A readable, articulate and persuasive account of why the Internet's most powerful impacts on the shape of business, politics and society may be yet to come. Castells ... is the nearest thing the Internet has to a founding philosopher. ... One of Castells' great strengths is his ability to combine academic rigour with an appetite to engage with current social and economic trends. He brings to this task an impressive array of knowledge about cities, labour markets, business history and technology. As a result his writing combines a sense of excitement and energy, with the sage judgment needed to resist glib simplifications and address the complex factors driving the Internet.' Financial Times

'[An] excellent, readable, nontechnical summary of the history, social implications and likely future of Internet business.' Publishers Weekly

'A compelling analysis of the influence of the Internet, considering topics as diverse as individual communication and freedoms, the new dynamics of social movements, business networks in the new economy, and geographic development patterns such as metropolisation and digital divide ... Castells addresses the network society from a rich set of perspectives, taking into account both social and economic theory.'
Erkki Liikanen, European Commissioner for Enterprise and Information Society

'Among technology's intelligentsia Castells has quickly earned a reputation as a pioneer, someone who has hacked out a logical, well-documented, and coherent picture of early 21st century civilization, even as it rockets forward largely in a blur.' The Christian Science Monitor

'A superb guide to the workings of the Internet and its wider implications. ... [Castells] brings a sociologist's understanding of the importance of culture in business to his analysis of the Internet. ... stands supreme as a wise and insightful guide to the web.' Management Today

'The Internet is shaping society and in turn being shaped by society. It takes a scholar of Manuel Castells's range to do justice to this phenomenon. His book is learned without being pompous, and insightful without being impenetrable. If we ever get a discipline of Internet studies, this will be one of its founding texts.'

John Naughton, author of A Brief History of the Future; The Origins of the Internet

'Manuel Castells has proved once again that he has an unmatched synoptic capacity to make sense of the complexities of a networked world, and here writes with clarity and insight about everything from the history of the technology to the subcultures that have done so much to shape it.'

Geoff Mulgan, author of Communication and Control and Connexity; Head of the Prime Minister's Forward Strategy Unit, Number 10, Downing Street

'Thoroughly researched ... [and] truly global in scope. Castells provides balanced coverage of e-business and the new economy; the politics of the Internet, including privacy and freedom; and the geography of the Internet. ... Highly recommended for academic libraries.' Library Journal

THE
INTERNET
GALAXY

Reflections on the Internet, Business, and Society

Manuel Castells

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Chapter 1

Lessons from the History of the Internet

The story of the creation and development of the Internet is one of an extraordinary human adventure. It highlights people's capacity to transcend institutional goals, overcome bureaucratic barriers, and subvert established values in the process of ushering in a new world. It also lends support to the view that cooperation and freedom of information may be more conducive to innovation than competition and proprietary rights. I shall not recount this saga, since there are several good chronicles available to the reader (Abbate, 1999; Naughton, 1999). Instead, I will focus on what seem to be the critical lessons we can distill from the processes that led to the formation of the Internet, from the building of the ARPANET in the 1960s to the explosion of the world wide web in the 1990s. Indeed, the historical production of a given technology shapes its content and uses in ways that last beyond its original inception, and the Internet is no exception to this rule. The history of the Internet helps us to understand the paths of its future history-making. However, before embarking on interpretation, to simplify the reader's task, I will summarize the main events that led
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to the constitution of the Internet in its current form; that is, as a global network of computer networks made user-friendly by the world wide web, an application running on top of the Internet.


The origins of the Internet are to be found in ARPANET, a computer network set up by the Advanced Research Projects Agency (ARPA) in September 1969. ARPA was formed in 1958 by the Defense Department of the United States with the task of mobilizing research resources, particularly from the university world, toward building technological military superiority over the Soviet Union in the wake of the launching of the first Sputnik in 1957. ARPANET was only a minor program emerging from one of ARPA’s departments, the Information Processing Techniques Office (IPTO), established in 1962 on the basis of a pre-existing unit. The aim of this department, as defined by its first director, Joseph Licklider, a psychologist turned computer scientist at the Massachusetts Institute of Technology (MIT), was to stimulate research in interactive computing. As part of this effort, the building of ARPANET was justified as a way of sharing computing time on-line between various computer centers and research groups working for the agency.

To build an interactive computer network, IPTO relied on a revolutionary telecommunications transmission technology, packet switching, developed independently by Paul Baran at Rand Corporation (a Californian think-tank often working for the Pentagon) and by Donald Davies at the British National Physical Laboratory. Baran’s design of a decentralized, flexible communication network was a proposal from the Rand Corporation to the Defense Department to build a military communications system able to survive a nuclear attack, although this was never the goal behind the development of ARPANET. IPTO used this packet-switching technology in the design of ARPANET. The first nodes of the network in 1969 were at the University of California, Los Angeles, SRI (Stanford Research Institute), the University of California, Santa Barbara, and the University of Utah. In 1971, there were fifteen nodes, most of them university research centers. The design of ARPANET was implemented by Bolt, Beranek and Newman (BBN), a Boston engineering acoustics firm converted into applied computer science, which was founded by MIT professors, and usually staffed by MIT and Harvard scientists and engineers. In 1972, the first successful demonstration of ARPANET took place at an international conference in Washington, DC.

