THE REFUSAL OF TIME / PETER GALISON

PART I: A RIVER OF ABSOLUTE TIME

On Saturday September 28, 1889, representatives from eighteen countries gathered in Sèvres, outside Paris. They were there to bring the world under the measure of a single meter known as **M**, and a single kilogram represented as **K**, to give their blessing to a particular ruler and weight. The conference arbitrarily chose one meter stick and one sample weight from thirty nearly identical copies, declaring: "This prototype of the meter will represent from now on, at the temperature of melting ice, the metric unit of length… This prototype [of the kilogram] will be considered from now on as the unit of mass."[1] Each delegate strode solemnly to receive his country's copy of the iridium-platinum X-shaped bar, his nation's exemplary weight.

Until the sanctioning ceremony, **M** and **K** had been but two of many carefully measured standards. No one among them was yet recognized as the one perfect length or weight. All were certified to be within two ten-thousandths of a meter of all of their counterparts; for example, one bar might be 1.0001 meters long compared with another, that measured 0.9998 meters. But at 1:30 pm that afternoon, the officials loaded the "chosen ones," **M** and **K**, into a triple-locked vault. **M** was first placed inside a sealed, felt-lined brass cylinder, and K into a triple bell jar. Standard-bearers then took **K** for burial along with its six 'controls' (from the French *témoins*, which literally translates as "witness.") These copies of the kilogram were "witnesses" in the truest sense, chosen to bear witness should anything untoward befall the standard.

The director of the International Bureau of Weights and Measures locked the case with two keys, secured the inner basement door with a third key, and bolted the exterior door, locking it with a fourth and a fifth key. The president of the conference then handed the keys in sealed envelopes to the director of the International Bureau, to the general guard of the National Archives, and to the President of the International Committee for Weights and Measures.

At that moment, **M** and **K**, two of the most precisely forged and measured objects in history, the most individually specified human-made things, became, in burial, the most universal. What had been measured now defined the meter. **M** as One Meter, no more, no less. From it, every other length in the world took its measure. **K** was One Kilogram—every atom and asteroid, every galaxy and giraffe, would be measured in terms of those two metal objects, buried deep underground at the Pavillon de Breteuil in Sèvres.

1. "Conférence générale des poids et mesures. Rapport sur la construction, les comparaisons et les autres opérations ayant servi à déterminer les équations des nouveaux prototypes métriques. Présenté par le Comité International des Poids et Mesures" (Paris: Gauthier-Villars et Fils, 1889), cited in Peter L. Galison, *Einstein's Clocks, Poincaré's Maps: Empires of Time* (New York: W. W. Norton & Company, 2003), p. 88.

Here was a way to populate Plato's heaven: the single buried object became a universal guide. Governments wanted conventions to govern railroads and temperature, electrical power, gears, and steam engines. Most of all, they wanted to standardize time. From a master clock in the control room of the Paris observatory itself, situated on Rue du Télégraphe, pipes carried pulses of air—that is, pulses of time—under the streets to reset clocks throughout the city. Citizens gathered around the public clocks in their arrondissement to admire the coordinated time. Soon they began to demand even greater precision—adjustments that would make their clock display noon, but corrected to take into account the seconds it took the pulse to traverse the city.

Not everyone, however, was so enthusiastic. In August 1880, a Parisian poet Georges de Porto-Riche (living above the central workshop for the pneumatic distribution of time) heard the driving pulses, absorbing the beats without variation or limit. Here was the rhythm of everything modern, correct time pulsed to all Parisians. Porto-Riche successfully sued the company, protesting that the pressure blasts of airtime were destroying the very foundations of his muse in his, the most creative of all jobs.

Meanwhile, French administrators looked with anxiety and admiration at the American system of electrical time networks, and the British system of undersea cables to link clocks around the nation's vast empire. When a cable reached the shores of Recife in Brazil, Emperor Pedro II came down to the beach to witness the arrival of European time. Time synchronized to the globe's zero point, the Royal Observatory in Greenwich.

