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From Moss Cam to Spillcam

Techno-Geographies of Experience

Web cameras are now a common technology for remotely viewing ecological processes, including everything from animal activity to freeway traffic. Cameras fix upon phenomena that may be studied over time or in absence of direct human intervention. Any number of organisms, from falcons to badgers and turtles have been "caught" on camera while undertaking migratory or nesting activity that may have been previously unrecognized. These image-based modes of monitoring are also meant to provide important information for protecting organisms.[1] Similarly, web cameras may be used to report on and monitor environmental calamities, as was the case with the British Petroleum (BP) oil spill in the Gulf of Mexico.[2] Concerned onlookers could focus on the ruptured pipe connecting to the underground oil well and watch a steady plume of oil spilling into the Gulf. Image capturer, reporting device, surveillance technology, and visual sensor: the web camera increasingly operates as a generator of environments of attention and concern.

In this chapter, I first address the proliferation of cameras—from web cameras to camera traps, animal-borne cameras and eco-drones—for environmental study and engagement. Rather than discuss cameras in the context of the proliferation of visuality and images, however, I focus on the ways in which cameras, images, and image practices are remade into sensors, sensor data, and sensor practices. As much as they produce images of environmental activity, cameras also operate as sensing and measuring devices, converting physical stimuli into electrical signals that transform into sensor data within extended sensor networks. Cameras-as-sensors concresce as distinct technical objects and relations, and in the process they articulate environments and environmental operations. The becoming environmental of computation, in this case, includes the invention of a "technogeographical milieu," as Simondon calls it,[3] where the webcam is involved in constructing distinct environments that are both technical and geographical.

Web cameras, camera traps, animal-borne cameras, and eco-drones now operate within sensor networks, and the images they produce are often processed as another mode of (image-based) sensor data. These shifts in the practices of processing image data as sensor data are productive of sensor environments that create distinctly different engagements with *imaging,* not necessarily as an a priori fixation of visuality, whether as an epistemological or disembodied register,[4] but instead as a processual data stream that irrupts in moments of eventfulness and relevance across data sets comprised of multiple sensor inputs. Image sensor data, in this case, is part of sensor *systems.*

In this chapter, after first briefly discussing a range of cameras-as-sensors that are in use in environmental study and engagement, I go on to consider the distinct modalities of sensation and environment that webcams articulate. Engaging with long-standing science and technology studies and media theory discussions of visuality, I focus on two renderings of sensation across cameras and sensors in the work of Donna Haraway and Katherine Hayles. In her discussion of the "Crittercam," a camera affixed to organisms, Haraway discusses processes whereby cameras are involved in the "infolding" of sense and how this might reorient the ways in which we consider the "sight" of cameras. Hayles considers how the "distributed" sensation of RFID tags, as a version of a passive sensor, influences the animation of environments and changes the agencies of sense.

I work through these two discussions of sense and technology to consider how sense is embodied and distributed across more-than-human entities (as discussed in chapter 1) and examine how environments are critical to the generation of sense. In this way, I consider how sensor environments shift a focus from *bodies of sense to environments of sense.* As discussed in the introduction, this is another way of engaging not only with the becoming of *subjects of experience* but also with the *becoming of superjects of experience.* Importantly, the way in which I am encountering environments is not simply as a place or site, but as a processual condition that is individuated along with sensing technologies and subjects. Webcams and other cameras-as-sensors operate as technologies that generate new modes of sensor data while also individuating new relations and possibilities for relations within and through environments.

From this perspective, I then consider two rather different web cameras and the ways in which they articulate specific techno-geographies of experience. The first camera, Moss Cam, was briefly discussed in the last chapter as one of several webcams located in the James Reserve ecological study area. On the one hand, this webcam offers distinct ways of thinking about biomonitoring and phenology, where sensors gain access to—or experience—environmental data vis-à-vis a close relationship to monitoring organisms that are expressing changes in environments.

In this sense, the sensor network crosses electrical, physical, chemical, and biological registers of experience. Yet, on the other hand, the Moss Cam operates within a wider array of sensors and sensor data, and is one of several webcams that have been a point of public engagement with ecological research. It is these sensor relationships and sensor environments that I expand upon in the context of the becoming environmental of computation, where webcams become part of sensor systems.

In comparison to the Moss Cam, I consider Spillcam, a webcam that captured a plume of oil leaking into the Gulf of Mexico from the the Deepwater Horizon oil spill that occurred on April 20, 2010. BP made Spillcam available for public viewing as the result of a direct request by U.S. senator Edward Markey through the now-disbanded Select Committee on Energy Independence and Global Warming.[5] Markey argued that the live video feed should be available for the American public to monitor progress being made toward stopping the oil and gas leak and to assist scientists and engineers in estimating the flow rate of the spill.[6] BP made the live video feed available on May 19, 2010, nearly one month after the blowout, and it became an immediate source of public attention. While the Spillcam was made available to attempt to make an image of environmental catastrophe into an actionable and accountable object, the image data captured by Spillcam proliferated into multiple other effects and relations.

Figure 2.2. Cornell Herons Pond Cam in Ithaca, New York; a webcam that is part of the Cornell Lab Bird Cams project. Additional birds that may be observed via webcam include barn owls in Texas and Laysan Albatross in Hawaii, among many others. Screen capture.

From Moss Cam to Spillcam, here are two different versions of monitoring and sensing set in motion. Based on a comparative discussion of these two web cameras, I conclude this chapter with an expanded consideration of the ways in which cameras-as-sensors generate techno-geographies of experience. I ask: What are the distributions and individuations of sensing that concretize through Moss Cam and Spillcam? How do these image-sensor-milieus create and express experiences beyond the visual- and human-oriented toward other operations of sense? And how do these cameras-as-sensors generate distinct environments and environmental practices? In other words, what are the ways in which these camera-sensors become environmental, as they make specific techno-geographies of experience?

