A Brief History of the Internet

Leonard Kleinrock

Professor, Computer Science, UCLA

35th Anniversary of the Internet
UCLA
October 29, 2004

The Big Bang !

(or the birth of the Internet)

by Leonard Kleinrock 1989

- It was back in '67 that the clan agreed to meet.
- The gangsters and the planners were a breed damned hard to beat.
- The goal we set was honest and the need was clear to all:
- Connect those big old mainframes and the minis, lest they fall.

- The spec was set quite rigid: it must work without a hitch
- It should stand a single failure with an unattended switch.
- We decided UCLA would be first node on the net
- As the best researchers out there, we would be the perfect bet.

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The Big Bang !

- I suspect you might be asking "What means FIRST node on the net?"
- Well frankly, it meant trouble, 'specially since no specs were set.
- For you see the interface between the nascent IMP and HOST
- Was a confidential secret from us folks on the West coast.

- BBN had promised that the IMP was running late.
- We welcomed any slippage in the deadly scheduled date.
- But just ahead of Labor Day, it was plopped down at our gate!
- Those dirty rotten scoundrels sent the damned thing out air freight!

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The Big Bang !

- As I recall that Tuesday, it makes me want to cry.
- Everybody's brother came to blame the other guy!
- Folks were there from ARPA, BBN and Honeywell.
- UCLA and ATT and all were scared as hell.

- We cautiously connected and the bits began to flow.
- The pieces really functioned - just why I still don't know.
- Messages were moving pretty well by Wednesday morn.
- All the rest is history - packet switching had been born!

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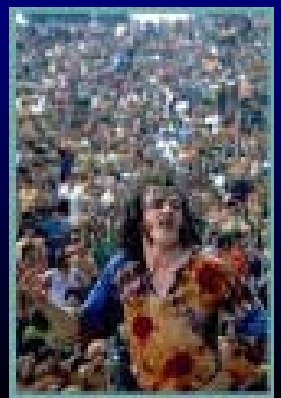
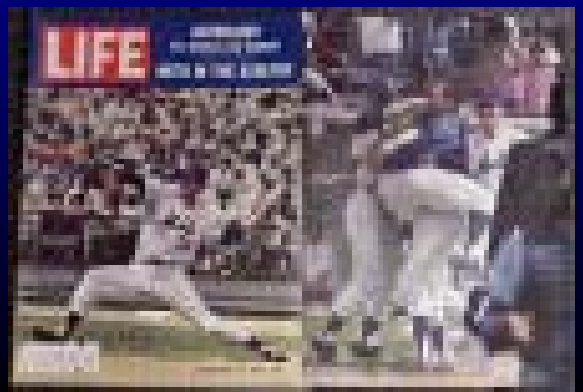
Let's Go Back to the Beginning

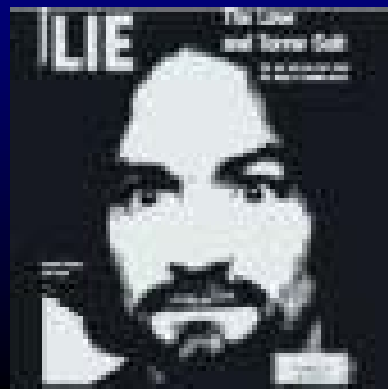
1969 Was an Incredible Year!

- The first man landed on the moon
- The Woodstock Festival took place
- The Mets won the World Series
- Charles Manson went on a killing spree
- The Internet was born

and nobody noticed!!







Before the Beginning!

- 1957 Sputnik launched
- 1958 ARPA formed as a response
- 1959-62 A mathematical theory of packet networks is created at MIT by Kleinrock…

  - 1961 1st paper on modern data networking

  - 1962 1st paper on packetization

  - 1962 Paul Baran suggests transmission of data using fixed size message blocks

  - 1962 JCR Licklider 1st Director of IPTO; gives his vision of a galactic network

  - 1963 Kleinrock joins UCLA faculty
  - 1964 Baran publishes reports "On Distributed Communications"
  - 1964 1st book on packet nets published

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Leonard Kleinrock

Massachusetts Institute of Technology
Research Laboratory of Electronics
Cambridge, Massachusetts

APPROVED
COMMITTEE ON GRADUATE STUDY
and RESEARCH
ELEC. ENG. DEPT.
By LMS Date 7/24/61

Information Flow in Large Communication Nets

Information Flow in Large Communication Nets
Proposal for a Ph.D. Thesis

Leonard Kleinrock

Leonard Kleinrock

May 31, 1961

May 31, 1961

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th ANNIVERSARY
NTERNET @ UCLA

Information Flow in Large Communication Nets

Leonard Kleinrock

"The purpose of this thesis is to investigate the problems associated with information flow in large communication nets. …."

"…The nets under consideration consist of nodes, connected to each other by links. The nodes receive, sort, store, and transmit messages that enter and leave via the links…."

Time lapse between initiation and reception

Channel capacity

Under what conditions does the net jam up?

Storage capacity size

Routing doctrine

Transient behavior and recovery time

© Leona

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Leonard Kleinrock

The procedure for servicing is as follows: A unit upon arrival joins the end of the queue, and waits on line in a first come first served fashion until it finally arrives at the service facility. The server picks the next unit in the queue and performs a unit of service upon it. At the end of this time interval, the unit leaves the system if its service is finished; if not, it joins the end of the queue with its service partially completed. Obviously, a unit whose service time is n intervals long will be forced to join the queue a total of n times before its service is completed. Another assumption must now be made regarding the order in which events take place at the end of a time interval. We shall assume that the unit leaving the service facility is allowed to join the tail of the queue before the next unit arrives at the queue from outside the system (referred to as a late-arrival system). The case with reversed order has also been solved, but will not be reported on here, since the results are not essentially different.

Upon arrival, a unit finds some number of units, m, in the system. The expected value, E(m), of the number m is known[3] to be

$$E(m) = \frac{\rho}{1-\rho}\sigma$$

where

$$\rho = \frac{\lambda Q}{1-\sigma}.$$

We are now ready to state the following theorem.

THEOREM 3: The expected value, T_n, of the total time spent in the late-arrival system for a unit whose service time is nQ seconds, is

$$T_n = \frac{nQ}{1-\rho} - \frac{\lambda Q^2}{1-\rho}\left\{1 + \frac{(1-\sigma\alpha)(1-\alpha^{n-1})}{(1-\sigma)^2(1-\rho)}\right\}$$

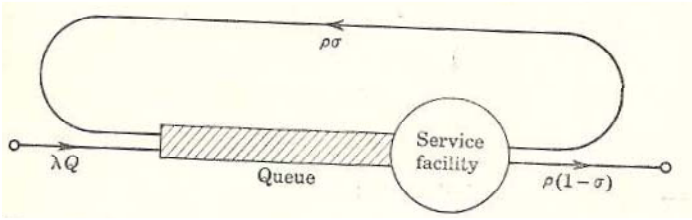
where

$$\alpha = \sigma + \lambda Q.$$

Now, instead of the round-robin type of structure just described, we shall consider a strict first come first served system in which each unit waits for service in order of arrival, and, once it is in service, each unit remains until it is completely serviced. Then for T_n defined as before, we state the following theorem.

THEOREM 4: The expected value, T_n, of the total time spent in the first come first served system for a unit whose service time is nQ seconds, is

$$T_n = \frac{1}{1-\sigma}QE(m) + nQ$$



Kleinrock's 1961-2 Dissertation

- Created a mathematical theory of data networks
  - Channel capacity limited
  - Mean response time as key metric
  - Optimal assignment of channel capacity
  - Choice of priority queueing discipline
  - Concept of breaking messages into fixed size blocks
  - Choice of routing procedure
  - Design of topological structure
- Developed underlying principles of data networks that are the basis of the Internet

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Before the Beginning!

- 1965 Doug Englebart develops mouse and concepts of hypertext 
- 1965 Larry Roberts and Tom Marill connect MIT Lincoln Labs with SDC over a dial-up line
- 1965 Donald Davies coins the word “packet” 
- 1966 Larry Roberts/Tom Marill publish first paper on network experiments 
- 1966 Robert Taylor joins ARPA and brings Roberts there to develop ARPANET 
- 1967 Davies creates 1-node NPL packet net
- 1967 Wes Clark suggests use of a mini-computer for network packet switch 

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The First Packet Network Experiment - 1966

TOWARD A COOPERATIVE NETWORK OF TIME-SHARED COMPUTERS

Thomas Marill

Computer Corporation of America, Cambridge, Massachusetts

and

Lawrence G. Roberts

MIT, Lincoln Laboratory, Lexington, Massachusetts*

APPENDIX

MESSAGE PROTOCOL FOR TX-2/Q-32 LINK

This Appendix describes the message protocol for use with the link between the Q-32 at System Development Corporation in Santa Monica, California, and the TX-2 at Lincoln Laboratory in Lexington, Massachusetts.

Each character consists of eight data-bits, sent least significant bit first, preceded by a zero start bit and followed by a one stop bit. When not transmitting a character, the link transmits a one continuously.

Table 1. Special Characters for Message Protocol

Octal	*ASCII*	*Meaning*
HEADER		
201	SOH	characters for monitor
202	STX	characters for user
221	DC1	data for monitor
232	SS	data for user
END OF MESSAGE		
203	ETX	end of message
ACKNOWLEDGMENT		
225	NACK	message in error, repeat
234	FS	message OK, but wait
206	ACK	message OK, send next message
QUERY		
230	CNCL	resend last acknowledgment
SYNCHRONIZATION		
226	SYNC	ignore
SPECIAL FUNCTIONS		
220	DLE	help/break
233	ESC	panic.

All information transmitted is sent in the form of messages consisting of a header character, body, end-of-message character, and a checksum. All messages are acknowledged.

