The First Days of Packet Switching

Leonard Kleinrock

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SIGCOMM Tutorial

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UCLA
UNIVERSITY OF CALIFORNIA, LOS ANGELES
Office of Public Information
405 Hilgard Avenue • Los Angeles, California 90024
Dial: "UCLA-585"

Release

Thursday, July 3, 1969

Tugend – UCLA 520

UCLA TO BE FIRST STATION IN NATIONWIDE COMPUTER NETWORK

UCLA will become the first station in a nationwide computer network which, for the first time, will link together computers of different makes and using different machine languages into one time-sharing system.

Creation of the network represents a major forward step in computer technology and may serve as the forerunner of large computer networks of the future.

The ambitious project is supported by the Defense Department's Advanced Research Project Agency (ARPA), which has pioneered many advances in computer research, technology and applications during the past decade. The network project was proposed and is headed by ARPA's Dr. Lawrence G. Roberts.

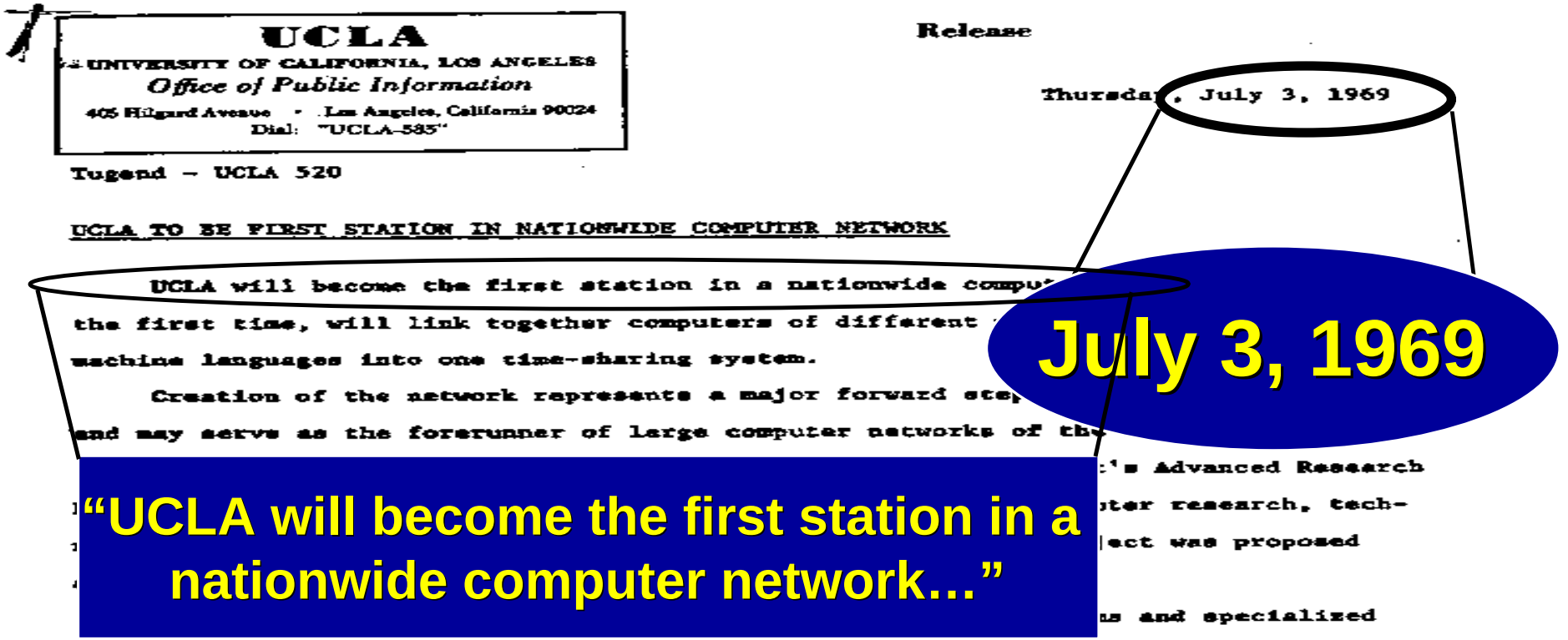
The system will, in effect, pool the computer power, programs and specialized know-how of about 15 computer research centers, stretching from UCLA to M.I.T. Other California network stations (or nodes) will be located at the Rand Corp. and System Development Corp., both of Santa Monica; the Santa Barbara and Berkeley campuses of the University of California; Stanford University and the Stanford Research Institute.

The first stage of the network will go into operation this fall as a subnet joining UCLA, Stanford Research Institute, UC Santa Barbara, and the University of Utah. The entire network is expected to be operational in late 1970.

Engineering professor Leonard Kleinrock, who heads the UCLA project, describes how the network might handle a sample problem:

Programmers at Computer A have a blurred photo which they want to bring into focus. Their program transmits the photo to Computer B, which specializes in computer graphics, and instructs B's program to remove the blur and enhance the contrast. If B requires specialized computational assistance, it may call on Computer C for help.

-more-



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The processed work is shuttled back and forth until B is satisfied with the photo, and then sends it back to Computer A. The messages, ranging across the country, can flash between computers in a matter of seconds, Dr. Kleinrock says.

UCLA's part of the project will involve about 20 people, including some 15 graduate students. The group will play a key role as the official network measurement center, analyzing computer interaction and network behavior, comparing performance against anticipated results, and keeping a continuous check on the network's effectiveness. For this job, UCLA will use a highly specialized computer, the Sigma 7, developed by Scientific Data Systems of Los Angeles.

Each computer in the network will be equipped with its own interface message processor (IMP) which will double as a sort of translator among the Babel of computer languages and as a message handler and router.

Computer networks are not an entirely new concept, notes Dr. Kleinrock. The SAGE radar defense system of the Fifties was one of the first, followed by the airlines' SABRE reservation system. At the present time, the nation's electronically switched telephone system is the world's largest computer network.

However, all three are highly specialized and single-purpose systems, in contrast to the planned ARPA system which will link a wide assortment of different computers for a wide range of unclassified research functions.

"As of now, computer networks are still in their infancy," says Dr. Kleinrock. "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."

