TIME, ART, AND SCIENCE / PETER GALISON

At the start of 1921, just as Einstein was becoming a world figure, a poet and playwright wrote to him, wondering if modern painting and poetry might have been an "intuitive anticipation" of his discoveries. Einstein replied a few days later with his own handwritten query: "What do artistic and scientific experience have in common?" Both, he told the poet, offer the opportunity for us as humans to extract ourselves from the pain and tumult of everyday life: "Where the world ceases to be the scene of personal hopes, wishes, and wants, where we face it as free creatures, admiring, questioning, beholding, there we enter the realm of art and science." Like philosopher Arthur Schopenhauer, Einstein wanted to quiet the self so that both reason and art could speak through us: "Common to both [art and science] is loving devotion, the being above the personal, stemming from our will." For Einstein, the difference between the two pursuits is to be found in their mode of expression: "We perform science when we reconstruct in the language of logic what we have seen and experienced; but when we communicate through forms whose connections are not accessible to the conscious mind, yet we intuitively recognize them as something meaningful—then we are making art."[1]

True, in *Refusal*, William Kentridge and I were distinctly less abstracted from the world than Schopenhauer might have had in mind. Both of us like the back and forth between things and thoughts—we are inclined to admire the ambition of Platonism, yet to see it as rather unforgiving when it comes at the cost of a dismissal of all "hopes, wishes, and wants." Indeed, the hope is that the images and conversations in this book convey something of the run-up to the controlled charivari of these last years making *Refusal*: filming, fabricating, experimenting with images, objects and sound to recreate a metaphysical melodrama about time, reversibility and fate.

But Einstein's second observation perfectly captures the spirit of our work —the connections to experience that, while meaningful, are sometimes not accessible to the conscious mind. Links and transitions are openly associative. Notions of time flow back and forth between science, art, and history. *Refusal* encourages that circulation.

When William Kentridge and I began collaborating on *Refusal of Time* in 2010, two things were clear. The first was that we would avoid subordinating the art project to a physics lesson—this would not be an illustrated science lecture. Science does not need another text with pictures, and art does not need to aestheticize exposition. Our second resolution was to avoid treating science as a reality effect for art. For decades, films, novels, and other artworks have enlisted specialized knowledge to provide a contrived authenticity, a background to action. Getting the vocabulary and actions "right" for scientists in a laboratory did not interest us. We did not want science-as-backdrop any more than we wanted art-as-illustration.

1. Albert Einstein, "The Common Element in Artistic and Scientific Experience," in *Menschen. Zeitschrift neuer Kunst* 4 (1921): 19, reprinted with notes in M. Janssen et alia, eds., *The Collected Papers of Albert Einstein* (Princeton: Princeton University Press, 2002), volume 7, pp. 379-81, hereafter CP 7: 379-81.

What we did want was something more elusive: an *intensification* of our encounter with time. We wanted an exploration that begins in physics and its cultural, imperial, and philosophical history. My work was about the history of time at the turn of the century,[2] while William Kentridge has returned time and again in his art to the fin-de-siècle colonial and revolutionary past. Our work together would be an exploration that would move through the history of science and colonialism through an interplay of images, sounds, movement, objects, and thoughts.

For almost a thousand years, clock time has held a grip on the practical dimension of life that is also imaginary. Chiming clock towers multiplied across the cities of Europe in the 14th and 15th centuries, and their imposing presence regulated daily life. Time towers did more than simply tell the time: they represented a city's autonomy. No self-respecting city of the 1300s could be without one. In 1425, Magdeburg wanted a public clock "for the honor of the city and the utility and comfort of the citizens." Clock towers presided over cities' symbolic autonomy—and at the same time, enforced orderly administration and "law and order" on citizens, which included calling burghers to prayer and merchants to business. Time measurement also limited activities, restricting the time of testimony in court and prolonged torture sessions (except, it seems, the torture of "strong people" and "obstinate Jews accustomed to denying things").[3] Time has always been more than simply time; clocks have always been both the quintessential mechanical tool and far more than a tool.

Clocks regulated bodies, but Renaissance bodies also *became* clocks. In some key experiments, Galileo used his own heart as a clock: in one trial, a hundred-pound lead ball fell 100 braccia (about 200 feet) in "four heartbeats"; elsewhere, he assured his reader that his claims were precise to a "tenth of a pulse-beat."[4] There is something rousing about seeing in Galileo's science not merely the cold quantification of the world that Edmund Husserl lamented in the new science, but instead, recognizing the fact that Galileo made measurements with his own body: a *heart clock*. From this perspective, Galileo had not reduced the world to the dead circulation of geometry; but instead, he built a new science based on the life force of the body. We return to human measure again and again in *Refusal*: bodies as breathing, ticking, yet all-too fragile clocks.

