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Wireless Play and Unexpected Innovation

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At the age of nineteen, college student Shawn Fanning—nicknamed "Napster" for his messy hair—wrote the popular eponymous music-sharing software and demonstrated the viability of a "peer-to-peer" architecture for file sharing. "I was at Northeastern University playing with the idea and getting feedback from my roommates," he has said, "it was really my first Windows application." Two years later, Fanning was on the cover of *Time* Magazine, Napster had forty million users and Fanning eventually made an estimated $1 million.[1] For Fanning, the situation was unprecedented. He said, "If you're a musician or actor, you know that if you're successful, some level of fame goes along with that. You're prepared. But how often does that happen to a programmer?"

An answer to Shawn might be: "More often, these days." It is true that few programmers other than Fanning have been featured in *Rolling Stone* magazine, but stories like Fanning's are a staple of popular press coverage about new media technologies. Napster's story is captivating because it contains all of the elements of excellent drama: youth, humble beginnings, success, fame, hubris, failure, and a reversal of fortune (Napster went bankrupt in 2002 after legal challenges by recording artists). But it is also captivating because it seems to teach us about qualities of digital media. The large electronic communication systems that are familiar to everyday life are cable television networks, satellites, telephone systems, and the Internet. These systems and the popular cultural products that they carry (such as films and television shows) usually require millions of dollars in capital investment to produce. If teenagers can create their own infrastructure or popular content at home, out of software, this appears to be a dramatic shift in the ordinary state of things. It may be that digital media allow individual creators more power than ever before.

Napster is software infrastructure—it isn't music but it is a way to distribute music. Beyond Napster, this new power to create is celebrated even more regularly for content than for the infrastructure that carries it. For example, in 1997, Jyoti Mishra (a.k.a. "White Town") created the song "Your Woman" in his bedroom with free software and an Atari ST. Within four weeks it was #1 on the U.K. pop charts. *Wired* magazine, writing about the big business of music that year, wondered hyperbolically "how long they can hold out before cheap technology and the distributive power of the [internet] take over."[2]

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These are not singular examples. There are many exciting stories being told about digital media and innovation, and they posit this shift in power toward new forms of diverse or even distributed creativity. While the internet was generically reputed to increase anyone's ability to produce their own content, recent examples are more specific and well documented. To name just a few, blogs and MySpace allow fast and cheap online publishing for anyone. New video game "fan site kits," in-game scripting languages, and level editors allow the players to write portions of mainstream games. New audio software has greatly increased the ability to create digital music, and revitalized the genre of music that is composed entirely of other music, called a "mashup." To reiterate, this trend is not limited to the production of new content—it also includes some production of new communication systems themselves. For instance, new techniques to interconnect Web-based applications allow programmers to quickly create a "software mashup" by combining powerful existing Web applications without much new programming labor. Although the celebrated innovators can be any age, much popular attention has focused on the young. Lawrence Lessig, the most prominent advocate of loosening legal restrictions that encumber this sort of innovation, wrote recently about the application of copyright law to fan-produced Anime Music Videos. He observed "This will be the next big copyright war—whether this form of noncommercial creativity will be allowed." "When ordinary people hear both sides [of the argument], and more importantly, see the creativity their kids are capable of, 90 percent will be with us."[3]

The excitement is not limited to commentators and scholars: kids themselves relish the idea of more freedom and capability. Alister B. and Stuart C. Dunbar, finalists in the Global Kids Digital Media Essay Contest for teenagers, wrote about how the Linden Scripting Language (LSL) used in *Second Life* became an escape and a source of power for them. Alister was forced to home school after encounters with bullies, and turned to LSL development. ("Hey, I'm a nerd," he commented.) Stuart described LSL scripting as an escape he compared favorably to his earlier heavy use of marijuana. After turning to *Second Life*, Stuart wrote, "There's nothing I can't do."

This chapter will examine one example of new technology in some detail—wireless communication technologies—and attempt to determine what is really new about the present moment. Has digital media promoted creativity in some new configuration, and shifted power to individuals or the young? (In Fanning's metaphor, are young programmers the new rock stars?)

There Are Good Reasons to Expect Transformation

The writing about the power of the internet and of digital media in the 1990s has been charged and found guilty of hyperbole, utopianism, essentialism, determinism, ethnocentrism, and more. Most of the bombastic claims about the transformative power of new media may have been nothing more than the result of the affluence common in that decade, a millennial optimism that was filtered through the academy as scholarship.[4] Yet, there is good evidence that some things are indeed transformed as the result of digital media, and that there is some reason still to take notice of a transformation with respect to innovation.

The convergence of once-distinct media technologies is the reason that innovation on, in, and with communication systems has special characteristics.[5] Convergence literally means "coming together," but this distracts from the real significance of the phenomenon. The less exciting part of convergence is the idea that a common format or common ownership could allow a converged media system to reap substantial economies of scope and scale. Even

though this is the less exciting form of the effects of convergence, it is worth reviewing here as it is a foundation for why one would expect a reorganization of media and communication at this historical moment.

Economists use the phrase "economies of scope" to refer to situations where producing more than one product can be more efficient than producing just one. For instance, if a cable company also offered telephone service (as many U.S. cable providers now do), the same marketing budget can be used to promote both products. Consumers could be offered one bundle including many media services, resulting in one price for a package including telephone calls, internet service, on-demand movies, television, and cable channels—all represented on one bill. This saves the company money when producing these products (i.e., it does not need a separate billing system for each), but it also can attract consumers who see media products as related and value the simplicity of making a single payment to one provider. In this sense, convergence refers to the coming together of media and telecommunications companies into merged enterprises that offer products across all media forms.

The conversion of media technologies into related digital formats also promises substantial economies of scale, a phrase that refers to situations where producing a larger number of units of the same product allows the cost of making each one to drop. This is familiar to most people as the rationale behind mass production. If convergence led to more sales, this could straightforwardly lower costs at a converged company, but in a slightly more subtle scenario, within a hypothetical converged company that provided content for film, television, and the internet, content developed for one media system could be slightly repackaged and transmitted over another, creating new efficiencies in production and duplication. In effect, what had been related but fundamentally different products (film, television) might become essentially the same product with economies of scale extending across all media forms.

It is worth pointing out that this situation in media is not new. The telegraph and related technologies sparked similar excitement about synergies with newspapers in the media convergence dreams of the nineteenth century (though this was not then known by the word "convergence").[6] New developments in telegraph technology such as the printing telegraph (invented in 1846) and then-new "online" media formats like the stock ticker or ticker tape machine (invented in 1857) convinced some newspaper companies that the future of media would see converged, integrated companies providing content simultaneously for multiple formats. This didn't come to pass for a number of reasons, but chief among them was that the new formats still required a large amount of effort to interconnect and demanded different sorts of expertise. This may be a cautionary note for the enthusiasms of today.

New Access to the Means of Production

While "convergence," meaning a coming together of producers for economies of scope or scale (or to produce the same content in related formats) is an old situation for communication technology, part of the recent excitement about convergence is different. The preceding section identified itself as presenting the less exciting dynamics of convergence for our purpose here. The more exciting portion relates to the properties of digital information. Once-distinct analog media like film, music, telephone calls, and television have been digitized and now share a common structure of binary code. Profoundly, this means that the means of reception in communications have also become the means of production and the means of distribution—all are now computers.

The simplest route to demonstrate this is by example. In 2007, if the owner of a relatively cheap personal computer installs the free software package *Asterisk*, the computer becomes a telephone exchange. If the user installs *Photoshop*, the computer becomes a photographic studio. *Audacity* or *Garage Band* produce an audio recording studio. *MythTV* or *Linux4.TV* produce a personal video recorder or a cable set-top box. That the means for media production and reproduction are so cheap and readily available is a new phenomenon, and it is remarkable that one common device may act as a receiver, editor, and transmitter for a variety of products. In addition, as the products are themselves digital data files, reproducing and manipulating them need not degrade their quality, require additional materials, or impose additional expense.

