ESSAY

# Kits and Revolutions

## *An MIT economist's lesson in Kitonomics 101.* BY MICHAEL SCHRAGE

**The Industrial Revolution began with kits.** In 1763, Glasgow University's scale model Newcomen steam engine broke, so the physics professor asked the school's resident mechanic to fix it. A talented instrument maker, this university employee didn't just get the machine working again, he figured out a clever way to improve the design by turning a surgical syringe into a piston and condenser.¶ That Scottish mechanic was James Watt, and he partnered with Birmingham, England's Matthew Boulton to commercialize the design. But rather than producing finished steam engines for the coal mines and breweries that used steam power, they sold engineering "kits" — with extensive instructions — that required on-site assembly. Boulton & Watt made a killing, and transformed their age.

This rough template has foreshadowed technological revolution ever since. Whether in radio, auto, aircraft, electronics, or personal computers and the internet, communities of kit-building talented amateurs — not credentialed elites — have disproportionately influenced early innovation. The proliferation of cheap kits better signals a market sector ripe for revolution than the presence of expensive "cutting-edge" products.

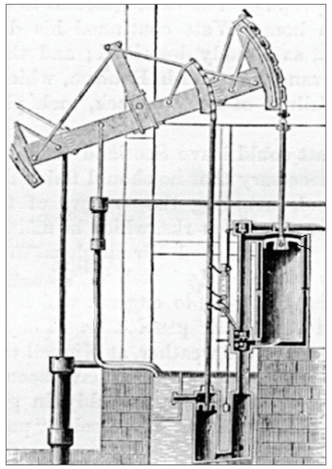
In other words, "kitonomic" innovation doesn't follow the money; the money follows the kits. Although government research funding and industrial investment undeniably matter, they shouldn't eclipse the importance of bottom-up mechanisms for human capital formation, such as kits.

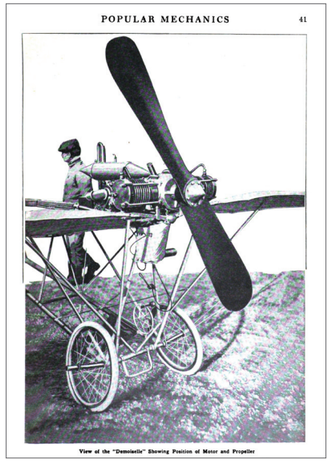
Talented amateurs don't just build kits; kits help build talented amateurs. And healthy innovation cultures — and successful innovation economies — need the human capital that their talent embodies. Kits are integral, indispensable, and invaluable ingredients for new value creation.

### ELECTRONICS, AIRPLANES, AND AUTOMOBILES

The great book on kits, their economic impact, and their technocultural appeal has yet to be written. But history strongly suggests that the more pervasive a technology, the likelier its origins are traceable to a homebrew/hobbyist ethos built around (and with) kits. As deliberately unfinished engines of innovation, kits inspire improvisational ingenuity, insight, and investment.

So while there may be no "Steve Jobs of Kits" yet, there is surely no Steve Jobs without kits. There's no Bill Gates or Akio Morita without kits either. Their market-transforming entrepreneurial leaps all emerged from kit-enabled cottage industries. The two Steves — Jobs and Wozniak — literally built Apple from kits. Gates and Paul Allen started Microsoft as a software systems






**KITS AS CATALYSTS**

James Watt's early steam engine kits, circa 1776, sparked the industrial revolution. In 1910, *Popular Mechanics* featured the first-ever free airplane plans (by Alberto Santos-Dumont). Henry Ford's early models became platforms for customization and upgrades.

## "KITONOMIC" INNOVATION DOESN'T FOLLOW THE MONEY; THE MONEY FOLLOWS THE KITS.

**FROM KITS TO COMMERCIAL GIANTS:**

Sony's founders Akio Morita and Masaru Ibuka showing their early radio conversion kits (AM to shortwave).

A-P Photo/Kyodo News

supplier for DIY computer kit builders. Morita and Masaru Ibuka launched Sony with kits to turn AM radios into shortwave receivers. From the prewar "cat's-whisker" playfulness of crystal radio kits to postwar floods of surplus electronics, kits became a medium, mechanism, and marketplace for next-generation invention.

Kit sensibilities, which value interchangeable parts and amateur tinkerability, enabled other revolutions as well. Aviation innovation, from the Wright Brothers' wind-tunnel experiments through Lindbergh's *Spirit of St. Louis,* reflects diligent amateur contributions as much as sophisticated engineering. Serious analysis of early aircraft production affirms that its earliest pioneers explored modifiable kits as much as finished planes (Alberto Santos-Dumont offered the first free airplane plans in the June 1910 *Popular Mechanics*).

