

CE 443 - Computer Networks

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Acknowledgments: Some of the slides are fully or partially obtained from other sources. Reference is noted on the bottom of each slide, when the content is fully obtained from another source. Otherwise a full list of references is provided on the last slide.



What happens when you click on a URL?

- When you click on a URL, 17 messages are exchanged on the internet
 - 6 message to translate the server name to IP address
 - 3 messages to setup a TCP connection
 - 4 messages for your browser to send the HTTP “get” request, and server response (assuming the page it self fits in one message)
 - 4 messages to tear down the connection

History



Early communication over Long Distance

- Between human beings
- Letter and messenger
 - Information carried by physical objects
 - Speed limited by transportation means: horse, bird, train, car
 - Bandwidth? Distance? Security?
- Fire
 - Early optical communication
 - Speed of light
 - Bandwidth? Distance? Security?



Communication Using Electrons

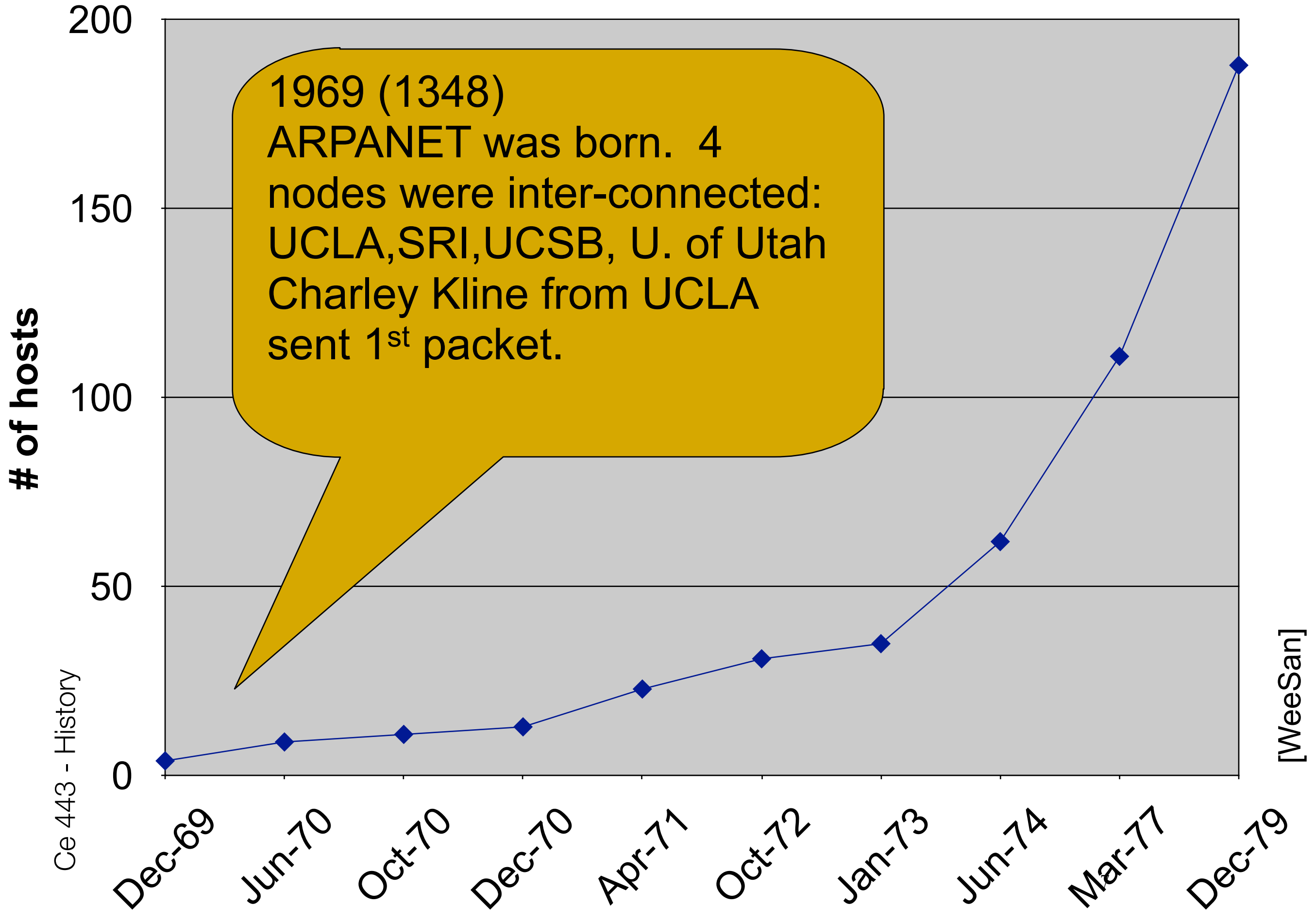
- 1827 (1206) Ohm's Law
- 1837 (1216) "Workable" telegraph invented by Samuel Morse
- 1838 (1217) demonstration over 16 kilometers at 10 w.p.m.
- 1851 (1230) Western Union founded
- 1868 (1247) Transatlantic cable laid
- **1876 (1255) Alexander Bell invented the telephone**
- 1885 (1264) AT&T formed
- 1892 (1271) First automated commercial telephone switch



Age of Telephones

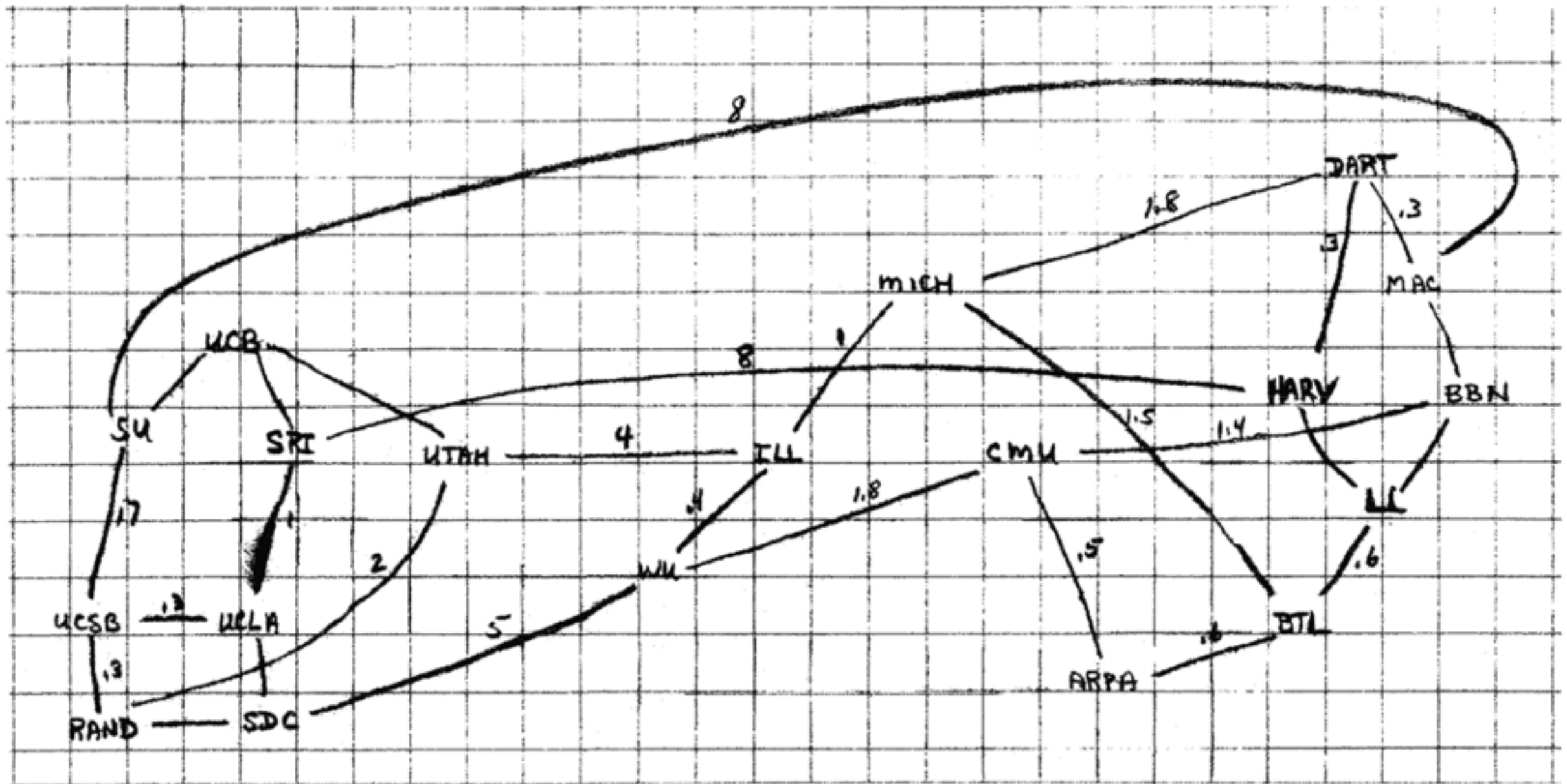
- 1903 (1282) 3 million phones in the U.S.
- 1915 (1294) First transcontinental telephone line
- 1948 (1327) Transistor invented by Bell scientists
- 1963 (1342) Digital transmission introduced
- 1965 (1344) 1ESS central office switch introduced
- **1969 (1348) Arpanet was born**
- 1985 (1364) Last telegraph circuit closed down
- 1999 (1378) Last 4ESS install in ATT network

Internet Hosts

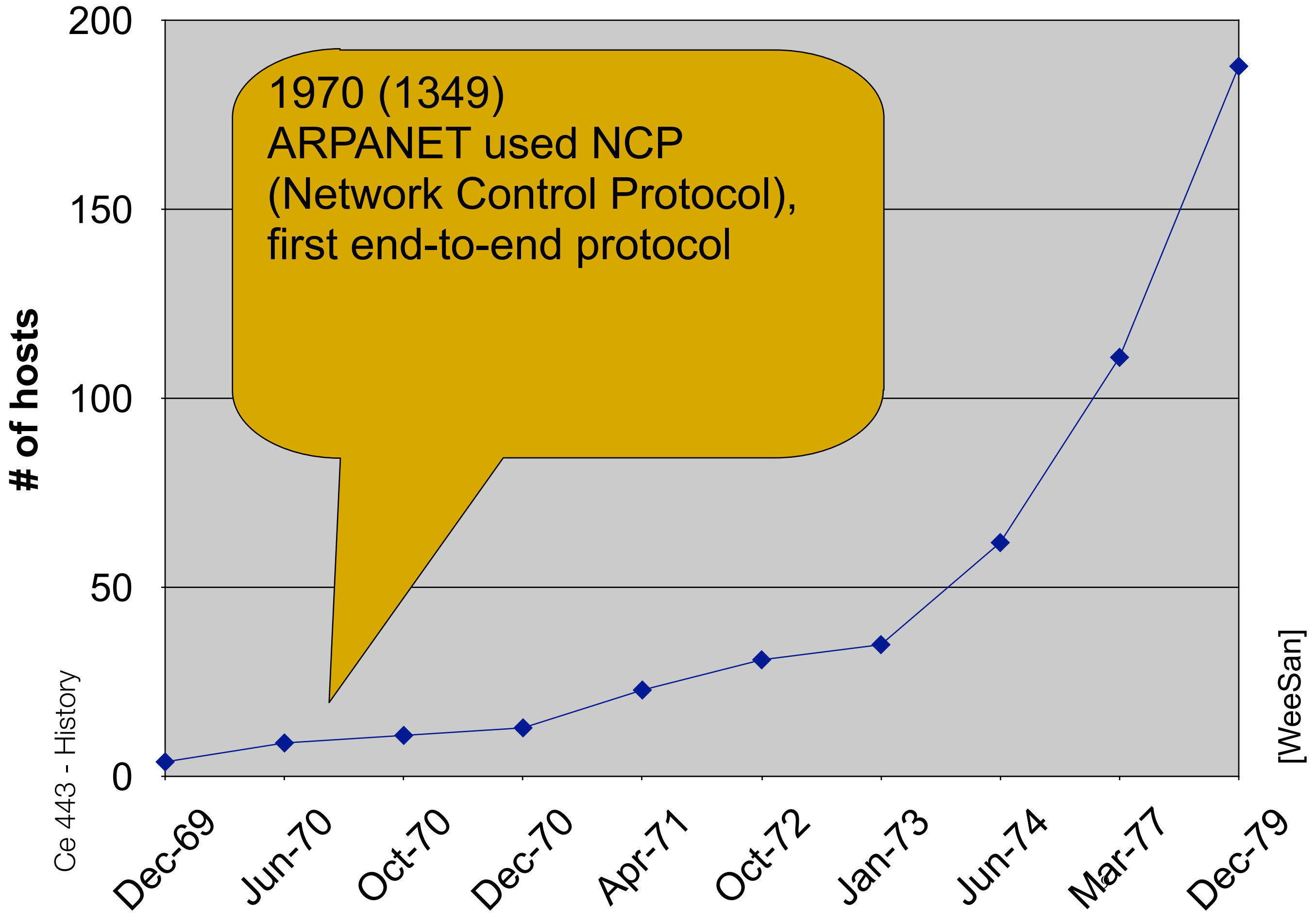


ARPAnet plan

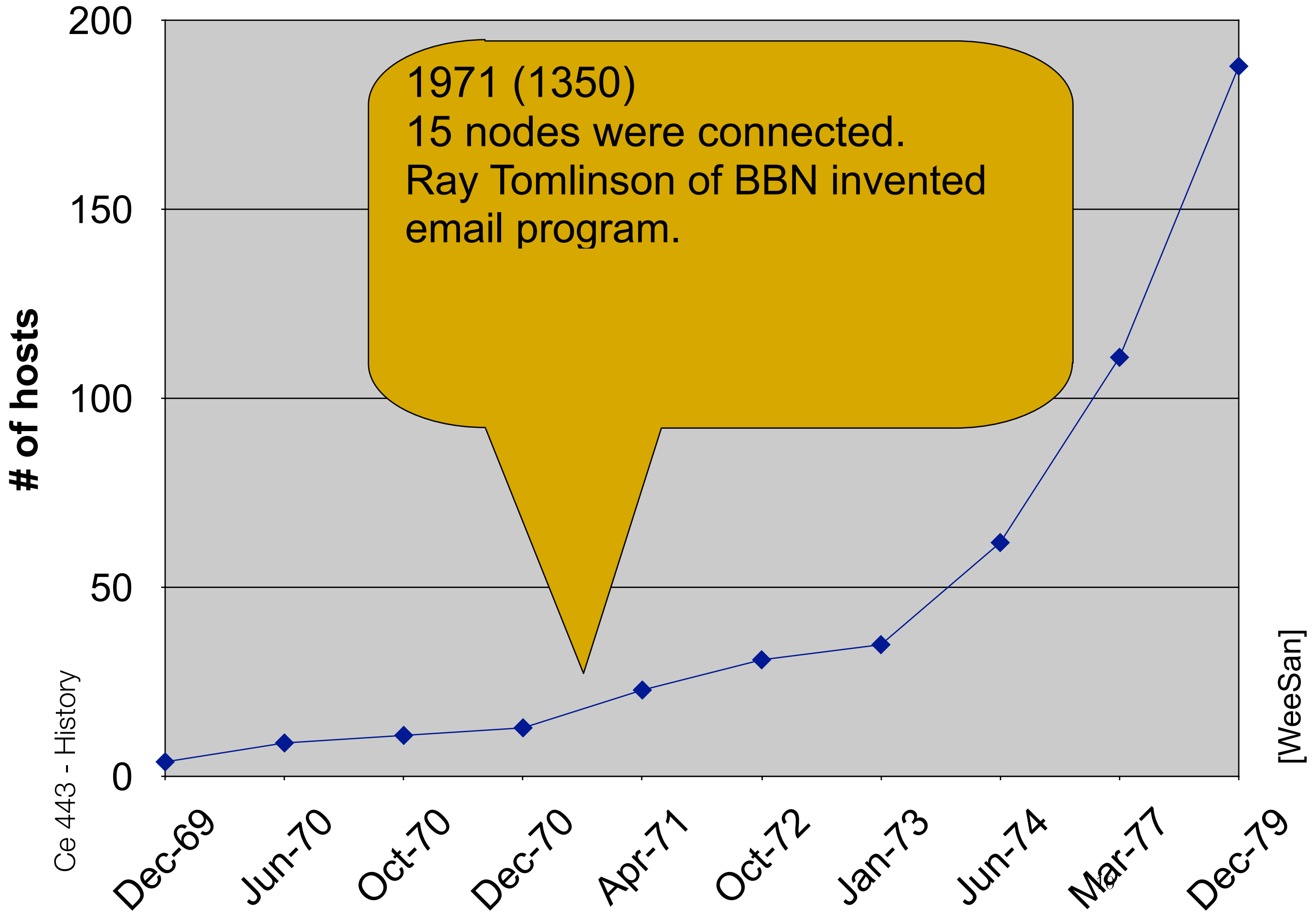
Rough sketch by Larry Roberts, late 1960s.



