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Peter Galison
Interviewed by B. R. Cohen

B. R. Cohen (BC): Because your scholarship in the history of science and technology is now paired with a blossoming career in documentary filmmaking, and because there are any number of ways we could get started in our discussion, let me begin with the film work. Your documentary from 2008, *Secrecy*, examines the security-versus-freedom axis. How much should a democratic public know? How much of our security is compromised if we reveal what the analysts know, the Central Intelligence Agency (CIA), the National Security Agency (NSA), the Federal Bureau of Investigation (FBI)? This is about the contested value of transparency, that's the starting point?

Peter Galison (PG): *Secrecy* began when my coproducer, Robb Moss, and I asked, To what extent is national security secrecy a balancing act between safety, on the one hand, and democratic deliberation, on the other? That was the starting question, though it wasn't the ending one.

BC: What's the main path of the film? And what, then, was the ending question?

PG: We started with one side saying, "We must have more secrecy, because otherwise we'll end up with more 9/11-type terror," and the other side responding, "We must have less secrecy, or the very possibility of deliberative democracy will be lost." We talked to people from the NSA, from the military and nuclear weapons labs, from the CIA, from the critics of secrecy from the Federation of American Scientists and the National Security Archive—as well as to people who, for one reason or another, got caught up, sometimes fatefully so, in the secret world. As we began to push, another set of issues emerged which led away from that starting question: the problem of the nature of information itself. What *are* secrets? What is the information that is being sequestered? What is its nature? And how does information move?

79

BC: You mean the circulation of information and then knowledge?

PG: When you speak about secrecy, as soon as you try to block information from flowing, you are probing the nature of knowledge. That question (what counts as knowledge?) interests me tremendously, not just in this film but in all of my work. Here every notion of secrecy presupposes some idea of what knowledge is—what it is you're trying to protect and what kinds of actions you can take to halt knowledge from circulating where you don't want it to go. Masking information—keeping secrets—requires some conception of what information is, and how it moves, in order to block it. Secrecy is an anti-epistemology.

BC: How did you get at those layers in the documentary, between questions of national security and onto the foundations of knowledge?

PG: We tried to talk about the ways those questions were part of the same world. Suppose you are a censor, sitting in a windowless room, assigned the task of keeping forbidden knowledge from falling into the wrong hands. What do you block? Back in World War I, the Espionage Act and other legislation would have pushed you to go after dangerous utterances: to black out mentions of troop demoralization, to suppress indicating where General X would be inspecting the troops on January 22. In World War II and the Cold War, you would have had a different, harder task: prevent whole systems of scientific know-how from moving. You would have wanted to keep an enemy from knowing how to use centrifuges to separate the explosive kind of uranium. This meant forbidding the dissemination of vast, expensive, and interconnected scientific and engineering efforts covering everything from machines and raw materials to theoretical knowledge. Technical understanding isn't just isolated bits; you can deduce some things from others. Suppose you stop publishing at all on some topic (as the Allies did on fission)—the very *absence* of fission articles told the Germans a lot. The world of science and technology is a lot trickier than propositional statements—in a world of connections, even blocked knowledge reveals something.

BC: But how do you make a film about invisible things, the unseen or unseeable?

PG: The premise for the film came out of my interest in the encounter of physics with nuclear weapons secrecy: war work shot physics to the forefront of defense concerns in the mid- to late twentieth century, and the model of secrecy presented by the Manhattan Project soon dominated many other domains as well. I wanted

8 0

to think about how to visualize the process of secret making and secret keeping. That became the motivation for the film. But your question is a good one—it troubled Robb Moss and me endlessly. How do you make tangible and visible that which, by definition, has been cast out of the light? *Secrecy* is, in a sense, a film that can't be made. This very difficulty pushed us to invent new techniques to make the invisible visible. We used a sealed-off soundstage for the interviews so people were not in their natural environments—we wanted to get away from the everydayness of most stand-up interviews. We wanted a look that had a more hermetic feel to it. We used animation to discuss things that went beyond things the interviewees could picture. For example, we'd be following someone looking for weapons of mass destruction in Iraq, following them with a flashlight in a deep underground repository in Iraq, then trying to imagine what they were picturing. At that point, we slid from live action to an almost German expressionist animated vision. The animation became a kind of unconscious extension for the conscious (representational) parts of the film.

BC: What about practical aspects, like your choice of material?

