Visualization in the Age of Computerization

Edited by
Annamaria Carusi, Aud Sissel Hoel,
Timothy Webmoor and Steve Woolgar

Routledge
Taylor & Francis Group
NEW YORK LONDON

First published 2014
by Routledge
711 Third Avenue, New York, NY 10017

and by Routledge
2 Park Square, Milton Park, Abingdon, Oxon OX14 4RN

Routledge is an imprint of the Taylor & Francis Group,
an informa business

Library of Congress Cataloging-in-Publication Data

A catalog record has been requested for this book.

ISBN13: 978-0-415-81445-4 (hbk)
ISBN13: 978-0-203-06697-3 (ebk)

Typeset in Sabon
by IBT Global.

Printed and bound in the United States of America
by IBT Global.

Contents

Figures

9 Visual STS

Peter Galison

INTRODUCTION: VISUAL SCIENCE AND TECHNOLOGY STUDIES (VSTS)

Behind the most significant accomplishments of the last thirty years of science and technology studies (STS)—behind laboratory studies and actor network theory, at the center of our ventures into scientific intellectual property, authorship, historical epistemology, media studies, book history, discourse analysis, participant-observation and the philosophy of experimentation—in back of all this is a turn toward *locality*.[1] Divided as the various approaches may be about methods and priorities, our complex of disciplines is no longer satisfied with global claims about universal norms and transhistorical markers of demarcation. Localization was key in Steven Shapin and Simon Schaffer's (1985) examination of Boyle's Pall Mall laboratory in its social, class and political location; localization is the sine qua non of Ian Hacking's (1983) insistence on practical intervention—specific procedures at the Stanford Linear Accelerator Center, not Mertonian norms full stop. "*So far as I'm concerned*," Hacking wrote, "*if you can spray [positrons onto a niobium ball] they are real*." Harry Collins (1981) aimed for a local account of repetition when he challenged textbook truisms by showing how crucial person-to-person contact was for the replication of a laser. In different ways and with different tools, the STS field-cluster has utterly rejected the intellectual historical conceit that ideas leapt from great book to great book, or arose from a miasmic Zeitgeist.

Tools for excavating the local have come from across the disciplinary map. Ethnographers and sociologists, historians and philosophers, gender theorists and media historians—all have wanted to know about the shifting, productive nature of scientific practice in *particular* times and places.[2] Work increasingly crosscuts these genres—historically inflected ethnography, for example, takes present-day laboratories-in-the-world, expands sources to new forms of the (digital) archive, observation-participation, locates the present within a historical trajectory.

But here and there, something new is emerging from within the local: attention to the visual—as source, evidence and form of reasoning. We are

by now familiar with the idea that diagrams, charts, maps and photographs can serve as a fundamental part of scientists' argumentation. What about science and technology studies itself? Can the visual function there too as a form of research, not just popularization or illustration?

Can documentary film, for example, be scholarship—can it be something more than another means of advancing the public understanding of science, more than another box of raw material? Is the analytical power of propositional concepts the very essence of research, and do words alone leave nothing out, other than superficial reportage or arbitrary art? Can there be a kind of knowledge, an epistemological contribution from film that supplements and enriches our understanding of science-in-practice? For all too long, many in the scholarly community have held film (and now the more capacious category of digital-visual material) at arm's length—the sneaking text scholar's suspicion lingers that the visual might be irredeemably incapable of explanation.

In 1960, Jean Rouch, one of the great ethnographic filmmakers, teamed up with sociologist Edgar Morin to produce *Chronicle of a Summer*, a defining contribution to film history in technique (it introduced dual-system [portable] sound, making sync sound possible in the field); in genre (it launched cinema verité, following a group of young French workers and students in the summer of 1960); and in structure (it proffered reflexivity by including filmed responses of participants in the film as they watched a first version). Marxist sociologist Lucien Goldmann responded acerbically. Hegel, he explained, had long ago shown "the truth is the whole"—and these filmic glimpses into particularity were nothing if not partial. Goldmann judged "Chronicle's" conversations, recorded in the streets, factories and homes of Paris, to be bits unintegrated into "global structures," and so "extremely poor in relation to the more complex structure of reality."[3] We see in the film: a young man, lost in the shifting economy of 1960 awakening in his bedroom, his mother bringing him breakfast; workers laboring on the production line; university students trying to find their way; a young woman, a concentration camp survivor, wandering through Paris and remembering her father, whom the Nazis had murdered. Toward the end of the film Rouch and Morin portray these and other participants watching the film in which they have just appeared and responding to it—commenting on their own and others' actions and statements, pushing, tentatively, on the difficult questions of authenticity and representation.

Unmoved, Goldmann judged the film fatally particular, *too local* since such sequences were untied to a sociological "global context." For Goldmann, it came to this: "The film maker, who does not have the possibility of filming concepts . . . can only seize [the larger context] through its reproduction at the level of individual beings and concrete situations which are the only things directly available to him: which is to say, on the level of fiction."[4] For Goldmann, nonarbitrary reality was accessible *only* by mediating ever more *abstract concepts* and these were, irreducibly, unavoidably

textual. Citing Marx and Hegel when it came to human realities, concepts were essential: "The truth is never immediate."[5] Goldmann's cutting final judgment: Inevitably local, cinema verité was forever condemned, in virtue of its particularity, to the status of mere fiction.

Since locality, materiality and particularity are indeed the hallmarks that have become, for our present moment of scholarship, central to the very fabric of science and technology studies, we can ask the next question: What *kind* of locality does film afford? I will argue that visual locality extends and complements textual locality—and as such opens the possibility of a generative, visual scholarship that puts on offer precisely what Goldmann disliked, a dense, unexpected immediacy that offers new forms of context. In the following sections, I shall turn to a spectrum of works in STS and visual anthropology that might pencil in the opening contours of this new register of STS—both uses by scientists of images (which I will call a first-order VSTS) and uses of film and media studies to explore scientific practice (which I will refer to as second order). In the final section at the request of the editors, I want to turn to my own trajectory into film and digital media as a way of complementing written analysis. Perhaps thinking through some of what has worked—and some of what has not—might be of use to others.

VISUAL SCHOLARSHIP IN THE WORLD OF WORDS

Against Goldmann, the interpretive social sciences and allied branches of philosophical, literary and art historical studies have embraced the local. Impatient with a rigid commitment to behavior and reason as algorithmic rule-following and with a fierce patrolling of scientific borders, historians, sociologists and philosophers turned to more instantiated knowledge. Back in 1962, Thomas S. Kuhn, reaching for the postanalytic Wittgenstein, pointed to the way scientists followed exemplars (e.g., Newton's calculation of planetary orbits) rather than simple free-floating propositions (e.g., force is proportional the product of masses and inversely to the square of the distance).[6] Piecewise transported to other contexts, eighteenth- and nineteenth-century astronomers could calculate other phenomena, and the ability to apply examples in this way came to define (for Kuhn) a scientific community. Exemplary problem solutions picked out the right kinds of laws and entities with which to proceed. Clifford Geertz agreed—only the densely *instantiated* aspect of culture was of interest as he took up philosopher Gilbert Ryle's (1968) notion of a thick description. The local, social and conventional context gave meaning to an event where the event alone would be undefined or ambiguous. Only this denser context could distinguish an eye twitch from a conspiratorial wink. In Geertz's hands, thick description blossomed into a way of doing anthropology: A Balinese cockfight (1973, 412–454), with all its complexities of convention,

in-group solidarity and regulated behavior, captured a local culture in its density. No mere set of covering rules and universal structures governing kinship or wealth transfer could capture this overlay of enacted, symbolized and agreed-upon meanings.

Film offers an approach to the material and social world of science that complements the work of written material foregrounding the local. Film and other visual media subvert text in productive ways. And yet within science studies, film has played only a glancing, secondary role, serving either as source material or as popularization. This is so even at the level of exhibitions: Whereas an art museum presenting an exhibit on Rembrandt's school addresses a mixed audience of engaged viewers, a science museum addresses schoolchildren. Films about science, even where they do not just address the yellow school bus, do see themselves as a way of increasing public understanding of results.

Why? Among historians, perhaps it is because history so often prides itself—in a way not too different from Goldmann—on explaining scientifically its object of study. Writing, so it is assumed, excels at characterizing an episode, partitioning it into periods and explaining it by an ordering externality: economics, psychology, bureaucracy, political allegiance. In the recent study of science, there is an additional appeal: Writing can contrast whole cultures, splintering them into distinct, complex islands in time or in space, each with its own internally coherent, local system of symbols, values and meanings, each with its cosmogenesis, propagation and kinship structures. Anthropologists have excelled at such holistic inquiry, from Franz Boas's anthropological relativism through Geertz's thick descriptions on Bali (1973, 1983) on to the present. There was a moral-political thrust behind this enterprise: a sense that cultures differed in many ways, even radically, but that in the end there was no hierarchy of culture—no meaningful way of *ranking* Baffin Island relative to Berlin.