-UCLA-

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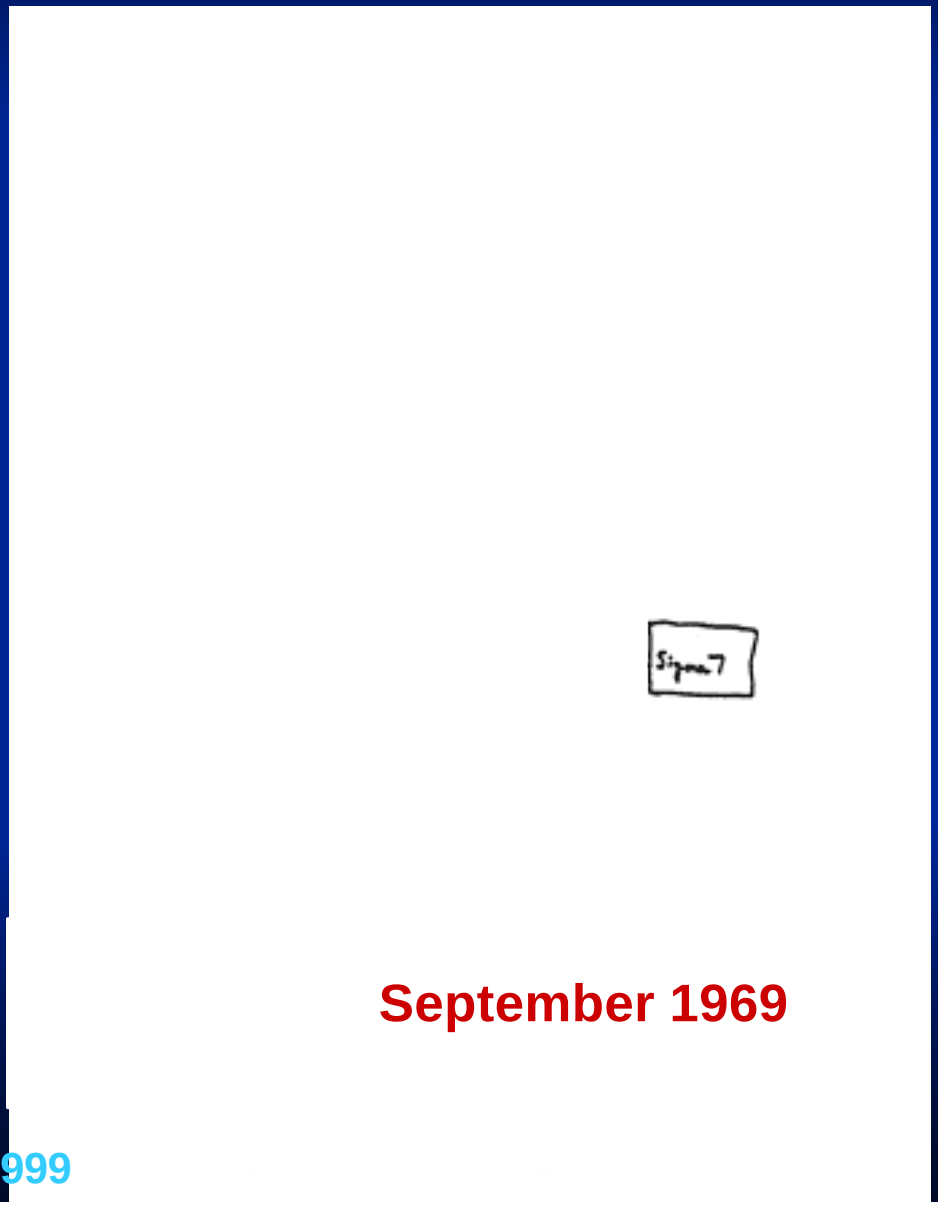
-UCLA-