PG: Pragmatically speaking, it was a matter of selecting notable cases that would exemplify the questions you were just asking. Key was looking at three quite specific, and troubling, stories that had a visible dimension and guided thousands of subsequent secret actions. One is the 1953 Supreme Court case *United States v. Reynolds* [345 U.S. 1 (1953)]. A second is the case of Khalid El-Masri [*El-Masri v. Tenet*, 437 F.Supp.2d 530 (E.D. Va. 2006)], a German citizen who, in 2003, was grabbed off a bus in Europe, thrown into a black site (the Salt Pit) in Afghanistan, tortured, and eventually released when the CIA finally came to understand that this fellow had had the misfortune of having the same last name as a bad actor they were pursuing. The third is *Hamdan v. Rumsfeld* [548 U.S. 557 (2006)]—a case that also went to the Supreme Court, successfully challenging the prerogative of the president to establish military commissions without congressional consent. That first case, the *Reynolds* decision, set out the legal "state secrets" doctrine still in force today and as such represents a type of superprecedent. Essentially, the air force wanted the ability to exclude certain information from court review (a crash report about a fatal B-29 accident)—and, astonishingly, the Supreme Court assented, without ever looking at the contested material. The self-exemplifying tragedy was that in this paradigmatic case there in fact were no secrets at all in the material the air force withheld. After 9/11, the state secrets privilege had become a routine way that the government kept certain cases even from arriving in court.

BC: We jumped in, but I wanted to ask about your background too. You're a historian and physicist by training, though known mostly for your work in the history of science and science and technology studies. What was your dissertation work in physics?

PG: The doctorate in physics was on high-energy particle theory.

BC: That sounds, let's say, nontrivial. Was that a long-term ambition?

PG: You know, I left high school at a somewhat early age, and I'd done a reasonable amount of physics before leaving, and then went to work in a lab in Paris before going to college. Then I came to college and studied history of science at Harvard, where you could do quite a bit of science in parallel to history. I studied mathematical physics—and chose as my historical area European social and intellectual history. So I kept going in physics—oriented mainly toward the more fundamental, theoretical area of particle physics. After my PhD in the history of science I had a three-year postdoc at the Society of Fellows, where I used the second and third years to write a dissertation in theoretical physics (technically, it was the second part of a single dissertation—Harvard rules). I'd already completed my coursework, so working on the dissertation research was possible. I left Harvard in 1983 after that two-part work. The first, "How Experiments End," became the book of that name. The second was this thesis in theoretical physics about unified theory and focused on the structure of the Higgs particle (the critter that the European Organization for Nuclear Research recently saw in its huge accelerator).

BC: How did this work? You graduated from high school and worked in a laboratory in France. So, okay, this isn't a well-worn path for high school graduates. A "reasonable amount of physics"? Who jumps from high school to a Parisian lab?

PG: [*Laughs.*] Oh, I had family in France and I'd spent a lot of time there, so that route wasn't entirely far-fetched. I abbreviated my answer there, but there's a family history that helped set me on the way. You have to remember too, it was also a highly political time, a good time to get out of high school, and, like many teenagers, I wanted to get out of Dodge. Plus, I was interested in French literature and physics, and I didn't think anyone would hire me to think about literature. So I went to the École polytechnique, a kind of a hybrid, if you can imagine, between West Point and the Massachusetts Institute of Technology, and they had a very

82

good lab there in physics—no doubt amused by an American student who wanted to join (there were very few back then), they offered me a position as a research assistant in their plasma physics laboratory. So I did that, and I took a course with one of my heroes, the great mathematician Laurent Schwartz.

BC: A story that begins in Paris in the seventies.

PG: Well, yes, it was political in the streets, and I had been very involved in anti-Vietnam activity back in high school. I found Paris fascinating, awash with demonstrations and late-night meetings about the war, about the meaning of Kafka, or about which of seven strands of Trotskyism or Maoism the disputants preferred. It was a wild time. But I had a great year. Then I went to Harvard.

BC: Let me get back to *Secrecy*, then, because I can see the physics elements coming out in your choice of topics and connection to atomic and nuclear material, and I recognize that the stories in the film are historical examples. But now I'm wondering how your historical sensibilities shaped the film.

PG: You're asking a historiographical question about film, a forum with different audience demands and expectations, a different public import. As I was pursuing this, I realized that in thinking about secrecy within a historical context, Robb and I could approach the material in two ways. One is to follow what Michel Foucault called an *archaeological* history, asking, how can you reconstruct past ways of understanding the world in the past's own terms? As I understand it, this is a way to understand a culture like an anthropologist, to say, let's try to understand a culture and all the aspects of what makes it go and map them out in a way that makes it as comprehensible to us as possible. It tries—though it's never fully possible since we can never divest ourselves of our present views—but it tries to understand the past extracted between the time you're studying and now. And that I understand to be the project of archeological history.

BC: As opposed to a genealogical history, you mean.

PG: Right. An archaeological history of secrecy might look at the major strands of secrecy from Babylonian signet rings to NSA satellite intercepts. There's royal secrecy and proprietary secrecy, military secrecy, sexual secrecy, competitive secrecy—and I'm just naming a few. Restricted to warfare alone, we could have asked how secrecy played out in the Civil War and World War I and so on through

World War II, Vietnam up to the multifront conflicts since 9/11. But instead we wanted to say, look, we live in a world where secrecy is central to our most fundamental political debates, including one of the most weighty: Should we go to war? What happens when secrecy conflicts with detainee rights? Ultimately, how does a vast extension of secrecy challenge the very idea of deliberative democracy?