Correspondingly, we are by now long familiar with the great switching of *scientific* cultures from Thomas Kuhn (classical to relativistic physics) or Paul Feyerabend (scholastic to Galilean physics). Similarly disjunctive alteration can be found in the epistemic ruptures in the neo-Kuhnian STS work of, for example, Pickering (1984) (S-matrix to field theory), and many others in the 1980s and 1990s. In a Kuhnian mode, we can say, "These two (scientific) cultures are radically disjunct, they differ ontologically, epistemologically, nomologically, precisely as the Boasian analyst would set two (anthropological) cultures apart because they differ in their accounts of origin, social order and reproduction."

Helpful as these radical contrasts can be, they can also override the material and affective phenomenology of practice. When visual anthropologist David MacDougall shows, through extended shots, a Turkana bridewealth negotiation in *Wedding Camels* (1980) we see much more than the results of the camel trading. With time and attentiveness, we see the exchange of looks within families and between them. In the regards and emotions of life

in process, in persistent, recognizable bodily gestures, faces, tones of voice, the idea of absolute otherness is, to a certain extent, undermined. MacDougall means this to be so—he precisely wants us to encounter a commonality not only between the groups in discussion but also between them and us (MacDougall 1998). Incipient visual STS does, and could expand on, precisely this bridging effect. Think of (or better look at) the remarkable real and time-lapse images produced by William Newman on a website as he and Lawrence Principe photographed and filmed the making of alchemical icons, like the "Tree of Diana"—a surprising silver dendrite structure that grows from a globular configuration of mercury and silver. Suddenly, what has seemed for generations to reside in the purely metaphorical, lyrical or fantastical world of the alchemist comes closer to us than the distancing of print description could afford. Here is a visually enhanced website that makes a difference.[7]

Novel digital techniques now offer intriguing ways to cut across both text and images. One project, a multiauthored locative investigation into the Zenon Corporation (1945–1960) offers an example. Zenon had the task in those years of developing a classified system of distributed computation, one that is now thought to be a first, large-scale attempt to build a computational network. Half a century ago, company officials stored documents in a basement safe beneath the famous Sullivan building in Chicago. Recently rediscovered, the trove is now, appropriately enough, being examined by a team of architects, historians and other scholars with the goal of producing a tablet-useable augmented-reality display, that will allow proximate and distant viewers to make use of the building's internal sites as well as engaging with the computer historical documents, correspondence and other metadata (Burdick et al. 2012). With layers of inquiry possible, there will be no single path through the material. This is the kind of digital project (I actually don't like the term digital humanities, which seems too restrictive) that immediately suggests a myriad of possible analogue inquiries in laboratory history (for example).

Much older than such relatively new nonlinear, layered projects is the field of visual anthropology. Over almost a century, ethnographic filmmakers have carved out a domain with its own journals, meetings and of course films (see, e.g., Barbash and Taylor [1997]). Indeed, almost a hundred years ago, anthropologists, like Robert Flaherty, began using film to approach the discipline in a new way: to offer a visual record of everyday "native" life. His *Nanook of the North* (1922) explored the rapidly vanishing "traditional" Inuit practices of walrus hunting, trading, shelter construction and family relations—even if Flaherty was later criticized for intervening and reconstructing in a myriad of unrevealed ways (Rothman 1997, ch. 1). In 1974, ethnographer and ethnographic filmmaker Margaret Mead published "Visual Anthropology in a Discipline of Words," militating for film, and categorically rejecting excuses for avoiding moving images. She lamented the long-held belief that anthropology should mainly rely on elders' words

as they recalled the old ways. She dismissed the often-repeated claim that film takes so much skill that it could not be widely taught. And she refused to cede the field because of cost, saying astronomers and physicists hadn't abandoned their instruments because telescopes and accelerators did not come cheap (Mead 1974). Much of this part of Mead's argument resonates even more strongly today—who can argue that cost and work are insuperable obstacles in the era of miniature digital cameras and nonlinear editing?

Mead went on to argue that filmmaking promised a hugely more effective form of *documentation*, a dense record appropriate to a discipline of density: "for the illumination of future generations of human scientists" (Mead 1974, 4). Now this promise of an ideal archive no longer carries much weight in the interpretive social sciences—such a value-neutral observation protocol holds no more sway in anthropology than it does in history or sociology. And yet the idea of an *excess* in documentary film remains, a surplus captured that might be unintended, even unnoticed in the filming.

For all her radicality in lobbying for visual anthropology, Mead's razor-sharp separation of documentation from interpretation does not seize the ambition of late twentieth- and early twenty-first-century documentary and ethnographic filmmakers—and certainly did not rise to the ambition of the Geertzian ambition of narrating a culture through specificity. What survives from the stance of Mead or Gregory Bateson, and very vibrantly in the last decades of observational cinema, is a remarkable reengagement with some aspects of early cinema. Hollywood habituated audiences to privileged camera angles—impossible places for the camera, such as shooting from behind a fireplace, through the flames into the room; cameras shot as if through walls, mirrors or ceilings. By contrast, mass market films taught viewers to accept ever shorter shot lengths, along with a myriad of other conventions, such as match cuts (a visual similarity) that simulated continuity. As MacDougall (1998, 202) notes, "Implicit in a camera style is a theory of knowledge"—and the sudden changes of shot, match cuts and privileged angles vest knowledge in the filmmakers, who were after "essence."

MacDougall's own, more self-abnegating style of no-style ascribed a finite, observational knowledge to the maker, letting shots run long, filming from announced and physically possible positions. He began subtitling "native" speakers, instead of mute action interpreted by an all-knowing narrator; and his characters gained specificity and locality through real names and the registration of their own (subtitled, translated) words—for example, in MacDougall's *Wedding Camels*. At least some ethnographic filmmakers from the 1960s began putting the viewer in the position of a mortal filmmaker—not looking over the shoulder or listening at the feet of an omniscient observer (MacDougall 1998 204–205; Grimshaw and Ravetz 2009).

Documentary can put the observational process itself under pressure, as Errol Morris does in *The Thin Blue Line* (1988), where, through film-based recreations, he shows that the police account of a murder could not have taken place. In Morris's film, cinema *makes* the argument; the

documentary becomes itself a generator of forensic evidence, and in fact reshaped a capital case. One can imagine film recreations serving an analogous role in STS. Suppose, for example, we wanted to know what impeded reproduction of a Transversely Excited Atmospheric (TEA) laser—was it the failure of print to capture what would be present in a moving, visual record? Was it something in the tone or gestures of the original designers that never found its way into documentation? Was it the ability of the replicators to ask follow-on questions? Was it some ineffable presence in the laboratory, a kind of unspoken confidence that the thing would work? With film, one could begin to explore—possibly eliminate, or in any case narrow—the spectrum of possibilities.

Other recent films open the observational eye to foreground the often-hidden interaction of scholar and subject. Anthropologist Stéphane Breton's *Them and Me* (2001) opens with our seeing Breton's camera-eye view as he walked down a rainforest path, following and filming a group of Guineans. Suddenly, one of the highlanders turns and says to the camera, "Do you like bananas?" From that moment on, we are sometimes painfully aware of the anthropologist—Breton offering work, paying the locals and endlessly negotiating, sometimes jokingly, sometimes tensely, with the highlanders for position and authority. Locality is here embraced by the investigator, not so much by reflexivity at the end (as in *Chronicle*) as by inclusion.

One is reminded of MacDougall's comment that film style brings a theory of knowledge—and each of these moves does just that: the filmmaker-directed explorative recreations, the filmmaker's self-implication in the events observed, the self-conscious importation of stylized elements of transitions, the long shot rather than quick takes. Each choice surfaces the nature of knowledge production—in objects, among people and for us as we struggle to understand.

Film excels in depicting locality, materiality, scale, affect. Film plays with duration and simultaneity, setting people and work into immediate context, making landscape and built environment into characters, not described once but persistently present. Film reinserts a factory worker at the lathe among the machinery in each frame—not once, as in print, but over and again. Film can capture the simultaneity of reactions in a group shot, the scale and scope of a world as it acts on those in it. Film, as a time-based medium, conveys duration of work processes, permits simultaneity of appearance and action and mixes argument and affect. Returning to Goldmann's anti-*Chronicle* screed (claiming film fails as scholarship because it is too local and therefore insufficiently conceptual), one thinks of Kant, whose *Critique of Pure Reason* (A51/B75) was precisely about the fundamental relation between intuition (perception) and understanding: "Thoughts without content are empty, intuitions without concepts are blind. The understanding can intuit nothing, the senses can think nothing. Only through their union can knowledge arise."[8] When we pit conceptual abstraction *against* sensory particularity, we do so at our peril.

WHAT COULD VISUAL STS BE?

In a certain first-order sense, STS already knows the start of the argument I am making here: For the last thirty years, we have explored in a myriad of ways how concepts, algebra and text have never exhausted how science works. *Images*—diagrams, drawings, bubble chamber pictures, anatomical plates, astrophotographs, cartoons—and other elements of visual culture are inescapably part of science, irreducible to propositions alone. My argument is that at a second order, STS is also using and has the potential to use much more intensively images to establish its arguments—photographs of laboratory interiors, blueprints, patents and instruments. The interpretation of a notebook page, the gloss of a lithograph of a skull, the analysis of watercolor of a cloud study—these are using visual materials as constitutive parts of a scholarly argument, and not just as decorative illustrations (e.g., when writing about Joseph Fourier, inserting an otherwise uncommented-upon portrait).