Others watched from the shadows. On Thursday February 15, 1894, a young French anarchist, Martial Bourdin, traveled from Westminster Bridge to Greenwich. Two lab assistants in the computing room heard a huge explosion. One recorded: "I immediately remarked to Mr. Hollis, 'That is dynamite! Spot the time.'" 4:51 was recorded in the books, observed with the precision for which the assistants were trained. Anarchists pointed to a police setup; the police suspected an anarchist conspiracy.[2] Joseph Conrad imagined a secret agent caught in the crossfire of cheats, manipulators, and careerists. His conniving First Secretary of a foreign power told his fellow conspirators that there were better forms of terrorism than assassinations or the destruction of artworks—the best form would be an assault on science, ideally a bomb striking the heart of pure mathematics; besides that, "the attack must have all the shocking senselessness of gratuitous blasphemy." It must attack the heart of material prosperity. "The blowing up of the first meridian [time zero] is bound to raise a howl of execration."[3]

But the never-ending expansion of the time-unification zone continued. Cables snaked under the sea down the West Coast of Africa, landing at the colonial capitals, like Dakar. It crossed the seas and headed up into the Andes, wound down into

2. Cf. Galison, *Einstein's Clocks, Poincaré's Maps* (see note 1), p. 159.
3. Joseph Conrad, *The Secret Agent* (Stuttgart: Tauchnitz, 1953), pp. 28-29.

Haiphong Harbor… Everywhere that telegraph lines could reach, the time signals did, too. Time, weight and length began to cover the globe: a planetary machine that would bring the world under one ticking clock.

And yet, standards change. It seems that **K** has lost fifty millionths of a gram over the past 120 years—relative to the control weights buried with it. No one can explain this loss. But at this rate, in 2.4 billion years, the entire weight will be gone. Then the standard weight will be the guide to the masses of every weight in the universe and yet there will be nothing in the bell jar at all. This suggests an intriguing outcome for the future. An empty bell jar could contain the ideal (vanished) cat, another the ideal (departed) typewriter, a third the ideal (disappeared) phonograph… An entire universe populated by the nonexistent failed objects that are actually the most real of all, owing to their lack of reality.

PART II: A PECULIAR CONSEQUENCE

Albert Einstein, the iconic physicist of the twentieth century, was born in 1879. So was his friend the terrorist physicist Friedrich Adler. The two took classes together in Zurich; both married Slavic women, both couples had children about the same age, both families lived in the same house at 12 Mousson-Strasse. Here, Adler reported to his father, were parallel lives. Einstein and Adler retreated to the attic to think physics: "The more I talk to Einstein," Adler related, "the more I realize that my favorable opinion was justified… We find ourselves in agreement on questions which the majority of other physicists would not even understand."[4] Both followed the physicist-philosopher Ernst Mach, both despised old ideas of absolute time that made no connection with tangible things. When Einstein left for Prague, he wrote, "I wish that Adler would become my successor."[5] In 1908, both applied for the same job—but Adler cautioned the authorities, "If it is possible to obtain […] Einstein […] It would be absurd to appoint me."[6] Einstein was chosen; Adler abandoned physics for politics.

Einstein pointed to the peculiarity of light: unlike a bus or even sound, we can never begin to catch up to light, not even by a fraction. Einstein's time and simultaneity were nothing but measures and signals: there was no universal duration, no comforting notion of a River of Absolute Time. He imagined a clock of pure light, a flash bouncing back and forth between a mirror at your feet and one above your head. One bounce, one click. Fly by another person and he sees your light as traveling on a slant. A slanting track from one mirror to the other

4. Friedrich Adler to Viktor Adler, Zurich, October 28, 1909, cited in Rudolf Ardelt, Friedrich Adler. *Probleme einer Persönlichkeitsentwicklung um die Jahrhundertwende* (Vienna: Österreichischer Bundesverlag, 1984), p. 166.
5. Einstein to Alfred Stern, Zurich, December 6, 1910, in *The Collected Papers of Albert Einstein, vol. 5, The Swiss Years: Correspondence, 1902-1914*, ed. Martin J. Klein et al., English translation supplement, trans. Anna Beck (Princeton: Princeton University Press, 1993), doc. 236, p. 168.
6. Friedrich Adler to the Board of Education of the Canton of Zurich, 1908, cited in Ronald Florence, *Fritz: The Story of a Political Assassin* (New York: Dial, 1971), pp. 44-45.

is longer than a perpendicular one—but light always travels at the same speed, so it takes longer on the slant. As night follows day, a person standing still watching you says your moving light clock is running slow.

Einstein: "This yields the following peculiar consequence."[7] Every person in motion carries with them their own private time. One twin flies out and back, returning to find his double, his twin, has already been dead for a thousand years. Einstein refused to accept what he called the "universally audible tick-tock"[8] of classical physics. "Newton, forgive me,"[9] he wrote.