The next step was to make ARPANET’s connection with other computer networks possible, starting with the communication networks that ARPA was managing, PRNET and SATNET. This introduced a new concept: a network of networks. In 1973, two computer scientists, Robert Kahn, from ARPA, and Vint Cerf, then at Stanford University, wrote a paper outlining the basic Internet architecture. They built on the efforts of the Network Working Group, a cooperative technical group formed in the 1960s by representatives from the various computer centers linked by ARPANET, including Cerf himself, Steve Crocker, and Jon Postel, among others. For computer networks to talk to each other they needed standardized communication protocols. This was partly accomplished in 1973, at a Stanford seminar, by a group led by Cerf, Gerard Lelann (from the French Cyclades research group), and Robert Metcalfe (then at Xerox PARC), with the design of the transmission control protocol (TCP). In 1978 Cerf, Postel, and Crocker, working at the University of Southern California, split TCP into two parts, adding an inter-network protocol (IP), yielding the TCP/IP protocol, the standard on which the Internet still operates today. However, ARPANET continued for some time to operate on a different protocol, NCP.

In 1975, ARPANET was transferred to the Defense Communication Agency (DCA). In order to make computer communication available to different branches of the armed forces, the DCA decided to create a connection between various networks under its control. It established a Defense Data Network, operating on TCP/IP protocols. In 1983 the Defense Department, concerned about possible security breaches, decided to create a separate MILNET network for specific military uses. ARPANET became ARPA-INTERNET.
and was dedicated to research. In 1984, the US National Science Foundation (NSF) set up its own computer communications network, NSFNET, and in 1988 it started using ARPA-INTERNET as its backbone.

In February 1990 ARPANET, technologically obsolete, was decommissioned. Thereafter, having released the Internet from its military environment, the US government charged the National Science Foundation with its management. But NSF’s control of the Net was short-lived. With computer networking technology in the public domain, and telecommunications in full deregulation, NSF quickly proceeded with the privatization of the Internet. The Defense Department had decided earlier to commercialize Internet technology, financing US computer manufacturers to include TCP/IP in their protocols in the 1980s. By 1990 most computers in America had networking capabilities, laying the ground for the diffusion of inter-networking. In 1995 NSFNET was shut down, opening the way for the private operation of the Internet.

In the early 1990s a number of Internet service providers built their own networks and set up their own gateways on a commercial basis. Thereafter, the Internet grew rapidly as a global network of computer networks. This was made possible by the original design of ARPANET, based on a multi-layered, decentralized architecture, and open communication protocols. Under these conditions the Net was able to expand by the addition of new nodes and endless reconfiguration of the network to accommodate communication needs.

Nonetheless, ARPANET was not the only source of the Internet as we know it today. The current shape of the Internet is also the outcome of a grassroots tradition of computer networking. One component of this tradition was the bulletin board systems (BBS) movement that sprung from the networking of PCs in the late 1970s. In 1977, two Chicago students, Ward Christensen and Randy Suess, wrote a program, which they called MODEM, enabling the transfer of files between their PCs, and in 1978 another program, the Computer Bulletin Board System, which made it possible for PCs to store and transmit messages. They released both programs into the public domain. In 1983, Tom Jennings, a programmer, then working in California, created his own BBS program, FIDO, and started a network of BBSs, FIDONET. FIDONET is still the cheapest, most accessible computer communication network in the world, relying on PCs and calls over standard telephone lines. In 2000, it comprised over 40,000 nodes and about 3 million users. Although this represented only a tiny fraction of total Internet use, the practice of BBSs and the culture exemplified by FIDONET were influential factors in the configuration of the global Internet.

In 1981, Ira Fuchs, at the City University of New York, and Greydon Freeman, of Yale University, started an experimental network on the basis of IBM RJE protocol, thus building a network for IBM users, mainly university based, which came to be known as BITNET (“Because it’s there,” referring to the IBM slogan; it also stood for “Because it’s time”). When IBM stopped funding in 1986, users’ fees supported the network. It still lists 30,000 active nodes.

A decisive trend in computer networking emerged from the community of UNIX users. UNIX is an operating system developed at Bell Laboratories, and released by Bell to the universities in 1974, including its source code and permission to alter the source. UNIX became the lingua franca of most computer science departments, and students soon became adept at its manipulation. Then, in 1978 Bell distributed its UUCP program (UNIX-to-UNIX copy) allowing computers to copy files from each other. On the basis of UUCP, in 1979, four students in North Carolina (Truscott, Ellis, Bellavin, and Rockwell) designed a program for communication between UNIX computers. An improved version of this program was distributed freely at a UNIX users’ conference in 1980. This allowed the formation of computer communication networks. Usenet News, outside the ARPANET backbone, thus considerably broadening the practice of computer communication.

In the summer of 1980 Usenet News reached the computer science department of the University of California, Berkeley, where there was a brilliant group of graduate students (including Mark Horton and Bill Joy) working on adaptations and applications of UNIX. As Berkeley was an ARPANET node, this group of students developed a program to bridge the two networks. From then on, Usenet became linked to ARPANET, the two traditions gradually
merged, and various computer networks became able to communicate with each other, often sharing the same backbone (courtesy of a university). These networks eventually came together as the Internet.

Another major development resulting from the UNIX users’ tradition was the “open source movement”—a deliberate attempt to keep access to all information about software systems open. I shall analyze in more detail, in Chapter 2, the open source movement, and the hackers’ culture, as essential trends in the social and technical shaping of the Internet. But I need to refer briefly to it in this summary account of the sequence of events that led to the formation of the Internet. In 1984, a programmer at MIT’s Artificial Intelligence Laboratory, Richard Stallman, reacting against the decision by ATT to claim proprietary rights to UNIX, launched the Free Software Foundation, proposing to substitute “copyleft” for copyright. By “copyleft” it is understood that anyone using software that had been made freely available should, in return, distribute over the Net the improved code. Stallman created an operating system, GNU, as an alternative to UNIX, and he posted it on the Net under a license that allowed its use on the condition of respecting the copyleft clause.

