5

Laboratory/Observatory

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INTRODUCTION

In considering the settings where geographical knowledge is produced, the laboratory and the observatory appear, at first glance, as places safely ignored. While geography developed as a science describing and explaining variation across the earth's surface, laboratories, it has been argued, are spaces designed precisely for *overcoming* geographical variation, chiefly through experimental technologies and rhetorics of replicability and standardization. It is perhaps the mark of their success that knowledge produced in laboratories appears to come from nowhere, and to be applicable anywhere. The observatory, another great fixed site of modern science, has historically been oriented toward what is now 'outer space', not the terrestrial sphere of geography. As spaces for science's technological instrumentation, and as models for the organization of scientific work, the laboratory and the observatory would also appear to contrast sharply with those modes of spatial organization more commonly associated with the making of geographical knowledge, such as exploration, survey, and reconnaissance – all premised, seemingly unlike laboratory work, on the spatial mobility of the observer.

We do not tend to imagine the makers of geographical knowledge as residing in laboratories. Daring or blundering explorers, plucky fieldworkers, tweedy academics, yes, but a team of investigators in white lab coats, or engineers with clipboards and coveralls? These figures are caricatures, of course, but to the extent that they either meet or unsettle our expectations about the subjects of geographical knowledge, and about the diverse spaces where geographical knowledge is made, they can be highly suggestive. How has geographical knowledge been transformed in science's recent technological revolutions, and by the institutional transformations that have reshaped the modern scientific landscape?

This chapter explores the nature of geographical knowledge as a laboratory product, particularly after the rise of laboratory-based Big Science in the mid-twentieth century. It also raises questions about how laboratories and other sites of observation have themselves been transformed to accommodate geographical scientific practices. The laboratory genealogies of remotely sensed geographical imagery – the tip of the iceberg of a rapidly transforming, geo-referenced knowledge base (Cloud 2002; Pickles 2004) – are still easily taken for granted, whether in geographic information systems or more widely distributed Internet-based mapping systems. Meanwhile, as the evolving nature of the observatory – and space-based platforms for earth observation, and unprecedented outer space visualizations – has stretched the terrestrial limits of the observatory, the relations between the earth and the heavens, a long standing concern of ancient and early modern geographers, have once again become increasingly difficult to disentangle (Livingstone 1992; Cosgrove 2001; MacDonald 2007). The 'final frontier,' as Peter Redfield (2000: 259) has observed, 'is less "finished" than reduced to the level of function, for human space now extends into outer space, with the planet itself woven into a vast technical system of satellites'. Taken together, a historical geography of laboratory and observatory, albeit sketched very loosely in this chapter, suggests not only the persistence of the laboratory but its widespread diffusion, in hybrid forms, in the trajectories of modern geographical knowledge production.

Before turning more explicitly to these trajectories, the chapter proceeds in the next section with a brief reconsideration of the laboratory as, in Knorr-Cetina's (1992) terms, an *enhanced* environment for producing natural knowledge and objects. If the laboratory works, in this sense, as a peculiar 'reconfiguration of the natural and social order' (Knorr-Cetina 1992: 113–14), then clearly the nature of laboratory sites and practices have shifted considerably over time and space. Actual laboratories, in practice, encompass a wide range of settings – not only places for housing experimental apparati but also as sites for scientific, technical and medical manufacturing and processing. At the same time, laboratory practices have not remained *only* at laboratories, as we conventionally think of them; they have been distributed to different social sites, and across disciplines and professions. We live in a world of testing and simulation, experiments and proving grounds. The earth itself has been fitted out to be something like a laboratory (or so we are told!), and the changing dimensions of geographical knowledge are part of these developments. Following a discussion of the interpenetration of laboratory and field sciences, the second half of the chapter turns to two profound transformations of geographical knowledge in the twentieth century: the transportation of laboratory techniques to the field in twentieth-century ecology (and later ecosystems ecology and earth-systems science); and the cartographic revolution launched by satellite and remote-sensing technologies. The purpose of the chapter is therefore to trace some of the more general transformations in the settings of scientific practices, pairing the rise of the laboratory and modern observatory with broadly changing geographic fields of vision.