Without doubt, VSTS can, like visual anthropology, capture process. For the visual anthropologist, building an igloo, preparing a dowry, herding sheep is important—for an STS attentive to science in the making as well as its finished products, this is crucial. We are, after all, very concerned with the creation and transfer of skills—skill in micropipetting, tracking animals, building particle detectors or analyzing data. Indeed, some of the most interesting claims of STS build on practices—the trained, skilled set of tools is one way to show the location of specific scientific work in a broader technical and even nontechnical world. Think of Joule's work on heat, which borrowed so powerfully from the stirring, insulating, temperature-measuring processes of his father's brewery. Otto Sibum has effectively used recreated instruments to get at materiality and work: Joule's, for example (Sibum 1995).

Let's dig down deeper into the *first order* (the study of scientific images that were mustered by the scientists to make their arguments) and second order (the use of a visually structured argument in the STS approach itself). Of course the two have no hard and fast boundary, but the difference in emphasis, at the limits, is clear.

First order: We could already see a role for a visual STS in the extraordinary outpouring of work *about* images and objects. These include an embrace of visual sources, not only diagrams but also photographs, cartoons, x-rays, drawings and simulated images. Out of this work, the STS constellation of fields bears directly on scientific epistemology. For example, we have a growing literature on diagrams—think of Bruno Latour's (1990) portrayal of diagrams as "immutable mobiles," sliding across time and space far more easily than words. Conversely, David Kaiser (2005) showed how *differently*, in fact, the "same" Feynman diagram worked in physics departments in Pasadena (Caltech), Berkeley (University of California) and Cambridge, Massachusetts (Harvard).[9] Such deepening inquiries

into the practical, *differentiated* epistemology of diagrams are important: They show how central the visual can be to the shared toolkit of practitioners—to the doing of scientific work. Indeed, image making, image modification and image use constitute a form of epistemology—debates over the evidentiary status of statistical data (assembled by electronic counters) as against "golden events" (recorded by photography) cut through many branches of fundamental physics (Galison 1987, 1997).

We have begun to reckon with the variety of ways by which images enter scientific practice. Jennifer Tucker (2005), for example, showed how swiftly photography joined science in Victorian England—as a form of virtually witnessed evidence, from psychical research to astronomy, balloon expeditions and botany. How images can shape the very formation of a new scientific field—such as the functional nuclear magnetic resonance images that have made the field complex of "neuro-X" so immediately recognizable (Dumit 2003). Think of the myriad functions that the visual has played in Victorian geological field sketches, maps and even cartoons (Rudwick 1988); or, as Hanna Landecker (2007), has shown, in the study of microscope-based films of cellular biology; the ways aerial photography reshaped mid-twentieth century urbanism (Haffner, 2013); or in the exceptionally interesting contrast Michael Lynch and John Law (1988, 1999) make between the uses of "impoverished" (but more effective) drawn bird figures and the "realistic" (but overdetailed) photographs.[10]

Hanna Shell's (2012) examination of filmic treatments of camouflage shows the chameleon-like function of visual disguise both for the military (snipers) and biology (adaptive coloration); Marga Vicedo's (2009) deconstruction of Konrad Lorenz's "mother imprinting" films functioned on many levels—mother duck Lorenz led ducklings, with film both as his witness and evidence. Alongside both, film helped him reinscribe himself from an important, Nazi-sympathizing ethologist to a leading cultural icon of postwar Europe. The evidentiary, witnessing and popularizing functions of photography and film are crucial in helping us understand the nature of scientific practice from the Victorian era to the present. David Kirby (2011), meanwhile, tracked the shifting, sometimes unstable role scientists have held advising Hollywood productions—these advisors offer clues to creating a "reality effect" of laboratory or field—while working under the genre, plot arc and aesthetic choices that directors and audiences expect.

Nature and science films not only convey evidence and reposition the scientist, as Gregg Mitman (2009) has demonstrated, but also carry implicit scientific politics. He points (for example) to James Algar's *Nature's Half Acre* (1951), which was distributed through Disney. That Academy Award–winning film, with its anthropomorphic privileging of natural harmony (and bourgeois values) above evolution, celebrated and humanized nature, while leaving Darwin (random variation, selective retention) entirely on the cutting-room floor. If Disney emplaced its scientific-political ideology in the birds, scientific film could also be explicitly normative. With the stakes

high, several social scientists of the 1930s wanted to use the medium to bolster democracy for a generation growing up in the shadow of fascism and Stalinism. As Javier Lezaun (2011) has shown, the child psychologist Kurt Lewin took this view, as he strove to establish a laboratory-instantiated, film-captured picture of democracy. "If Science," Lewin wrote, "is going to help to establish the reality of democracy for the young American it cannot be a science dealing with words. It will have to be a science dealing with facts; with facts of a very tangible nature; with facts close to the everyday of the individual person; with facts that matter."[11] Though he addresses far different topics (in Indian art, religion and politics), Christopher Pinney (2004) is after something similar when he suggests we need a "corpothetics" that directly implicates the viewer (as opposed to Enlightenment "aesthetics" that treats the viewer as distant, irrelevant).

Now turn to what might be labeled second-order use of image making—not images as the subject matter of inquiry, but instead images as a form, in its own right, of generating knowledge about the practice and place of science, technology and medicine. A few examples can illustrate ways that a VSTS filmmaking might complement print STS. To highlight the particularity of the visual, it is perhaps worth focusing on a few pairs of books and films—using documentaries not made to be part of a visual STS, yet highly suggestive of the kind of work such visual inquiries could do. Consider Frederick Wiseman's wry *Primate* (1974, fig. 9.1) alongside Donna Haraway's *Primate Visions* (1989). Haraway's study functions in several registers through several sites: It is a history of race, class and gender; it is a story of the Museum of Natural History in New York City—but also a narrative of colonial Africa, focused on Nairobi. It is about the ideology of big game hunting; about domestic interactions between the naturalist/hunter Carl Akeley and his two very different wives; and about "reading" the Museum of Natural History. Print easily flips between scenes and spaces, shooting elephants with bullets and film. *Primate Visions* can juxtapose the rhetoric of "manly triumph" vividly against "cultural decline."

Wiseman's film is confined to a single institution (Yerkes Primate Observatory in Atlanta), and it gathers its force by a fierce observational attentiveness to this one site—from technicians' artificial insemination of a primate through a young woman technician cradling and testing a diapered young animal, to the vicissitudes of the older apes, and eventually to experimentation on great apes, followed by their dissection and discard. The apes' vocalizations pierce the soundscape—so does the incessant clanging of steel-barred cages. Throughout, the camera holds the regard of the great apes, from newborns to 400-pound adults. Having witnessed these scenes in Wiseman's film, no viewer would see this labwork merely as a dismissible path to a crucial conclusion. Unnarrated, in black and white, the camera cuts back and forth between humans and apes, alongside sometimes disquieting, sometimes hilarious parallels, alongside measured, visceral violence. Trapped in the routine sounds and scenes of Yerkes, one learns

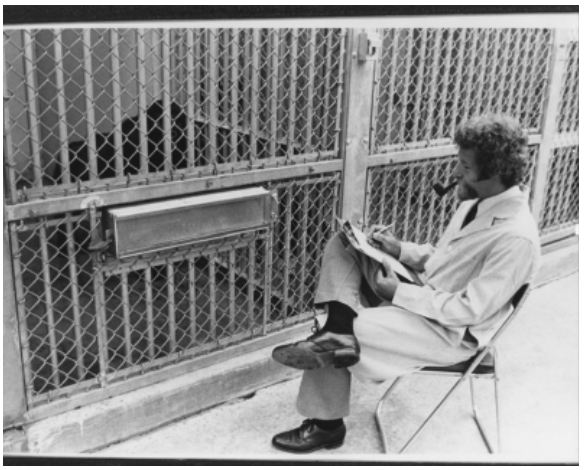

Figure 9.1 Still from *Primate*, directed by Frederick Wiseman (Zipporah Films, Inc., 1974) 16mm, 105 min., black & white. Photo provided courtesy of Zipporah Films, Inc.

about proximate not distal context; one sees the local production of science *in its place*—even if the scientific goals are never explained. Gender, power and interspecies relations in the laboratory are performed; they are thrown onto the screen—but *not* explained under an explicit conceptual frame grounded elsewhere. It is a very different, if complementary form of access to science-as-process than the equally rich, many-fold excursions of Haraway's reading of histories and symbols.

One could similarly contrast some of Wiseman's other, institution-based essay films: *Hospital* (1969), with its routine surgeries, waiting rooms and inner-city turbulence, might well be compared with Foucault's ([1963] 1973) *The Birth of the Clinic*. Both focus on the physician's encounter with the patient—the medicalization of interaction. But their forms of knowing differ; while Foucault attends to the radical structural shift in the "medical gaze" before and after the late eighteenth century, Wiseman's world is messier, more closely tied to circumstance: medicine in the midst of poverty, addiction and bureaucracy, and medicine on the phone, in the waiting room, and in cardiac surgery. Similarly, his *Missile* (1987) brings workspace interactions front and center: The film follows ICBM launch controllers at the 4315th Training Squadron of the Strategic Air Command at Vandenberg Air Force Base. Here are everyday rehearsals for entering codes, securing the control room and lofting the missile toward Moscow or Beijing. In one scene members of the 4315th celebrate receiving certificates for good performance (rapid launch); in another, yellow school buses ply their way around the base—in these small, extended moments a very

different contextual awareness emerges than from analytic works such as MacKenzie's (1993) *Inventing Accuracy*, where the author shows how 1980s first-strike global strategic thinking shaped seemingly "pure technical" reasoning about accuracy. Wiseman and MacKenzie localize missiles differently. Wiseman shows us the ordinariness of what it looks and feels like to learn the movement, callouts, switch flips and key-turns that will end a million lives. MacKenzie shows us how the gyroscopes on top of those missiles carried their first-strike design in their very being. We might see these as two kinds of truth that complement each other: textural on one side, structural on the other. If we ask how the technology of intercontinental ballistic missile launches works, one would be hard-pressed to say (Goldmann) that one of these responses is truth, the other fiction.