BC: How is that approach different?

PG: In choosing what part of the past to investigate—from the Manhattan Project through the Cold War into the terror wars—Robb and I constantly came back to the question of what we need to understand of the past to grapple with our *current* condition in the midst of the greatest expansion of secrecy in history. The *Washington Post* reported a few years ago that there are now 850,000 people with top-secret clearance. With each new conflict, secrecy drags its shroud further over our society. Like a ratchet, secrecy tends not to move in reverse.

What interests me is using film to do a history of the present—a task much closer to Foucault's genealogical history than to archeological history. Not to dig down in some past episode of history for its own sake, but to understand what choices were made that most decisively shaped things today. Focusing on a history of the present—putting how we got here front and center—was our choice, rather than studying all the many branches of the history of secrecy that lead out to historical dead ends.

BC: I think I need an example.

PG: Sure, let's look at the state secrets privilege so important today, for example—founded in that 1953 case *U.S. v. Reynolds*. There the air force accident report in fact contained terribly embarrassing information (about catastrophic maintenance, training, and flying errors) but not a single, genuine secret. We wanted to show that this decision was one of those decisive junctures: a political and judicial choice made in the Cold War to enhance presidential power, hugely, at the expense of the judiciary. It didn't have to go that way, but that's how it went. We're still living today with the consequences of that court decision made more than a half century ago.

BC: It feels as if this will get us into a "presentist" discussion, and we'll have to rehash debates about the place of Foucault in the field of history.

84

PG: The debate over Foucault isn't crucial here. This is how I see it: I want to understand in my work, and we wanted to understand in this film, how it comes to pass that the way we do things got this way. What choices were made, what were the contingencies and juncture points that existed that had to be taken to produce what we have today? It's not to sanctify the present. On the contrary. This is to say, as Friedrich Nietzsche does, for instance, that our ideas about morality involve decisions we made at different times in history, that there were choices we made and ones we didn't, and understanding those choices, that is the task before us today. But it's also to dethrone them as being the inevitable and only way things could have come out. It's about taking our concepts and cultural practices and ways of doing things and asking how they came to be. If you *de*sanctify the present, as I think this approach does, then you say that not any set of practices was inevitable. There were points at which we made decisions, and we at least should take responsibility for choosing something affirmatively instead of simply throwing up our hands and saying that things are the way they must be. In that sense, genealogical history begins with the present and asks about the contingencies that led to it, but it does so by following the historical path as it made its way—not by reading backward.

BC: But, and I almost asked this earlier, why did you make a *film* about secrecy? Why not write a book?

PG: Film and print each have certain things they do particularly well. If you want to explain something like kinship relations and what a second cousin once removed is, you can do that with a genealogical tree very easily. On the other hand, film captures very well the multiple meanings and allusions that are created if you begin to know how people are. People can express themselves in ways that allow a variety of meanings to play across a face, an interaction, a scene. You get a density that's very hard to achieve in print. Writing about state secrecy does certain things—film can do something else: it can show the way secrecy echoes through peoples' lives, through the analysts', interrogators' own way of thinking. And importantly, how secrecy can punch holes in peoples' lives—the lives of wives and children, for example, who for decades never knew what happened to their father, who was killed in events leading to the *Reynolds* crash.

BC: I want to risk a reference to *Manufactured Landscapes* [dir. Jennifer Baichwal; 2006]. This is the documentary about Edward Burtynsky's industrial landscape photography. There's also a book of the same name. I admit it; I was sur-

prised by the different experiences of watching the film and reading, viewing the book. The opening scene of the movie is this long tracking shot along the factory floor. It goes for like five, six minutes, slowly, without narration, and this is the introduction to the film. So you have to embed yourself into the scene, leaving you all this space to think about "what am I supposed to think" and "what's going on here," and "did I leave the iron on," and "what is all of this? What did I just get myself into watching?"

PG: Right, you have to live the time of the film. That tracking shot is radically different than a sentence that says, "There's half a mile of corridors here in this factory, each one with different machines, each making different extruded plastic." Nor can you simply list machines and products as text, because the reader would do what everyone does when he or she encounters a list: you'd read a couple of lines, then skip a few, and jump to the end. Film can allow many different layers of meaning to play around and against each other in ways that are more difficult in print. A facial expression, a tone of voice, a gesture; visual juxtapositions; the simultaneity of image and sound—these and much else give film a particular kind of density.

BC: You'd say the same for each of your films?

PG: I'll say it this way: in general, I'm interested in film as a way of thinking about political and moral questions in the context of science. That's how I ended up making *Secrecy*, just as my prior film, *The Ultimate Weapon* [coproduced with Pamela Hogan; 2000], was about the decision to build the hydrogen bomb, and the documentary I'm working on now—*Containment*, on nuclear waste. In *Containment*, I'm interested in a factual, crucial issue of national energy policy but also, and at the same time, in the terrible fear that rides through us about buried danger, the threat of cancer and deformation, that threatens to destroy us. I am interested in hard problems without easy solutions, problems that echo back and forth between the literal and the metaphorical.