Now a physicist without physics, Adler headed back to Socialist headquarters in Vienna where he met with Trotsky, directed the journal *Der Kampf*, and served as Party Secretary. Meanwhile, Einstein plunged ever deeper into space and time. World War I and its chauvinistic slaughter revolted both men. Einstein formed alliances with pacifists around Europe and, in 1915-16, he abolished the view of space as an empty volume, and instead made space and time into a curved, all-pervading field. There was no physics, petitions, or proclamations for Adler. On October 21, 1916, he picked up a Browning pistol, walked over to the prime minister of Austria as he ate lunch and put three bullets in his head. Condemned to die by hanging, a sentence later commuted, Adler sat in a cell and began corresponding with Einstein—about the paradox of twins and their clocks.

Einstein spoke out for Adler, gave interviews about Adler's work in physics, protested to those who would listen that Adler was one of the purest souls that he had ever encountered. Einstein: "My compassion for him has grown so strong that I really would like to do something for him." To the emperor: "His Majesty! […] The political murder, of which Fritz Adler is guilty, shook the well-being of every justifiably sensitive person in the deepest way. With not a single word will I prettify this gruesome act […] However, it seems to me to have to do with a tragic accident rather than a crime. Few can have known Herrn Adler so well as me." "Purest character." "Unparalleled selflessness." "Unqualifiedly reliable and honest." "I herewith submit to your majesty, from the bottom of my heart, a plea for you to invoke the law of clemency, in the event that Adler is sentenced to death."[10]

Einstein to the condemned Adler himself: "How much I would like to discuss the relativity problem with you!"[11] Adler: "I awoke Saturday with the solution to a small

7. *The Collected Papers of Albert Einstein, vol. 2, The Swiss Years: Writings, 1900-1909*, ed. John Stachel et al.,English translation supplement, trans. Anna Beck (Princeton: Princeton University Press, 1989), doc. 23, "On the Electrodynamics of Moving Bodies," p. 153.

8. *The Collected Papers of Albert Einstein, vol. 7, The Berlin Years: Writings, 1918-1921*, ed. Michel Janssen et al., English translation of selected texts, trans. Alfred Engel (Princeton: Princeton University Press, 2002), vol. 6, doc. 44a, "The Principal Ideas of the Theory of Relativity," p. 5.

9. Paul Arthur Schilpp, ed., *Albert Einstein, Philosopher—Scientist*, 2 vols. (La Salle, Ill.: Open Court, 1970), vol. 1, p. 31.

10. *The Collected Papers of Albert Einstein, vol. 10, The Berlin Years: Correspondence, May-December 1920*, and Supplementary Correspondence, 1909-1920, ed. Diana Kormos Buchwald et al. (Princeton: Princeton University Press, 2006), pp. 73-74.

11. Einstein to Friedrich Adler, April 13, 1917, in *The Collected Papers of Albert Einstein, vol. 8, The Berlin Years: Correspondence, 1914-1918*, ed. Robert Schulmann et al., English translation supplement, trans. Ann M. Hentschel (Princeton: Princeton University Press, 1998), doc. 324, p. 615.

[physics] problem."[12] "I have found a decisive criterion in relativity theory that rules against [...] Einstein."[13]

Adler: I refuse Einstein's times. It cannot be that time passes slower for one twin than the other; how could they be different? How could one age and the other not? Wouldn't the first twin's view of the second just be exactly like the second twin's view of the first? Nonsense, Einstein replies, "We imagine my standard clocks as having been produced identically [...] by a clockmaker who enjoys a world monopoly."[14] These timepieces are transported everywhere. One is sent out and then returns—the traveling one that turns around is measurably accelerated, the other is not. No symmetry. Then Adler invented a thought machine—with a meter and battery—that he hoped would bring down relativity. Bang: Einstein's theory would die. This time, the target shot back: Einstein, September 1918: "Your bias for absolute time [...] is exposing itself."[15]