Putting this principle into practice, in 1991, Linus Torvalds, a 22-year-old student at the University of Helsinki, developed a new UNIX-based operating system, called Linux, and distributed it freely on the Internet, asking users to improve it and to post their improvements back on the Net. The result of this initiative was the development of a robust Linux operating system, constantly upgraded by the work of thousands of hackers and millions of users, to the point that Linux is now widely considered one of the most advanced operating systems in the world, particularly for Internet-based computing. Other groups of cooperative software development based on open source sprung from the UNIX users’ culture. Thus, in the year 2001, over 60 percent of world wide web servers in the world were running on Apache, which is an open source server program developed by a cooperative network of UNIX programmers.

What made it possible for the Internet to embrace the world at large was the development of the world wide web. This is an information-sharing application developed in 1990 by an English programmer, Tim Berners-Lee, working at CERN, the Geneva-based, European high-energy physics research center. Although he was not personally aware of it (Berners-Lee, 1999: 5), Berners-Lee’s work continued a long tradition of ideas and technical projects that, for the previous half-century, had imagined the possibility of linking up information sources via interactive computing. Vannevar Bush proposed his Memex system in 1945. Douglas Engelbart designed his On-Line System, including graphics interface and the mouse, working from his Augmentation Research Center in the San Francisco Bay area, and he first demonstrated it in 1968. Ted Nelson, a radical, independent thinker, envisioned a hypertext of interlinked information in his 1965 Computer Lib manifesto, and worked for many years on the creation of a utopian system, Xanadu: an open, self-evolving hypertext aimed at linking all the planet’s information, past, present, and future. Bill Atkinson, the author of the graphics interface of the Macintosh, developed a HyperCard system of interlinking information while working at Apple Computers in the 1980s.

But it was Berners-Lee who brought all these dreams into reality, building on the Enquire program he had written in 1980. Of course, his decisive advantage was that the Internet already existed, and he could find support on the Internet and rely on decentralized computer power via workstations: utopias could now materialize. He defined and implemented the software that made it possible to retrieve and contribute information from and to any computer connected via the Internet: HTTP, HTML, and URI (later called URL). In cooperation with Robert Cailliau, Berners-Lee built a browser/editor program in December 1990, and named this hypertext system the world wide web (www). The www browser software was released by CERN over the Net in August 1991. A number of hackers from around the world set themselves up to develop their own browsers, on the basis of Berners-Lee’s work. The first modified version was Erwise, developed at the Helsinki Institute of Technology in April 1992. Soon after, Viola, at the University of California, Berkeley, produced his own adaptation.
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The most product-oriented of these modified versions of www was Mosaic, designed by a student, Marc Andreessen, and a staff member, Eric Bina, at the University of Illinois's National Center for Supercomputer Applications. They incorporated into Mosaic an advanced graphics capability, so that images could be retrieved and distributed over the Internet, as well as a number of interface techniques imported from the multimedia world. They publicized their software on the Usenet in January 1993. Thereafter, Andreessen took a programming job in a small firm at Palo Alto. While there, he was contacted by a leading Silicon Valley entrepreneur, Jim Clark, who was leaving the company he had founded, Silicon Graphics, looking for new business adventures. He recruited Andreessen, Bina, and their co-workers to form a new company, Mosaic Communications, which was later compelled to change its name to Netscape Communications. The company posted on the Net the first commercial browser, Netscape Navigator, in October 1994, and shipped the first product on December 15, 1994. In 1995, they released Navigator software over the Net free for educational uses, and at a cost of 39 dollars for business.

After the success of Navigator, Microsoft finally discovered the Internet, and in 1995, together with its Windows 95 software, introduced its own browser, Internet Explorer, based on technology developed by a small company, Spyglass. Other commercial browsers were developed, such as Navipress, used by America On Line for a while. Furthermore, in 1995, Sun Microsystems designed Java, a programming language that allowed applications programs ("applets") to travel between computers over the Internet, so enabling computers to run programs downloaded from the Internet safely. Sun released Java software free on the Internet, expanding the realm of web applications, and Netscape included Java in its Navigator browser. In 1998, to counter Microsoft's competition, Netscape released over the Net the source code for Navigator.

Thus, by the mid-1990s, the Internet was privatized. Its technical, open architecture allowed the networking of all computer networks anywhere in the world, the world wide web could function on adequate software, and several user-friendly browsers were available to the public. While the Internet had begun in the minds of computer scientists in the early 1960s, a computer communication network had been established in 1969, and distributed computing, interactive communities of scientists and hackers had sprung up from the late 1970s, for most people, for business, and for society at large, the Internet was born in 1995. But it was born with the marks of a history whose analytically relevant features I shall now emphasize and interpret.

The Unlikely Formula: Big Science, Military Research, and the Culture of Freedom

First of all, the Internet was born at the unlikely intersection of big science, military research, and libertarian culture. Major research universities and defense-related think-tanks were essential meeting points between these three sources of the Internet. ARPA/NET originated in the US Defense Department, but its military applications were secondary to the project. IP TO's main concern was to fund computer science in the United States, letting scientists do their work, and hoping something interesting would come out of it. Baran's design was indeed a military-oriented proposal. It played an important role in the building of ARPANET because of its packet-switching technology, and because it inspired a communications architecture based on the three principles on which the Internet still operates today: a decentralized network structure; distributed computing power throughout the nodes of the network; and redundancy of functions in the network to minimize the risk of disconnection. These features embodied the key answer to military needs for survivability of the system: flexibility, absence of a command center, and maximum autonomy of each node.