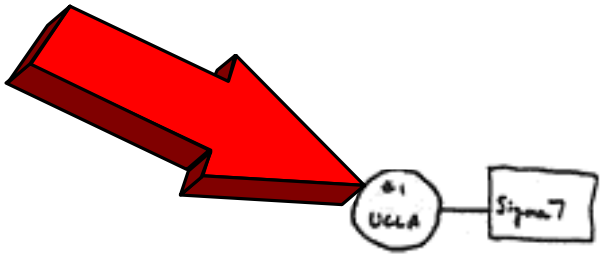
What It Looked Like in 1969



September 1969

What It Looked Like in 1969

The Interface Message Processor IMP



THE ARPA NETWORK

September 1969

The IMP

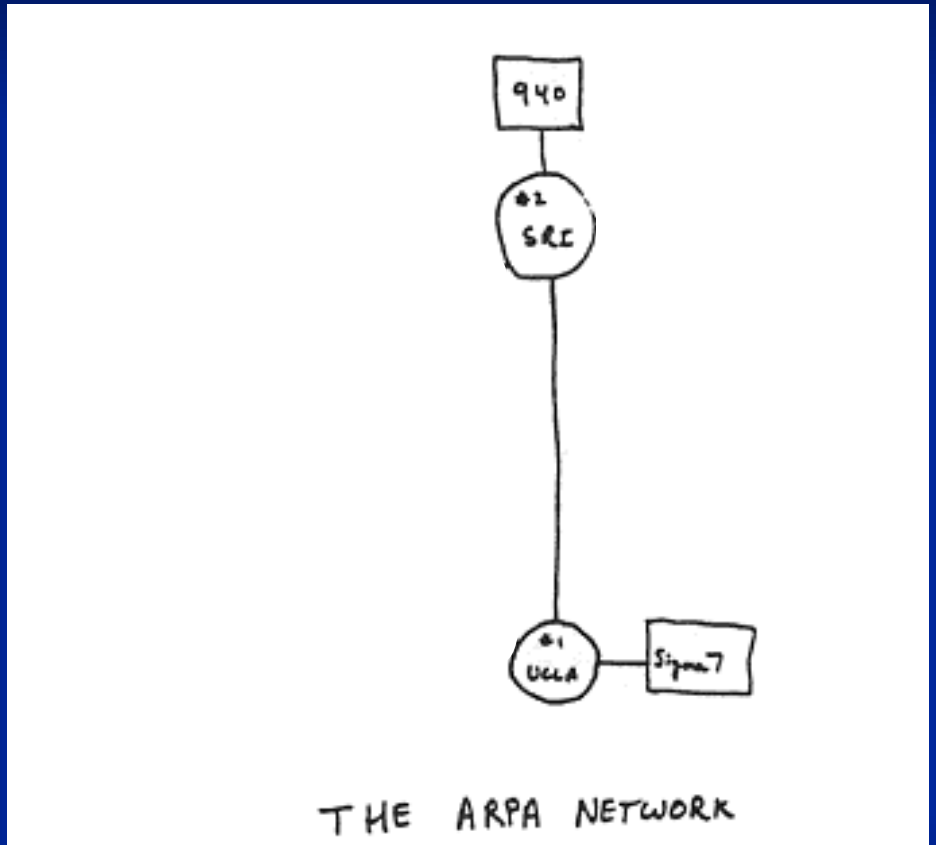
1969

The IMP

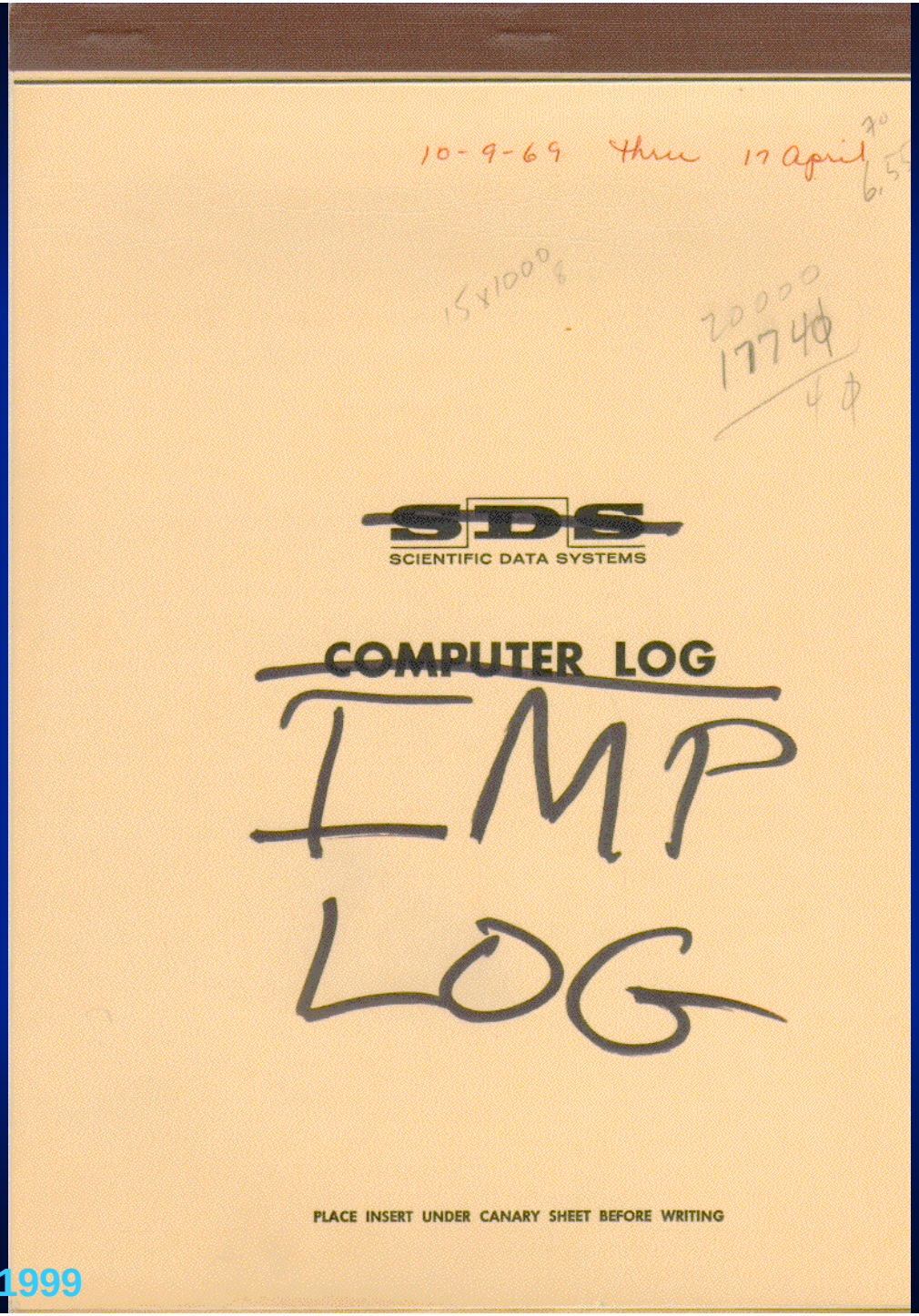
1969

Today

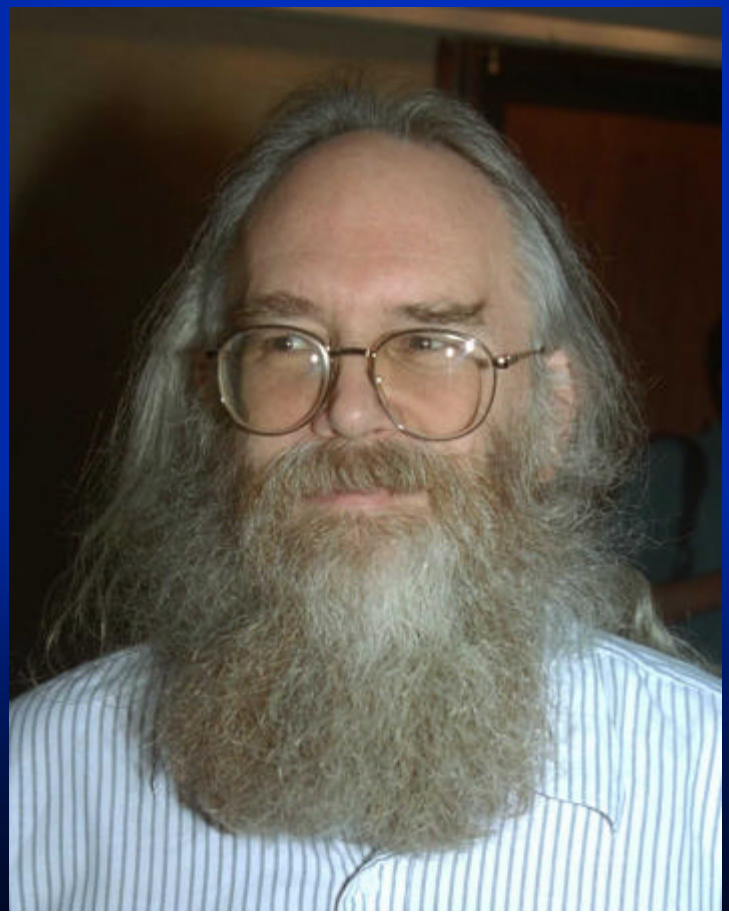
What It Looked Like in 1969



October 1969

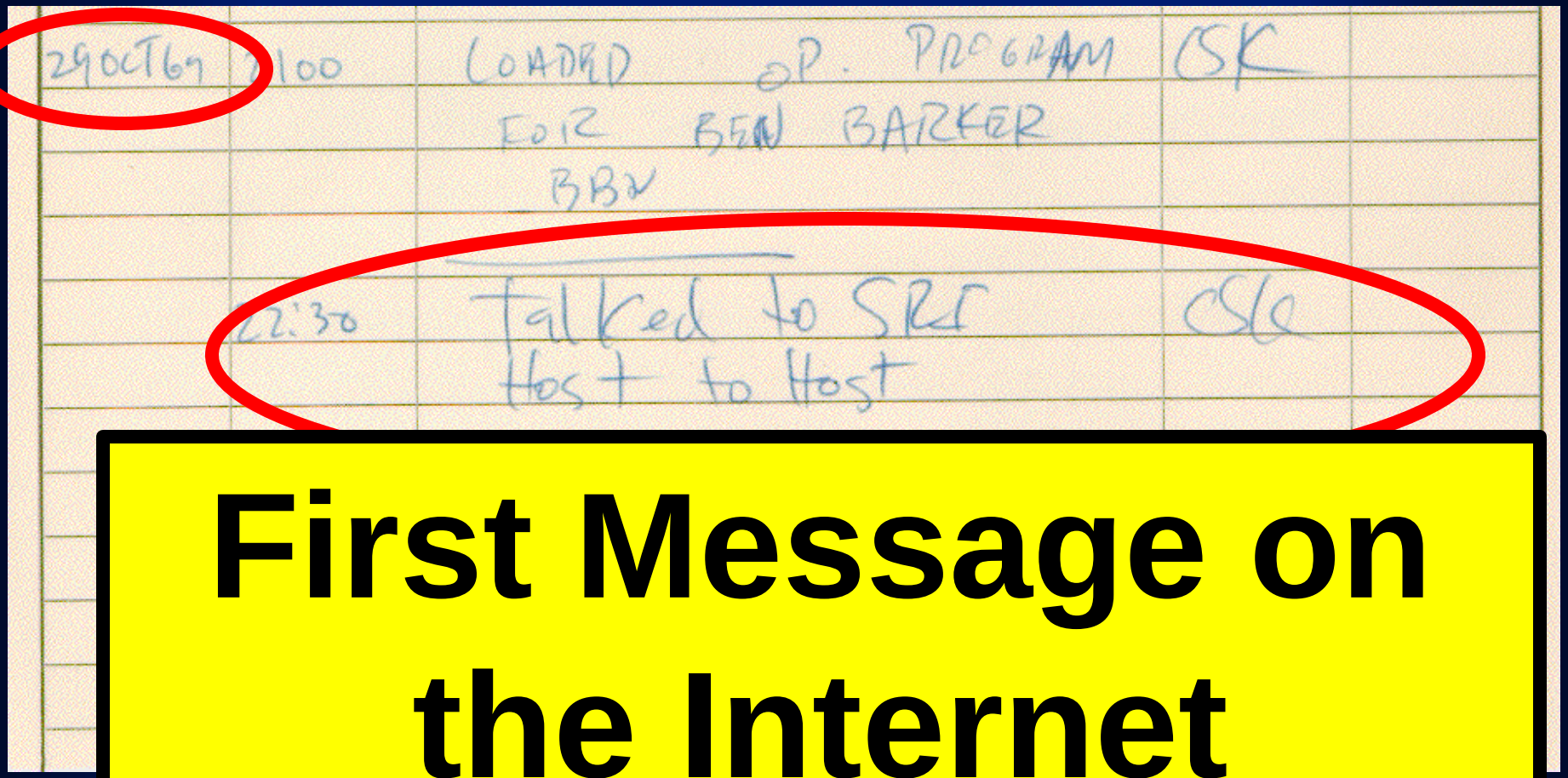


Who Had the Foresight to Keep This Log?



