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

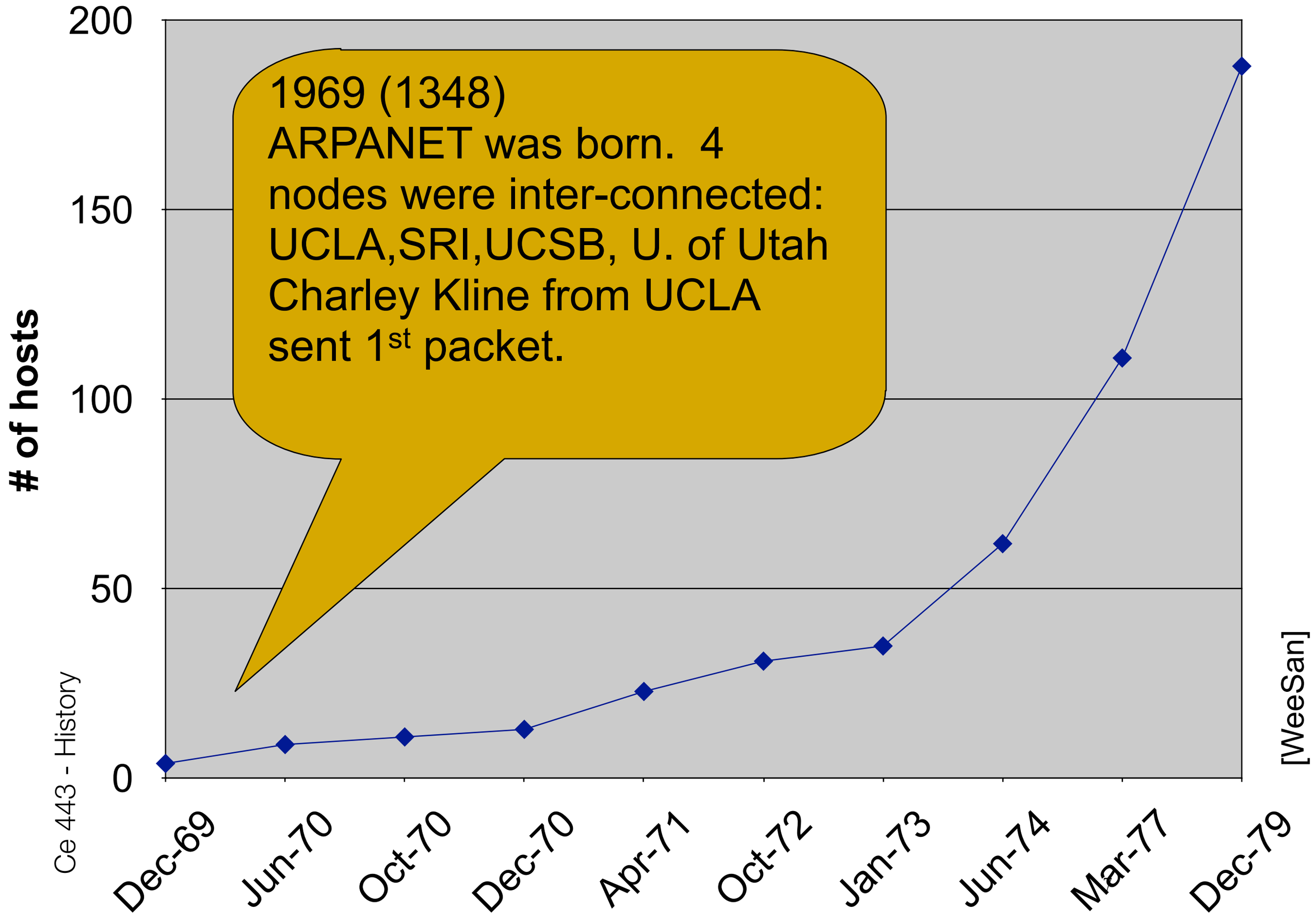
- 1827 (1206) Ohm's Law
- 1837 (1216) "Workable" telegraph invented by Samuel Morse
- 1838 (1217) demonstration over 16 kilometers at 10 w.p.m.
- 1851 (1230) Western Union founded
- 1868 (1247) Transatlantic cable laid
- 1876 (1255) Alexander Bell invented the telephone
- 1885 (1264) AT&T formed
- 1892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

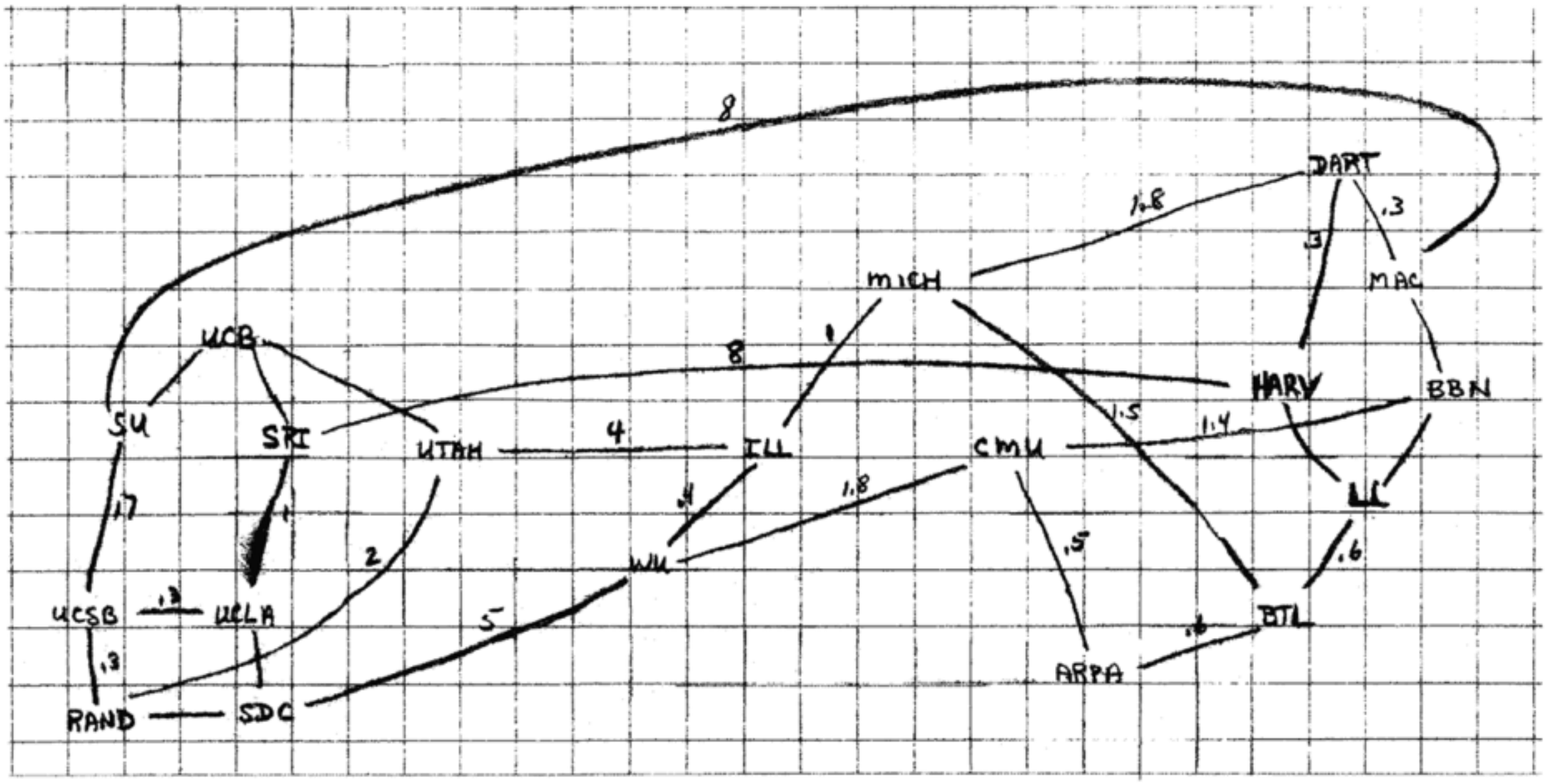
1969 (1348)
ARPANET was born. 4 nodes were inter-connected: UCLA,SRI,UCSB, U. of Utah
Charley Kline from UCLA sent 1st packet.



[WeeSan]

ARPAnet plan

- Rough sketch by Larry Roberts, late 1960s.



[Feamster15]

Internet Hosts

1970 (1349)
ARPANET used NCP
(Network Control Protocol),
first end-to-end protocol

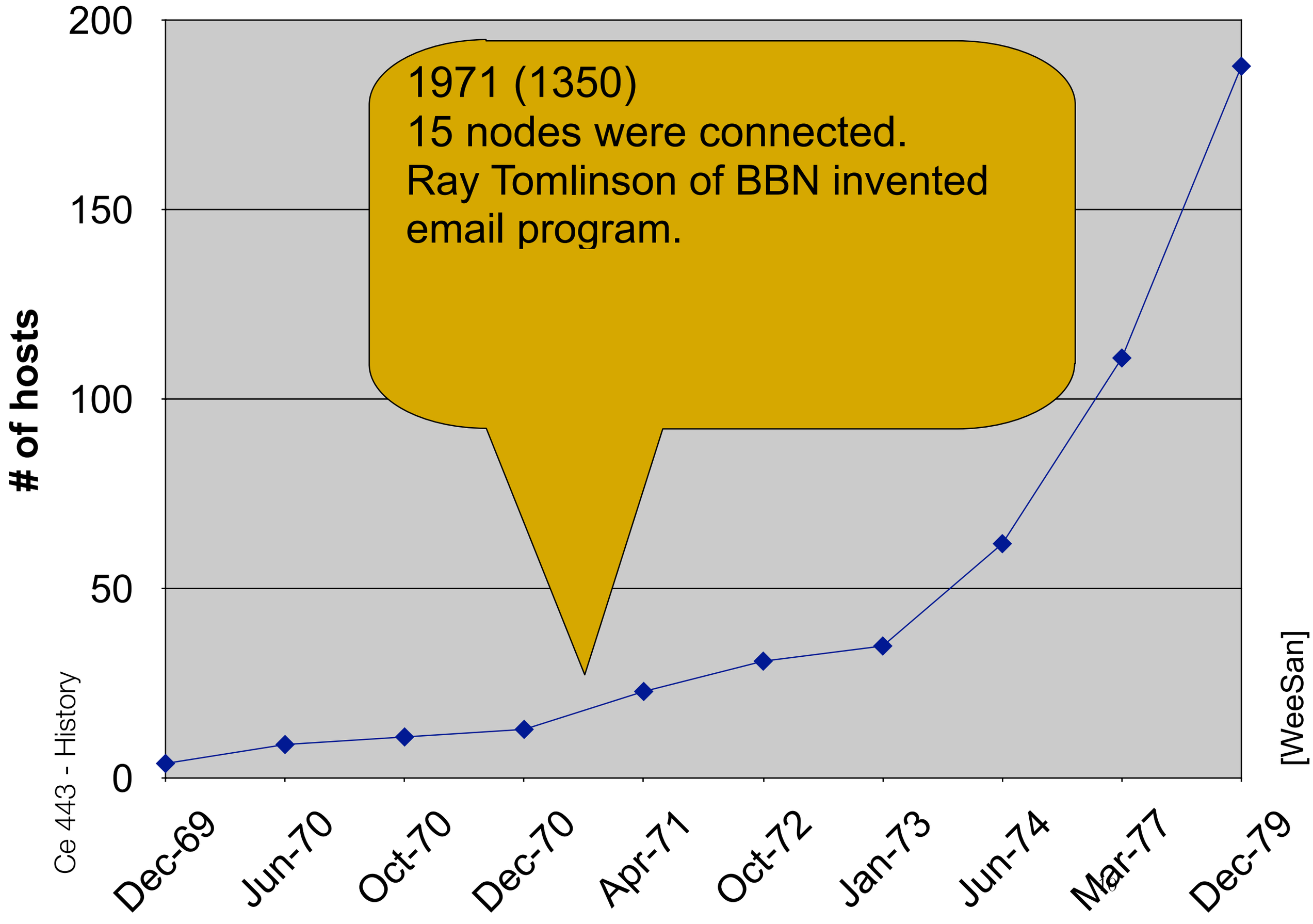
# of hosts

200
150
100
50
0

Dec-69
Jun-70
Oct-70
Dec-70
Apr-71
Oct-72
Jan-73
Jun-74
Mar-77
Dec-79

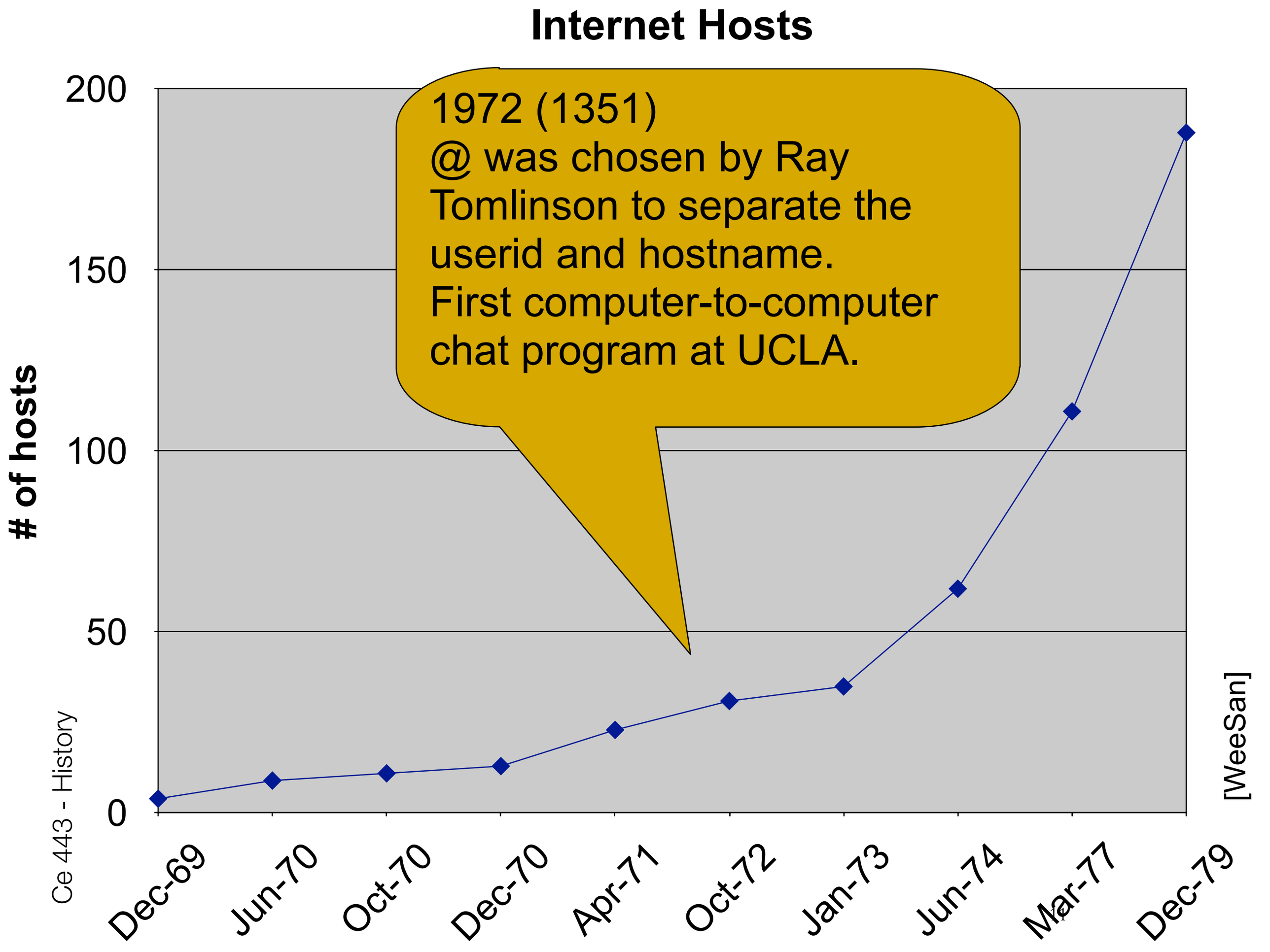
[WeeSan]