Most discussions of convergence until very recently treated these benefits as though they would only accrue to large corporations seeking efficiency gains in their operations. While it was clear to many scholars of digital media and telecommunications that a single platform—the computer—would change the production of cultural products, it was not clear until very recently that these benefits might extend to the general population of computer users.[7] Although commentators linked computers and the emancipation of information and production as early as the 1970s, this had been a minority view.[8]

In the previous examples of computer applications like *Garage Band* and *Asterisk*, note that the malleability of computing resources and its implication extends far beyond content to include the networks that distribute content. Before digital convergence, communication systems and their configuration consisted of relatively fixed arrangements of electro-mechanical components that were difficult to change. In fancier language, the logical architecture of the network and its physical architecture were the same.[9] Earlier, change involved building (or at least moving around) heavy and expensive wires and switches. With computerization, while manipulating these systems may not be trivial, at least it often involves the comparatively easier task of changing the digital instructions for how to do things. Significant changes in infrastructure may now be a *conceptual* rewiring like Shawn Fanning's peer-to-peer software. Napster only changes the instructions for how to transfer information, whereas with networks before convergence this sort of change could require an *actual* rewiring, with screwdrivers.

There is then some basis to believe that developments in digital media might actually prefigure new abilities to manipulate and reconfigure any of the systems of communication in society. The chance to reunite the traditional producers of communication in the oral tradition (the people) and the modern, technical means of production for communication is a heady possibility well worth investigating. Claims that digital media allow or cause new forms of creativity and production were part of the hyperbole surrounding the internet in the 1990s, it is true, but careful scholarship has found that tools like the internet have new potential to enable innovation and experimentation in ways that were formerly impossible (or at least very difficult).[10] After convergence, software and media can potentially be easily combined, reworked, and shared, and the results include important new artifacts and organizational forms such as open-source software.[11]

Despite this optimism, it is important to keep in mind that one major problem with earlier writing about digital media has been that technology was portrayed as an exogenous force outside history, politics, and culture. To demonstrate that anything is different or exciting about the present moment should require detailed and earnest consideration of the past as a point of comparison. At the same time, any investigation must remember that technology is built by people who spend money and time to shape its development to serve their own

interest, not to simply facilitate the expression of a technology's innate potential. If digital media assists in a shift of any significance, there should also be signs of inertia and resistance. If a shift in power is underway, those who could be usurped should be expected to fight back.

Locating Production and Innovation in Digital Media

Garage, dorm, and bedroom producers of new digital media projects make for exciting headlines, but the excitement about those headlines begs the question: Where would one reasonably expect new innovation to come from? It may be that the garage, dorm, and bedroom are not such unusual places for technological production.

The claim that digital media allows new sorts of creativity and innovation from new or unusual sources tells as much about the preconceptions about how innovation ought to work as it does about the purportedly novel situation today. The story of garage innovation echoes many historical stories of invention that have been viewed skeptically by the scholarly literature on science and technology. While today's "inventor-heroes" usurp or bypass existing industries, older stories of invention also portray inventors who tinker in the garage and accidentally discover the foundation for a major industry. The birth of the personal computer, for example, is often told this way.[12] Whether David or Goliath comes first, both versions are very much in circulation. Noticing press accounts of younger people discovering things in garages does not yet demonstrate that innovation in digital media differs in a fundamental way from the innovation that came before.

Although professionalized research and development is an endeavor that has really flourished in the developed world only in the latter part of the twentieth century, it has a strong hold on consumer consciousness, and on the thinking in some branches of economics. Consumers might be likely to imagine that new media-related products originate at laboratories or product development facilities dedicated to that purpose by the same companies that normally supply them with these products. Indeed, "user" or "consumer" has been opposed to "producer" in most writing about media and computer technology.[13] However, a definitive work on this question, Eric Von Hippel's *Sources of Innovation,* convincingly demonstrates that in some fields, users develop most or even all of the innovations.[14] Consumers, after all, are the ones with the most intimate knowledge of the uses for a technology or product. They are the ones frustrated by missing features or services that could be commodified—omissions that to them are obvious.

In the area of cultural products, user-driven innovation seems almost obvious. This comes into focus by turning away from conduit for a moment and focusing on content. In the culture industries, it is readily accepted that stars were fans first; they were likely "users" of older instances of a media genre before contributing their own innovation. Rather than the "R&D" of the consumer products' world, media firms have evolved strategies like "A&R" (artist and repertoire departments) and independent film festivals to scout for new products rather than developing them in house. With cultural products, consumption can easily blur into production. One could argue that most truly committed music fans also play an instrument, and they might even learn to do so by playing their favorite song from the radio.

This may seem a far cry from infrastructure and technology innovation. After all, we are told that performers are artists and that they have something called "talent," while programming is a skill that can be taught. Yet since computing's early days, programmers have been "derided for their adherence to artisanal practices,"[15] and they have been compared to artists and surgeons as often as to coders.[16] The professionalization of programmers has

been as incomplete as the professionalization of musicians and artists. (You can get a degree in computer science, in music, and in multimedia production, but the successful figures in every one of those fields agree that the superstars can be self-taught.) Detailed studies of programming labor have found that it is creative and performative, with some programming languages providing an infinite number of ways to resolve a single task of any complexity, just as there are an infinite number of ways to write a novel.[17]

Programmers are not being compared to artists here in order to congratulate them. By reminding ourselves that programming is an activity that may not require formal training and can be advanced by virtuosos, examples like Fanning seem less unusual. The advent of the internet has produced a pantheon of programming virtuosos (the rock stars of new media) from Tim Berners-Lee to Bram Cohen.[18] These innovators are often used to embody a "bottom up" or nontraditional path to innovation that lies outside the traditions of corporate R&D, but the situation is more complex than this.

It is true that while some of these "rock stars" had formal educations in computer science, they often pursued groundbreaking work well outside a traditional research and development context. While some held jobs in computing, these jobs were often not particularly related to the innovations they produced. Berners-Lee proposed the World Wide Web while working at a particle physics laboratory (Organisation Européen pour la Recherche Nucléaire), not while working in the R&D lab of an internet company. While Craig Newmark was trained in computer science, he developed the Web application *Craig's List* as a hobby and (like Berners-Lee) because he wanted to *use* something like *Craig's List*, not because he wanted to run it.

The distinction that is important here is not commercialization: Newmark would later commercialize *Craig's List* and incorporate as a for-profit company, but when he originally conceived of the project it was as a user of the internet, not as someone whose job was devoted to developing new applications. *Craig's List* started as a hobby. These user-driven innovations (to use Von Hippel's term) can be distinguished from the innovation path espoused during the dot-com boom of the late 1990s in trade press books about start-up companies.[19] That celebrated entrepreneurial path in digital media involves start-ups and venture capital funding and a desire to get rich, but this is quite different from hobbyists or college students who yearn to *use* the technology they are inventing.[20] Innovation in digital media is often portrayed as David versus Goliath, meaning "start-ups versus corporate R&D." But both the funded start-up company and the corporate R&D lab are Goliath if one is interested in the comparatively tiny user innovator. The young innovators like Fanning may represent the new promise of digital media.

The remainder of this chapter will seek innovation in digital media by turning to cases. Specifically, there should be case studies of technological development that help us to evaluate the present situation by putting in play all of the dynamics introduced so far. These include the young, convergence, production in a nontraditional context and dramatic shifts of function in the evolution of a technological system.

