**ARPANET**

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*For the producer, see Gerald Donald. For the seventh episode of the second season of the television series* The Americans*, see Arpanet (The Americans).*

See also: History of the Internet

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| **ARPANET** | |
| ARPANET logical map, March 1977 | |
| **Type** | data |
| **Location** | United States |
| **Protocols** | NCP, TCP/IP |
| **Established** | 1969 |
| **Current status** | evolved into NSFNET |
| **Commercial?** | No |
| **Funding** | Defense Advanced Research Project Agency (DARPA) |

The **Advanced Research Projects Agency Network** (**ARPANET**) was an early packet switching network and the first network to implement the protocol suite TCP/IP. Both technologies became the technical foundation of the Internet. ARPANET was initially funded by the Advanced Research Projects Agency (ARPA, later Defense Advanced Research Projects Agency (DARPA)) of the United States Department of Defense.

Packet switching was based on concepts and designs by Americans Leonard Kleinrock and Paul Baran, British scientist Donald Davies and Lawrence Roberts of the Lincoln Laboratory. The TCP/IP communication protocols were developed for ARPANET by computer scientists Robert Kahn and Vint Cerf, and incorporated concepts by Louis Pouzin for the French CYCLADES project.

**History**

Packet switching—today the dominant basis for data communications worldwide—was a new concept at the time of the conception of the ARPANET. Prior to the advent of packet switching, both voice and data communications had been based on the idea of circuit switching, as in the traditional telephone circuit, wherein each telephone call is allocated a dedicated, end to end, electronic connection between the two communicating stations. Such stations might be telephones or computers. The (temporarily) dedicated line is typically composed of many intermediary lines which are assembled into a chain that stretches all the way from the originating station to the destination station. With packet switching, a data system could use a single communication link to communicate with more than one machine by collecting data into datagrams and transmitting these as packets onto the attached network link, as soon as the link becomes idle. Thus, not only can the link be shared, much as a single post box can be used to post letters to different destinations, but each packet can be routed independently of other packets.

The earliest ideas for a computer network intended to allow general communications among computer users were formulated by computer scientist J. C. R. Licklider of Bolt, Beranek and Newman (BBN), in April 1963, in memoranda discussing the concept of the "Intergalactic Computer Network". Those ideas encompassed many of the features of the contemporary Internet. In October 1963, Licklider was appointed head of the Behavioral Sciences and Command and Control programs at the Defense Department's Advanced Research Projects Agency (ARPA). He convinced Ivan Sutherland and Bob Taylor that this network concept was very important and merited development, although Licklider left ARPA before any contracts were assigned for development.[5]

Sutherland and Taylor continued their interest in creating the network, in part, to allow ARPA-sponsored researchers at various corporate and academic locales to utilize computers provided by ARPA, and, in part, to quickly distribute new software and other computer science results. Taylor had three computer terminals in his office, each connected to separate computers, which ARPA was funding: one for the System Development Corporation (SDC) Q-32 in Santa Monica, one for Project Genie at the University of California, Berkeley, and another for Multics at the Massachusetts Institute of Technology. Taylor recalls the circumstance: "For each of these three terminals, I had three different sets of user commands. So, if I was talking online with someone at S.D.C., and I wanted to talk to someone I knew at Berkeley, or M.I.T., about this, I had to get up from the S.D.C. terminal, go over and log into the other terminal and get in touch with them. I said, "Oh Man!", it's obvious what to do: If you have these three terminals, there ought to be one terminal that goes anywhere you want to go. That idea is the ARPANET".

Meanwhile, since the early 1960s, Paul Baran at the RAND Corporation had been researching systems that could survive nuclear warand presented in the United Kingdom National Physical Laboratory (NPL) the first public demonstration of packet switching on 5 August 1968.

**Creation**

[](http://en.wikipedia.org/wiki/File:Leonard-Kleinrock-and-IMP1.png)

Len Kleinrock and the first Interface Message Processor

By mid-1968, Taylor had prepared a complete plan for a computer network, and, after ARPA's approval, a Request for Quotation (RFQ) was issued for 140 potential bidders. Most computer science companies regarded the ARPA–Taylor proposal as outlandish, and only twelve submitted bids to build a network; of the twelve, ARPA regarded only four as top-rank contractors. At year's end, ARPA considered only two contractors, and awarded the contract to build the network to BBN Technologies on 7 April 1969. The initial, seven-person BBN team were much aided by the technical specificity of their response to the ARPA RFQ, and thus quickly produced the first working system. This team was led by Frank Heart. The BBN-proposed network closely followed Taylor's ARPA plan: a network composed of small computers called Interface Message Processors, similar to the later concept of routers, that functioned as gateways interconnecting local resources. At each site, the IMPs performed store-and-forward packet switching functions, and were interconnected with leased lines via telecommunication data sets (modems), with initial data rates of 50kbit/s. The host computers were connected to the IMPs via custom serial communication interfaces. The system, including the hardware and the packet switching software, was designed and installed in nine months.