BC: This film work, along with your more traditional historical work and your art and architecture collaborations, they all circle around presenting evidence in different ways, most of them visual. That is, most of your work has led you to bring the visual elements of argument making in science to the foreground. An article you cowrote with Lorraine Daston in 1992 called "The Image of Objectivity" eventually led to the full book *Objectivity* that came out in 2007 and is about

8 6

objective image-making. Without debriefing on every publication, I did want to ask about the order of things since your perhaps most influential book, *Image and Logic* (1997), was published in between. Did that original objectivity study lead to *Image and Logic*?

PG: No, actually it was the other way around. In *Image and Logic*, I was tracking down a historiographical problem about different subcultures in physics and how they communicate with each other through visual and nonvisual means. It was about the kind of evidence we get from data, numbers, and the kind we get from images, something that had come up for me in *How Experiments End*. My research for *Image and Logic* began when I was looking at atlases of cloud chambers, in which they all talked about what could be objectively depicted. As it turned out, these physics atlases were built on the idea of medical atlases. So in 1989 I went down to the basement of the Stanford medical school library to see what they looked like; I had no idea. It was astonishing. There were thousands of atlases, atlases of hands and skulls, atlases of embryos and physiological crystals. The list goes on and on—pathological atlases and normal atlases—even atlases of normal deviations. Many of them talked about the nature of objectivity and what an objective image was. They were written for biomedical people, not as public display items; they weren't sermonizing to the public or popularizing. There was all this discussion about the nature of the image and its status.

BC: But then the larger set of issues from *Image and Logic* led to your exploration of no less than the history of objectivity itself, right?

PG: Well, Lorraine Daston and I started looking through the atlases with the thought that this would be a path to the objectivity problem that would disaggregate the scientists' sense of objectivity from the myriad of other uses. It was a hard enough problem without mixing a myriad of other debates, for example, the journalism arguments about objectivity or the social science disputes around Max Weber.

BC: I run into technological determinism a lot, especially when teaching engineering students, that the technology, the instrument, determines the outcome, that it's the machine itself and not the person operating it that produces the evidence. On this view, one history of the objective image would be about the invention of the camera and photography. You know, "the camera doesn't lie," "seeing is believing," and so on.

PG: We started our inquiry thinking that the film camera might be a crucial turning point but found it just wasn't the case. The camera obscura is one example— just a black box with a hole in the front that projects an image upside down, so it's basically a dark room. We had lots of examples in the eighteenth century of people who would make an image that way, tracing the projection of the image of the thing they're drawing . . . and then idealizing it. Later, the device was used to very different ends—and in particular without the "improvement" of idealization. It showed us that having a device didn't determine the way it was used. In turn, neither is it the case that you're forced into a mimetic form of objectivity if you have a photographic camera; the device alone does not force you to espouse self-abnegating objectivity. Nor was it the case that the photographic camera was the only way to get to this mimetic form. We found people pressing leaves or tracing in other ways—and saying *that* was objective. In short, there are many different mechanical modes of transferring an image to a page that did *not* involve the photographic camera. Just having the technology did not determine the epistemological frame. It may aid and expand our concepts of it, and articulate it, but it is not enough. I think it's dangerous to ascribe too much to the tool.

BC: You and Daston discuss objectivity and the objective self, showing that it has to be about subjectivity and the subjective self too. It's about the human virtues and individual character traits that accompany different ideals of objectivity. So just now you used the term "self-abnegating," this denial of the self, and you're talking about mimetic form, as in imitating nature, I take it. Can you explain that?

PG: This is another example of my interest in finding where the abstract and concrete merge together. I had been thinking a lot and talking to my friend, the philosopher Arnold Davidson, about Foucault, and how to interpret the historicity of self, which led me to think about the objectivity problem in a different way. In 1999 I wrote a piece called "Objectivity Is Romantic," the argument of which was that the necessary condition, the condition of possibility for mechanical objectivity, is that you have a will-based self. Because without a self that is centered in the will, the idea that *objectivity* could be defined as "the suppression of the will" wouldn't make sense. Before the late eighteenth century, the will existed as one faculty among others. If you ask anyone in the seventeenth century how the self is structured, you would have a collection of faculties that should be beholden to the royal control of reason, and reason would then control the various bits of memory and imagination and so on, maintaining order among the many different faculties. In the late eighteenth century, people begin to say that the self is grounded not in

88

a king-like function of reason but rather under the exercise of the will. (Of course, this is challenged later, by Freud, among others, who says that the will is actually no longer master in its own house.) But this idea of the will becomes very central in the late eighteenth century. Without a certain concept of the self, you would never have a concept of objectivity identified with self-abnegation. I would put it this way: the objective image is indissolubly tied to a concept of self. We act, and depict objectively, just in the measure that we suppress the volatile will. Subjectivity and objectivity always enter together, like left and right, up and down. They are not independently definable.

