TIME LIFE & MATTER

Science in Cambridge

Collection of Historical Scientific Instruments
Department of the History of Science

Since 1672 Harvard University has been acquiring scientific instruments on a continuous basis for teaching and research.

The Department of the History of Science

Collection of Historical Scientific Instruments

The Collection of Historical Scientific Instruments, established by David P. Wheatland in 1948, is dedicated to collecting and preserving examples of historically significant scientific instruments and technological apparatus across all the major fields of science. The resulting collection functions as a resource for teaching and research in the history of science and technology, as well as a means of educating the general public about the important roles played by material culture in the making of modern scientific disciplines.

Originally associated with the Harvard library system, the Collection became affiliated with the Department of the History of Science in 1987. With the completion of a new wing in the Science Center in 2003, the Collection has become fully integrated into the research and teaching of the Department of the History of Science, offering support for work by undergraduates, graduate students and faculty, as well as researchers from around the world. The Collection offers remarkable opportunities for exploring the history of the complex relationship of scientific ideas, material culture, and technology.

With the addition of instruments from various departments and donations from private benefactors, the Collection now contains over 20,000 objects dating from about A.D. 1400 to the present. A broad range of scientific disciplines is represented, including astronomy, navigation, horology, surveying, geology, physics, biology, medicine, chemistry, psychology, mathematics, and communication. Significant instruments, displaced by new technologies, continue to be incorporated into the holdings of the Collection. Many documents detailing the purchase and use of the instruments are preserved and are available for research in the University Archives.

In 2005 the Collection celebrates the opening of the Putnam Gallery, a permanent exhibit of instruments representing the remarkable breadth and historical significance of the materials in the collection. A gallery on the second floor features exhibits curated by faculty, students, and invited artists and researchers.

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Professor of the History of Science
Amalie Moses Kass Professor of the History of Medicine
Director, Collection of Historical Scientific Instruments, 2005

Sara J. Schechner, Ph.D.