The first-generation IMPs were built by BBN Technologies using a rugged computer version of the Honeywell DDP-516 computer configured with 24KB of expandable magnetic-core memory, and a 16-channel Direct Multiplex Control (DMC) direct memory access unit. The DMC established custom interfaces with each of the host computers and modems. In addition to the front-panel lamps, the DDP-516 computer also features a special set of 24 indicator lamps showing the status of the IMP communication channels. Each IMP could support up to four local hosts, and could communicate with up to six remote IMPs via leased lines. The network connected one computer in Utah with three in California. Later, the Department of Defense allowed the universities to join the network for sharing hardware and software resources.

**Misconceptions of design goals**

It is commonly stated that ARPANET was designed to survive a nuclear attack. In *A Brief History of the Internet*, the Internet Society denies this:

It was from the RAND study that the false rumor started, claiming that the ARPANET was somehow related to building a network resistant to nuclear war. This was never true of the ARPANET; only the unrelated RAND study on secure voice considered nuclear war. However, the later work on Internetting did emphasize robustness and survivability, including the capability to withstand losses of large portions of the underlying networks.

The RAND study was conducted by Paul Baran and pioneered packet switching.[8] In an interview he confirmed that ARPANET did not share his project's goal, but also argued that his work had greatly contributed to the development of ARPANET.[14] Additionally, minutes taken by Elmer Shapiro of Stanford Research Institute at the ARPANET design meeting of Oct. 9-10 1967 indicate that a version of Baran's routing method and suggestion of using a fixed packet size was expected to be employed.

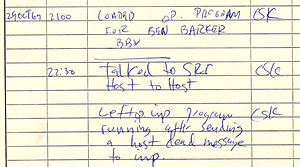
The ARPANET incorporated distributed computation (and frequent re-computation) of routing tables. This was a major contribution to the good survivability that the ARPANET had, in the face of significant destruction - even by a nuclear attack. Such auto-routing was technically quite challenging to construct at the time. The fact that it was incorporated into the early ARPANET made many believe that this had been a design goal.

The ARPANET was in fact designed to survive subordinate-network losses, but the principal reason was that the switching nodes and network links were unreliable, even without any nuclear attacks. About the resource scarcity that spurred the creation of the ARPANET, Charles Herzfeld, ARPA Director (1965–1967), said:

The ARPANET was not started to create a Command and Control System that would survive a nuclear attack, as many now claim. To build such a system was, clearly, a major military need, but it was not ARPA's mission to do this; in fact, we would have been severely criticized had we tried. Rather, the ARPANET came out of our frustration that there were only a limited number of large, powerful research computers in the country, and that many research investigators, who should have access to them, were geographically separated from them.

The ARPANET was operated by the military during the two decades of its existence, until 1990.

**ARPANET deployed**

[](http://en.wikipedia.org/wiki/File:First-arpanet-imp-log.jpg)

**Historical document:** First ARPANET IMP log: the first message ever sent via the ARPANET, 10:30 pm, 29 October 1969. This IMP Log excerpt, kept at UCLA, describes setting up a message transmission from the UCLA SDS Sigma 7 Host computer to the SRI SDS 940 Host computer.

The initial ARPANET consisted of four IMPs:

* University of California, Los Angeles (UCLA), where Leonard Kleinrock had established a Network Measurement Center, with an SDS Sigma 7 being the first computer attached to it;
* The Augmentation Research Center at Stanford Research Institute (now SRI International), where Douglas Engelbart had created the ground-breaking NLS system, a very important early hypertext system, and would run the Network Information Center (NIC), with the SDS 940 that ran NLS, named "Genie", being the first host attached;
* University of California, Santa Barbara (UCSB), with the Culler-Fried Interactive Mathematics Center's IBM 360/75, running OS/MVT being the machine attached;
* The University of Utah's Computer Science Department, where Ivan Sutherland had moved, running a DEC PDP-10 operating on TENEX.