Einstein proposed using their exchange as part of a kind of play, a pair of opponents joined in opposition: "Dialogue About Objections to the Theory of Relativity."[16] The Critic: "I want to tell you right away: today I have come to you personally in order to make it impossible for you to shirk [responding] as has happened before [...]. I assure you, I will not yield until you have answered all my questions." Of course, the literary counterparts struck up a dialogue right away, each upholding their own clock. The Relativist responded with a dialogue within the dialogue: one from the point of view of stay-at-home Twin 1 and the other from the point of view of the traveler, Twin 2. Lo and behold! Though they describe the situation differently, the twins agree: the traveling twin ends up younger. "This completely clarifies the paradox you referred to," says the Relativist. The Critic: "Your argument leaves me more convicted than really convinced." Sitting in prison, condemned for assassination, on the warpath against Empire and Einstein, Adler was indeed surely more "convicted" than any other critic of relativity. Two weeks later, the Austro-Hungarian Empire collapsed. Adler walked out of prison free, a revolutionary hero. The following year, starlight was captured bending around the sun—and Einstein became an enduring symbol of a bloody new century.

Orbiting twins, flying twins, accelerating twins—always separating and reuniting. Or separating, then returning to find that their home has long since disappeared, a casualty of time.

12. Friedrich Adler to Katja Adler, mid-February 1917, in *Rudolf Neck, Arbeiterschaft und Staat im ErstenWeltkrieg 1914-1919*, 2 vols. (Vienna: Europa- Verlag, 1968), vol. 1, doc. 140, p. 235.
13. Friedrich Adler to Viktor Adler, in *Rudolf Neck, Arbeiterschaft und Staat im ErstenWeltkrieg 1914-1919* (see note 12), vol. 1, doc. 147, p. 244.
14. Einstein to Friedrich Adler, August 4, 1918, in *The Collected Papers of Albert Einstein, vol. 8* (see note 11), doc. 594, p. 618.
15. Einstein to Friedrich Adler, September 29, 1918, in *The Collected Papers of Albert Einstein, vol. 8* (see note 11), doc. 628, p. 660.
16. *The Collected Papers of Albert Einstein, vol. 7* (see note 8), doc. 13, pp. 66ff.

PART III: SOCIETY FOR THE DESTRUCTION OF INFORMATION

The most important message: "Here is the time at the Paris Observatory." Poincaré telegraphed this dispatch from the Paris Observatory to London, Washington and Dakar—in order to construct a world map around Paris. Einstein imagined his time message sent along the Swiss railway by a flash of light: Bern to Muri, reflected back to Bern: "Bern, train arriving here, 7 pm."

By redefining time into a time coordinating procedure (send out a light signal, take note of the signaling time), physicists had cracked the absoluteness of simultaneity and entangled time with space. "Gentlemen," Hermann Minkowski told his 1908 audience, "space by itself and time by itself are doomed to fade away into mere shadows. Only a union of the two will retain an independent reality."[17] Space/time, the three spatial dimensions plus time, had become a vast, open stage on which all the actions of the world would be performed.

In the frantic twentieth-century shadow world of illusory "time by itself" there were messages everywhere: saturating newspapers, post offices, telegraph lines and airwaves. With information, the counter-world of the destruction of information emerged. Censors plastered white spaces over newspaper articles. Postal workers blacked out letters from the battlefront; radio jammers pumped interference into the ether to block news. Noise versus information.

Information had to be destroyed. Yes, we live in a society dominated by information technology, and we have grown used to counting: a 14 K e-mail message, a 2.4 MB picture, a 100 KB compressed song. But we also live in a society that is concerned with the destruction of information. Facilities stand ready to crush your hard drive, shred your reports, delete your phone records, and pulverize your disks. You can pay for documents to be shredded—the tinier the pieces, the more expensive the cut.

Precious data requires more reliable destruction. Confidential material, governments say, should be sliced into 2 mm strips. Commercially sensitive pages should be cut into 2 × 15 mm particles. Just a few years ago, top-secret documents were sometimes snipped into 0.8 × 11.1 mm pieces. But who knows what information snoops might be able to reconstruct? Remember the Iranian carpet weavers hired in Tehran to sew back together the fragments left in the so-called Den of Spies? Now the National Security Agency wants information blasted down to 1 × 5 mm.

But if you really need information destroyed, you want to see it happen before your eyes. You can have a vehicle pull up, and then you can watch through a peephole as the pages are sliced, cut, and burned. You can have them carted to a secure facility where they are shredded, air-blown into oblivion, compressed into transportable cubes, bound up with powerful bands, dumped in acid, and transformed into toilet paper. Other companies turn your documents into animal bedding, playground surfaces, and briquettes.