While all this sounds very much like military strategy, the catch here is that Baran's proposal was rejected by the Pentagon, and no one ever tried to implement it. In fact, some sources suggest that ARPA did not know of Baran's 1964 publications on "distributed networks" until Roger Scantlebury, a British researcher who had been working on similar technologies, brought them to the
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attention of IPTO’s director at a symposium in Tennessee in October 1967 (Naughton, 1999: 129–31). Baran’s concepts were critical for the building of ARPANET, but this experimental network was built with a non-military purpose by the scientists working at and around ARPA (Abbate, 1999).

What their purpose was is in fact unclear, besides the general aim of developing computer networking. The explicit goal was to optimize the use of expensive computer resources by on-line time-sharing between computer centers. Yet, the cost of computing quickly came down, and time-sharing was no longer a major need. The most popular use of the network was electronic mail, an application first developed by Ray Tomlinson, a programmer at BBN, in July 1970. It is still the most widely used application on today’s Internet. What the evidence suggests is that IPTO was used by computer scientists at the cutting edge of a new field (computer networking) to fund computer science throughout the university research system, so that, in the 1960s and 1970s, most funding for computer science research in the United States came from ARPA (it was still the case in 2000).

A network of talented scientists and engineers (among them Joseph Licklider, Ivan Sutherland, Lawrence Roberts, Leonard Kleinrock, Robert Taylor, Alex McKenzie, Frank Heart, and Robert Kahn) was formed over time, then expanded with the help of a generation of outstanding young researchers, particularly Vinton Cerf, Stephen Crocker, and Jon Postel, students of Kleinrock at UCLA. The original nucleus of ARPANET designers came mainly from MIT, including one of MIT’s spin-off companies, BBN (initially working on acoustics), and from the Lincoln National Laboratory, a major military-oriented research facility in the shadow of MIT. Key members of the network (among others Roberts, Kleinrock, Heart, and Kahn) were graduates of MIT. But academics from other research universities also became part of this informal, yet exclusive club of computer scientists, particularly from UCLA, where Kleinrock, one of the leading theoreticians in the field, was teaching, as well as from Stanford, Harvard, the University of Utah, the University of California at Santa Barbara, and the University of California at Berkeley.

These researchers/designers circulated in and out of ARPA, research universities, and quasi-academic think-tanks, such as RAND, SRI, and BBN. They were protected by the visionary directors of IPTO, among whom were Joseph Licklider and Robert Taylor. IPTO enjoyed considerable freedom in managing and funding this network because the Defense Department had entrusted ARPA with autonomous judgment about how to stimulate technological research in key areas without suffocating creativity and independence, a strategy that eventually paid off in terms of superiority in military technology. But ARPANET was not one of these military technologies. It was an arcane, experimental project whose actual content was never fully understood by the overseeing congressional committees. Once ARPANET was set up, and new, younger recruits came to IPTO in the 1970s, there was a more focused, deliberate effort to create what would be the Internet. Kahn and Cerf clearly intended so, and designed an architecture, and the corresponding protocols, to allow the network to evolve as an open system of computer communication, able to reach out to the whole world.

So, ARPANET, the main source of what ultimately became the Internet, was not an unintended consequence of a research program going sideways. It was envisioned, deliberately designed, and subsequently managed by a determined group of computer scientists with a shared mission that had little to do with military strategy. It was rooted in a scientific dream to change the world through computer communication, although some of the participants in the group were content with just fostering good computer science. In accordance with the university research tradition, ARPANET’s creators involved graduate students in the core design functions of the network, in an atmosphere of totally relaxed security. This included the use of ARPANET for students’ personal chats and, reportedly, discussions about marijuana procurement opportunities. The most popular electronic mailing list in ARPANET was SF-Lovers for the use of science fiction fans. Furthermore, the transition to the civilian Internet, and then to its privatization, was managed by the National Science Foundation, with the cooperation of the academic community of computer scientists that had
developed over the years around IPTO. Many of these scientists ended up working for major corporations in the 1990s.

However, to say that ARPANET was not a military-oriented project does not mean that its Defense Department origins were inconsequential for the development of the Internet. For all the vision and all the competence these scientists displayed in their project, they could never have commanded the level of resources that was necessary to build a computer network and to design all the appropriate technologies. The Cold War provided a context in which there was strong public and government support to invest in cutting-edge science and technology, particularly after the challenge of the Soviet space program became a threat to US national security. In this sense, the Internet is not a special case in the history of technological innovation, a process usually associated with war: the scientific and engineering effort around World War II constituted the matrix for the technologies of the micro-electronics revolution, and the arms race during the Cold War facilitated their development.

The lucky part of the ARPANET story was that the Defense Department, in a rare instance of organizational intelligence, set up ARPA as a funding and guidance research agency with considerable autonomy. ARPA went on to become one of the most innovative technology policy institutions in the world, and in fact the key actor in US technology policy, not just around computer networking, but in a number of decisive fields of technological development. ARPA was staffed by academic scientists, their friends and their friends’ students, and was successful in building a network of reliable contacts in the university world, as well as in the research organizations that spun off from academia to work for the government. An understanding of how the research process works led ARPA to grant considerable autonomy to researchers contracted or funded by the agency, a necessary condition for truly innovative researchers to accept involvement in a project. ARPA’s hope was that, out of massive resources and scientific ingenuity, something good would happen from which the military (but also the US economy) could benefit.