The first successful message on the ARPANET was sent by UCLA student programmer Charley Kline, at 10:30 pm on 29 October 1969, from Boelter Hall 3420. Kline transmitted from the university's SDS Sigma 7 Host computer to the Stanford Research Institute's SDS 940 Host computer. The message text was the word *login*; on an earlier attempt the *l* and the *o* letters were transmitted, but the system then crashed. Hence, the literal first message over the ARPANET was *lo*. About an hour later, after the programmers repaired the code that caused the crash, the SDS Sigma 7 computer effected a full *login*. The first permanent ARPANET link was established on 21 November 1969, between the IMP at UCLA and the IMP at the Stanford Research Institute. By 5 December 1969, the entire four-node network was established.[21]

**Growth and evolution**

In March 1970, the ARPANET reached the East Coast of the United States, when an IMP at BBN in Cambridge, Massachusetts was connected to the network. Thereafter, the ARPANET grew: 9 IMPs by June 1970 and 13 IMPs by December 1970, then 18 by September 1971 (when the network included 23 university and government hosts); 29 IMPs by August 1972, and 40 by September 1973. By June 1974, there were 46 IMPs, and in July 1975, the network numbered 57 IMPs. By 1981, the number was 213 host computers, with another host connecting approximately every twenty days.

In 1973 a transatlantic satellite link connected the Norwegian Seismic Array (NORSAR) to the ARPANET, making Norway the first country outside the US to be connected to the network. At about the same time a terrestrial circuit added a London IMP.

In 1975, the ARPANET was declared "operational". The Defense Communications Agency took control since ARPA was intended to fund advanced research.

In September of 1984 work was completed on restructuring the ARPANET giving U.S. military sites on their own Military Network (MILNET) for unclassified defense department communications. Controlled gateways connected the two networks. The combination was called the Defense Data Network (DDN). Separating the civil and military networks reduced the 113-node ARPANET by 68 nodes. The MILNET later became the NIPRNet.

**Rules and etiquette**

Because of its government ties, certain forms of traffic were discouraged or prohibited. A 1982 handbook on computing at MIT's AI Lab stated regarding network etiquette:

It is considered illegal to use the ARPANet for anything which is not in direct support of Government business ... personal messages to other ARPANet subscribers (for example, to arrange a get-together or check and say a friendly hello) are generally not considered harmful ... Sending electronic mail over the ARPANet for commercial profit or political purposes is both anti-social and illegal. By sending such messages, you can offend many people, and it is possible to get MIT in serious trouble with the Government agencies which manage the ARPANet.

**Technology**

Support for inter-IMP circuits of up to 230.4 kbit/s was added in 1970, although considerations of cost and IMP processing power meant this capability was not actively used.

1971 saw the start of the use of the non-ruggedized (and therefore significantly lighter) Honeywell 316 as an IMP. It could also be configured as a Terminal Interface Processor (TIP), which provided terminal server support for up to 63 ASCII serial terminals through a multi-line controller in place of one of the hosts.[27] The 316 featured a greater degree of integration than the 516, which made it less expensive and easier to maintain. The 316 was configured with 40 kB of core memory for a TIP. The size of core memory was later increased, to 32 kB for the IMPs, and 56 kB for TIPs, in 1973.

In 1975, BBN introduced IMP software running on the Pluribus multi-processor. These appeared in a few sites. In 1981, BBN introduced IMP software running on its own C/30 processor product.

In 1983, TCP/IP protocols replaced NCP as the ARPANET's principal protocol, and the ARPANET then became one subnet of the early Internet.

The original IMPs and TIPs were phased out as the ARPANET was shut down after the introduction of the NSFNet, but some IMPs remained in service as late as 1989.

The *ARPANET Completion Report*, jointly published by BBN and ARPA, concludes that:

... it is somewhat fitting to end on the note that the ARPANET program has had a strong and direct feedback into the support and strength of computer science, from which the network, itself, sprang.

In the wake of ARPANET being formally decommissioned on 28 February 1990, Vinton Cerf wrote the following lamentation, entitled "Requiem of the ARPANET":

It was the first, and being first, was best,  
but now we lay it down to ever rest.  
Now pause with me a moment, shed some tears.  
For auld lang syne, for love, for years and years  
of faithful service, duty done, I weep.  
Lay down thy packet, now, O friend, and sleep.