CAMERAS, CITIZENS AND THE SHIFTING PROCESSES OF IMAGES-AS-SENSORS

Web cameras now make available a vast array of creatures that would typically elude detection. From pine martens and shrews, to bear and deer, salmon and hawks, raccoons and wolves, any number of organisms can be tuned into, whether through cameras at ecological study centers, national parks, zoos, or even individual back yards, as well as Wildlife TV offered up on holiday retreats. Web cameras focus both on the relatively near-at-hand, including squirrels and garden birds, as well as the remote and difficult to access, including whales, polar bears, snow leopards and even (purportedly) Big Foot. It is also possible to take a DIY approach and install your own webcam, for instance, in the form of a bird cam complete with a nest box that connects a camera feed to a television set. One slightly more epic project even proposes to link up animal webcams in a sort of "Interspecies Internet." Similar to the Internet of Things, the Interspecies Internet would allow one to tune in to a worldwide distribution of organisms and interact with them—where for instance, one could sing along with bonobos as they play piano accompaniment from their remotely located home in the zoo.[7]

In addition to web cameras, there are multiple other imaging techniques for sensing and capturing data about organisms and environments. Camera traps are a common and typically more low-tech method for capturing images of rare animals in order to estimate animal populations.[8] This method has most frequently been used to estimate densities of large cats such as tigers, where camera traps will be located in sites with obvious animal activity, such as paw prints or scratch marks. A typical camera trap consists of a thermal or infrared motion sensor, camera and flash, as well as data storage that allows data to be downloaded on a periodic basis.

Animal-borne cameras are now in frequent use as well, where organisms from household cats to marine animals are affixed with cameras, often along with GPS trackers. With these methods, image journeys are created that are meant to provide clues about animals' habits and spatial journeys.[9] Eco-drones are also emerging as yet another camera-based mode of sensing, where wildlife can be surveyed from an aerial perspective and illegal poaching monitored. These practices, along with all of the above mentioned image-based techniques for monitoring organisms, are often presented as key ways in which to study creatures in order to protect them, although most frequently the emphasis is on nonintervention and noninteraction in order to study creatures "in the wild." And this is the point at which public engagement can also come into play, where people may gain access to organisms without apparent interference or disruption.

From the standpoint of public engagement, the mass viewing of secretive creatures often constitutes a residual or secondary use for web cameras, where they are deployed within scientific study in much different ways and for different purposes. Indeed, what is striking about so many webcam video feeds is that nothing seems to be happening, and it is difficult to "make sense" of the images in any usual way. Beyond the frequent error messages, broken links, and notices that video feeds are offline, typical views captured consist of images empty of any obvious activity, including nests that have been vacated or forest scenes that are studies in a minimalist composition.

As I write this text, I am watching a webcam of barn owls on Wildlife TV.[10] In the frame is a sleeping owl, still as a statue. Flies and midges scatter across the camera lens, feathers and dung line the floor of the nest box, and a square light at the back of the frame indicates that beyond this view there is another world in waiting past the entrance to the box. Some time later, the barn owl stirs, paces, spreads his wings once, then twice, and launches in a seemingly grandiose gesture merely to move to his stoop, another space of waiting. Many images and video clips made available of sighted animals are selected as "highlights," where a notable activity does occur. These highlights are often silent, even black-and-white night shots, and feature glimpses of animal motion, typically a moment lasting from thirty seconds to a few minutes, capturing some scurrying and nosing around, a flash of glowing eyes, and a swift exit into some other space.

Within the larger span of inactivity, human viewers of webcam images become pattern detectors and image analyzers as they wait for signs of activity, which is detected and reported in forums focused on organisms of interest. Indeed, new scientific data has emerged from "armchair" citizen scientists watching web cameras, who, for instance, have witnessed a Great Horned Owl attack the nest of a sleeping Great Blue Heron at 3 a.m. and emailed a report of the activity to scientists at the Cornell Lab of Ornithology who set up the cameras. Here, someone keeping watch over a bird in the small hours of the night detected new data, since in this case the heron made an intense screeching sound to ward off the owl, and this particular heron vocalization had not previously been recorded.[11] Between eight and ten million people watch the webcams set up by the Cornell Lab,[12] and these citizen scientists watching webcams are "filling in the dots," since "all these little data points get put together and then we see a larger picture."[13]

Commenting on another instance of a citizen scientist making a new discovery, this time of an elephant seal eating a hagfish witnessed vis-à-vis an underwater webcam, Steven Mihaly, staff scientist at Ocean Networks Canada, notes, "We have reams and reams of this video data that we could try to mine using data mining techniques, but the best data miners we know out there are people like you—the citizen scientists."[14] Watching, identifying, counting: the work that algorithms, machine learning, or lab techs might otherwise perform becomes the occupation of vigilant webcam watchers, citizen sensors of sorts, who might be as attentive to moments of significant data capture as they are to the attachments they form with distant creatures. Here are images, not framed and fixed, but rather in process and operationalized. Citizen sensing becomes a project of intensive if distant watching, and web cameras become sensors in an extended network that connect up environmental phenomena with actions of detecting, analyzing, and reporting.

Scientific Observation and Practices of In/visibility

Nature is what happens when we are not there, or this seems to be the message with many of these imaging technologies. From the remote to the out-of-hours to the inaccessible or hidden, cameras cross into spaces and temporalities to "sense" what would otherwise be unapproachable. It is by now well established that scientific observation often takes place through visual modalities, which access phenomena beyond the usual registers of human sight.[15] Yet in this case, rather than micro- or macrovision, what unfolds is a mode of vision that attempts to absent humans. Gregg Mitman discusses how the camera and technologies such as biotelemetry and Landsat imaging made possible the active monitoring and protection of "nature" seemingly without human intervention. These sensing devices not only allowed humans to remain relatively remote and distant—even "invisible"—from their sites and objects of study, but the scale of the devices also allowed "the researcher to integrate instruments 'as part of the living system.'"[16] However, human participation and intervention emerged in other ways through the assumed absence of people from wilderness spaces and the perceived need to manage these spaces toward this end.[17]

The objectivity of images, the invisibility of human intervention, the ways in which automation or distributed sensing might provide a greater fidelity to ecological processes: these are currents that have run through science and technology studies and feminist technoscience engagements that examine how images operate within and beyond scientific practice.[18] Stengers suggests that an important move in the study of science and technology is to take seriously the claims made by these fields, since this may open up new or experimental ways of thinking about questions and problems posed and the facts that take hold in particular environments. In another way, Haraway undertakes this project by reworking the "modest witness" of scientific observation to consider how to "*refigure* the subjects, objects, and communicative commerce of technoscience into different kinds of knots."[19] Rather than approach vision or scientific observation as presenting a "view from nowhere," Haraway seeks to demonstrate how the embodied and situated encounters we have with visual technologies can provide an entry point for generating other knowledge practices.[20]

With these situated viewing practices in mind, I turn now to consider one particular visual technology—the Crittercam—that Haraway discusses in just this way as an embodied and situated encounter, and compare this to Hayles's discussion of distributed sensing, drawing these together into a consideration and proposal for a particular environmental approach to sensing that reworks how we might describe the operations of cameras-as-sensors. Beyond visualizing the invisible or gaining access to activity that typically goes on in the absence of humans, I suggest that cameras for ecological study are generating new modalities of sense, participation, and environment that exceed the usual considerations of in/visibility and non/intervention.