Internet Hosts

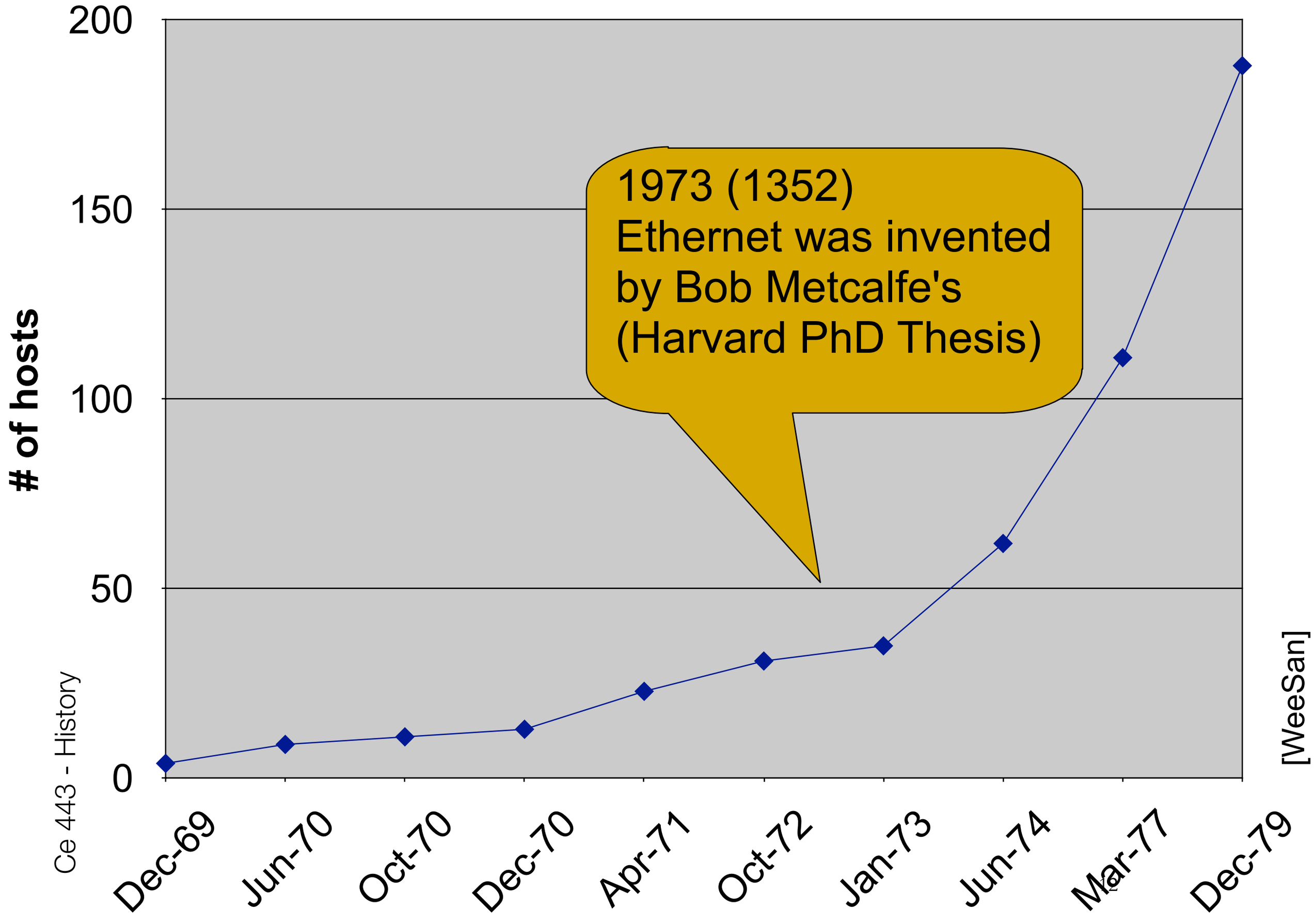


Internet Hosts

1972 (1351)
@ was chosen by Ray Tomlinson to separate the userid and hostname.
First computer-to-computer chat program at UCLA.

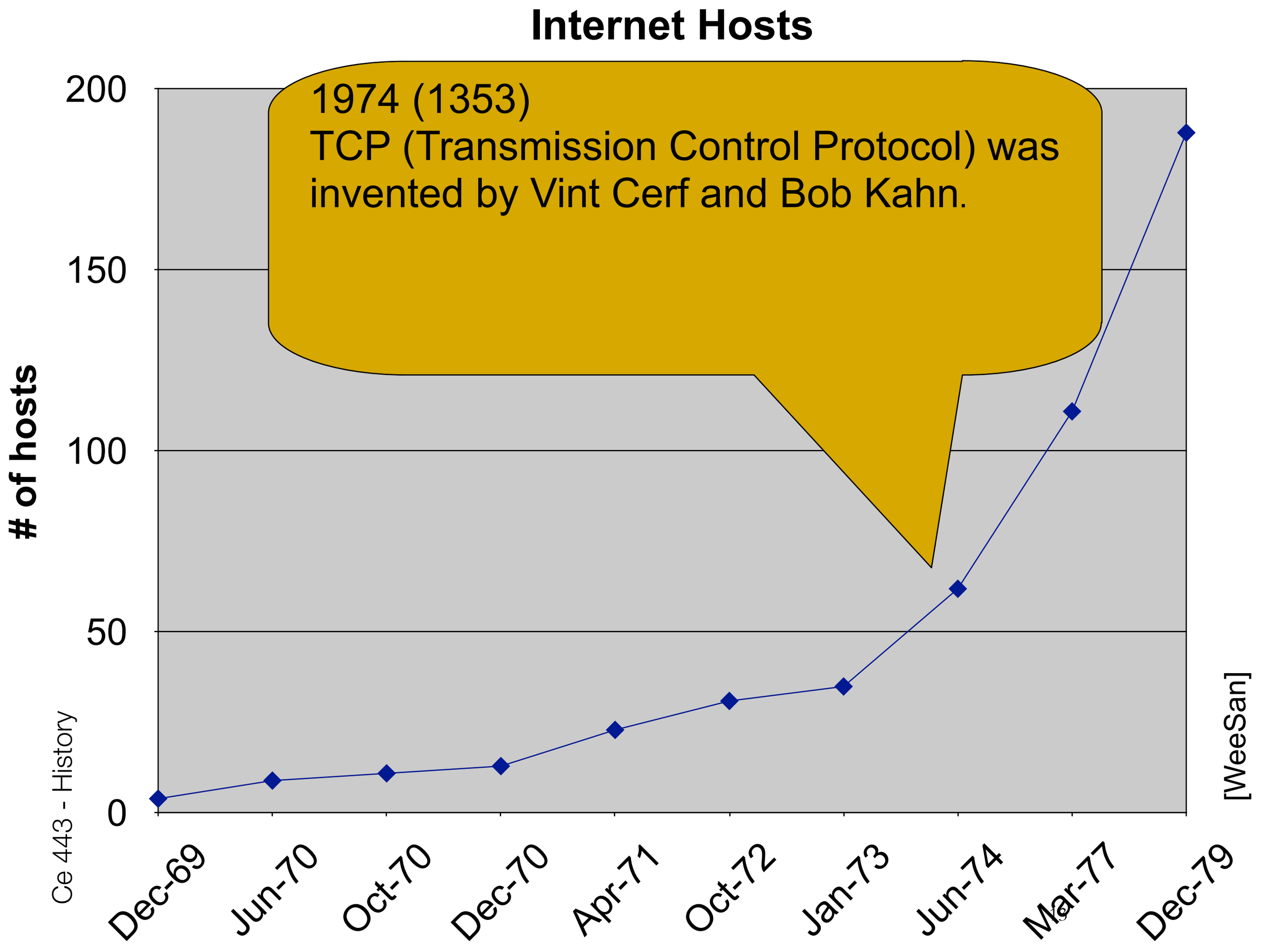


Internet Hosts



Internet Hosts

1974 (1353)
TCP (Transmission Control Protocol) was invented by Vint Cerf and Bob Kahn.



Internet Hosts

1975 (1354)
First mailing list was created
by Steve Walker.