It turned out to be the right strategy, even in military terms. In the 1980s, when it became clear that the US had achieved technological superiority in conventional warfare, particularly in electronics and communications, the Soviet Union’s strategy was reduced to the unthinkable option of a massive nuclear exchange. In fact, as I have argued in a joint study of the Soviet Union with Emma Kiselyova (Castells and Kiselyova, 1995), the realization of this technological inferiority was one of the main triggers for Gorbachev’s perestroika, ultimately leading to the disintegration of an apparently mighty empire. The Soviet Union had also anchored its science and technology system in its military complex. But, unlike the United States, Soviet science was largely trapped in the security apparatus, with its corollary of secrecy and performance-oriented projects, which ultimately undermined technological innovation in spite of the excellence of Soviet science. ARPA’s policy of flexibility and academic freedom paid off in terms of military strategy, while unleashing the creativity of US academics, and providing them with the resources to transform ideas into research, and research into workable technologies.

Once ARPANET became operational in 1975, it was transferred to the Defense Communication Agency, which started to use the network for military operations. Paradoxically, the importance of inter-networking for the armed forces favored the early adoption of the Internet protocols that laid the ground for their diffusion. The uneasy coexistence of military planners and academic researchers who were using the network set the stage for the separation of the network into MILNET (military) and ARPA-INTERNET (research) in 1983, and for the creation of NSFNET in 1984. In turn, as soon as a military-funded technology became available for civilian use, the Defense Department had a political interest in commercializing it, distributing it free, and actually subsidizing its adoption by US computer manufacturers. History cannot be re-written, but with our current script, without ARPA there would have been no ARPANET, and without ARPANET, the Internet as we know it today would not exist.

In Europe, packet-switching technology, computer communication, and transmission protocols were developed in public research centers, such as Britain’s National Physical Laboratory, or government-sponsored research programs, such as the French Cyclades.
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And while the design of the world wide web was the result of individual creativity and initiative (Berners-Lee was a staff member supposedly working on improving the documentation system at CERN, and not on inventing software), Berners-Lee’s and Cailliau’s work was made possible by the understanding, first, and the support, later, of a highly respected international public research institution, which just happened to be working on a completely different field of science (Berners-Lee, 1999; Gillies and Cailliau, 2000).

In sum, all the key technological developments that led to the Internet were built around government institutions, major universities, and research centers. The Internet did not originate in the business world. It was too daring a technology, too expensive a project, and too risky an initiative to be assumed by profit-oriented organizations. This was particularly true in the 1960s, at a time when major corporations were rather conservative in their industrial and financial strategies, and were not ready to risk funding and personnel in visionary technologies. The most blatant illustration of this statement is the fact that in 1972, Larry Roberts, the director of IPTO, sought to privatize ARPANET, once it was up and running. He offered to transfer operational responsibility to ATT. After considering the proposal, with the help of a committee of experts from Bell Laboratories, the company refused. ATT was too dependent on analog telephony to be ready to move to digital switching. And so, to the benefit of the world, a corporate monopoly missed the Internet. Even as late as 1990 when the US Office of Technology Assessment held a hearing on the NREN, no telephone company accepted an invitation to take part in it. One company explicitly said that it had no interest in this development (Steve Cisler, personal communication, 2001).

But if corporate business did not have much vision, neither did public companies. In another significant example, the British National Physical Laboratory (NPL) researchers built two computer networks, Mark I and Mark II, based on Davies’s packet-switching technology. Davies (appointed director of a research division of NPL in 1966) tried to convince the General Post Office to set up a national computer communications network. If implemented in the late 1960s it would have preceded ARPANET. Yet the Post Office showed little interest in computer communication, and when it finally ceded to the pressure of the business world to build a data transmission network in 1977, it used a system developed by Telenet, a US-firm based on ARPANET technology. Thus, British packet-switching technology never left NPL’s internal networks, and the development of the Internet in the UK had to wait for the global expansion of American computer networks.

What emerges from these accounts is that the Internet developed in a secure environment, provided by public resources and mission-oriented research, but an environment that did not stifle freedom of thinking and innovation. Business could not afford to take the long detour that would be needed to spur profitable applications from such an audacious scheme. On the other hand, when the military puts security above any other consideration, as happened in the Soviet Union, and could have happened in the US, creativity cannot survive. And when government, or public service corporations, follow their basic, bureaucratic instincts, as in the case of the British Post Office, adaptation takes precedence over innovation. It was in the twilight zone of the resource-rich, relatively free spaces created by ARPA, the universities, innovative think-tanks, and major research centers that the seeds of the Internet were sown.

The Internet and the Grassroots

These seeds germinated in a variety of forms. The culture of individual freedom sprouting in the university campuses of the 1960s and 1970s used computer networking to its own ends—in most cases seeking technological innovation for the pure joy of discovery. The universities themselves played a major role in their support of community networks. Examples of this university-grassroots connection were, among many others, Boulder, Colorado; Blacksburg Electronic Village; Cleveland FreeNet; Chetluc Suite in Halifax, Nova Scotia. Without the cultural and technological contribution of these early, grassrooted computer networks, the Internet would have looked very different, and probably would have not embraced
the whole world. At least, not so quickly. After all, Tim Berners-
Lee's idealistic approach to technology was not too far removed
from the agendas of cultural revolutionaries, such as Nelson
or Engelbart. The fast diffusion of computer communication
protocols would not have happened without the open, free distribution
of software and the cooperative use of resources that became the code
of conduct of the early hackers. The advent of the PC considerably
helped the spread of computer networking, as shown in the
global spread of FIDONET. But most networks required a backbone
anchored in more powerful machines, and this was only possible
because of the contact between science-based networks and student
hacker communities in the universities. Universities were the
common ground for the circulation of innovation between big
science's exclusive networks and the makeshift countercultural
networks that emerged in all kinds of formats. The two worlds were
different, but with more points of contact than people usually
think.