Crittercam and Infolding Sense

Haraway analyzes the technosensorial implications of webcams through a discussion of Crittercam, a project developed between marine scientists and National Geographic that involves affixing video cameras to various creatures, from whales to sharks to clams (and eventually to land animals), to capture images and details of these organisms' habitats.[21] She focuses on marine deployments of animal-borne cameras, and moves through the different forms of sight that are articulated through the coupling of animal, camera, and often-distant human viewer.

The National Geographic description of Crittercam indicates that this animal-borne camera is "a research tool designed to be worn by wild animals. It combines video and audio recording with collection of environmental data such as depth, temperature, and acceleration."[22] Not simply creating images, the camera is part of a project that produces multiple forms of sensor data, which complement the images gathered. Similarly, the project material notes:

> These compact systems allow scientists to study animal behavior without interference by a human observer. Combining solid data with gripping imagery, Crittercam brings the animal's point of view to the scientific community and a conservation message to worldwide audiences.[23]

The Crittercam produces both scientific data and an appeal for conservation. Haraway addresses these aspects of how the material hardware, the data, the animals, scientists, and more are involved in a complex set of encounters that attempt to provide more information about marine environments and which unfold into a heterogeneous set of relations.

Beyond cameras peering upon animals and their habitats, or humans acting in a simply voyeuristic manner, Haraway suggests that technologies and bodies (of humans and more-than-humans) become articulated as "'infoldings of the flesh.'"[24] The possibilities of perception, in her (post-)phenomenological-inspired account, occur through the meetings of bodies—whether human, more-than-human, or technological. These infoldings are zones of interaction, contact points from which "worldly embodiment" emerges.[25] For Haraway, the emphasis is not on a human sensing-subject who decodes images of animals but rather on the bodily and material meetings (and all that facilitates these meetings) across technologies, humans, and more-than-humans.

These sensory encounters also produce the possibilities for inhabitations, where mutual embodiment is a process of making worlds. From this vantage point, she considers how the Crittercam as a technology is both "always in formation," as well as "always compound."[26] Sensation occurs at the ongoing meetings of *multiple* bodies—to be multiple is to multiply, or to generate shared (compound) experiences and worlds.

Crittercam is a relevant point of departure for this discussion of camera-as-sensor, since with this device Haraway moves from an analysis about the *viewing of* others into a technological relation that involves *becoming with* others. Moving from sensation as a process of perceiving objects to a shared if asymmetrical practice, she articulates how these infoldings occur through the "flesh"—and this flesh, these bodies, and the possibilities of sensation are undertaken together in lived experiences. Haraway's account moves toward unsettling the human as a fixed processor of sensory stimuli and instead considers the collective creation of sensory worlds. Yet is it possible that the worlds that are constituted through these infoldings are more than flesh, and that shifting sensory modalities are not only infolded but also always becoming concrete as *environments* through these processes? Haraway's discussion signals toward but passes over the matter of "worldly embodiment." Yet what worlds not only come into being but also shift to in-form new possibilities of individuals and infoldings through these camera and image encounters? I suggest that the *worldly* aspects of embodiment that are so much a part of this becoming together might also require a more detailed consideration of the role of environments—as processual techno-geographies of experience—in expanding these sensory tales.[27]

RFID and Distributing Sense

Haraway's analysis of the bodily shifts that occur at the meetings of Crittercams, more-than-humans, and humans demonstrates how these technologies are not just reporting devices but rather are generative of experiences and material relations. Indeed, technologies such as cameras and the wider range of sensors and radio-frequency identification (RFID) tags now proliferating in environments do much more than simply allow for new modes of distant observation and data gathering. In addition to shared or remote modalities of sense, cameras and sensors redistribute the locations, agencies, and processes of sensing operations. Hayles suggests that "an animate environment" now surrounds us that is involved in producing sensory information in and through which humans are but another contributor to sensory processing.[28] Sensor technologies not only gather information but also perform distributed sensing processes for which direct human intervention or participation may not even be necessary.

Hayles speculates that humans might even potentially become rather marginalized within sensor environments that form their own sensory exchanges. The implications of such distributed sensing potentially may then involve experiences other than infolding sense. As she writes,

> Combined with embedded sensors, mobile technologies and relational databases, RFID destabilizes traditional ideas about the relation of humans to the built world, precipitating a crisis of interpretation that represents both a threat to human autonomy and an opportunity for re-thinking the highly politicized terrain of meaning-making in information-intensive environments.[29]

With these formations of ubiquitous and embedded computing, Hayles suggests that sense is distributed within and automated throughout environments in ways that challenge human sense-making. Sensory processing is not directed through human sensing-subjects primarily but is instead located throughout automated sensing processes. As it is decoupled from human subjects, sensing as a process of making meaning, and of generating capacities to make sense and act on information, can occur beyond the realm of human intervention. Indeed, many of the cameras trained on environments are not connected up to human bodies or eyes, but rather work through image analytics to detect patterns and send alerts when significant change is detected. In this case, cameras-as-sensors could be seen to operate in ways that Hayles identifies: as seemingly autonomous agents that are recasting practices of sensing and interpretation.

While webcams and related sensor technologies might raise issues of surveillance and monitoring,[30] surveillance is not the only issue to which these technologies give rise. In other cases, early work on web cameras focused especially on new qualities of telepresence, or the ability to know things from a distance.[31] Distance presented a new way of understanding mediation: as sensation understood through a more filtered and remote rather than immediate engagement.[32] Mediation, however, is a term that typically suggests the relative fixity of subjects and objects in an exchange of information—with the filtering process seemingly acting as the location of transformation.

Both surveillance and telepresence are arguably, as Hayles suggests, ways of encountering technology that "are primarily epistemological," or issues about "who knows what about whom."[33] But while monitoring is an important part of the operations of sensor technologies, it may be overemphasized at the expense of also taking into account a range of other sensory processes. Shifting sensor environments present issues that are as much ontological as they are epistemological.[34] Ontologies of sense—and the environmental practices and politics to which they give rise—are then a necessary point of focus for understanding the orientations of these technologies.