SCIENCE'S WORKSHOPS

Laboratories, like geographers, are easily caricatured. In popular imagery, one characteristic that stands out is a sense of spatial separation or 'boundedness': the sterile environment of a modern biomedical laboratory, the secured gates and passageways of a classified weapons laboratory (see Figure 5.1), or alternately, the social isolation of the Victorian 'country physics laboratory.'[1] The need for separation is of course often a practical matter, reflecting requirements for setting controlled conditions for experiments, spaces free of biological contamination, secured settings for secret military or industrial research, and spaces for storing and operating valuable and bulky machines. But the development of tropes of separation in the laboratory sciences is also the result of the cultural work of scientists themselves, who have often been at pains to set their work apart as separate, in the landscape and within built environments as well as in its cognitive authority, from intervening influences. The history of the

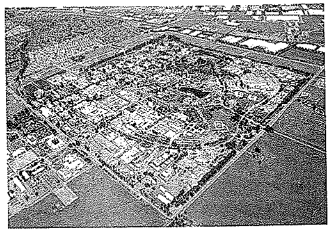


Figure 5.1 Lawrence Livermore National Laboratory,occupying one square mile of land forty miles southeast of Berkeley, California, was constructed on a site which had been used to house a particle accelerator as part of the Manhattan Project. Before that, the site had been in use as a naval air station.

Source: Lawrence Livermore National Laboratory [llnl.gov (public domain)].

laboratory as a site for concentrated scientific and technical work, however, is not just a story of isolation from external influences; the enduring cultural power of the laboratory as a bounded space suggest not a separation from but rather the intricate and subtle interconnections between the laboratory and its larger social worlds.

Laboratory has its etymological roots in *laboratorium*, from the turn of the seventeenth century, as in a specialized site for particular forms of labor; that is, a workshop. Science's early modern workshops could take shape as relatively private spaces within an otherwise public household, as Livingstone (2003) describes the workspace that the English natural philosopher John Dee carved out from his family residence, or it could be defined by more complex spatial arrangements, as exemplified by the separate street access to Robert Boyle's basement laboratory, which provided a separate entry point, from otherwise posh Pall Mall quarters, to accommodate the need for the public (albeit socially regulated) witnessing of Boyle's experiments (Shapin and Schaffer 1985; Livingstone 2003: 21–29). Shapin's (1988) analysis of the circulation of experimental practices within and across different kinds of scientific spaces also sheds light, in particular, on the relational qualities of scientific spaces, and the patterns of circulation between workshops for private experimentation – places for tinkering with things, for getting the experiments to work properly – and more public settings for experimental demonstrations and rhetoric. But while experimentation has, perhaps ever since, occupied a central place in notions of the laboratory, it is also important to recognize the persistence of different but related meanings that the laboratory has come to embody. *Webster's* for instance, in its first definition for laboratory, indicates 'a building, part of a building, or other place equipped to conduct scientific experiments, tests, investigations, etc., *or to manufacture chemicals, medicines, or the like.*'[2] The two processes – experimentation and manufacturing – were indeed intertwined in the rise of the modern scientific laboratory.

While laboratories have for long functioned as productive workshops for scientific and technical knowledge, invention and artifacts, it was during the so-called laboratory revolution of the mid- to late-nineteenth century, against the backdrop of rapid industrialization in Europe and North America, that laboratories became more strongly associated with technical manufacturing and industrial methods. Aided by improved microscopy and other new technologies of instrumentation and experimentation, the laboratory came to acquire greater prestige during this period as the pre-eminent site for investigating natural phenomena in expanding areas in the life sciences such as animal and plant physiology. At the same time, the commercial, military, pharmacological and public health applications of laboratory products created new demands, and new opportunities, for the industrialization of laboratory processes. Thus, Pasteur's development of an anthrax vaccine at his Paris laboratory in 1881, the result of interplay between the laboratory and agricultural sites of the anthrax cattle disease and, ultimately, the extension of specific laboratory techniques to the farm (Latour 1983), was organized not just as a space for experimentation but also as one of production tied to the extension of laboratory products across rural France.