Jon Postel

29OCT69	2100	LOADED IMP. PROGRAM FOR BEN BARKER BBN	CSK
	22:30	Talked to SRI Host to Host	CSK
		Left Imp. Program running after sending a host dead message to Imp.	CSK

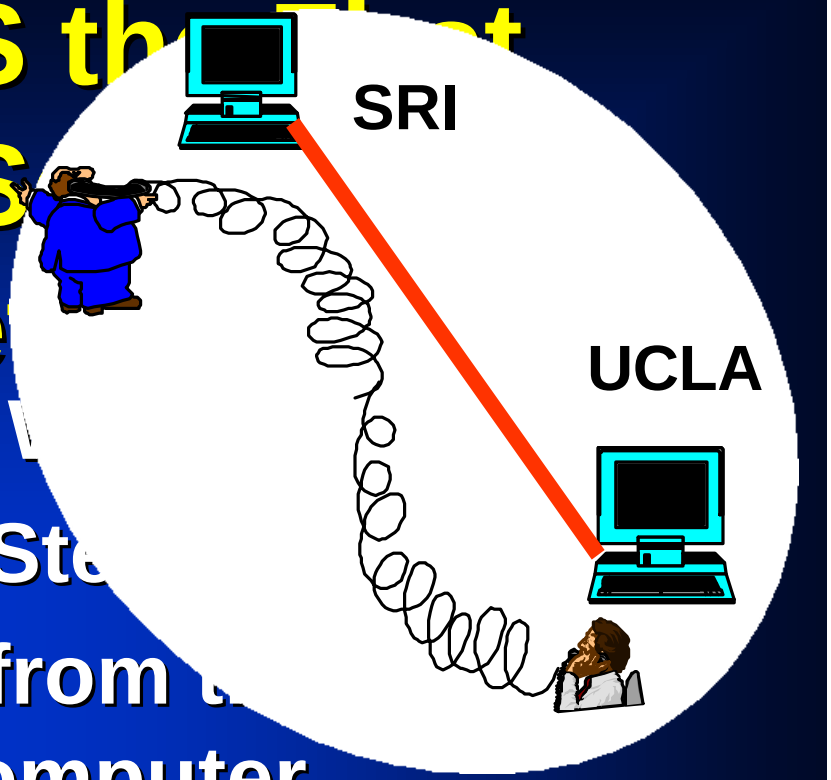


First Message on the Internet - ever!

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

- Was it “What hath God Wrought”?
- Was it “This is a Giant Step for Mankind”?
- 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”?