Isaac Newton wanted to see beyond things and bodies and thus imagined a two-fold reality: "true, absolute, mathematical" time inflecting the "sensorium of God" versus the "relative, apparent, and common" time that we mortals measure with mere clocks.[5] In other words, he presented a clock of truth and a human clock. Since Newton's time, that ordinary, all-too-measurable clock time has appeared everywhere. It wired up schools and factories, and was installed for public display all around the cities, inside government buildings and on our wrists. Throughout *Refusal*, we wanted to disrupt

2. Peter Galison, *Einstein's Clocks, Poincaré's Maps* (New York: W.W. Norton, 2003).
3. Gerhard Dohrn-van Rossum, *History of the Hour: Clocks and Modern Temporal Orders* (Chicago: University of Chicago Press, 1998): On clock towers and town autonomy ch. 5; on Magdeburg specifically, p. 146; on "law and order," pp. 155-56; on torture and time, p. 278.
4. Domenico Bertolini Meli, *Thinking with Objects* (Baltimore: Johns Hopkins Press, 2006), pp. 98, 103, 111.
5. Isaac Newton, *The Mathematical Principles of Natural Philosophy*, Motte, translator (London: Printed for B. Motte, 1729), p. 9. http://books.google.de/books/about/The_mathematical_principles_of_natural_p.html?id=Tm0FAAAAQAAJ&redir_esc=y, accessed June 2, 2012.

that coordinated ubiquity. We took metronomes and blew them up large in projections, synchronizing the motion of the dancer-musician to them. We played with the automaticity of the player piano, with the code-like inscriptions of paper rolls, with moving images of projections through the perforated paper. The new wires of the world even came to the arts: I love Hector Berlioz's 1844 fantasy of a future town, Euphonia, set in 2344, in which the conductor used his telegraphically-linked baton to direct distant musicians, from different walks of life among the population.[6] With Philip Miller, we morphed this musical science fiction of time control into wired-up drums.

The physics of time measurement has always been more than just science. Take Greenwich Observatory—the site of longitude zero, the time standard against which the world would be measured. Before it was chosen in 1884 to be that first of all north-south lines, competitors disputed the dominance of this London suburb. French astronomers and statesmen understood that whoever controlled the zero-meridian thus controlled the maps, and became the symbolic divider of the planet.

French refugee anarchist Martial Bourdin knew it too, when, in February 1894, he took a bomb from London's anarchist refuge, the "Freedom Club," and headed across town and up the path toward the observatory to blast the center of time. He failed in that mission only because his weapon detonated prematurely, killing him, and leading later that day to mass arrests at the Club. Joseph Conrad transformed the incident into his most famous short story, *The Secret Agent* (1907). That account, in turn, seized the imagination of the mathematician-terrorist Ted Kaczynski (the Unabomber). In 1984, in the midst of his bombing campaign, Kaczynski wrote to his family that he was reading Conrad for the twelfth time—while signing his bomb letters "FC" for "Freedom Club," mimicking Conrad's anarchists, who used "FP" to stand for "Future of the Proletariat."[7] A conflict over imperial time that had begun within science had thus worked its way out of equations and into statecraft, European culture, fiction, and then into a violent political-cultural confrontation regarding 20th century technology.

So, when we hybridize the Greenwich story of art and scientific history in *Refusal*, our goal is not to fictionalize an old, isolated fact. It is to explore, within art, a part of our 'world of time' that is *already* a century-old amalgam of the wild interplay of science, politics, and narrative. With this as a backdrop, there was nothing for it: we fragmented the attack on Greenwich and projected it onto five screens, set the "Club Autonomie" in Dakar instead of London, pumped music everywhere, striped the human/pneumatic world with its crazy, quilt-like longitude lines, and, when the dynamite exploded, had it shatter the worlds of anarchism and astronomy onto paper, and into music and dance.