Moving from Hayles's observations to those of Simondon, moreover, we could say that an animate environment presents an *ontogenesis of sense,* where such distributions require rethinking sense toward process and practice. Rather than see humans as marginalized entities within animate and sensing environments, we might then consider how human sensing practices are in-formed and individuated differently, how they concresce—even more than infold—with technologies and within environments in different registers. In this way, sense ceases to be an ontologically prior category or relation, where the five human senses are but a rough guide for understanding how sensation becomes possible. Sensor technologies can be understood as in-forming ontological processes that make sensation possible, as well as generating entities and environments that take hold through these sensory processes.

Webcams and Environments of Sense

Distributed sites of sensation, as discussed in chapter 1, include a rather heterogeneous range of participants that contribute to sensory processes, from humans to more-than-humans, technologies, sites, and more. These environments of sensation suggest an alteration to the trajectories through which sensorial encounters are configured, so that sense—or experience—is not exclusively about immediacy or coming into contact but instead also refers to sensory capacities that concresce in relation to *environments* of sense.[35] Experience occurs within a techno-geographic milieu, since it unfolds within technical and geographical conditions that are further generative of worlds, environments, and relations.

Environments do not necessarily refer to a fixed *sense of place,*[36] in this respect, but rather involve the making of distributions and articulations of experience. Environments, furthermore, are not the static ground across which species-sensor encounters are located, nor are they containers for these meetings. Rather, they are a critical contributor to the distributions and possibilities of sense—as informed and in-forming milieus.[37] More than the bodies of humans, animals, and technologies infolding to form sensory capacities and meetings, by attending to techno-geographies of experience it might be possible to consider how bodies are not the only zones of sensory formation and processing.

Such an approach, where environment might be understood as a more dynamic condition, further resonates with Simondon's discussion of the techno-geographical milieu. In this sense (not dissimilar to Whitehead's focus on subject-superjects of experience), Simondon attends to the ways in which distinct environments concretize along with the unfoldings of particular technical objects. Simondon notes that a technical object is a unit of becoming, and this becoming extends not just to the evolution of the object itself but also to the environment in and through which it is sustained and interacts.[38] However, this is not simply a project of making environments but rather involves the production of processes that ensure the continuation of those environmental conditions that sustain technical objects. The production of a machine involves the production of an external milieu along with the possibility for these entities and relationships to recur and have a shared effect.[39] This is what Simondon refers to as a techno-geographical milieu.[40]

The technical milieu of the technical object works in relation to a geographical milieu where its operations are translated or transduced. In forming a transductive relation with the geographical and meteorological world in order to perform its operations, the technical object is also acting on that world, just as the geographical world is in-forming the technical object. Neither a dialectical stance nor a simple humanization of nature, Simondon describes this process as one whereby the technical object concretizes the meeting of these worlds, which are not one and the same, and may even be in conflict with one another.[41]

Simondon makes the point that as both an adaptive and concretizing process, the technical object expresses while also creating particular environments that may have had a latent or virtual presence and that spring into life at a certain critical point in the operation of a technical object. This is the point at which a "concretizing invention"[42] generates a techno-geographic environment, which supports the further functioning of the technical object. A viable technical object is the very vehicle through which the possible integration of the technical and geographical is able to occur—it in-forms these shared milieus and it exchanges energy across them so that they become interwoven and creative of new environments and conditions for technical functioning.

Techno-geographies then describe a particular process that resonates with the becoming environmental of computation. Simondon focuses on traction engines and audiometers and electric clocks in the context of his study of milieus and the relative situation of technical objects as elements, individuals, or ensembles. In a different way, I move this discussion of techno-geographies into a consideration of computational sensors to include a focus on the camera-as-sensor that is not just a technical element but also a sort of technical individual, which is expressive of the milieus in which it operates. This discussion also seeks to build on the variations of technologies and sense as discussed by Haraway and Hayles: how infoldings and distributions of sense might create further inquiries into techno-geographies of sense. Environments of sense play an important role in thinking through sensor technologies, including the web camera. I now discuss this techno-geographical orientation in the context of Moss Cam and Spillcam. The Moss Cam and Spillcam might be understood as sensors that are within and constructive of environments, producing visual and other multisensory records of sites, but also making new formations of environments.

MOSS CAM: IMAGING AN ECOLOGICAL OBSERVATORY

Moss Cam—the first web camera I discuss here in the context of techno-geographies of sensing—tracks the processes of *Tortula princeps,* or Star Moss, at the James Reserve. Discussed briefly in the last chapter through the sorts of biosensing and biomonitoring that can be understood to occur through mosses, this particular web camera–sensor is at work in a larger sensor network at the James Reserve. The Moss Cam is a sensor in the form of a web camera, a device that is by no means new or unusual, except in this deployment as part of a sensing lab it begins to raise new questions about the creation and use of environmental images as a form of sensory data within an expanded sensor system.

The James Reserve Moss Cam is one of many web cameras fixed on sites of study, including a Meadow Cam, Creek Cam, and Bird Cam.[43] This pervasive form of remote viewing is commonly found at work in sites of ecological study. Yet web cameras now operate as one of an assortment of sensors for ecological monitoring, which include acoustic, CO_2, light level, and temperature monitoring devices.[44] Although primarily gathered for ecological study, at the time of this fieldwork the moss images were also viewed by interested publics via a website and online repository of images.[45]

The Moss Cam has its gaze fixed on a granite boulder speckled with mounds of Star Moss, which moves in and out of phases of lush green active photosynthesis and patchy brown senescence. Star Moss is a species of moss that is particularly desiccation tolerant and has the ability to dehydrate over the course of months or years and yet regenerate and begin photosynthesis within five minutes of exposure to water.[46] The Moss Cam allows for a long-term continuous observation of the patterns of dehydration and rehydration that characterize the Star Moss lifecycle. The Moss Cam consists of both a video camera and infrared camera, coupled with a weather station that provides data on temperature, moisture, light, and CO_2 levels. Sensor technologies track the chemical, physical, and biological interactions within these ecosystems from a detailed and on-the-ground perspective. Sensation and the environmental formations that concretize here are relational and dynamic processes.