17. Hermann Minkowski, *Raum und Zeit, Jahresberichte der Deutschen Mathematiker-Vereinigung* (Leipzig: B. G.Teubner, 1909), p. 1.

The Code of Ethics for information destroyers urges its followers not to ever, ever confuse recycling with destruction. Reconstruction looms, ever more sophisticated—so build disintegrators and granulators that slice paper until it will pass through a fine mesh, hammermills that pound bits through mesh, piercing, tearing, grinding.

Yet somewhere, deep in the background, lie the laws of physics that say that information is never lost. Information always remains, somewhere, and in theory, it could be recovered somehow. Is there a quantum demon somewhere, or an imaginary computer?

Not long ago, the most famous scientist of the late twentieth century, Stephen Hawking, argued that there was a way that information could be destroyed—a method far beyond the dreams of hammering, smashing, grinding wreckers. On the contrary, here was a method that would theoretically remove the information forever and absolutely without the possibility of recovery: drop an encyclopedia into a black hole and it would never return. Not even an imaginary demon could ever recover those words.

From the surface of the Earth, if you want something to escape from our planet's gravity, you have to shoot it up at about 10 km/second. If Earth weighed more for the same volume, you would need an even greater speed [...] If that "escape velocity" exceeded the speed of light—300 000 km/second—then nothing, not even light, could escape its gravitational pull. This is what happens in a black hole.

According to some key supporters of the general theory of relativity, an encyclopedia may fall into a black hole, but no messages can escape, not the slightest one. Imagine volumes A-Z falling smoothly into a black hole, sailing past the point of no return, gone forever. John Wheeler (who coined the name "black hole") says, "Every black hole brings an end to time and space and the laws of physics [...] as surely as the Big Crunch will bring an end to the Universe as a whole."[18]

Black hole absolutists said information could theoretically be annihilated, without hope of recovery. Against that view, the opposing physicists wanted physics to provide a way out, so that the fundamental laws of physics could survive. Memory must not vanish. Entropy and information, they insisted, could not be sucked out of the universe. Some thought the information would leak out like bits of ash floating up from a fire. Others hoped that the words of the encyclopedia would be locked within a tiny remnant at the center of the black hole—in a box that would be secure even if the black hole evaporated into nothing but random light. Still others began to describe vibrating strings stuck to the horizon, the trace of all in-falling things. The strings would preserve the encyclopedia long after it had crossed over into darkness.

According to many leading quantum (string) theorists, all the information of the world encyclopedia would remain there, forever, scrambled, like sparkling

18. John Archibald Wheeler and Kenneth Ford, *Geons, Black Holes, and Quantum Foam: A Life in Physics* (New York: W. W. Norton & Company, 1998), p. 350.

ashes from a fire, but still there, still inscribed on the surface of a bubble. Every article on aardvarks and arithmetic, and the last entries on Zanzibar and zygotes would all be there in this holographic trace that would continue to preserve all of our work and imagination… The long trail of words wound around the final splintering of space/time.

The battle pitted two compensating desires against each other. On one side lies the black hole as an absolute finality—like the Big Crunch, bookending our craving for a fresh start. On the other side, there is a black hole—the universe—seen as a kind of hologram. Information that falls into the black hole remains there in some sense, always surviving on the outside, etched, as it were, onto the event horizon.

String theory was the enduring hope for anti-absolutists. Strings—tiny loops and lines of vibrating matter—would save information from ultimate destruction. But taking strings seriously had other consequences for time. For string theorists in the opening years of the twenty-first century, time itself seemed to fail. A century ago, Minkowski had pronounced that space and time as separate concepts were doomed to fade into mere shadows. Now, a leading string theorist says, "Space and time are doomed." Another insists that it is "almost certain" that "space and time are illusions." A third adds, "Space/time […] we're going to have to give [it] up."[19]

The end of time. This time, not because our mortal clock runs down, not even because time depends on motion, or because motion itself is a shadow of frozen space/time. No, here, physics refuses time much more completely: time becomes an illusion, like our sense that water is smooth because our hands are too coarse to sense the atoms that constitute it. The refusal of time: time as nothing but the crude approximation of an obsolete science.■

19. Cf. David Gross, "Einstein and the Quest for a Unified Theory," in Peter Galison, Gerald Holton, and Sylvan Schweber, eds., *Einstein for the 21st Century* (Princeton: Princeton University Press, 2008), p. 296.

This text was written at the beginning of our work on The Refusal of Time.