BC: It seems clear that a larger theme your work helps build is this: you look to both sides of a supposed line of separation and show that they aren't so separate after all. Maybe that's too general, but let me ask about that specifically with reference to *Einstein's Clocks, Poincaré's Maps.* This book's about the era leading to relativity theory and how Einstein and Henri Poincaré were developing their ideas about time and space as they worked with real-world, physical means of travel and communication and moving through time and space. It is not just about physics and is only incidentally connected to the history of technology. It's about both at once. This again has the materiality of science, the things of the scientific world, right at the center. Not counting the films, that book is probably your most publicly accessible version of that idea of the thingness of science.

PG: That seems right. In the book you have the French scientist Henri Poincaré dealing with the problem of simultaneity, asking how we know when two things happen at the exact same time. He is not satisfied with Isaac Newton's insistence that there is a true, absolute, and mathematical time that exists in the "sensorium of God." In a new and innovative science-oriented philosophy journal, Poincaré set out what everybody, in more recent times, has read as a pure metaphor, the kind of science-fiction reasoning that our contemporary philosophy loves. Poincaré had a way of synchronizing clocks.

BC: Beyond trying to look back and forth really, really fast?

PG: [*Laughs.*] I think even more than fast head-turning. Poincaré asks his audience to imagine two telegraphers who are sending signals back and forth to determine longitude. Say, telegrapher A sends the signal at noon and knows it takes one-thirtieth of a second to go six thousand miles to telegrapher B. Well, then, Poincaré tells his readers, telegrapher B should clearly set his clock to noon plus

one-thirtieth of a second when he gets the signal. Now the two clocks are synchronized, and whenever events occur at both at the same clock reading, those events are simultaneous. Synchronization is now a procedure, not a wish or divine allusion.

BC: And Einstein?

PG: Einstein's working on similar issues, he says, in words more famous than those of Poincaré: imagine a train comes into the station at seven o'clock. Then Einstein asks himself—and the reader—"What do I mean by that?" "Well," says the twenty-six-year-old patent clerk, "I mean the small hand of my clock is in front of my nose just when the front light of the train also pulls by the front of my nose." Then, "What do I mean when I say that the train arrives at seven o'clock at the station down the track? How does one synchronize the train's distant position and the time on my clock right here to know that two things are happening simultaneously?" Like Poincaré, Einstein sets out a protocol for syncing the clocks, with even greater care. That move was the capstone of many years of reasoning about relativity. Sometime in mid-May 1905, Einstein made the establishment of simultaneity a procedure—to his best friend: "I know how to solve the problem." Many years of work, many pieces already in place—but then, with the syncing of time, he had it.

BC: Except the trains and telegraphers are metaphors in our usual understanding of the story. But are you asking how it came about that scientists used these metaphors?

PG: I want to go even further and say that it's not just that the metaphors had a historical origin but that understanding the rootedness of these machines in that time tells us a lot about how scientists then were thinking. When Einstein and Poincaré were talking about telegraphers and trains, they were actually moving among very different domains of action. Poincaré in this period really was responsible for a planet-covering network of military telegrapher-geographers who really were exchanging electrical signals to coordinate real clocks. On their measurements were built the maps that told sailors where they would find land—and where they would run aground on deadly shoals. He was, in fact, actually going back and forth between writing about coordinating clocks in the annals of the Paris Bureau of Longitude, where in 1898 he was a senior scientist and soon its head. And yet he was also presenting the new notion of time and simultaneity in philosophy con-

ferences and then, by December 1900, moving over to the physicists at their conferences to tell them how coordinating clocks could help in their understanding of space and time. He's oscillating back and forth constantly. The coordination of clocks had become a central question in cartography, philosophy, and physics—as if three searchlights had converged with singular intensity on a single spot under the tent of understanding. The signal-exchange definition of simultaneity is *both* literal and figurative, routine mapmaking and abstract philosophy, technology and fundamental physics. It's true, we've read the telegraphs and tracks as pure fictions, but I wanted to ask, what are these guys *really* doing? One can look into these metaphors and see them as being *both* literal (really involved with trains) and allusive at the same time.

BC: There's the theme again; it keeps coming up.

PG: That's not by accident. In a way, a lot of the work I do is reliteralization—bringing the half-forgotten literal, material world back into focus so it illuminates the metaphors from behind, so to speak. It's going back and really trying to sort of pick out the practices, the way people are thinking about their work before they become deracinated.

BC: I suppose that the analogy available by this point is that the distinction between the literal and the figurative is like the distinction between science and society. They are both post hoc distinctions.