# of hosts

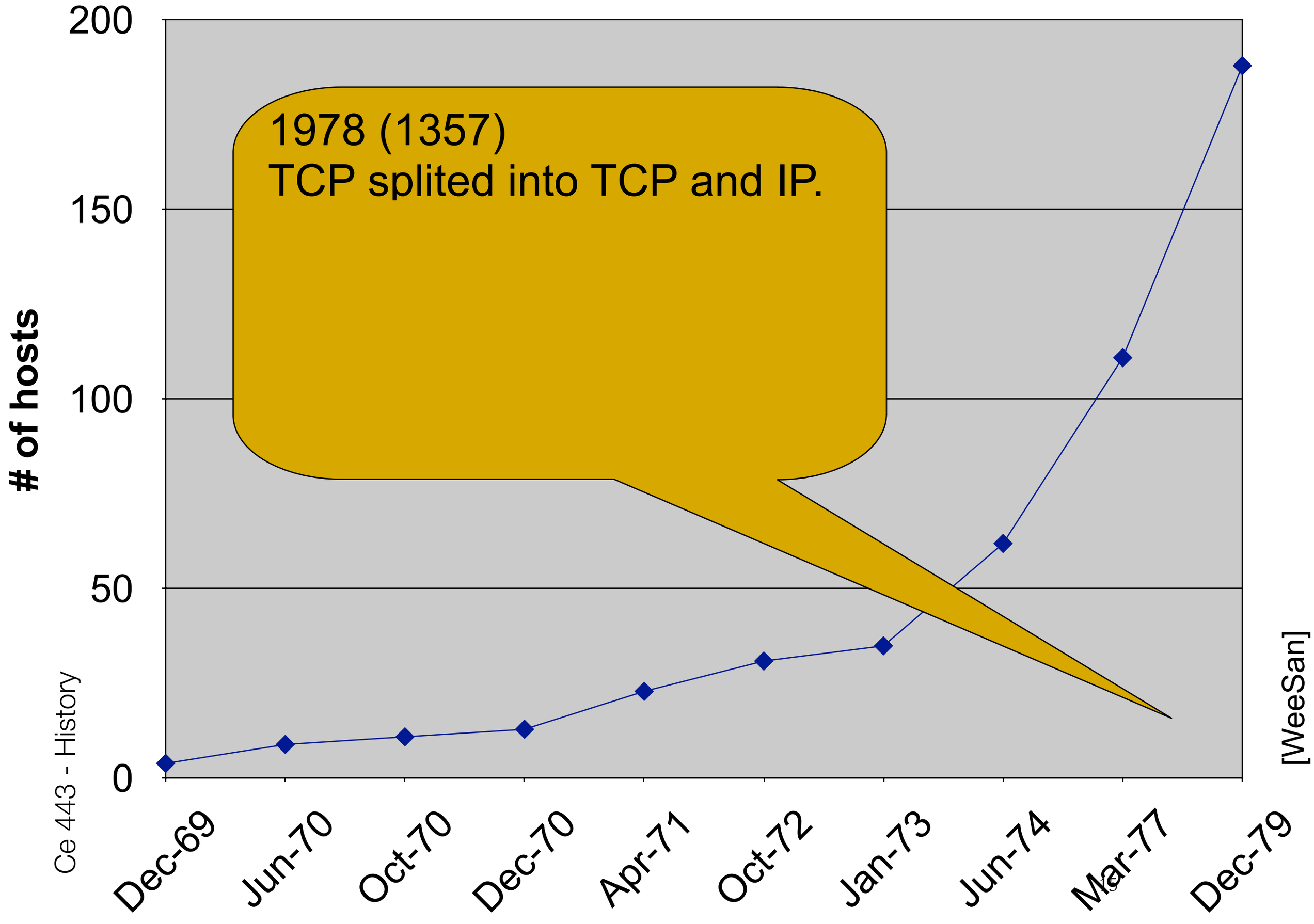
200
150
100
50
0

Dec-69
Jun-70
Oct-70
Dec-70
Apr-71
Oct-72
Jan-73
Jun-74
Mar-77
Dec-79

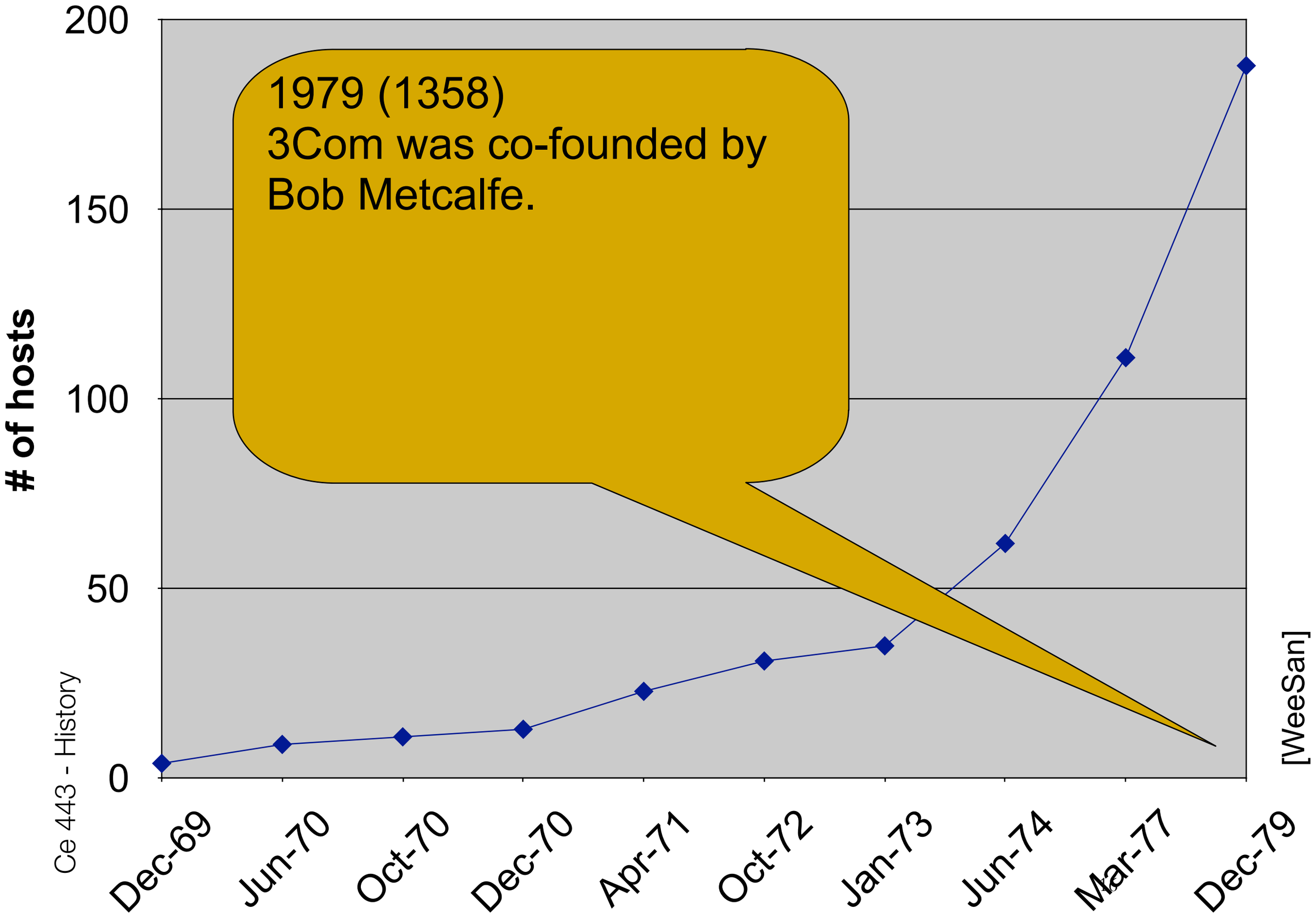
Ce 443 - History

[WeeSan]

Internet Hosts



Internet Hosts



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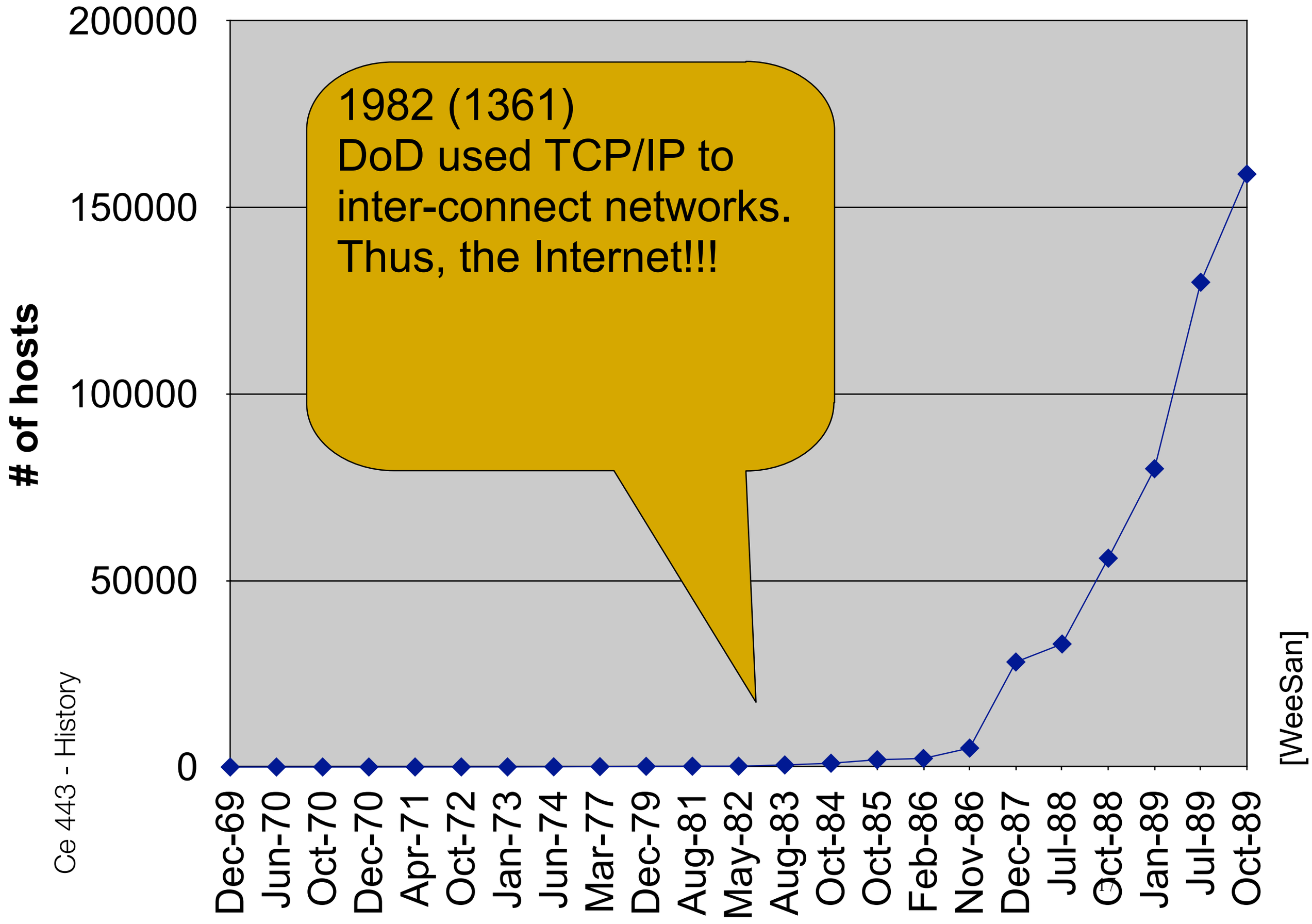
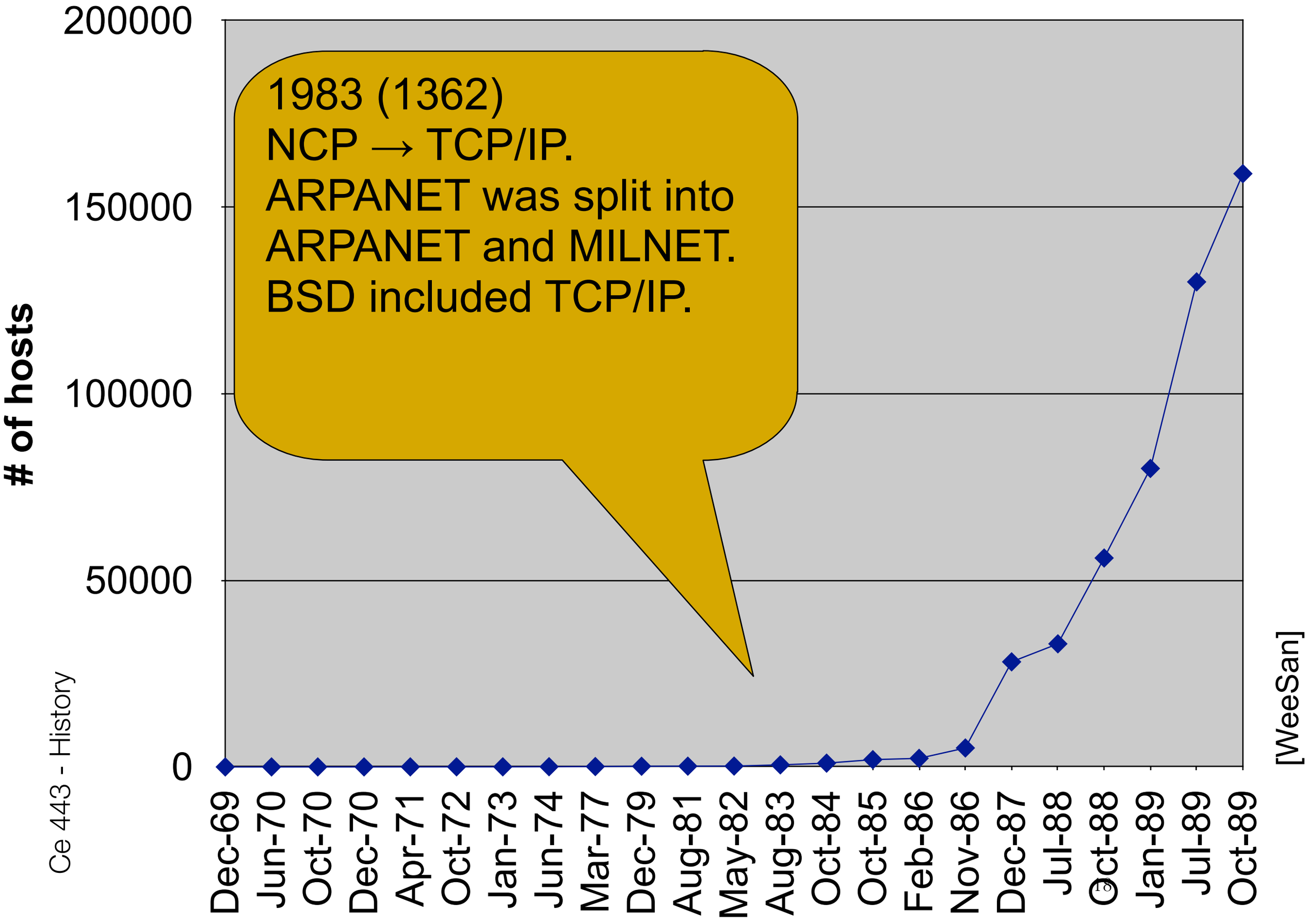
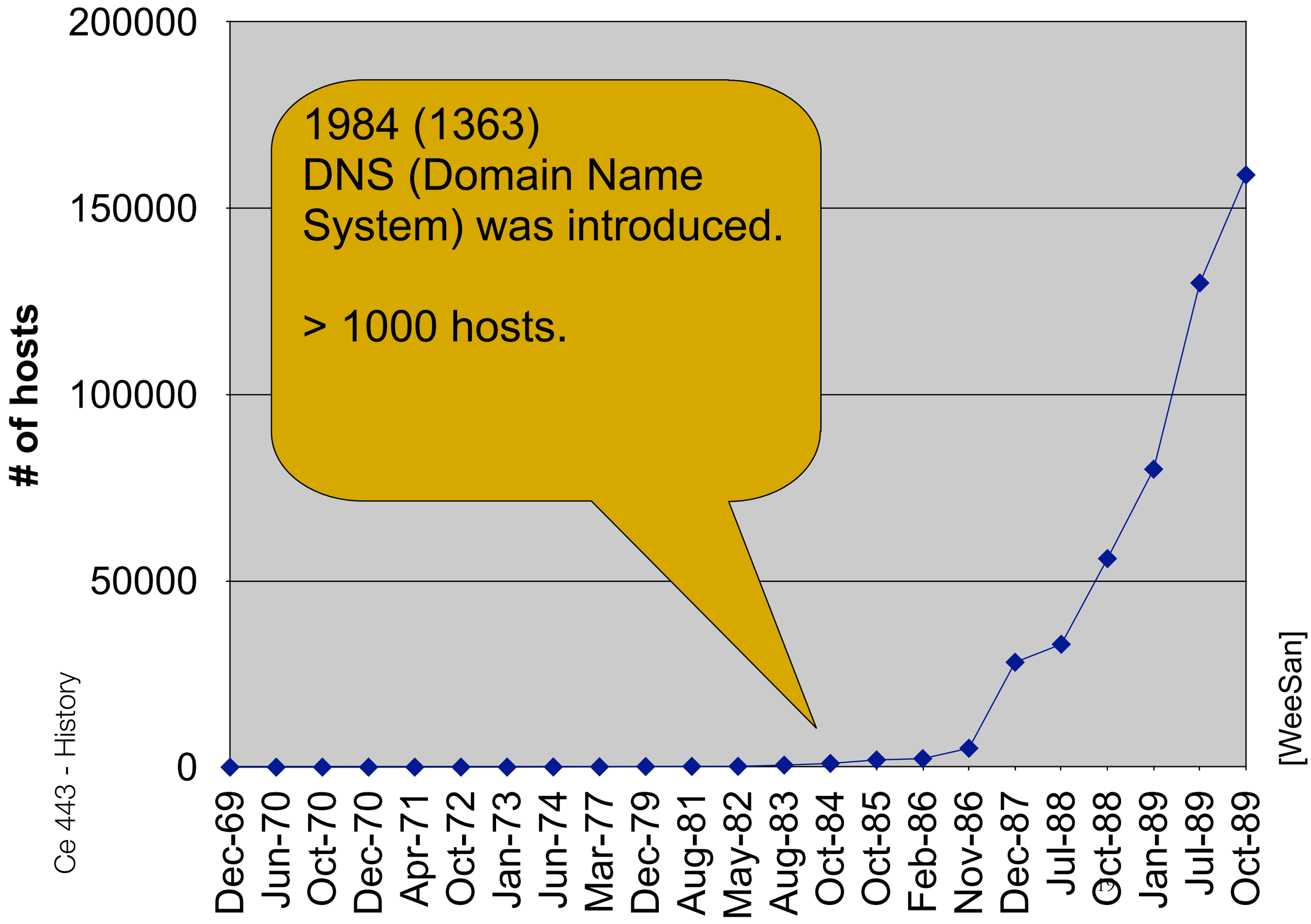
Internet Hosts



