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As We May Think: The Legacy of Computing Research and the Power of Human Cognition

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Originally published in *The Atlantic* in 1945, Vannevar Bush's essay "As We May Think" detailed a post-war agenda for computing research focused on extending human cognition and scientific discovery. Bush envisioned a futuristic machine called the Memex, a portmanteau of "memory" and "index," which would be capable of storing and indexing all human records, books and communications. The Memex would provide an "enlarged intimate supplement to one's memory." Bush's vision evoked a new era of scientific discovery in which scientists would quickly access an unlimited storehouse of data and follow associated "trails" of information, accelerating the pace of human discovery, collaboration and innovation.



Bush's vision directly influenced generations of computing pioneers and Federal investments in computing research and infrastructure starting with J.C.R. Licklider and Douglas Engelbart. At ARPA, Licklider funded research that led to the backbone of the Internet and broadband communications and to time-sharing computers. The research of Douglas Engelbart at SRI International led to the "mother of all demos" featuring the introduction of the computer mouse, video conferencing, hypertext, word processing, hypermedia, and a collaborative real-time editor.

This foundation has inspired numerous virtuous cycles of Federal investment, groundbreaking research, industry innovation and commercial adoption. Federal research has been instrumental in the creative discovery of many of the components of modern computing systems. For example, a recent Congressional briefing, "Deconstructing the iPad: How Federally Supported Research Leads to Game-Changing Innovation," detailed the legacy of Federal investment leading to the invention of GPS, integrated circuits, capacitive sensing, and graphical user interfaces.

Vannevar Bush did not simply envision new technologies, but new ways of working together leading to human insight and discovery. The impetus to support large-scale collaborations led the way to the invention of hypertext and the world wide web, wikis and Wikipedia, email and social media. Taken together, this first era of networked computing has created a foundation of human connectivity, information search and management, and knowledge distillation. Another way to make this point is to list the top eight Internet sites today, which include Facebook, Google, Twitter, YouTube and Wikipedia.

We have only taken the first steps toward Bush's vision. While the first era was dominated by establishing connectivity, the next era will be about discovery. Even more transformative than these past steps, the combination of "big data," computational analytics, new interaction paradigms



including mixed reality and adaptive learning, and new everyday decision making and scientific practices will make our current information age look like the stone age. As before, this vision needs investment in fundamental research.

And the potential payoff? A health care system in which the lag between vetted discoveries and health care delivery is measured in months not decades. Logistics and transportation systems that respond, in real time, to fluctuations in demand and traffic. An educational system focused on discovery and knowledge generation, not memorization and out-of-date training.

Bush, Licklider, and Engelbart understood that the power of computing technologies is directly measured by how computing extends human expertise: knowledge, learning, communication and discovery. We are at the beginning of a tremendous partnership between people and computing.