environmental sensing—and the possibilities of sense—through a theoretical and empirical engagement with technologies and practices of sensing, citizenship, and environmental change. *Program Earth* explores the assertion made by a diverse range of researchers and practitioners that distinct practices of observation connect up with and enable distinct political possibilities.[86] It asks: How do different sensing practices operationalize distinct affective and political capacities? And what are the ways in which these computational sensors *become environmental,* as they take hold and create new feelings for the real?

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