There are four types of messages. Each has a unique header character that determines both the destination of the message (user or monitor) and the mode of the message (character string or binary data). The specific characters used are listed in Table 1.

The body of the message has a maximum length of 119 characters if the message is a character string and 118 characters if the message is binary data. If the message consists of binary data, the first character of the body is a count character equal to the total number of characters in the body including the count character. Two through 118 are legal values.

Larry Roberts – Aug 1999

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The Arpanet Beginning

- 1967

"So you want me to do research?
Buy me a Big computer…
…with all the power everyone else has!"

ARPA's reply:
An offer you can't refuse!

Join a NETWORK!

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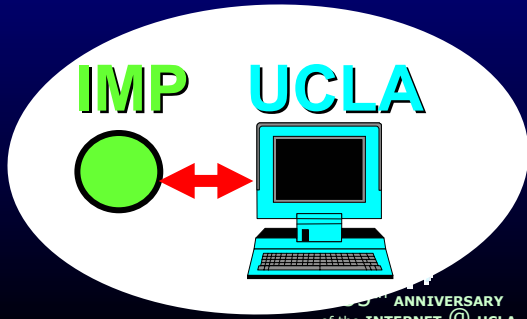
The Arpanet Beginning

- 1967 ARPA gathers the "gang"
- 1968 Roberts publishes ARPANET plan 
- 1968 RFP for a network goes out
- 1968 BBN wins the contract under the leadership of Frank Heart and the system design of Robert Kahn  
- 1968 UCLA selected to be the first node and serve as Network Msmnt Center
- 1969 (Jan-Aug) BBN & UCLA are Busy!
- 1969 UCLA puts out Press Release
- 1969 8/29 BBN sends first switch to UCLA
- 1969 9/2 First data moves from UCLA Host to UCLA switch



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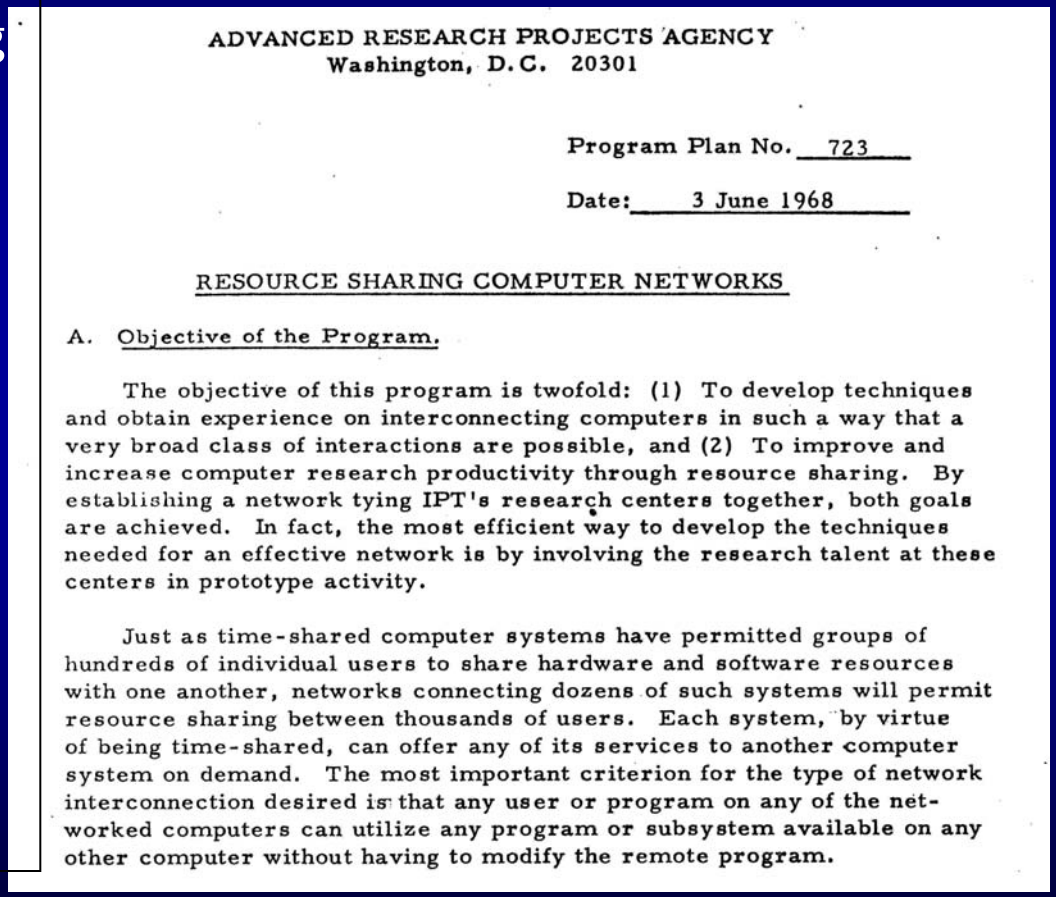
ARPANET Program Plan

June 3, 1968

In ARPA, the Program Plan is the master document describing a major program. This plan, which I wrote in 1968, had the following concepts:

1. Objectives – Develop Networking and Resource Sharing
2. Technical Need – Linking Computers
3. Military Need – Resource Sharing - Not Nuclear War
4. Prior Work – MIT-SDC experiment
5. Effect on ARPA – Link 17 Computer Research Centers, Network Research
6. Plan - Develop IMP's and start 12/69
7. Cost – $3.4 M for 68-71



ADVANCED RESEARCH PROJECTS AGENCY
Washington, D.C. 20301

Program Plan No. 723

Date: 3 June 1968

RESOURCE SHARING COMPUTER NETWORKS

A. Objective of the Program.

The objective of this program is twofold: (1) To develop techniques and obtain experience on interconnecting computers in such a way that a very broad class of interactions are possible, and (2) To improve and increase computer research productivity through resource sharing. By establishing a network tying IPT's research centers together, both goals are achieved. In fact, the most efficient way to develop the techniques needed for an effective network is by involving the research talent at these centers in prototype activity.

Just as time-shared computer systems have permitted groups of hundreds of individual users to share hardware and software resources with one another, networks connecting dozens of such systems will permit resource sharing between thousands of users. Each system, by virtue of being time-shared, can offer any of its services to another computer system on demand. The most important criterion for the type of network interconnection desired is that any user or program on any of the networked computers can utilize any program or subsystem available on any other computer without having to modify the remote program.

Larry Roberts – Aug 1999

Packetcom

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The BBN Team

- **Project team:**
  - 1 part-time manager,
  - 1 communications expert,
  - 3 programmers,
  - 2 electrical engineers
- **Who were the players**
  - Frank Heart,
  - Bob Kahn,
  - Will Crowther,
  - Dave Walden,
  - Bernie Cosell,
  - Severo Ornstein,
  - Ben Barker
- **The Machine:**
  - .5MHz,
  - 32K bytes of memory,
  - half memory for program, and half memory for store and forward storage
- **H516 computer was the size of a refrigerator**
- **50kbs modem rack was the same size**

Il team di sviluppo dell'IMP alla BB&N, 1969 (fonte: www.bbn.com)

Truett Thach, Bill Bartell, Dave Walden, Jim Geisman, Bob Kahn, Frank Heart, Ben Barker, Marty Thrope, Will Crowther, e Severo Ornstein

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The UCLA Software Team

- Steve Crocker, Team Head

- Vint Cerf

- Jon Postel

- Charley Kline

- Bill Naylor

- Mike Wingfield (one-man hardware team)

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My 1969 vision …

UCLA

UNIVERSITY OF CALIFORNIA, LOS ANGELES

Office of Public Information

Avenue • Los Angeles, California 90024

Dial: "UCLA-535"

Thursday, July 3, 1969

Ucla Press Release

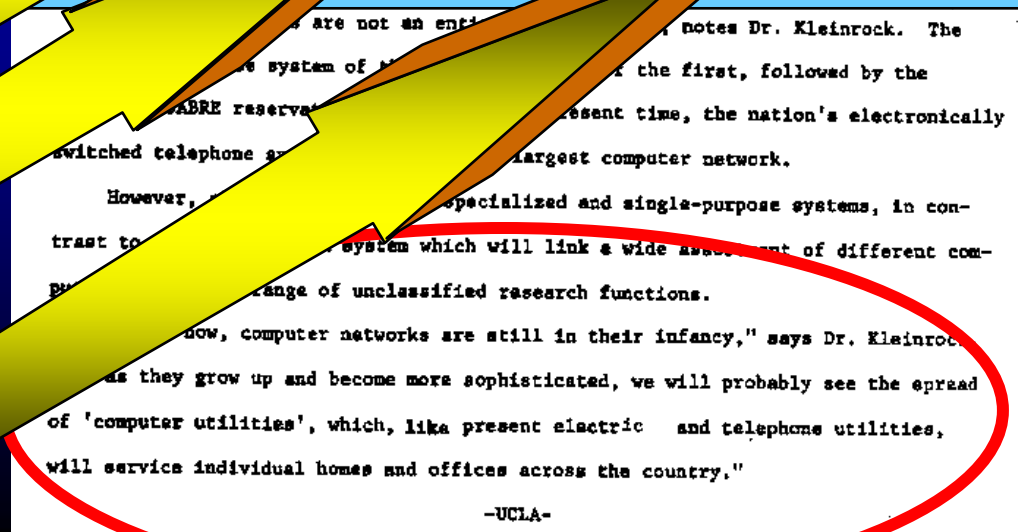
July 3, 1969

"As of now, computer networks are still in their infancy. But as they grow up and become more sophisticated, we will probably see the spread of 'computer utilities' which, like present electric and telephone utilities, will service individual homes and offices across the country."