Stephen Hawking writes in the register of physics and popular science—his *Brief History of Time* (1988), with ten million copies sold, stands as the world's best-selling popularization of science. Hélène Mialet (2003) uses STS tools to bring Hawking out of the mythological clouds, showing that the physicist exists not just as an isolated individual but also through assistants, technologies, students and nurses. By contrast, Errol Morris in *his Brief History of Time* (1991) covered Hawking through a highly produced character sketch that moves among stage sets, theory, images and biography. Taken together, the Hawking and Mialet texts and the Morris film show *different* contexts—Hawking presents a popularized, synthetic version of results in quantum gravity; Morris follows a filmic logic of association and sharp-focused, psychologically dense materiality; and Mialet peels back the layers of a decentered figure.

Morris enthusiastically uses high production values—drawing on a long career in the production of vivid, precise television advertisements—to depart from Wiseman's rough-hewn verité style.[12] Michel Negroponte chooses a third camera style, neither verité nor staged. In his expressive, impressionistic film (*I'm Dangerous with Love*, 2009, fig. 9.2) Negroponte follows Dimitri Mugianis, former musician, now dispensing an illegal hallucinogen, ibogaine, through the underground world of heroin addicts trying to shake their habit. Negroponte's is a much wilder, more expressionistic film than Wiseman's or Morris's. *Dangerous* certainly is *not* a white paper report about scientific institutions or clinical trials—instead, it is a highly subjective excursion into the improvised administration of a dangerous Schedule 1 drug, recently turned to a dramatically new use. Hope and panic, even near-death experiences of desperate people populate the screen, and the camerawork is correspondingly often handheld, not to show (verité) authenticity of grainy black-and-white footage but to capture the feeling of situations edging out of control. Along the way, we follow Mugianis's therapeutic trips in North America, his Bwiti shamanistic initiation in Gabon and his awkward import of that experience back into the margins of America. How different this is from Jeremy Greene's (2007) analytic work showing how a commercial blood-pressure drug, Diuril,

came into existence accidentally—designed as a diuretic by Merck, Sharpe & Dohme. Once the company understood the antihypertensive properties of their product, its marketing teamed created an unprecedented drive on doctors using journal advertisements, visits from markers, orchestrated journal articles and the soon famous model, the "Diuril Man" that stood on physicians' desks from coast to coast. Here the complementary nature of film and print are laid out even more strikingly—through different kinds of locality: documentary analysis of advertising firms, their market plans and Big Pharma, but also images of a shamanistic initiation and a drug regimen administered on the fly, about to spin out of control. Drugs permeate our biological condition today, licit and illicit, high-tech/high-capitalization and street corner hustle, observational-expressionist cinema and analytic writing. STS needs both kinds of understanding; print and camera position each offer their own range of epistemologies.

In the postverité world, the long or immersed or reflexive camera positions each bring their own form of knowledge. But the digital age has begun to expand that repertoire even farther as camera size and location are no longer limited by proximity to the eye of the shooter. Nowhere is this illustrated more strikingly than in Lucien Castaing-Taylor and Véréna Paravel's *Leviathan* (2012, fig. 9.3). It is, I suppose, about commercial fishing off New England, but the point of view has shifted as the camera moves from the shoulder to a very small waterproof cam at the end of a pole. Sometimes the viewer is sloshed over by dead fish as they slide back and forth with the

Figure 9.2 Dimitri Mugianis, photograph by Ashley Valmere, still from *I'm Dangerous with Love*, directed by Michel Negroponte (Blackbridge Productions, 2010), DVD, 82 min.

Figure 9.3 Still from *Leviathan*, directed by Véréna Paravel and Lucien Castaing-Taylor (Arrête ton Cinéma, 2012), DVD, 87 min.

pitch of the boat. Sometimes we move along the surface of the water by a run-off spout spewing a mix of seawater and fish blood. Sometimes we are below water altogether as a mix of fish parts, netting and starfish flicker by. Where are we epistemologically? Not so much in the Latour-Callon world of actants—scallops here, like people, nets and birds, are washing by, more in flux than networked nodes. This cam-eye perspective is a point of view that was just a few years ago technically impossible; but it is now more than an electronic alteration. Here in the visceral, off-human perspective is a shift away from character and broad explanatory context—and toward a carefully constructed, sensual, horrifying, dizzying moving image. Is it knowledge? Certainly. Is it subordinated to a conceptual partition, an economic or actor-network explanation of the economics, biography or regulatory structure of fishing in the early twenty-first century? Not at all.

Film and texts here each facilitate and impede particular forms of understanding.[13] Both recreate worlds, but they are very different. Greene, MacKenzie, Mialet and Haraway cut across spaces and registers to provide conceptual-explanatory schemes. Wiseman, Morris, Negroponte, and Castaing-Taylor and Paravel, by contrast, use different means (observational juxtapositions, recreations, immersive, off-human filming), and together offer a probing phenomenological vision of the sci-tech world. Is text contextual and film isolated? Not at all: Text and film each pick out *different* contexts, textual and textural. It seems to me a bit like imaging a distant star: Look with a radio telescope, an optical telescope and a gamma ray telescope, and each could be said to simultaneously obscure and reveal. Together, print and visual STS could offer a more dimensional, denser understanding of the world of science, technology and medicine.

FILMING AND WRITING SCIENCE

Now a hard cut to a more personal point of view, to the back and forth trajectory I have taken, between filming and writing. When I was writing *How Experiments End* in the early 1980s, images entered in three ways. First, as a matter of content, I was struck that some of the experimenters I was studying relied so heavily on visual forms of evidence—I was immensely struck by the way a cloud chamber image or two (like the one that persuaded Carl Anderson of the reality of the positron) could have such persuasive force. By the time I finished the book, it had become clear to me that experimenters using cloud chambers or bubble chambers, for example, had a very different working epistemology than those immersed in counters and their associated statistics. This evidentiary contrast later became a guiding theme of *Image and Logic*. Second, I had in mind a role for images beyond the mounting of an argument. As an exploratory move, I wanted the images as a whole to form a counterpoint argument of *How Experiments End*. That is, I wanted the reader to be able to read the book two ways: with text and image—or on a different plane through images and captions alone, a kind of parallel, flip-book story among machines, evidence, diagrams and architecture. The idea was to make a kind of graphic narrative, one that would use photographs, diagrams and other imagery to tell the book's story, but in a way that would complement the main text. My hope was that as the reader went from devices the size of a table to that of a factory, I wanted the scale shift to register in more than words.[14]

Around the time I was writing *How Experiments End* (in the early 1980s), I was also testing to see if I could push a level down, to the development of instruments—hydrogen bubble chambers, for example. One day, I was wandering around the remains of an old hydrogen liquefaction plant in Denver with one of its creators and he remarked that the bubble chamber hydrogen supply had come ready to go from work on the . . . [mumble]. I asked again. Mumble. Finally, more clearly: "It came from the nuclear device on Eniwetok," the site of the first (liquid) hydrogen bomb. I went back to the archives, where, buried in a box of purchase orders, I saw the packing forms that had sent the liquefier from the Pacific to Berkeley, where it became a workhorse of one of the most successful campaigns of particle physics ever conducted. Working backwards, I began to see how so much of the postwar physics boom began in the surplus equipment, novel forms of organization and technical skills developed in the World and Cold Wars.[15]

I wanted to know too how the physicists understood themselves—two questions fundamentally interleaved: What did it mean to be a physicist, what counted as physics in 1920, 1950 or 1980? To know one, one had to know the other. I began talking quite a lot with Luis Alvarez at Berkeley, who had played such a large role in World War II radar and nuclear projects—and went on to be a key figure in the Cold War. I spoke with Hans Bethe, Edward Teller, too, and read extensively in their and others' archival

papers. What struck me about the early Cold War—from 1947 to 1952—was how volatile positions were toward the nuclear ramp-up that followed Hiroshima and Nagasaki. It first seemed hopeless to find an order; toward the hydrogen bomb one saw with so many of the figures what seemed a random flipping: for it, against, it, for it, against it, resigned to it. With Barton Bernstein, we began trying to sort this morass of moral-political positions—and eventually I came to see that it was far from an uninterpretable mess. Instead, it was rather sharply periodized by historical inflection points (Galison and Bernstein 1989). A general acceptance during World War II; a turn against new nuclear weapons after the human effects of Japanese bombings; an acceptance that H-bombs should be a part of the package of nuclear arsenal in the period after the start of the Cold War, and a profound polarization following the Russian detonation of their first bomb, "Joe 1," in the summer of 1949.