Internet Hosts



Internet Hosts

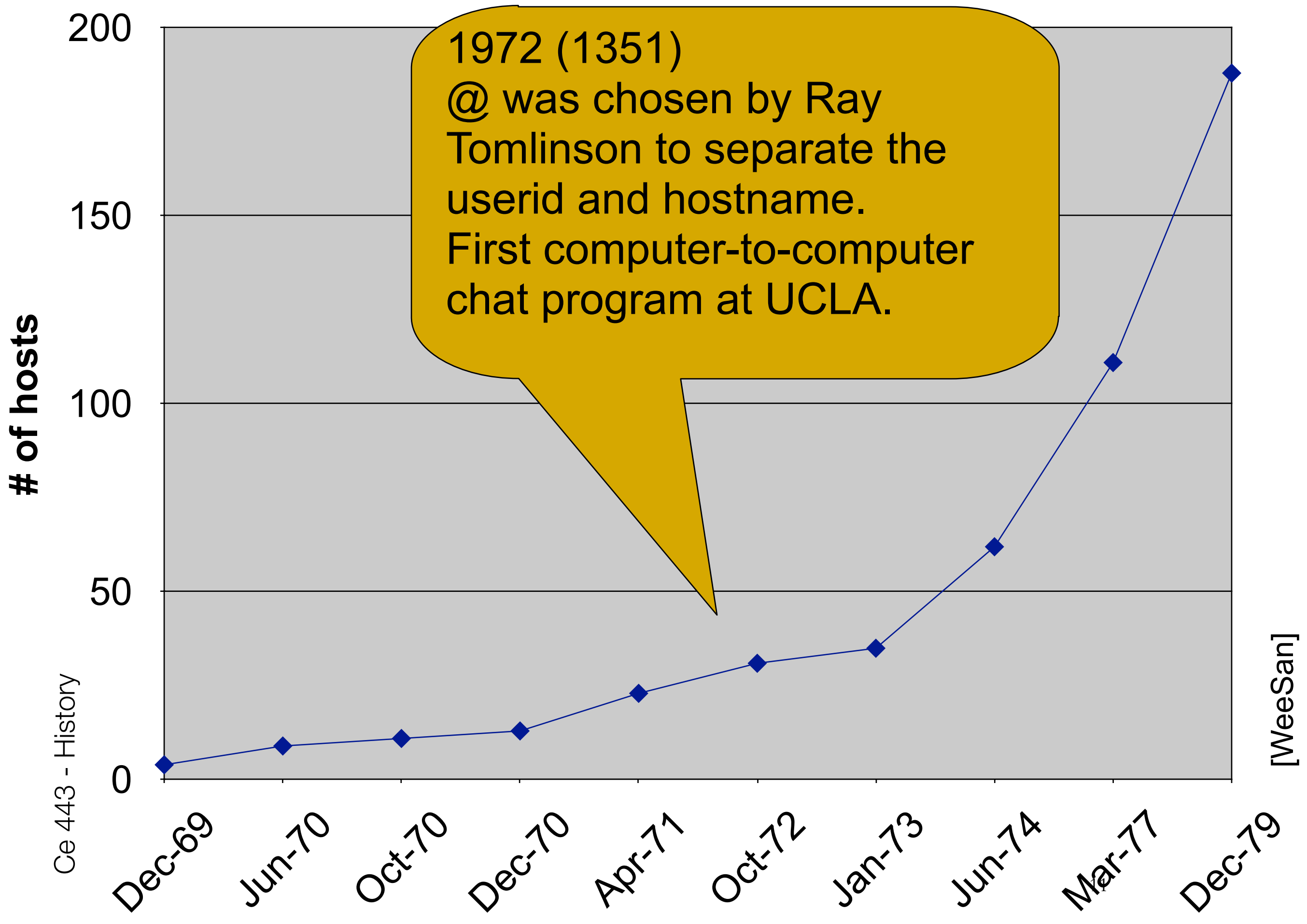


1971 (1350)
15 nodes were connected.
Ray Tomlinson of BBN invented
email program.

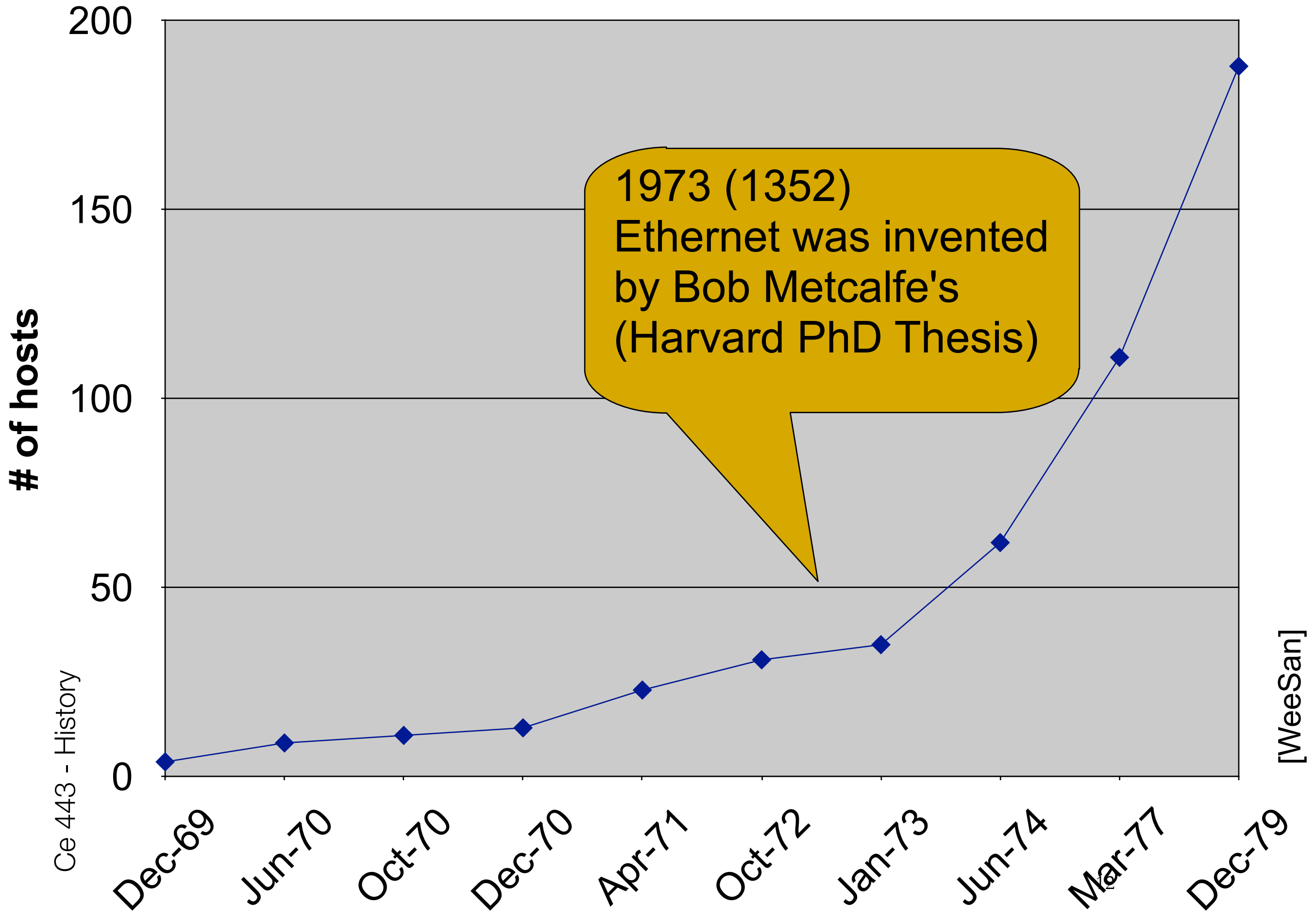
Ce 443 - History

[WeeSan]