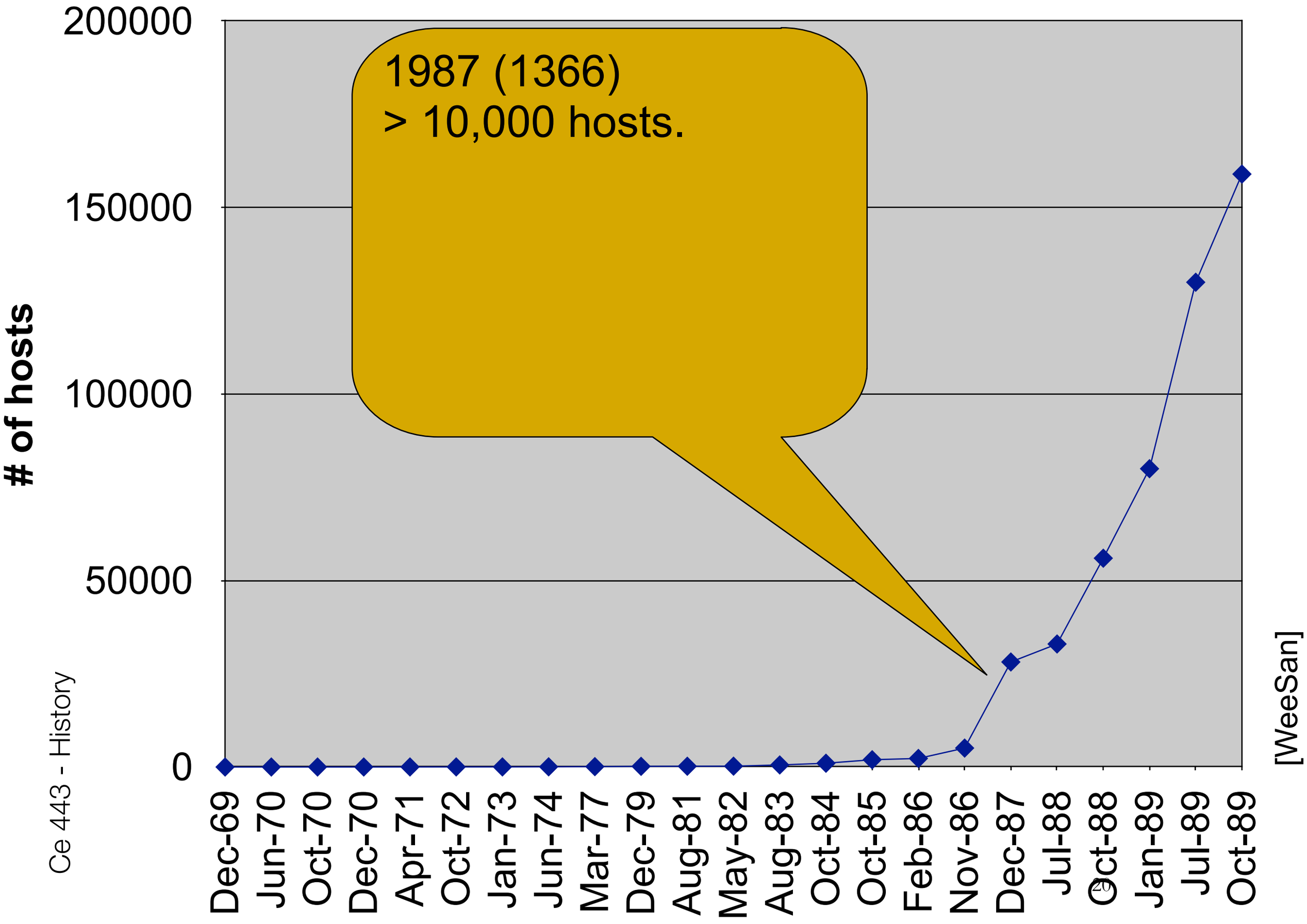
Internet Hosts



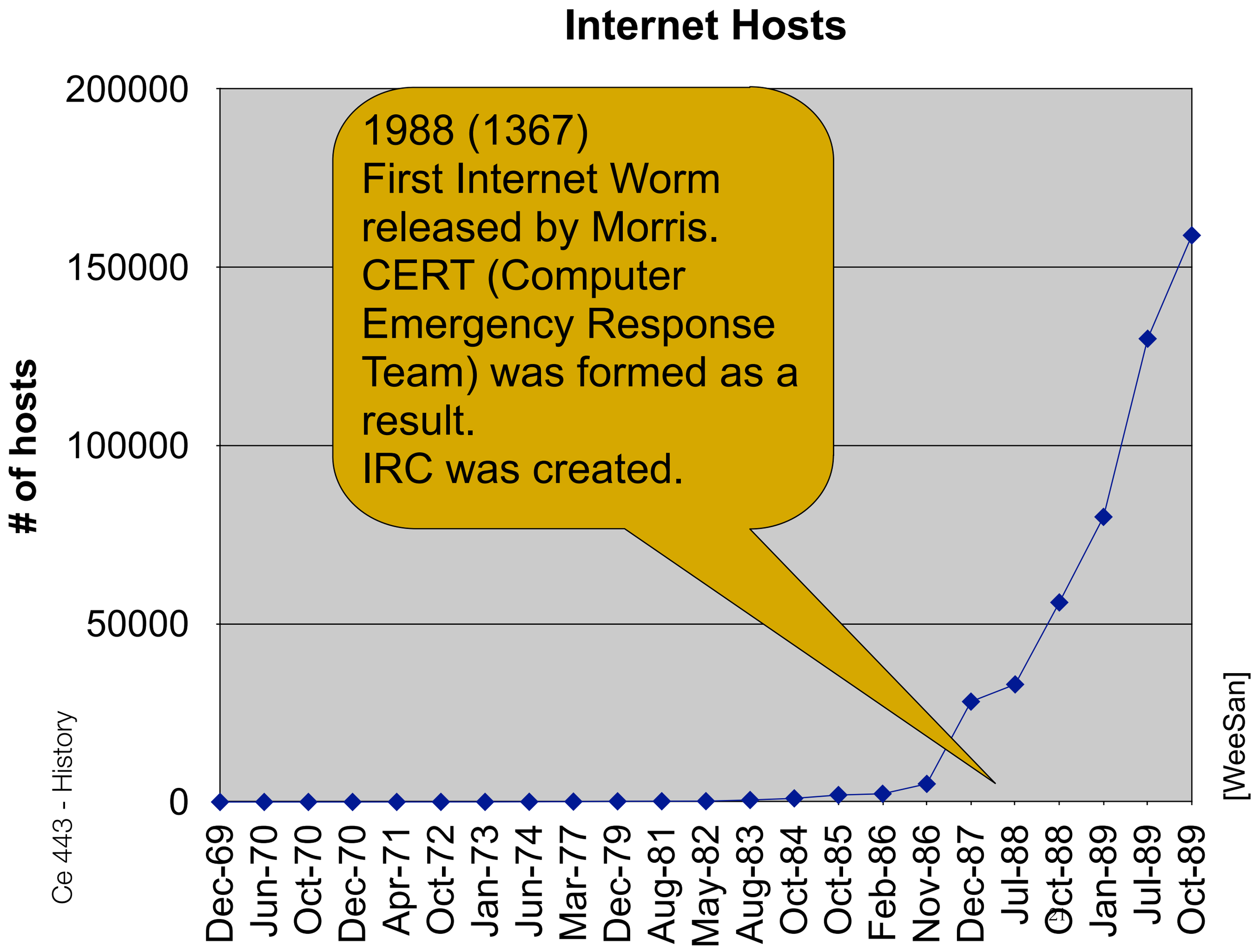
Internet Hosts



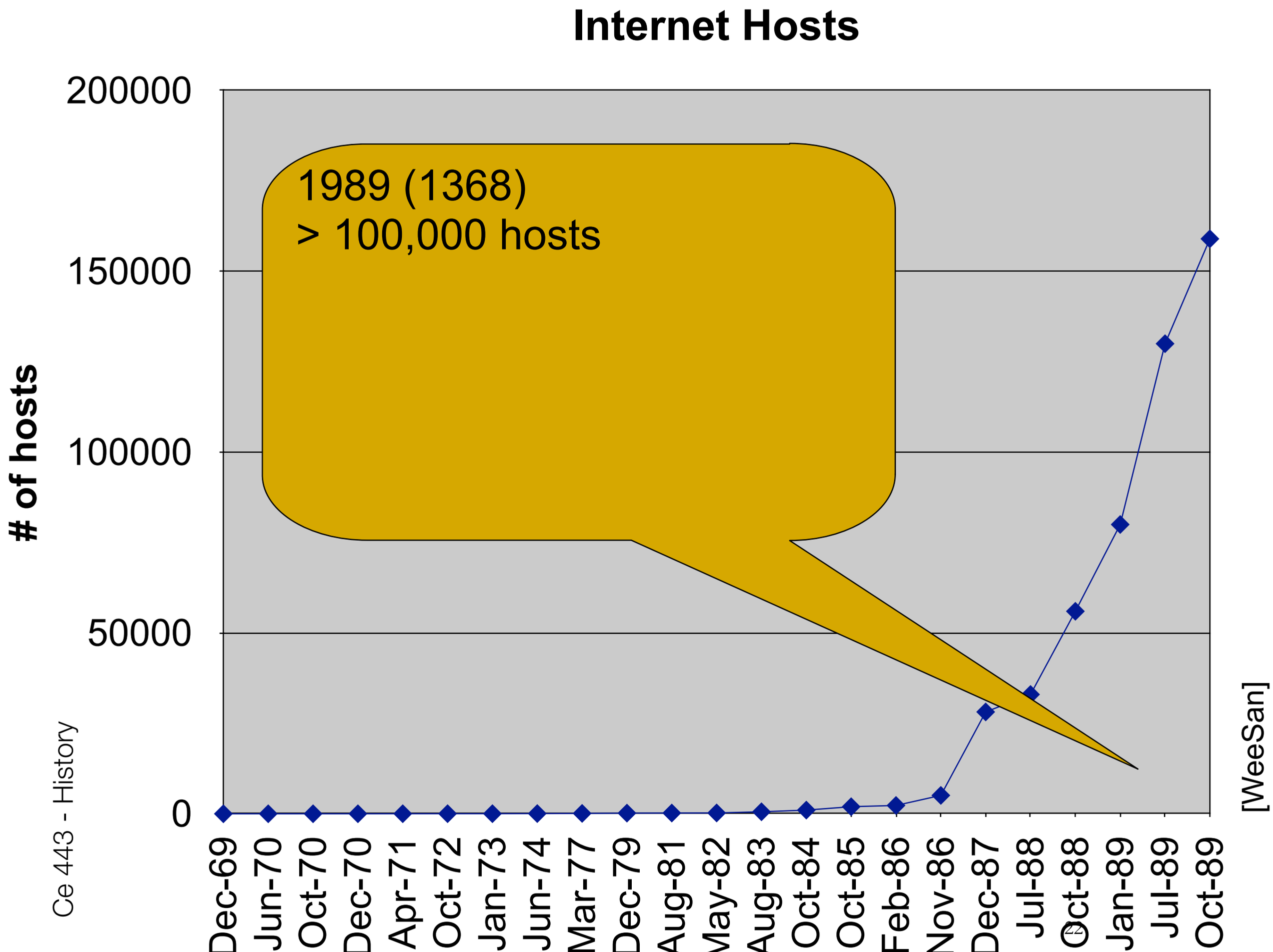
Internet Hosts

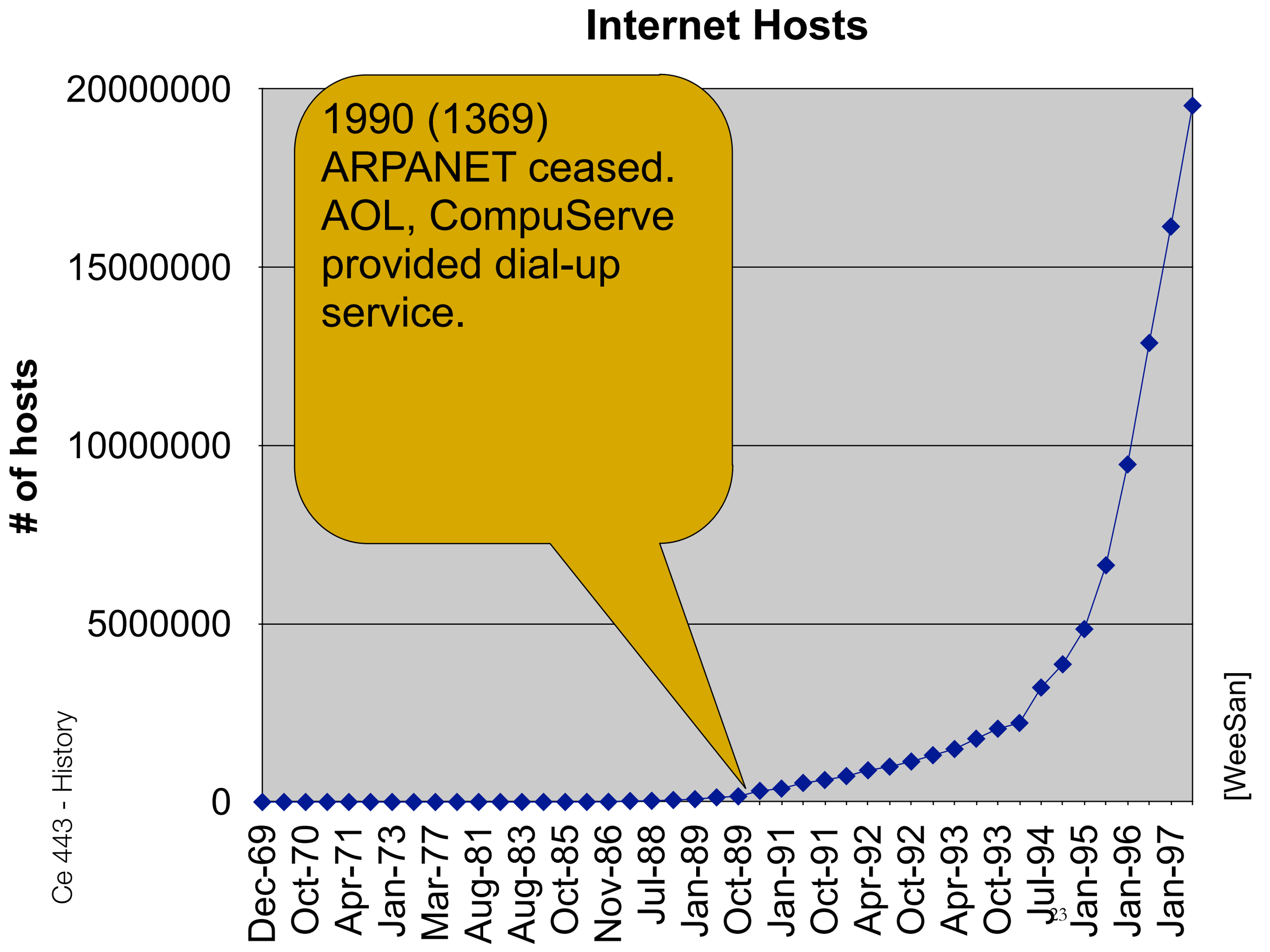


Internet Hosts

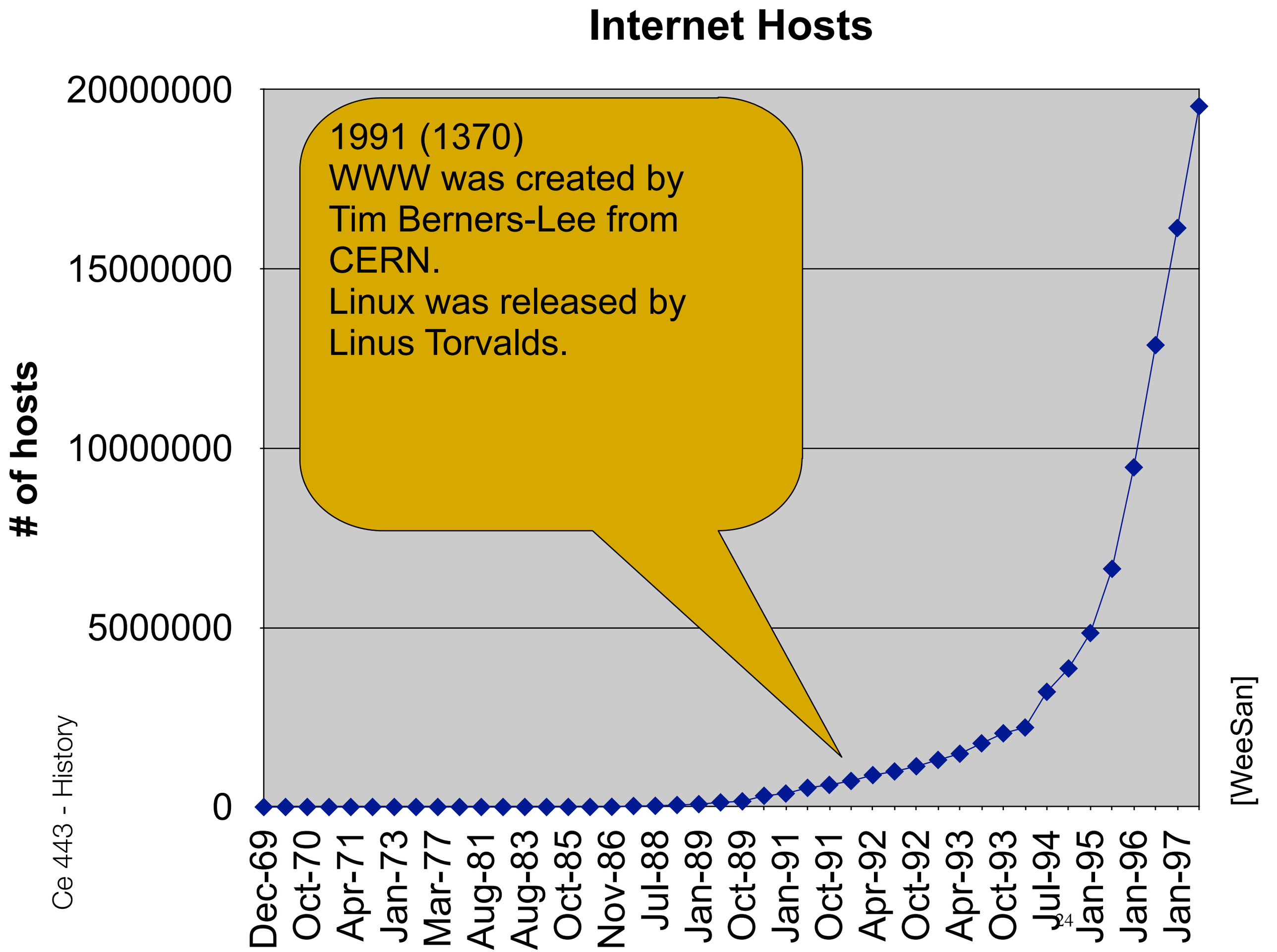


Internet Hosts

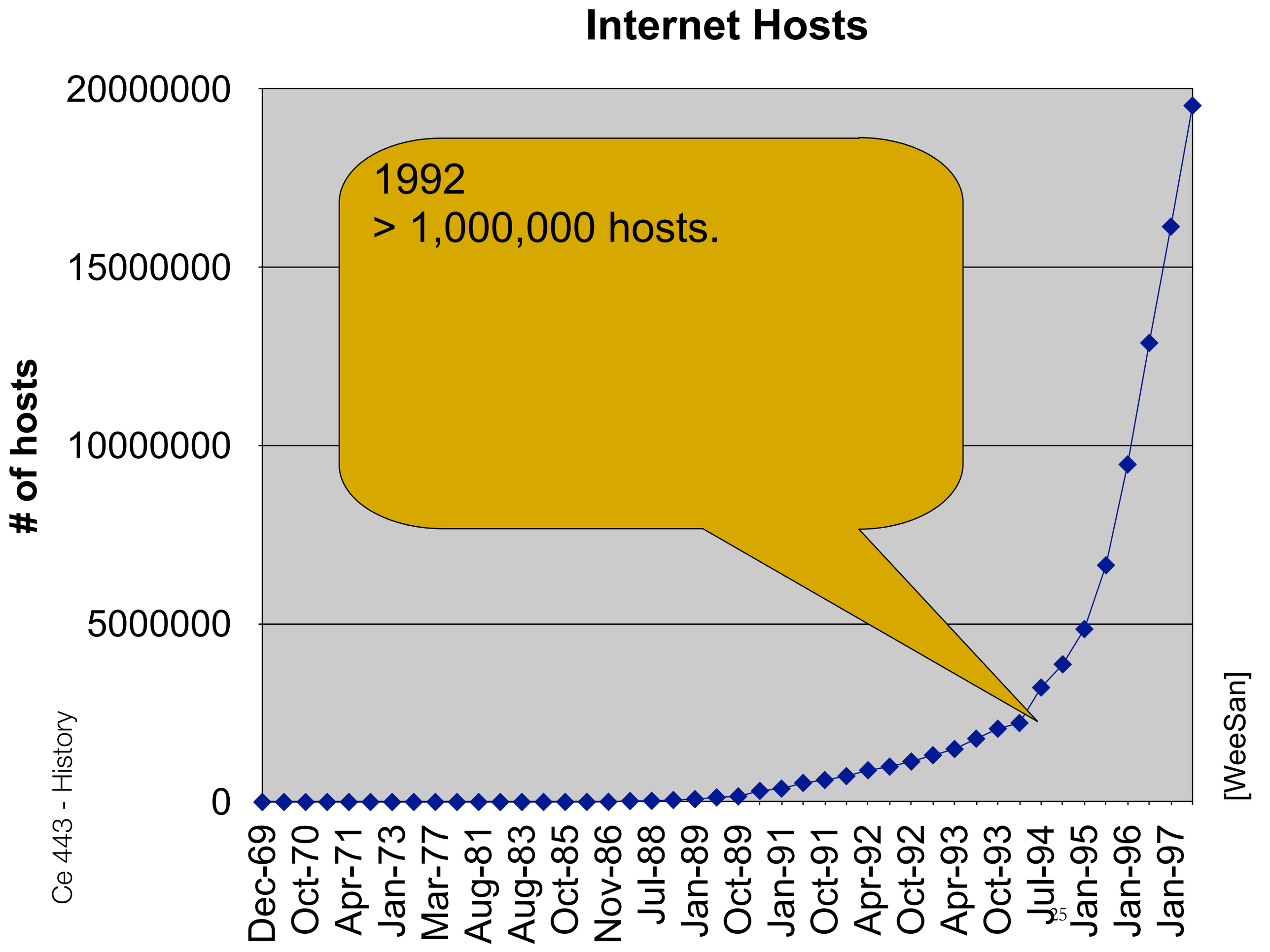


