15-292 History of Computing

The Internet

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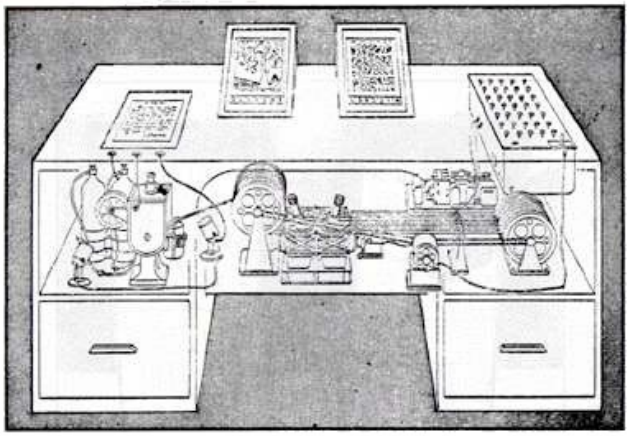
A Vision of Connecting the World – the Memex

- Proposed by Vannevar Bush
  - first published in the essay "As We May Think" in Atlantic Monthly in 1945 and subsequently in Life Magazine.
    - "a device in which an individual stores all his books, records, and communications, and which is mechanized so that it may be consulted with exceeding speed and flexibility"
  - also indicated the idea that would become hypertext
- Bush's work was influential on all Internet pioneers
  - Project Xanadu – Ted Nelson (1960s)
  - HyperCard – Bill Atkinson/Apple (1980s)

2

The Memex



Memex in the form of a desk would instantly bring files and material on any subject to the operator's fingertips. Slanting translucent viewing screens magnify supermicrofilm filed by code numbers. At left is a mechanism which automatically photographs longhand notes, pictures and letters, then files them in the desk for future reference (*LIFE* 19(11), p. 123).

3

The Memex

4

The Impetus to Act

- 1957 - U.S.S.R. launches Sputnik I into space
- 1958 - U.S. Department of Defense responds by creating ARPA
  - Advanced Research Projects Agency
  - "mission is to maintain the technological superiority of the U.S. military"
  - "sponsoring revolutionary, high-payoff research that bridges the gap between fundamental discoveries and their military use."
  - Name changed to DARPA (Defense) in 1972

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Early work

Baran (L) and Davies (R)

- Paul Baran began working at the RAND corporation on secure communications technologies in 1959
  - goal to enable a military communications network to withstand a nuclear attack.
  - use of a decentralized network with multiple paths between any two points (distributed computing)
  - devised dividing complete user messages into message blocks before sending them into the network
- Donald Davies of Britain's National Physics Lab had begun working on related concepts in 1965
  - Introduced the term "packet"

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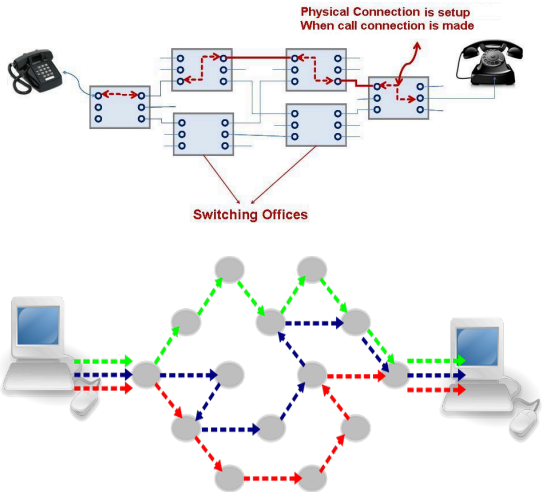
Circuit Switching vs. Packet Switching



medium.com

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J.C.R. Licklider ("Lick")

- Wrote *Man-Computer Symbiosis* in 1960
  - outlined the need for simpler interaction between computers and users
- Formulated the earliest ideas of a global computer network at MIT in 1962
- 1962-1964, Licklider was head of the ARPA Information Processing Techniques Office (IPTO)
  - set up ARPA research contracts with leading research institutions (Stanford, MIT, UCLA, etc …)
  - proposed an "Intergalactic Computer Network" to link the institutions
  - promoted standards among the various computing facilities