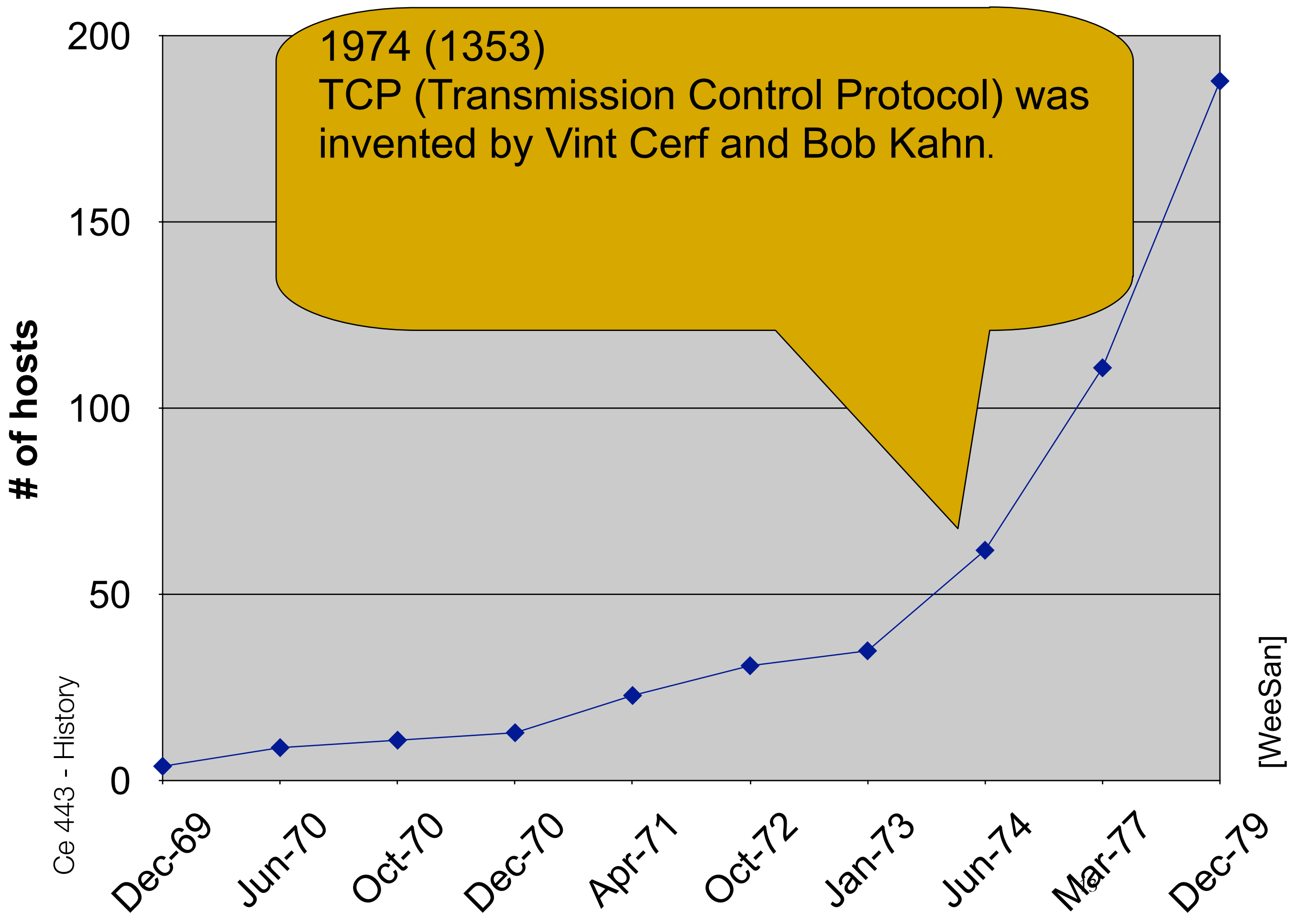
Internet Hosts



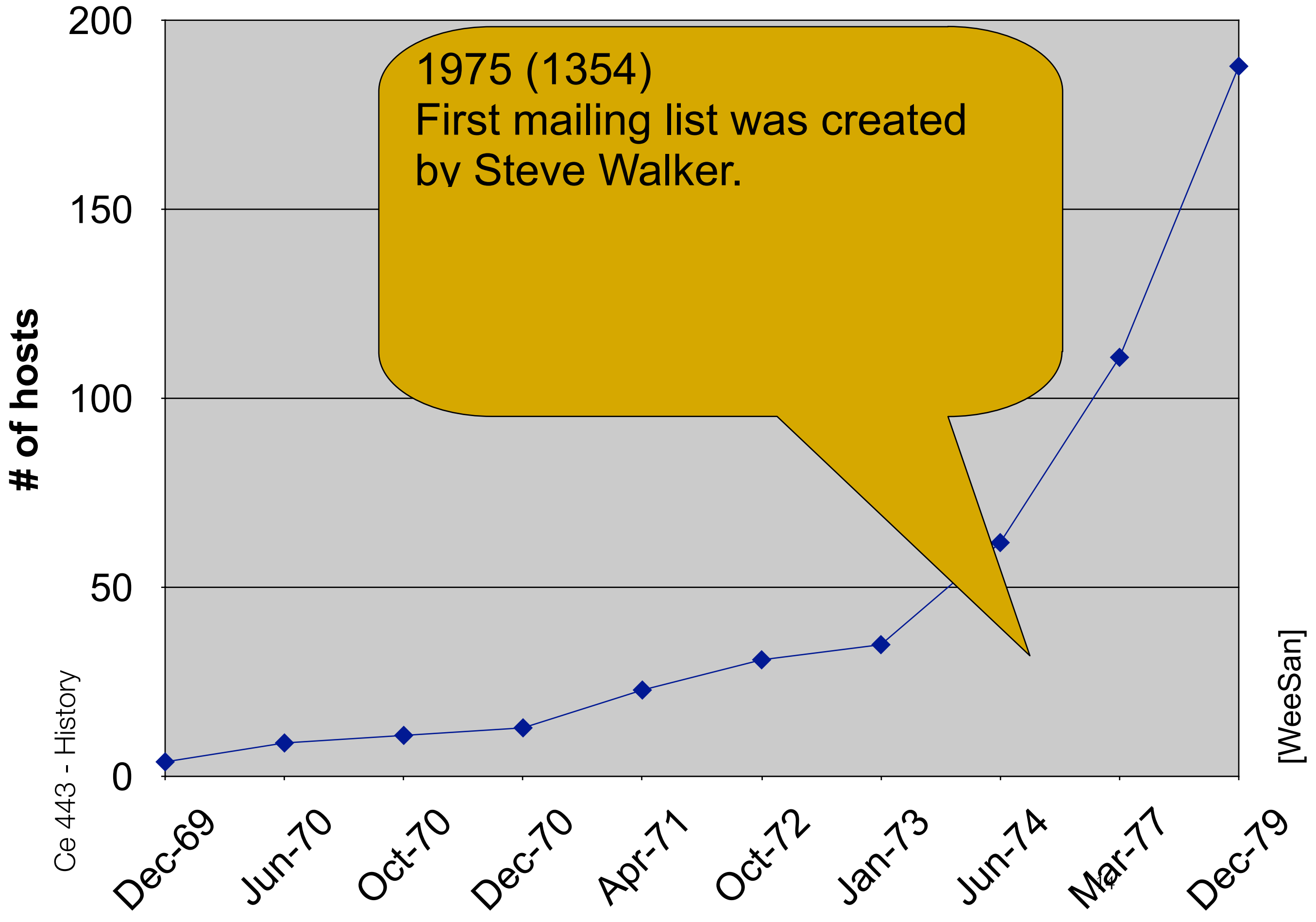
Internet Hosts



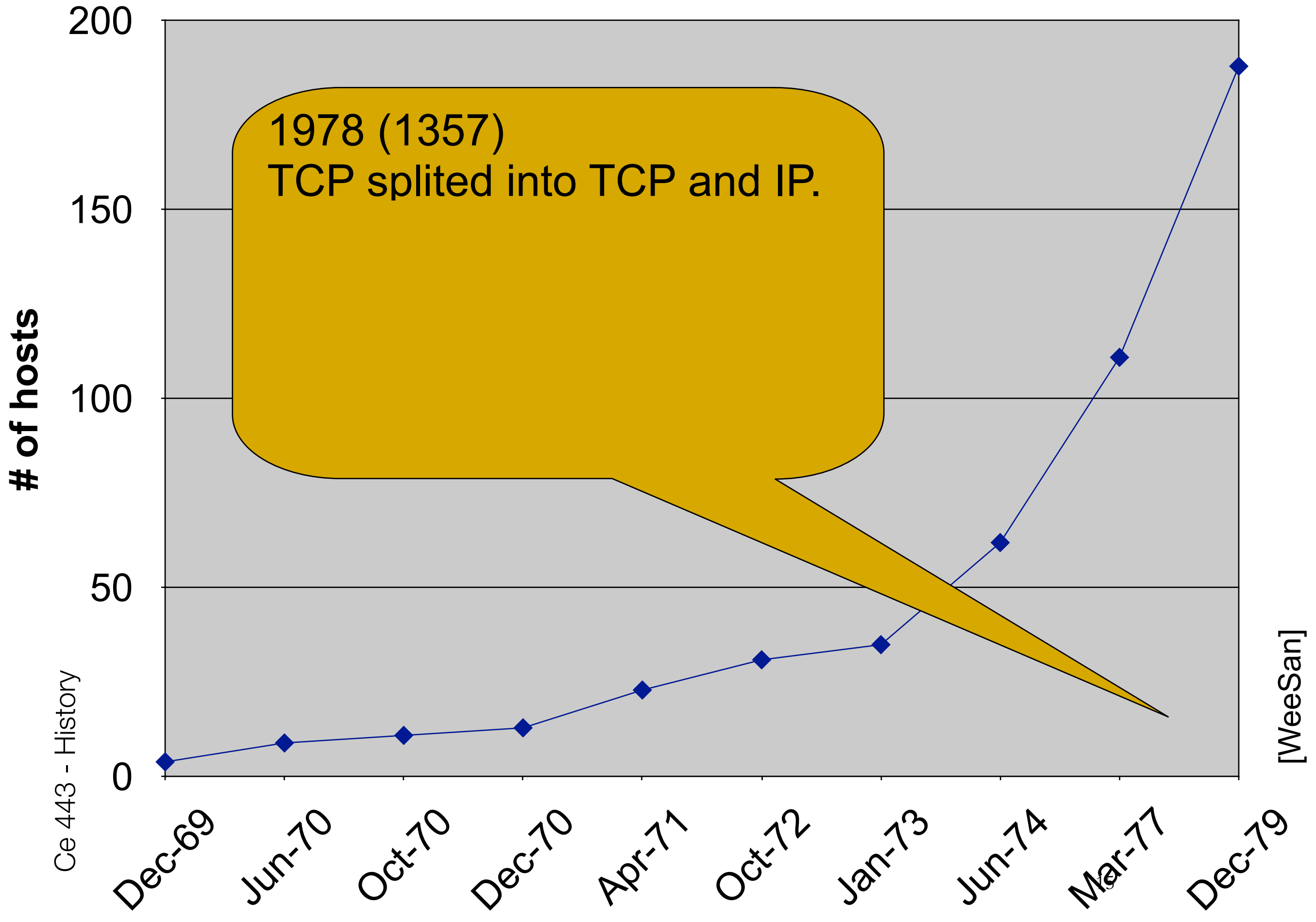
Internet Hosts



Internet Hosts



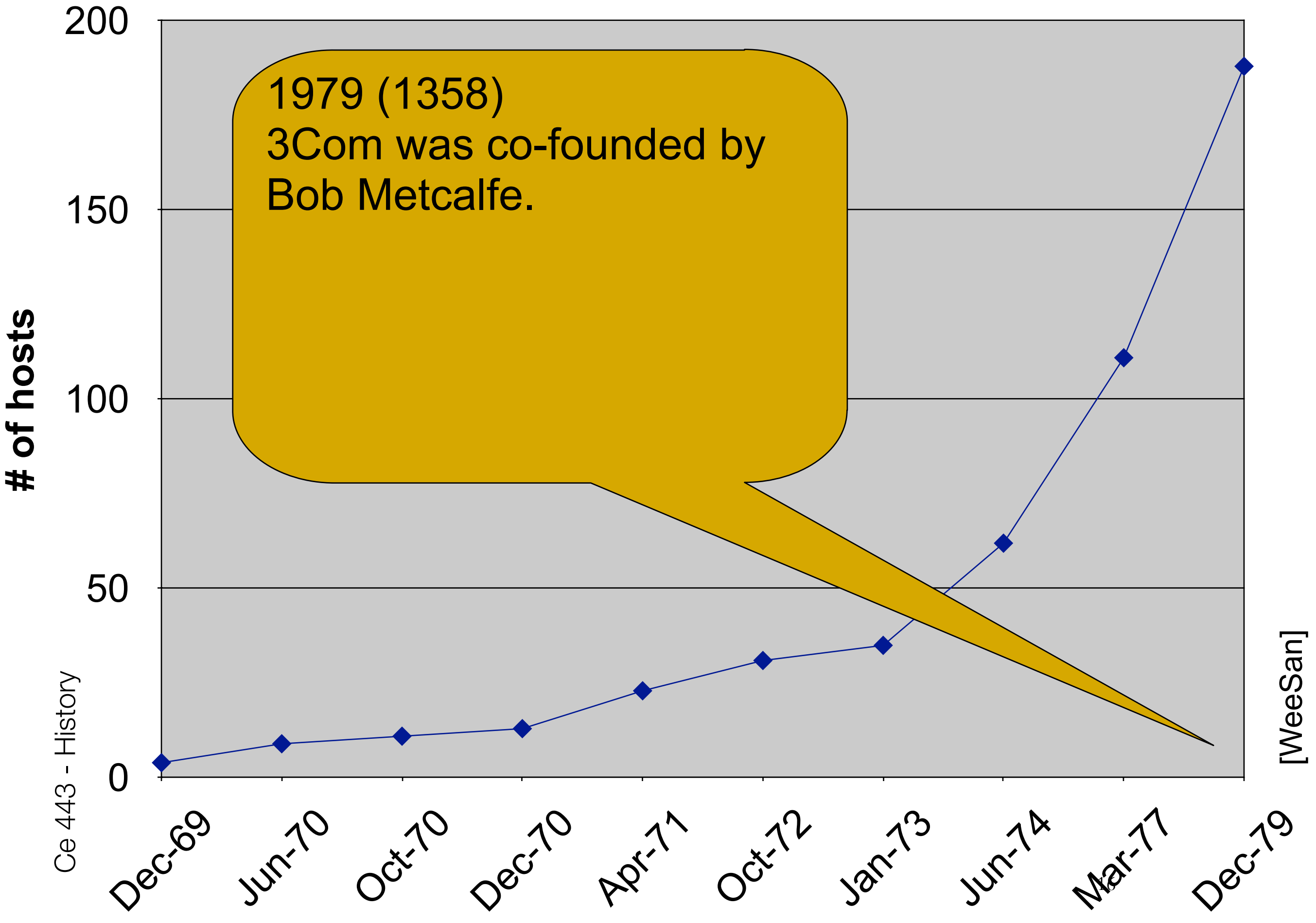
Internet Hosts



Ce 443 - History

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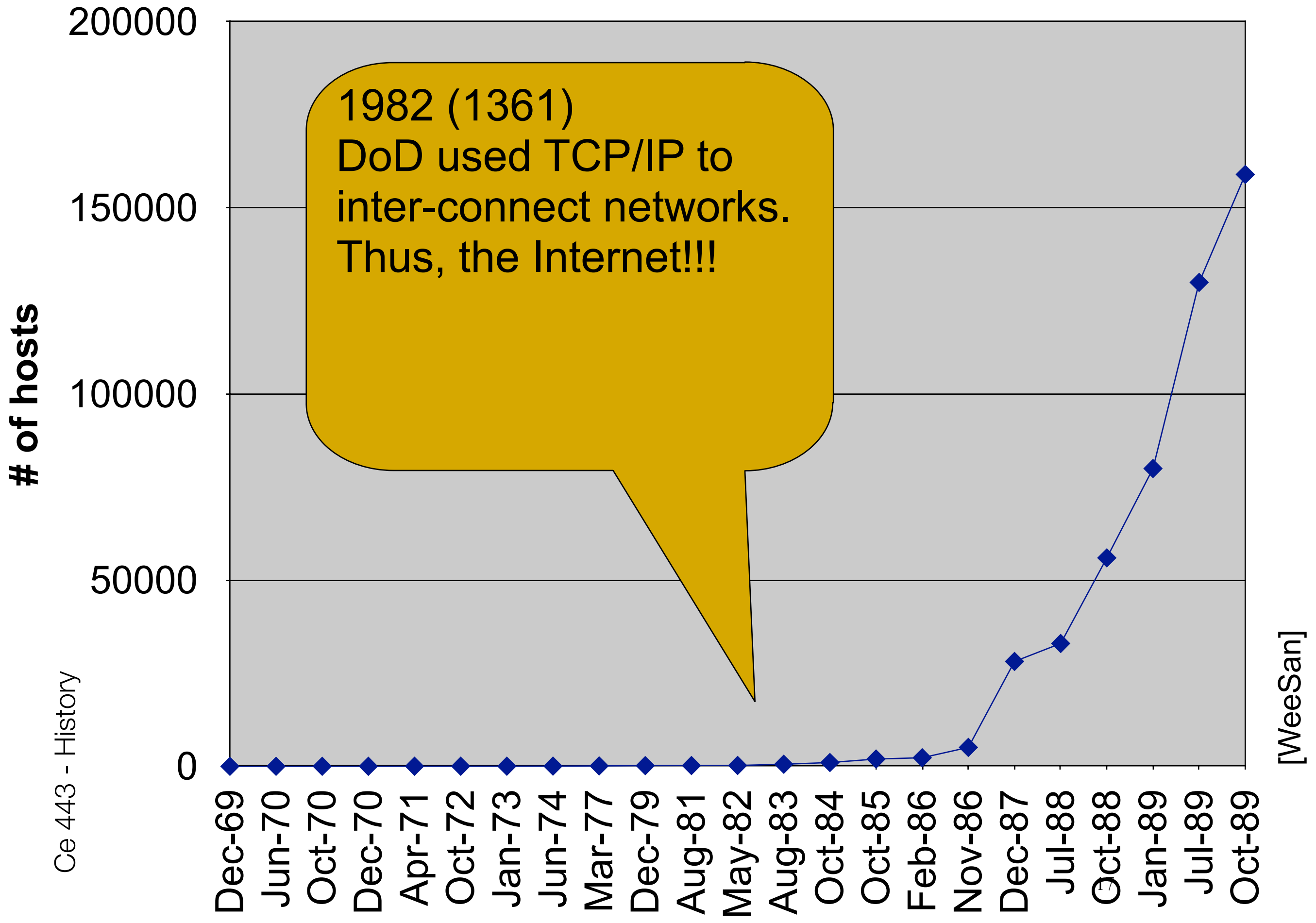
Internet Hosts



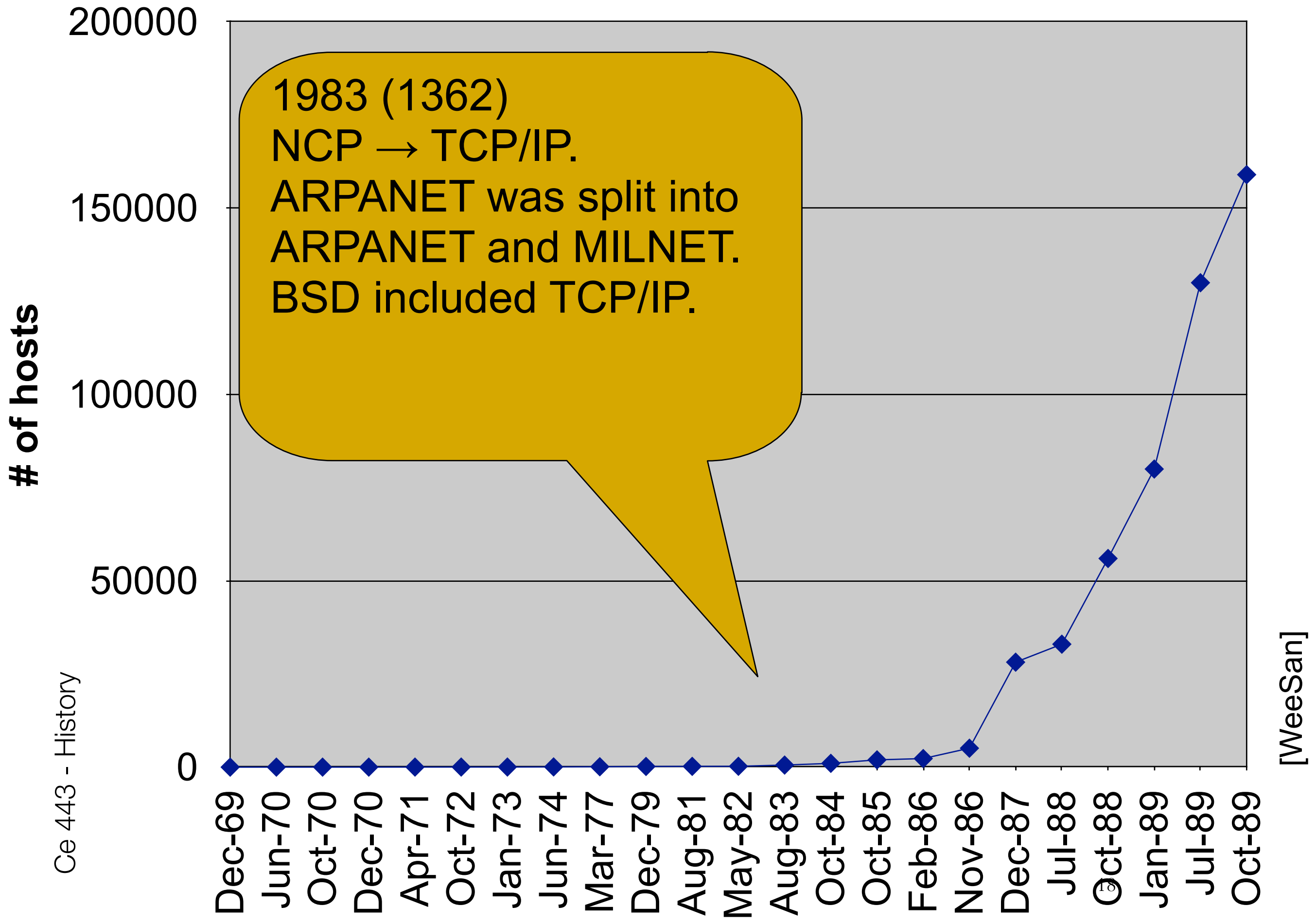
Ce 443 - History

[WeeSan]