Geolocation, From Big Government to Small Subculture

In order to look more closely at this elusive notion of innovation in digital media, where innovation starts, and where innovation leads, it is essential to spend time with the gritty detail of examples of new media technologies and ideas about them. This section will do this via a discussion of some little-known developments from wireless communication technology,

starting with geolocation. This particular example is useful because geolocation is a significant new technological ability, and the story of much of its development has not been written. (This relative obscurity will help avoid the distraction of hype and enthusiasm, as this technological area is obscure enough that it has little popular awareness and no popular inventor-heroes.) Today's wireless innovation makes an interesting case study because "new developments" in wireless is an old topic with a long history, studied extensively by generations of historians and media scholars, thus providing a useful point of comparison.[21]

For our purposes, this story begins in 1993, when the U.S. Air Force launched the last Navstar satellite required to complete the Global Positioning System (GPS).[22] GPS technology precisely locates moving people and objects on the Earth's surface, and in 1993 this was firmly a government effort. The same GPS devices that today produce driving directions for the affluent originally cost twelve billion tax dollars to build. GPS was developed by the U.S. Department of Defense and Raytheon, and they intended it as a means to guide intercontinental ballistic missiles to their target. GPS fits all of the criteria that have been proposed to define a "large technological project," a term of art defining that special sort of undertaking that includes "big science" and "big military" projects representing an expensive and complex societal effort.[23] These large projects (like Boston's "big dig" or the Apollo Program) address objectives that are thought to be impossible to achieve without a massive financial investment and a centrally managed sociotechnical system to control it. Large public projects like these are sometimes contrasted to networks and private systems that begin as small, isolated parts and then become large (like the railroads or telephone systems) through interconnection, consolidation, or some form of agglomeration. Unlike projects that can start small, by this logic, geolocation and landing on the moon both require a gigantic investment in infrastructure before the desired results can be achieved even once. While GPS has its stories of individual inventors and pioneers, the "S" for "system" in GPS required multiple satellites to be launched and millions of dollars to be spent before the first person could use them even once to locate anything.

GPS, in other words, is a system that was as far as possible from the decentralized, participatory ethos of digital media that now excites some commentators. But just a decade later in 2003, when the "next-generation" of geolocation technology was advanced by the Skyhook Wireless Corporation to improve upon performance of GPS, the new version was built on the backs of disaffected teenage digital media hackers. Without much fanfare, the innovative infrastructure for geopositioning had shifted from a network of military satellites to a network of emergent media practices—from big government to small subculture.

Generically called "software-only positioning," Skyhook's new replacement for (or supplement to) GPS takes advantage of the prevalence of wireless internet consumer products in cities. After 1999, short-ranged wireless internet access devices became a fantastically successful information technology product across the developed world, both in homes and in businesses of many types. The most popular type of wireless internet, called "Wi-Fi" (a term coined by a naming consultancy that does not stand for anything), allows high-speed communication without a cable between computers at a range of about 150 feet. These devices were often purchased by broadband subscribers who wanted to connect a cable modem or DSL line to their home office without the trouble of running new wiring.

Anyone who bought a $70 Wi-Fi access point for their house after 1999 has been steadily transmitting a unique number from it as long as it has been turned on. This number is part of the protocol that allows these devices to interconnect with your computer. In a massive survey, Skyhook inventoried these numbers across the twenty-five largest cities in the United

States, and compiled a database that identified exactly where in the United States each unique number had been found.

When a user of Skyhook's software-only positioning system opens their laptop in a moving car, the laptop's now-commonplace wireless internet chip listens for these numbers, and then Skyhook's database correlates them with locations from their earlier inventory. As long as most Wi-Fi users haven't turned off their access points (or moved, or bought new ones), Skyhook delivers an address more reliably than the Pentagon, and with more precision.[24]

This is a significant advance. In the urban canyons of cities, the line of sight from a GPS receiver to Navstar satellites is likely to be blocked or limited, causing the GPS system's notoriously poor performance in urban areas. But the denser the city, the more Wi-Fi signals there are, making the place where GPS is least accurate to be the most accurate for software-only positioning. GPS usually requires a specialized receiver (or at least a chip), and this provides a measurement of location that is accurate to within about 20 feet 95 percent of the time. In contrast, the promotional literature for software-only positioning claims accuracy rates within one foot.[25]

Wireless Play and Accidental Infrastructure

To say that all this came from disaffected teenagers isn't meant to imply inspiration or provenance, but to be taken literally. Skyhook's survey of Wi-Fi networks and its correlation of addresses originated in the folk practice of "wardriving," a quasi-legal hobby invented by computer enthusiasts.[26] As Drew explains in the underground instructional video "Responsible War Driving," wardrivers discover wireless signals by driving around the city with modified computers that "show us exactly where [people] are." All this is fun, Drew says, because of "the interesting maps you can create and explore."[27]

While driving around, a wardriver brings along a laptop or palmtop computer connected to a GPS receiver. Software like *Netstumbler* or *Kismet* logs the Wi-Fi networks that the computer has discovered along with the latitude and longitude where they were found. The results can be visualized using free mapping software like *GPSMap* or *JiGLE/DiGLE*.

Some of the pleasure in wardriving obviously comes from being privy to information that other people don't have, even if it is simply knowing where to find invisible signals. Typically, wardrivers don't use the Wi-Fi they find for any purpose other than to map it. Wardrivers like to trade stories about interesting Wi-Fi access point identifiers they have found ("im_watching_you" "garyisgay" "nojohnissupergay").[28] The fact that driving slowly and systematically down every street in a neighborhood is a suspicious activity adds excitement, and some wardriving sites refer to trips as "adventures." As one "tips and tricks" site advises: "Do not draw unwanted attention to yourself . . . do not be nervous of [sic] police officers."

It is difficult to get a clear picture of the average wardriver. Information on any small subculture is hard to come by (the most prominent Web service devoted to wardriving had 54,768 registered users in 2006), but wardrivers generally prefer anonymity or pseudonymity because of the uncertain legal status of their hobby.[29] They need to be old enough to have access to a car, but at least some are not much older than that. This younger group is joined by an older cohort that has previous experience in amateur radio. They appear to be predominantly male, and some of them are technically sophisticated when compared to the general population. Postings to Web forums that betray personal information say things like: "I have my rig running when I'm delivering pizza." "I wardrive between home and school."

"I need to do some college hw [homework]." "My gf [girlfriend] isn't into wardriving." "I've been a radio hobbyist all my life, a ham in the 80's."

Wardriving became more of a group activity, and more like a sport, with the introduction of opportunities for coordination, teamwork, and competition. Early efforts included "group" wardriving dates discussed on message boards in 2001–2002, attempts to wardrive at the same time in different places (and compare notes) like the "World Wide Wardrive" in 2002, and attempts to cultivate a Wardriving Meet-up at http://www.meetup.com.[30] Artists attempted to collaboratively produce Wi-Fi maps with volunteer wardrivers, while groups like NZ Wireless pioneered a way to organize treasure hunts using wardriving equipment (the treasure is a set of specific unique identifying numbers for Wi-Fi access points that have to be collected).[31] At this time, articles appeared in "serious" publications pointing out that wardriving might have useful applications.[32]

A major shift in the utility and character of wardriving as an activity arrived when Web services became popular that allowed pseudonymous hobbyists to pool their efforts into one shared dataset. That is, a shared dataset that allowed them to both cooperate and compete in a systematic way. Drew (introduced earlier) created the internet site http://www.wifimaps.com, while Arkasha, Bobzilla, and others (these are online pseudonyms) created "WiGLE"—the Wireless Geographic Logging Engine. These services allow wardrivers to submit their results over the internet and aggregate them. By 2005, thousands of young wardriving hobbyists using WiGLE had cooperatively mapped five million Wi-Fi networks.