PG: Yes, exactly. This is why I think of my core interest as one of recovering. After the fact, long after the fact, we forget that Poincaré was actually working with real and brave souls who clambered up mountains and sailed across oceans to pull telegraph cables into huts to time the arrival of signals from Paris. Some suffered, others died. We forget that Einstein's patent office actually was responsible for evaluating clock coordination patents for use along rail lines. We take the material that is so tightly bound to the abstract and eviscerate it, make it into pure fiction. I want to recapture the forgotten material side of our abstractions. For Poincaré, measuring longitude with telegraphic signals *is* about making maps, and yet it is *also* about philosophy and physics, about a profound epistemological critique of what we mean by space, time, and simultaneity.

BC: Both Einstein and Poincaré lived their metaphors.

PG: Yes, yes, we see Einstein working in the patent office, where he encounters on a daily basis these patent applications for clocks and timekeeping and instruments of the sort. We think after the fact, "Oh, isn't it amazing that this patent clerk finished the theory of relativity with a metaphor of trains in thought experiments, isn't it amusing that Poincaré invoked longitude-hunting telegraphers." But those physical, material, everyday elements are not incidental; they are part of the world Einstein and Poincaré inhabited. This is like the anatomical pictures I was looking at in those medical atlases. They're both about who we are *and* about the classification of pathological skulls or high-altitude clouds. I am interested symmetrically in the kinds of practices people engage in, whether they are algebraic geometers or pathologists, calculators or illustrators.

BC: This counters the prevailing public images that hold those distinctions or privilege one kind of work over another, the theoretical or the practical. Maybe that's what you're up against.

PG: The thing is, we are always embedded in the world. For me, attending to the material, to practices (not just results), does several things at once. It makes clear just how close science and technology actually are, it re-embeds science in its time and place, and it opens up an understanding of science to a larger public. With relativity, for example, I think it's possible and actually helpful for people to think about it by thinking about clocks and trains. Getting at the materiality of science offers a benefit for getting at the active, dynamic center of scientific ideas.

BC: It has explanatory benefits, you mean; it makes the history of science more available.

PG: Well, and a few other things. In fact, I'd say there are three main reasons for this kind of reliteralizing. First, the explanatory or maybe pedagogical is one, which for me is also personal—it's how I understand things. It's my way of going about grasping things—be it a concept in mathematics or philosophy or political theory. Often when people speak very abstractly, it's useful to reason through something quite specific, something tangible, often visible. I find it very helpful to have specific examples in front of me, to remove the idea of metaphors as free-floating and bring them back to the original materiality they grew out of. So part of my motivation is explanatory.

Second, reliteralization is also a political intervention. I think that what people

can't understand in a specific way, a specific, tactile, or visible way, is often out of the possibility of real political engagement. I think that's why it's so important that we have the film about things like the Holocaust or the questions that have interested me, secrecy or nuclear weapons or nuclear waste. It's easy to pass these off as abstractions—and then they fade like dust in the wind. Getting back to the material, the specific, the visible often helps us understand where ideas come from—*before* the ideas get tidied up into abstract packages.

Third, reliteralization interests me aesthetically: the sudden juxtaposition of very material and very abstract things. I find it amusing, engaging, evocative that the sensorium of God or the meaning of time and space could stand hard against wires, tracks, and telegraphers.

I want to be able to picture stuff, in film, in exhibits, in writing, that captures concrete abstraction: "nuclear waste" isn't a platonic idea floating free—it is, often enough, sludge the thickness of peanut butter, boiling in leaking million-gallon tanks. It's hard to visualize radioactivity in the abstract. But in *Containment*, Robb Moss and I are working on that visual register: million-gallon tanks of sludge stored at the Savannah River Site or Hanford Nuclear Reservation can be more concrete if we have a vibrant picture of them, a way to envision through film the difficult choices we face about nuclear material that will be with us longer than human civilization is old.

BC: This sounds like the experience of the Burtynsky film, about ways to add texture and bring to life the experience, that is, not just the static image.

PG: True. Getting a sense of texture and scale is part of understanding. In the nuclear case, the term *recycling* or *reprocessing* of nuclear waste gives us the impression that it's like recycling newspaper. Well, not quite. You are putting used nuclear rods into gigantic vats of boiling nitric acid, and the stuff is then passed through pipes and filters and ends up in these fifty million-gallon tanks at the Savannah River Site. I think that visualization is important to our having the possibility of national political conversations about what these are. As in *Secrecy*, it is important to have an idea beyond abstract phrases. Think of "enhanced interrogation techniques." No one could know what that meant from the term alone.

BC: So are you using visualization as a proxy for the artistic endeavors?

PG: Yes, I think they're connected, the explanatory, political, and aesthetic. To me, there's a pleasure at the aesthetic level of seeing things thought to be abstract as having a concrete form. Part of it is connected with something I love from Freud, where he says that the comic is always about taking something abstract and suddenly reducing it to something concrete. Many jokes work in this comic register. You may think I'm too easily amused, but I always thought it was very funny to think that, when Einstein was talking about trains and railroad stations, he might be, can you believe it, also talking about real trains and railroad stations. I like that unexpected confluence. And, it is true, that's part of what I find aesthetically interesting about film.