Henry Ford's Detroit likewise evolved from homebrew subcultures of internal combustion and steam-powered hackers. Pre-industrialism, automobile DIYers relied on quasi-interchangeable parts and tools to craft their horseless carriages. Mass production was Ford's greatest innovation. But his breakthrough created more than a mass-market automobile; his Model T's and A's became kitonomic platforms for customization and technical upgrades. The general public — not just hobbyists — bought kits to make their Fords better, as documented by Kathleen Franz in her book *Tinkering: Consumers Reinvent the Early Automobile*.

Indirect "kitfluence" is comparably powerful. Adolescent model airplane competitions, for example, led Paul MacCready into aeronautical engineering and the creation of 1977's human-powered *Gossamer Condor*. The 1931 Grunau Baby glider construction kits proved essential to Nazi Germany's efforts to rebuild its aviation industry. And in the late 50s and 60s, MIT's Tech Model Railroad Club helped inspire DIY computing's "hacker" ethos, according to Steven Levy's *Hackers*. All of the most intriguing narratives of industrial innovation feature kits as either essential props or compelling plotlines.

### KITS FOR GREEN TECH AND BIOTECH?

Looking back is easy. Looking around — and forward — to evaluate potential kitonomic influences is the greater challenge. To what extent do contemporary kits meaningfully anticipate future transformations? Does an absence or scarcity of kit-powered innovation communities stifle market development?

Government agencies and venture capitalists in America and Europe have been infatuated with "green tech" investments and "greenovation" markets. But neither breakout products nor breakthrough entrepreneurs have yet redefined the category. No Heathkits or Altairs of eco-sustainable kits have emerged to capture the hearts, minds, or imaginations of "human capital," and government subsidies and regulations appear to be the dominant market force. Might that help explain the sector's ongoing economic challenges?

Biotechnology invites the same argument. For years, many high-tech observers (myself included) have wondered if bio-hackers and "bathtub biotech" would drive bio-innovation. Might bundling low-cost recombinant DNA reagents, gene guns, and DIY PCR machines into kits make "re-engineering life" irresistible to hobbyists? If bio-hacking kits had attracted even 10% of the community that homebrew computing did, would pharma, veterinary

medicine, agriculture, bio-materials, or bio-informatics have become more vibrant?

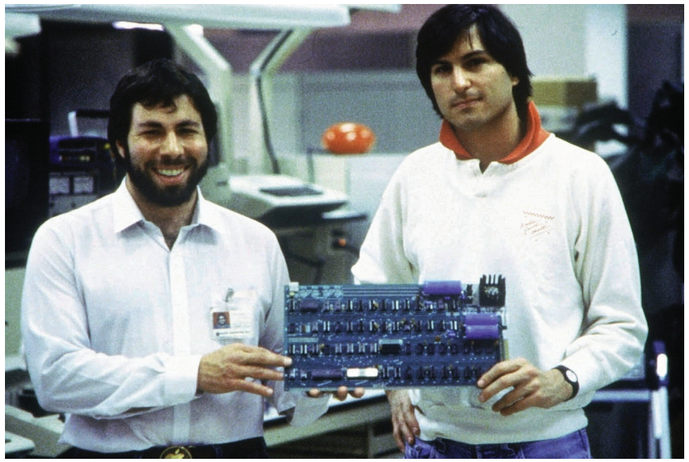
These questions are no more hyperbolic or science fiction-y than extrapolating the iPad from the Apple I or even anticipating cheap mobile telephony from germanium crystal wireless kits. Quite the contrary: the mix of kits and talented amateurs encourages such speculation. Just as the presence of kit culture signals greater things to come in a field, its absence limits vitality and diversity.

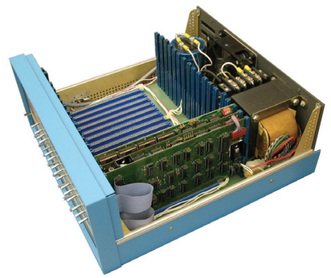
Consider autonomous vehicles. Progress in the field crawled along for decades while the Pentagon was funding the problem through its usual contractor process. But then in 2004, the first DARPA Grand Challenge invited student groups and talented amateurs into the field. Through this and two successive competitions (the last in 2007), the winning vehicles leaped from being incapable of staying on an empty desert road to completing an urban course while obeying all traffic laws and avoiding other vehicles. And all for mere peanuts in defense budget terms.

Along these lines, don't Dean Kamen's FIRST Robotics competitions and *Wired* editor Chris Anderson's DIY Drones venture (see page 26), both of them DIY and kitonomic, suggest robotics futures more varied and "out of control" than anything envisioned inside the Pentagon?