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THE PUTNAM GALLERY

THEMATIC AREAS

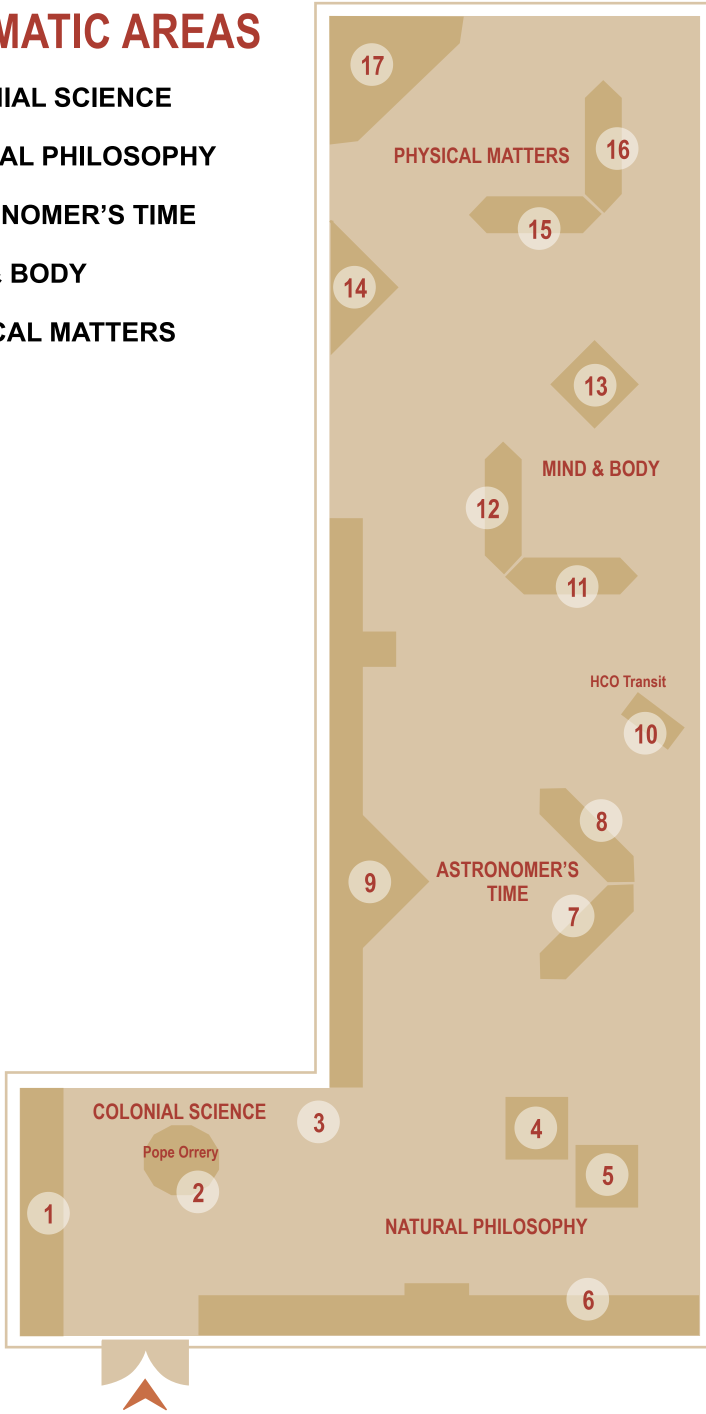
COLONIAL SCIENCE

NATURAL PHILOSOPHY

ASTRONOMER'S TIME

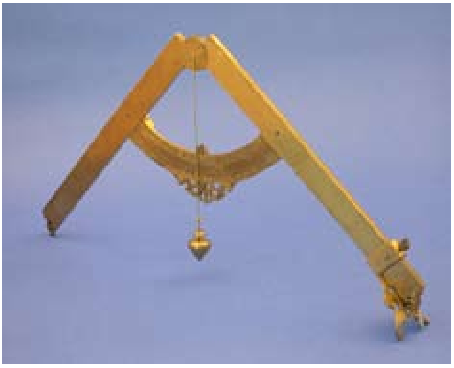
MIND & BODY

PHYSICAL MATTERS



Problem-Solving Instruments

Mario Biagioli
Professor of the History of Science



Early modern European instruments fall into two broad categories: mathematical and philosophical instruments. All the devices in this display case, dating from about 1400 to the early 1600s, belong to the first category.

At this time, mathematics comprised not only geometry and arithmetic but also many other fields and practices we now associate with physics and engineering, such as mechanics, optics, astronomy, hydraulics, surveying, navigation, cartography, horology, gunnery, and fortification. Very few of these fields—astronomy being the best example—were taught in early modern universities. Most others were practiced and learned in a remarkably wide variety of settings—workshops, arsenals, courts, vocational schools, religious orders, and battlefields—often by people who did not hold university degrees. Theirs was not, however, a predominantly oral culture like that of the visual artists. By the second half of the sixteenth century (especially in England) one could find a substantial number of textbooks in the vernacular for learning various mathematical disciplines and their instruments. In some cases, one could even learn how to build them.

To contemporary eyes, the distinctive feature of the mathematical disciplines and their many instruments was their utilitarian function. Mathematical instruments (like the people who designed, made, and used them) were not expected to provide new insights into the workings of nature, but to get a specific job done: find time (sundials, astrolabes, nocturnals), aim a cannon and calculate the amount of powder for a shot of a certain bore and material (Galileo's geometrical and military compass), detect stellar positions and track planetary motions (astrolabes), direct ships more or less toward their destination (compasses, backstaves, sea astrolabes, globes), perform the calculations required by merchants and bankers (sectors, slide rules, Galileo's compass), measure a piece of property or map a region (theodolites), lay roads and canals at the appropriate slope (levels), draw maps of countries and charts of seas, provide material models for students of astronomy and cosmography (celestial and terrestrial globes, armillary spheres), help the draftsman scale up or down technical drawings, or trace complex curves (reduction compasses, drawing instruments), etc. Some of these instruments (sundials, astrolabes, armillary spheres) had long historical roots, but others (nocturnals, theodolites, backstaves, sectors, sliding rules) were newcomers that reflected the emerging needs of early modern navigators, merchants, and engineers. Another distinctly early modern feature of these instruments was their connection to print. We think of instruments as solid objects of brass, ebony, glass, and wood, but their use could require various sorts of printed matter: ephemerides, compendia, maps, instruction manuals, etc. In a few cases, the instruments themselves could be made of paper and purchased in books (some of them of the pop-up kind).