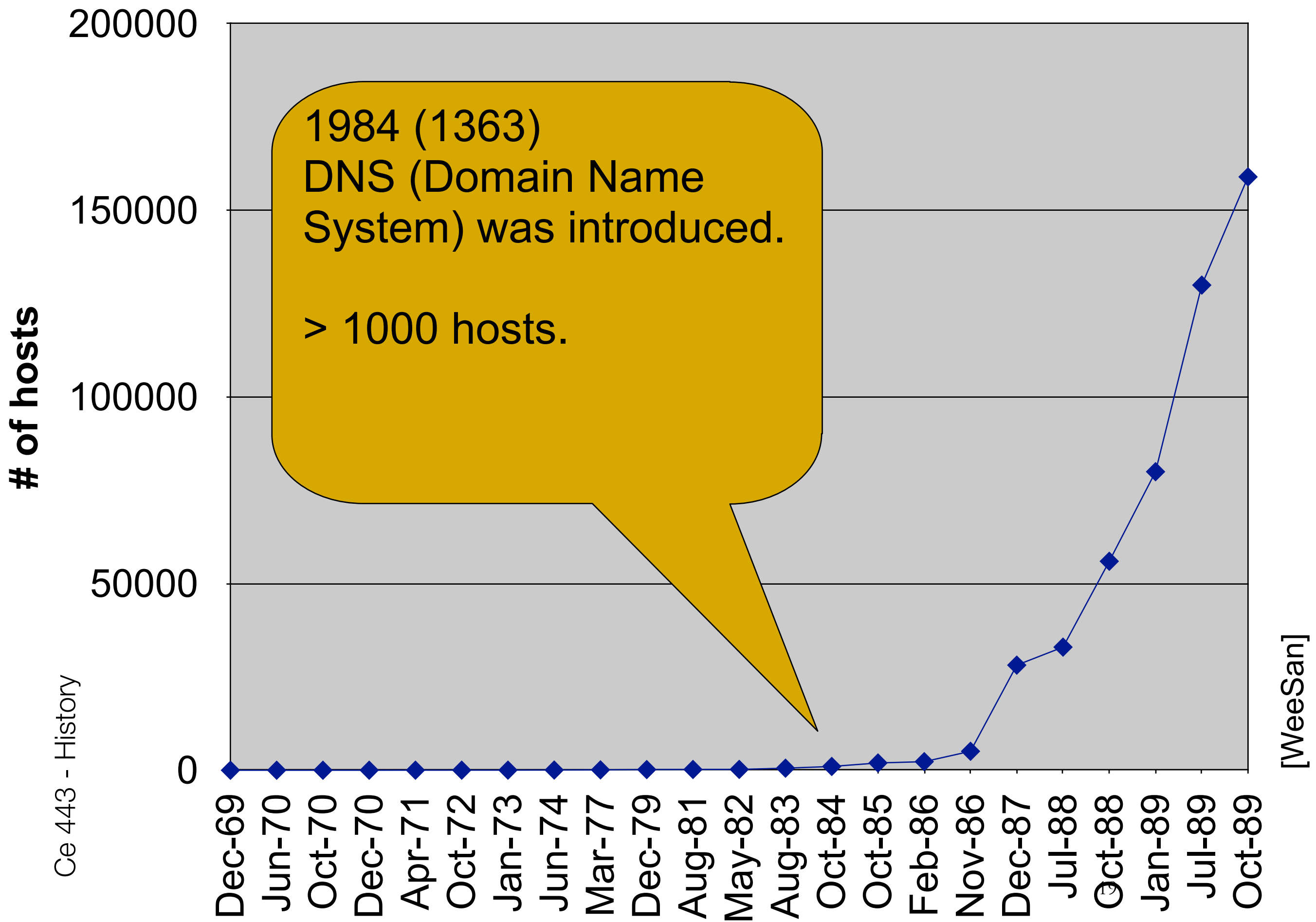
Internet Hosts



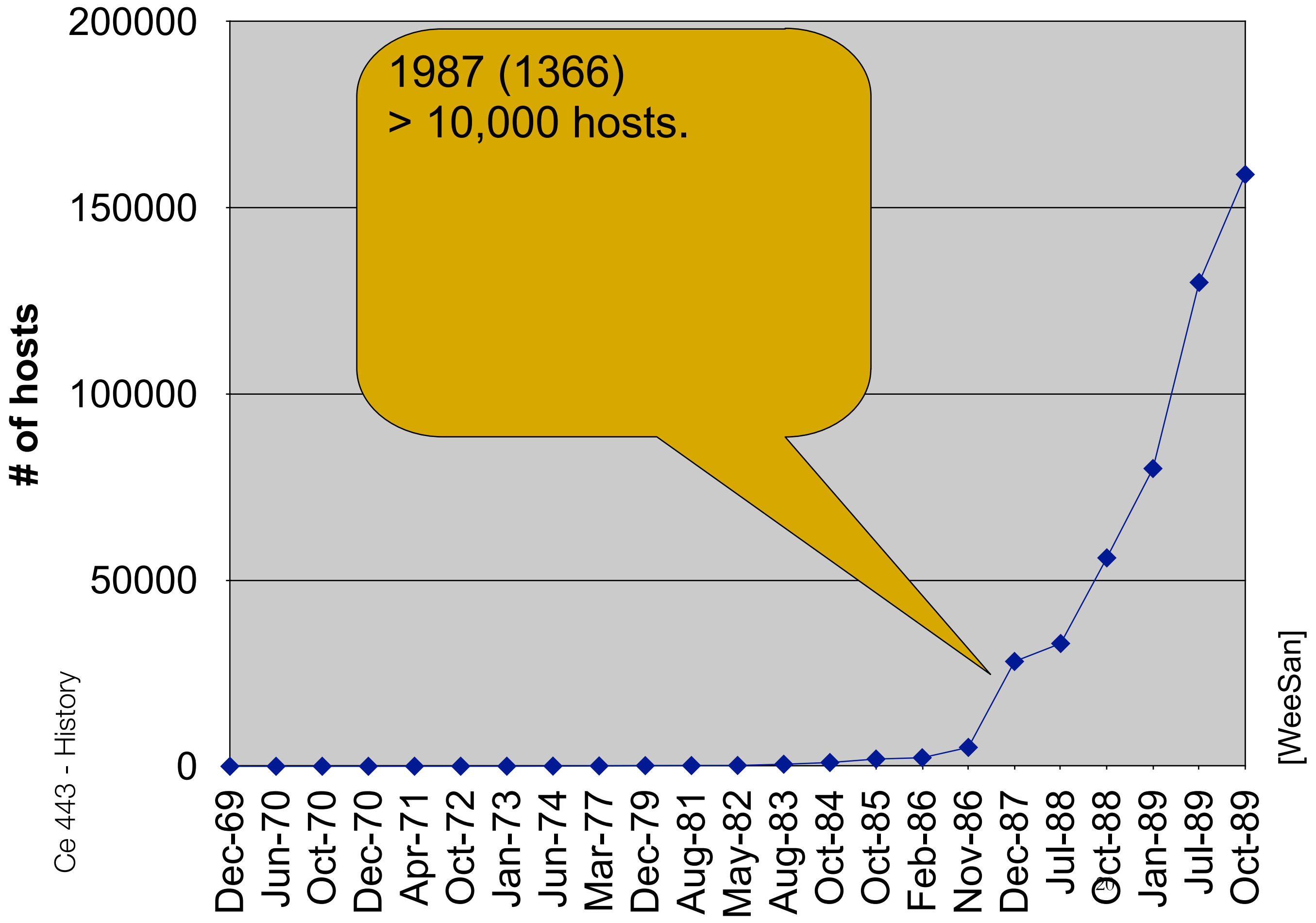
Internet Hosts



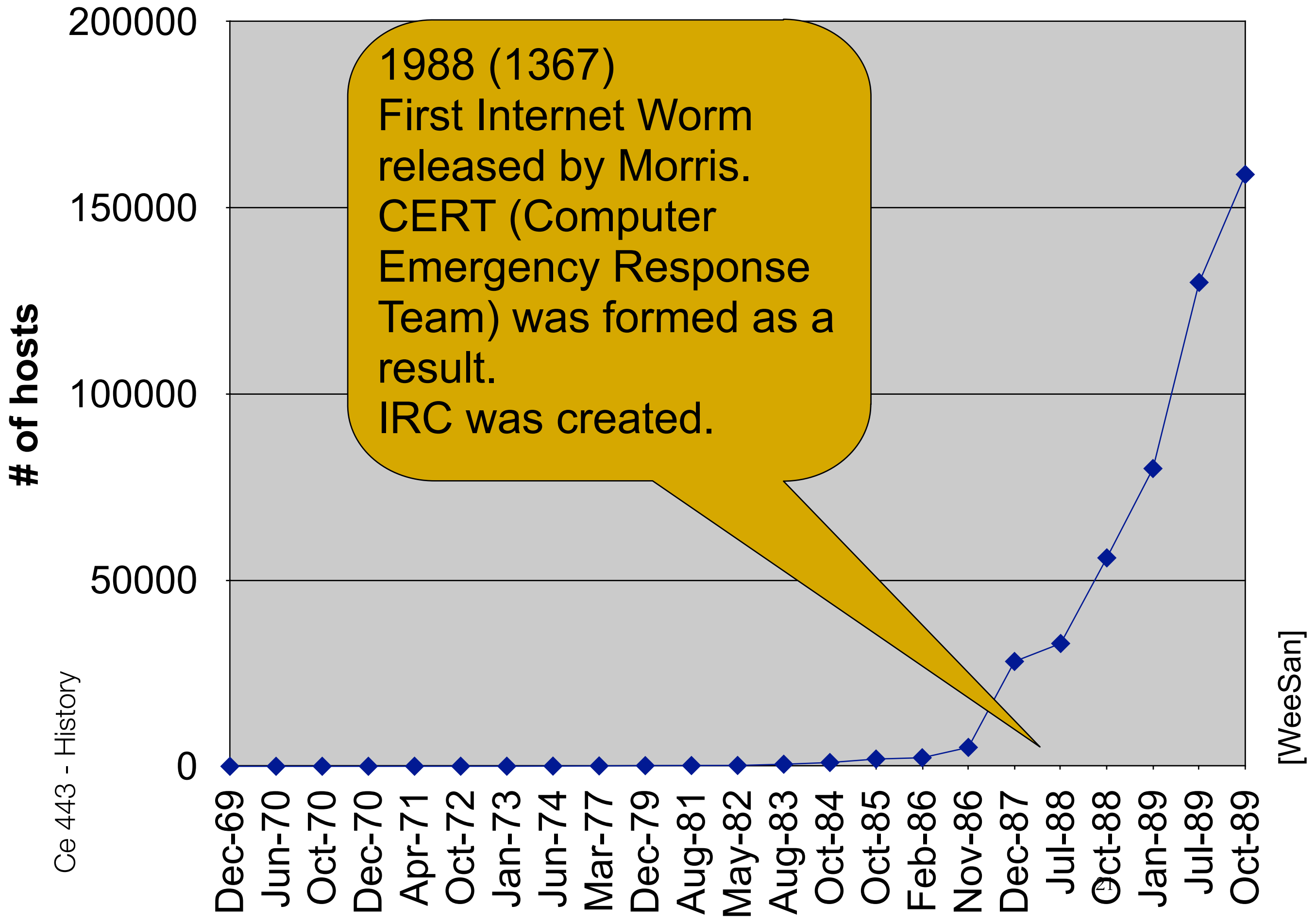
Internet Hosts



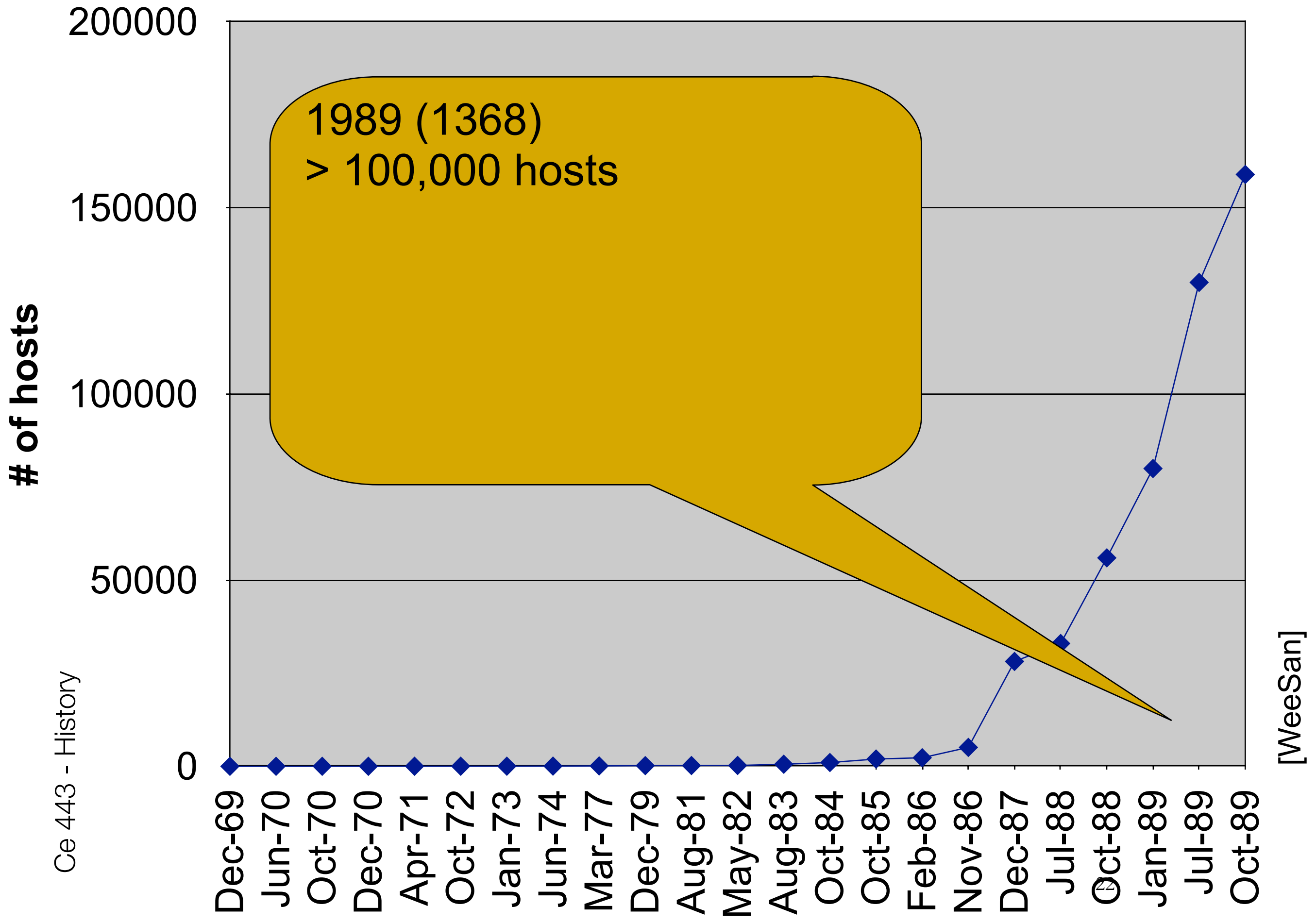
Internet Hosts



Internet Hosts



Internet Hosts



Internet Hosts

of hosts

20000000

15000000

10000000

5000000

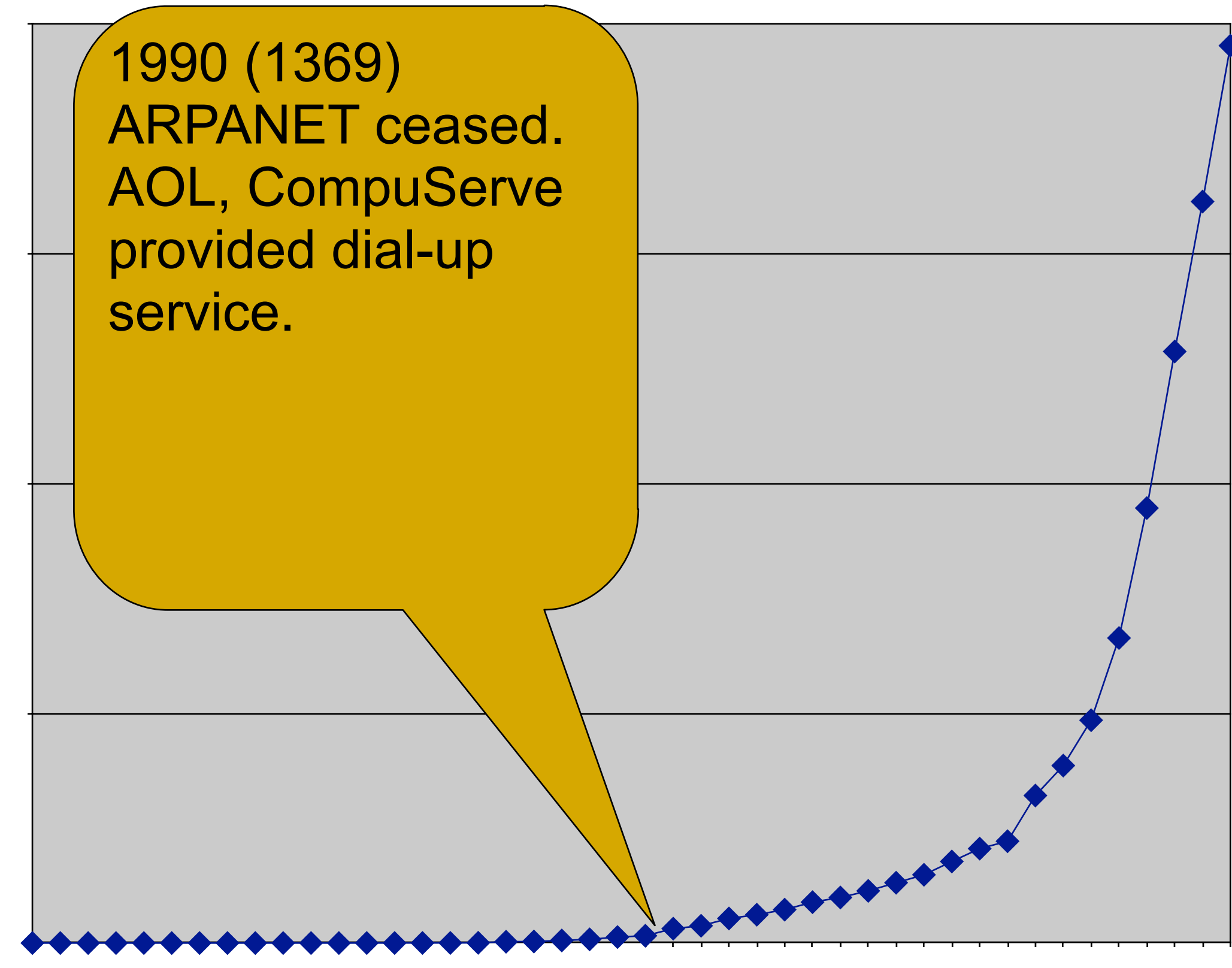
0

Dec-69
Oct-70
Apr-71
Jan-73
Mar-77
Aug-81
Aug-83
Oct-85
Nov-86
Jul-88
Jan-89
Oct-89
Jan-91
Oct-91
Apr-92
Oct-92
Apr-93
Oct-93
Jul-94
Jan-95