Evoking open-source software production, these sites allowed individual hobbyists with no connection to each other to collaborate on producing a result that was much greater than each individual part: a global map of Wi-Fi.[33] But just as crucially, the sites defined a venue in which avid enthusiasts could compete against each other, creating a new incentive for the discovery of more networks. An example posting to the blog chroniclesofawardriver.org is illustrative. It reads: "Congratulations go out to mark571 for claiming 2nd rank earlier this morning. . . . Mark571 is currently 11,248 above my ranking and doesn't appear to be slowing down any—watch out 1st!"[34]

None of this was supposed to lead to geolocation. However, when entrepreneurs conceived of the possibility of software-only positioning and wanted to test its viability on a large scale, they found that wardriving enthusiasts were the ones in possession of the largest datasets locating Wi-Fi. Arkasha and Bobzilla of WiGLE allegedly sold their aggregated Wi-Fi database to Microsoft, creating a minor controversy among the wardriving community that was less about the hobby's commodification than it was about the sharing of the spoils. (One wardriver, mc_sikes, posted on the WiGLE forum asking "Now that wigle sold the data to Microsoft, are wardrivers going to get paid?") In this way, some of the same bits of data produced by the hobby have made their way into prototypes and even commercial software-only positioning products by Navizon, ekahau, Skyhook, and Microsoft.

General Prerequisites for Unexpected Innovation in Digital Media

From one perspective, the story of software-only positioning links terribly disparate actors, events, and technologies in a web of happenstance that is difficult to believe. To recap, a hypothetical middle-class urbanite in Pennsylvania buys a Wi-Fi access point to connect their cable modem in the living room to their computer in the upstairs den. Some time later, an anonymous hobbyist drives by (perhaps it was "SignalSeeker"), hoping to collect the device's ID number as part of a treasure hunt. In Chicago, Bobzilla and Arkasha like to play with

maps and computers, and so in their spare time they build a system to share this hobbyist data online and rank "SignalSeeker" against "Psychic Amish Stumbler" and other players. Later, they sell SingalSeeker's early results to Microsoft Research. Back in Pennsylvania, this turns out to help a passing motorist in a rented SUV to find their hotel. The SUV's on-board navigation system uses software-only positioning, but this works especially well when it is combined with a guidance system for ICBMs (the GPS).

Is this an amazing sequence of events, or is it ordinary? While the details of this particular story are little known, it is only as strange as we need it to be. In fact, parts of the broad sketch might seem familiar. The internet, as its history is sometimes told, was invented as a Cold War communication system designed to survive nuclear attack. It was then transformed by computer geeks who wanted to summarize old Star Trek episodes and share pornography.[35] In another version, supercomputing exists because of the military need for complex simulations of nuclear weapons, but the National Center for Supercomputing Applications was the birthplace of the first graphical World Wide Web browser, written by a part-time college student and now used by everyone.[36] There are many other narratives like these. Wi-Fi and software-only positioning's juxtaposition of military technology, play, and production may seem particularly novel, but it is just this combination of purposes that Timothy Lenoir has highlighted with the brilliant phrase "the military-entertainment complex."[37]

The basic ingredients that unite geopositioning, the internet, and the graphical Web browser are a large-scale institutional or government investment refined or repurposed by upstart users. The pleasant surprise in these tales is the unexpected outcome: a technology has dramatically shifted function. These accounts of innovation invite the reader to celebrate the romantic notion of the individual, the "expressive, exploring, transfiguring idea of the individual" rather than the calculating utilitarian.[38] A handful of contrarian kids have created (or inspired) a new technology that has real economic value. Horkheimer and Adorno's classic rule that in the enlightenment "whatever does not conform to the rule of computation and utility is suspect," has been observed in part by finding new value and utility in media and software play and exploration. This play is linked with the young, as play is so often linked.[39]

Is this sort of innovation a new feature of digital media? Software-only positioning leveraged a number of other existing digital infrastructures to produce a new and unexpected resource. That is, the large technological project of the GPS first provided a centralized geolocation system that could be bootstrapped into a better decentralized one (software-only positioning requires GPS). The large technological project of the internet provided a converged digital communication infrastructure that could be employed to transmit and coordinate a variety of media, from e-mail to a wardriver's log files or mapserver. The large installed base of cheap consumer Wi-Fi access points accidentally provided the signaling mechanism that in the GPS would have required a satellite. The large installed base of Wi-Fi chips in laptop computers (and, more recently, some cell phones) provided the antenna that in the GPS would have required a specialized handheld receiver. "Playing with maps" and mapservers on the internet is an acceptable and encouraged pastime for programmers, thanks to the many popular examples of hobbyist programming provided by the open-source software movement. "Playing with Wi-Fi" and wardriving developed as a small but coherent subculture that provided its adherents an interesting pastime and an identity. Seen this way, the innovation of software-only positioning was a logical combination of these building blocks.

Speaking more abstractly, requirements for this innovation that could be applied to other examples could include that, (1) rich sets of information are freely available to be played with

and repurposed, (2) information resides in a digital format that aids in its ready duplication, transfer, and manipulation, (3) cheap or free communication via the internet allows the coordination of disparate, distant actors, (4) important features of existing digital systems are documented and programmable so that they can be easily reconfigured by those who have the skill, and (5) a subculture exists or can be created that provides incentives to participate.

Stated in this more abstract manner, many of the new media technologies employed by youth subcultures also fit this general template, as do the interesting software recombination projects mentioned earlier called "software mashups." Social networking services like MySpace and Friendster have promoted themselves as a youth fad and induced individuals to produce a whole (e.g., a network) that is much more interesting than any single person's profile. The photo sharing service Flickr does much the same, relying on the extensive existing infrastructure of digital cameras. If the five-part template introduced above represents a real departure from previous innovation, 2008 could be the edge of a digital media renaissance, where form, tool, genre, and infrastructure are newly amenable to change and recombination. But this conclusion is premature because it asks us to assume that these features are new. Before generalizing about the "new" present, we should look for the Bobzillas and SignalSeekers of the past. Analog wireless play, after all, was pioneered by young boys and this led to what we now think of as radio.[40]

"New Wonders with 'Wireless'—And by a Boy!"

To those who have read the history of wireless innovation a hundred years ago, the parallels to the Wi-Fi experimenters of today are uncanny. The argument here is not that parallels can be found in history for the current situation—history is a large domain, and so it is almost always true that some sort of historical parallel can be found for any situation. The argument here is instead that wireless history offers exactly the same sorts of roles, behaviors, and activities: not a roughly comparable situation but an almost identical one. In the first days of Wi-Fi, much was made of the "Pringles Cantenna": a Wi-Fi antenna produced by enthusiasts who modified a potato chip can. A hundred years ago, the phenomenon was exactly the same, but the can used was Quaker Oats.

In the exemplary *Inventing American Broadcasting,* Susan Douglas coined the phrase "the cult of the boy operator" to describe the culture of radio amateurism and the press coverage that promoted it in the early years of the twentieth century.[41] As a point of departure, she refers to a 1907 article from the *New York Times Magazine* headlined "New Wonders with 'Wireless'—And by a Boy!" The star of this feature was twenty-six-year-old Walter J. Willenborg, an ordinary student with a facility for manipulating wireless equipment. A subsequent article in 1908 emphasized that "even today there are young folks who make [a] mistake in thinking that all great things that are worth doing have been done; all the great discoveries made; all the grand inventions finished."[42] Willenborg was an example of the white middle-class boys who were advancing the grand inventions of wireless. They did this by participating "in contests of strength, power, and territory,"[43] and by eavesdropping on otherwise inaccessible signals. Douglas asserts that for the amateur operators of 1908, technical prowess in wireless was an important new way to be a man. The middle-class masculinity of the day was dominated by physical and natural contest. As formal education increased in popularity and duration and everyday life became more urban for most people, there had to be some way to reclaim "a sense of mastery" using other means: technology.[44] Boy operators could still "triumph over nature if they controlled the right kind of machine."[45]

Scholars of media technology have given these boys enormous credit for shaping the development of radio as a system. The introduction of the inexpensive crystal set provided the means for amateurs to affordably experiment with radio, and the amateur audience that they developed foreshadowed the use of radio as a mass medium for entertainment. By many accounts, the most societally significant innovation in early radio was not a characteristic of the receiver or transmitter, but the idea of mass broadcasting itself. With radio, "it is not only that the supply of broadcasting facilities preceded the demand; it is that the means of communication preceded their content."[46] Radio companies of the time were focused on taking business away from cable and telegraph operators, and were reeling from the collapse of a speculation-related bubble in the stock market. After later developments in the regulation of radio, the significance of amateur operators would sharply decline, but in developing a very early audience of hundreds of thousands of users and uses for radio, amateurs demonstrated the viability of a system of mass broadcasting that would later be commercialized as "the media." What we know as radio was invented by young boys like Walter J. Willenborg. In their play, they invented the content and the audience.