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Bob Taylor

- Director of ARPA's IPTO (after Licklider & Ivan Sutherland)
- When he took over, the Intergalactic Computer Network was not actually connected
- He had a direct connection to ARPA computers around the country
  - Different researchers used different computers that could not talk to one another
- Taylor continued Licklider's vision, proposing to link them together in a uniform network (funded $1 million)
  - the U. S. government's best return on an investment in its history?
    - maybe the Louisiana Purchase or the purchase of Alaska
- Taylor would later supervise Xerox PARC

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Larry Roberts

- Sometimes called "the father of ARPANET"
- Built first transcontinental network from MIT to Santa Monica
- Strong-armed by Taylor to link ARPA computers
  - Roberts was ARPANET's principal architect
- Used packet switching & IMPs

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ARPANET

- The Advanced Research Projects Agency Network (ARPANET) was the world's first operational packet switching network.
- Project launched in 1968.
- Required development of IMPs (Interface Message Processors) by Bolt, Beranek and Newman (BBN)
  - IMPs would connect to each other over leased digital lines
  - IMPs would act as the interface to each individual host machine
  - Used packet switching concepts published by Leonard Kleinrock, most famous for his subsequent books on queuing theory

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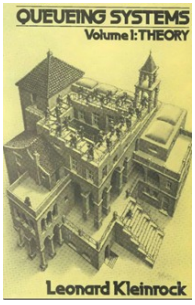
Len Kleinrock

- Queueing theorist & engineer
- Really formalized packet switching research while at MIT
- Later joined ARPANET effort while at UCLA
- Oversaw installation of ARPANET's first IMP at UCLA



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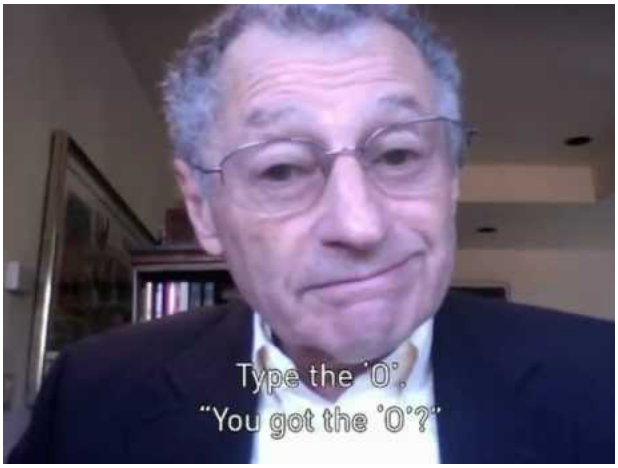
History of the ARPANET



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The Initial ARPANET

- Initial ARPANET deployed in late 1969 with four hosts:
  - University of California at Los Angeles (UCLA) (SDS Sigma 7)
  - Stanford Research Institute (SRI) (SDS 940)
  - University of California at Santa Barbara (UCSB) (IBM 360/75)
  - University of Utah (DEC PDP-10)

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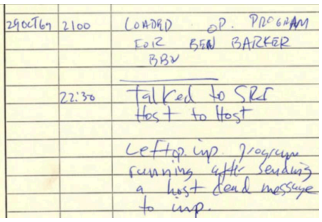
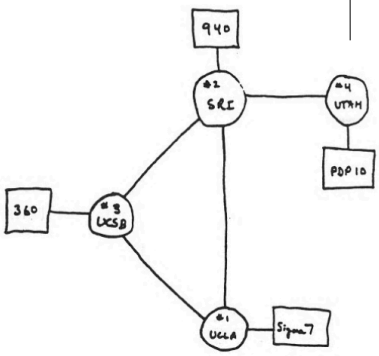
IMPs