It was then in the early 1980s that I saw John Else's *Day after Trinity* (1981), which I found electrifying. Here was a film about science and technology that was not a glorification of the atomic bomb, a diatribe against armaments or a ginned-up story of the race to build it, but instead an exploration of J. Robert Oppenheimer—how in the context of the war, he went from being a somewhat shy, philosophically inclined physicist to the leader of a massive effort to build the atomic bomb. That film opened a world to me—for the first time, I began to think about how I could merge my interest in filmmaking with the kind of science studies that intrigued me. I began to imagine filming people I knew—Hans Bethe, for example—alongside archival and other visual footage to try to get, while it was still possible, a film account of the *moral-political* history of the hydrogen bomb.

Making *Ultimate Weapon* took my collaborator, Pamela Hogan, and me a good long time—more than a decade. We first worked on video through the dreadful, "portable" system of analogue videotape—a camera (a Sony, I believe) linked by cable to a half-inch videotape recorder. Though at the time, the fairly heavy cameras could be carried (not just put on a tripod), editing—*linear* editing—meant that in order to insert a section, call it C, on one tape between shots A and B (located on another tape in the order AB), you would need to first put the tape with shots AB on it into a video player, call it the source player, and copy just A to a fresh tape on the target recorder; second, put the tape with shot C on the source player and copy that after the copy of shot A on the target tape (now the target tape has shot sequence AC). Third, put your first tape with AB back on the source player and copy shot B onto the target tape after the portion of the tape with AC. Now you have on the target tape ACB, as desired, but this target tape is a generation down from your original A, B and C—more snow, more flickering. By the time you had done some serious editing, you had to squint, pray and imagine your way to decoding what was on your working tape. The most often copied pieces would be so many generations from the original that it looked like it was just in from Alpha Centauri.

Beyond technical horribleness, I had no real sense in the late 1970s and early 1980s what I could do with video filming. Science documentaries tended, on the whole, to be pedagogical or visual white papers. The topics (the story of DDT, for example) were important but not very cinematic: the race to X, the discovery of Y, the wonder of Z. It was a time when some of us—from history, sociology and philosophy—were beginning to think about science as process, not results; it was a time when the goal was not to celebrate or popularize discoveries but to explore science as a process.

Some of my Zeno-like progress was of practical origin (the nightmare of analogue video editing), but it was more than that. I had to *un*learn much of what I took for granted in writing. Take interviews: I had done hundreds of oral history interviews—they were crucial to so much of my work as I tried to bring history into the present. So I thought I was pretty good at it, and would just move the interview onto film. Wrong. In an interview for print, ellipses and fragmentary excerpts, contextualized in the surrounding sentence, are your friends. Ellipses (cutting away bits) are not such good pals on film. You can also conduct a print interview most anywhere: A fly lands on the forehead of your interview subject in a print interview and she swats it away—you don't even notice. Film it—and no one will see anything but the fly. I once hiked out to the middle of nowhere to film the pilot of the fallout-filter plane who, in 1949, had discovered that the Russians had detonated a bomb. I drove miles and miles in the Western desert sun, clambered up to his apartment over his grown children's garage, set up in the killing heat . . . and lost the interview because I forgot to turn off the refrigerator. It was humming, loudly and intermittently.

Worse still, I'd get affectively flat responses to questions, which didn't matter much for print. My question to a hugely creative figure at the intersection of computer design, math, physics and bomb design: "Was it surprising to have use of one of the first computers to calculate the force of the H-bomb?" Interviewee: "No, I wouldn't say exciting. But it gave good results." Pamela Hogan turned to me and said, "We came to Los Alamos to get this?" So I tried again. Me (approximately): "So, people think that putting a simulated weapon on the computer is pretty standard—is that right?" Interviewee: "Standard? That was the first time anyone had run that computer at all—and the first thing we ever put on it was the hydrogen bomb. It was anything but usual."

But worst of all—worse than learning to see, worse than juggling affect, content and scene simultaneously—were more structural problems. My first idea was to take the article Bernstein and I had written and put it into a script. There would be six stages:

1) World War II through Hiroshima.
2) End of World War II through the failure of the Baruch Plan in 1947.
3) Failure of Baruch Plan to the Russian bomb, "Joe 1," in 1949.

4) Joe 1 to Teller and Ulam's January 1950 sketch of a plausible H-bomb design.
5) Teller-Ulam idea through the first H-bomb test in late 1952.
6) Early Cold War, after Joe 1.

In print, this partition had put order into the apparent flip-flops—for example, once there was a plausible design that the physicists assumed the Soviets would soon find, many dissenters gave up.

Why *not* build a film that way? Because an illustrated lecture is not a film. This blatantly obvious fact was the hardest lesson of all. I'd worked so hard for so long to put order onto material, to make sense of a vast morass of archival and oral material, it was hard to give up. And my periodization chart that made sense of why Fermi (for example) changed his mind after Joe 1 . . . or why Bethe changed his after seeing the Teller-Ulam solution in January 1951. True, one can force film into written structures, use charts, divide into chapters with intertitles . . . but then the specificity of film is lost. Yes, you can rig a schooner with immense outboard engines to move faster in the water. But if speed is your goal, it is the wrong tool for the job. If you want to explain what a second cousin once removed is, use a kinship chart. If you want to make a point-by-point comparison of postmodern architecture of the 1980s with modernist architecture of the 1960s, print serves well. A very good book in STS, Steven Shapin and Simon Schaffer's *Leviathan and the Air-Pump*—one of my favorite works in the field—starts as follows: "Our subject is experiment. We want to understand the nature and status of experimental practices and their intellectual products."[16] That launched the book well—but it is inconceivable as a way to begin a film. Film needs to hit the ground in the material and particular.

What I slowly learned was that film did other things. In one scene from the H-bomb film, Theodore (Ted) Taylor, one of the hotshot young thermonuclear weapons designers of the 1960s and his wife, Cara, were talking to each other about explosions. Ted: "Big explosions, quite aside from making weapons, people being killed, big bangs, I've always loved them." He then turns to Cara, who is looking at him with a mixture of affection and utter incredulity. "But," she says softly, "you don't go to the fireworks to hear the bang." Ted: "Well, I did." That exchange of looks, words and body position, the density of the interaction—it was a quip in a lifelong conversation.

Film could also contain images, both moving and still, that were themselves part of the contested nuclear era. Oppenheimer, General Groves and their colleagues actually starred in a recreation of the race to the bomb—we could use those performances. The mission to detonate the first hydrogen bomb was filmed and projected by the Atomic Energy Commission (AEC) for the relevant congressional committees. Visual material that might seem to be purely a record was more than that; it was an integral part of the historical production of the thermonuclear weapon. We could and did use some of those visual fragments too, repurposing them. Indeed, this reuse

of material to different ends is fast becoming an important feature of ethnographic and documentary filmmaking today. Greg Mitman and Sarita Siegel, for example, have found and digitized anthropological footage shot in Liberia in the 1920s, in the boom years of Firestone's rubber exploitation. They are, at the time of this writing, in the process of retracing that expedition, showing the old clips at villages that were stopping points on the trajectory taken by the Western anthropologists ninety years ago (and filming the encounters). Mitman and Siegel have found that people take these "archival" film segments up in ways far different from anything expected by the original makers. The clips become part of a reconstruction of history, much of which was shattered in the long and brutal Liberian civil war. At the same time for individuals, some of whom are seeing their direct relatives, the film and film viewing become part of a more personal, familial reassessment. Out of this back and forth between history and contemporary, reciprocal anthropology, the director/authors are making a film (*Where the Cotton Tree Grows*) that is, all at once, about the circulation of goods, like rubber, the migration of diseases and the fragmentary rebuilding of familial and national history. Could this be done with print? Hardly. *Reading* a 1926 journal to a town meeting in Liberia simply would not have the density, affective, personal or historical, of this rediscovered and repurposed ethnographic film.

Getting back to H-bombs—my film with Pamela Hogan, *Ultimate Weapon: The H-bomb Dilemma*, came out in 2000. It was then that I began collaborating with Robb Moss, whose films (e.g., *The Same River Twice* [2003]) use observation to record the personal, in very innovative ways. While working on the intersection of the history of physics and the development of nuclear weapons, I had begun thinking about the dynamics of classification. On a purely analytic level, secrecy was important because it seemed to me a kind of "anti-epistemology." To come up with a process that would block transmission, was, in effect, to show what your theory of knowledge was. I began writing about this negative account of knowledge (Galison 2004). But secrecy is more than epistemology—in our conflict-riven world, too much secrecy about political and military matters is a threat to the very possibility of deliberative democracy. At the same time, secrecy is never *just* a matter of procedure—and I was intrigued by our society-wide psychological fascination with forbidden knowledge. Think of the American congressmen who prized secret (but false) reports of Iraqi nuclear weapons above open (as it turned out, verifiable) reports that no such rebuilt weapons program existed.