A specific group of nonprofessionals in the past contributed valuable innovations to the social organization and the technological system of radio. They initially organized their activities as play and as "just fooling around," and they initially sought to serve only their own interests. While their greatest contribution was the idea of broadcasting (for instance, they were the first to transmit music over the radio), this was only one of many contributions. As they had limited resources, their contributions often emphasized overcoming these constraints. For instance, the American Radio Relay League managed the first transatlantic transmission by shortwave in 1921—a feat that without shortwaves required giant industrial machinery consuming large amounts of power.

Some of the rules and games of wireless play are identical, even after ninety years. NZ Wireless's Wi-Fi treasure hunts, mentioned earlier, are the same sort of organized seeking for particular signals that early radio amateurs pursued under a variety of names.[47] Much like the wardrivers of the twenty-first century, the early twentieth century pioneers often organized themselves while at play, and some activities took the form of a contest. Starting in 1916, the U.S. amateurs began to organize large-scale radio relays that would convey messages across the country (in 1916, a message from Iowa reached both coasts in about an hour).[48] These relays emphasized different characteristics of wireless technology at different times (e.g., some were speed contests, some experiments with reliability checks). The organizational vehicle for these relays, called the American Radio Relay League, became the dominant membership association for amateur radio.

Bobzilla and Arkasha's creation of WiGLE (the Wireless Geographic Logging Engine) on the internet to organize wardrivers was then a newer version of an old effort. Bobzilla and Arkasha used a dedicated Web server and computer programming expertise to harness the latest geographic information systems (GIS) and technologies. In 1916, W. H. Kirwan bought "a large map of the United States and a pair of compasses," and when he wanted to communicate with amateur stations, he produced mass mailings of 1,000 letters.[49]

So, the users of radio and software-only positioning both have some maverick teenagers to thank. With this in mind, the account of the wireless wardriver accidentally helping the driver of the rented SUV should start to seem less strange. The development of any technology involves a complicated tangle of associations that looks odd whenever anyone stops to look at it closely enough.[50] In these accounts, the involvement of youth, whimsy,

and play often seems to be the most exciting and unexpected feature of invention. But this shouldn't seem strange either, as this combination is a leftover from the Enlightenment discovery of the imagination and its transformation through the eighteenth century into an attitude that glorifies creativity, "... freedom, originality, genius, the arts, and the innocent and uncorrupted character of childhood vision."[51] All of this is to say that linking teenagers playing around to new kinds of invention is in the longer view an awfully familiar "unfamiliar story."

The Prerequisites Revisited: What's Different Now?

Earlier, this chapter posited five general prerequisites for unexpected innovation in digital media. Summarized again concisely, they were as follows: (1) rich sets of data, (2) digital formats, (3) cheap communication, (4) open, documented interfaces, and (5) a subculture of innovators. After a short detour to the history of wireless play and radio amateurism ninety years ago, it should now be clearer that surprising things can also be accomplished with poor sets of data, expensive communication, and analog formats (the first three prerequisites).

If the new availability of data in a digital format combined with the cheap ability to communicate it is all that is truly new (our first three prerequisites), then there has been no revolutionary shift in innovation, but instead a simpler quickening. If the Shawn Fannings of the world are not a new phenomenon, it may still be that there are more chances to innovate in this manner now. Von Hippel depicts an acceleration of user-driven innovation across society in just this way: not as a wholesale transformation, but as a change in scale. "[R]apid technological advances in computer hardware and software and networking technologies have made it much easier to create and sustain a communal development style on ever-larger scales," he writes, due in part to "prepackaged infrastructural support" for subcultures of innovators.[52]

The fourth prerequisite—open, documented interfaces—simply isn't new. Open interfaces can be thought of both as a feature of a technology's development over time and as a decision made by the organizations involved in technology production. That is, radio was malleable by young boys in the 1920s in part because the knowledge of radio was so new (and so sparse) that it could be readily grasped and manipulated. The apparatus employed in early radio was much simpler than that used in later developments (such as satellite radio). While in the modern example of geolocation, GPS and Wi-Fi were open standards, freely available, there is no reason that they need be public, and in fact all of the operation of GPS used to be a government secret. Open interfaces can be found throughout the history of technology development in situations where firms found it more expedient to share information about technology and compete on some other field. (This is related to the business strategy of actively sharing technological innovations rather than keeping them secret, called "free revealing").[53]

While the fifth prerequisite (a subculture of innovators) has garnered a lot of attention recently, the young inventor-hero and the subculture of innovation is surely not a new phenomenon (as Walter J. Willenborg would agree, if he were still living).

This nuance separating a simple quickening of some features of innovation versus a wholesale transformation of innovation is of the utmost importance. This nuance has been lost in the public debate about the transformative power of digital media, and this has consequences for action. If fans of distributed creativity and decentralized innovation can locate some fundamental notion of positive empowerment inside the nature of digital media, they

need to do nothing. As digital media marches across the landscape, power will shift, creativity will blossom, and we only have to pause and appreciate the results ("There's nothing I can't do," as Stuart wrote). Instead of this view, the preceding discussion suggests that there are historical precedents for the current excitement. "Programmers are the new rock stars" is nothing more than the latest installment of a recurring phenomenon, as amateurs were the new radio stars. In a longer historical perspective, doing nothing but waiting for the transformation won't work. The transformation won't arrive, and there is a need to figure out why not. Amateurs are not radio stars today—or to speak more generally, these positive phenomena seem associated with the birth of a communication technology, but then they disappear. It is also worth asking why these features of distributed innovation and creativity failed to transform society in the past—after all, here it is needing transformation again.

Innovation by Whom and for What?

A useful way to conceptualize the state of digital media and innovation today, then, isn't as a "transformation," but as something much more worrying: it is the predictable process of things staying the same while established centers of power and structure exert their influence. Arkasha, Bobzilla, Walter J. Willenborg, and Shawn Fanning have almost been collected from central casting to play the role of a young innovator. There is a reason that the role is typecast: the population of innovators in information technology is remarkably homogeneous. There is even a word to distinguish the class of people who can participate in configuring information technology, and that word is "nerd." (Remember Alister B. wrote, "Hey, I'm a nerd," to justify his own scripting habits.) Little systematic demographic data exist on the new or old waves of innovators, but a moment's examination reveals that information technology innovators inhabit an overwhelmingly privileged world. Recent reports of a new "participatory culture" arising from digital media beg the question: Who may participate, for what purpose?[54] The answers don't reveal a new world where anyone can be discovered to be a rock star or a rock star programmer. Instead, content and technology production seem to rest firmly with the same sorts of people we would expect after a review of radio amateurs: these are white, well-educated young men, typically from middle-class backgrounds.