While the web camera is constantly trained to the boulder, allowing any visitor to the James Reserve website to observe the latest state of the moss, it is also set to automatically capture images of the moss at least once per day, and as often as every fifteen minutes, and stores a record of the moss up to 35,040 times per year. In this continual tracking, questions arise regarding how best to manage data, and whether automatic harvesting is the best use of sensors, or whether a more particular or opportunistic use of sensors to gather data at expected times might be devised. Yet in the continual tracking that is made possible, observations potentially also become available not just to scientists but to anyone anywhere who might access particular data sets online. The James Reserve includes a "virtual observatory," with archived data from underwater ecologies to auditory signatures of woodpeckers.[47] Such ecological and virtual observatories are the format through which many sites of environmental interest throughout the world are increasingly made available as remote visual experiences or data sets.

While a web camera, by virtue of being a camera, might be construed as a representational device, in its operation as a sensor, within an extended sensor environment, it operates more as an "imager."[48] As an imager, the web camera activates alternative practices of sense that are connected up with networks of sensory monitoring. This sensory data is crosschecked and compared across data sets and even connected up with other data sets formed from remote sensing images. The images generated in the Moss Cam ecological observatory operate less as pictorial, scenic, or representational registers of environments, and more as continual data grabs. No single Moss Cam image stands alone. Instead, it is plugged into sensory performances and capacities that compare and relate the ecological processes of moss to its own ongoing development and its responses to local conditions.

The Moss Cam documents the daily processes of a patch of moss through an interconnected network of sensors that create a dynamic picture of environmental conditions. Images of moss growth and senescence form a detailed report of this microenvironment at a moss-covered boulder in the James Reserve.[49] The images gathered from the Moss Cam are not typical depictions of organisms, however, since the data are gathered in recurring sequence and understood in relation to other ecological sensing data. In this way, distinct data relations and ecologies concretize through webcam images. These are the techno-geographies that are generated through the operations of cameras-as-sensors.

Characterized less by a comprehensive view and more through amalgamations of sensor data and processes, where one image is a moment articulated within a larger set of relationships, these images as sensor data become dynamic accounts of changing relationships within specific sites, and they fuse together as particular renderings of environments. These images are not fixed representations of environments, but rather are temporal markers of visual sensing data within larger data sets—the environments that can be read through these images must be assembled and compared within and in relation to other data sets and processed through image analytic techniques: environments that concretize are not captured in one image but are formed through shifting relationships across sensing technologies, data, sites, ecological study, and practice, and the more-than-humans that inhabit these sites.

In order to understand the phenology, or seasonal timing of mosses, it is also necessary to compare the time of year, temperature, moisture levels, and light levels, among other data, in order to establish which changes may be occurring—and may be detectable—through this sensory data. These sensory relations become the basis for understanding environmental processes, where a sensory arrangement of moss dehydration, CO_2 levels, and light and temperature levels, as captured through sensors that gauge these phenomena, may be assembled in a distant database through which new sensory practices and questions may arise. The continual capture of images, rather than a single or even sequence-based rendering, in-forms the basis for understanding ecologies—the relationships between organisms and environments. But it also becomes a way of rendering environments as both processual and multisensory arrangements, which are remotely and automatically sensed in the field, and which publics in turn encounter through ecological observatories and websites.

The field of sensory relations multiplies through these studies, as does the need to compare sensed criteria: the time-sequenced imaging of moss is only one aspect of its study, which also involves comparing a wide range of environmental data from many different sensors. These multiple sensors provide a general sense of environmental conditions, and images provide the basis for refining

Figure 2.3. Moss Cam with weather station at James Reserve. Image and infrared data are compared to weather observation data to understand the moss lifecycle. Photograph by author.

observations and estimates in relation to moss growth. This "sensor fusion" provides a more nuanced way to ask ecological questions about the distribution of moss, including why it follows particular distribution patterns, and why it prefers a particular niche. The sensor arrangements and deployments are set up in order to reach toward a better understanding of the ecological processes of moss. Such ecological observatories redistribute sense not necessarily as a single or even infolded zone of contact but rather as a processual relay of relationships, cross-checked and compared, and made possible through the techno-geographies of sensor environments.

Ground Truth

The Moss Cam images and data present the opportunity to "ground truth" other data that is collected through remote sensing. Detailed, on-the-ground observations provide a way to corroborate more distantly gathered data, and so these views from the ground are seen to offer a truth, or "truing," of more abstract observations. Remotely sensed images are typically "cleaned up" based on a number of assumptions and are not necessarily comparable to the fine-grained sensor data captured "on the ground," through microsensing technologies. The concrete environments of sensing then become an important part of how ecologies are understood.

More abstract models and projections might allow for speculation as to the relationship between increased levels of CO_2, increased temperatures, and moss growth, but sensor devices such as the Moss Cam offer a way to study the detailed patterns of growth and responsiveness of a distinct organism in situ. Since traditional methods of studying moss often involve working in a controlled chamber in a laboratory, there is a risk that the study of moss, including the use of sensors, would destructively modify the organisms under study. In order to measure moss CO_2 respiration, it is necessary to have the measurements take place in situ. The environment—and the ecological interactions and processes that occur there—is an important part of the sensory practices for studying moss. Sensing ecological processes is an interaction that requires not necessarily a sensing subject and a sensed object, but rather involves fields of response and resonance that might need to be read through other subject-superjects of experience and practices of detection.

The ground of ground truth is not, however, the final point of resolution in these sensor environments. Instead, it is a reminder of the constant need to draw connections across phenomena. Ground here is connection and concretization. The specificity of observations becomes a way to correct or correlate more remotely sensed data. Ground truth sensor data is then a much different perspective from which to understand environments, in comparison to those more global or aerial views that might guide both ecological study and environmental imaginations.[50] Sensory practices are bound into forms of environmental understanding, and so are "situated," as Haraway has suggested.[51] Situated sensing and seeing refer not just to the embeddedness of researchers but also to the concrescence of entities and prehensions that form an expression of any given milieu. Sensor technologies may be observing a designated ecological site, but sensation also occurs between humans and more-than-humans, where the status of moss at any given time may be an indicator of the changes it is sensing. In this way, the empirical measurements of the environmental conditions of moss express a multispecies sensing of environments, as discussed in chapter 1.