Against reason, Robb Moss and I began thinking about how we could make a film about national security secrecy (fig. 9.4)—against reason because if one listed filmable topics from the most obviously visual to the least, I'm not sure what would be farther *down* the list than secrets: the things that could be neither spoken nor shown. Yet even this idea—filming the hidden—intrigued us. But the style would have to break with that of

Figure 9.4 Still from *Secrecy*, directed by Peter Galison and Robb Moss (Redacted Pictures, 2008), DVD, 85 min.

Ultimate Weapon in a variety of ways. We set ourselves some rules from the beginning: no narrator, no pundits, but instead people—analysts, interrogators, journalists, citizens—all caught up in the system of secret making and keeping. Above all, we had to figure out a way to convey the part of secrecy that went beyond the rules of classification. We wanted also to convey the affect that surrounded secrecy. What did people want from secrecy, what effects did it have on those inside—and outside?

Here is an instance that did not work. Early in the project, Robb Moss and I went down to Maryland to film a Department of Energy official, who had played a central role in protecting secrecy around the nuclear arsenal. He had many important things to say, including his and many of his colleagues' view that *over*classification, rather than putting a cordon sanitaire around the deepest secrets, actually degraded secrecy by abusing it. So there we were, shooting as this fellow moved around his Chesapeake Bay waterfront, wavelets lapping on sand, wind gently swaying the leaves in the trees. *Nothing* about this scene had anything to do with secrecy; indeed, the whole situation radiated the *opposite* of secrecy.

This called for a major shift; it was then that we began sketching out the idea of a carefully controlled sound stage of light and dark and an aesthetic that would make the theme of visibility and obscurity, and the shifting flows of information. In this period (2003–2007), digital tools advanced far beyond those of the all-too analogue editing of *Ultimate Weapon*—both storage and processing speeds made possible immediate access to a great deal of footage,

cut, fade, slow down, in quick succession. Take slowing-down: In analogue, either one films a scene with specialized high-speed equipment and then projects it at normal speed—or one laboriously inserts copies after each frame (frames ABC become AAA, BBB, CCC, etc.) Such laborious, expensive work is now an easy and routine component of any digital editing suite. A more elaborate and fluid effect interpolates between the images on one frame and its successor, a feat simply impossible before digital. We used this effect (combined with increasing the contrast of the original film clips from World War II) in slowing down a short segment of Japanese planes diving toward Pearl Harbor—we wanted our black and white, high-contrast xeroxes of documents to be visually echoed in some of the moving sequences.[17]

Documents were central to secrecy and to our story of its dynamics. Our first secrecy episode (of three) was about the legal case that established the State Secrets Privilege, *Reynolds v. the United States*. Back in the early 1950s, the family of a civilian engineer killed in an Air Force crash sued the government to get the accident report. The government refused, and in 1953 the Supreme Court backed the withholding of evidence. The justices themselves would not read the contested document. When the family discovered the crash report years later, they found that, in fact, no secrets had been in the report. By then it was too late—the State Secrets Privilege had become a pillar of national security secrecy, a kind of superprecedent for a myriad of other cases. The fruit of that poisoned tree had grown into a full-blown toxic orchard.

Film could convey, more than print, the life-altering effects this blacked-out information had had on the wives and children of the men killed. In the spaces of censorship, we spin theories. To my surprise, secrets were never just routine, bureaucratic business, even to those who work with them every day. When a senior person at the National Security Agency said, "Secrecy is like forbidden fruit, you can't have it . . . makes you want it more," he was not alone in invoking biblical-sexual knowledge. Almost every person in the film (those for more as well as those for less secrecy) moved fluidly between matters of state and personal secrets. To capture this overflow of associations we enlisted an animator, whose German-expressionist-like animations, white lines on black background, formed a kind of unconscious of the film, an extension of arguments when the words no longer sufficed. In filmed footage, American soldiers break through to an underground bunker in Iraq, and begin rooting through rooms and crates—the play of a flashlight dissolving into a digitally manipulated, animated sequence of what they hoped to find. Later in the film, a former CIA interrogator, Melissa Mahle, described on camera the impact of her years of deception on her relation with her mother; she spoke of the effect of having her father pay for a sham wedding, when the real one had to be held in secret. Images in the sequence shift from wedding photos to a gestalt-shifting animation of two figures, faces to a silencing finger held vertically. Such imagery can carry implicitly a density of associations.

Robb Moss and I are now in the midst of another project: *Containment*, about nuclear waste. In several hundred tanks, each the size of the Capitol dome, sit staggering amounts of radioactive waste, the detritus of making or refashioning seventy thousand nuclear warheads. This high-level waste has the consistency of peanut butter; some tanks are still boiling, while others are in danger of exploding from the hydrogen gas "burps" emerging from their depths. It would be fatal to approach the outside of a tank if it were above ground. Yet not a single country has a fully worked-out plan of how to handle this reprocessed material. High-level waste is leaking into the groundwater and crawling into the Columbia River. Film—from digital cameras inside these million-gallon tanks—make visible these extraordinarily toxic sites inside inaccessible weapons factories.

Nuclear waste inescapably extends far over space and time (Macfarlane and Ewing 2006; Masco 2006). In terms of space, lands of the nuclear weapons and power establishment are bigger than some American states. The health problem of waste is one of migration through water, air and soil, and into living bodies. One side of the moral-political conundrum hinges on who lives near these sites—in many cases, Native Americans and African-Americans, or in other countries rural Pacific Islanders, Tibetans and Algerians.[18] In terms of time, because many fission and transuranic elements have long half-lives (plutonium's is 24,100 years), there is a second moral-political issue—nuclear waste will affect people for ten half-lives (a quarter of a million years), raising the question of intergenerational equity.

This twinned set of problems (material-present and imaginative-futurological) set the two broad parameters of *Containment*. We are using observational filmmaking to capture the texture of adjacent communities and the industrial plants of weapons, power and burial sites in the nuclear waste complex. But nuclear waste is with us for the future *longue dureé*. So the film must also follow the people (astronomers, science fiction writers, semioticians, anthropologists) whom Congress and the Department of Energy asked to imagine scenarios of inadvertent intrusion into the waste sites, ten thousand years from 1989. Another team would then use these envisioned blunders to design monuments that would deter our descendants from killing themselves by exposure to the buried isotopes. This warning structure prompted us to join interviews and observational film with excursions into animation and simulation. It is a way of capturing the dual nature of radiological experience—*picturing* "scenarios" alongside the quotidian efforts of mining and political wrangling is a way to inhabit the ordinary physical and the range of fear and forecast that always accompanies the big atomic projects. Nuclear waste, like national security secrecy, is precisely the kind of topic that VSTS can effectively address. For here lie arenas where understanding can be advanced by visualizing otherwise hidden aspects of science, the state and contemporary life—with allusions and materialities riding side by side.

Just a few years after *Secrecy*, there are more useable digital tools—for depicting a consequential but imagined far future. We can use 3-D-animation to bring planned monuments into fully visual forms. We can take a graphic narrative of a scenario and insert limited animation into one or two elements, as a way of registering the incompleteness of these schematics of future societies. These elements fill out the world of nuclear waste in a way that print cannot—because the world of radioactivity, risk and disposal is never just about statistics. For better or worse, the fate of nuclear power, weapons and waste is bound up with our shifting collective understanding of our obligations to the far future. Knowing, *picturing* what lies behind the fence, in the tank, under the ground, matters.

CONCLUSION: TRUTH IN THE DISTAL, TRUTH IN THE IMMEDIATE

Some of the most interesting work in STS these days cuts across the pure disciplinary categories of history, philosophy, sociology and anthropology. No doubt that is and will be ever more true in VSTS. Borrowing from the sophisticated and interesting tradition of visual anthropology (and the more recent field of visual studies) would be a good idea—I have tried to point to some of the remarkable work that has marked that line of visual achievements. I hope at the same time that three features of STS itself can continue into the heartland of what is a burgeoning field.

STS has in some of its strongest work taken on the knowledge constituting standards that form and define fields of scientific and social scientific work. What constitutes a proof, an experiment, an observation? What counts as a proper form of knowledge circulation or certification? How does one become a qualified scientist—how are clashes resolved or demonstrations brought to a close? STS has already made a powerful mark by exploring the mix of cognitive, institutional/political and ethical considerations, asking about the history and trajectory of experiment, probability, curiosity, objectivity and quantification.

When Wiseman entered the Yerkes lab, he was not asking about the scientists' own questions—he very deliberately wanted to stand outside of their concerns, their arguments or their own account of why they were there. That distanced stance led to enormous insight, alongside extremely funny visual and comportment parallels between apes and humans. In transforming Hawking's own *Brief History of Time* into film, Morris essentially set aside Hawking's own constant return to the physics, and in its place set front and center an imaginative, visual biography of Hawking, from childhood (or its memory) into a kind of thought-governed future.

In my view, STS is at its best when it refuses any bright-line division between content and context—it shines precisely by asking about sociality

and the science, about ethics alongside epistemology. I hope that we can use VSTS to push on these sorts of problems, to drive them further, and to forge new alliances with digital innovation, visual anthropology and visual studies. Some of the deep political problems of our time would benefit hugely if we could find ways to visualize them into the fabric of local concerns. Drones and data mining, bio-privacy and emerging diseases come to mind—to name just a few sites of concern, ones where drawing the hidden into the visible could make both an analytic and a societal intervention.