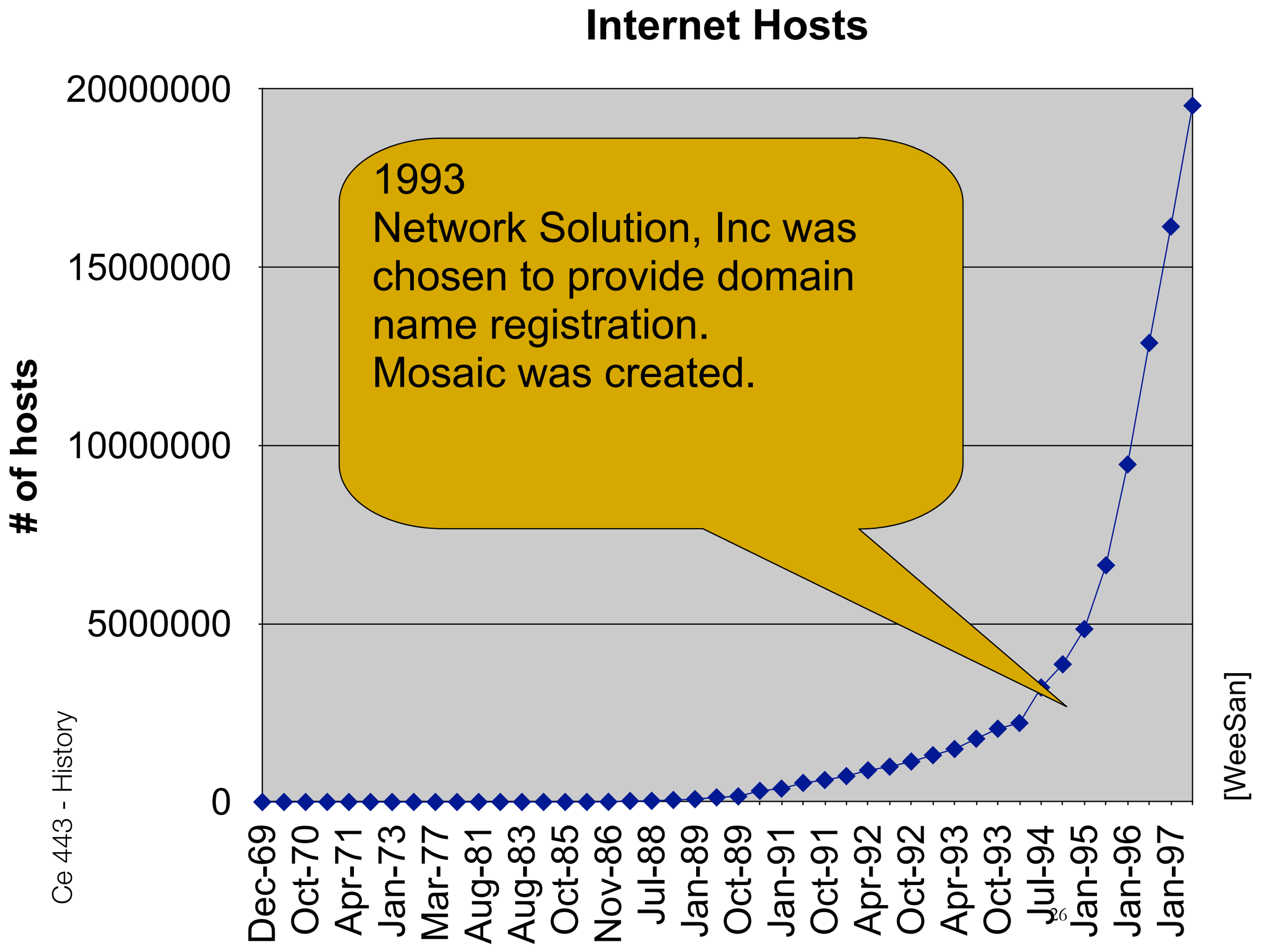

Internet Hosts
20000000
15000000
10000000
5000000
0
# of hosts
1990 (1369)
ARPANET ceased.
AOL, CompuServe
provided dial-up
service.
Dec-69
Oct-70
Apr-71
Jan-73
Mar-77
Aug-81
Aug-83
Oct-85
Nov-86
Jul-88
Jan-89
Oct-89
Jan-91
Oct-91
Apr-92
Oct-92
Apr-93
Oct-93
Jul-94
Jan-95
Jan-96
Jan-97
[WeeSan]