Race and privilege are not raised here just to point out the ongoing inequality of society (although that would be reason enough). Instead, when considering the topic of innovation, the scholarship very clearly states that *who* innovates is absolutely critical to the kinds of innovations produced.[55] Creators of our new technologies overwhelmingly imagine themselves as the users (at least at first), whether they work in an R&D lab or not. Who they are, the kind of things they like, and the kind of things they want dictate the limits of their imagination for new inventions and features. As discussed earlier, many innovations come from users, and so it is uncontroversial to point out that the user and technology developer can be the same person, as in von Hippel's phrase "user-innovator." However, more fundamentally, scholarship in technology studies has found that any technological innovation is itself an act of projection where a designer actively constructs an idealized use and user for their product. This idealized or projected user—sometimes called "the reflexive user"—is intermingled with the developer's own identity, and this process is more prevalent during the earliest days of a technological system, as Bardini and Horvath have shown for the evolution of the personal computer.[56] While this concept has been used to describe technology production, there is

no reason not to extend this idea to content. In the production of media content, it isn't a surprise that the directors, writers, and artists strive to produce film, text, and artwork that they would like, and to capture the attention of an audience like themselves and their friends.

This is a valuable shift in perspective because it invites us to stop searching for bottlenecks, or at least to reconceptualize them. In past fears about cultural domination, the concentration of cultural production, and technological disenfranchisement, the focus has always been on the few people that seem to get to decide "for the rest of us." The large technology producers, talent scouts, television executives, the Hollywood studio system are to blame, and have to be eliminated or bypassed. But today's excitement about digital media has bypassed the bottlenecks, and revealed a mass of creative people who often look just like, and aspire to be just like, large technology producers, talent scouts, television executives, and the Hollywood studio system.

Just a few examples will cement this point. In 2007, the potato chip brand Doritos followed a recent trend toward embracing consumer-produced marketing and partnered with Yahoo! Video to hold the "Crash the Super Bowl Contest." In brief, anyone could create and submit their own thirty-second commercial for Doritos, and Yahoo! Video users could vote for their favorite. Doritos would then pay to air the winning spot during the Super Bowl—long the most important and expensive (and therefore exclusive) venue for television advertising. The amateur users banded together and produced . . . a professional set of Doritos' commercials. One of the common remarks posted to the Yahoo! and YouTube sites of the contenders was that the videos were "so professional." Indeed, they were indistinguishable from the recent output of any professional ad agency, and the participants in the contest wrote about how they hoped for professional media jobs.

There is more to these Doritos than what has been made by recent cultural criticism. For instance, recent essays have pointed out that replacing mass media gatekeepers with distributed creativity hasn't unleashed a dynamo of creativity that was formerly repressed; it has only revealed the atrocious taste of the masses. (Jaron Lanier crystallized this critique with the phrase, "The hive mind is for the most part stupid and boring.")[57]

Most of the content and technology producers in the wireless case studies reviewed earlier do not aspire to a viable alternative infrastructure or new form of cultural organization, but this isn't because they have poor taste. They aspire to participate in the structures that exist already, or to build their own structures that are very similar, but have them in charge. This isn't their failing, it is their motivation—what makes their actions comprehensible. In the case of geolocation, Wi-Fi experimentation was a route for many technology amateurs to professionalize. Experiments with wireless systems, treasure hunts, and amateur collectives became items on the resumes of many who later went into some aspect of the information technology industry (if they didn't start there in the first place). Before Wi-Fi became widespread, wireless network engineering was not a common job classification and did not have a career path. When young wireless experimenters reminisce about their successes, they say things like, "it got us some consulting work," "I do consulting for [wireless] companies now," "it got him a job in Milwaukee in the end," "we split that off into a private company," "it attracted attention for my business," "it got you and me a skill set, which got us pretty nice jobs," and "now we have a business plan."[58] Studies of early technology experimenters across history have shown that technology tinkering can be an excellent route to becoming an insider.[59] But for this strategy to work, the tinkerer can't be that far from an insider in the first place.

Production Values: A Permanent Gulf

A meaningful confusion may still be lingering after the examples of wireless and Doritos. Above, Yahoo! Video and YouTube users were able to ape major advertising agencies using only desktop equipment, and wireless amateurs of the present were sometimes depicted conducting essentially the same activities as well-financed corporations (such as the assembly of national Wi-Fi databases). Is this, then, what is new about digital media—that producers with so few resources are able to perform the same way as well-funded institutions? Unfortunately not: recall that radio amateurs in the past also performed these feats, and better. They were able to provide both transcontinental and transatlantic message service. It is not new that poorly financed contributors can have a role in new technology or content development or that barriers to entry are low in some technological areas. The presence of user-driven innovation and peer production now does not particularly indicate that a transformation is underway. For the earlier writing about convergence, it was an error of reasoning to think that the benefits of digital convergence would accrue only to producers and corporations, and not to users. But it is another sort of error to think that this implies that the differential in resources between producers and corporations no longer matters. In media industries, production values have historically been the route to enforcing the boundary between professional and amateur content. In the United States, most people have been able to record their own music (or even their own television show) for some time and distribute it themselves, or air it on a local radio station or public access station. Still, there is an ever-evolving professional "sound" and a "look" that are difficult to emulate. Just as the style of one genre becomes widely imitable (as in the thirty-second Doritos television commercial), other forms slide farther out of reach as studios develop and invest in new technologies for lighting, editing, and computer-generated animation. Today, it may be easy to make your own Web page, but it is difficult to make a database-driven, Flash-enhanced, interactive site that looks the same as one produced by a large media corporation. The effects achieved by professional media industries are designed to look expensive and to be expensive in order to police this boundary. This may be one reason that the user interface has presented such an obstacle to open-source software development. By far the most successful open source products are server side and have little user interface and therefore little need for a look-and-feel that competes with Microsoft or Apple.

To scale the wall of production value and try to produce something that will be an entrée into professionalization, the amateur will face a number of daunting obstacles. Whether the vehicle is writing, photographs, film, or software, to even make an attempt requires literacy and entails a large investment in education. Worse, all of these objects contain cultural markers that do more than separate professional production values from amateur ones; they also reinforce the dominant conceptualization of the audience or the user. These range from male terminology in computing to the dominance of affluent perspectives in fiction writing.

Waiting for a Transformation, or Working for It

All this means that the people puzzling over interesting stories of peer production and unexpected innovation in digital media may not have discovered the route to any sort of revolution. Wanting a decentralized emancipatory technology badly enough may suffice for seeing one. This desire to build or find the "machine in the garden" (the American pastoral ideal resurgent, the preference for the diffuse over the centralized) is a powerful and

alluring current in Western thought.[60] But taking von Hippel's earlier point seriously, *most* innovation may be user-driven. The innovator's garage, basement, and even youth may be completely normal. Peer production of content or infrastructure is then emphatically not a crack in the armor of an evil monolith, or a shift in power relations, but a more ordinary point of entry and commodification. A&R may be the new R&D, but the A&R department isn't run by artists, and any artist who has dealt with one will tell you that A&R's ascendancy doesn't mean that the talent will be getting a better deal anytime soon.

Reflect, for a moment, on the evolution of the newspaper as a capsule version of the other technological accounts developed in this chapter. While the newspaper has been written about as the epitome of the one-to-many, "mass" media form, the earliest newspapers in America were printed with blank pages at the end so that the readers could write in their own content. It is extravagant to think this affordance as "peer production" or as a way to redistribute the power of the press. Instead, it seems born of the material conditions of the newspapers of the day. They were infrequent, rare, expensive, and they tended to circulate through many hands and many sets of eyes. Indeed, before 1830, the American newspaper had no paid reporters (there was yet no profession of reporter), and instead relied upon the publisher's own writing and contributed letters. Again, it is too much to think that printing these letters was a democratic gesture (they usually came from the publisher's friends, and they were one more thing the publisher didn't have to write).[61] Today, nonprofessionals still have a means of entry into the pages of a newspaper: the "letters to the editor" section. Although they are often studied by journalism professors, letters to the editor have not been found to be a significant source of power to anyone. They may have the least power to influence the development of the communication technology that carries them (the newspaper). Indeed, professional journalists almost uniformly hold letter writers in contempt, and implement the letters' section in ways that are actively antidemocratic.[62] Even the accessibility of the technology of print itself is confusingly open to interpretation. While in democratic theory the press has been described as open to "anyone," it still requires literacy, technological expertise, cultural capital, and (for publishers, not letterwriters) it has been expensive. For much of its history, the American newspaper has been a discussion vehicle for affluent white men. The newspaper is surely not a perfect comparison to wireless, the internet, or digital media, but it does serve to highlight the longstanding history of user-contributed content and some of its complications. In secondary school civics classes, teenagers can start their own (small, badly financed) newspapers and contribute letters to existing newspapers, but this is stiflingly mainstream and not a transformative new practice with communication technology. It is no surprise that both scholars and teenagers themselves prefer to talk about the potential of *Second Life*.