But What WAS th[illegible]t Message Ever S[illegible] Interne[illegible]



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- Was it “This is a Giant St[illegible]
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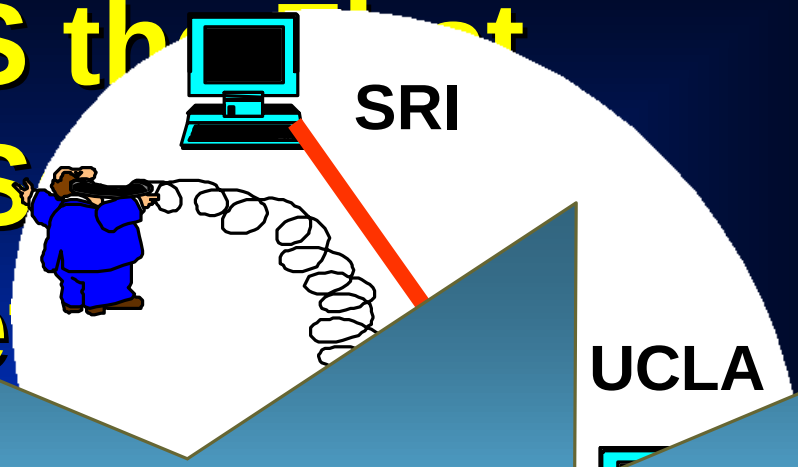
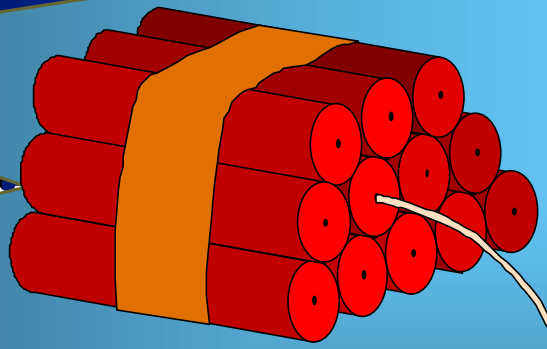
But What WAS th[illegible] That Message Ever S[illegible] Interne[illegible]



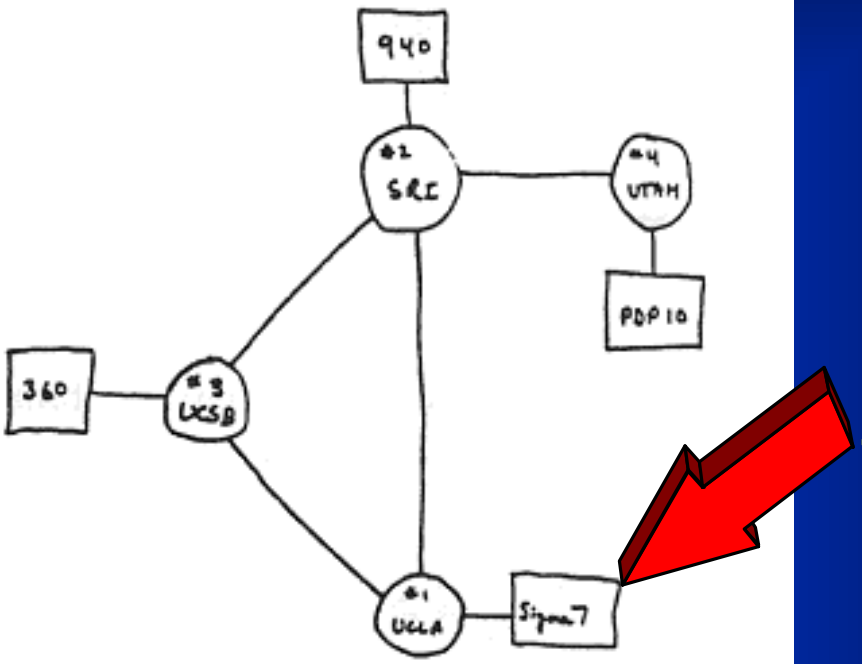
- Was it “What hath Go[illegible]
- Was it [illegible]
- It was sin[illegible]
- We s[illegible]
- We [illegible] get the “G”?



Crash!

[illegible] “O”? [illegible]EP!