In Germany, to take a nearby example from the same era, industrializing cities fitted out with gas lines provided the settings for the small power engines that were becoming *de rigueur* for the new 'factory–laboratories' of experimental physiology, churning cranks attached to machines which simulated aspects of bodily motion, breathing, and circulation processes, and helping to produce a regularity of force that matched well with industrial ideals of precision and standardization (Dierig 2003). The physiology laboratories did more than just draw power from the new industrial infrastructure; they also borrowed industrial modes of organization for managing the increasing volume of laboratory work. The physiologist Emil du Bois-Reymond, for one, sought explicitly to direct his Berlin institute 'like a factory', modeled, most likely, after departmental divisions of labor in the Siemens & Halske Company, when he established separate units under the management of department supervisors, physiologists, laboratory assistants and other technical workers (Dierig 2003). It can be assumed that, by the time the US established its Bureau of Government Laboratories (later Bureau of Science) in Manila, Philippines, in 1901, tasked with a battery of chemical and biological tests for gauging the nature of America's new tropical possessions (e.g., of tropical soils, food and crops, water, coal and minerals and vast quantities of bodily emissions) for various branches of the colonial state, *and* the extraction, processing and bottling of serums (Anderson 2006), the intertwining of experimentation, materials processing and manufacture had been normalized in the mission of the large-scale government laboratory. These trends would persist in the expansion of large-scale

industrial research laboratories in the United States during the late nineteenth and early twentieth centuries, from Edison's Menlo Park laboratory to the Bell Labs, which bridged the transition from traditional workshop to industrial management methods.

The multiple functions of the modern laboratory can be considered together through what the phenomenologist Knorr-Cetina (1992) calls the configuration model – or 'processing approach' – for understanding the laboratory sciences. For Knorr-Cetina (1992: 116), the laboratory is 'an enhanced environment which improves upon the natural order in relation to the social order'. Through the development of a range of social, experimental and machine technologies, laboratory settings allow for the isolation of natural variables, the reshaping of relations between people and things, and a reconfiguration of nature *as* new objects opened for interpellation. This reconfiguration, she argues, has relied on three key advantages provided by the laboratory wherein some of the fundamental limits of nature may be practically transcended: (1) nature does not have to be accommodated *as is*; it can be investigated in partial forms; (2) natural objects do not have to be accommodated *where* they normally reside (i.e., in their local ecological settings); they can be brought to the laboratory in different forms and investigated or processed there; and (3) events do not have to be examined only *when* they occur naturally; natural processes can be replicated to allow for continuing investigation. Thus, 'escaping the need to accommodate objects within the natural order … is epistemologically advantageous; it is the detachment of objects from a natural environment and their installation in a new phenomenal field defined by social agents' (Knorr-Cetina 1992: 117). Before exploring the question of how geography's natural objects may be extracted from the earth's surface and installed elsewhere, it is useful to turn briefly, with Knorr-Cetina, to the case of astronomy, which constitutes an important forerunner to the rise of Big Science in the twentieth century, and which is also suggestive of the centrality of image processing in the contemporary earth and environmental sciences.

Astronomy was in some ways at the vanguard of the industrialization of scientific knowledge production during the late nineteenth and early twentieth centuries. Investment in large telescopes, and the development of vertically structured research organizations – which included unskilled and semi-skilled (and gendered) divisions of labor, along with mechanized data collection procedures – contributed to the making of the modern observatory as a proto-site for the large-scale, heavily capitalized, coordinated research projects that would, after World War II, become known as Big Science (Galison 1992; Lankford and Slavings 1996). The development of photometric and spectroscopic techniques enabled the wholesale acquisition of data at sites such as the Dudley and Harvard College Observatories in Massachusetts, the US Naval Observatory in Washington and the Mount Wilson and Mount Palomar Observatories in Southern California, facilitating the publication of vast catalogs mapping tens of thousands of stellar observations. Some of these same observatories, with the support of the Carnegie Institution, still sponsored astronomical *expeditions* for viewing the southern skies from, for example, Peru and Argentina, and worked toward the establishment of new observatories in South America and the Pacific in the first decades of the twentieth century. But astronomy was no longer limited to direct observation by telescope; imaging technologies – made possible by investment in large-scale scientific technology at the observatories, and the emerging planetary network of observatories – allowed the objects of astronomical research to 'become detached from their natural environment and … made to be continually present and available for inquiry in the laboratory' (Knorr-Cetina 1992: 118). Thus reworking scales of space and time in the business of data collection and analysis, Knorr-Cetina argues, the field of astronomy shifted from one organized, in the first instance, around field observation, to an 'image processing laboratory science'.