Internet Hosts

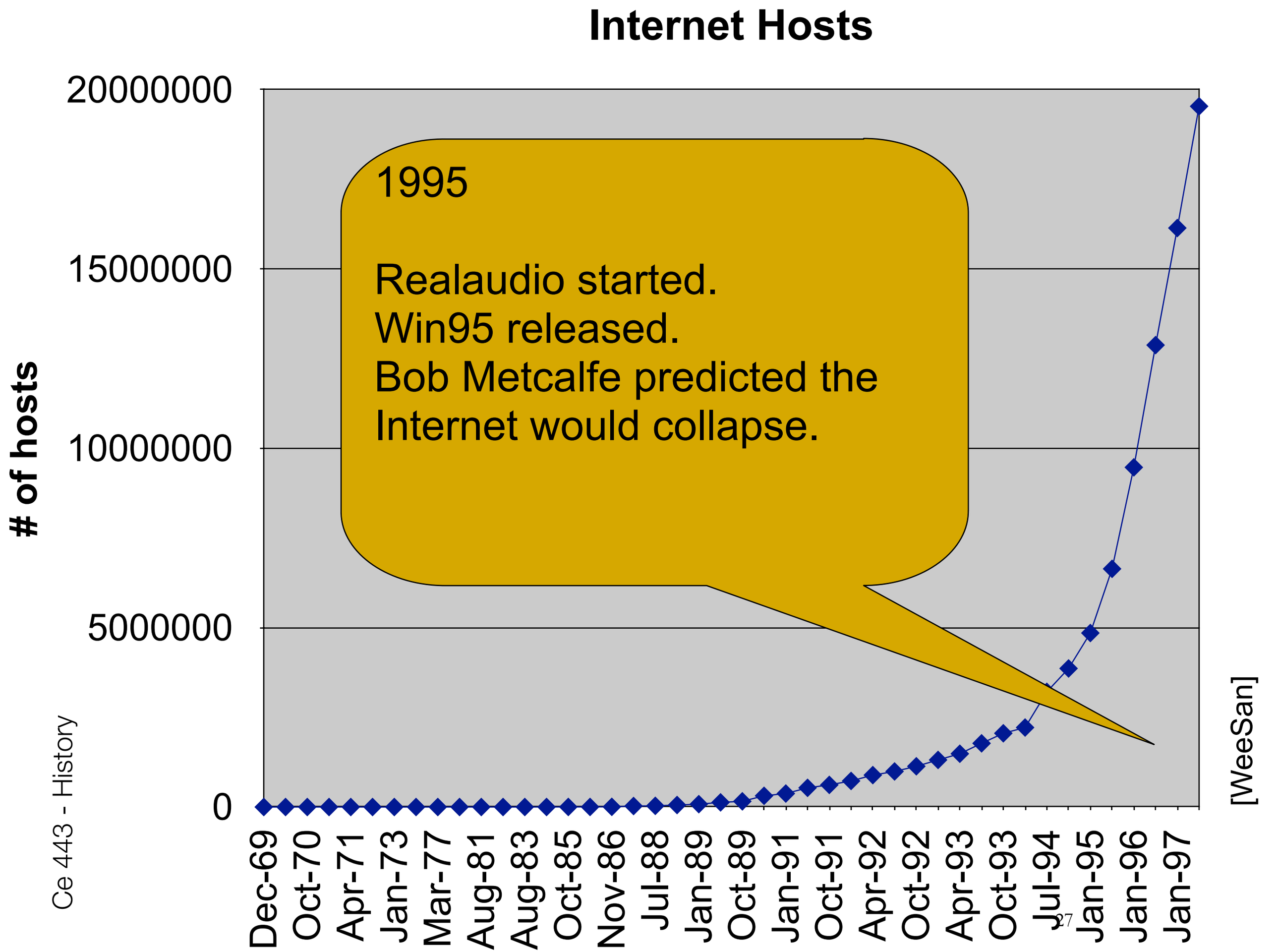


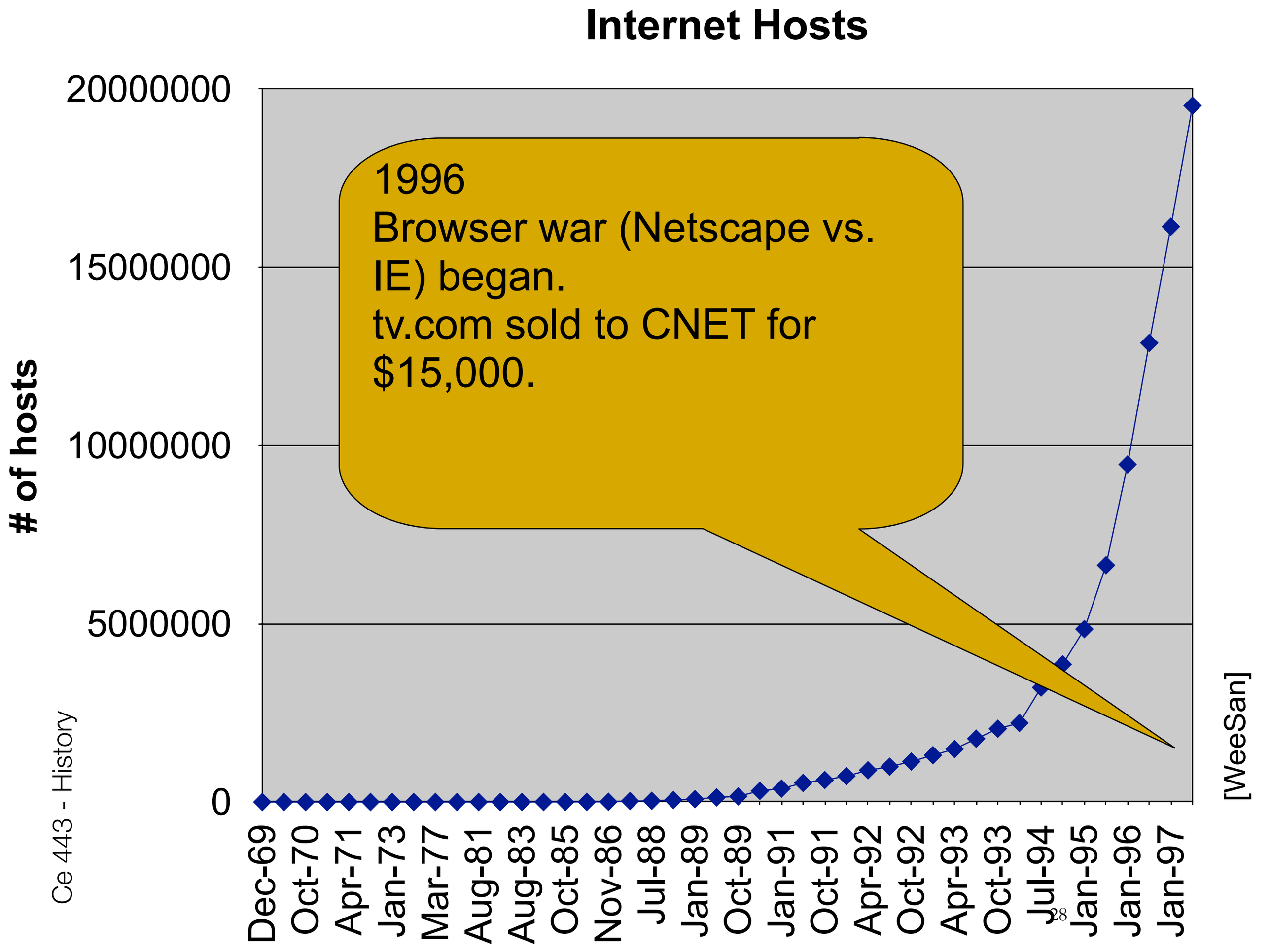
Internet Hosts




Internet Hosts
# of hosts
20000000
15000000
10000000
5000000
0
1993
Network Solution, Inc was chosen to provide domain name registration.
Mosaic was created.
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
[WeeSan]

Internet Hosts




Internet Hosts
20000000
15000000
10000000
5000000
0
# of hosts
1996
Browser war (Netscape vs. IE) began.
tv.com sold to CNET for $15,000.
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
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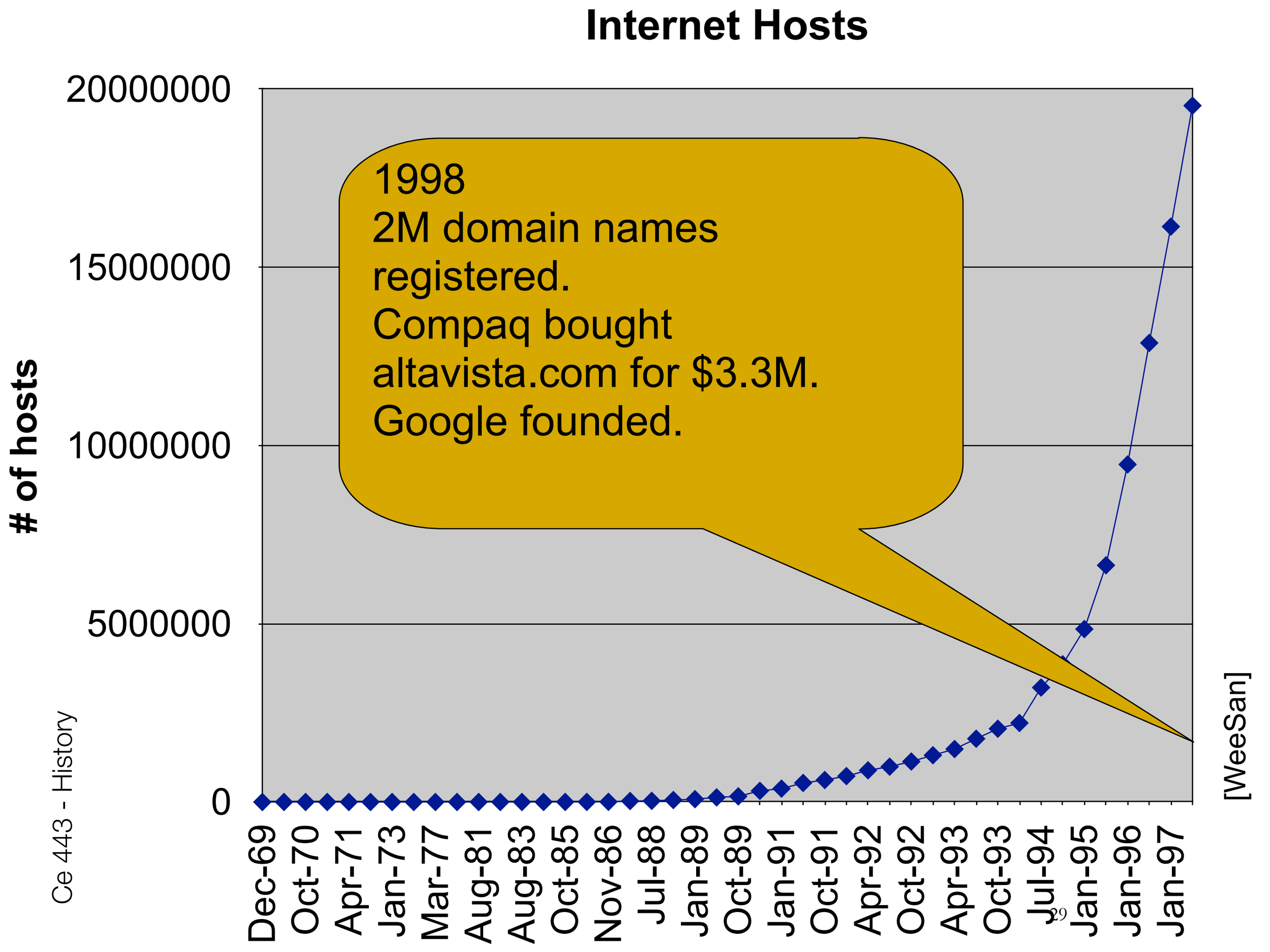
Jan-95
Jan-96
Jan-97
[WeeSan]


Internet Hosts
# of hosts
20000000
15000000
10000000
5000000
0
1998
2M domain names registered.
Compaq bought altavista.com for $3.3M.
Google founded.
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
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Jul-94
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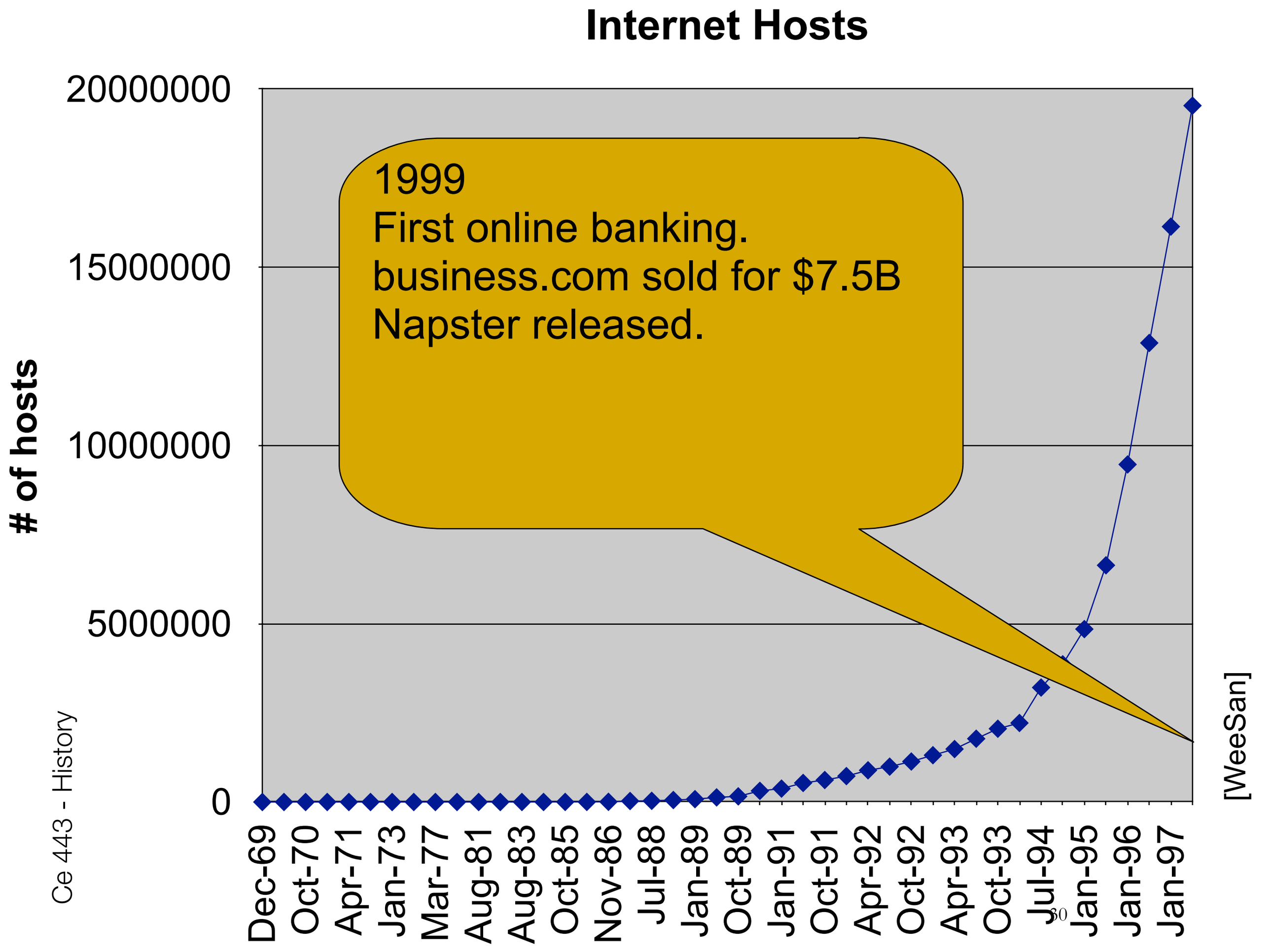
Jan-96
Jan-97
[WeeSan]