BC: There's something of William Blake's "Auguries of Innocence" in here: "To see a world in a grain of sand, / And a heaven in a wild flower."

PG: Maybe so, that may be right.

BC: I have to guess it's even more apparent in your science/art collaboration with the artist William Kentridge.

PG: That project, *The Refusal of Time*, actually fits perfectly in our line of conversation here. It comes from our mutual interest in this late nineteenth-century moment when machines wore their functioning on their sleeve, so to speak. It's not like trying to understand how the computer-aided fuel injection works in a contemporary car, which is quite an elaborate bit of electronics buried in integrated circuits. In the late nineteenth century, machines were about cogs and gears, trains, and plugs being put into switchboards; you could see where the signal went. There was something elegantly visible about it. Even the old calculating machines, the earliest computers, borrowed from telephone switches and switchboards: a world of modernity in the click-click-click.

BC: Where did the project start?

PG: Well, logistically, it began through a mutual friend and colleague of mine at Harvard, David Edwards, who runs a space in Paris called Le Laboratoire, a place for technical innovation where he joins up scientists and artists. He asked if Kentridge and I would like to meet. At the time, Kentridge was in New York putting together his opera *The Nose*, and we met there and began to talk. I went

to rehearsals of *The Nose*; we walked around the exhibit he was preparing at the Museum of Modern Art; he read *Einstein's Clocks, Poincaré's Maps* and other things I had written, along with viewing a film, I think. We began to talk about ways to collaborate around something specific around art and science, both of us quickly seeing a common interest in that late nineteenth-, early twentieth-century moment. Eventually, we settled on doing something with "time" that emerged from *Einstein's Clocks.*

BC: Sure, but besides the mutual interest in time, what are you really after?

PG: We went back and forth on that. We began to like this idea of people struggling *against* the regulation of time, partly because it evoked the issue of colonialism, which we're both interested in: time was being exported through cables partly for the cause of mapping to grab territory and fight anticolonial movements, in Senegal and other parts of Africa. Kentridge was interested in this for his own reasons—he is South African, and his work has engaged with its history and politics. He'd been engaged with apartheid, antiapartheid movements, and the human toll racial oppression had brought.

BC: So, in this case, it's about the abstractions of time as a social mechanism and concretization of time as a measured technique, a technology.

PG: We're trying to do what you'll now recognize as familiar—yes, imagining and visualizing the abstract. So he and I talked about how to do that. He had ideas about signals, like light signals from earth going out into space and back. He'd read a book by amateur astronomer Felix Eberty from the nineteenth century, where images from earth, if you went far enough out, you could still see something like Christ on the cross or some other event in history. I began to sketch out a three-part structure, which would have these three moments: the imposition of absolute time—sort of the Newtonian moment; the breaking up of that absolute time into relative time by Einstein—talking about times, not time; and then this strange new epoch we are in now, questioning time and space around the edges of a black hole. We had a workshop at Kentridge's studio in Johannesburg, where we started thinking about ways to make these ideas material. I showed him pictures and images of the way people handled this, some work I'd done in *Einstein's Clocks, Poincaré's Maps* on preelectrical coordination of clock systems that would have the French pulsing air underneath the streets of Paris to synchro-

nize clocks. I thought that was extremely funny, the idea that you would pump time under Paris in pipes. And we began, with his team, including the wonderful composer Philip Miller, to imagine a joining of film, performance, dance, and music in those three acts.

BC: It's interesting too, at least at a personal level. You began your career as a teenager in *a* lab in Paris, and now you're back at Le Laboratoire, *the* lab, in Paris.

PG: Hah! I hadn't thought of that—absolutely. All of this is connected, maybe more so than you might have thought. The lab I worked in back then was the plasma physics laboratory (Laboratoire de physique des milieux ionisés) at École polytechnique. This was surely part of my interest in Henri Poincaré, who had taught at École polytechnique, indeed embodied the school for generations. So I do think this complex of interests for me lies behind *Einstein's Clocks, Poincaré's Maps*, and that book in many ways led to my collaboration with Kentridge.

BC: The explanation of which I just disrupted, sorry.

PG: Back to Parisian time pipes, right. Anyway, then we worked long hours with the composer Philip Miller, talking about ways to convey the idea of information. What about Morse code? What about Morse code visualized? Maybe we could send signals over wires? I liked the ways perforated sheets looked inside the player piano, and maybe that could look like information and we could project light through the perforations that look like dots and dashes, to represent Morse code. The Morse code itself seemed too crude, too literal. So, really, one thing led to another, and we ended up with an idea of how these three acts would work. Absolute time, relative time, black hole time.

BC: I have to ask a prosaic question, and I don't mean to be facetious here, but on the subject of time—how do you have the time for all of this? I mean, I could be asking that as a matter of calendar and scheduling and travel, a scholar, a filmmaker, a writer, but to the point of our conversation, this brings up the finite biological, organic elements of time.