It is also important to look at what mathematical instruments were not and what, in some cases, they became. If mathematics was about problem solving, natural philosophy was about investigating natural processes and their causes. Seventeenth- and eighteenth-century instruments like the telescope, the microscope, the air pump, the electrical machine, the barometer, and the thermometer (in the next display) are good examples of philosophical instruments— instruments that did not, primarily, solve problems, but rather detected or produced new objects and effects. In some cases, however, the difference between a mathematical and philosophical instrument was not in the conception or design but in the contexts of use. The telescope started out as a mathematical instrument (to detect enemy ships and troops from a distance) but quickly became a philosophical one when Galileo used it to make unprecedented astronomical discoveries. Similarly, late sixteenth-century English devices for the measurement of geomagnetism (like Norman's dip circle) were developed as navigation-related mathematical instruments, but became philosophical instruments because of the role they could play in the study of magnetism.

On left, geometrical and military compass made according to Galileo's specifications by Marcantonio Mazzoleni, Padua, circa 1603, for presentation to the Duke of Mantua, Vincenzo Gonzaga. Below, planispheric astrolabe made in the workshop of Jean Fusoris, Paris, circa 1400.

Making Nature Visible

Steven Shapin
Franklin L. Ford Professor of the History of Science

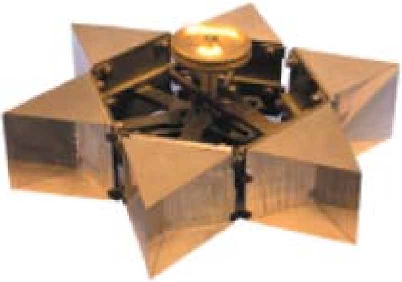
In the 17th and 18th centuries, scientific instruments were enlisted to perform a wide range of functions. Some, like the thermometer, barometer, and marine chronometer, measured natural phenomena on whose precise value depended a number of practical activities. Some gave entry to worlds otherwise inaccessible: the very small (microscopes) and the very distant (telescopes). Others allowed the hidden powers of nature to become spectacularly visible (like the Leyden Jar), or modeled the natural world on a manageable scale (like the orrery). And still others provided spaces in which one could do scientific experiments (like the air-pump). The early modern period saw the invention of many of these instruments, but, more than anything else, it saw the origins of present-day confidence that nature could be known most effectively through the mediation of instruments.

On right, air pump with Magdeburg hemispheres by Jean Antoine Nollet, Paris, circa 1740-1750. Below, a dramatic demonstration of the advantages of lightning rods, an exploding thunder house by John Prince, Salem, 1789.

All disocoveries in optics provide hope of a discovery in astronomy.

Cultures of Astronomy

Jimena Canales
Assistant Professor of the History of Science



At the beginning of the twentieth century, a distinguished physicist explained how "all discoveries in optics provide hope of a discovery in astronomy." The telescope had been one of such optical discoveries, giving birth to numerous other astronomical finds. The role of optics in astronomy increased as astronomers built bigger instruments. By the second half of the nineteenth century, telescopes had reached the gargantuan scale of the "Leviathan of Parsonstown," 70 feet in length and carrying a six-foot diameter mirror. By aiming it at nebulae, astronomers studied the age of the universe—its beginning and end. They brought astronomy to bear on evolutionary theory, thermodynamics, political economy, and, controversially, even on religion. In the nineteenth century, with the spectroscope, astronomers analyzed the chemical composition of the universe. Showing that the same fixed elements appeared in both sublunar and celestial spheres, their research had broad cosmological implications. With these optical devises, scientists shifted scales from macroscopic to microscopic domains. They moved from the present to the past and future.

Yet prismatic and lenticular optics were only a few of many other earthly disciplines that shed light on the astronomical nature of the universe. Mathematics, physics, chemistry, natural history, geology, meteorology, and even physiology played similarly important roles. Even outside of the domain of pure science, practices of navigation and exploration affected astronomy as much as commerce. Numerous other technologies and practices, such as model building, drawing, telegraphy, photography, slide projections, and cinematography, forever changed its face. Institutes of metrology standardized both astronomical units (such as the earth-sun distance) and mundane measures of length, weight, time and electricity. Reaction-time experiments became as central to astronomy as to physiology and experimental psychology. Even anonymous observatory employees, such as computers (initially mostly men) and scanners (initially mostly women), marked astronomical practices and affected scientific work environments beyond observatories. By looking at science through the lens of earthly instruments and instrumental practices, the astronomical universe appears less unified and more diverse; less of a universe and more of a multiverse.