Jan-96
Jan-97

1990 (1369)
ARPANET ceased.
AOL, CompuServe
provided dial-up
service.

Ce 443 - History

[WeeSan]



Internet Hosts

of hosts

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10000000

5000000

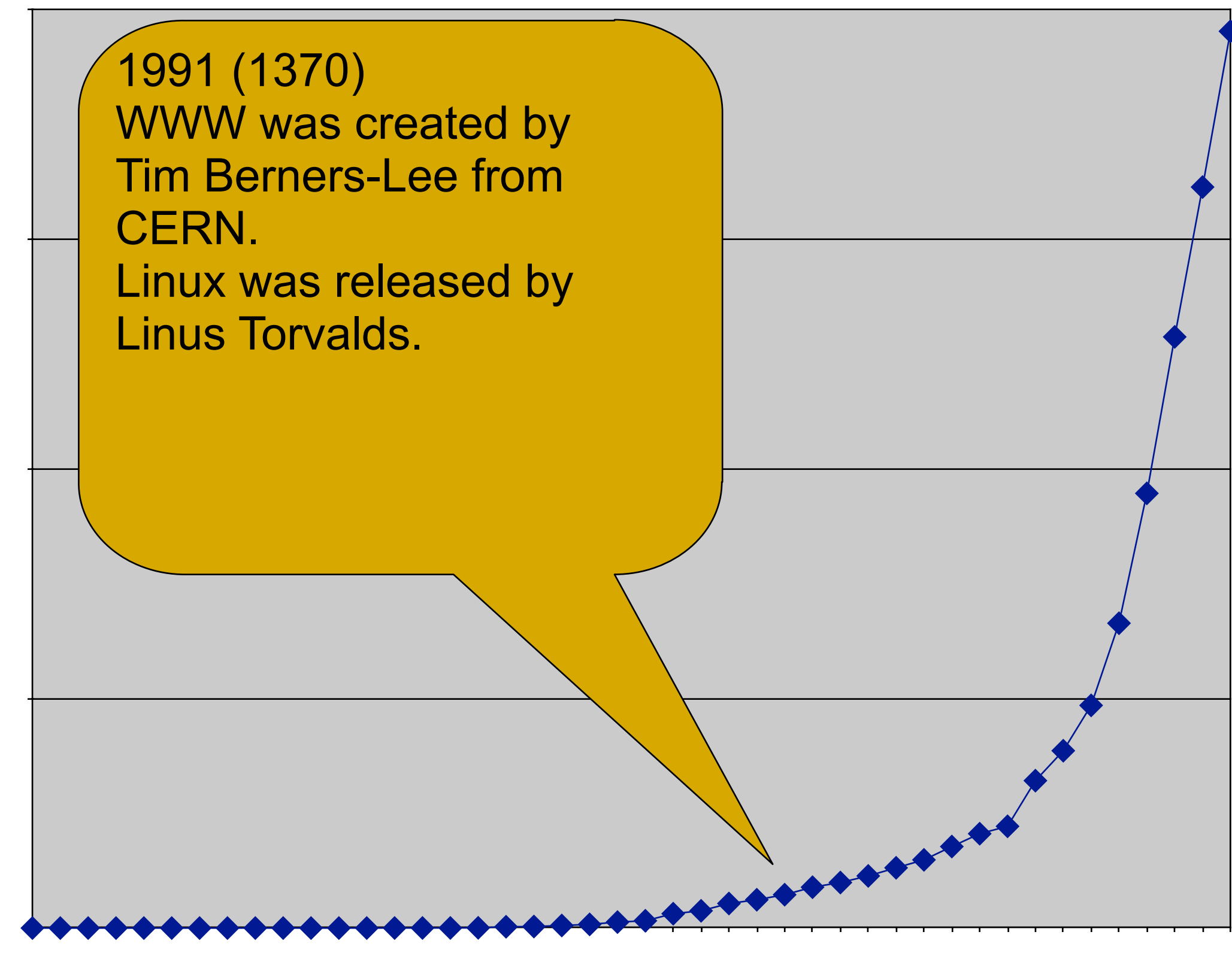
0

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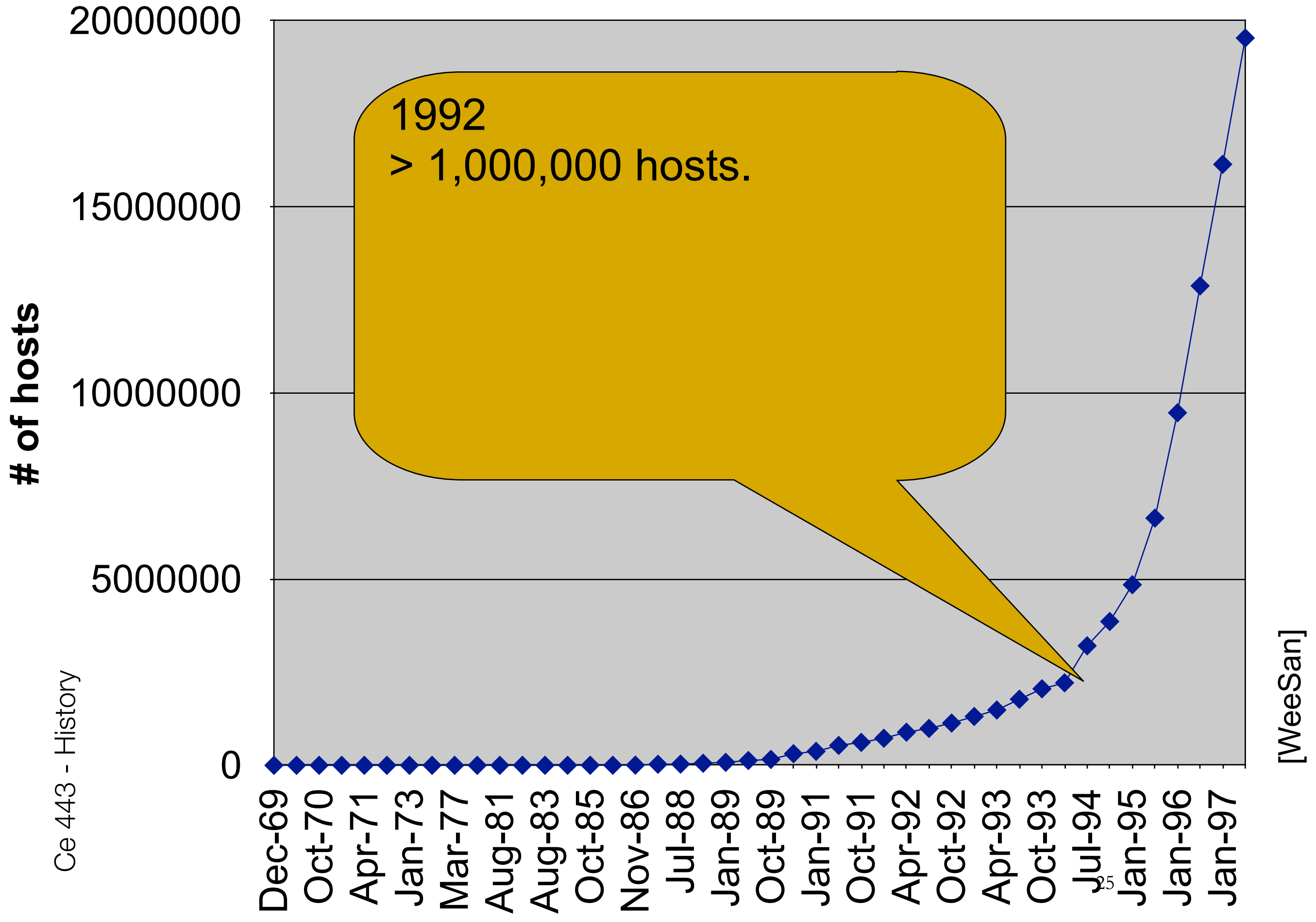
1991 (1370)
WWW was created by
Tim Berners-Lee from
CERN.
Linux was released by
Linus Torvalds.

Ce 443 - History

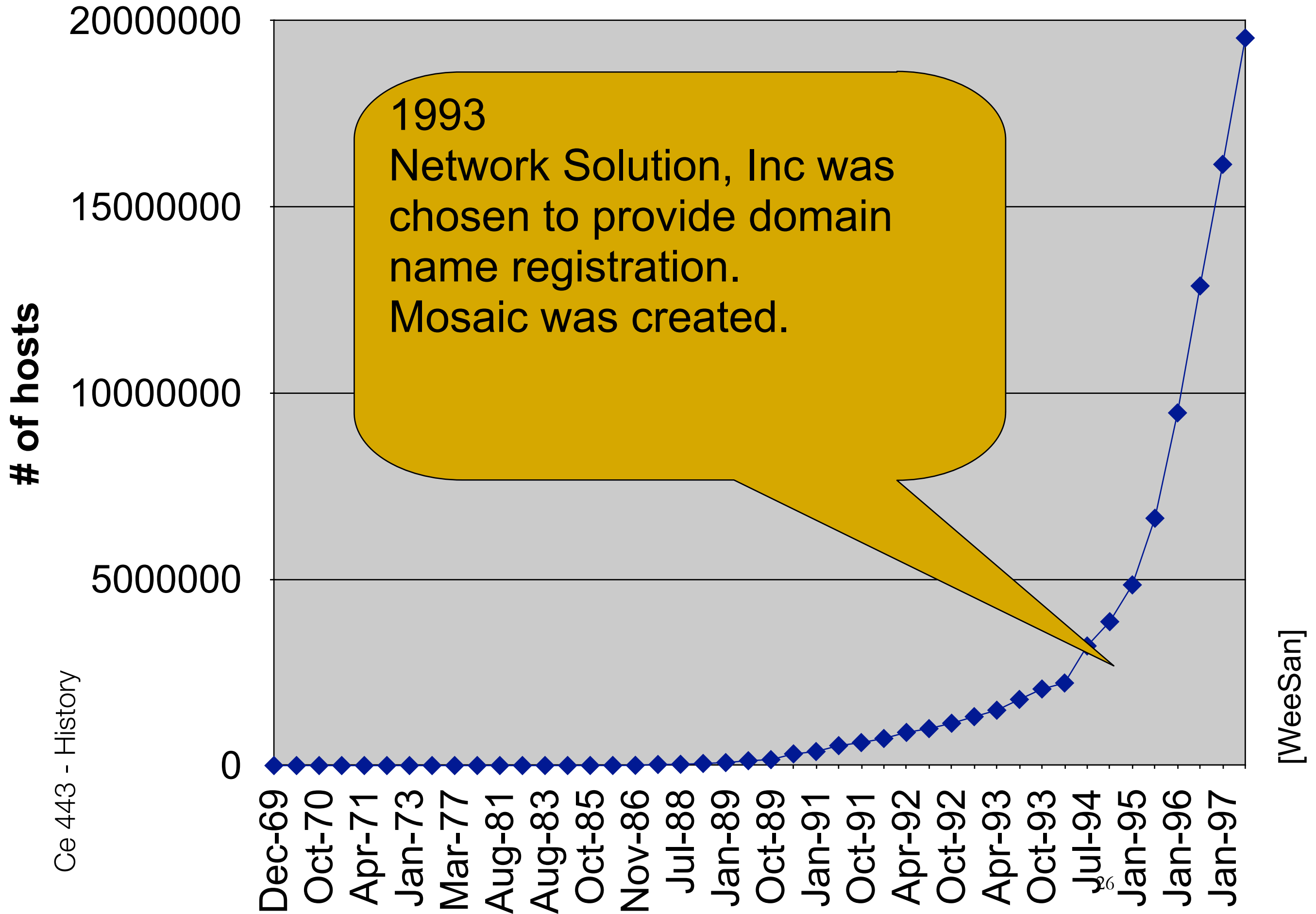
[WeeSan]