Internet Hosts
20000000
15000000
10000000
5000000
0
# of hosts
1999
First online banking.
business.com sold for $7.5B
Napster released.
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
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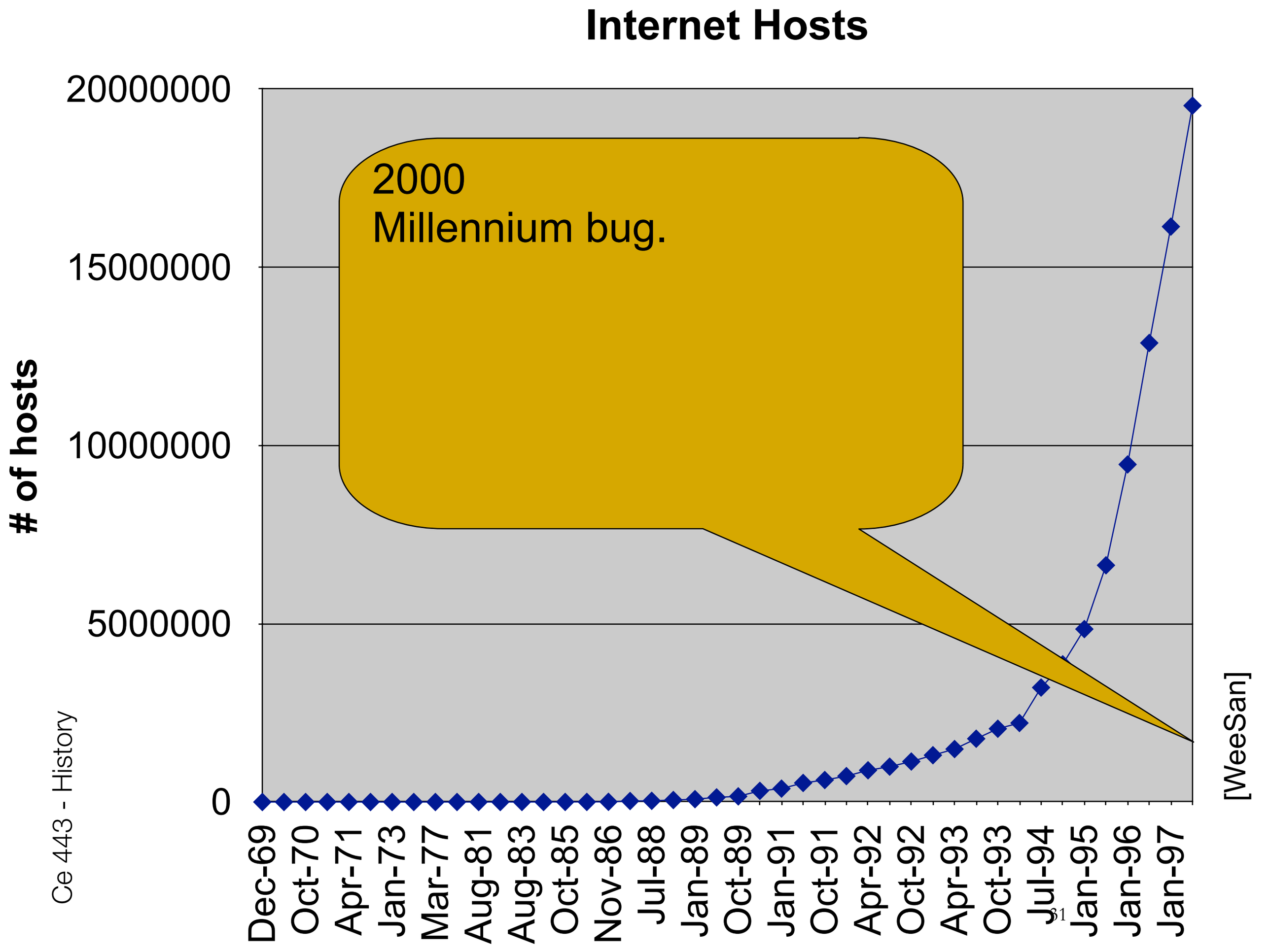
Oct-93
Jul-94
Jan-95
Jan-96
Jan-97
[WeeSan]


Internet Hosts
20000000
15000000
10000000
5000000
0
# of hosts
2000
Millennium bug.
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
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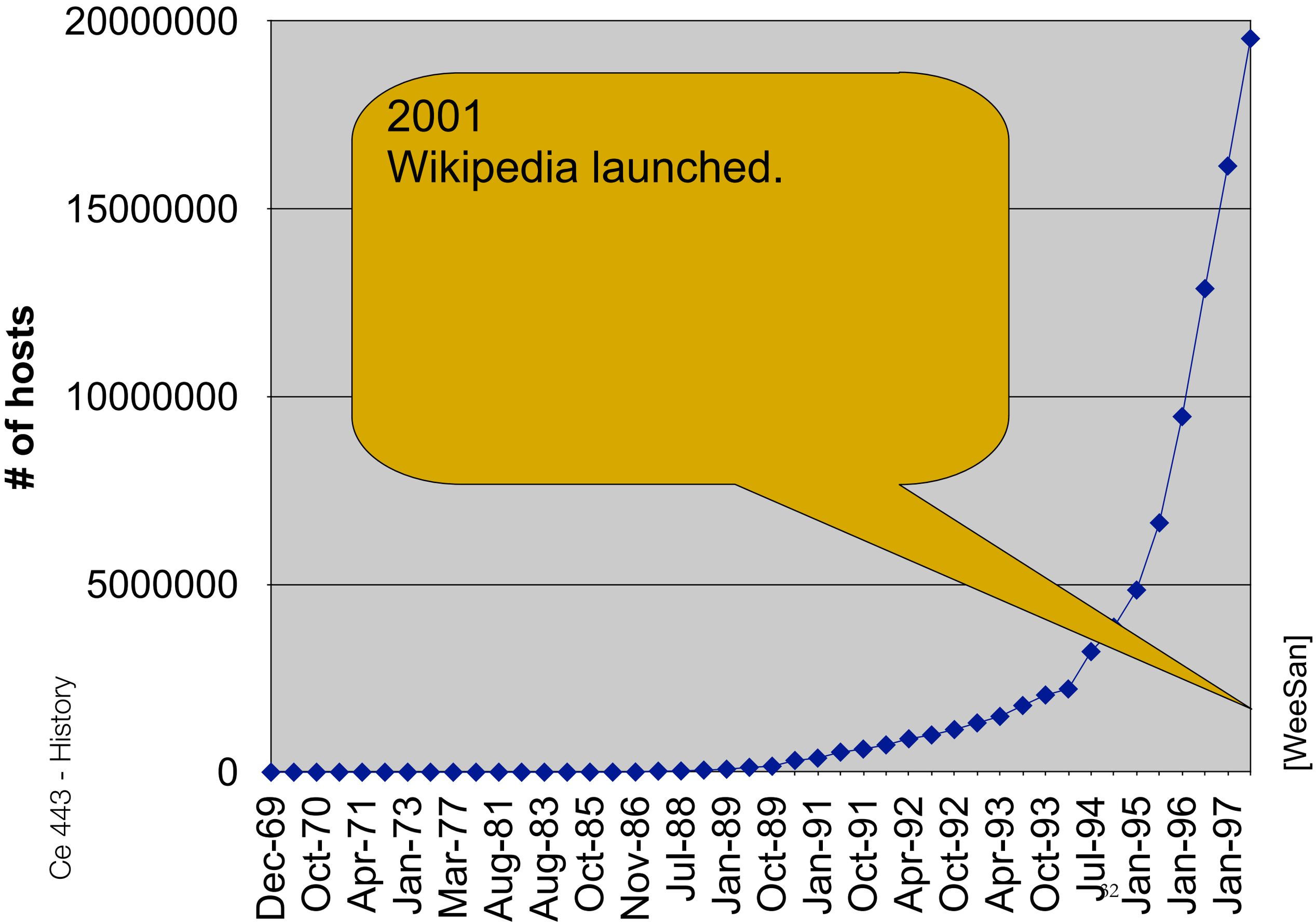
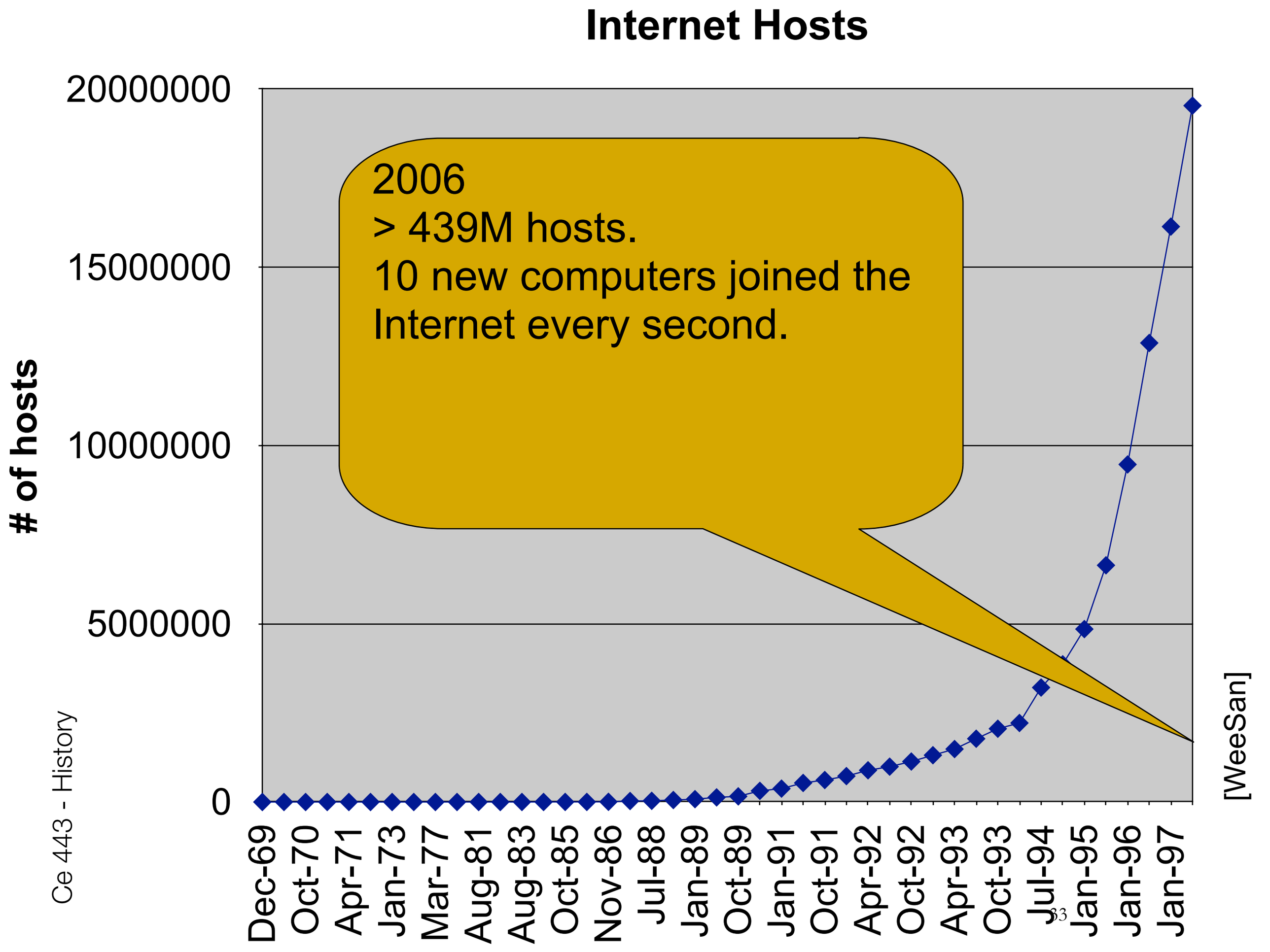
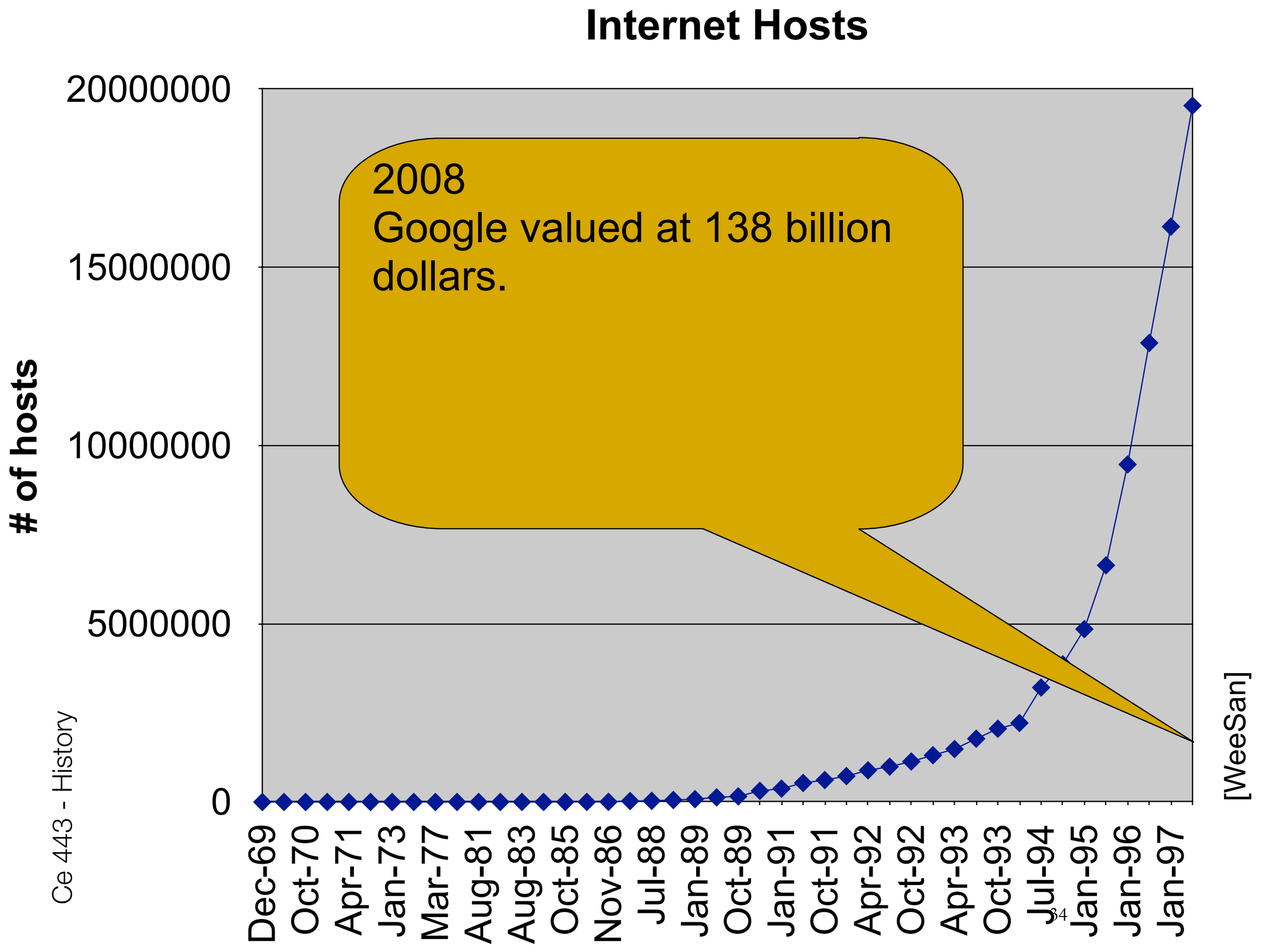
Jul-94
Jan-95
Jan-96
Jan-97
[WeeSan]