What It Looked Like in 1969



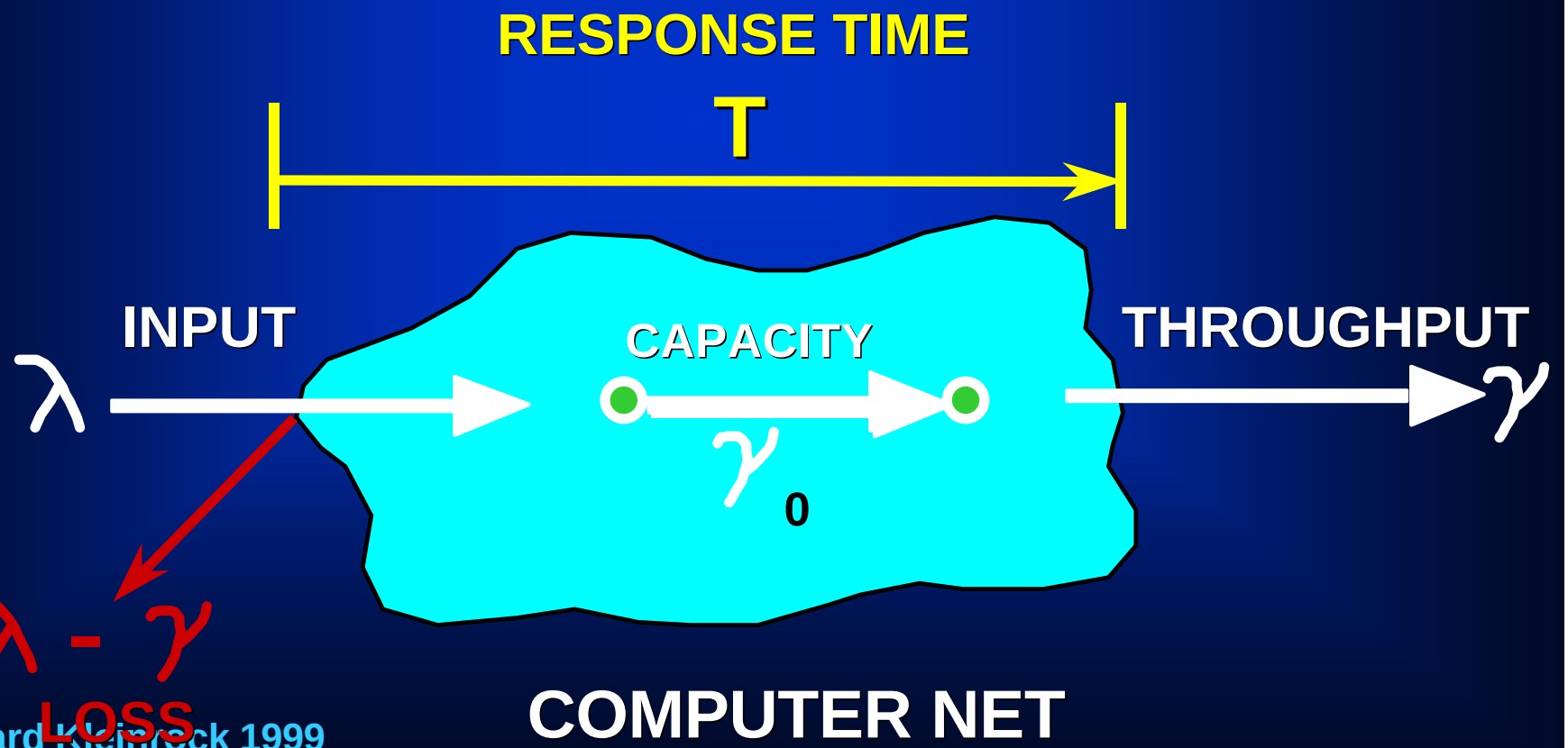
THE ARPA NETWORK

December 1969

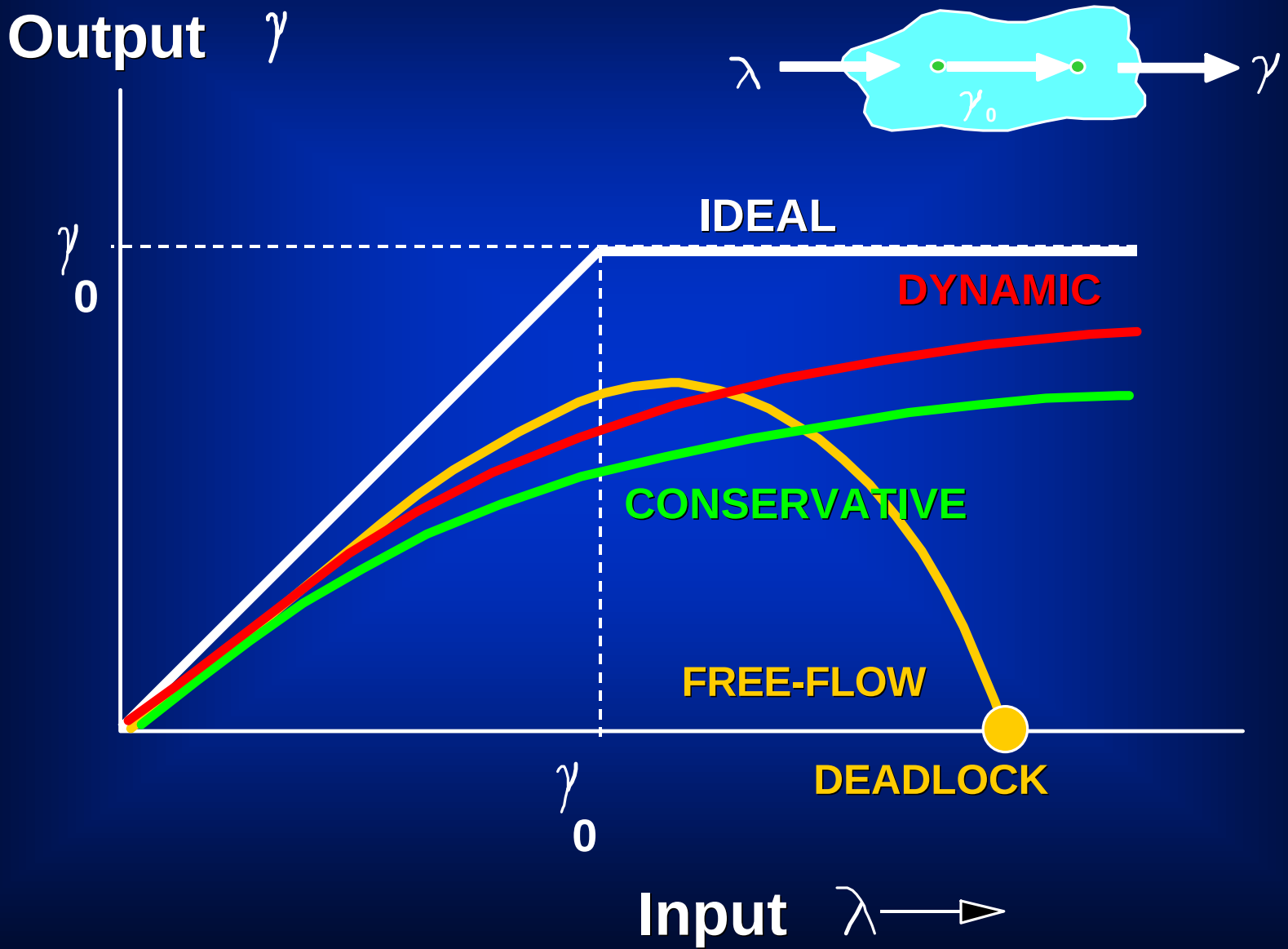
UCLA serves the Network Measurement Center

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

Response Time
Throughput
Loss



Flow Control



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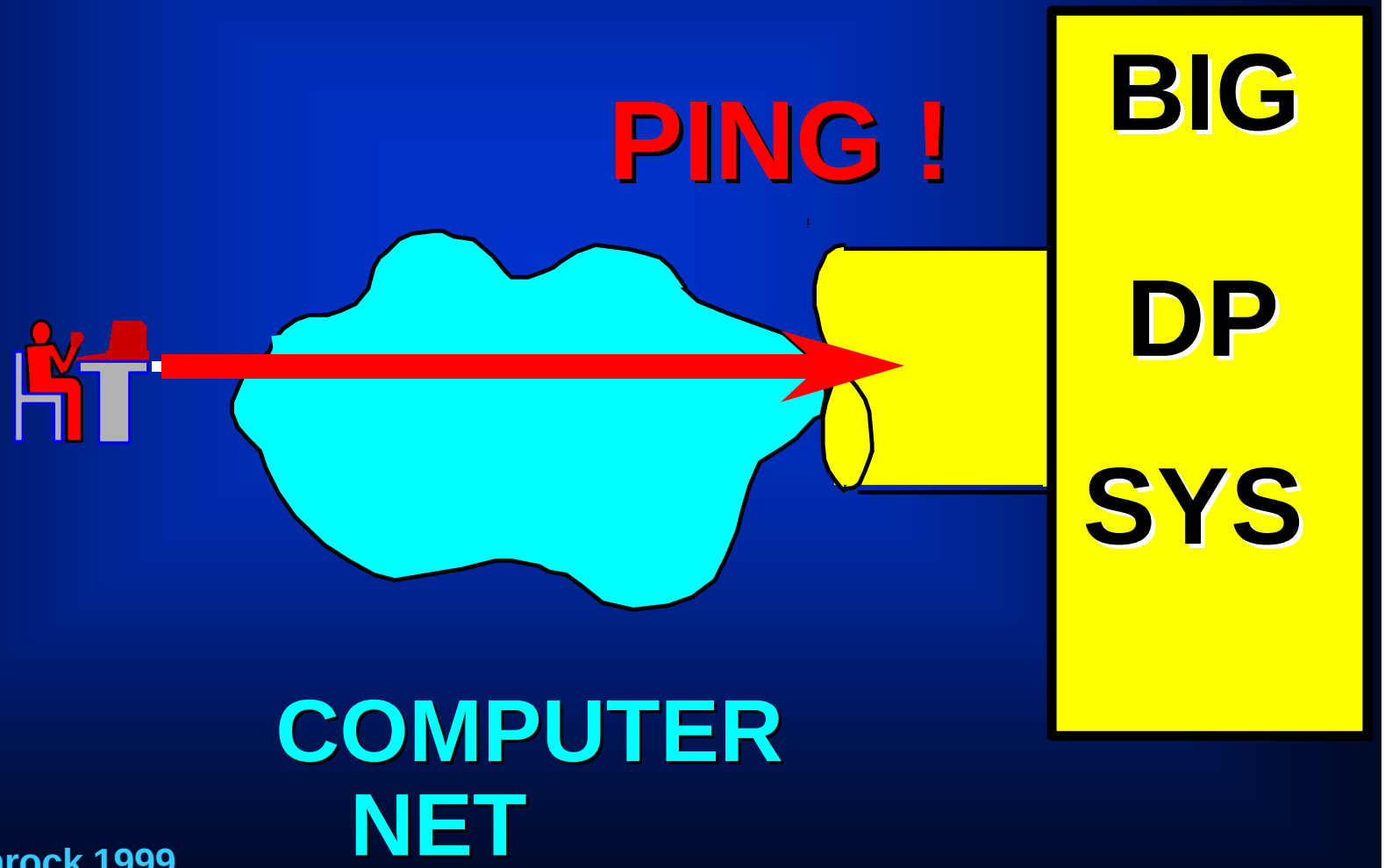