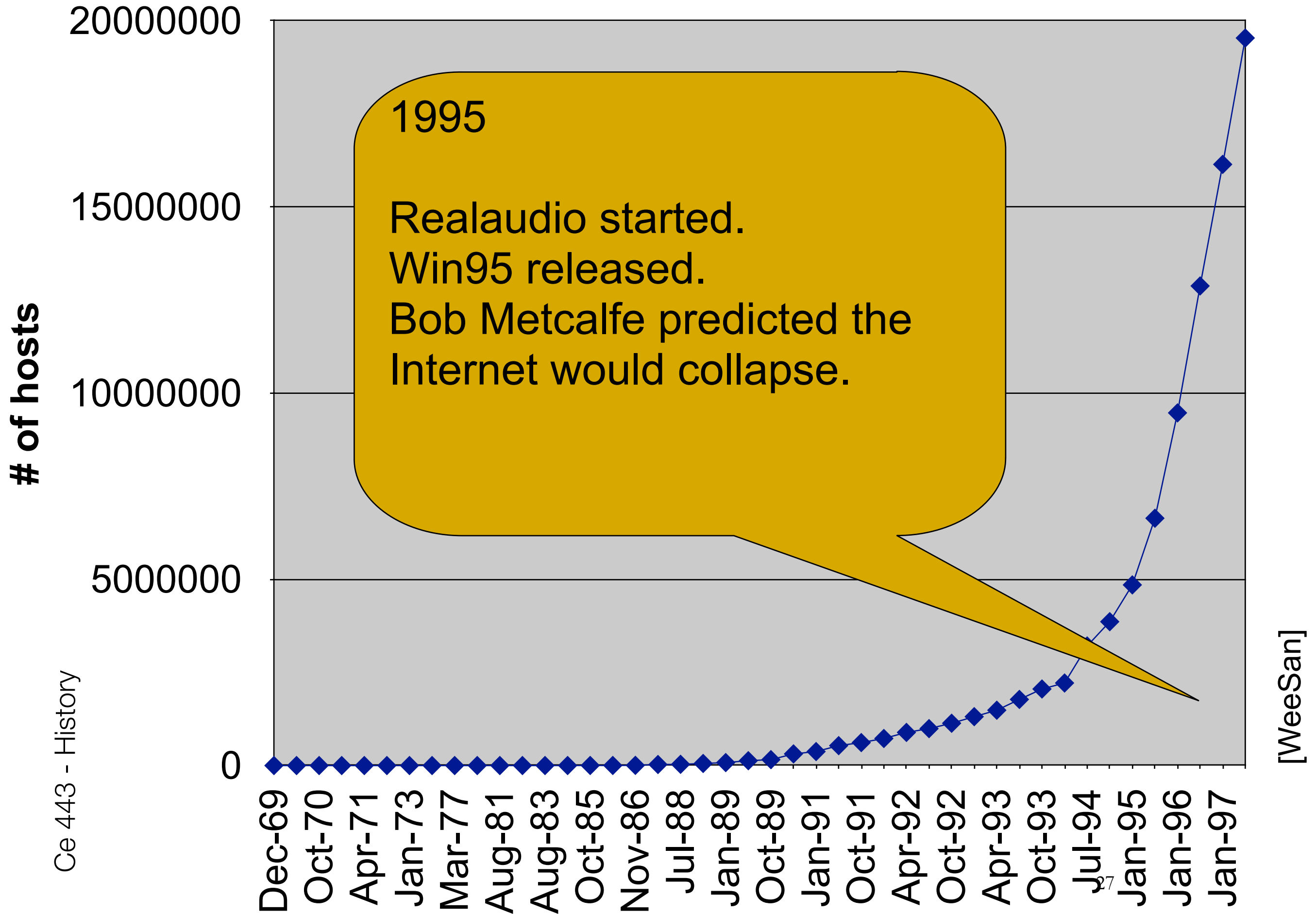
Internet Hosts



Internet Hosts



Internet Hosts



Internet Hosts

of hosts

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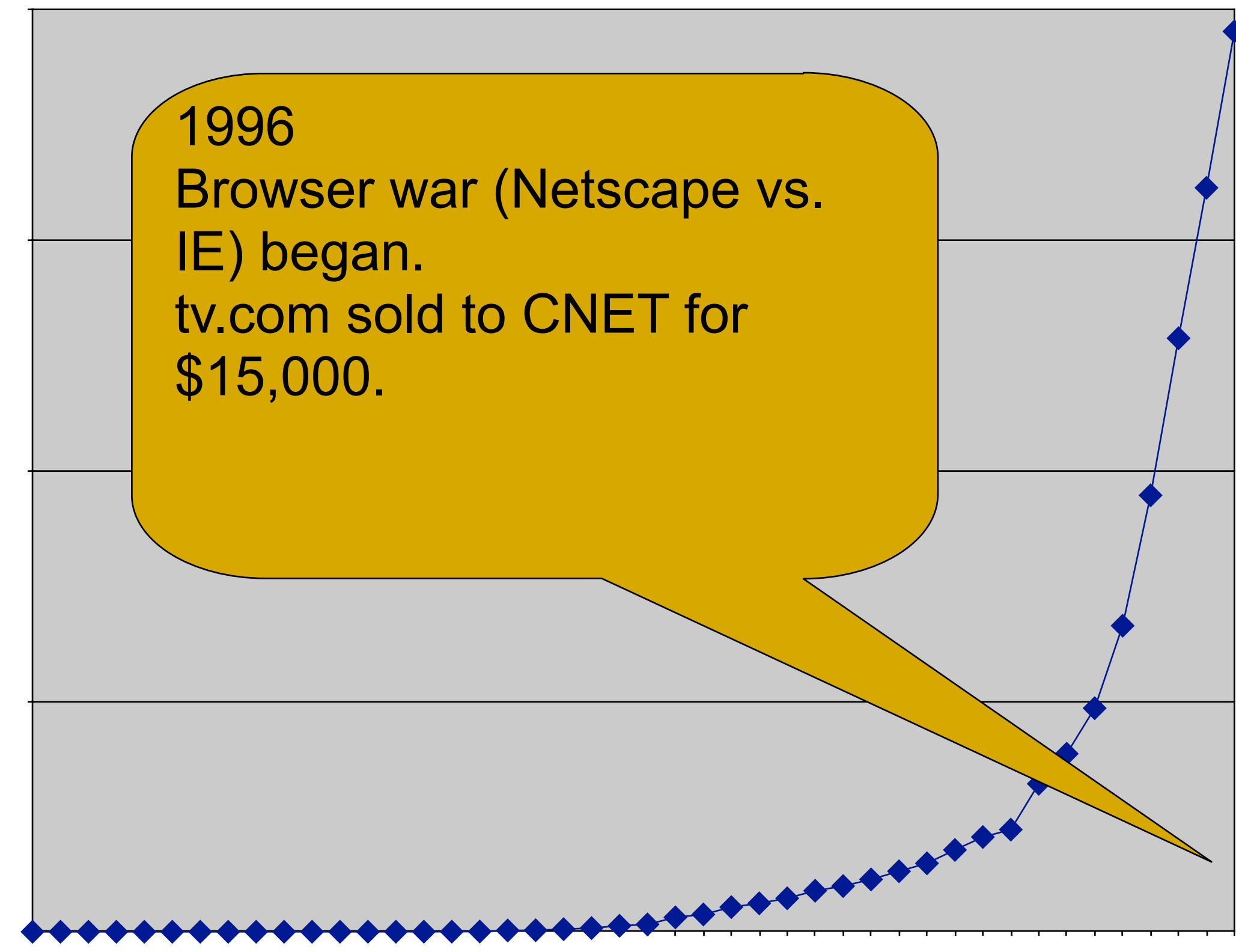
1996

Browser war (Netscape vs. IE) began.

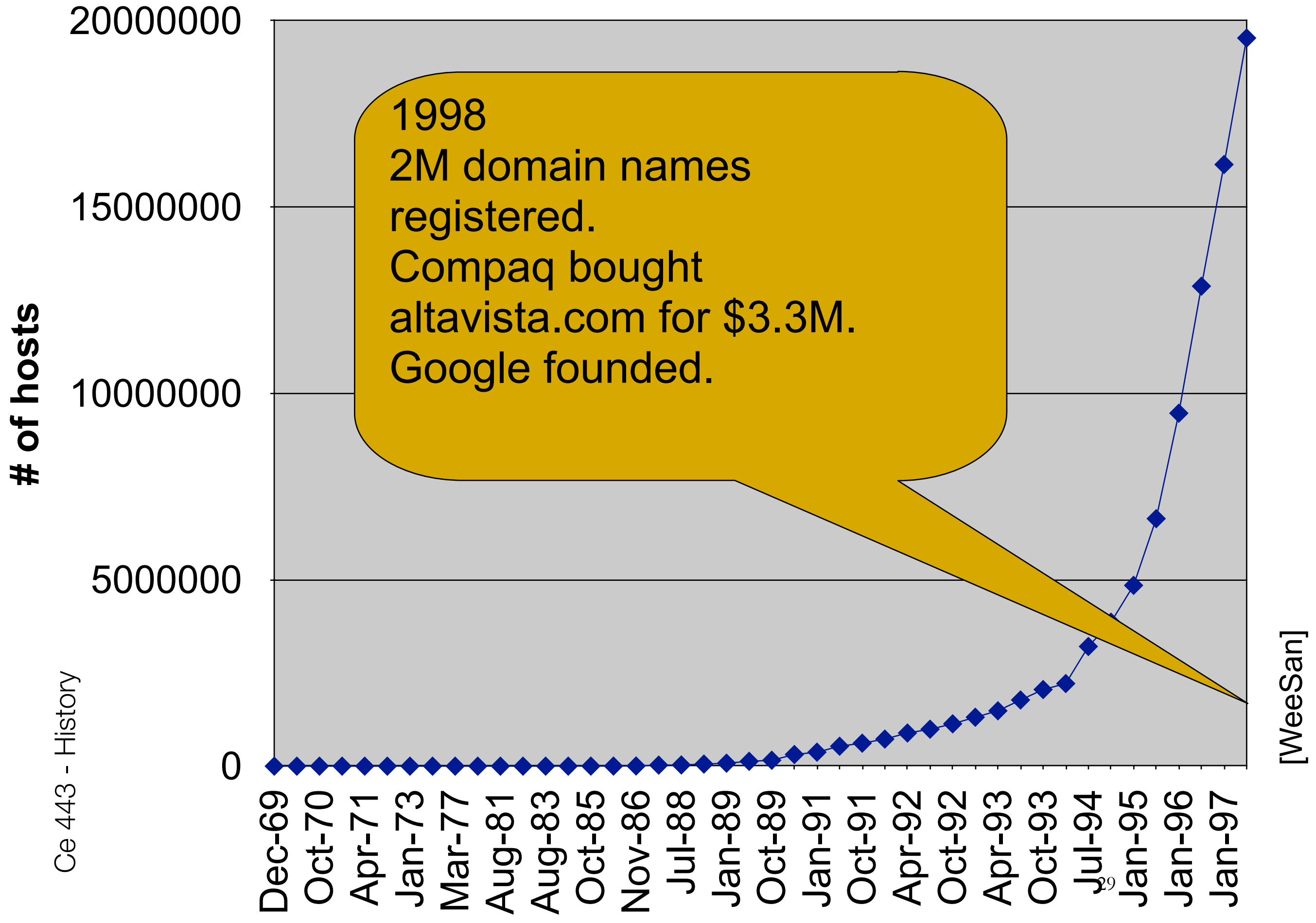
tv.com sold to CNET for \$15,000.

Ce 443 - History

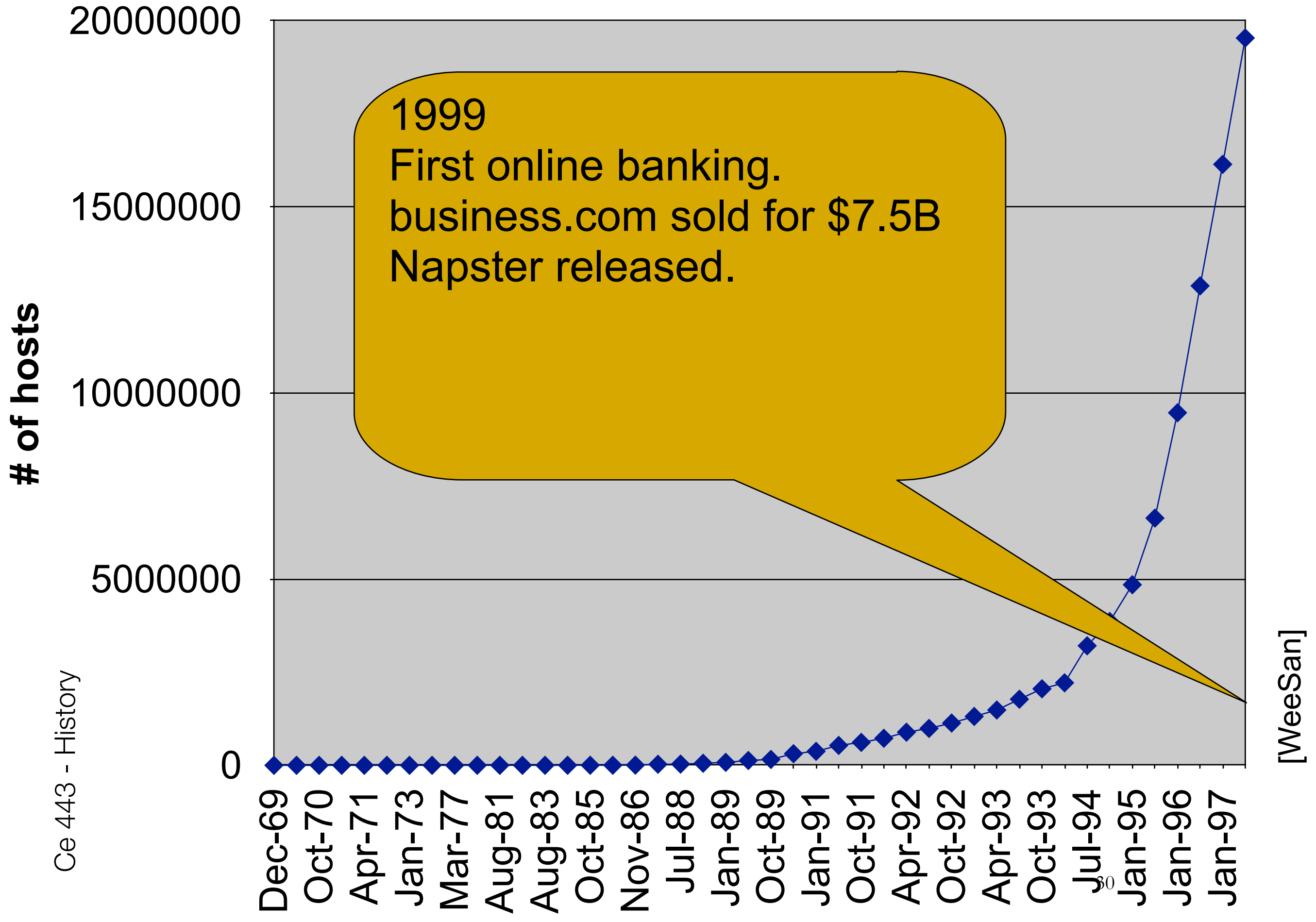
[WeeSan]