Web-based IP Services

Plug in From Anywhere Always On

Ubiquitous



…are not an enti… notes Dr. Kleinrock. The …system of t… the first, followed by the …ABRE reserva… …esent time, the nation's electronically switched telephone a… …largest computer network.

However, … …specialized and single-purpose systems, in contrast to … …system which will link a wide assor…nt of different com- pu… …range of unclassified research functions.

"…ow, computer networks are still in their infancy," says Dr. Kleinrock… …as they grow up and become more sophisticated, we will probably see the spread of 'computer utilities', which, like present electric and telephone utilities, will service individual homes and offices across the country."

-UCLA-

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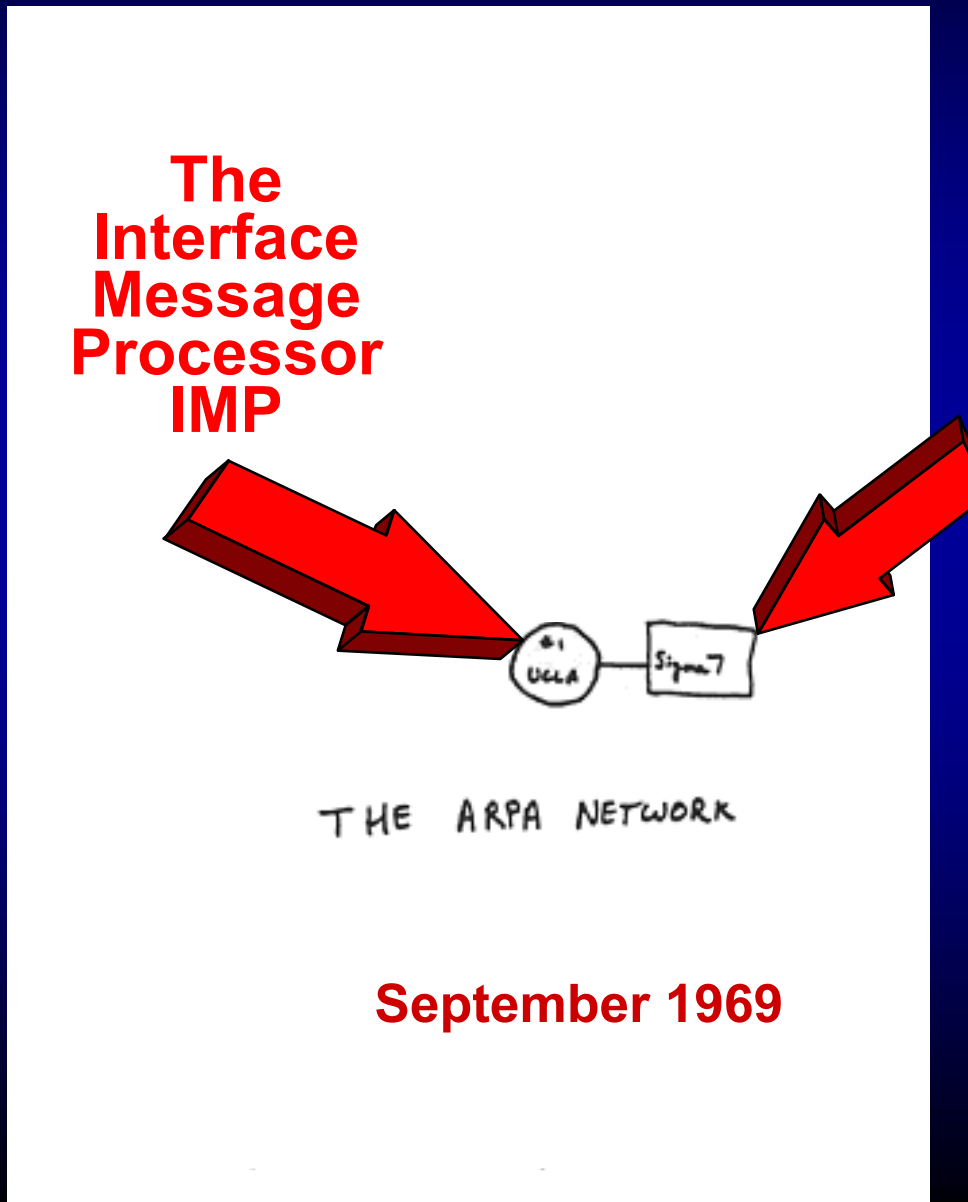
What It Looked Like in 1969



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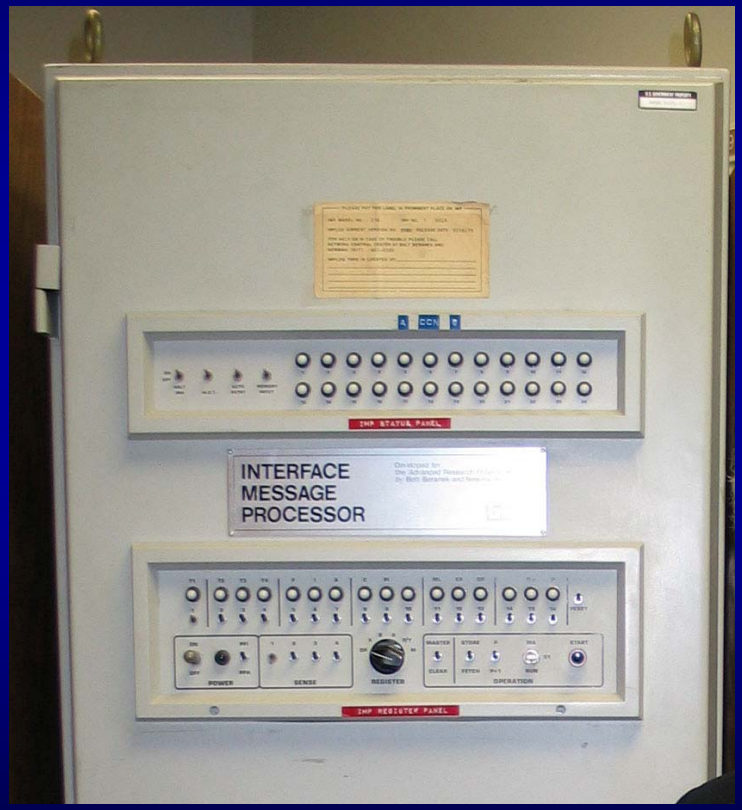
The 1969 IMP



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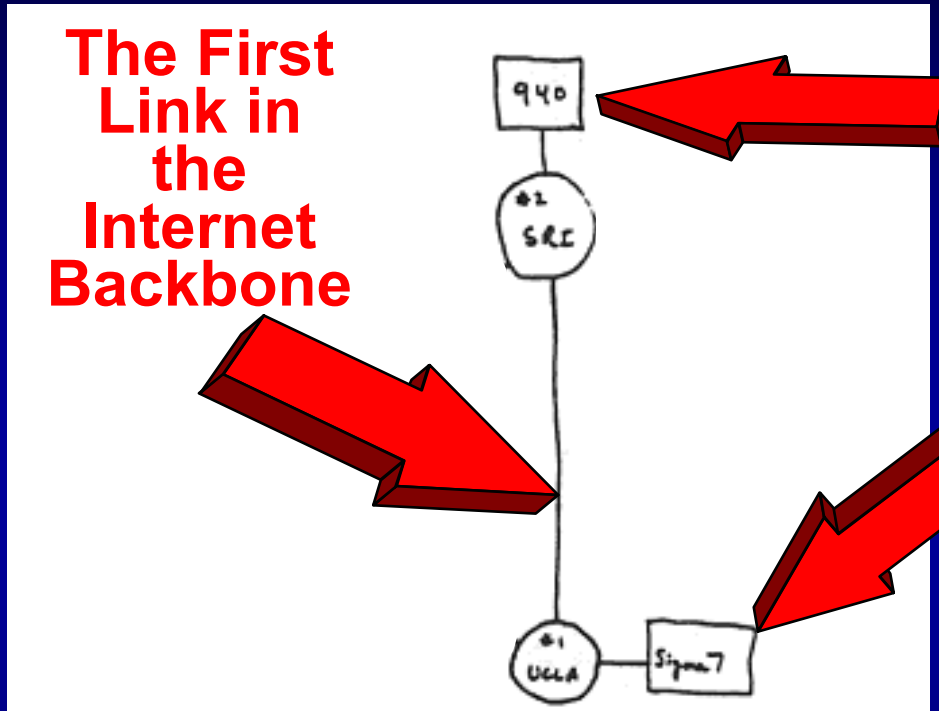
What It Looked Like in 1969