This change of focus is not to remove researchers or humans from the sensory environments (who are also "embedded" in their own ways), but rather to consider in greater detail the distributions of sense within the extended environments where the Moss Cam is located. Visualizing and imaging (among other sensory modalities) are situated and distributed practices, located across a technogeographical sensorium of ecological research sites and sensor technologies, website and publics, organisms and sensor data. Such multilocatedness shifts the focus on sensory modalities from ecology-technology to a field of sensory relations that

Figure 2.4. Spillcam example footage. BP video from Remotely Operated Vehicle (ROV) monitoring the plume of oil, gas, and mud escaping from the ruptured BP pipe. Screen capture.

might be seen as a specific techno-geography that is articulated through any given webcam. In this way, environments and ecological processes concresce in relation to technologies. Webcams tune into and take account of particular environmental processes, and the image data they generate are further synthesized with other sensor data, forming subject-superjects of experience. The objects sensed are not just immediate data or encounters but also a non-sensuous field of perception that is part of the "vague" conditions in-forming the possibilities of sense.[52]

SPILLCAM: IMAGING AN ENVIRONMENTAL DISASTER

As mentioned in the introduction to this chapter, Spillcam emerged as a live image of the Horizon Deepwater oil spill, which resulted from an offshore oil rig in the Gulf of Mexico exploding due to a buildup of methane in the drilling riser. The explosion led to the worst oil spill to date, with an estimated 4.9 million barrels of oil leaked—at one point over 88,000 square miles of the Gulf were closed to fishing.[53] Spillcam was the publicly accessible live video made available from remotely operated vehicles (ROVs) that BP used in its attempt to stop the leak, but which became a site of environmental monitoring and call for accountability and transparency.

Markey, who requested the live video be made available, argued the feeds were not the sole property of BP, but rather that the public had "a right to the information that they contain and to be able to see for themselves BP's progress in containing this ongoing environmental disaster."[54] As the offshore oil well involved drilling in the deep ocean, the actual scale and volume of the leak was relatively undetectable. Located five thousand feet underwater, the ruptured pipe and blowout preventer could only be accessed through ROVs, which captured footage of the spill.

Not only would the live video feed provide a tool of public accountability; it could also, Markey suggested, be a scientific research tool, where "our best scientists and engineers" could be provided "with information that could be helpful in developing much needed solutions to the ongoing oil spill, both in terms of subsea operations and surface spill response."[55] When the live video feed was made available on May 19, 2010, it purportedly received upwards of one million views, crashing the Select Committee on Energy Independence and Global Warming's website and temporarily putting the House of Representatives' web system out of order.[56] Spillcam became a popular reference point in news media, and as it received viewers in the millions, the number of sites hosting the live feed also multiplied to three hundred or more, and "Spillcam" entered the English lexicon as a top word for 2010.[57]

As the Spillcam captured and transmitted images of oil leaking from an underwater pipeline in the Gulf, it simultaneously became a way to make BP accountable to publics, while also providing a way to visually monitor the rate of the leak and the likely composition of the material flowing out—whether oil, gas, or mud. At the time of its going online through the committee's website, a message announced, "You are watching a live video feed of the BP Oil Spill from the ocean floor, 5000 feet below the surface," as well as a disclaimer: "Please note that these live streams may freeze or be unavailable at times."[58]

Real Time

The single Spillcam feed multiplied into twelve Spillcams as numerous viewpoints from ROVs were sought to observe and study the plume of oil gushing into the Gulf and the rate and volume at which it was flowing.[59] From Ocean Intervention III, to Viking Poseidon, Boa Deep C, Skandi, Enterprise, and Q4000, the ROVs that provided the video feeds streamed real-time footage of the plume of oil as it drifted through the Gulf. Public fixation upon the video footage, as well as anger and concern about the disaster, was writ large in multiple forum posts on websites that featured the live video. The *Huffington Post* logged a total of 1,038 comments, with proposals to show the live feed in Times Square 24/7 and make BP show the feed on flat screen televisions in every window of every BP gas station across the country. At the same time, there was concern that the video feed provided a false sense of transparency and that the camera views were presented so as to show the least damage, or that since BP was controlling the feed, anyone watching it would be increasing site traffic through BPs websites.[60]

In contrast to the ground truth that the Moss Cam camera-as-sensor is meant to provide, here in the water and spill-filled depths of the Gulf an attempt at providing accountability through a real-time live video feed becomes a site of questioning. The real-time flow of Spillcam images introduces uncertainty, indeterminacy, and even a restless but seemingly helpless fixation. One commentator in the *Washington Post* suggested that watching Spillcam was like viewing a horror film crossed with Andy Warhol's *Empire,* where "there is no sound and nothing happens, except the inexorable, unending flow. You watch a little, and then a little more, and then you can't stop watching as a steady plume of dark brown oil belches upward from the floodlit, rocky ocean floor."[61] Unlike cinema, however, the Spillcam was not a representational narrative or documentary record, but rather a real-time image that captured the ceaseless flow of oil into the Gulf.

Embedded within an urgent flow of events, the Spillcam became a technogeography of experience, expressive of real-time environmental emergency. Colors of the spill were watched closely as indicators of the progress of the environmental disturbance: the darker the plume the more likely oil was seeping out, the more muddy in hue, the more likely the oil was being stopped and drilling mud and other sediment were the primary effluvia. Drawing on Helmreich, we could say that the "'empiricity' of the spill" played out not just through evidence of oil on the shoreline and models of oil-in-seawater movements,[62] but also through

Spillcam images that tied into these techno-geographical systems of sensing and experience that made the oil apprehensible. Real-time images captured through Spillcam made this technical object into a particular type of camera-as-sensor—working alongside other sensor systems while also organizing attention toward the environmental catastrophe that was unfolding. In the process, observing becomes an experimental action, a real-time generation of a sensory system.