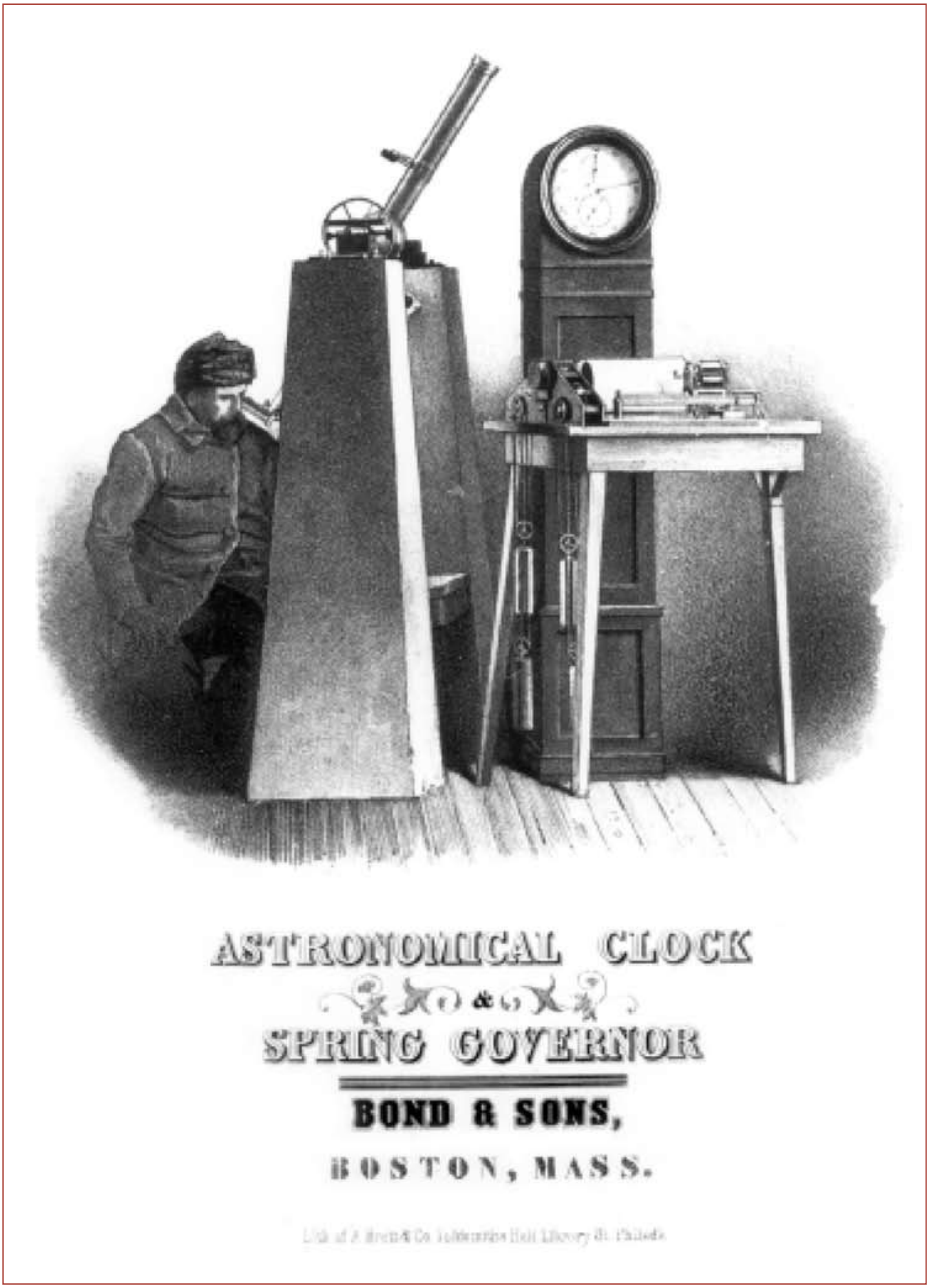
Above right, universal equatorial mount with refracting telescope by George Adams, London, before 1795. Above left, prism train from a spectroscope for a telescope, American, circa 1860-1880.