Such changes were not limited to the starry fields of astronomy – it is precisely the similarities between astronomy and the experimental laboratory sciences, each reprocessing bits and pieces of nature across transitory states, to which Knorr-Cetina draws our attention (1992: 127), as kernels of nature are put through standardizing processes, 'smashed into fragments, made to evaporate into gases, dissolved into acids, reduced to extractions, mixed up with countless substances, shaken, heated and frozen, reconstituted and rebred into workable objects'. The laboratory and the observatory, in this view, persist as workshops of a kind, dedicated settings for nature's scientific and technical overhaul. These practices are not, however, fully contained within the physical, architectural space of the laboratory. While the rapid growth of Big Science during the second half of the twentieth century was significantly anchored to laboratory settings, the *lab* has also become something more socially generalized as well. Knorr-Cetina's description of the emergence of laboratory techniques in matters as diverse as psychoanalysis and military war games underscores this point; the laboratory has also become a virtual space coexistent with practices of experimentation, simulation and scientific manipulation.

Laboratories have traveled, in this sense, as methods; that is, experimental technologies and epistemologies adapted to the field, but also, it should not be overlooked, as communities. For many environmental scientists today, the lab is thought of as a research working group, a relational community rather than a brick and mortar scientific laboratory, although such labs of course still require certain spatial and technical infrastructures to function. The colloquial modern abbreviation of 'the lab', when used to describe a research community, however, even with its interesting removal of *labor* from the *laboratory*, still draws its metaphorical power from traditional laboratory settings, including the classroom laboratory. Returning to *Webster's*, this social diffusion of the laboratory turns out to be reflected in an expansive, secondary definition of laboratory as '*any* place, situation, or set of conditions … conducive to scientific experimentation, investigation, observation, etc.,' or, for that matter, 'anything *suggestive* of a scientific laboratory.'[3] The next section of the chapter turns to the intersection of the laboratory, and laboratory methods, with external environments, and in particular to the twentieth-century transformations of North American ecology and cartography which remain, in some ways, at the heart of twenty-first-century geographical knowledge.

LABORATORY EARTH

Laboratory Earth continues to grind out the answer – experimentally. Schneider 1996: 96.

The very idea of 'the field' in the biological sciences, the historian of science Rob Kohler (2002) suggests, may have been product of the mid-nineteenth-century laboratory revolution in physiology, a new category for describing scientific settings which were *not* the laboratory. Although laboratory- and field-based sciences are often considered in opposition to one another, a number of recent studies, including Kohler's *Landscapes and Labscapes*, have begun to focus instead on the evolving interconnections between the two orientations, in the environmental as well as the engineering sciences.[4] Kohler explores in particular the intellectually productive 'lab-field border zone' in biology, illustrating how laboratory methods have shaped scientific practices in the field, both directly and indirectly. This was the case in the wake of the nineteenth century, as field scientists – *née* natural historians – sought to keep pace with the increased prestige and credibility of the laboratory sciences, turning to increased quantification and instrumentation in data collection, along with the development of new experimental approaches in natural and quasi-natural settings. But while distinctions between lab and field have collapsed in some areas, Kohler's work also makes explicit a number of the fundamental ontological differences between the two categories: while laboratories have been prized for their uniformity, facilitating the development of generic and rule-bound conceptualizations of the natural, nature in the field tends to be valued for its particularity, complexity and historical–geographical contingency; whereas the creation of laboratory spaces has generally involved the work of fitting out places, technically and architecturally, for running experimental programs, and using standardized equipment or standardized organisms such as mice or flies, the natural objects and processes under investigation in the field are often valued for being geographically variable, unrepeatable, and less controlled by investigators working outside the laboratory apparatus (see also Kuklick and Kohler 1996). The field, in this sense, remained at some level that which could *not* be produced or simulated. But could it nevertheless be turned into something 'suggestive of a scientific laboratory'?

Kohler's answer, for the history of the biological field sciences at least, is yes, but only by balancing the need for elements of observational and experimental control with the need for the natural variability and historical–geographical particularity of places and landscapes. The development of lab-like practices in ecology and field biology, in technologies, research design and experimental rhetoric, adapted to the more contextually authentic, *less* socially enhanced, and often quite challenging conditions of the field, took shape as hybrid practices, a range of solutions to both practical and epistemological problems. Among these solutions was the language of experiment – experimental methods and philosophy that could be adapted to different kinds of scientific settings.