## MASS INTEROPERABILITY

The ultimate kits — meta kits — emerge when people develop their kit building blocks to work with each other. You see this with open source hardware like Arduino as well as the ongoing "appification" of software and digital services. Popular open standards and protocols subvert traditional business models, giving rise






**GAME CHANGERS**

(clockwise from top): The Steves, Wozniak and Jobs, proudly show their Apple I kit; the first homebrew Apple computer; Microsoft's first software was for the Altair 8800b kit computer

➡ (Oppostie) MakerBot Industries is revolutionizing desktop 3D printing as the Arduino microcontroller is making physical computing accessible to all.

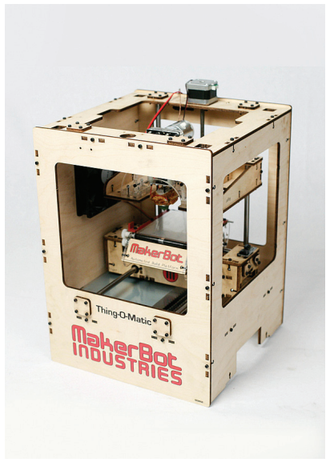
DB Apple/dpa/Corbis (Woz and Jobs); Ed Uthman (Apple I)

to global DIY R&D that enjoys far more brainpower than any company department, no many how many hot-shot engineers and designers it has hired. Perhaps this is why Microsoft — despite intense internal political battles — decided to turn Kinect into a DIY kit platform.

Consequently, the most exciting mass production consumer sectors increasingly defer to Web 2.0-ified economies of mass interoperability. As serial entrepreneur Joe Kraus brilliantly observed, "The 20th-century mass-production world was about dozens of markets of millions of people. The 21st century is all about millions of markets of dozens of people."

Yes, it is. Remarkable, isn't it, that kit mindsets and methodologies appear critical to both? The modularity, hackability, and improvisability that have made individual kits successful in the past become even more valuable when linked to higher-bandwidth swirls of wiki-ed and networked information. Higher-bandwidth and broader interactions between people facilitate higher-bandwidth and broader interoperability between kits. As tool chains and other innovation ecosystems evolve to be more kitlike, kits evolve into hardier innovation ecosystems.

And as (relatively) accessible





MakerBot Industries (top)

technologies ensure the diffusion, dispersion, and development of technical knowledge and skills, the most talented of amateurs won't just "follow the instructions." They'll advance well beyond them, and invent possible futures. The technologies may be new, but the patterns of human behavior are not.

Academic thought leaders from Berkeley's Henry Chesbrough to MIT's Eric von Hippel celebrate "open innovation" as a profound paradigm shift in value creation. For Chesbrough, open innovation revitalizes stale innovation processes in established enterprise. For von Hippel, greater openness promotes a "democratization of innovation" worldwide.

**THE MORE PERVASIVE A TECHNOLOGY, THE LIKELIER ITS ORIGINS ARE TRACEABLE TO A HOMEBREW/ HOBBYIST ETHOS.**

### TOWARD A STRATEGIC KIT INITIATIVE

Following this model, IP shifts from "intellectual property" to "innovation populism". What better instantiates open innovation than a kit, which entwines innovative components, innovative bundling, and, of course, innovative documentation and collaborative support?

But the transcendent issue is not whether open, proprietary, or "walled garden" kits represent the optimal format. It's that — no matter what regime is chosen — kitonomics appears to play an increasingly vital role.

If kits can influence and even drive sustainable innovation, then commercial and not-for-profit organizations alike should be asking what their SKIs (strategic kit initiatives) should look like.

Already we've begun to see these concerns materialize in NGOs and philanthropies in emerging markets (see "'Design for Hack' in Medicine," page 20). A growing number of development experts such as NYU's Bill Easterly believe customizable kits represent a better aid format than finished products. (Victor Papanek's classic *Design for the Real World* — more than E.F. Schumacher's *Small Is Beautiful* manifesto — best articulated this "appropriate technology" design emphasis.)

The smart money — are you listening, Gates Foundation? — would be on kits as mission-critical ingredients for dramatically stimulating quality-of-life and standard-of-living innovations in the world's poorer populations. After all, history indicates that kits are how emerging markets emerge.

And now, desktop fabrication and manufacturing literally bring another material dimension to what kits can be. The ability to integrate and interoperate digitally designed atoms and bits, to share physical objects remotely with download-and-print ease, can't help but transform design — and by extension, everything else.

What happens when the same hobbyist/homebrew subculture that spawned a Gates, a Jobs, and a Michael Dell grows around kit-built 3D printers in Brazil's favelas and India's public housing? How might microentrepreneurial design collaborations in Guangzhou yield high-impact kits inexpensive enough to seed talent and innovation throughout the world?

No meaningful answers to those questions yet exist. But we can be sure that the future of innovation is inextricably linked to the future of kits. ◪

Michael Schrage is a research fellow at MIT's Sloan School Center for Digital Business and London's Imperial College Innovation and Entrepreneurship Group. He explores how organizations use models, prototypes, and experiments to manage innovation.