The history of time and the coordination of time in around 1900 form a kind of parable. Here was a world covered by cables that began at imperial observatories and were hauled over land and under the oceans, across beaches and up mountains… and this all occurred in a world that had only barely begun to wire up its few electric lights. It was a world

6. Hector Berlioz, *An Evening With the Orchestra*, Jacques Barzun, editor and translator (Chicago: University of Chicago Press, 1956, 1973), twenty-fifth evening: "Euphonia, A Musical City. A Tale of the Future."
7. Serge F. Kovaleski, Washington Post, 9 July 1996, p. A1: "During 26 years in the Montana wilderness, [Kaczynski] pored over Conrad's writings. […] 'Ted said he was reading Conrad's novels for about the dozenth time,' said Washington attorney Anthony P. Bisceglie, counsel to Kaczynski's brother and mother."

in which interconnected clocks were occupying an increasingly central role that riveted railroad magnates, astronomers, and stock traders while—*ça va sans dire*—enraging anarchists. Even some ordinary towns revolted, unhappy with having their own, locally determined noon taken away in favor of zoned time. "Give us back our sun," is another form of resistant refrain that recurs in *Refusal*. Sparked along wires and pumped through pneumatic tubes under Paris and Vienna, time went from metaphysics to coordinated signals.

For my part, the path to this project came through other work on the shifting time-scape of the 1900s, on the disorienting collision of absolute time drawn from the heavens with the pipes and cables of the Victorian age. In France, a country that has long celebrated its mathematicians, Henri Poincaré stood out: perhaps the country's leading mathematician, he opened up whole domains of pure mathematics, invented chaos theory, wrote philosophy that was still studied more than a century later, and pushed foundational issues in the physics of time further than anyone, with the exception of Einstein. More surprising to us now, this consummate theorist took on the responsibility of heading the French Bureau of Longitude in Paris—a matter of enormous practical significance in the world of 1890s stepped-up travel. Anyone in the northern hemisphere could pick out their latitude—how many degrees south of the North Pole they were—just by observing the North Star. But longitude—how far east or west one was from a reference point (like London or Paris) was much harder. Since the earth rotates, in order to establish how far east or west you were, you needed to *simultaneously* compare the stars above you with the stars above your reference point. In the late 19th century, mapping the world meant having two telegraphers exchange signals in order to synchronize their clocks and compare their local times. Were they off by eight hours? In that case, they were a third of the way around the world from one another. Poincaré, who was in charge of astronomers on the ground, took synchronization a step further, concluding that this practical coordination of clocks via signal exchange *defined* simultaneity, for maps, physics, and philosophy.[8]

In longitude, we find a metaphor that, as more recent readers, we have too easily mistaken for our own, ever increasingly bizarre, hypothetical philosophical examples and counter-examples. But for Poincaré, his map-making telegraphers were a metaphor, but also more than a metaphor. Signaling across transatlantic cables, up and down the coast of Africa, across the landmass of Europe: these pulsed signals were a military-colonial reality. They represented an application of time coordination *and* a new philosophy of simultaneity *and* a reformation of the physics of time.

Refusal of Time continues this node of signaled time, this interconnection of colonial, cartographic technologies and the abstractions of time physics. It relies on a to-and-fro between abstract time, and time in the physical, visual, musical world. Many elements contribute to this controlled chaos. Philip Miller's music, for instance, draws not only on European and African sources, but also on clicks and tonal signals, on the pneumatic pumping of time, but also the fragile breaths of the human body. Then there is the "Elephant," the huge steam-engine-like machine that stands at the entrance to the installation, resembling a pump or a loom, or even an oversized

8. Galison, *Einstein's Clocks, Poincaré's Maps*, cited above.

version of a player piano. There are instruments and performances by Bham Nthabeni in various parts of the piece, from his dance and music to the back and forth with projected metronome. Dada Masilo also dances everything from anarchism to a fateful march in various parts of the work. Here and elsewhere, we were looking to evoke and extend an embodied history of time. This emerges vividly, or finds its way into William Kentridge's drawings, acting, and animation; Philip Miller's music; and the films we made to provoke a dialogue between psychology and the physics of time. Our aim was to approach time through allusion and incorporation, as opposed to illustration.

Like Poincaré, Einstein participated *in* the technology; he did not just allude to it. His father and uncle made electrical systems, everything from meters to generators, motors, or even devices that could double as electric clocks. Far from being a disembodied mind, Einstein had patents on gyrocompasses, even refrigerators—he watched the parade of modern technology go by from the most crucial, active station of patent examiner. When Einstein stood at his lectern at the Bern patent office, and wrote what became the most famous physics paper of the last two centuries, the one on special relativity, he began with two initial principles: the laws of all physics, not just mechanics, should be the same for any constantly moving observer. Also, light was always measured as passing at the same speed, 186 000 per second. But these two principles, each of which he found unavoidable, seemed to conflict. Wouldn't light appear to be going faster than its usual speed if one headed toward the source, fast?