In the confusion of blown-out rigs and leaking oil, toxic dispersant and devastated marine life, loss of livelihood and loss of life, the live video feed provided a shattering if steady stream of images of oil gushing into the deep sea and ROVs at work attempting to plug the well. At the same time, scientists monitoring the site were using any number of methods to assess the volume and rate of the plume, often through sensing techniques that were not visual but rather were acoustic, chemical, geolocated, temperature-based, and focused on producing a molecular "fingerprint" of the oil and gas hydrocarbons in order to trace oil found throughout the Gulf and link it to the BP spill.[63] Attention was directed toward studying the flow of currents with gliders communicating to satellites and with

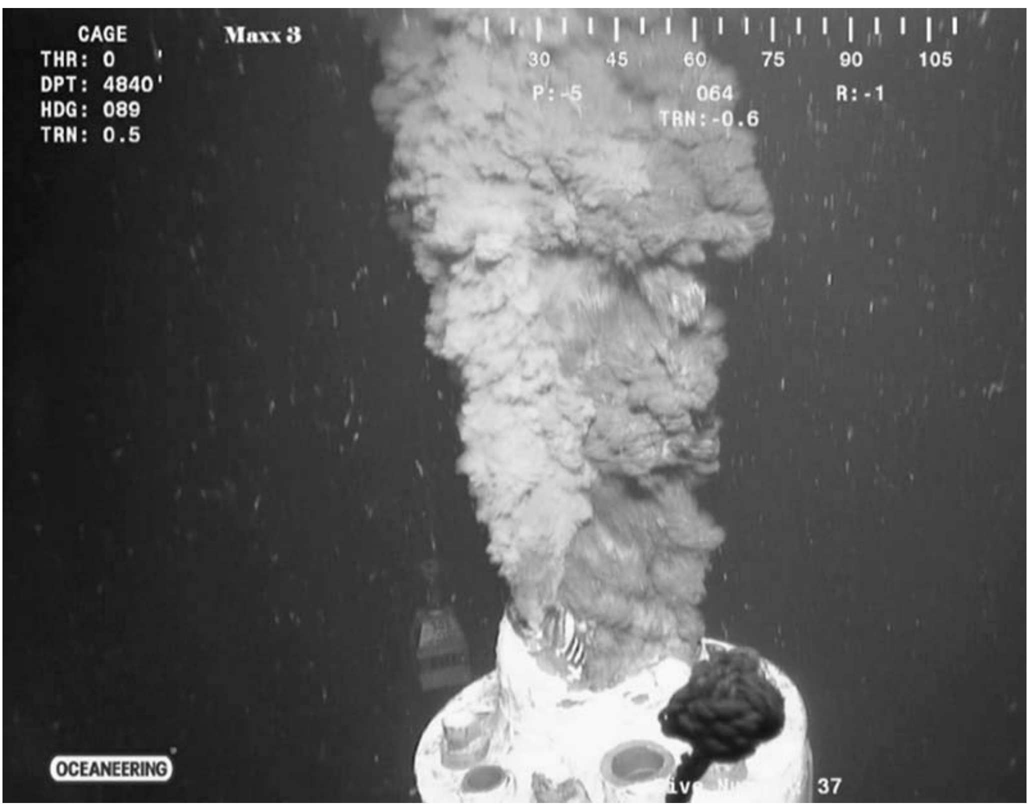

Figure 2.5. Additional Spillcam footage, as captured by the Oceaneering Remotely Operated Vehicle (ROV) monitoring the BP Deepwater Horizon well and broken pipe. Screen capture.

drifter cards retrieved by citizen scientists, as well as to assessing the impact of oil on deep-water coral and benthic organisms.[64]

These various projects that focused on providing more "clarity" within a complex environmental disaster operated alongside and in another register to the Spillcam images. Although the leak was eventually stopped on June 15, 2010, and the well was capped on September 19, 2010, the effects of the oil spill continue to play out in the Gulf region, where human and more-than-human health are affected in ways that are not yet fully established are still being revealed. The "ground-truth" and "real-time" accounts that sensors, whether as images or other forms of marine data, are able to provide is not a clear and easy project, since this is an environment that is shifting and will continue to change as hydrocarbons settle into organisms and ocean sediment, bodies, and instruments, which will continue to individuate in this transforming environment of sense and experience.

TECHNICAL MILIEUS AND AMPLIFYING ACTIONS

Spillcam presents a much different point of view than Moss Cam—the latter, a still, green, and seemingly uneventful moss-boulder slumbering within an ecological study area; the former, a temporary if dynamic instrument of environmental disaster and accountability. But each camera or compound of cameras operates in a more sensor-operationalized milieu and less as an individual and fixed representational image. Each camera-as-sensor articulates different environmental processes. They are bound up with the becoming environmental of computation through image-sense events that produce much different operations and inhabitations of "vision" along with multiple other forms of sensor detection.

In *The Five Senses,* philosopher Michel Serres suggests that we attend to environments and spatial practices as characterized more by "visits" rather than views.[65] With this provocation in mind, it is possible to approach the becoming environmental of computation in a way that does not unify into a singular visual frame, but rather engages with a multiplicity of sensing in and through technogeographies of experience. With web cameras used for ecological study and citizen sensing, this multiplicity of environments and experiences concresces across ecological study, technological sensing, data collection and processing, public engagement, and environmental action.

Rather than discuss the complementary or alternative contributions that may be made through the expanded array of human senses, from hearing and touch to smell and taste, the distributed sensing of sensor technologies creates an entirely different arrangement of sense. The camera as sensor, imager, and program operates within a sensing environment that is not delineated according to human bodily senses but instead within units of measurability and comparison.[66] Sensing concresces through conditions of fusion, generality, ground-truth, real-time, and transformations across organisms and environments. In this respect, sensing takes place more as a program or operation rather than a process of mediation between subjects and objects. Here, sensing occurs not as a hierarchy of the five senses but as a distinct set of contingent relations that make possible practices ranging from scientific empirical assessment to environmental action, and where processes that may be detected give rise to communication to diverse publics about environmental change.

But these expanded practices of sensing require more elaboration—even within a visual framework. For instance, the Moss Cam, as part of an ecological observatory, is not just a visual technology, it is also a "machinery" that establishes a processual engagement with imaging.[67] "Objects" become expressed as information through processes and infrastructures that enable organisms and environments to be transformed into digital entities. The practices and technologies that facilitate the entry of a so-called "natural" object into a dataspace (such as the lizard discussed in chapter 1) and the sensory or visual processes whereby these transformations are made might even be referred to as a "digitectomy,"[68] where in order to make certain creatures visible or relevant—in this case, sensible as digital objects—they must find expression within distinct practices of scientific seeing.[69]

While an approach that emphasizes the heterogeneous if multiple sites and processes through which organisms are processed and transformed to become observable articulates a compelling map of sense-based transformations, there is still the notion that preprocessed organisms exist, organisms that might be available to literal seeing, but not visible within (constructed) scientific spaces. Arguably, this analysis focuses on scientific processes that render their object visible, whereby natural objects are made into legible items of scientific relevance. Might this view also focus on the ways in which interpreting human subjects make objects relevant for study through observation and instrumentation? If we return to the discussion in chapter 1, however, we might consider how the experiment is always involved with the experience of subject-superjects. Such an approach moves beyond discussions of the real or the constructed to a consideration of the registers of interpretation and experiential arrangements that are put into play with and through sensing practices—which do not, furthermore, hinge on establishing the veracity of a substantialist object for a human mind to decode.