Synchronicity

Peter Galison
Joseph Pellegrino University Professor

For much of the nineteenth century—and the twentieth century, too—electrical time coordination is inseparable from the very formulation of modernity. Signals flashed outward from the great observatories of Greenwich, Paris, Washington D.C., and from the Harvard Observatory here in Cambridge. Through overland wires and undersea cables, these signals set international boundaries and mapped whole sectors of the world, symbolically and practically, for colonial conquest. Electrical pulses also coordinated time on railroad lines: Harvard actually owned its own set of telegraph wires to Boston so it could sell time across an expanding region of New England. Indeed, time signals fit hand in glove with the establishment of global time zones: coordinated time regulated work, systematized long-distance commerce through stock exchanges, and became the proud—and also despised—sign of an accelerated, connected world. Scientists pressed hard for the extension of the temporal net: beginning in the mid-nineteenth-century, they demanded the synchronization that would make possible a range of new scientific studies, from the migration of bird flocks to the shifting fronts of weather systems and aurora borealis. A large collection of observers could hardly compare notes if each participant set her or his watch by an unregulated, local time.

By the time Henri Poincaré and Albert Einstein began to take apart the foundations of length and duration around the turn of the twentieth century, they too used synchronized clocks to attack the Newtonian categories of absolute space and absolute time. Both scientist-philosophers were at crossing points of the altogether practical and the very abstract. Poincaré had key responsibilities at the Paris Bureau of Longitude, the hub of time coordination for the French empire. In 1898 he introduced his reformation of time through a more-than-metaphor of telegraphers finding longitude. Meanwhile, young Einstein was a rising star within the Bern Patent Office, the gathering point for the burgeoning Swiss production of electro-coordinated clocks. He launched his 1905 relativity paper—the most famous in all of physics— with an extended more-than-conceit of clocks and train arrival times. Both Poincaré and Einstein contended that two events were simultaneous if they occurred at the same time as measured by clocks, electrically coordinated so as to take into account the time it took to get from one clock to the other. This new synchronized-clock formulation of simultaneity became a model not only for physics but also for what a well-grounded concept should be. Clocks—we keep coming back to clocks.



On left, detail of astronomical clock by William Bond & Sons, Boston, circa 1867, which distributed standard time to New England. Above, William Cranch Bond's apparatus for his "new American method" of determining longitude and distributing time electrically along telegraph wires—a transit instrument, astronomical clock, and chronograph—as depicted in Charles Rodgers, *American Superiority at the World's Fair* (Philadelphia: 1852).

The Laboratory of Thought

Anne Harrington
Professor of the History of Science

When William James, in the 1890s, invited German psychologist Hugo Munsterberg to leave Freiburg and become permanent director of his newly founded psychological laboratory at Harvard, he was importing more than just a new faculty member. Munsterberg had been a student of the acclaimed psychologist Wilhelm Wundt in Leipzig, who had established a particular methodological vision for the very young field of psychology (still decoupling itself from philosophy), that would now, under Munsterberg's leadership, put its stamp on the emerging field at Harvard.

The vision was described as "physiological psychology," but not because it aimed to relate mental events to physiological ones. It envisioned itself, rather, as an independent experimental discipline that used the methods and, to some extent, the actual instruments of physiology to illuminate basic processes of the mind. Much of the resulting experimental work was one of two types. In the first type, individuals were exposed to some sensory stimulus (e.g., the sound of a tuning fork, a visual illusion), with the aim of gaining insights into the general human limits of sensory experience, the "just noticeable differences" in different gradients of human sensory experience, or the ways in which higher-order principles of mind imposed order onto sensory experience. In the second type of experiment, individuals were asked to perform some simple task, often involving a shift of attention from one stimulus to another; and their reaction times were then recorded. Early experimental psychology placed great store on reaction-time data. The hope was that such data would serve as a basis for what Wundt had fondly called a "mental chronometry" of higher order mental processes, illuminating especially such phenomena as volition.

All of these experiments required the implementation of elaborate social rules and roles. Highly trained subjects (and there were only a handful of these) had to adopt a very specific mental stance that was supposed to guarantee reliable introspective reporting, and they had to agree to respond to the instructions of the experimenter in very controlled and artificial ways. The enormous difficulties involved in generating the requisite social dynamics for each and every experiment was one reason why this first experimental psychology at Harvard and elsewhere would eventually be largely replaced by so-called behaviorist psychology (that could use experimental animals for its experiments and focus on what they did, rather than what they were thinking!). Even before this happened, Munsterberg at Harvard had already begun to extend and democratize the psychological laboratory, by investigating new ways in which it might be made useful in the larger world of commerce and the law, and on naïve subjects. Indeed, in the second decade of the 20th-century, one of first so-called "lie detector" instruments was developed by one of Munsterberg's graduate students, William Moulton Marston (who notoriously went on later to create the comic strip, "Wonder Woman"!).