But in the end, reporting on a nascent subject matter, the hope is that these reflections will be seen as an invitation, not a defended territory with a new set of walls. The best moments of science and technology studies have come from moments of openness—new means to deepen our understanding of scientific practice in the world—from history, philosophy and sociology of science to gender, media and colonial inquiries. Visual STS should build on work already accomplished through STS studies of still and moving images as evidence. It should attend to what can be learned both from the history of visual anthropology and from that of documentary film, as well as from the steps now being taken in nonlinear presentations, and see how they might touch on the fields of science, technology and medicine. Still images and sound recordings, film and interactive web design, interdisciplinary locative digital projects, experimental and observational filmmaking—the possibilities are many. By making as well as writing, we can get at the embedded, material particularity of science in ways that will sharpen our understanding of science, technology and medicine as they change.

Sometimes, contra Goldmann, there is truth not just in abstraction but through local, human and material concepts concretized precisely through the sense-density of film and other visual media. We have the possibility of exploring new ground not by opposing STS but by developing an enriched VSTS—to convey with greater immediacy the scale, scope, duration and materiality of our scientific-technical world.

NOTES

1. On locality in Actor Network Theory (ANT), see, for example, Latour (1987); on scientific authorship's site specificity, see Galison and Biagioli (2003); on book history in the history of science and STS and its dependence on historically specific context, see Johns (1998); on the means of transmission itself as a form of local, material analysis, inflected by history, see Kittler (1999)'s analysis of everyday communicative devices like the typewriter or phonograph.
2. On locality in laboratory studies, see Galison (1987, 1997) and Shapin and Schaffer (1985); on exemplifying local studies of procedure with larger claims of historical epistemology, see, for example, Davidson (2001) and Daston and Galison (2007); on the local sociology of confirmation and repetition, part of the empirical program of relativism, see, for example, Collins (1981); on ethnomethodography and discourse analysis, see Garfinkel (1967) and Lynch (1993).

3. Lucien Goldmann, "Cinema and Sociology: Thoughts on *Chronique d'un été*," in *Anthropology, Reality, Cinema: The Films of Jean Rouch*, ed. Nick Eaton, trans. John Higgins, 64–66 (London: British Film Institute, 1979), 64.
4. Ibid., 65.
5. Ibid.
6. Thomas S. Kuhn, *The Structure of Scientific Revolutions* (Chicago: University of Chicago Press, 1962).
7. On Newman's work: http://www.indiana.edu/~rcapub/v29n1/alchemy.shtml. For a time lapse image of the Tree of Diana as it grows, see Newman: http://webapp1.dlib.indiana.edu/collections/newton/chemlab/webvids/silvertree/silvertree_Large.mov
8. Immanuel Kant, *Critique of Pure Reason,* trans. and ed. by Marcus Weigelt (London and NY: Penguin, 2007), 86.
9. For good starting points on visualization in science, see, for example, the essays in Lynch and Woolgar (1990) and Biagioli (1999).
10. Michael Lynch and Steve Woolgar celebrated the turn from purely propositional knowledge to the visual, all while rightly cautioning back in 1988 against too easily supposing that images could travel independently of context. See their edited volume (1990).
11. Javier Lezaun, "Demo for Democracy," *Limn* 001, accessed September 9, 2012, http://limn.it/demo-for-democracy/.
12. Morris (2011) reflects on the complexity of photographic context, the meaning of "manipulation" and the political valence of both.
13. A particularly good statement of "what images want" (as compared with print) can be found in an interview with W. J. T. Mitchell from January 2001, in Dikovitskaya (2005, 238–257); there may be no Chomsky of images, but there is no surplus in pure text to compare with that of an image.
14. In 1988, the year after *How Experiments End*, I read with fascination the just then translated work by Klaus Theweleit: *Männerphantasie*, a study of the right-wing German *Freikorps* between the wars. Theweleit used images from Japanese anime to home photos to string an argument complementary to that of the text, about the relevance of the fearful body-armored militaristic culture of the 1920s to the much later present of his own relation to his own fascist father, and the broader culture of the mid-1970s.
15. See, for example, Galison (1988). The physical infrastructure of physics once it was inflected by war went from building equipment in the 1930s for $1,000 to imagining the construction of bubble chambers for $1 million just a few years later. This change in scope altered the very self-conception of physicists—how they fit into the world, what spaces the laboratories resembled, how they related to industry, to the military, to society in general. In my work, confrontation with all this came to a head in the 1980s—from the inside out, as I began to see the embedding of instrumentation into the wider world of technical, military and industrial apparatus. And outside in: The huge expansion of nuclear weapons at that time dominated discussion not only inside physics but also throughout international politics.
16. Steven Shapin and Simon Schaffer, *Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life* (Princeton: Princeton University Press, 1985), 3.
17. Aiming for that same "xerographic" visual quality, we used an effect that has its origin in a very old technique known in animation circles as "rotoscoping." Back in the 1910s, Dave and Max Fleischer built an apparatus to project individual film frames on a frosted glass where they could draw the image, quite famously in "Koko the Clown." This let them create a one-to-one illustrated version of a film sequence made with a real actor, which

formed the basis of a famous series begun in 1915, about situations conjured through drawing, *Out of the Inkwell*. Our interest in rotoscoping was not so much a fairy princess so much as an immense landscape of offices and laboratories. So we strapped a video camera on a library pushcart, and rolled it down MIT's iconic "infinite corridor." We then increased the contrast (digitally), printed out the individual frames into a stack of images and xeroxed that pile over and over until we had the stark look we wanted. We then rescanned this digital sequence of frames into the film, and looped it. The final product reads as if it were a kind of precomputer document in motion.

18. On nuclear environmental justice, see Schlosberg (2007), Shrader-Frechette (2002) and Stoffle and Evans (1992). STS-derived concerns enter in another way too: Addressing nuclear waste inevitably involves the establishment of *trading zones* (e.g., Galison 1997; Gorman 2010)—regions of limited coordination in the midst of global clashes. With nuclear waste, we, as a society, must grapple with fundamental conflicts of the myriad stakeholders, driven by conflicting goals of profit, military power, climate change and environmental justice—alongside more recent ethical concerns about intergenerational equity. By following the president's Blue Ribbon Commission as it tries to navigate its way among warring stakeholders, we have, in the making of *Containment*, a field laboratory for studying an STS trading zone in action.

REFERENCES

Banks, Marcus, and Howard Morphy. 1997. *Rethinking Visual Anthropology*. New Haven: Yale University Press.

Barbash, Isisa, and Lucien Taylor. 1997. *Cross-Cultural Filmmaking: A Handbook for Making Documentary and Ethnographic Films and Videos*. Berkeley: University of California Press.

Biagioli, Mario. 1999. *The Science Studies Reader*. New York: Taylor Francis.

Burdick, Anne, Johanna Drucker, Peter Lunenfeld, Todd Presner and Jeffrey Schnapp. 2012. *Digital Humanities*. Cambridge, MA: MIT Press.

Collins, Harry M. 1981. "'Son of Seven Sexes': The Social Destruction of a Physical Phenomenon." *Social Studies of Science* 11 (1): 33–62.

Davidson, Arnold. 2001. *The Emergence of Sexuality: Historical Epistemology and the Formation of Concepts*. Cambridge, MA: Harvard University Press.

Dikovitskaya, Margaret. 2005. *Visual Culture: A Study of the Visual after the Cultural Turn*. Cambridge, MA: MIT Press.

Dumit, Joseph. 2003. *Picturing Personhood: Brain Scans and Biomedical Identity*. Princeton, NJ: Princeton University Press.

Feyerabend, Paul. 1975. *Against Method*. London: New Left Books; Atlantic Highlands: Humanities Press.

Foucault, Michel. (1963) 1973. *The Birth of the Clinic: An Archaeology of Medical Perception*. Translated by Sheridan Smith. London: Tavistock.

Galison, Peter. 1987. *How Experiments End*. Chicago: University of Chicago Press.

Galison, Peter. 1988. "Physics between War and Peace." In *Science, Technology, and the Military*, vol. 1, edited by Everett Mendelsohn, M. Roe Smith and Peter Weingart, 47–86. Boston: Kluwer.

Galison, Peter. 1997. *Image and Logic: A Material Culture of Microphysics*. Chicago: University of Chicago Press.

Galison, Peter. 2004. "Removing Knowledge." *Critical Inquiry* 32: 229–243.

Galison, Peter. 2010. "Secrecy in Three Acts." *Social Research: An International Quarterly* 77 (3): 941–974.