This study on the Moss Cam, Spillcam, and their extended sensor environments then decenters the human subject as the primary locus of sensation and considers how sense data concresce through environments of sensibility and subjects of experience. The points of sensation discussed here are not so much about "nature" being transformed into "data" but rather about how the collecting and processing of data—these programs of sensing—in-form and contribute to the ways in which sensing becomes superjectal, or to how subjects of experience arrive at subject-superjects of experience. This approach also signals the ways in which sensory relations hold together *as processes*. Most importantly, this is a way of considering how facts, organisms, ecological processes, and computationally enabled image-sensors come to have a foothold within particular environments. Organisms are not constructed into digital entities, but rather, organisms concresce and are encountered through computational environments and environmental attachments. In other words, these organisms would not exist without the environments in and through which they are individuated and concresce.

In this sense, new environments come together through sensor technologies—through the altered perspectives, practices, and ontologies set in motion through these sensory processes.[70] To understand these different sensory concretizations of environments, it is useful to consider alternative accounts of sensory operations that occur across bodies, environments, and technologies. Sensing as a techno-geographical project offers up a different material arrangement that displaces bodies as sites of processing and sensing. Bodies constitute distinct if different sites of sensing within a more distributed set of sensor relations. Such sensing operations revise ideas about embodiment or mediation, since not only is there no originary experience to be mediated but also there are many sites through which sensing and experience occurs.

There is a diverse range of sensory studies, briefly signaled at the beginning of this chapter, which move through visual and other sensory modalities to connect up with other possible relational practices. While embodiment has served as a way to rethink visual technologies by challenging the notion of a detached observer, there is still much work to be done in thinking through what new "situated knowledges," as Haraway suggests, might gain a foothold at this juncture. In this respect, María Puig de la Bellacasa suggests, in relation to Haraway's situated knowledges, that by "affirming the embodied and situated character of material and semiotic technologies of vision" it is possible to also "affirmatively transfigure the meanings of objectivity and open possibilities for committed knowledge practices."[71] Haraway contrasts the view from nowhere with situated knowledge, "the view from a body," which challenges the free-floating and disinterested gaze of science.[72] For Bellacasa, this suggests a practice of touch, of "knowledge-as-touch" that would circumvent the possibility of knowing from nowhere.

But this body, which importantly locates sensing and knowing in one type of fleshy-site, may require even further situating. Not only is sensing superjectal and techno-geographical, it is also individuated in distinct ways in relation to the sites, bodies, and technologies that meet there. As the Moss Cam and Spillcam cameras-as-sensors demonstrate, the meetings of technologies, organisms, and sites are situated, individuated, and concresced in environments that are also on the move in these sensory formations and techno-geographical milieus. And it is these very sensory formations that further in-form our ability to respond to environments from a committed inhabitation.

The committed position that opens up through situated knowledges raises a final question about how superjects of experience organize human participation in citizen sensing and even environmental politics. The "armchair" citizen scientists discussed at the beginning of this chapter describe one type of environmental practice that concretizes at the techno-geographical juncture of webcams and more-than-humans, as well as watchful human participants. Sensor-generated ecological data is often gathered with the purpose of articulating more exactly the scale and details of environmental change, but here monitoring extends to include other types of citizen interventions. These watchful humans are seen as vigilant "live eyeballs," as well as caring participants who might even be able to make citizen arrests if they see poaching occurring—where, for instance, drones, webcams, or traffic cameras could capture wildlife trafficking of elephants, rhinos, or large cats.[73]

There is an "ethos of ecological monitoring," as Helmreich has suggested, where sensor technologies act as the "eyes" watching over environments under study.[74] To observe is to watch over, to attempt to mitigate harm, and to act in time to prevent environmental calamity. The fine-grained, pervasive, and constant quality of these observations in-forms our sensory practices in relation to environments: always on, always aware, and constantly gathering information. While Helmreich draws on McLuhan's assertion that media technologies alter our sense ratios and make possible distinct practices within these media environments, the question remains as to which sensory and environmental practices settle in relation to sensor technologies.

It may be that these sensor environments of ecological monitoring comprise an even greater store of information from which to act, where the politics of sensing across these distributed and pervasive sites seem to influence even more extensive possibilities for environmental action. Yet the risk is that monitoring could become an end in itself, where sensory data amasses in excess, but these often-distant sites of ecological study present detailed sensory datasets that do not translate into environmental practice. One way to test this concern may be to return to the sites of sensation and to consider the ways in which infoldings, distributions, and environments of sense may recast the scope of our multiple and diverging environmental engagements.

As I have suggested in this discussion of the Moss Cam and Spillcam, these sensor environments move discussions of sensation—and environments—beyond mediated/immediate, nature/culture, or direct/indirect to cross over into infoldings, distributions, and techno-geographies of sense. These sensory operations do not rely on a framework of mediation, where sensing subjects decode objects of sense, but rather they point toward dynamic formations of sense that concretize through distinct techno-geographical relations. As Combes has written in relation to the milieu of technics:

> It is Simondon's virtue to have seen that technics *as network* now constitutes a milieu that conditions human action. Out of that milieu, we need simply to invent new forms of fidelity to the transductive nature of beings, both living and nonliving, with new transindividual modalities for amplifying action. For, in our relation to preindividual nature, multiple strands of relation—to others, to machines, to ourselves—entwine in a loose knot or node, and that is where thought and life come once again into play.[75]

Techno-geographies offer up not just an approach to working through the generative meetings of technical objects and environments but also to the forms of relation that may become sites of invention and amplification. In his discussion of techno-geographical milieus, Simondon is not insisting on a particular relation to environments, but rather is searching for new relationships to technology.[76] His work indicates how, in our techno-geographical milieus, environments and technology might be co-constitutive. The webcam, seemingly an agent of description, representation, and nonintervention, might actually in-form engagements, while environments also in-form webcam processes. From "armchair" citizen science to biomonitoring to petropolitics, the webcam-sensor operates in a modality of "technical culture" and techno-geographical experience, which are further generative of practices that become self-sustaining. In this way, we could ask how cameras-as-sensors concresce with environments, relations, and technical systems, and what possibilities there are for connecting up with worlds of sense that these devices would make present and actionable.