PG: I don't know, they all flow out from one another—that's the direction I see it from. I've been thinking about visualization and the role of images and ways to illustrate since my earliest research, which is what got me interested in film, which worked in parallel with other opportunities to explore kinds of evidence

and argument and so on. If you start from my vantage point, all of these projects are emanating from the same core interest that has become the main trope for our discussion: reliteralization.

BC: To that point, then, as we finish, you've mentioned *Containment* and you're finishing a book, "Building Crashing Thinking." Are those related?

PG: The film [*Containment*] grew out of the last chapter of the book, which is about technologies that reform the self. And, yes, here again I'm interested and amused by these technologies that do something very far from the merely mechanical. Each of the six chapters is about a different technology that in some way both reflects and alters the constitutions of the self. Each is a kind of dual movement, asking, first, how technologies can only come into existence if you believe certain things about what the self is and, second, how once these technologies become ubiquitous they can teach us in a wider sense how to think about who we are. The first one is the Rorschach test, where I follow the making of the Rorschach and what that meant and what he was up to, the draft versions of the famous ten cards, why he thought you could use something like these forms to get at the inner characteristics of the self. To your question, the last chapter is about nuclear waste and how it changes our relationship to the land and how we see ourselves and what's natural and unnatural and what's human and what's not human. That led me to *Containment*.

BC: You said earlier that the film seeks to make ideas about radioactivity more visible, and I can understand that. So the documentary seeks to congeal the abstract and concrete, but along what lines? Toward what end?

PG: Robb and I are exploring this practical question of which we have no choice but to deal with: we're coming on seventy years of nuclear waste accumulation, all held in very unsafe, unstable circumstances. It's in rotting barrels and open pits. We have it in tanks filled with sludge, a by-product of making the plutonium for weapons. We have spent fuel from reactors, about sixty-five thousand tons of it from the civilian side and fifteen thousand tons from the weapons side. We have a huge amount of this stuff in badly arranged circumstances, and we're just beginning to deal with it at a moment when some parts of the world are thinking of expanding nuclear power. The Chinese are considering adding one hundred nuclear plants; the United States is adding four reactors, two in South Carolina,

two in Georgia, even while the echoes of Fukushima are very much in the air; and Germany is trying to ramp down its program. So it's a huge and global issue.

BC: Not to mention the existing waste out there.

PG: Yes, even if another reactor never turned on again, we'd still have this enormous legacy of seventy years of nuclear activity. So the question is, what's going to happen to it? There's only one licensed nuclear burial site in the United States, in fact in the world right now, and that's in Carlsbad, New Mexico, at a place called the Waste Isolation Pilot Plant. In that deep underground salt repository, as we speak, people are bringing down these containers of transuranic waste—waste above uranium on the periodic table—and placing it in salt, where within a couple of decades it will be crushed and sealed off from the outside. All the while, one of the demands Congress made of this place is that it be isolated from human use for a period of not less than ten thousand years. So you have this practical problem, with containers of transuranic waste being put in place by skilled miners a half mile underground, with a demand that far exceeds any previous attempt to control and predict what human life and practices will be like ten millennia in the future. That combination of what I think of as a state science fiction, a required need on moral political environmental grounds, to what's going to happen to this waste, and the absolute necessity of engaging with this—because we can't leave the waste where it is in rotting barrels—that combination of the practical demands and the enormous difficulty of thinking about such a problem intrigues me tremendously. The film is a way of exploring the combination of these very practical issues that involve mining and environmental justice and transportation safety. It's about getting this stuff out of very dangerous circumstances, and at the same time it's an enormously challenging moral demand, asking, more or less, how do you warn the future of what we've done?

BC: You're pursuing that trinity of explanatory, political, and aesthetic elements, all of a piece?

PG: It's the confluence of those three streams that puts the concrete and the abstract together. That's the payout for what we've been talking about, that's the reason these recovery projects keep coming up for me. It isn't that this is a long process of gradual rising from the concrete which we eventually dismiss before coming to something more valuable at the level of the abstract that we appreciate. It isn't a gradual continuous spectrum. I also don't think of it this way: that

9 8

these things start at the realm of the abstract and then move into physics, and then from pure physics they move to applied, and then from abstract engineering they eventually appear in something concrete on the shop floor. Those two spectrums, that it's a slide from one to the other—it's too easy to think of this as a long set of steps that separates something valuable from something ordinary.

BC: But, overall, this is your way into the history of science, isn't it, melting the theoretical and practical, the figurative and literal?

PG: Even at their most abstract, things contain within themselves this very concrete dimension, and I like exploring that. I like exploring that in writing and in film. I want to see democracy through secrecy, the history of twentieth-century physics through photographs and machines, and objectivity through the lithographs, engravings, and X-ray images of scientific atlases. I'm constantly fascinated by that flashing back and forth between prosaic materiality and abstract visionary pictures of the world. Understanding things and thoughts together, understanding how they are both simultaneously present, is to get a grasp on the fabric of science in a way that, at least for me, nothing else does.

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