Leonard Kleinrock and an Interface Message Processor



Lab notebook entry for early communication on ARPANET

Early sketch of ARPANET's first four nodes



THE ARPA NETWORK

DEC 1969

4 NODES

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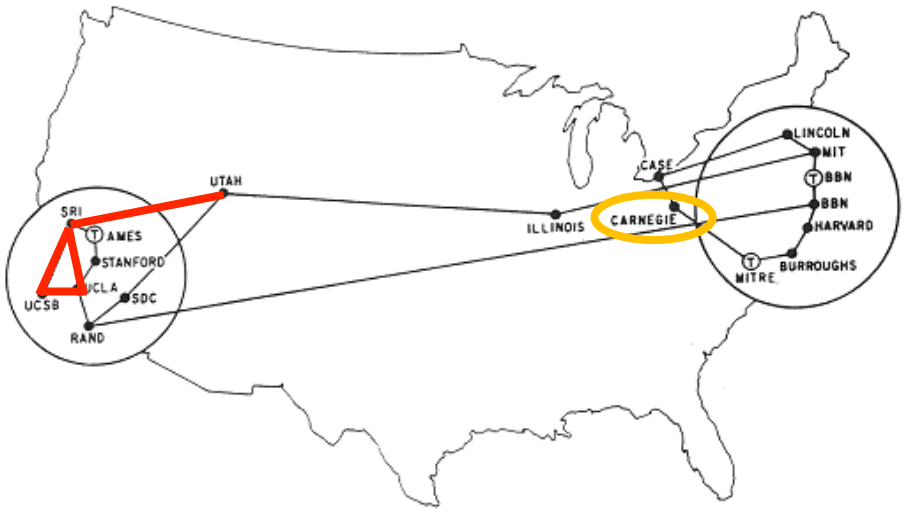

MAP 4 September 1971

cybergeography.org

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Vinton Cerf

- Known as the “father of the Internet”
  - co-designed the TCP/IP protocol with Robert Kahn
  - led effort for its adoption in 1980s
  - in the mid 1980s, he led the engineering of MCI Mail, the first commercial email service to be connected to the Internet.
- Served as founding president of ISOC (Internet Society) from 1992-1995.
- In 1997, he was presented the U.S. National Medal of Technology, along with Kahn

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Robert Kahn

- Known as the “father of the Internet”
  - co-designed the TCP/IP protocol with Vinton Cerf
- In October 1972 he organized a large, very successful demonstration of the ARPANET at the International Computer Communication Conference (ICCC).
  - This was the first public demonstration of this new network technology to the public.
- In 1997, he was presented the U.S. National Medal of Technology, along with Cerf

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History of the ARPANET

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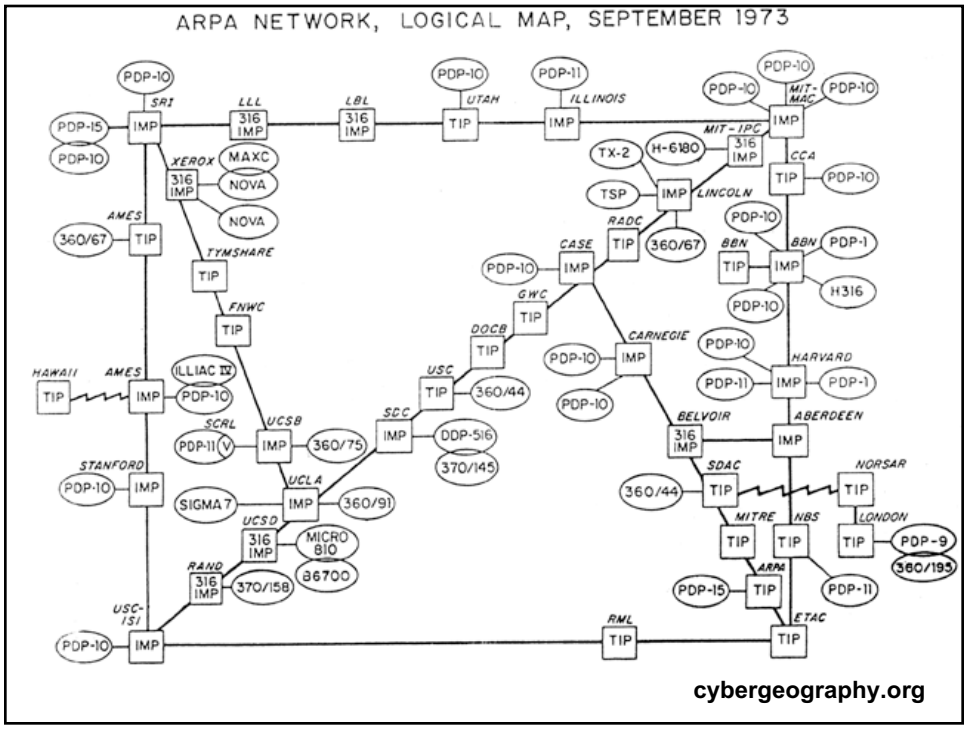