Experimentalism in the field was not always an end in itself, nor, in the environmental sciences more generally, was experiment ever the only means of abstracting and generalizing data – the spatial survey continued to compel scientists into the field, and to provide useful forms of data storage and organization, most obviously, the map, through which spatial variation and place-based qualities could be compared and expressed in relation to one another. But Kohler's lab–field border zone does suggest a kind of diffusion of the laboratory into the field as part of a more general shift away from esthetic, narrative and personal engagements with nature in scientific writing among early twentieth-century ecologists, and toward increasing quantification, statistical analysis and ideals of experimentally produced knowledge and elements of laboratory control (see also Mitman 1996).

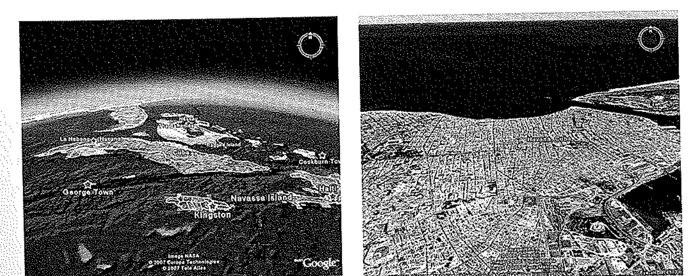
The starting point for field scientists to make their worksites more like laboratories was to rig their field sites up with instruments. Some physiological laboratory technologies, such as sensors, were made more mobile or durable for the field, either to be transported by scientists and technicians or to be installed in 'outdoor laboratories' and field stations as permanent observational features. It was a short step from here to deliberately *modify* aspects of the field site itself; for example, putting up fences to keep particular species in or out of an area, or creating experimental quadrats in which species might be removed or introduced and compared, to modify the natural conditions of field-based experiments. By fitting field sites with instruments, and extending specific controls over the conditions of nature in which their experiments resided, field researchers developed scientific spaces which could be thought of as natural laboratories, but as labs in which natural objects and processes nevertheless retained more elements of their historically and geographically situated complexity. If, for Knorr-Cetina, the laboratory constituted an enhanced environment, then for Kohler, the early twentieth-century ecologists had constituted the natural environment as a kind of enhanced laboratory for studying nature in situ.[5] Human and cultural ecologists – most prominent on the American scene were the Chicago School urban sociologists – similarly extended and adapted the ideal of the laboratory to more complex environments (see Gieryn 2006). Later, the abundant buffer zones surrounding nuclear reactors, production and testing facilities (many of them condemned rural landscapes left to grow over) offered ecologists the space to experiment on a grander scale, and the emergence of American ecosystems ecology, with wide-reaching implications across the environmental and engineering sciences, followed such studies of environmental impact, ecological succession and engineering remediation at nuclear production sites such as the Hanford nuclear reservation and the Savannah River Plant (Kirsch 2007).

Although it is widely acknowledged that World War II and the ensuing Cold War mobilization profoundly transformed American science and technology research, and certainly in some ways, the international scientific landscape, scholars have only recently begun to explore how these processes changed the nature of geographic knowledge.[6] Expanding that historiography will also require a repositioning of the laboratory in the history of geography. In John Cloud's revealing genealogies of geographic information systems (and other contemporary mapping systems), for example, the entire history of their creation, and that of the geodetic earth more broadly, is threaded through laboratory and lab-like settings, such as the MIT Photogrametric Laboratory, Boston University's Optical Research Laboratory, the US Navy Photographic Interpretation Center, the Mapping and Charting Research Laboratory at Ohio State University, among others. The sites recall the continuous image processing first enabled in the industrial observatory. The expanding place of the laboratory in the production of geographic knowledge, bound up at these sites in the development of new technologies

of observation, image processing and automated cartography, contributed to the geodetic revolution underlying subsequent digital cartographic transformations (see Figure 5.2). These facilities, stretching technically into rocketry and the orbital paths of space-based earth observation, were developed, or transformed from existing uses, to enable a great reconvergence of cartography, geography and geodesy, Cloud argues, around geo-strategic demands for a precise figure of the earth, which was required for the positioning of nuclear missiles and other military surveillance and targeting systems. The result of this reconvergence, much of which occurred in settings in which access to information was secreted and complexly differentiated, Cloud (2002: 262) describes as a 'reconfiguration of the geospatial sciences in their entirety' during this period.

