

COMPUTER SCIENCE

The computer connection

A closer look at the collaborations that fueled the digital revolution

By **Dov Greenbaum**^{1,2*} and **Mark Gerstein**²

Inspired by successes of the late 20th century—including large-scale genomics projects and deep-space missions—everyone in science today seems to extol the virtues of multidisciplinary teamwork. It's now de rigeur, for example, to unite teams of chemists, clinicians, and geneticists for a big translational research project. But how do teams really work? And, more to the point, how do you build teams that function successfully?

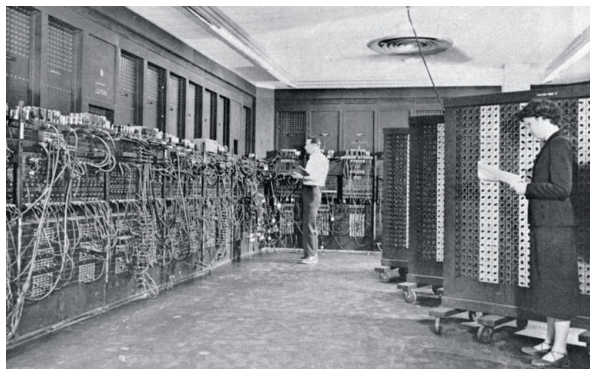
In his deftly researched and presented book *The Innovators: How a Group of Hackers, Geniuses, and Geeks Created the Digital Revolution*, Walter Isaacson tells the story of the people who invented the computer and the Internet. Although historical in nature, the book provides insights into the nature of teamwork that are directly applicable to the science of today.

Throughout the narrative, Isaacson makes a compelling case that the most transformational advances in computing have come from combinations of people with complementary skillsets. From the collaboration of theoretical physicist John Bardeen and experimental physicist Walter Brattain, who invented the first transistor, to that of programmer Grace Hopper and hardware specialist Howard Aiken, who developed the first computer that automatically executed long computations, Isaacson maintains that “most of the great innovations of the digital age sprang from an interplay of creative individuals.” He singles out solo players, like John Atanasoff—who is often credited with producing the first electronic, digital computer—as less impactful, arguing that “innovation comes from teams more often than from the lightbulb moments of lone geniuses.”

In some instances, the teams Isaacson describes seem almost straight out of Hollywood casting, featuring members with similar expertise but with very diverse dispositions and outlooks. For example, the team that founded Intel—electronics mavens Robert Noyce, Gordon Moore, and Andy Grove—had very different personalities: Noyce provided the strategic vision, Moore was detail-oriented and couldn't delegate responsibility, and Grove was the goal-oriented tactician.

Successful collaborations can still exist when individuals dislike or even hate each other. Isaacson uses the contentious relationship of Larry Roberts and Bob Taylor, who worked together to create the global Internet precursor, ARPANET, and the infamous feud between Steve Jobs and Bill Gates—who liberally misappropriated work from each other and from Alan Kay—to illustrate this point.

Isaacson even includes teams not consciously working together in his analysis, demonstrating how one individual can provide the vision and the other the execution. For instance, although they never worked together, computer scientist Tim Berners-Lee provided the vision and conceptual underpinning of the Web, while software engineer Marc Andreessen wrote the first user-friendly browser.



Betty Snyder and Glen Beck program ENIAC, the first general-purpose electronic, digital computer.

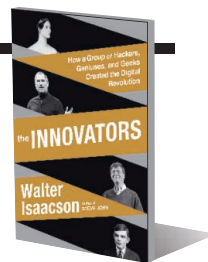
Successful teams were frequently embedded in larger institutional structures that promoted disruptive innovation by forcing multidisciplinary collaborations. Isaacson credits Vannevar Bush, the director of the U.S. Office of Scientific Research and Development during World War II, with establishing a successful framework for collaboration across academic, military, and industrial institutions. Perhaps unintentionally, these institutions may have further facilitated innovation by giving many of Isaacson's protagonists a wide berth. For example, a pervasive laissez-faire attitude regarding the use of computing infrastructure allowed an

The Innovators How a Group of Hackers, Geniuses, and Geeks Created the Digital Revolution

Walter Isaacson

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early Google to exploit Stanford's bandwidth and a budding Microsoft to take advantage of Harvard's military-funded computing facilities. The generous sharing of proprietary innovations by Xerox, AT&T, and other established companies also helped fledgling tech companies such as Apple, Texas Instruments, and Fairchild to freely build upon earlier accomplishments.

Isaacson does more than just describe the individuals who were involved in the creation of computing and the Internet. He also elaborates on many technical innovations in a clear and accessible fashion, allowing a broad readership access to the inner workings of the Difference Engine, integrated circuit, and PageRank algorithm, among others. Nonetheless, there are some important contributions missing from his story. Despite the text lavished on Linux, for example, there's little discussion of the early history of its pre-

cursor, Unix. There is also a dearth of information on the initial founding of IBM. These notable omissions notwithstanding, one is left with an intuitive understanding of the history of computing from mechanical calculators to electronic computers and, eventually, to software algorithms.

From complementary duos and collegial co-workers to synergistic rivals and unaware collaborators, one can find elements of Isaacson's teams in many contemporary big-science endeavors. However, recent shifts away from traditional, institutionalized science may moot many of Isaacson's take-home lessons. The phenomenon known as “citizen science” harnesses large groups of disparate, unconnected individuals with even more diverse personalities and expertise, who lack the structure and incentives of large institutions and often even lack classical scientific training. Citizen science initiatives are nevertheless successfully coalescing under unified goals and have led to productive collaborations in fields including structural biology and astronomy (1, 2).

REFERENCES AND NOTES

1. Foldit: Solve Puzzles for Science; <http://fold.it>.
2. Galaxy Zoo; <http://galaxyzoo.org>.

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