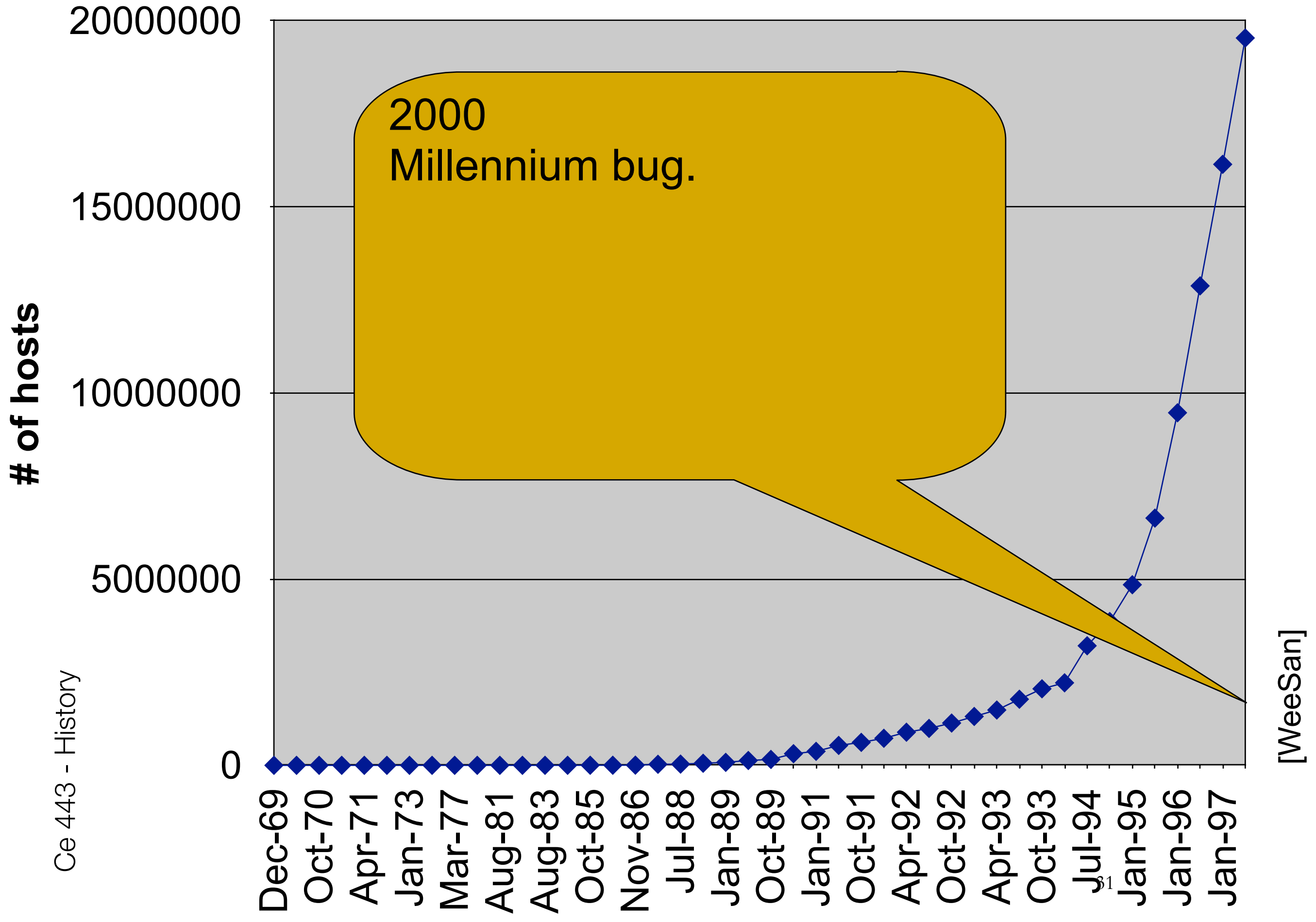
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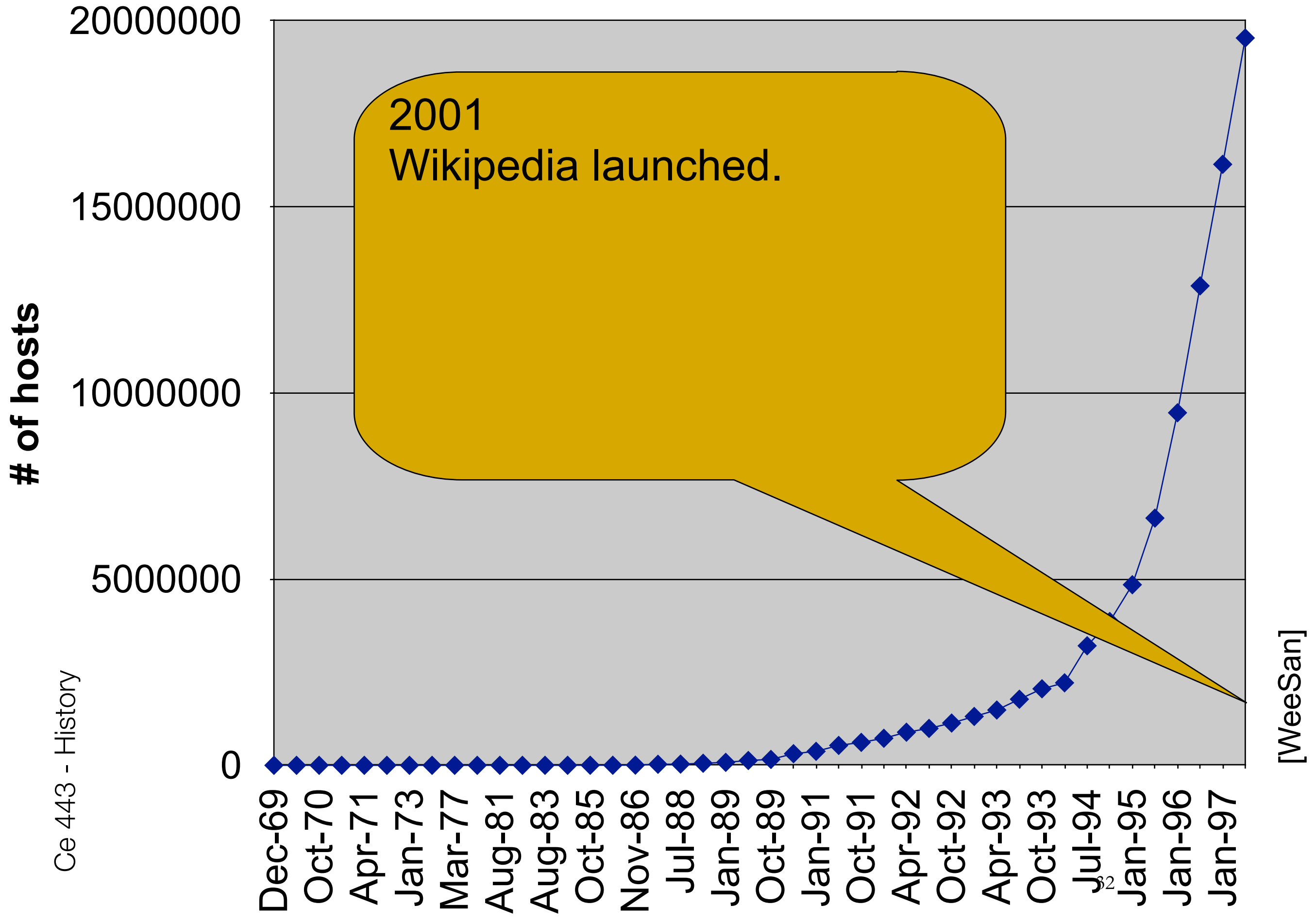
Internet Hosts