The point is not, of course, to reduce these developments to products of their physical settings or built environments, nor to limit developments in geographic knowledge to only those rendered by the image-processing laboratory sciences. It is rather to put forward a view of the laboratory model as something diffuse, but nonetheless quite real, in geography. In particular, the striking ascendancy of laboratory techniques of experiment and simulation for organizing scientific work during this period in many ways set the contexts and conditions in which the makers of geographical knowledge – from academic geography professors to computer scientists and image processing technicians to NASA systems engineers and astronauts – could work.

In situating the changing nature of geographic knowledge production in terms of an expansion of laboratory sites and technologies across multiple nodes of a military–industrial–scientific complex, it is useful then to recover the more expansive notion of the laboratory as a site of scientific and technical processing and manufacturing, a space designated, though not always exclusively, for integrated scientific and technical work. The large nuclear weapons laboratories at Los Alamos and Livermore and the development of a US 'national laboratory' system, and NASA's Jet Propulsion Laboratory (among others) were all developed with the participation – and typically, the administration – of universities, and they later diversified into massive, multi-program



(a) (b)

Figure 5.2 Google Earth views of Cuba. Without the Cold War convergence of geography, laboratory-based image processing, and space-based observation, cartographic images like these, and the technological capabilities that they reflect, would be unthinkable.

Source: "Cuba and vicinity." 21°31'18.33" N and 77°46'52.20" W; "Havana, Cuba." 23°07'58.61" N and 82°22'00.00" W. Both images created through *Google Earth*, accessed 10/10/2007.

laboratories characterized by group and interdisciplinary models of scientific work (Westwick 2003).[7] Much of this World War II and post-war growth, as Cloud's story suggests, also occurred *within* universities, beginning during World War II when federal research funding to universities increased fifty-fold, an environment in which both large and small-scale laboratories continue to proliferate. In 1950, with the onset of the Korean War and a hardening of Cold War policies, US federal research funding to universities doubled to $1.3 billion annually; by 1953, it had already surpassed its World War II peak (Leslie 1993). Overall, university budgets expanded by twenty times (in constant dollars) between 1946 and 1991. While the Department of Defense and the Office of Naval Research remained major contributors to these ends, they were joined, during the 1960s, by the NSF, NASA and NIH, among others, as key US federal funders of university-based scientific research. Until the establishment of the International Biological Program in 1968, the Atomic Energy Commission was the largest funder of ecological research in the US, helping to create what Haraway (1997: 12) would describe as the 'technoscientific planetary habitat space called the ecosystem'.

Geography was not immune from the impacts of these changes in the conditions of scientific and technical knowledge production; transformations in geographical knowledge were in fact a part of these developments, changes which quickly became internal to the geographical, cartographic and ecological sciences. As Barnes and Farish (2006: 807) have argued, during the Second World War and ensuing remobilization, 'a different model of science emerged', one that was often mathematical and theoretically abstract, and worked conceptually through the development of models and simulation. The model was expensive, organized around the interdisciplinary collaboration of scientists working in teams toward specific goals, and bound up in a pervasive militarist geopolitics wherein the 'entire Earth became a generalized space of American military strategy' (ibid.: 808). The authors turn for insight to Pynchon's Percival Pointsman, from *Gravity's Rainbow*, who asks, 'Suppose we consider the war itself as a laboratory?' But for Barnes and Farish:

> This is no supposition. It happened. The Second World War and the Cold War, whether intentionally or not ... served as and produced a series of laboratories, experiments producing new kinds of knowledge that spiraled out to refashion the world. Barnes and Farish 2006: 821.

No longer, in a world orbited in perpetuity by observation and communications satellites which help to define our planet and ourselves, can the boundaries between laboratory and 'the world', and the knowledge that circulates between them, be taken for granted.

Barnes and Farish argue that these changes made their way, though haltingly, into postwar American human geography in, for example, new conceptions of the region, often oriented around geopolitical visions, and in the increased use of mathematics in the social sciences at the time. But the laboratory model is clearly most evident today in physical and environmental geography, and in the recently emerged subfields of remote sensing and *geographical information systems* (GIS), now defined more broadly under the umbrella of geographic information science.[8]