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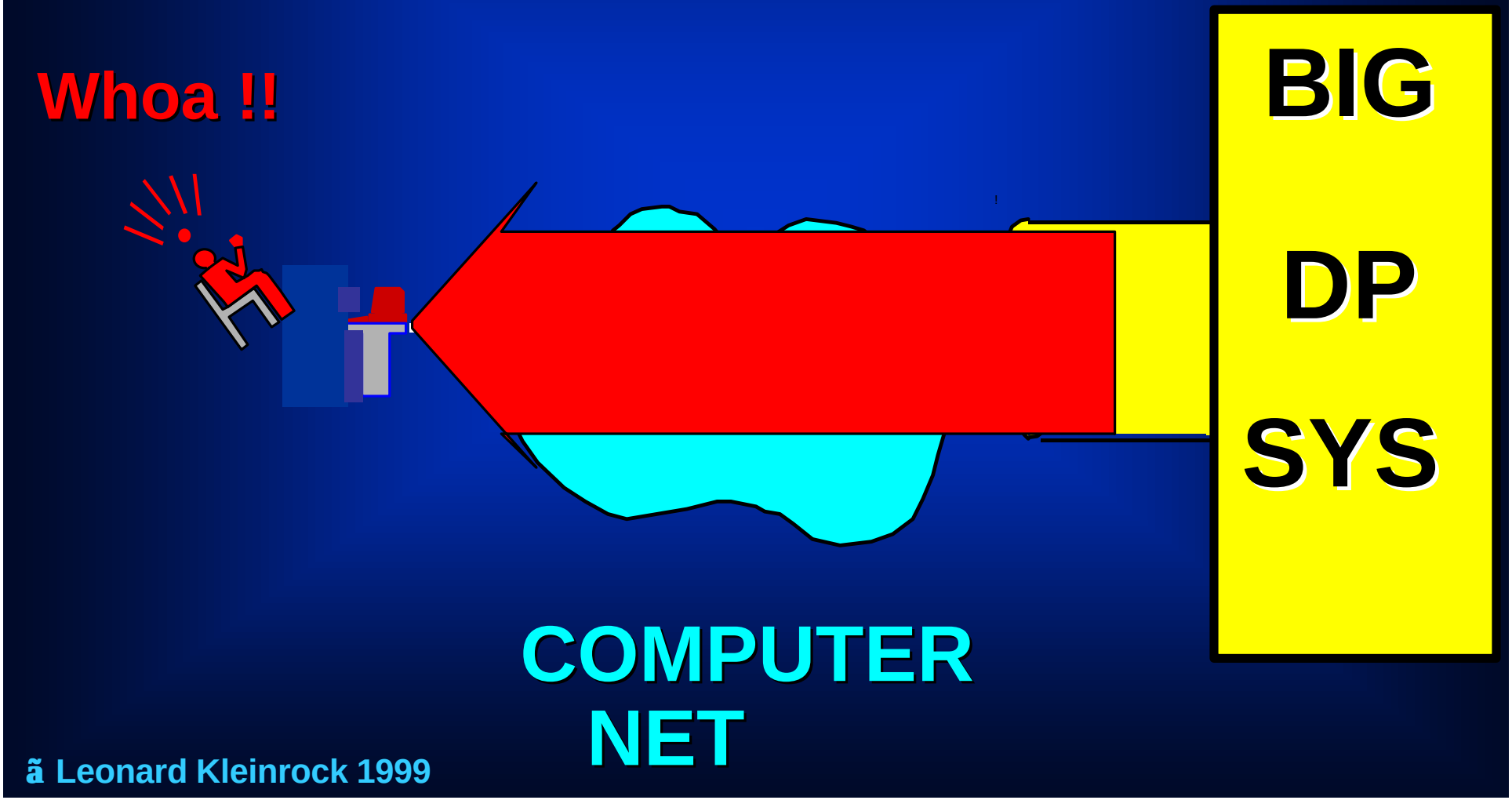

