emerging field of IR astronomy in the 1960s and 1970s, a professor of astrophysics at Cornell University for many years, and the author of the 1973 textbook *Astrophysical Concepts*. He also led key review committees for NASA as it built its four highly successful space-based Great Observatories, which were launched in the 1990s and 2000s.

In his new book, Harwit makes a careful distinction between cosmic messengers, such as electromagnetic radiation, cosmic rays, gravitational radiation, and neutrinos, and the fundamentally distinct phenomena discovered by decoding their messages, such as exoplanets, fast radio bursts, and merging black holes. He makes a compelling case for why our knowledge may be ultimately limited by explaining how and why the universe blocks many of its messengers: The electromagnetic spectrum is bounded at longer wavelengths at about 10^6 cm because of the ionized interstellar medium; at shorter wavelengths, the bound is about 10^{-19} cm, below which photons are destroyed by their interaction with microwave photons from the cosmic microwave background.

A more basic problem, however, is that as the universe is examined with ever-finer temporal, spatial, and energy resolutions, the messages become unreliable because of propagation effects. Perhaps the most fundamental example is the way gravitational lensing obscures the arrival time and direction of all conceivable messengers.

The first half of the book is devoted to describing the known cosmic messengers, the instruments used to detect them, and how they have enabled the discovery of fundamental phenomena. It is an impressive tour of the most important advances in astrophysics, one that is enlivened by anecdotes and background material on the discoveries and discoverers. Harwit's coverage is largely fair, although it is possible to quibble with details.

In the second half of the book, Harwit estimates anew the number of astronomical phenomena likely to still be discovered. He argues that astronomers have identified 60 distinct phenomena up to now and, using statistical inference, calculates that his previous estimate of roughly 100 total phenomena was accurate. Harwit suggests that extrasolar asteroids traversing the solar system and as-yet-unknown properties of dark matter and dark energy are possible new messengers that could enable the discovery of some of the 40 phenomena still out there to be uncovered.

In the final chapter, Harwit reflects on how we should move forward in astronomical research given those limitations. Although he has few concrete recommendations, he nevertheless expounds on a wide range of issues: whether large research consortia should be favored over smaller efforts, whether expensive new instruments require international collaboration, how to keep young scientists in the field when they can use their analytic skills to earn far higher salaries elsewhere, and how to move humankind to barren planets.

Cosmic Messengers should be of interest to a wide audience of astronomers, other scientists, historians of science, government agency planners, and anyone who wants to see the fruits of curiosity-driven research. It will also be a valuable resource to students and others aiming to place their research into a much larger context.

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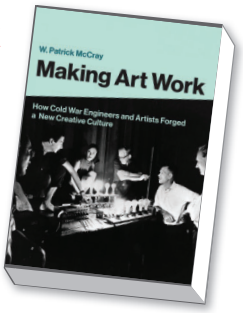
The two cultures, revisited

Making Art Work
How Cold War Engineers and Artists Forged a New Creative Culture

W. Patrick McCray
MIT Press, 2020.
$45.00



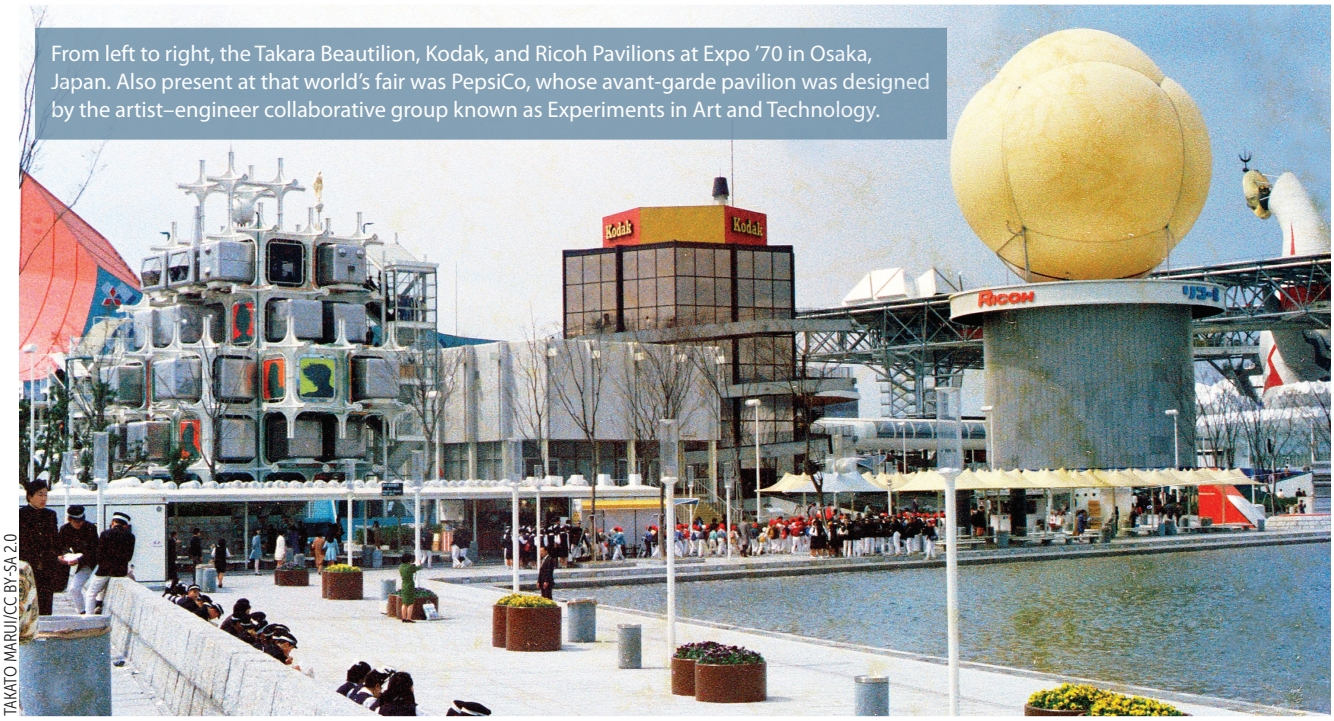
The 1959 pronouncement of C. P. Snow that the humanities and sciences make up two separate cultures has been a lightning rod for discussion ever since the novelist and physical chemist put forward his famous thesis. In the 1960s, for example, the pages of Physics Today were rife with responses to Snow (see Physics Today, September 1961, page 62; July 1966, page 160; and the article by Jerome Ashmore, November 1963, page 46). But was the divide as extreme as Snow believed it to be?