The First Link in the Internet Backbone



SRI

UCLA

October 1969

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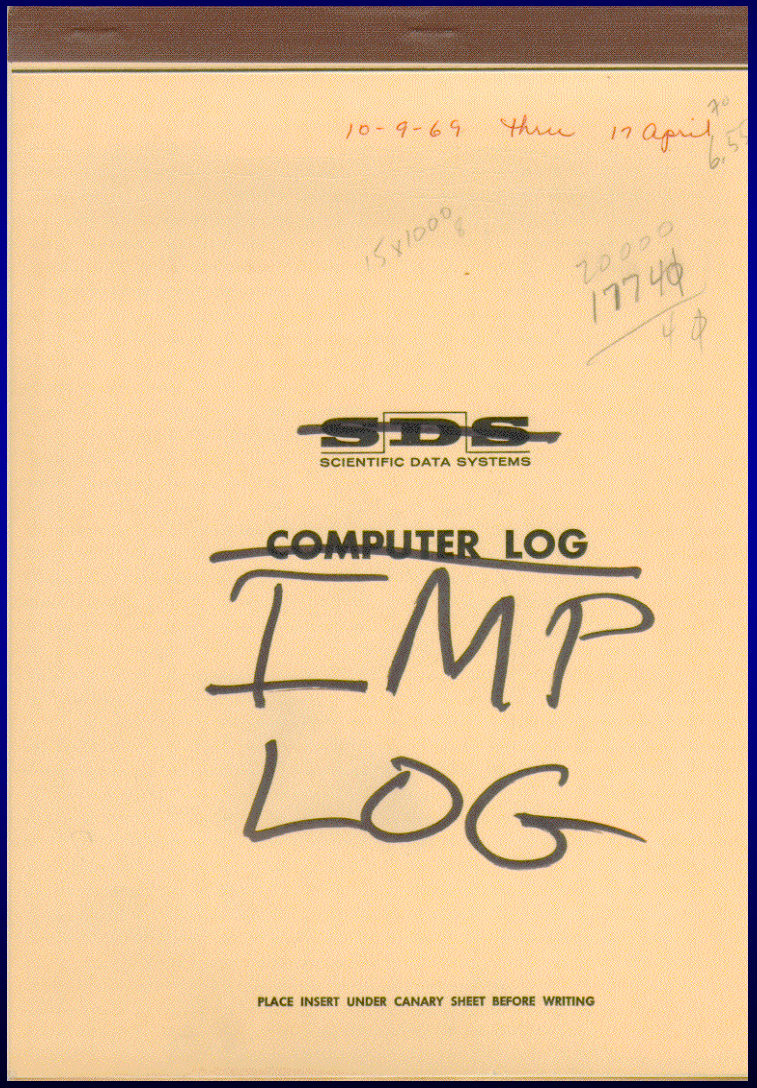
We Decided to Keep a Log



Who had the forsight to do this?

Jon Postel

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10/9/69	1:30pm	SRI called - Tried Debug test prog SL1000 but it didnt work.	Jan	
10/9/69	400pm	SRI called. we tried some things at their instructions Nothing worked.	Jan	
10/10/69	0007	Reload Operation al test program I left the tape on the reader	Jan Jan	

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DATE	METER	PROBLEM & REMEDY	OPERATOR	DOWNTIME
10/10/69	0030	Tried Charley's Program with Gordo. We can send Messages to our IMP But Messages from our IMP to Host (#7) get garbled !	Jon	
10/10/69	0930	Dan pushed some buttons at SRI's direction (THORP - BBN)	Jon	

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10/13	9:17p	Test sk_tal. Please do not touch.	MJT
10/14	4:46	Test in progress - will be checked tomorrow AM	
10/14	6:50pm	The above is unreadable and not signed Please try harder.	Jon

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17 Oct 69	1080	Called SRI (Marty) to arrange switch to operational program. Tried to Load Debug SL1900 at his request. Destroyed 2 copies before third & final copy OK. Then Punched out 2 more copies. Dumped Contents of a few memory cells for him.
	1120	Operational Program loaded however one copy is bad due to

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DATE	METER	PROBLEM & REMEDY	OPERATOR	DOWNTIME
12:30	28NOV69	operational program running		
		(I don't know which) Nov 15	Jon	
?		lots of people played		
		without logging	Jon	

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16 Jan	1150	We turned Main Power on		
		and pushed little Red Button		
		and IMP powered on	Jon & Dave K.	

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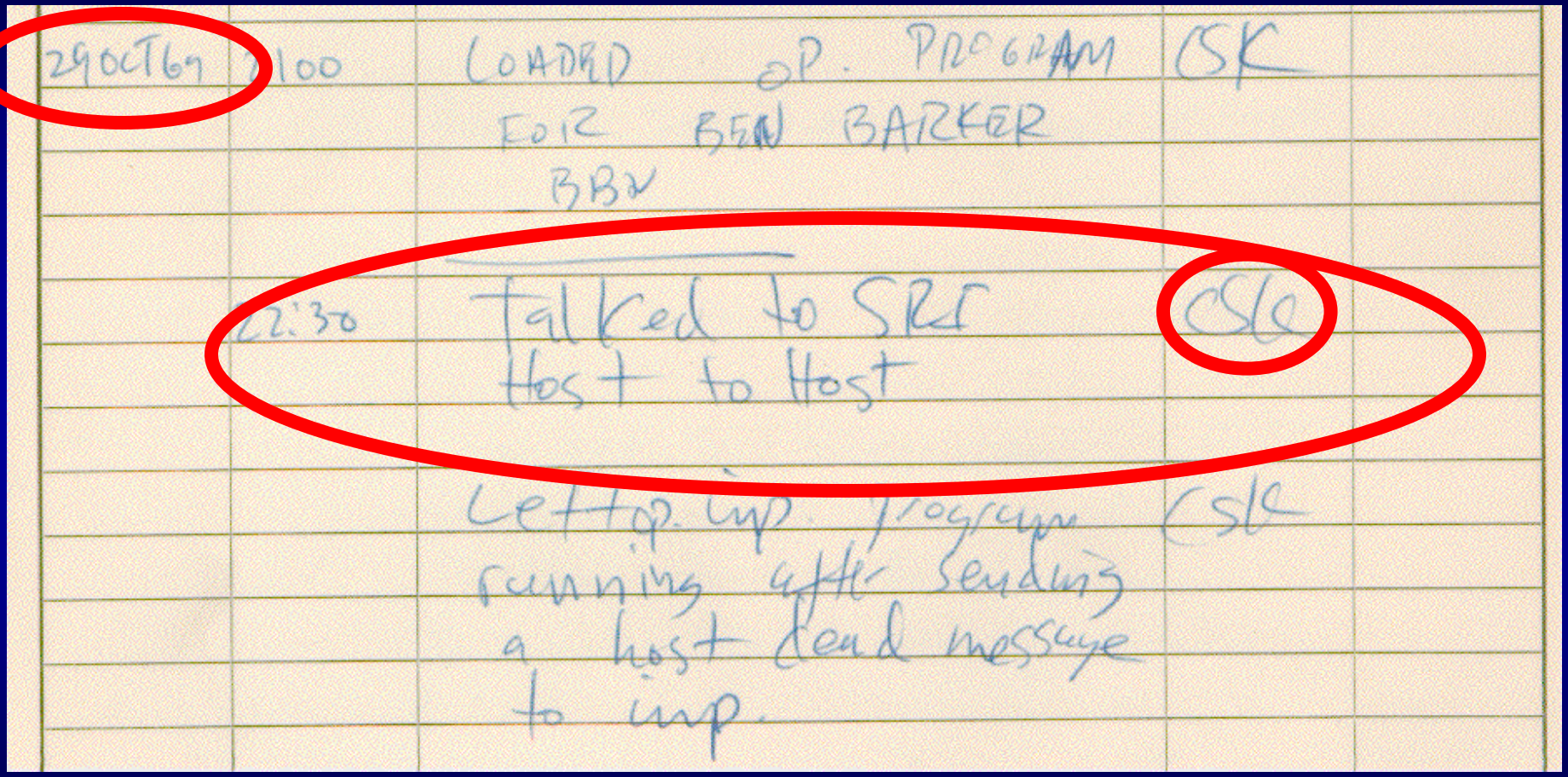
An Important Entry



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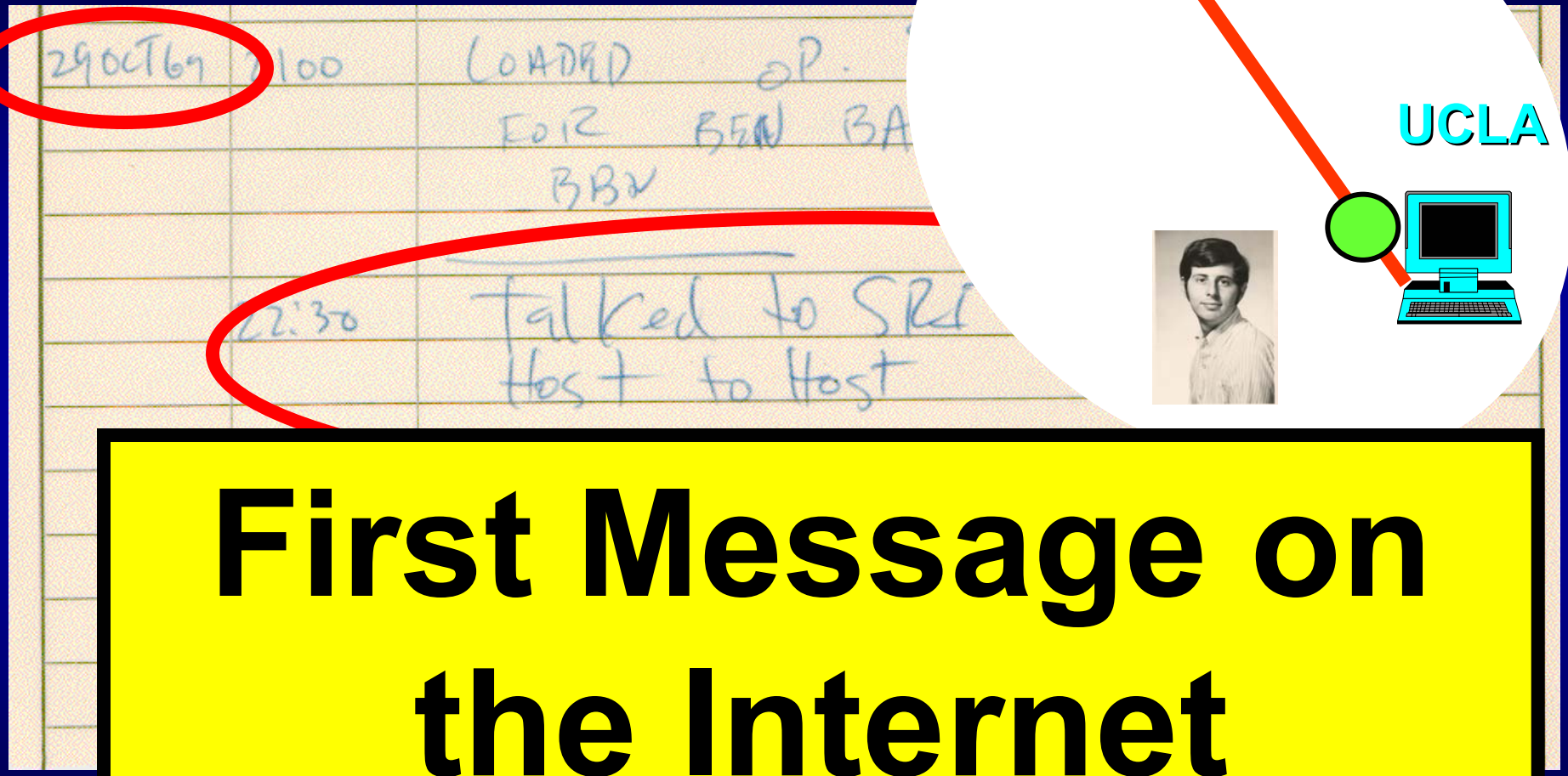
An Important Entry