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TCP/IP

- Instead of the network being responsible for reliability, as in the ARPANET, the hosts became responsible.
  - TCP – Transmission Control Protocol
    - included error-correction techniques
  - IP – Internet Protocol
    - assumed that the end host would deal with transmission errors
  - With the role of the network reduced to the bare minimum, it became possible to join almost any networks together, no matter what their characteristics.
  - One popular saying has it that TCP/IP will run over "two tin cans and a string".
- In 1983, TCP/IP protocols became the principal protocol of the ARPANET

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TCP/IP

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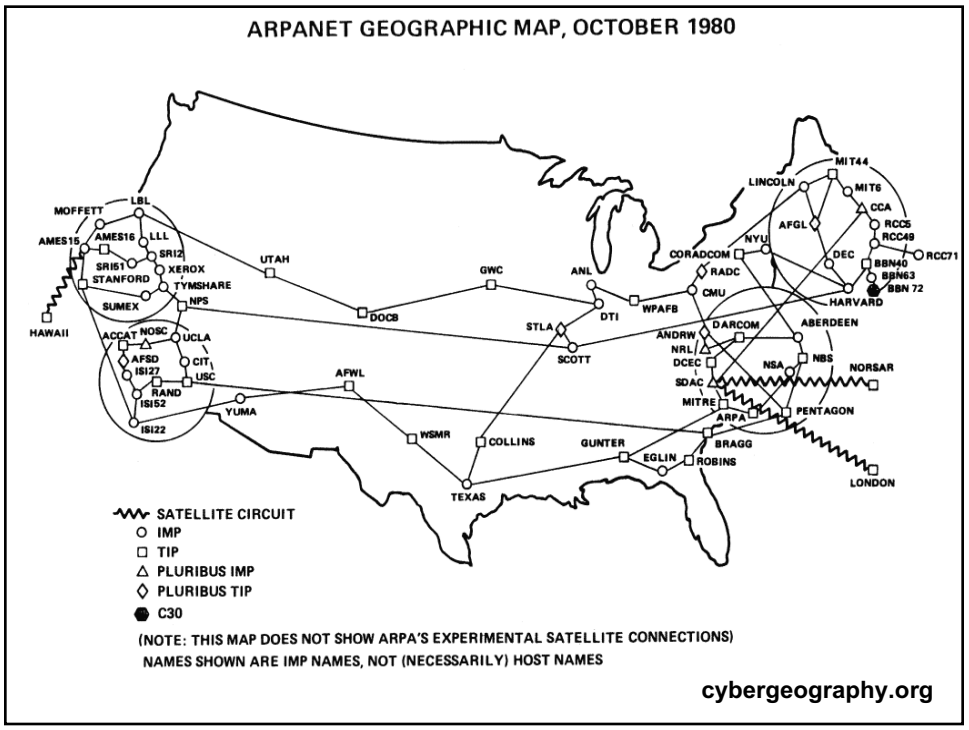

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Additional Internet Developments

- Electronic mail was introduced in 1972 by Ray Tomlinson of BBN.
  - E-mail took off as the largest network application for over a decade.
- Usenet (1979)
  - a system of distributed discussion groups
  - it existed even before the Internet, as an application of Unix computers connected by telephone lines
  - The first nodes connected were University of North Carolina and Duke University.
- The Smiley Emoticon `:-)` (1982)
  - Created at CMU by Prof. Scott Fahlman.