Instruments from William James's and Hugo Munsterberg's experimental psychology laboratory: On left, Hipp chronoscope measuring one-thousandth part of a second, by Peyer, Favarger & Co., Neufchâtel, Switzerland, circa 1892. On right, waterfall illusion, William James, Cambridge, circa 1885.

Early experimental psychology placed great store on reaction-time data.

Instrumentalizing Medicine

Charles Rosenberg
Professor of the History of Science & Ernest E. Monrad Professor in the Social Sciences

Men and women have always sought to understand their own bodies. Only recently have we begun to achieve that goal, to see, to predict, and to manage those processes beneath the skin that determine health and illness. In the last two hundred years, physicians and basic scientists have come closer and closer to success. Instruments that track, measure, inscribe, and represent have been central to this fundamental change.

In our new world of bureaucratic—and technology—defined medicine, patients have become in some fundamental way the aggregate output of the tools that probe, image, and analyze their bodies' functions and components. Disease is not simply a biopathological event in a particular body but an aggregate of thresholds, blood chemistry readings, and images assembled in social space. These events constitute in sum an extraordinary intellectual and organizational achievement, but one that has concerned those wary of technology's dehumanizing potential for at least a century. A hundred years ago humanists in medicine were already warning that patients were becoming numbers on charts, shadows on x-ray plates, and smears on slides. We can not understand this central reality of intellectual and social history without an understanding of the instruments—from stethoscope to microscope, from kymograph to electrocardiograph, from laryngoscope to MRI—that have both constituted and facilitated this unfinished revolution in human society.

Above, kymograph by Georges Secretan, Paris, circa 1875. Below, clastic model of the human eye by Louis-Thomas-Jérôme Auzoux, Paris, 1891.

Instrumental Reason

Peter Galison
Joseph Pellegrino University Professor

Sure, we could see the history of twentieth-century physics through the grid of its changing set of basic objects. We would begin with the electron of the late nineteenth century and speculate about whether it came in positive form too. Then we would add the proton, the "heavy electron," and, after World War II, hundreds of new fundamental entities. Then the list would shrink as physicists came to understand many of these as combinations of a few quarks.

Another strategy might be to narrate physics through its grand theories: 1905—special relativity; 1915—general relativity; 1925/26—quantum mechanics; 1947-48—quantum electrodynamics; and onward through the gauge theories, theories of super-conductivity; the struggles over string theory.

Sampled in the cases here are fragments of another, material history of physics—history through the working machines of knowledge making. In the old cyclotron control panel is the physical remnant of a long, slow cycle that characterized physics over the last 75 years: from isotope production for cancer treatments through the study of the nucleus through particle physics and back to the use of specialized beams to irradiate hard-to-excise tumors.

If accelerators produced the high-speed particles, it was in detectors that the physics itself took shape. One tradition (of images) made visible the interactions of particles: cloud chambers, nuclear emulsions, and bubble chambers. Each aimed to take the careering trajectories of elementary particles and to capture their tracks on film that could be carefully analyzed by physicists, by physics students, by (mostly women) scanners, by electronic computers. Another tradition of detector making eschewed pictures and their slow analysis in favor of the high-speed and

highly selective electronic devices that could count events. Count an event if detectors A and B were hit—but not counters C and D. Such "logic" devices allowed quick intervention, high statistics, and a tremendous ability to pull out a particular kind of event from vast pool of events. Printed into these machines were therefore two competing epistemologies: an objective receptivity that recorded all that occurred—and a selective manipulation that allowed an active distillation of the phenomena. Gradually, over the last quarter of the twentieth century, physics can be seen through its material culture—through the long-standing rivalry of image and logic that slowly, with difficulty, merged into the controllable, digitized image.

Above, Cloud chamber in which the mass of the cosmic muon first measured by Jabez Curry Street and Edward C. Stevenson, Cambridge, Massachusetts, 1937. Below, control console of the Harvard cyclotron built in 1947 and used until 2002.

NOTES

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