According to the historian of science W. Patrick McCray, it was not. In his new book, *Making Art Work: How Cold War Engineers and Artists Forged a New Creative Culture*, McCray delves into collaborations in the 1960s between engineers at companies like IBM and Bell Labs and modern artists in the postwar US such as Robert Rauschenberg, Claes Oldenburg, and Deborah Hay. He illustrates how artistic and scientific cultures were not irreconcilable but complementary: During that decade, some of the biggest names in the arts world relied on the technical skills of engineers to bring their artistic ideas to life.

Making Art Work centers on three figures and examines the communities they worked in as both managers and makers. The first is Frank Malina, an aeronautical engineer-cum-artist who founded the arts and technology journal *Leonardo*. The second figure is the artist Gyorgy Kepes, who developed a visual-design program at MIT and founded the university's Center for Advanced Visual Studies. The bulk of *Making Art Work* focuses on the final individual, Billy Klüver, a Bell Labs electrical engineer with close ties to the New York avant-garde art scene who founded Experiments in Art and Technology (E.A.T.), an organization that fostered connections and collaborations between artists and engineers.

McCray adroitly moves between intellectual concepts from a range of disciplines. Historians of science and technology will be able to comfortably orient themselves in McCray's analyses of big science, paradigm shifts, and tacit knowledge. Likewise, historians of modern art will appreciate his careful description of artist–engineer collaborations like the performance series *9 Evenings: Theatre and Engineering* and the E.A.T.-designed Pepsi Pavilion at Expo '70 in Osaka, Japan.

Importantly, McCray observes that engineers often served as "invisible technicians," a category defined by the historian of science Steven Shapin in a 1989 article about skilled craftsmen whose contributions to 17th-century English laboratory experiments were omitted from later histories of science. Like those early-modern craftsmen, the engineers who



From left to right, the Takara Beautilion, Kodak, and Ricoh Pavilions at Expo '70 in Osaka, Japan. Also present at that world's fair was PepsiCo, whose avant-garde pavilion was designed by the artist–engineer collaborative group known as Experiments in Art and Technology.

TAKATO MARUI/CC BY-SA 2.0

collaborated with artists often failed to gain recognition: Although many artist–engineer collaborative works appeared in museums and art galleries, individual engineers regularly went unnamed in exhibition materials and press coverage. Along similar lines, McCray points out that the art-and-technology movement was largely dominated by white men. In the Los Angeles County Museum of Art's 1971 *Art and Technology* exhibition, for example, all 16 collaborative works featured were by white men.

Making Art Work differs from other studies of the art-and-technology movement in its focus on the history of engineering. Previous works have argued that the movement waned in the late 1960s because of increasing criticism of the artists for accepting money from and collaborating with corporations, which were often profiting from the US war effort in Vietnam. But McCray asserts that broader economic trends in the field of engineering were also a reason for the movement's decline: They disrupted a generation-long period of job stability for US engineers and made art-and-technology collaborations less feasible for them. That argument suggests that scholars should take a closer look at the history of engineering in the 1970s.

Making Art Work concludes by outlining what McCray terms a second wave of art-and-technology collaborations that began in the 1990s. The new wave was presaged by the development of early consumer technology like the Sony Portapak, a portable video camera that came to market in 1965, but the widespread adoption of personal computers in the 1980s and the rise of the internet in the 1990s truly heralded a new age.

The second wave has already weathered periods of pessimism—after both the dot-com bubble and the Great Recession. It has also seen periods of optimism that have manifested in initiatives like STEAM, which attempts to integrate the arts into traditional STEM (science, technology, engineering, and mathematics) curricula. As McCray shows, however, attempts to blend the arts and sciences have foundered in the past because of different—although not incompatible—ways of thinking, communication styles, and common knowledge, which indicates that the two cultures have not yet found a smooth connection point. I have argued elsewhere that there are similar difficulties in bridging the histories of science and art.

Although *Making Art Work* is primarily intended for historians, it should also appeal to a wider audience because it addresses core questions about how humans worked with and reacted to technology in the mid 20th century. As McCray shows, the seemingly impermeable barriers between science and art have in fact been highly porous. The two cultures do, it seems, have common ground.

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