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Vint Cerf and Bob Kahn

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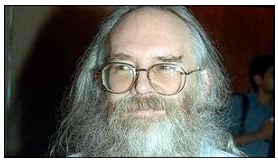
Jon Postel



- Part of ARPANET while at UCLA
- Designed domain name system
  - Top administrator for IANA - Internet Assigned Numbers Authority
    - overall authority for IP Addresses & Domain Names
- Credited for Postel's Law:
  - Be conservative in what you send, liberal in what you accept.
  - TCP/IP principle

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The Modern Internet emerges

- In 1984, the US military portion of the ARPANet was broken off as a separate network, the MILNET.
- During the 1980s, the connections expanded to more educational institutions and companies
- The National Science Foundation (NSF), became heavily involved in the Internet in the mid 1980s.
  - The NSFNet backbone, intended to connect and provide access to a number of supercomputing centers established by the NSF, was established in 1986.

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ARPANET out, Internet in

- At the end of the 1980s, the US Department of Defense decided the network was developed enough for its initial purposes, and decided to stop further funding of the core Internet backbone.
- The ARPANET was to be gradually shut down (its last node was turned off in 1989), and NSF took over responsibility for providing long-haul connectivity in the US.
- Another NSF initiative promoted regional TCP/IP networks that would connect with the Internet backbone
  - NYSERNet (New York State Education and Research Network)
  - BARRNet (Bay Area Regional Research Network)

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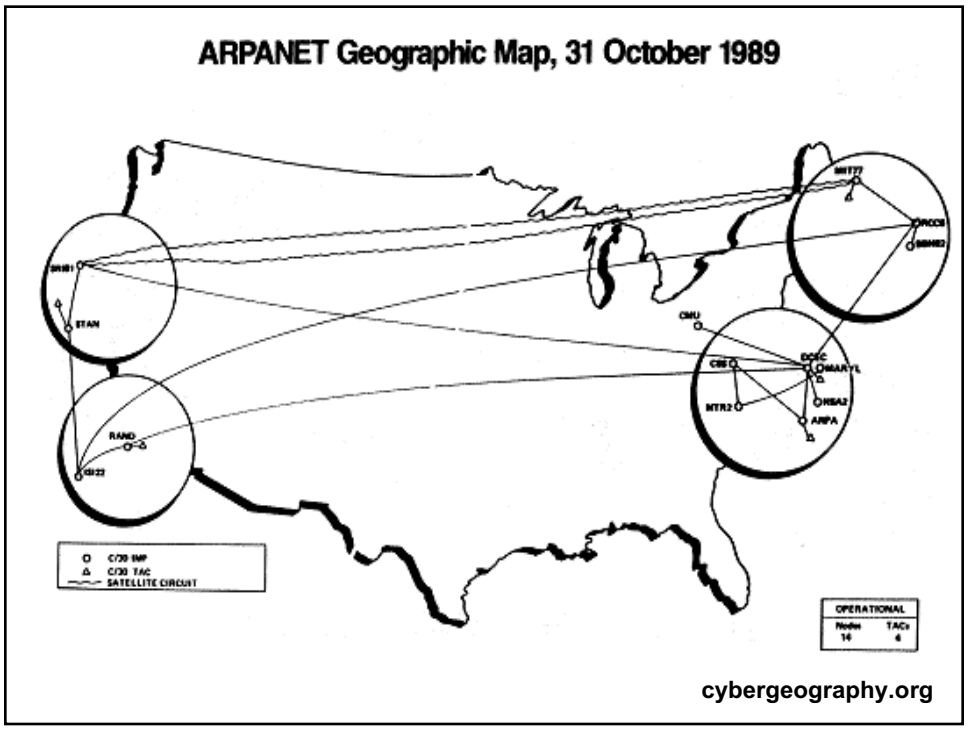
ARPANET Geographic Map, 31 October 1989
cybergeography.org