Galison, Peter. Forthcoming. "Blacked-Out Spaces: Freud, Censorship and the Topography of Mind." *British Journal in the History of Science*.
Galison, Peter, and Barton Bernstein. 1989. "'In Any Light': Scientists and the Decision to Build the Hydrogen Bomb." *Historical Studies in the Physical and Biological Sciences* 19: 267–347.
Galison, Peter, and Mario Biagioli, eds. 2003. *Scientific Authorship: Credit and Intellectual Property in Science*. New York: Routledge.
Garfinkel, Harold. 1967. *Studies in Ethnomethodology*. Englewood Cliffs: Prentice-Hall.
Geertz, Clifford. 1973. *Interpretation of Cultures: Selected Essays*. New York: Basic.
Geertz, Clifford. 1983. *Local Knowledge: Further Essays in Interpretive Anthropology*. New York: Basic Books.
Goldmann, Lucien. 1979. "Cinema and Sociology: Thoughts on *Chronique d'un été*." In *Anthropology—Reality—Cinema*, edited by Nick Eaton, 64–66. London: British Film Institute.
Gorman, Michael. 2010. *Trading Zones and Interactional Expertise*. Cambridge, MA: MIT Press.
Greene, Jeremy A. 2007. *Prescribing by the Numbers*. Baltimore: Johns Hopkins Press.
Grimshaw, Anna, and Amanda Ravetz. 2009. *Observational Cinema: Anthropology, Film, and the Exploration of Social Life*. Bloomington: Indiana University Press.
Hacking, Ian. 1983. *Representing and Intervening: Introductory Topics in the Philosophy of Natural Science*. Cambridge: Cambridge University Press.
Haraway, Donna. 1989. *Primate Visions: Gender, Race, and Nature in the World of Modern Science*. New York: Routledge.
Haffner, Jeanne. 2013. *The View from Above: The Science of Social Space*. Cambridge: MIT Press.
Hawking, Stephen. 1988. *A Brief History of Time*. London: Bantam.
Hocking, Paul, ed. 1974. *Principles of Visual Anthropology*. New York: Mouton de Gruyter.
Johns, Adrien. 1998. *The Nature of the Book: Print and Knowledge in the Making*. Chicago: University of Chicago Press.
Kaiser, David. 2005. *Drawing Theories Apart: The Dispersion of Feynman Diagrams in Postwar Physics*. Chicago: University of Chicago Press.
Kant, Immanuel. 2007. *Critique of Pure Reason*. Translated and edited by Marcus Weigelt. London and NY: Penguin.
Kirby, David. 2011. *Hollywood in Labcoats*. Cambridge, MA: MIT Press.
Kittler, Friedrich. 1999. *Gramophone, Film, Typewriter*. Translated by Geoffrey Winthrop-Young and Michael Wutz. Stanford, CA: Stanford University Press.
Kuhn, Thomas S. (1962) 1970. *The Structure of Scientific Revolutions*. Chicago: University of Chicago Press.
Landecker, Hannah. 2007. *Culturing Life: How Cells Became Technologies*. Cambridge, MA: Harvard University Press.
Latour, Bruno. 1987. *Science in Action: How to Follow Scientists and Engineers through Society*. Cambridge, MA: Harvard University Press.
Latour, Bruno. 1990. "Drawing Things Together." In *Representation in Scientific Practice*, edited by Mike Lynch and Steve Woolgar, 19–68. Cambridge, MA: MIT Press.
Latour, Bruno. 1996. *Aramis, or the Love of Technology*. Cambridge, MA: Harvard University Press.
Law, John and Michael Lynch. "Lists, Field Guides, and the Descriptive Organization of Seeing: Birdwatching as an Exemplary Observational Activity." *Human Studies* 11 (1988): 271–303.

Lezaun, Javier. 2011. "Demo for Democracy." *Limn* 0. Accessed September 9, 2012. http://limn.it/demo-for-democracy/.
Lynch, Michael. 1993. *Scientific Practice and Ordinary Action: Ethnomethodology and Social Studies of Science*. Cambridge: Cambridge University Press.
Lynch, Michael and John Law. 1999. "Pictures, Texts, and Objects: The Literary Language Game of Bird Watching." In *The Science Studies Reader*, edited by Mario Biagioli, 317–342. New York: Routledge.
Lynch, Mike, and Steve Woolgar, eds. 1990. *Representation in Scientific Practice*. Cambridge, MA: MIT Press.
MacDougall, David. 1998. *Transcultural Cinema*. Princeton, NJ: Princeton University Press.
Macfarlane, Allison M., and Rodney C. Ewing. 2006. *Uncertainty Underground: Yucca Mountain and the Nation's High-Level Nuclear Waste*. Cambridge, MA: MIT Press.
MacKenzie, Donald. 1993. *Inventing Accuracy: A Historical Sociology of Nuclear Missile Guidance*. Cambridge, MA: MIT Press.
Marcus, George E. 1995. *Technoscientific Imaginaries*. Chicago: University of Chicago Press.
Masco, Joseph. 2006. *The Nuclear Borderlands: The Manhattan Project in Post–Cold War New Mexico*. Princeton, NJ: Princeton University Press.
Mead, Margaret. 1974. "Visual Anthropology in a Discipline of Words." In *Principles of Visual Anthropology*, edited by Paul Hocking, 3–10. New York: Mouton de Gruyter.
Mialet, Hélène. 2003. "Reading Hawking's Presence: An Interview with a Self-Effacing Man." *Critical Inquiry* 29 (4): 571–598.
Mitman, Gregg. 2009. *Reel Nature: America's Romance with Wildlife on Film*. Seattle: University of Washington Press.
Morris, Errol. 2011. *Believing Is Seeing: Observations on the Mysteries of Photography*. London: Penguin Press.
Pickering, Andrew. 1984. *The Social Construction of Quarks*. Chicago: University of Chicago Press.
Pinney, Christopher. 2004. *"Photos of the Gods": The Printed Image and Political Struggle in India*. London: Reaktion Books.
Rudwick, Martin. 1988. *The Great Devonian Controversy*. Chicago: University of Chicago Press.
Ryle, Gilbert. 1968. "The Thinking of Thoughts: What Is 'Le Penseur' Doing?" *University Lectures* 18. University of Saskatchewan. Accessed August 27, 2012. http://lucy.ukc.ac.uk/CSACSIA/Vol14/Papers/ryle_1.html.
Sahlins, Marshal. 1995. *How "Natives" Think: About Captain Cook, for Example*. Chicago: University of Chicago Press.
Schlosberg, David. 2007. *Defining Environmental Justice*. Oxford: Oxford University Press.
Shapin, Simon, and Steven Schaffer. 1985. *Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life*. Princeton, NJ: Princeton University Press.
Shell, Hanna. 2012. *Hide and Seek: Camouflage and the Media of Reconnaissance*. New York: Zone Books.
Shrader-Frechette, Kristin. 2002. *Environmental Justice: Creating Equality, Reclaiming Democracy*. Oxford: Oxford University Press.
Sibum, Otto. 1995. "Reworking the Mechanical Value of Heat: Instruments of Precision and Gestures of Accuracy in Early Victorian England." *Studies in History and Philosophy of Science* 26: 73–106.
Stoffle, Richard W., and Michael J. Evans. 1992. "American Indians and Nuclear Waste Storage: The Debate at Yucca Mountain." In *Native Americans and*

Public Policy, edited by Fremont J. Lyden and Lyman Howard Legters, 243–265. Pittsburgh: University of Pittsburgh Press.
Tucker, Jennifer. 2005. *Nature Exposed: Photography as Eyewitness in Victorian Science*. Baltimore: Johns Hopkins Press.
Vicedo, Marga. 2009. "The Father of Ethology and the Foster Mother of Ducks: Konrad Lorenz as Expert on Motherhood." *Isis* 100: 263–291.

FILMOGRAPHY

Algar, James. 1951. *Nature's Half Acre*. Walt Disney Productions. 16 mm film, 33 min.
Breton, Stéphane. 2001. *Eux et moi* [*Them and Me*]. Arte Video. VHS, 63 min.
Castaing-Taylor, Lucien, et al. 2009. *Sweetgrass*. Cinema Guild. DVD, 100 min.
Castaing-Taylor, Lucien, and Véréna Paravel. 2012. *Leviathan*. Cinema Guild. DVD, 87 min.
Else, Jon. 1980. *The Day after Trinity*. Pyramid Film and Video. VHS, 90 min.
Flaherty, Robert. 1922. *Nanook of the North: A Story of Life and Love in the Actual Arctic*. Revillon Frères. 16 mm, 65 min.
Galison, Peter, and Pamela Hogan. 2001. *Ultimate Weapon: The H-Bomb Dilemma*. A presentation on the History Channel. GMG Films. DVD, 45 min.
Galison, Peter, and Robb Moss. 2008. *Secrecy*. Redacted Pictures. DVD, 81 min.
MacDougall, David, and Judith MacDougall. 1980. *The Wedding Camels: A Turkana Marriage*. University of California at Berkeley Extension Media Center. VHS, 108 min.
Morris, Errol. 1988. *The Thin Blue Line*. HBO Video. VHS, 101 min.
Morris, Errol. 1991. *A Brief History of Time*. Paramount Pictures. VHS, 80 min.
Moss, Robb. 2005. *The Same River Twice*. New Video. DVD, 77 min.
Negroponte, Michel. 2000. *W.I.S.O.R. (Welding & Inspection Steam Operations Robot)*. New Video. DVD, 75 min.
Negroponte, Michel. 2009. *I'm Dangerous with Love*. Blackbridge Productions in association with Cactus Three. DVD, 85 min.
Oxley, Chris. 2005. *Newton's Dark Secrets*. WGBH Boston Video. DVD, 54 min.
Wiseman, Frederick. 1969. *Hospital*. Zipporah Films. VHS, 86 min.
Wiseman, Frederick. 1974. *Primate*. Zipporah Films. VHS, 105 min.
Wiseman, Frederick. 1987. *Missile*. Zipporah Films. DVD, 115 min.