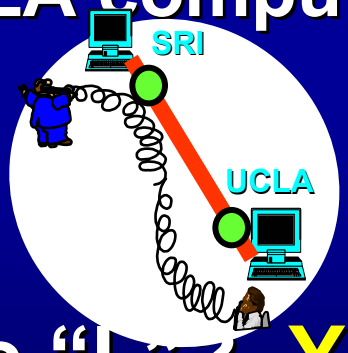


First Message on the Internet - ever!

© Leon

But What WAS the First Message Ever Sent on the Internet?

- Was it "What hath God Wrought" (Morse 1844)?
- Or "Watson, come here. I want you." (Bell 1876)?
- Or "One Giant Leap for Mankind" (Armstrong 1969)?
- It was simply a LOGIN from the UCLA computer to the SRI computer.



- We sent an "L" - did you get the "L"? YEP!
- We sent an "O" - did you get the "O"? YEP!
- We sent a "G" - did you get the "G"?

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But What WAS the First Message Ever [illegible] net?

- W[illegible]

© Leonard Kleinro[illegible]

But What WAS the First Message Ever S net?

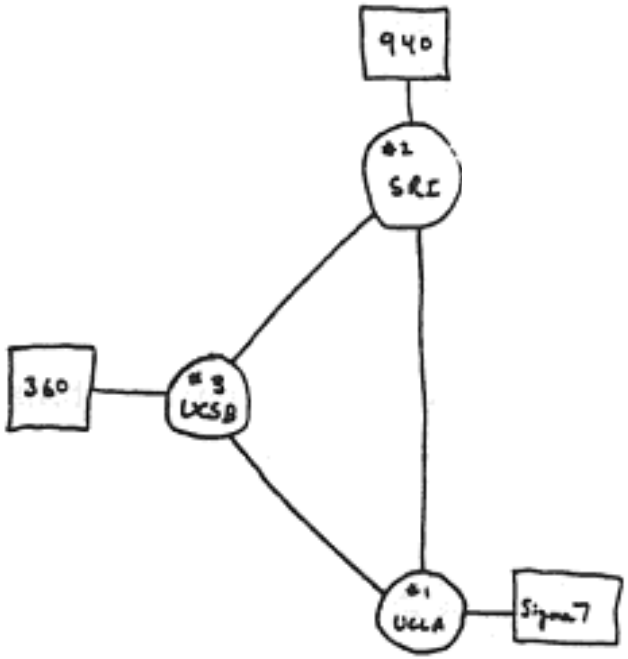
- W

© Leona

The Internet is Born !

At UCLA on October 29, 1969

What It Looked Like in 1969



THE ARPA NETWORK

November 1969

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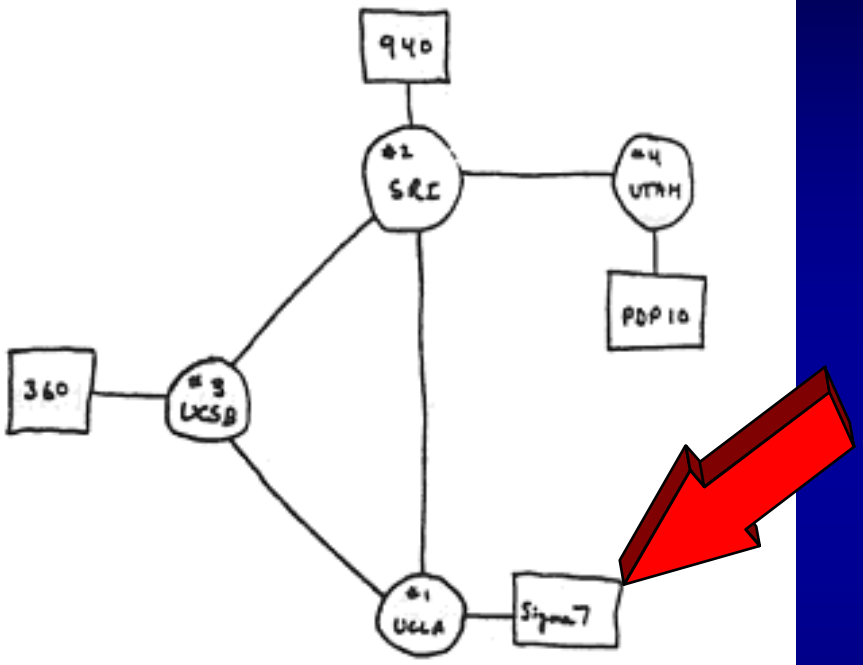
What It Looked Like in 1969



THE ARPA NETWORK

December 1969

UCLA serves the Network Measurement Center

The job is to stress the net to its breaking point!

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Growth of the Internet

- 1969 10/29 First Internet message
- 1969 Howie Frank assists topology design
- 1969 BBN releases Report 1822 spec
- 1969 Steve Crocker RFC #1 Host-Host Protocol and the NWG
- 1970 ARPANET spans US: UCLA <-> BBN
- 1970 Crocker and UCLA team release NCP
- 1971 BBN TIP - direct terminal access
- 1972 Ray Tomlinson introduce net email
- 1972 First public demo of ARPANET
- 1972 Norm Abramson' Alohanet connected to ARPANET: packet radio nets

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Network Working Group
Request for Comments: 1

Steve Crocker
UCLA
7 April 1969

Title: Host Software
Author: Steve Crocker
Installation: UCLA
Date: 7 April 1969
Network Working Group Request for Comment: 1

CONTENTS

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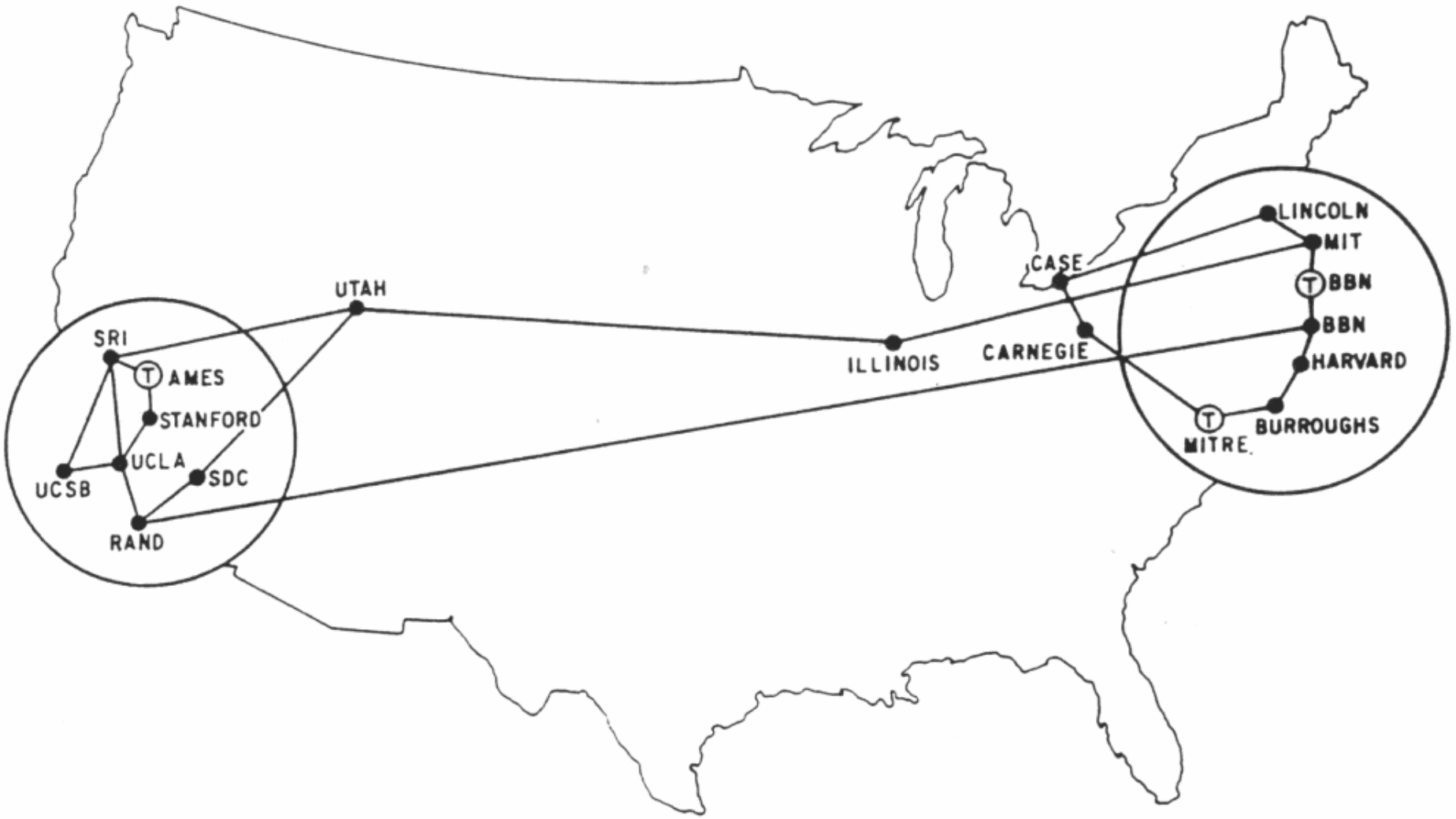
Aug 1971 ARPANET



MAP 4 September 1971

Growth of the Internet

- 1972 Bob Kahn introduces 4 rules for open-networking architecture. 
  1. Each distinct network had to stand on its own, and no internal changes could be required of any such network before being connected to the Internet.
  2. Communications would be on a best-effort basis. If a packet didn't make it to the final destination, it would quickly be retransmitted from the source.
  3. Black boxes (later called gateways and routers) would be used to connect the networks. No information would be retained by the gateways about individual flows of packets passing through them, keeping them simple and avoiding complicated adaptation and recovery from various failure modes.
  4. There would be no global control at the operations level.