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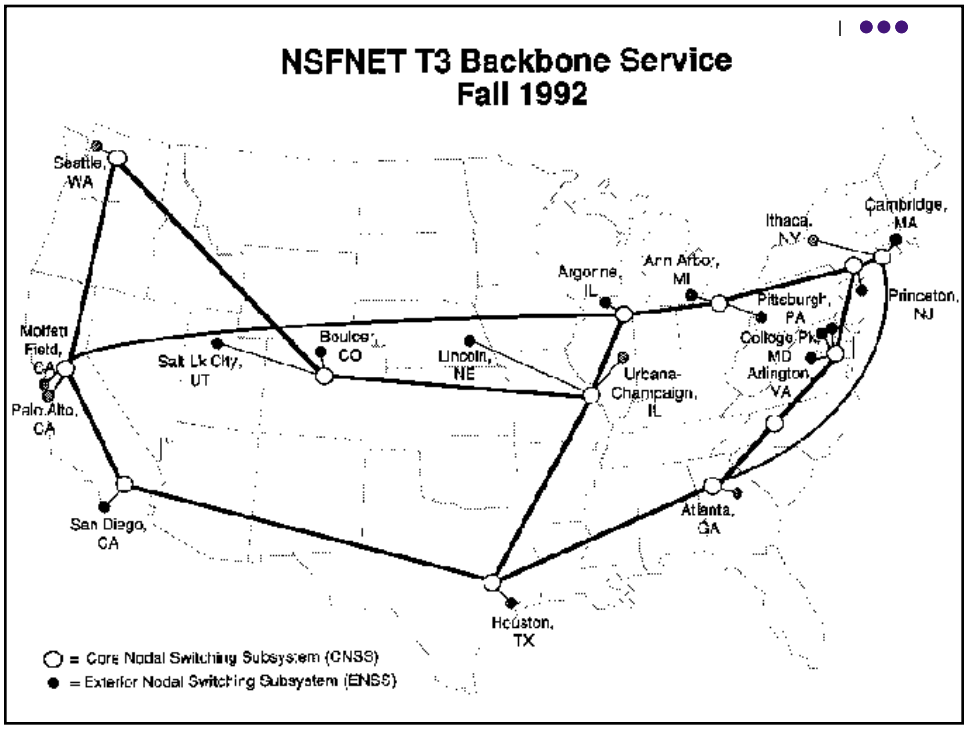
NSFNET T3 Backbone Service
Fall 1992
Seattle, WA
Palo Alto, CA
Moffett Field, CA
San Diego, CA
Salt Lk City, UT
Boulder, CO
Lincoln, NE
Houston, TX
Argonne, IL
Urbana-Champaign, IL
Ann Arbor, MI
Pittsburgh, PA
Ithaca, NY
Cambridge, MA
Princeton, NJ
College Pk, MD
Arlington, VA
Atlanta, GA
= Core Nodal Switching Subsystem (CNSS)
= Exterior Nodal Switching Subsystem (ENSS)

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NSFNet and ISPs

- NSFNet had restrictions: no commercial use.
- Other non-NSFNet networks were emerging:
  - BITNET, CSNET, UUCP
- During the late 1980s the Internet Service Provider companies provided access across the country
  - CompuServe, Prodigy, America Online

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Commercialization & Privatization of the Internet

- High Performance Computing Act of 1991
  - Introduced by Al Gore, signed by George H.W. Bush
  - Led to National Information Infrastructure (NII) and the National Research and Education Network (NREN)
  - Opened up Internet to new applications such as browsers and Internet commerce
- By 1994, the NSFNet lost its standing as the backbone of the Internet.
  - The NSFNet was dropped as the main backbone, and commercial restrictions were gone.

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