This chapter has tried to portray the linkage of play, young people, and innovation in digital media as ordinary and not transformative. It has tried to replace the popular accounts of "young rebels" who seek to overturn the established order with a portrait of the usual suspects (i.e., well-educated, white, male innovators; nerds; literate and skilled content producers) who are looking for a warm place inside the establishment. In this effort, wireless has been a particularly useful case study, as the parallels across history are unusually apt. They demonstrate that subcultures of innovators and ease of entry into technological and content production are old features of media, not new ones. Today does feature the advantage of digital formats, widespread access to rich sets of digital data, and cheaper communication than ever before. Since great feats of amateur innovation were already possible without these advantages, it is not clear that these features are transformative. One might not even find

them particularly encouraging when reminded that "amateur innovator" or "amateur content producer" is itself a privileged and difficult-to-obtain position depending upon literacy, other knowledge, social networks, class, race, and lifestyle. This is then the call for action for those who care about the democratic potential of decentralized production. Rather than wait for the technological changes to unfold, this analysis requires us to figure out why each instance of technological transformation from the 1920s to the 2000s never satisfies. "Participatory culture" will only move beyond the elite if the desire for decentralized control and widespread participation can animate changes in our society's fundamental structures of opportunity.

Notes

1. For a popular history of Napster, see Joseph Menn, *All the Rave: The Rise and Fall of Shawn Fanning's Napster* (New York: Crown Business, 2003).

2. Daniel Pemberton, Bedroom to Big Time, *Wired* 5, no. 6 (1997). http://www.wired.com/wired/archive/5.06/white_town.html.

3. lessig blog, The Read-Write Internet, 2006, http://www.lessig.org/blog/archives/003295.shtml.

4. James W. Carey, Historical Pragmatism and the Internet, *New Media & Society* 7 (2005): 443–455.

5. Milton L. Mueller, Digital Convergence and its Consequences, *Javnost/The Public* 6, no. 3 (1999): 11–27. http://dcc.syr.edu/rp1.pdf.

6. Dwayne Winseck, Back to the Future: Telecommunications, Online Information Services and Convergence from 1840–1910, *Media History* 5, no. 2 (1999): 137–157.

7. Yochai Benkler, *The Wealth of Networks: How Social Production Transforms Markets and Freedom* (New Haven, CT: Yale University Press, 2006).

8. For example, Ted Nelson's famous quote, "The purpose of computers is human freedom." See Theodore H. Nelson, *Computer Lib/Dream Machines* (Hugo's Book Service: Chicago, IL, 1974) and http://xanadu.com.au/ted/TN/WRITINGS/TCOMPARADIGM/tedCompOneLiners.html; For a review, see Fred Turner, *From Counterculture to Cyberculture* (Chicago: University of Chicago Press, 2006).

9. François Bar and Christian Sandvig, US Communication Policy after Convergence, Media, Culture & Society (in press).

10. Lawrence Lessig, *Free Culture* (New York: Penguin, 2004).

11. Steven Weber, *The Success of Open Source* (Cambridge, MA: Harvard University Press, 2004).

12. Martin Campbell-Kelly and William Aspray, *Computer: A History of the Information Machine* (New York: Basic Books, 1996).

13. Daniel Miller, Don Slater, and Lucy Suchman, Anthropology, in *The Academy and the Internet*, eds. Monroe E. Price and Helen F. Nissenbaum (New York: Peter Lang, 2004), 84–105.

14. Eric von Hippel, *The Sources of Innovation* (Oxford, UK: Oxford University Press, 1988). See also the literature on "Learning by Using," in *Inside the Black Box: Technology and Economics,* ed. Nathan Rosenberg (Cambridge, UK: Cambridge University Press, 1983).

15. Nathan Ensmenger, Letting the "Computer Boys" Take Over: Technology and the Politics of Organizational Transformation, *International Review of Social History* 48, no. 11 (2003): 154.

16. Frederick P. Brooks, *The Mythical Man-Month: Essays on Software Engineering*, 20th anniversary ed. (New York: Addison-Wesley Professional, 1995).

17. Sherry Turkle, *The Second Self: Computers and the Human Spirit*, reprint ed. (New York: Touchstone, 1985).

18. Tim Berners-Lee is credited with inventing the World Wide Web. Bram Cohen designed BitTorrent, the peer-to-peer file sharing system optimized to handle large files.

19. Examples of fiction in this genre include Po Bronson, *The First $20 Million is Always the Hardest. A Silicon Valley Novel* (New York: Random House, 1997), while trade press nonfiction summaries include Jerry Kaplan, *Startup: A Silicon Valley Adventure Story* (New York: Houghton Mifflin, 1995).

20. That is, programmers like Bram Cohen (designer of the peer-to-peer file sharing system *BitTorrent*) can be distinguished from Fanning and Newmark by their exact position of production—Cohen worked at a series of related start-up companies that were trying to commercialize peer-to-peer file sharing software before starting his own. Fanning and Newmark developed new applications as a creative experiment, and only later realized that their innovations had value.

21. For example, Erik Barnouw, *A Tower of Babel: A History of Broadcasting in the United States to 1933,* vol. 1 (New York: Oxford University Press, 1966); Clinton B. Desoto, *200 Meters & Down: The Story of Amateur Radio* (New York: American Radio Relay League, 1985); Susan J. Douglas, *Inventing American Broadcasting, 1899–1922* (Baltimore, MD: Johns Hopkins University Press, 1989); Susan J. Douglas, *Listening In: Radio and the American Imagination* (Minneapolis: University of Minnesota Press, 2004); Robert W. McChesney, *Telecommunications, Mass Media, and Democracy: The Battle for Control of U.S. Broadcasting, 1928–1935* (New York: Oxford University Press, 1995); Kristen Haring, The "Freer Men" of Ham Radio: How a Technical Hobby Provided Social and Spatial Distance. *Technology and Culture* 4 (2003): 734–761.

22. The National Academy of Sciences, The Global Positioning System: The Role of Atomic Clocks, *Beyond Discovery: The Path from Research to Human Benefit* (1997). http://www.beyonddiscovery.org/content/view.article.asp?a=458.

23. For a definition, see Bernward Joerges, Large Technical Systems: Concepts and Issues, in *The Development of Large Technical Systems*, eds. Thomas P. Hughes and Renate Mayntz (Boulder, CO: Westview Press, 1988), 9–36. For other examples, see Thomas P. Hughes, *Rescuing Prometheus: Four Monumental Projects That Changed the Modern World* (New York: Pantheon, 1998).

24. Several products combine GPS and software-only positioning. Ventures include Skyhook Wireless, ekahau, Navizon, and Microsoft Research's WiFi Positioning.

25. It is likely that this is not true. Still, software-only positioning offers more precision than GPS in urban areas.

26. Christian Sandvig, An Initial Assessment of Cooperative Action in Wi-Fi Networking, *Telecommunications Policy* 28, nos. 7, 8 (2004): 579–602.

27. See http://tv.seattlewireless.net/november/november2003.html.

28. See "best SSIDs you have seen" at http://www.broadbandreports.com/forum/remark,12349735~mode=flat.

29. See WiGLE at http://www.wigle.net/.

30. See http://www.worldwidewardrive.org/ and http://wardriving.meetup.com/about/.

31. See "Treasure Hunt Wi-Fi Style in Aukland" at http://nzwireless.org/content-3.html and "Use Wi-Fi to Play Access Point Games" at http://www.extremetech.com/article2/0,1697,1746269,00.asp.