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Growth of the Internet

- 1973 Cerf and Kahn design TCP  
- 1973 ARPA deploys SATNET – 1st international connection
- 1973 Bob Metcalfe develops Ethernet idea 
- 1974 Cerf and Kahn publish TCP specification
- 1975 ARPANET mgt transfers to DCA
- 1978 TCP splits into TCP and IP driven by Danny Cohen, David Reed and John Schoch to support real-time traffic.   This allows the creation of UDP.
- 1980 CSNET is funded by NSF in response to a proposal by Larry Landweber,  Dave Farber, Tony Hearn and Peter Denning   
- 1981 IBM introduces their first PC

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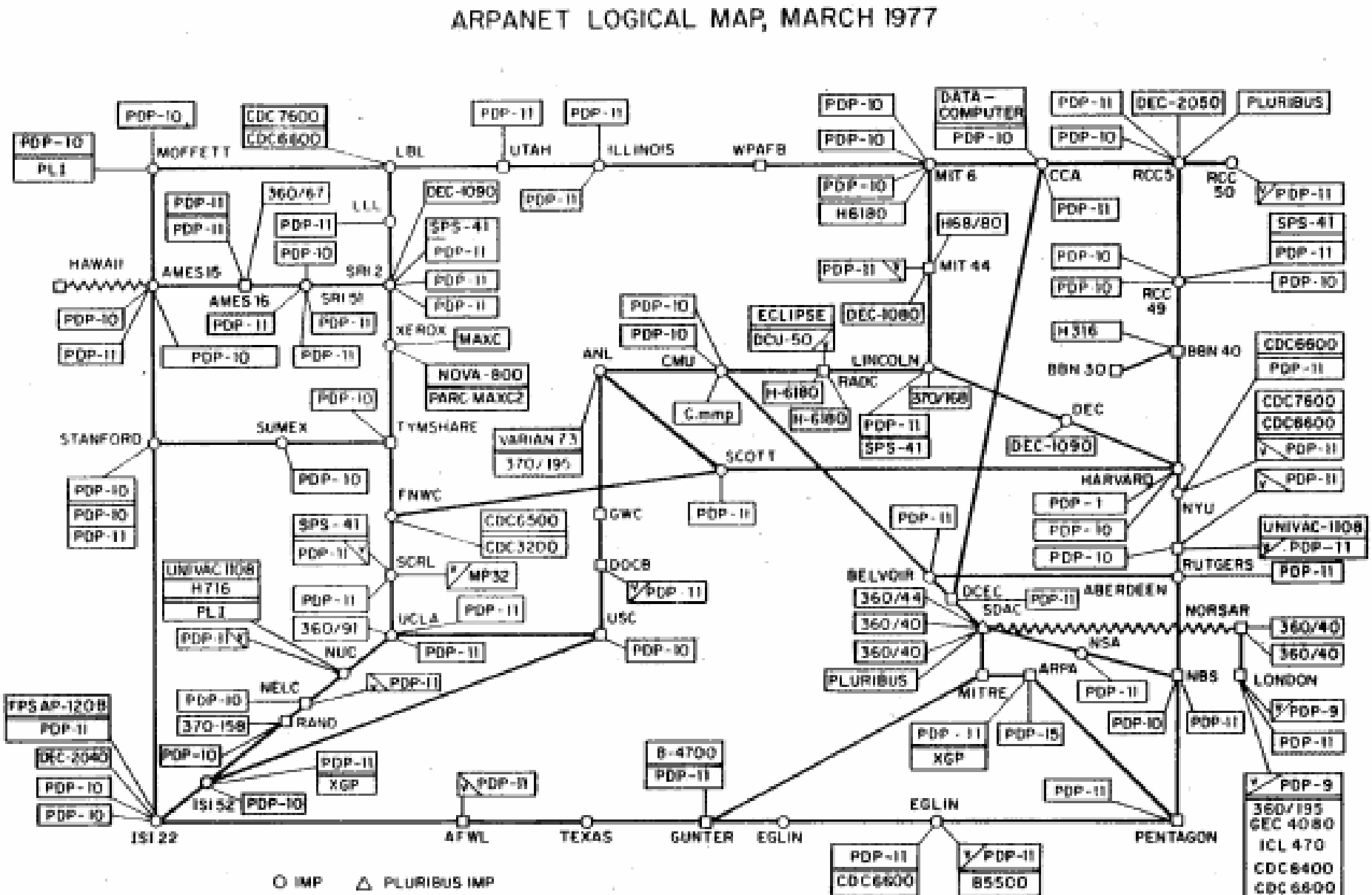
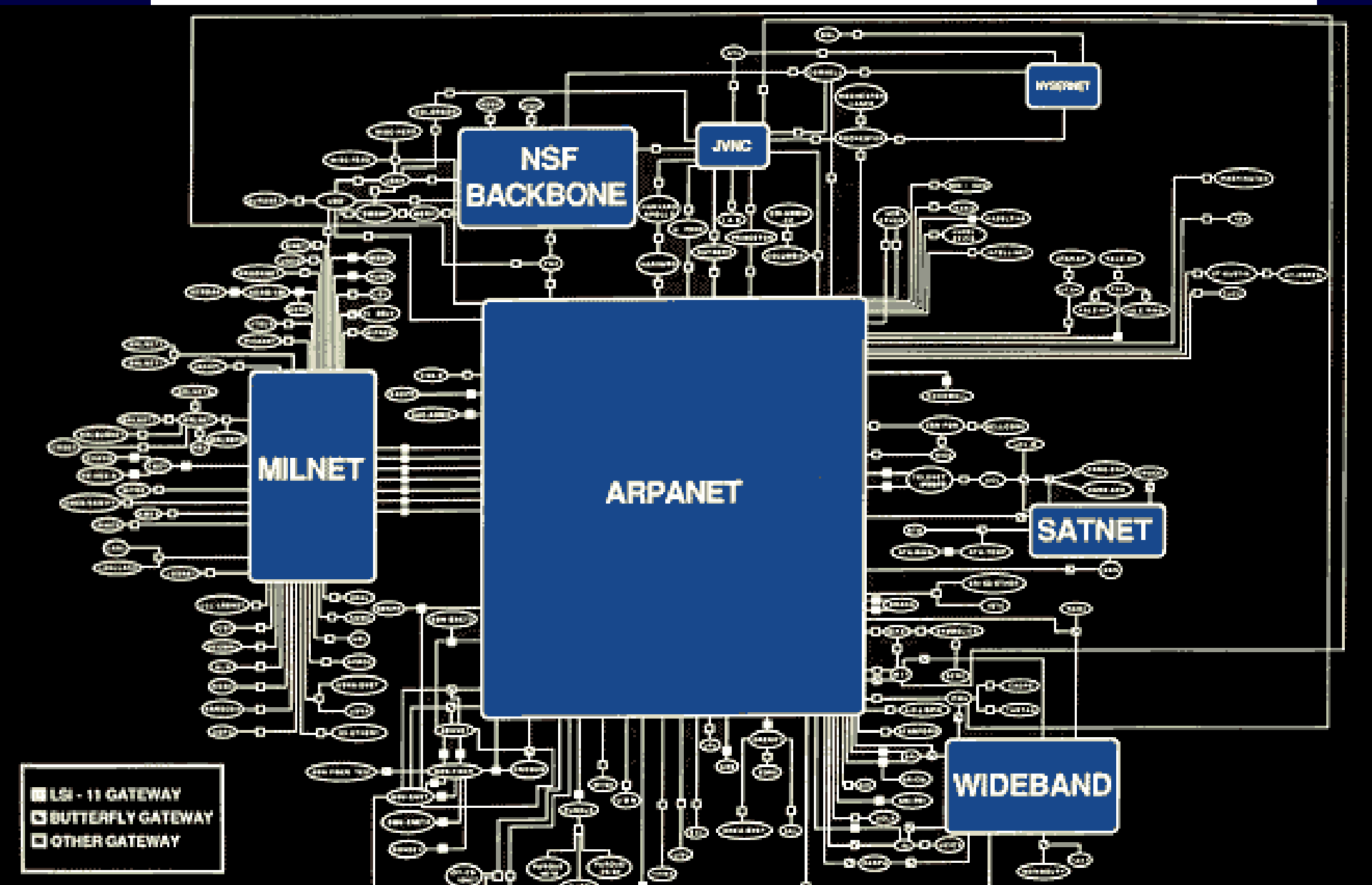
March 1977 ARPANET



Aug 1987 Internet Core



Growth of the Internet

- 1991 NSF opens Internet to commercial use
- 1992 Internet Society formed: Cerf at CNRI
- 1992 NSFNET upgraded to T-3 backbone
- 1993 Marc Andreeson Mosaic browser 
- 1994 Cantor & Siegel introduce spam
- 1994 BBN celebrates 25th anniversary
- 1995 dot.com boom starts with faith that a "new economy" is beginning
- 1996 Telecom Act deregulates data networks
- 1996 More email than postal mail in USA
- 1997 Internet2 consortium is established
- 1997 IEEE releases 802.11 (WiFi) standard

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Spam !