Graduate students played a decisive role in the design of
ARPANET. In the late 1960s, the Network Working Group, which
did most of the design of ARPANET's protocols, was composed
mainly of graduate students, including Cerf, Crocker, and Postel,
who studied together in the same secondary school in Southern
California, and then were students of Kleiman at UCLA. Feeling
insecure about their decisions, they communicated their work in
progress to BBN and other nodes of the IPTO's research network
through "request for comment" memos or RFCs, which provided
the style, and the name, for informal technical communication
in the Internet world up to our day. The openness of this format
was—and continues to be—essential for the development of the
Internet's infrastructure protocols. Most of these students were not
countercultural in the sense of the social movements' activists of
the time. Cerf certainly was not. They were too obsessed with their
extraordinary technological adventure to see much of the world
outside computers. They certainly did not see any problem in
having their research funded by the Pentagon or even in joining
ARPA (as Cerf did) in the midst of the Vietnam War. And yet they
were permeated with the values of individual freedom, of indepen-
dent thinking, and of sharing and cooperation with their peers, all
values that characterized the campus culture of the 1960s. While
the young ARPA Netters were not part of the counterculture, their
ideas, and their software, provided a natural bridge between the
world of big science and the broader student culture that sprang up
in the BBs and Usenet News network. This student culture took
up computer networking as a tool of free communication, and in
the case of its most political manifestations (Nelson, Jennings,
Stallman), as a tool of liberation, which, together with the PC,
would provide people with the power of information to free them-

The grassroots of the Internet, with their creation of autonomous
networks and conference systems, decisively influenced the de
telopment of commercial services in the 1980s, as business imitated
the communication systems created by alternative networks. On
the one hand, there were e-mail services developed by telecommu-
nications and computer companies (ATT, MCI, DEC and so on),
and wide area networks set up by major corporations for their
internal use. On the other hand, "on-line" services were offered by
companies such as Compuserve, America On Line (AOL), and
Prodigy. These services were not networked in their origin, but
they provided the ground on which Internet content providers
would later develop. These diverse uses of computer networking
did not develop from the ARPANet community but from the var-
iegated universe of alternative networks emerging from the
freedom culture.

The impact of autonomous networks was also decisive in the
global expansion of computer networking. The control of the US
government of ARPA-INTERNET was an obstacle to its connection
to the networks of other countries. UUCP-based networks became
global much earlier than the Internet, thus setting the stage for the
global Internet once networks were able to connect. After NSF
opened up NSFNET access to foreign networks, from 1990 to 1995
(when the Internet was privatized), the proportion of non-US net-
wvorks linked to the Internet doubled, from 20 to 40 percent of all
connected networks.
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An Architecture of Openness

From these diverse contributions emerged an Internet whose most distinctive feature was its openness, both in its technical architecture and in its social/institutional organization. Technically speaking, the flexibility of communication protocols allowed backbones such as ARPANET to connect to thousands of local area networks. The TCP architecture proposed by Cerf and Kahn in their seminal 1973 paper, “A Protocol for Packet Network Intercommunication,” published in 1974, and completed in 1978 with the IP protocol, provided standards compatible for different networking systems.

The openness of ARPANET’s architecture allowed the future Internet to survive its most daunting challenge in the process of becoming global: the difficult agreement on a common international standard. Telecommunication carriers and the post and telecommunications offices (PTTs) of major European governments supported a different communication standard, the x.25, which was approved in 1976 as the common international standard by the International Telecommunications Union. The x.25 protocols were not incompatible with TCP/IP, but because they had been designed separately they could not communicate. The debate was not purely technical. Under x.25 virtual circuits, the control and accountability of the network would be mainly in the hands of public network providers at the expense of private computer owners. This is why the European PTTs favored the option. On the other hand, ARPANET’s protocols were based on the diversity of networks. Furthermore, telecommunication carriers were reluctant to let private networks link up with their own networks. By the late 1970s, the PTTs were planning to organize computer data transmission in a series of separate, national public networks, connecting at their nation’s borders. Computer owners were expected to link up directly to the public network in their country, rather than set up their own private networks. In fact, Minitel, the French PTT telematic service provider, was based on this principle of a centralized, government-controlled, computer network. At the international level, CCITT (the relevant committee of the International Telecommunications Union) went on to assign network addresses to each country. The assumption was that computers would usually be connected to the public network, so the committee decided that most countries would not require more than ten network addresses, exceptionally two hundred for the United States. This logic was perfectly understandable in a world in which a few years earlier an IBM study had predicted that the world market for computers in the year 2000 would stabilize at about five computers, and in which, in 1977 (after the development of the personal computer), the chairman of DEC had declared that “there is no reason anyone would want a computer in their home.”