32. Simon Byers and Dave Kormann, 802.11b access point mapping, *Communications of the ACM* 46, no. 5 (2003): 41–46.

33. Or perhaps a "global" map—these maps have holes where wardrivers do not go.

34. See http://www.chroniclesofawardriver.org/?p=285.

35. Janet Abbate, *Inventing the Internet* (Cambridge, MA: MIT Press, 1999); Hughes, *Rescuing Prometheus: Four Monumental Projects That Changed the Modern World*, 1998; Thomas P. Hughes, The Organization of Federal Support: A Historical Review, in *Funding a Revolution: Government Support for Computing Research,* ed. Thomas P. Hughes (Washington, DC: National Academy Press, 1999), Ch. 4.

36. Paul N. Edwards, *The Closed World: Computers and the Politics of Discourse in Cold War America* (Cambridge, MA: MIT Press, 1996).

37. Tim Lenoir, All But War is Simulation: The Military-Entertainment Complex, *Configurations* 8, no. 3 (2000): 289–335; Tim Lenoir, Programming Theaters of War: Gamemakers as Soldiers, in *Bombs and Bandwidth: The Emerging Relationship between IT and Security,* ed. Robert Latham (New York: New Press, 2003).

38. Thomas Streeter, "That Deep Romantic Chasm": Libertarianism, Neoliberalism, and the Computer Culture, in *Communication, Citizenship, and Social Policy: Re-Thinking the Limits of the Welfare State*, eds. Andrew Calabrese and Jean-Claude Burgelman (New York: Rowman and Littlefield, 1999). See also Thomas Streeter, The Romantic Self and the Politics of Internet Commercialization, *Cultural Studies* 17, no. 5 (2003).

39. Max Horkheimer and Theodor W. Adorno, *Dialectic of Enlightenment*, trans. J. Cumming (New York: Herder and Herder, 1944/1972).

40. Carolyn Marvin, *When Old Technologies Were New: Thinking about Electric Communication in the Late Nineteenth Century* (New York: Oxford University Press, 1988); Douglas, *Inventing American Broadcasting, 1899–1922*.

41. For other discussions of radio amateurism and alternative radio, see Desoto, *200 Meters & Down* and Jesse Walker, *Rebels on the Air: An Alternative History of Radio in America,* rev. ed. (New York: New York University Press, 2004).

42. Douglas, *Inventing American Broadcasting, 1899–1922*, 189.

43. Ibid., 191.

44. This only alludes to the large literature in feminist technology studies and anthropology linking the "technical" to the masculine.

45. Ibid., 191.

46. Raymond Williams, *Television* (London: Fontana, 1974), 18–19.

47. Radio amateurs, for instance, collect specific signals by gathering QSL cards (a paper version of the code QSL, meaning, "I confirm receipt of your transmission"). For more detail, see Danny Gregory and Paul Sahre, *Hello World: A Life in Ham Radio* (Princeton, NJ: Princeton Architectural Press, 2003).

48. William H. Kirwan, The Washington's Birthday Amateur Radio Relay, *The Electrical Experimenter* 64 (1916): 24–25.

49. Ibid., 24.

50. This sentiment has been made most clear by Actor-Network Theory in technology studies; see Bruno Latour, *Reassembling the Social: An Introduction to Actor-Network Theory* (New York: Oxford University Press, 2005).

51. Brian Sutton-Smith, *The Ambiguity of Play* (Cambridge, MA: Harvard University Press, 1997), 129.

52. Eric von Hippel, *Democratizing Innovation* (Cambridge, MA: MIT Press, 2005), 99.

53. See Eric von Hippel and Georg von Krogh, Free Revealing and the Private-Collective Model for Innovation Incentives, *R&D Management* 36, no. 3 (2006): 295–306. An earlier historical moment when "free revealing" became an important strategy is the emergence of open scientific research—this also coincided with major changes in communication technology, see Paul A. David, Common Agency Contracting and the Emergence of "Open Science" Institutions, *The American Economic Review* 88, no. 2 (1998): 15–21.

54. "[W]e need to confront the cultural factors that diminish the likelihood that different groups will participate. Race, class, [and] language differences amplify . . . inequalities in opportunities for participation." See Henry Jenkins, *Convergence Culture: Where Old and New Media Collide* (New York: New York University Press, 2006), 258.

55. This is a large literature, but for an introduction specifically focused on communication technologies, see François Bar and Annemarie Munk Riis, Tapping User-Driven Innovation: A New Rationale for Universal Service, *The Information Society* 16, no. 1 (2000): 1–10.

56. See Bardini and Bardini and Horvath (1998). Bardini and Horvath define the "reflexive user" as ". . . the conceptual user resulting from the thought process of the designer anticipating the potential use of his or her design. This anticipation is made possible by a set of representations understood both as cognitive practices creating an image of the user (a mental representation), and as political practices, a sketch of a strategic plan aimed at allowing the designer to speak and act in place of this user-to-be." (Thierry Bardini and August T. Horvath, The Social Construction of the Personal Computer User, *Journal of Communication* 45, no. 3 (1995): 41).

57. Jaron Lanier, Digital Maoism: The Hazards of the New Online Collectivism, *Edge 183* (2006), http://www.edge.org/3rd_culture/lanier06/lanier06_index.html.

58. These quotes are taken from interviews with wireless entrepreneurs and experimenters taken from 2003–2007 for a related research project.

59. For the most comprehensive discussion of this phenomenon in communication technology, see Marvin, 1988.

60. Leo Marx, *The Machine in the Garden: Technology and the Pastoral Ideal in America* (New York: Oxford University Press, 1964).

61. For a discussion of the evolution of reporting and newspapers, see Michael Schudson, *Discovering the News: A Social History of American Newspapers* (New York: Basic Books, 1980).

62. See Karin Wahl-Jorgensen, The Construction of the Public in Letters to the Editor: Deliberative Democracy and the Idiom of Insanity, *Journalism* 3, no. 2 (2002): 183–204. Although the inclusion of letters from the public might be seen to be a democratic impulse, letters sections are used within newspapers to actively deride the public and to portray them in sensational and unrealistic ways, "allowing them to be dismissed as crazy and irrational" (p. 200).

Wireless Projection over Miracast offers several benefits: A simple connection experience that allows a user to find and connect to Miracast receivers. Implementation of the Miracast standard to ensure interoperability with hundreds of millions of Miracast devices. A native RTSP stack fine-tuned to work for Miracast, requiring no additional software is required outside the Windows 10 OS. Support for UIBC (User Input Back Channel), which allows inputs from the Miracast receiver (touch, stylus, mouse, keyboard and gamepad) to control the Miracast sender, if---and only if---the user explicitly al Today's wireless device is the sleek mobile phone nestling in your pocket. In coming years wireless will vanish entirely from view, as communications chips are embedded in a host of everyday objects. Such chips, and the networks that link them together, could yet prove to be the most potent wireless of them all. Just as microprocessors have been built into everything in the past few decades, so wireless communications will become part of objects big and small. The possibilities are legion. Gizmos and gadgets will talk to other devices--and be serviced and upgraded from afar. Sensors on bu Fifth-generation wireless will bring faster, more reliable connections and make the Internet of Things possible. When will 5G be available?Â What advantages will 5G offer? Each new generation of wireless technology has brought faster, more reliable cellular and internet connections. In the 1980's, first-generation technology made communication via cellphone possible. The next generation, 2G, allowed for more efficient and secure phone calls , and introduced mobile text messaging. 3G ushered in the smartphone era, and 4G/LTE gave us the high-speed connections that make it possible to stream high-definition video on our phones. Recommended.