- It surfaced as a critical and widely publicized event in April 1994 when two Arizona-based attorneys arguably became the two most hated individuals in the history of the Internet. It was Lawrence Canter and Martha Siegel, the famous "green card lawyers" who "spammed" the Internet.

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The First Spam email

- From: Laurence Canter (nike@indirect.com)
  Subject: Green Card Lottery- Final One?
  Newsgroups: alt.brother-jed, alt.pub.coffeehouse.amethyst
  View: Complete Thread (4 articles) | Original Format
  Date: 1994-04-12 00:40:42 PST

Green Card Lottery 1994 May Be The Last One!
THE DEADLINE HAS BEEN ANNOUNCED.

The Green Card Lottery is a completely legal program giving away a certain annual allotment of Green Cards to persons born in certain countries. The lottery program was scheduled to continue on a permanent basis. However, recently, Senator Alan J Simpson introduced a bill into the U. S. Congress which could end any future lotteries. THE 1994 LOTTERY IS SCHEDULED TO TAKE PLACE SOON, BUT IT MAY BE THE VERY LAST ONE.

PERSONS BORN IN MOST COUNTRIES QUALIFY, MANY FOR FIRST TIME.

The only countries NOT qualifying are: Mexico; India; P.R. China; Taiwan, Philippines, North Korea, Canada, United Kingdom (except Northern Ireland), Jamaica, Domican Republic, El Salvador and Vietnam.

Lottery registration will take place soon. 55,000 Green Cards will be given to those who register correctly. NO JOB IS REQUIRED.

THERE IS A STRICT JUNE DEADLINE. THE TIME TO START IS NOW!!

For FREE information via Email, send request to cslaw@indirect.com

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Canter & Siegel, Immigration Attorneys
3333 E Camelback Road, Ste 250, Phoenix AZ 85018 USA
cslaw@indirect.com telephone (602)661-3911 Fax (602) 451-7617

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Enter the Dark Side

- There is a dark side to the Internet that has developed over the past decade.
- The dark side includes
  - spam,
  - invasion of privacy,
  - pornography,
  - pedophilia,
  - denial of service,
  - worms,
  - viruses,
  - destruction of property,
  - identity fraud
  - and more

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Enablers for the Dark Side

- The Internet allows anyone to reach hundreds of millions of users
  - easily,
  - quickly,
  - at essentially no cost (in money or effort),
  - anonymously
- This is a perfect formula for enabling the dark side of the Internet.

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Source: Bill Cheswick

URL's Should Make Sense

- http://www…….
- The arcane language of the nerds
- http://lw15fd.law15.hotmail.msn.com/cai-bin/sbox?curmbox=F000000001&a=f387bdbf8e231350e4a9e38740d2c99e&f=33792&t=2AAAAAAADJkhwAHUCjjxnE6rKyMbyz92NqU4By6cj3eAF21ruaEq9DQ%24%24&p=AAAAAAAAAAIVTgkE1JLSazjVtkLIVgDdWBr%2aHRIzsKzfkRARfe6F2wCyCTe7poCDOIXOCcj8cj8cRzesJX%21Wpe8RUFTImuMMBtvboPWLSqnjwyCnYiCYpNISMb2h1LLzPF7VKgLqI6AnegCKaBIPIjXeN3o9oDzgF5YdH&utf8=0

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Growth of the Internet

- 1997 Leiner, et al publish "The Past and Future History of the Internet" 
- 1998 Blogs begin to appear
- 1998 VOIP equipment begins rolling out
- 1999 UCLA celebrates 30th anniversary 
- 1999 Napster rolls out 

- 2000 dot.com bubble begins to burst
- 2001 Napster forced to suspend service
- 2003 Flash mobs gain popularity
- 2003 World Summit on the Information Society (WSIS) convenes first meeting in Geneva
- Now What do the maps look like at this point?
- 2004 UCLA celebrates 35th anniversary

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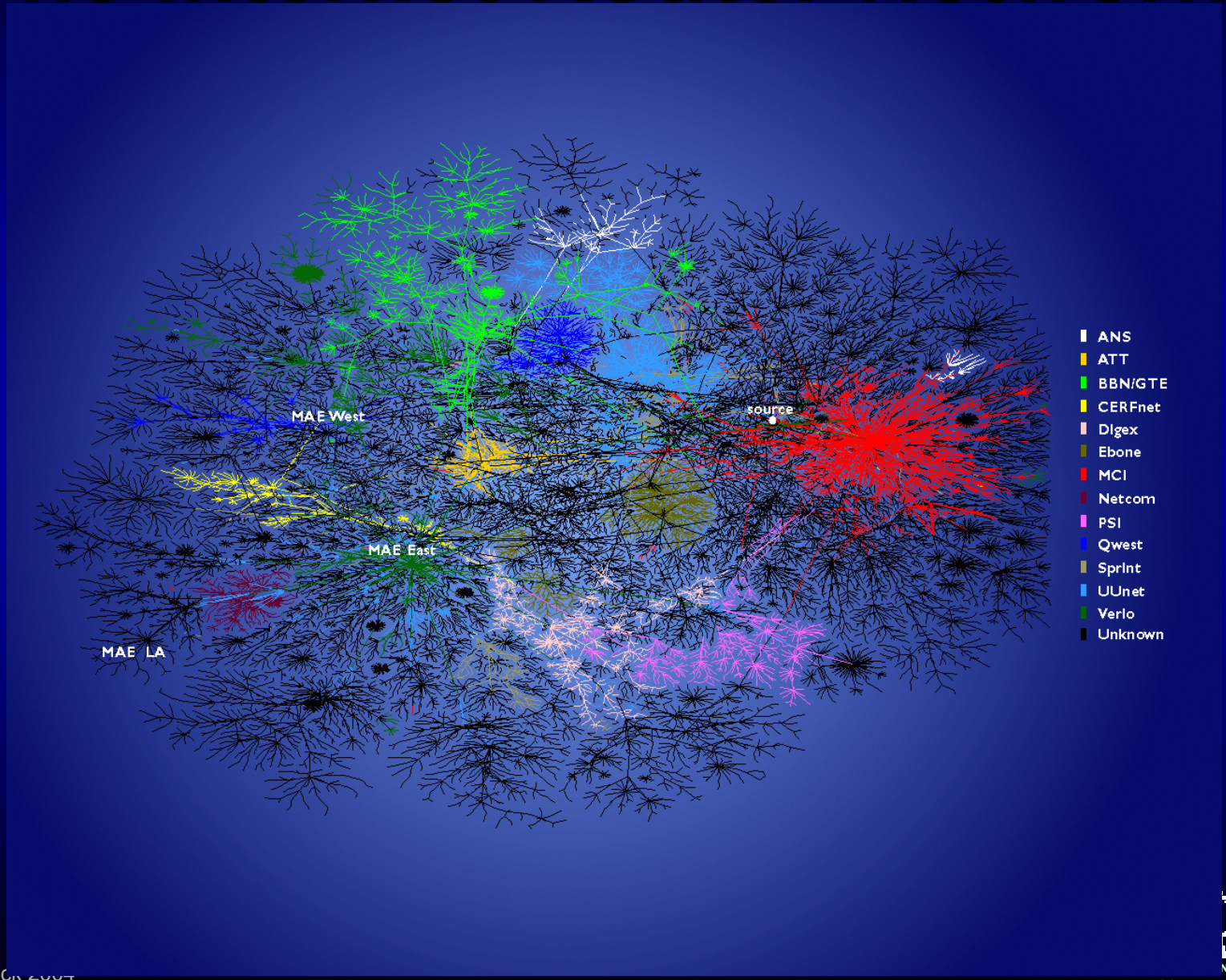
The Internet Router Network