In the end, x.25 protocols were adopted by public telecommunication networks and some commercial networks, while ARPANET and most US private networks went on using TCP/IP. The International Organization for Standardization (ISO) intervened in the matter, and when it failed to conciliate different interests between various governments, and between computer manufacturers and telecommunications operators, it approved the principle of layering of protocols. The Open Systems Interconnection (OSI) protocol became the official international standard. However, unable to impose this standard, ISO continued to approve a multiplicity of protocols, including TCP and IP. Because ARPANET’s protocols had the flexibility to integrate different networking systems, while the other protocols could not do so, TCP/IP standards were able to accommodate x.25-based protocols, and ultimately prevailed as the common standards for the global Internet.

Self-evolution of the Internet: Shaping the Network by Using it

The openness of the Internet’s architecture was the source of its main strength: its self-evolving development, as users became producers of the technology, and shapers of the whole network. Since nodes could be easily added, the cost remained low (provided that a backbone was available), and the software was open and available; by the mid-1980s (after UUCP allowed the connection between
ARPANET and Usenet) everybody with technical knowledge could join the Internet. A flurry of never-planned applications resulted from this multiple contribution, from e-mail to bulletin boards and chat rooms, the MODEM, and, ultimately, the hypertext. No one told Tim Berners-Lee to design the world wide web, and in fact he had to conceal his true intent for a while since he was using the time of his research center for purposes other than his assigned job. But he could do it because he could rely on widespread support from the Internet community, as he posted his work, and was helped and stimulated by numerous hackers from around the world. True, some of these hackers went on to commercialize his ideas, and made a fortune, while Berners-Lee, by his own choice, continued to work in the public interest, lately as chairperson of the World Wide Web Consortium (W3C). But by behaving as a true hacker he earned the respect of his community of reference, and his place in history; as was the case with Ted Nelson, Douglas Engelbart, Richard Stallman, Linus Torvalds, and so many other, less famous, hackers and anonymous users.

It is a proven lesson from the history of technology that users are key producers of the technology, by adapting it to their uses and values, and ultimately transforming the technology itself, as Claude Fischer (1992) demonstrated in his history of the telephone. But there is something special in the case of the Internet. New uses of the technology, as well as the actual modifications introduced in the technology, are communicated back to the whole world, in real time. Thus, the timespan between the processes of learning by using and producing by using is extraordinarily shortened, with the result that we engage in a process of learning by producing, in a virtuous feedback between the diffusion of technology and its enhancement. This is why the Internet grew, and keeps growing, at unprecedented speed, not only in the number of its networks, but in the range of its applications. For this sequence to take place, three conditions are necessary: first, the networking architecture must be open-ended, decentralized, distributed, and multi-directional in its interactivity; secondly, all communication protocols and their implementations must be open, distributed, and susceptible of modification (although network manufacturers keep some of their software proprietary); thirdly, the institutions of governance of the network must be built in accordance with the principles of openness and cooperation that are embedded in the Internet. Having analyzed the historical production of the first two conditions, let me now turn to the third one. It is, in fact, a remarkable story.

**Governance of the Internet**

I am not addressing here the relationship between governments and the Internet, which I shall examine with care later in the book (Chapters 5 and 6). In this chapter I focus on the procedures to ensure communication and coordination functions in the network. This refers, essentially, to shared protocol development, agreements on standards, and assignments of Internet names and addresses. Once these matters are settled, the decentralized structure of the Internet takes care of the rest, as each host and each network establishes its own rules. But how coordination functions are assured was critical for the development of the network, and remains crucial for its expansion beyond any central control.

In the early stages, in the 1960s, ARPA assumed benevolent authority over the network, and the Network Working Group (NWG) produced the technical standards by consensus, on the basis of request for comment (RFC) documents. It set the tone for future coordination tasks in the Internet: membership based on technical expertise, consultation with the Internet community, consensus-based decision-making. NWG was disbanded in the 1970s, once ARPANET began operation. Its role was assumed, within ARPA, by an Internet program, run by Cerf and Kahn, which took responsibility for protocol development. They established an advisory group made up of networking experts: the Internet Configuration Control Board (ICCB) which encouraged the participation of the overall Internet community in improving the protocols. In 1984, Barry Leiner, ARPA's network program manager, decided to broaden this coordinating group, and set up an Internet Activities Board (IAB), chaired by another MIT com-
puter scientist, Dave Clark. This new board included the leading experts from the institutions that had created ARPANET, but reached out to other networking experts from anywhere in the world. Indeed, membership of the IAB was open, at least in principle, to anyone with the interest and technical knowledge, although I suspect that experts from the Soviet Academy of Sciences would not have been welcome at the time. In 1989, with membership of the IAB then in the hundreds, the board was split into two organizations, both built on the basis of open working groups: the Internet Engineering Task Force (IETF), focusing on protocol development and other technical matters, and the Internet Research Task Force (IRTF), specializing in long-range planning for the Internet. Working groups communicated by e-mail but also met several times a year. Agreements reached by the working groups were published as RFCs and became the Internet’s unofficial standards, in a cumulative, open process of cooperation. Later on, relevant US government agencies, such as the NSF, NASA, and the Department of Energy, followed the IETF in adopting the use of the Internet’s protocols. Through this channel, Internet protocols became the networking standards for the US government at large.