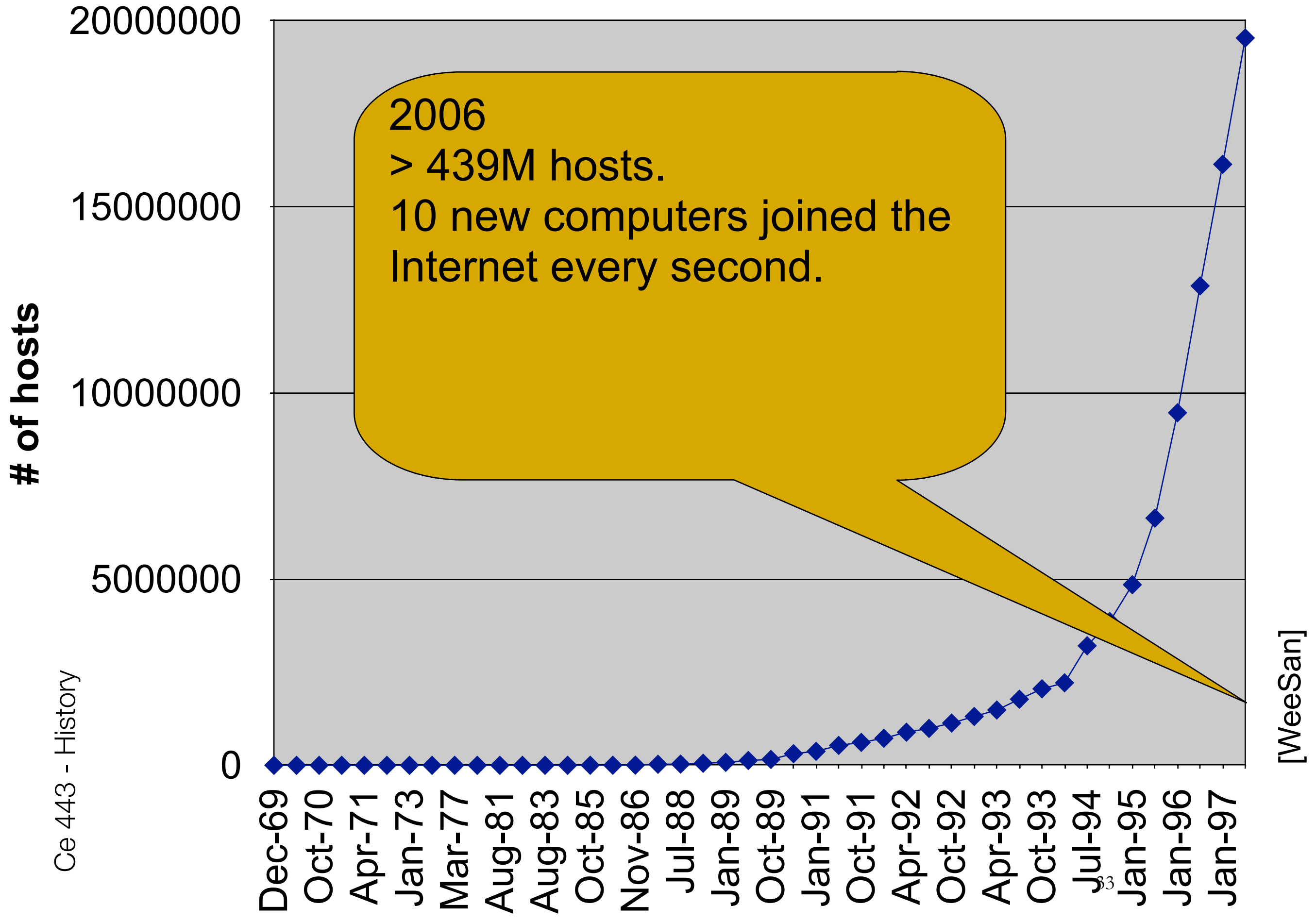
Internet Hosts



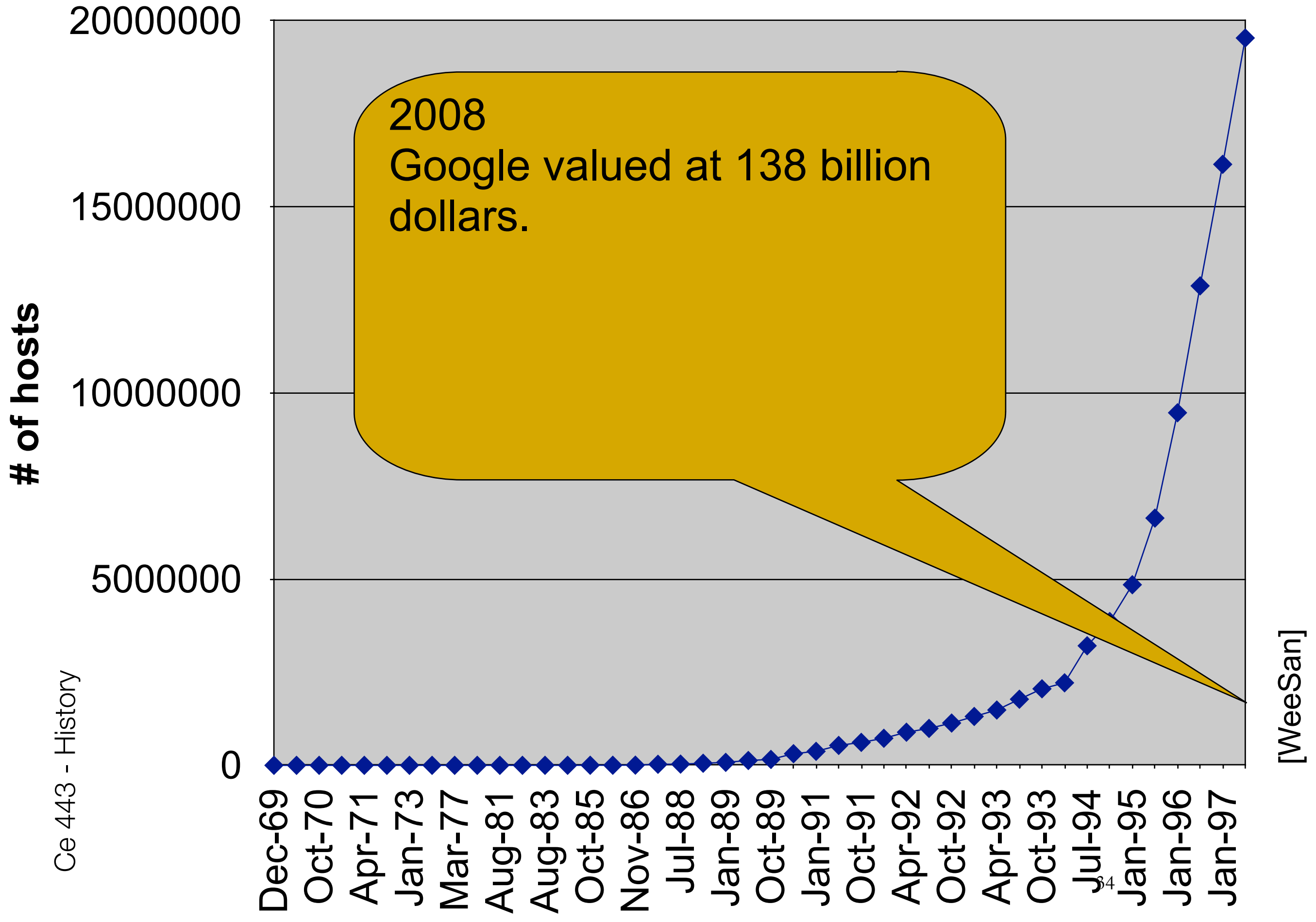
Internet Hosts

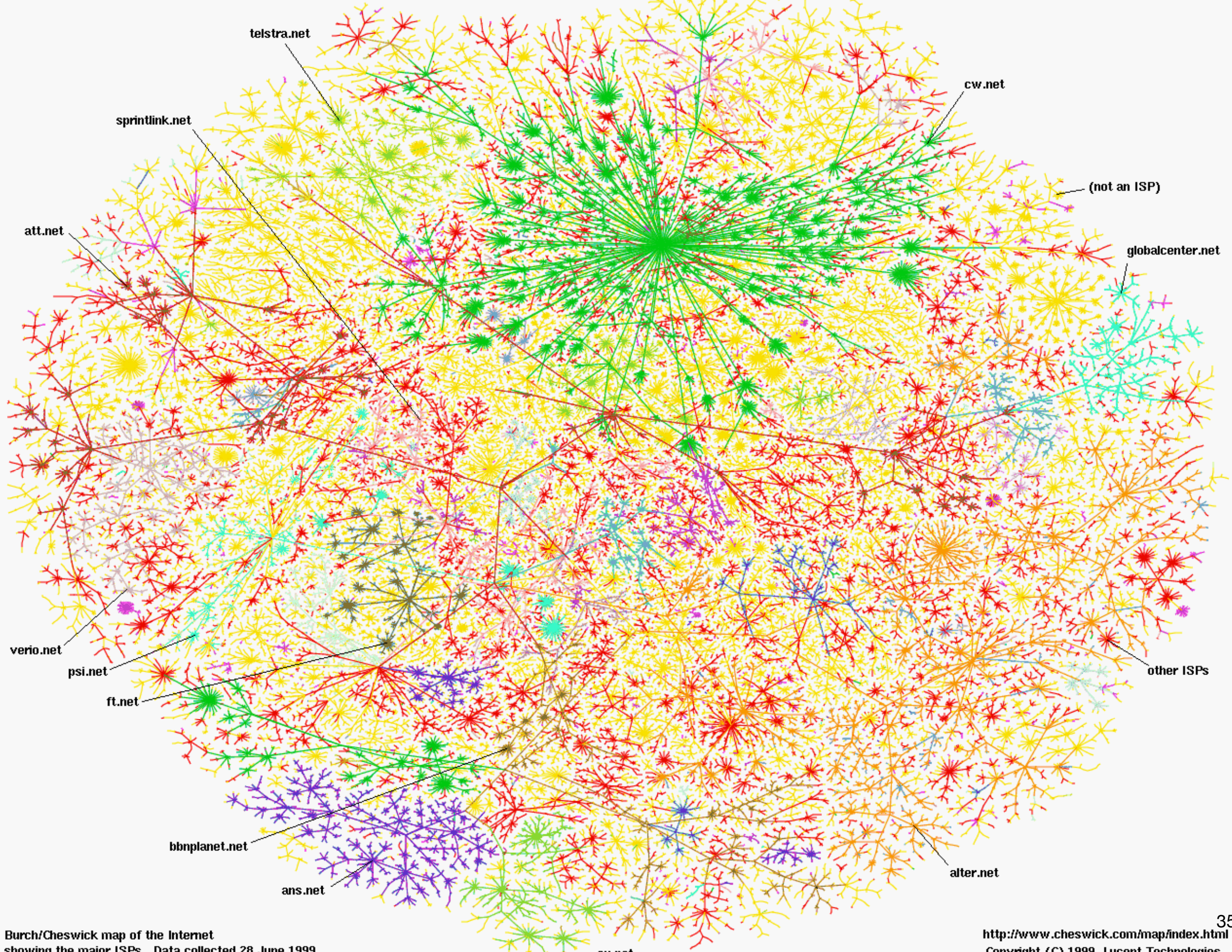


Internet Hosts

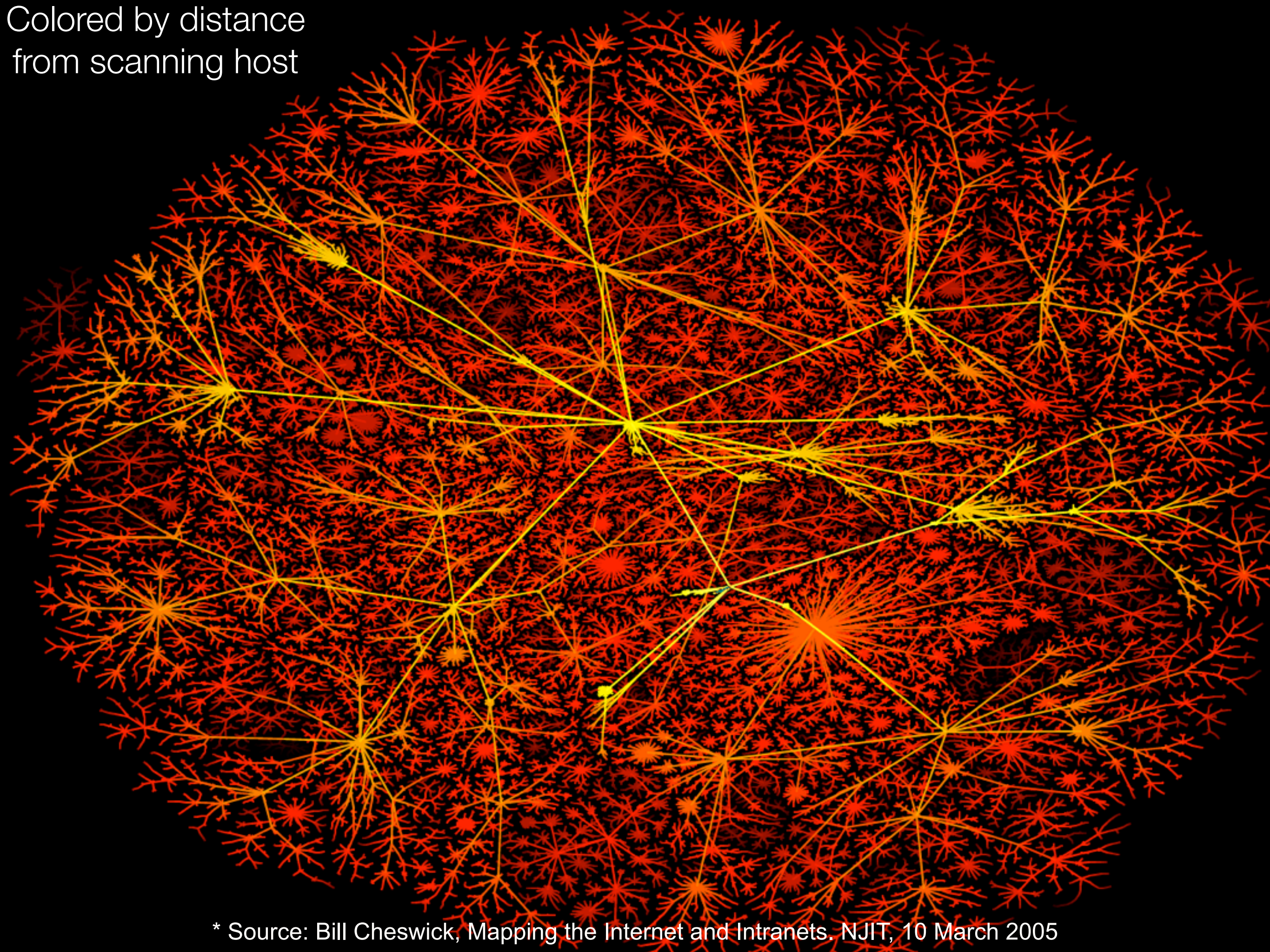


Internet Hosts





Colored by distance
from scanning host



* Source: Bill Cheswick, Mapping the Internet and Intranets, NJIT, 10 March 2005

New Applications

Email, remote terminal access (telnet) and file transfer (ftp) were the original ARPAnet applications.

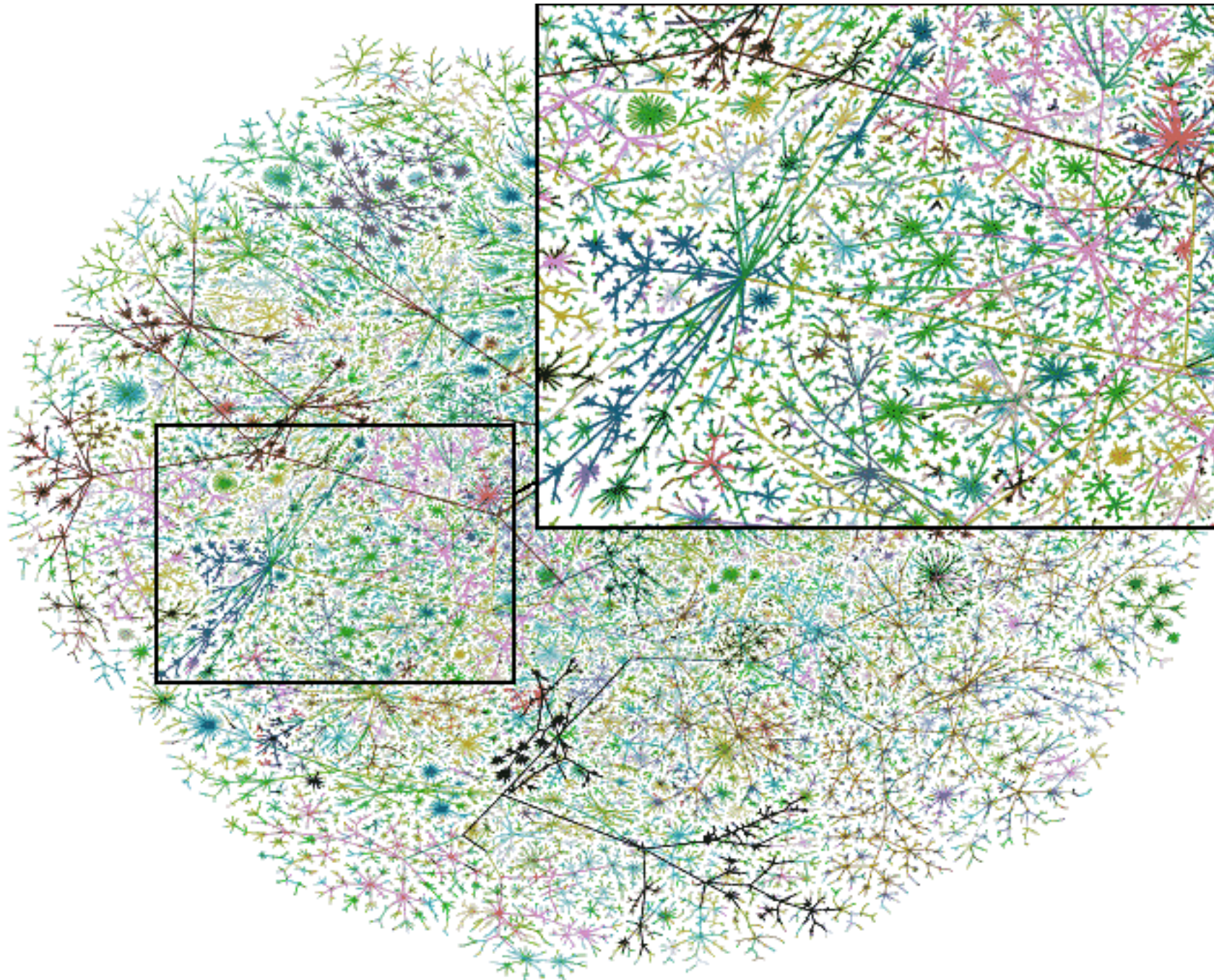
- **Audio/video** (1992...)
 - Telephony, conferencing, streaming media.
- **World Wide Web** (1993...)
 - browsing a mesh of hyperlinks.
 - Altavista search engine (Dec 1995)
- **Peer-to-peer** (2000...)
 - File sharing

Problem 1: Congestion

- Congestion Control matches offered load to available capacity.
 - TCP congestion control has done this since 1988
- **Problem:** insufficient dynamic range:
 - Slow and flaky wireless links.
 - Very high speed intercontinental paths.
- Some possible solutions do exist, but:
 - Change is hard, all solutions must interact well.
 - How to decide what is “good enough”?
 - How to get consensus on which solution to deploy?

Problem 2: Routing

(Internet map, 1999)



Source: Bill Cheswick, Lumeta

[Feamster15]

Problem 2: Routing

(which path to take through the net)

BGP4 is the only inter-domain routing protocol currently in use world-wide.

- Lack of security.
- Ease of misconfiguration.
- Policy through local filtering.
- Poorly understood interaction between local policies.
- Poor convergence.
- Lack of appropriate information hiding.
- Non-determinism.
- Poor overload behaviour.

Problem 3: Security

- We're reasonably good at encryption and authentication.
 - Not so good at actually turning these mechanisms on.
- We're rather bad at key management.
 - Hierarchical PKIs rather unsuccessful.
 - Keys are a single point of failure.
 - Key revocation.
- We're really bad at deploying secure software in secure configurations.
 - No good way to manage epidemics.
 - Flash worm: infect all vulnerable servers on the Internet in 30 seconds.

Problem 4: Availability/ Denial of Service

- The Internet does a great job of transmitting packets to a destination.
 - Even if the destination doesn't want those packets.
 - Overload servers or network links to prevent the victim doing useful work.
- Distributed Denial of Service becoming commonplace.
 - Automated scanning results in armies of compromised zombie hosts being available for coordinated attacks.

Details on the Course



Administrivia

- Website:
 - sharif.edu/~kharrazi/courses/40443-942/
 - You are expected to check the website regularly
- Textbook:
 - Computer Networks: A Systems Approach (Fourth Edition), by Larry L. Peterson, Bruce S. Davie, March 2007.
- Prerequisites: 40-181 Probability and Statistics
- Corequisites: 40-424 Operating Systems



Administrivia

- TAs
 - Solmaz Salimi
 - .
 - .

- Grading
 - 10% quiz
 - 40% homework
 - 20% midterm
 - 30% final



Policies

- Late Homework
 - One day late will cost you 25%, two days 50%, and three days 75%.
 - No homework will be accepted after the third day.
- Cell phones
 - Please turn them off before entering class.
- Cheating and Copying
 - First time you are caught you will get a zero for the task at hand.
 - Second time you are caught you will fail the course.
 - Providing your assignment to someone else is considered cheating on your behalf.



Acknowledgments/References

- [WeeSan] History of the Internet, WeeSan Lee weesan@cs.ucr.edu, www.cs.ucr.edu/~weesan/cs6/01_history_of_the_internet.ppt
- [Zhang07] Hui Zhang, 15-441 Networking, Fall 2007, School of computer science, CMU.
- [Peterson07] Computer Networks: A Systems Approach (Fourth Edition), by Larry L. Peterson, Bruce S. Davie, March 2007.
- [Feamster15] Computer Networks, COS 461, Princeton University Spring 2015.