Laboratories continue to evolve in different forms. On one hand, there are environmental quasi-laboratories, like the 26 sites included in the US Long Term Ecological Research network (LTER), a National Science Foundation-funded initiative since 1980 in which geographers have actively participated, dedicated to observation and modeling among environmental and social scientists over relatively long time periods. The program has supported active experimental programs in areas such as restoration ecology, urban hydrology, and more recently, so-called ecosystems services. The sites are located in diverse settings, from the Arctic to the Baltimore ecosystem, with the LTER network now fashioning its mission to 'provide the scientific community, policy makers, and society with the knowledge and predictive understanding necessary to conserve, protect, and manage the nation's ecosystems, their biodiversity, and the services they provide' (LTER 2007). On the other hand, labs continue to proliferate in perhaps more banal settings than the LTER site, and the tradition of the field station and natural laboratory into which it taps: it is hard to imagine that the near ubiquitous 'GIS lab' in university geography departments will not, one day, be studied as a paradigmatic architecture of late twentieth and early twenty-first-century geography. As a site for both teaching and research, even as geo-visualization technologies are becoming increasingly mobile, and Google Earth resides on every desktop, the GIS lab evokes a new version of the old geography of the laboratory, paradoxically located everywhere, nowhere and somewhere. And yet, if the modern laboratory was designed – like the factory – to fulfill the peculiar social needs of replicability and standardization, a space which could, theoretically, be *any*where, then the explosion of geo-referenced data and mapping interfaces, notwithstanding the history of computation, processing and cartographic visualization that have gone into their making, thus appears as something slightly different: the space of geo-informatics is one of *every* place. The changing character of geographic knowledge, of which the digital transition reflects one critical dimension, reflects not so much the disappearance of the laboratory as its *extension* into the infrastructure of continuous, planetary observation.

'Laboratory Earth', as the American climate scientist and public intellectual Schneider (1996: 96) puts it, continues – through science – to 'grind out the answer –experimentally'. It is an odd geographical construction, reflecting the semantic shift from earlier notions of the laboratory as a dedicated space for scientific and technical work which have made the laboratory also mean something *like* a laboratory, something suggestive of one, possibly a less socially exclusive scientific space. But in some ways, Schneider is right – not in describing the entire planet as a laboratory, but in exploding the distinction between lab and field. Laboratory Earth, a metaphoric space evoking, unsettlingly, both the controlled and the uncontrollable, containing the possibility of an experiment's unexpected outcomes, is a space that geographers have helped to produce. It is also a hybrid, resource-rich setting for the production of new information, knowledge and technologies. The laboratory and observatory, as historians of science have shown, are neither timeless nor placeless architectures of scientific work, and their ongoing transformations will likely continue to set the conditions for the production of geographical knowledge in ways that are both important and unforeseen.

NOTES

1 The latter, set in bucolic landscapes, are described, by Simon Schaffer (1998: 149–50), as 'production utopias', wherein social withdrawal could be seen as 'a precondition of access to universal truths'. For a reflection of the utopian scientific landscape in a contemporary high tech research park, see Havlick and Kirsch (2004).

2 *Webster's New Universal Unabridged Dictionary* (1996) my emphasis.

3 *Ibid*., my emphasis.

4 See, for example, Outram (1996); Latour (1999); Livingstone (2003: 135–78); Kirsch (2005).

5 This comparison can only be taken so far, for there are also key differences in the commitments of Knorr-Cetina and Kohler. While Kohler limits the scope of his observations to the practical and intellectual history of science, and (2002: 1–22) argues against the need for new theorizations of space, Knorr-Cetina expresses a clear interest in the positive distribution of the laboratory and laboratory sciences beyond the domain of science, and her laboratory studies have contributed explicitly toward constructivist theorizations of the laboratory as a social space.

6 See, for example, Cloud (2001, 2002); Smith (2003: 235–69); Barnes (2006); Barnes and Farish (2006).

7 As Peter Galison (1992) has observed, the emergence of the Big Science model in the United States during this period can also be attributed partly to the different relationships with engineers and engineering among American (and US-based) physicists as compared with physicists in Europe, exemplified in the development of particle accelerator technologies at sites such as Berkeley, Cornell and Stanford, wherein joint physics and engineering projects were seen as worthwhile endeavors.

8 As Johnston's (2003) recent study of the journal publication outlets of physical and human geographers indicates, geography's natural scientists tend to publish more frequently in interdisciplinary (mainly environmental science) journals than their social scientist and historical geographical counterparts, who tend to publish in disciplinary geography journals more regularly. The pattern suggests, among physical geographers, an identity as scientists somewhat 'above' the disciplinary level of affiliation and a perhaps more active sense of participation in interdisciplinary practices and in the large-scale institutional infrastructures of contemporary science.

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