By 1992, however, the Internet was expanding on a global scale, and the NSF was planning its privatization. On both grounds it was necessary to move beyond the direct control of the US government. So, in January 1992, the Internet Society was formed, a nonprofit organization which was given oversight of both the IAB and the IETF. Cerf and Kahn, widely trusted by the Internet community for their technical knowledge and their record of commitment to openness and consensus-building, took charge of the Internet Society. Under their impulse, international participation in the coordination functions increased substantially during the 1990s. However, with the internationalization of the Internet, the ambiguous status of its institutions (ultimately under the supervision of the US government, yet exercising their autonomy on the basis of the fairness and prestige of the Internet’s founders) came under attack from other governments, particularly in Europe. Furthermore, the process of privatization unbalanced the delicate equilibrium that had for years characterized the assignment of domain names.

In one of the most stunning stories in the development of the Internet, the US government had delegated authority for Internet addresses to an organization, the Internet Assigned Numbers Authority (IANA), set up and managed single-handedly by one of the original designers of the Internet, Jon Postel, from the University of Southern California. Postel, a computer scientist of impeccable integrity, was probably the most respected member of the Internet’s scientific community. His management was widely recognized as fair, sensible, and neutral, so that for many years he acted as a global arbiter for the assignment of Internet domains, with remarkable results in terms of the relative stability and compatibility of the system. Yet Postel died in 1998 at the age of 55. The trust in one man could not be replaced by global trust in a US government institution.

In fact, the Clinton administration had proposed the privatization of IANA and of other overseeing institutions of the Internet since 1997. The last legacy of Jon Postel was his design for the privatized institution that he offered to the US government in September 1998, one month before his death. His proposed organization, the Internet Corporation for Assigned Names and Numbers (ICANN), was approved by the US government in late 1998, and completed its formative phase in 2000. Although its actual practice and organizational structure are still unfolding, its by-laws embody the spirit of openness of the Internet community, decentralization, consensus-building, and autonomy that characterized the ad hoc governance of the Internet over thirty years, while adding a global orientation to its membership, although its administration is headquartered in Marina del Rey, California. It is a non-profit, private corporation that assumes the management of IP address space allocation, protocol parameter assignment, domain name system management, and root server system management, all functions previously performed by IANA under contract from the US government.

ICANN has four components: one at-large membership, and three supporting organizations, which deal with the substantive
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issues of Internet coordination (address supporting organization, domain name supporting organization, and protocol supporting organization). Each one of these organizations is decentralized in a diversity of working groups linked electronically and by regular meetings. ICANN's governing body is a board of eighteen directors, three appointed by each of the supporting organizations, and nine elected by the at-large membership in a worldwide electronic voting process. Any individual with technical knowledge can apply for membership. By 2000, there were 158,000 at-large members and the first at-large election was held. The election was organized by nominations issued both by advisory committees and by support from local constituencies. Each of the five posts elected in 2000 was assigned to a different area of the world to ensure some kind of global representation.

The romantic vision of a global Internet community self-representing itself by electronic voting has to be tempered with the reality of lobbying, powerful support networks, and name recognition in favor of certain candidates. And there is no scarcity of articulate critics of ICANN's lack of true democracy. Indeed, in the 2000 election, only 35,000 of the 158,000 members participated in the vote. Among the directors elected there was a hacker, former member of the notorious German Computer Chaos Club, to the alarm of government representatives. Furthermore, the links between ICANN and the US Commerce Department have not really been severed. Governments around the world, and particularly European governments, are extremely critical of what they see as American dominance of ICANN. For instance, ICANN refused recognition of the ".eu" domain address, applicable to all companies and institutions from the European Union. For European Union representatives this was a most important trademark to denote European companies working within the institutional rules established in the European Union, for instance in the protection of privacy on the Internet. Thus, the contradiction between the historical roots of the Internet in America, and its increasingly global character, seems to point toward the eventual transformation of ICANN into a culturally broader institution.

Yet, in spite of all these conflicts and shortcomings, it is revealing that the emerging institutions of the Internet in the twenty-first century had to be established, in order to be legitimate, on the tradition of meritocratic consensus-building that characterized the origins of the Internet. A similar, consensus-based, non-mandatory, open (albeit, often for a significant fee), international organization presides over the protocols and development of the world wide web: the World Wide Web Consortium, anchored in the US by MIT, in Europe by the French Institute INRIA, and directed, most naturally, by Tim Berners-Lee, now the holder of an MIT chair.

Without prejudging the effectiveness of these new institutions, the truly surprising accomplishment is that the Internet reached this relative stability in its governance without succumbing either to the bureaucracy of the US government or to the chaos of a decentralized structure. That it did not was mainly the accomplishment of these gentlemen of technological innovation: Cerf, Kahn, Postel, Berners-Lee, and many others, who truly sought to maintain the openness of the network for their peers, as a way to learn and share. In this communitarian approach to technology, the meritocratic gentry met the utopian counterculture in the invention of the Internet, and in the preservation of the spirit of freedom that is at its source. The Internet is, above all else, a cultural creation.

Note

1. "Liberarian" has a different meaning in the European and in the American context. In Europe, it refers to a culture or ideology based on the uncompromising defense of individual freedom as the supreme value—often against the government, but sometimes with the help of governments, as in the protection of privacy. In the US context, "libertarian" is a political ideology that primarily means a systematic distrust of government, on the understanding that the market takes care of everything by itself, and that individuals take care of themselves. I use it in the European sense, as a culture of liberty, in the tradition of John Stuart Mill, without prejudging the tools by which liberty is achieved.
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Reading Links


e-Links


www.icann.com
www.election.com/us/icann

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www.ispo.cec.be/el/InternetPoliciesSite/DotEU/May2000/EN.html
Various sites concerning ICANN and the Internet governance debate.

www.isoc.org/
The site of the Internet Society, overseeing the development of the Internet.