-Vinton Cerf

Senator Albert Gore, Jr. began to craft the High-Performance Computing and Communication Act of 1991 (commonly referred to as "The Gore Bill") after hearing the 1988 report toward a National Research Network submitted to Congress by a group chaired by Leonard Kleinrock, professor of computer science at UCLA. The bill was passed on 9 December 1991 and led to the National Information Infrastructure (NII) which Al Gore called the "information superhighway". ARPANET was the subject of two IEEE Milestones, both dedicated in 2009.

**Software and protocols**

The starting point for host-to-host communication on the ARPANET in 1969 was the 1822 protocol, which defined the transmission of messages to an IMP.[35] The message format was designed to work unambiguously with a broad range of computer architectures. An 1822 message essentially consisted of a message type, a numeric host address, and a data field. To send a data message to another host, the transmitting host formatted a data message containing the destination host's address and the data message being sent, and then transmitted the message through the 1822 hardware interface. The IMP then delivered the message to its destination address, either by delivering it to a locally connected host, or by delivering it to another IMP. When the message was ultimately delivered to the destination host, the receiving IMP would transmit a *Ready for Next Message* (RFNM) acknowledgement to the sending, host IMP.

Unlike modern Internet datagrams, the ARPANET was designed to reliably transmit 1822 messages, and to inform the host computer when it loses a message; the contemporary IP is unreliable, whereas the TCP is reliable. Nonetheless, the 1822 protocol proved inadequate for handling multiple connections among different applications residing in a host computer. This problem was addressed with the Network Control Program (NCP), which provided a standard method to establish reliable, flow-controlled, bidirectional communications links among different processes in different host computers. The NCP interface allowed application software to connect across the ARPANET by implementing higher-level communication protocols, an early example of the *protocol layering* concept incorporated to the OSI model.

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**Network applications**

NCP provided a standard set of network services that could be shared by several applications running on a single host computer. This led to the evolution of *application protocols* that operated, more or less, independently of the underlying network service. When the ARPANET migrated to the Internet protocols in 1983, the major application protocols migrated with it.

E-mail

In 1971, Ray Tomlinson, of BBN sent the first network e-mail (RFC 524, RFC 561). By 1973, e-mail constituted 75 percent of ARPANET traffic.

File transfer

By 1973, the File Transfer Protocol (FTP) specification had been defined (RFC 354) and implemented, enabling file transfers over the ARPANET.

Voice traffic

The Network Voice Protocol (NVP) specifications were defined in 1977 (RFC 741), then implemented, but, because of technical shortcomings, conference calls over the ARPANET never worked well; the contemporary Voice over Internet Protocol (packet voice) was decades away.

**Password Protection**

The Purdy Polynomial hash algorithm was developed for ARPANET to protect passwords in 1971 at the request of Larry Roberts, head of ARPA at that time. It computed a polynomial of degree 224 + 17 modulo the 64-bit prime p = 264 - 59. The algorithm was later used by DEC to hash passwords in their OpenVMS operating system, and is still being used for this purpose.

**ARPANET in popular culture**

* *Computer Networks: The Heralds of Resource Sharing*, a 30-minute documentary film [37] featuring Fernando J. Corbato, J.C.R. Licklider, Lawrence G. Roberts, Robert Kahn, Frank Heart, William R. Sutherland, Richard W. Watson, John R. Pasta, Donald W. Davies, and economist, George W. Mitchell.
* "Scenario", a February 1985 episode of the U.S. television sitcom *Benson* (season 6, episode 20), was the first incidence of a popular TV show directly referencing the Internet or its progenitors. The show includes a scene in which the ARPANET is accessed.
* There is an electronic music artist known as "Arpanet", Gerald Donald, one of the members of Drexciya. The artist's 2002 album *Wireless Internet* features commentary on the expansion of the internet via wireless communication, with songs such as *NTT DoCoMo*, dedicated to the mobile communications giant based in Japan.
* Thomas Pynchon mentions ARPANET in his 2009 novel *Inherent Vice*, which is set in Los Angeles in 1970, and in his 2013 novel *Bleeding Edge*.
* The 1993 television series "The X-Files" featured the ARPANET in a season 5 episode, titled, "Unusual Suspects". John Fitzgerald Byers offers to help Susan Modeski (known as Holly . . . "just like the sugar") by hacking into the ARPANET to obtain sensitive information.