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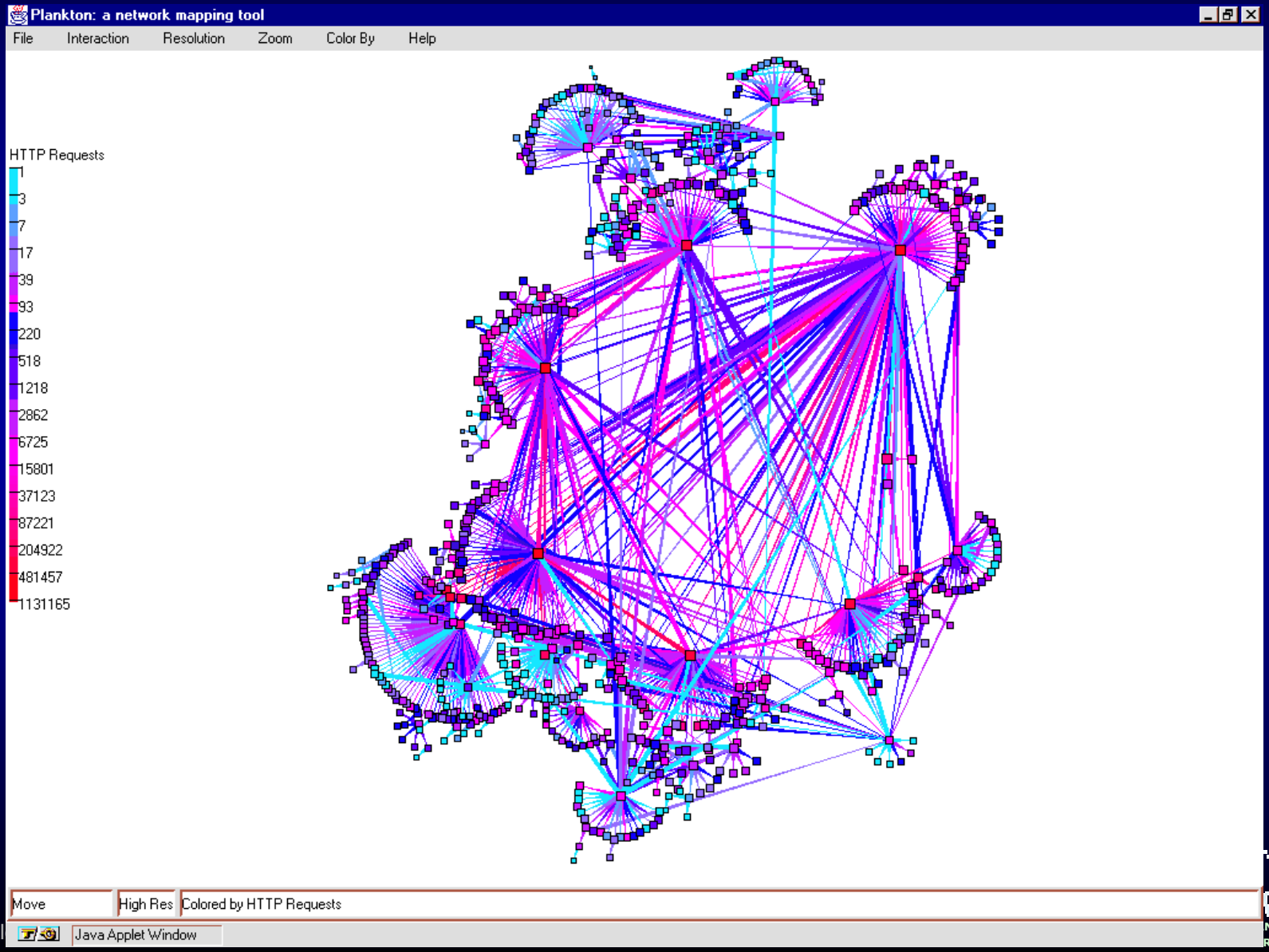
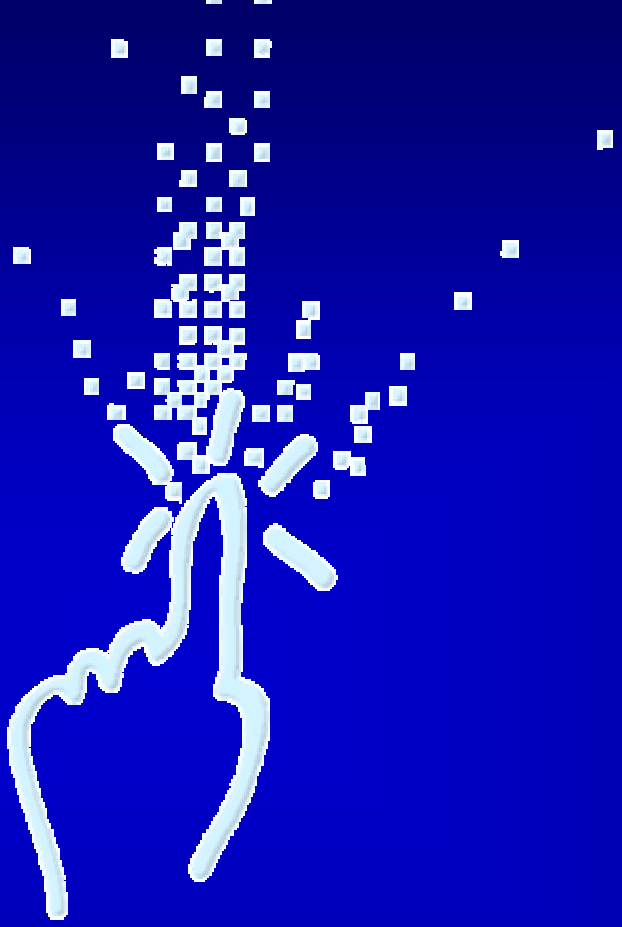
International Web Cache



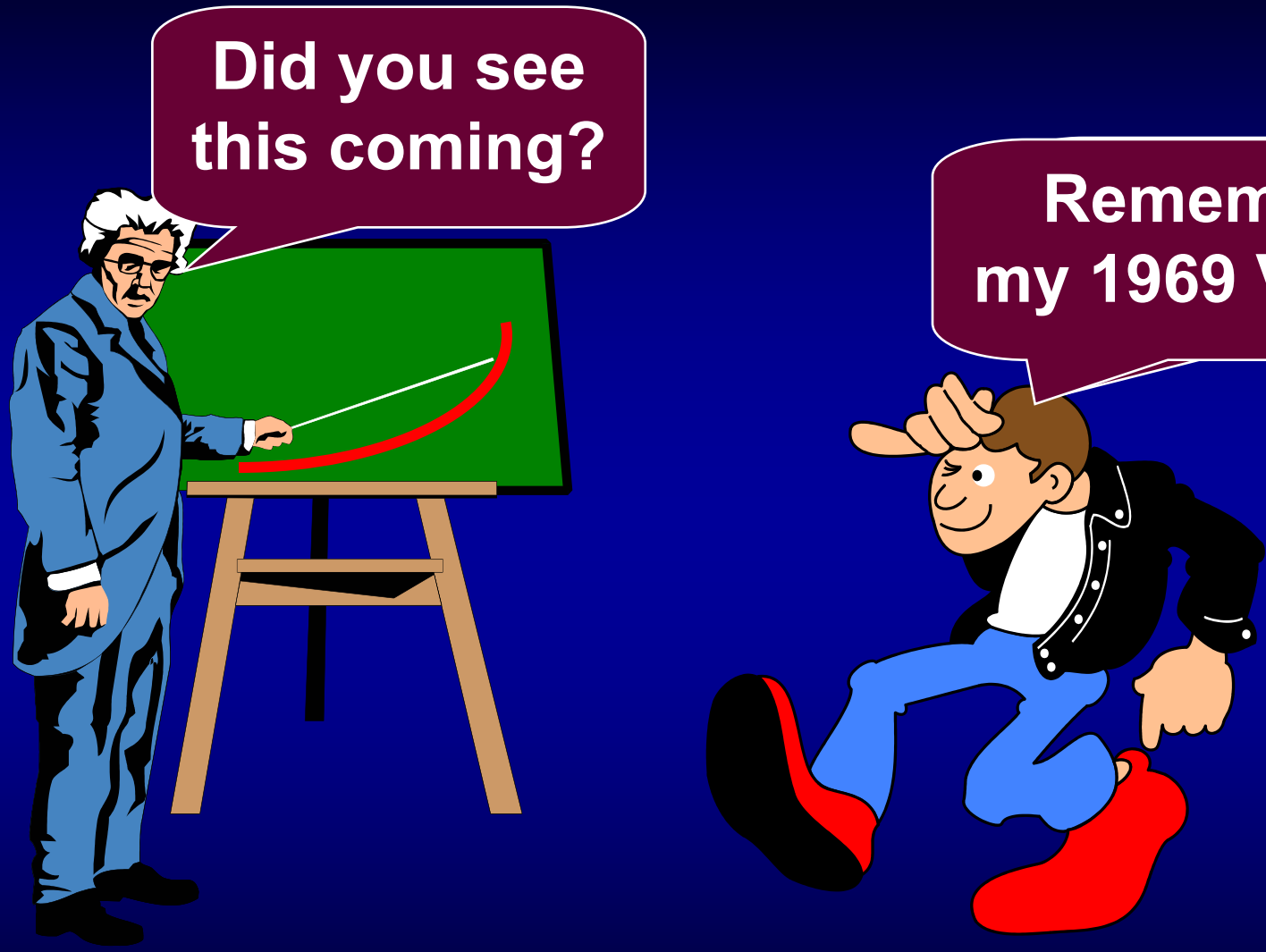
© Leonard Kl

NNIVERSARY
RNET @ UCLA



35th **ANNIVERSARY**

of the **INTERNET** @ **UCLA**



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So What Was My Internet Vision?

- The Internet technology will be everywhere
- Always accessible
- Always on
- Anyone can plug in any device anywhere
- Invisible

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The Internet Almost Got it Right

Yep The Internet technology will be everywhere

Yep Always accessible

Yep Always on

Nope Anyone can plug in any device anywhere

Nope Invisible

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Today's Internet Realities: The Good

- No one controls it
- No one can turn it off
- It serves everyone
- In many ways, it is an "open" network
- It provides a means to share works and ideas
- It is diversifying
- It is not centralizing
- It is owned by no one
- It is always turned on
- It is empowering
- It is a publishing machine
- It offers a means of self expression
- It is an innovation machine
- It is a marketplace of ideas, services, applications, and goods
- It connects communities of interest

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Today's Internet Realities: The Bad

- It invades our privacy
- It is capable of watching and tracking our behavior
- It frustrates us with delays
- It drowns us in junk
- It does not obey the laws of all countries
- It is a massive source of spam
- It contains pornography
- It spawns annoying and/or destructive viruses and worms
- It supports denial of service attacks
- It has developed into fences of proprietary products, services and information
- Its user interfaces are frustrating

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Thank You

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