"An analysis of the concept of time was my solution," Einstein reported a few years later, speaking of his breakthrough in May 1905. There is no absolute time, no "universally audible tick-tock," (as he once put it) only "an inseparable relation" between time and signaling.[9] This would resolve the oversight that had thwarted physics since Newton. What do we mean by "the train arrives at 7 o'clock?" Einstein asked. We mean that the little hand of my watch points to the '7' as the train engine goes by my nose. But what do we mean by "the train arrives at a distant station at 7 o'clock?" Now we need to coordinate clocks along the train track—which we do, says Einstein, by emitting a light signal from one's present point to the distant station and back—and by using the time in transit to synchronize the clocks. If the round trip takes two microseconds, then the one-way trip takes one. If I send my signal at noon, then on receipt of that signal, the distant stationmaster sets her clock to noon plus one microsecond. Is this a metaphor? Naturally. But it also goes beyond mere metaphor—synchronizing clocks along train tracks was a real issue (though not to this level of accuracy!). Einstein's suggestion—though we forget it when we treat his trains as a mere philosophical "what-if"—was seen in the context of train coordination. But pursued relentlessly, as Einstein did, strict attention to time coordination and his founding principles led him to show that 186 000 miles per hour was indeed the universal speed of light and that time and simultaneity were only fixed for each observer. In other words, there were "times" not "time".

9. Quotation from Einstein, "How I Created the Theory of Relativity," lecture given in 1922 in Kyoto, translated and reprinted in *Physics Today* August 1992, pp. 45-47; except the phrase "universally audible tick-tock" which is from Einstein, "The Principal Ideas of the Theory of Relativity," after December 1916, *Collected Papers* 7, pp. 1-7, on p. 5 cited in Galison, *Einstein's Clocks, Poincaré's Maps*, p. 13.

nine layers open to be filled with cubes. Generally, this led to the notion that reality is in three dimensions; mere projections are deceptive, two-dimensional shadows. As Plato's prisoners their heads held to watch the play of shadows, they were seeing only misleading images.

But the holographic idea approaches the problem the other way around. String theory is predicated on the notion that strings have a fundamental length (L)—nothing can be smaller. As Hawking and others had shown, the most information that can be encoded into a black hole is given by the number of patches L × L that could be inscribed on the surface of the horizon—*not* by the larger number of elementary volumes, L, on one side, that could fit into a volume of the black hole. In other words, the correct physics is given by the surface, not the volume. This reverses the reality-illusion relation. For a growing number of physicists, reality lies in the holographic image on the surface, and illusion in the four dimensions of space and time that we have taken as the real. Three spatial dimensions are perhaps nothing but a solace—and given the intimate interchangeability of time and space, time itself may be only a crude, conventional notion. In the physics of the early 21st century, amidst black holes and string theory, we find a kind of anti-Platonic cave: projection *is* reality. Were we prisoners constrained to watch the holographic image at the horizon, it is we who would see the richer, less illusory reality.

Seven years after the bet, on Wednesday, July 21, 2004, Hawking conceded that information from an encyclopedia falling into a black hole was not lost to oblivion, whereas other black hole annihilationists have not. This conflict, this tension between an end to all things and the survival of an image, the preservation of information, moves us one step farther in the history of time. Clocks of the heart, clocks of truth, clocks of light. And now, perhaps, clocks of illusion.

In *Refusal*, this battle haunts many of our images, from zoetrope sequences through reversals of film. It emerges in our film of projected perforated paper falling into darkness. It features in the form of destroyed texts, shredded paper, and thrown encyclopedia volumes. But above all, the black hole battle between the destruction and preservation of information appears in the way we use the procession of shadows that William Kentridge has, over many years, developed for other ends. Here, we deployed the figures to move inexorably toward the darkness, hauling their possessions, appetites and conflicts with them. It serves as a recapitulation of life, or a death march —the impact of which can be palpably felt, given our close proximity to deportation train track 13, in the Kassel Hauptbahnhof.

I suppose this movement toward fate and terror resides in every tick of every clock. For this movement, I wanted a giant clock to be dragged on a cart toward the last, engulfing shadow. Kentridge put two figures on the wagon, each pulling the clock hands in opposite directions. As our black hole heads toward the shadowy exit of this Kassel railway building, the two men pull ropes to yank the clock hands backwards and forwards, thus hovering on the verge of the destruction or preservation of time.

We try as best we can to refuse time. What else can we do?■

This text was written just before the Documenta 13 opening in June 2012.