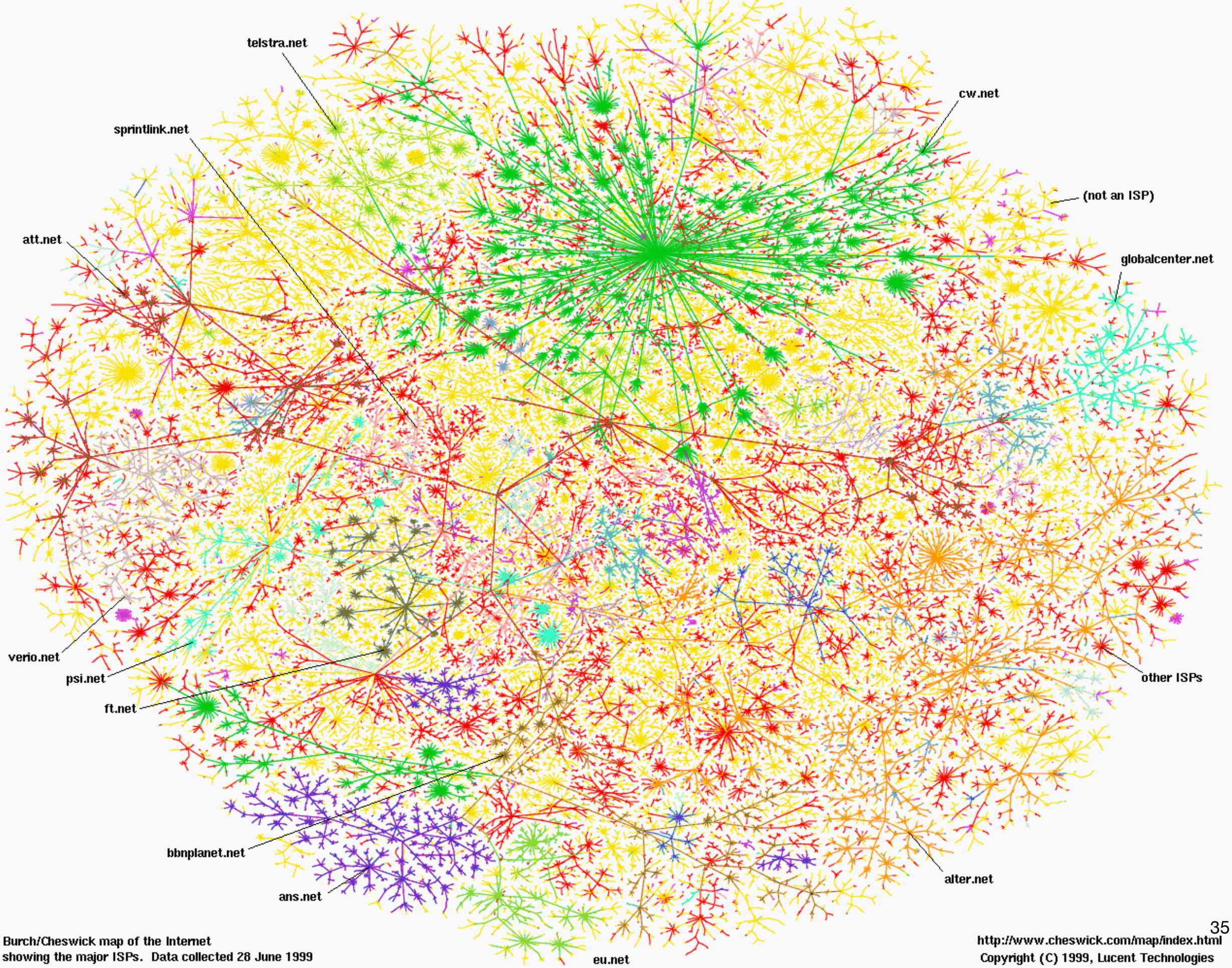
Internet Hosts



Internet Hosts



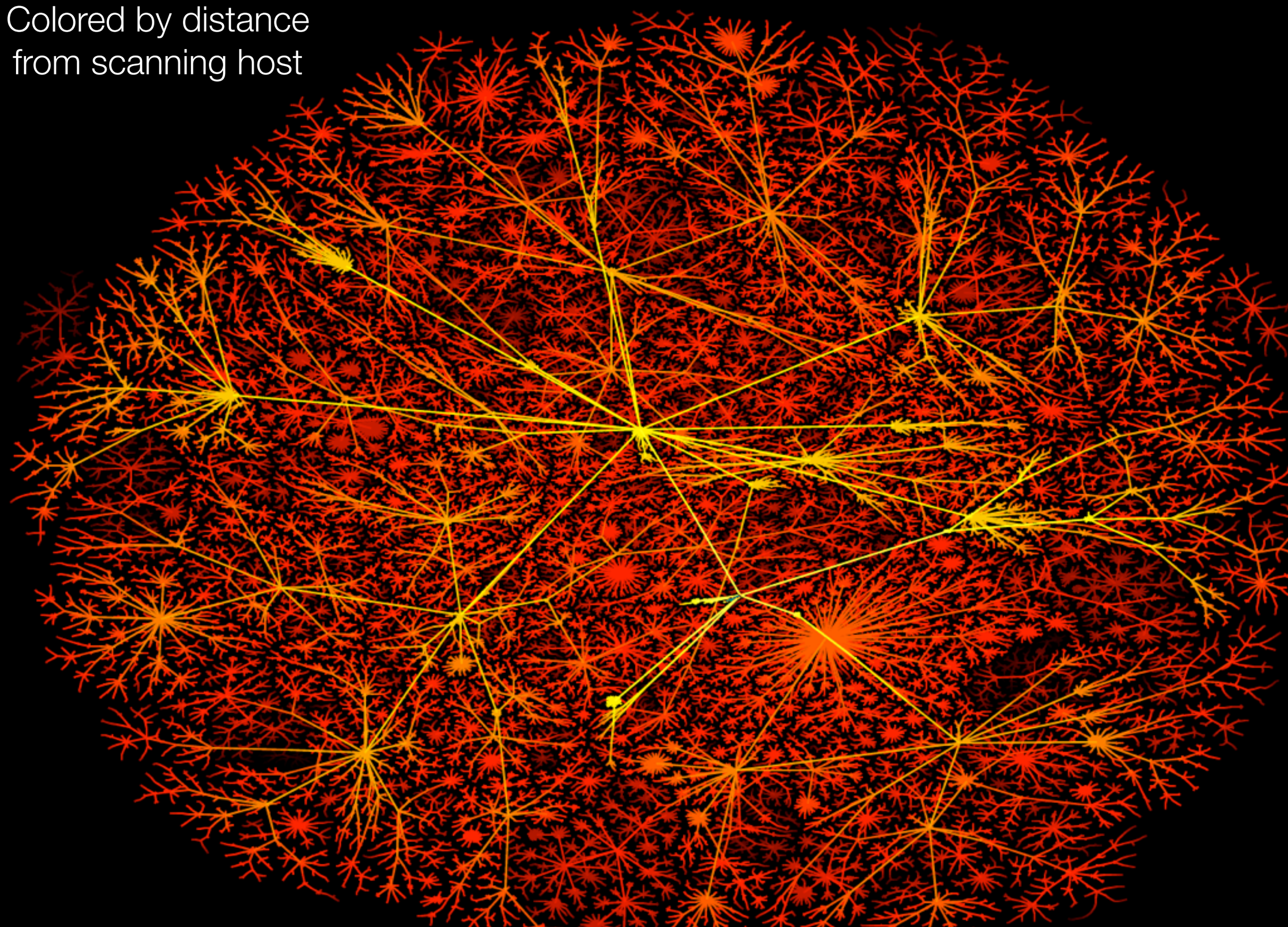

Internet Hosts
# of hosts
20000000
15000000
10000000
5000000
0
2008
Google valued at 138 billion dollars.
Dec-69
Oct-70
Apr-71
Jan-73
Mar-77
Aug-81
Aug-83
Oct-85
Nov-86
Jul-88
Jan-89
Oct-89
Jan-91
Oct-91
Apr-92
Oct-92
Apr-93
Oct-93
Jul-94
Jan-95
Jan-96
Jan-97
[WeeSan]



Burch/Cheswick map of the Internet
showing the major ISPs. Data collected 28 June 1999

http://www.cheswick.com/map/index.html

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
- Video on Demand
  - Netflix

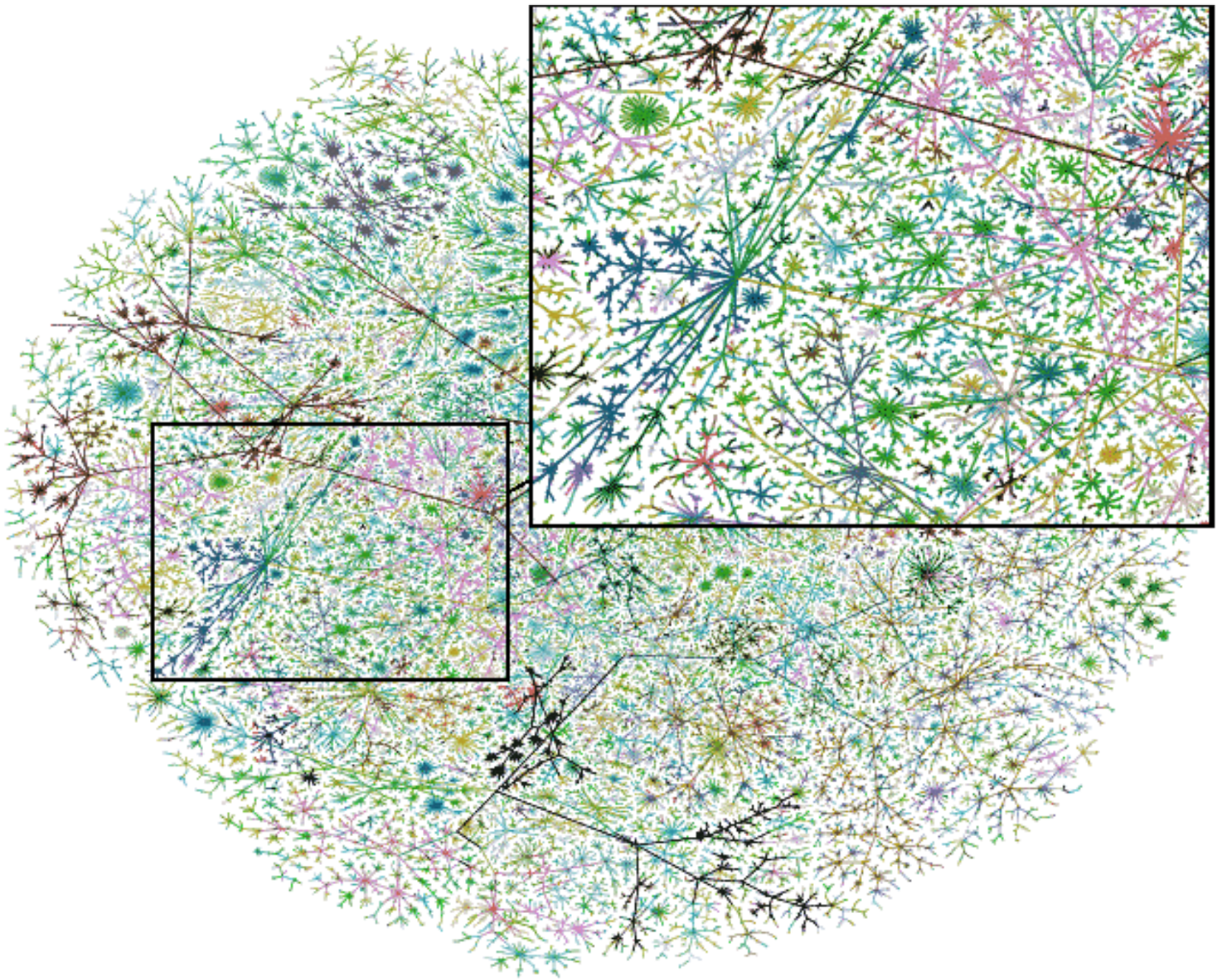
[Feamster15]

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?

[Feamster15]

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.

[Feamster15]

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.

[Feamster15]

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.

[Feamster15]

Details on the Course

Administrivia

- Website:
  - sharif.edu/~kharrazi/courses/40443-951/ (will be up soon)
  - 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
- You must also take, 40-416 with 40-443

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.