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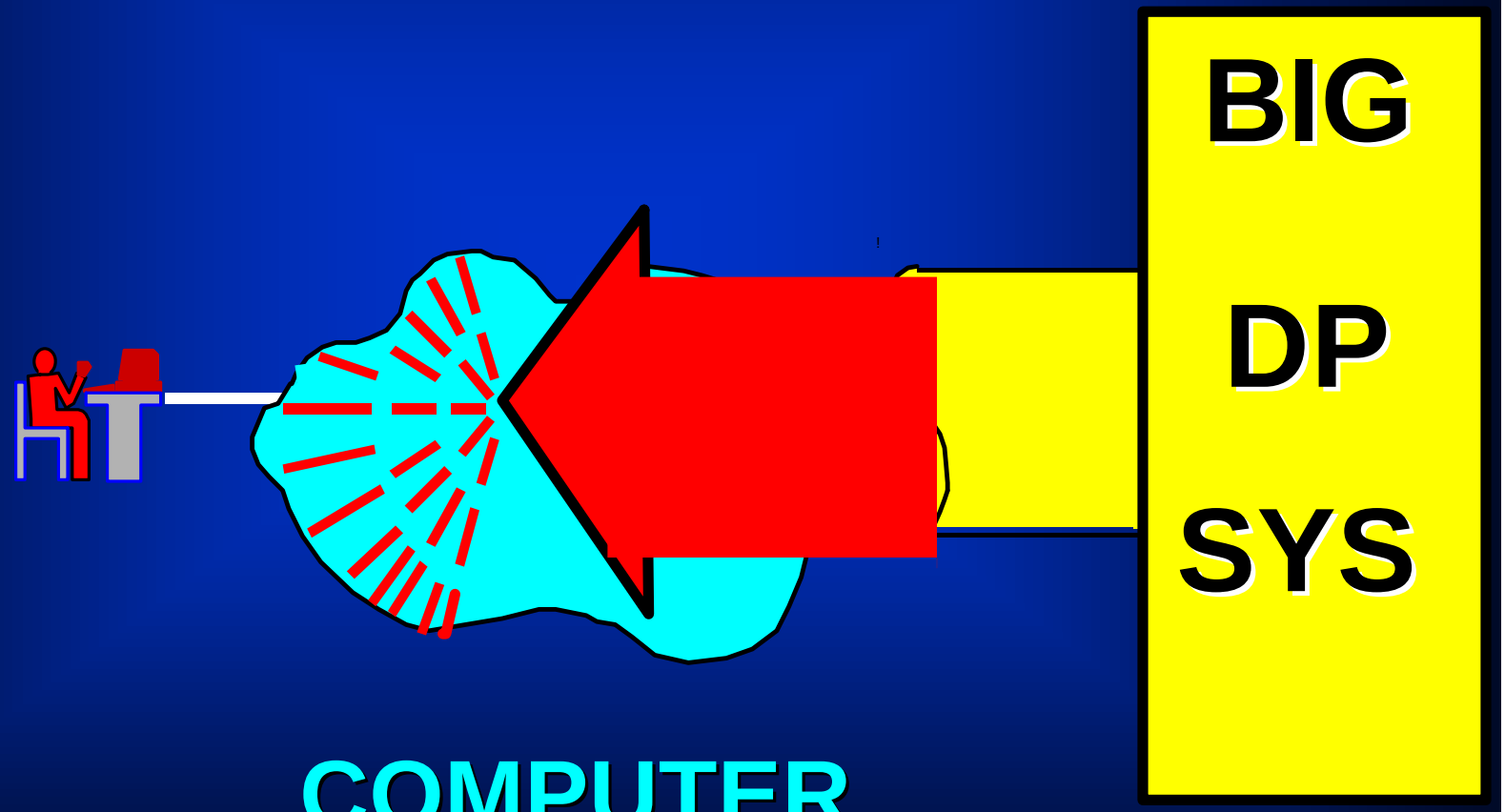
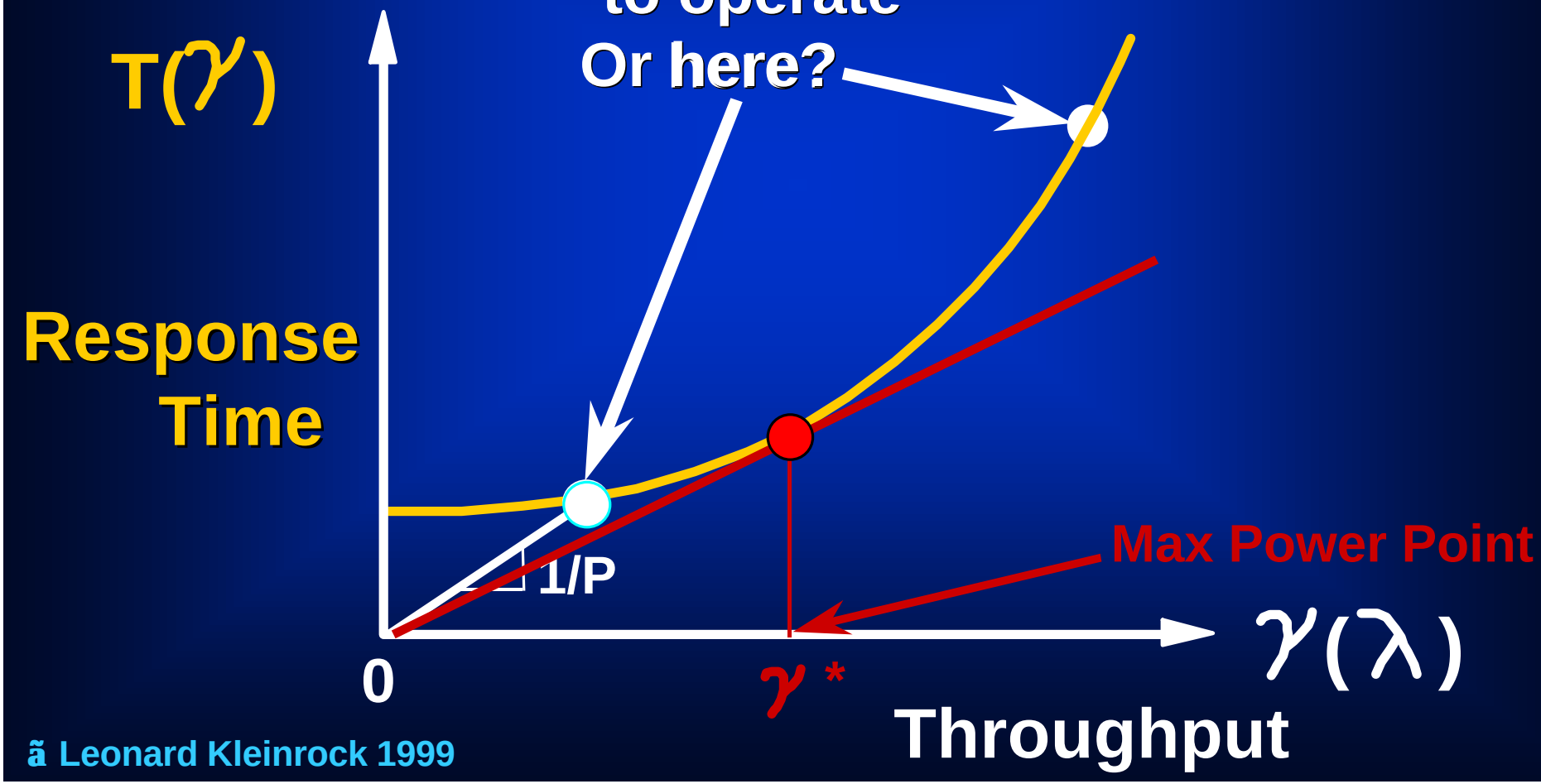


COMPUTER
NET

Response Time vs Throughput

$$\text{POWER} = \frac{\text{Throughput}}{\text{Response Time}} = P = \frac{\gamma}{T(\gamma)}$$



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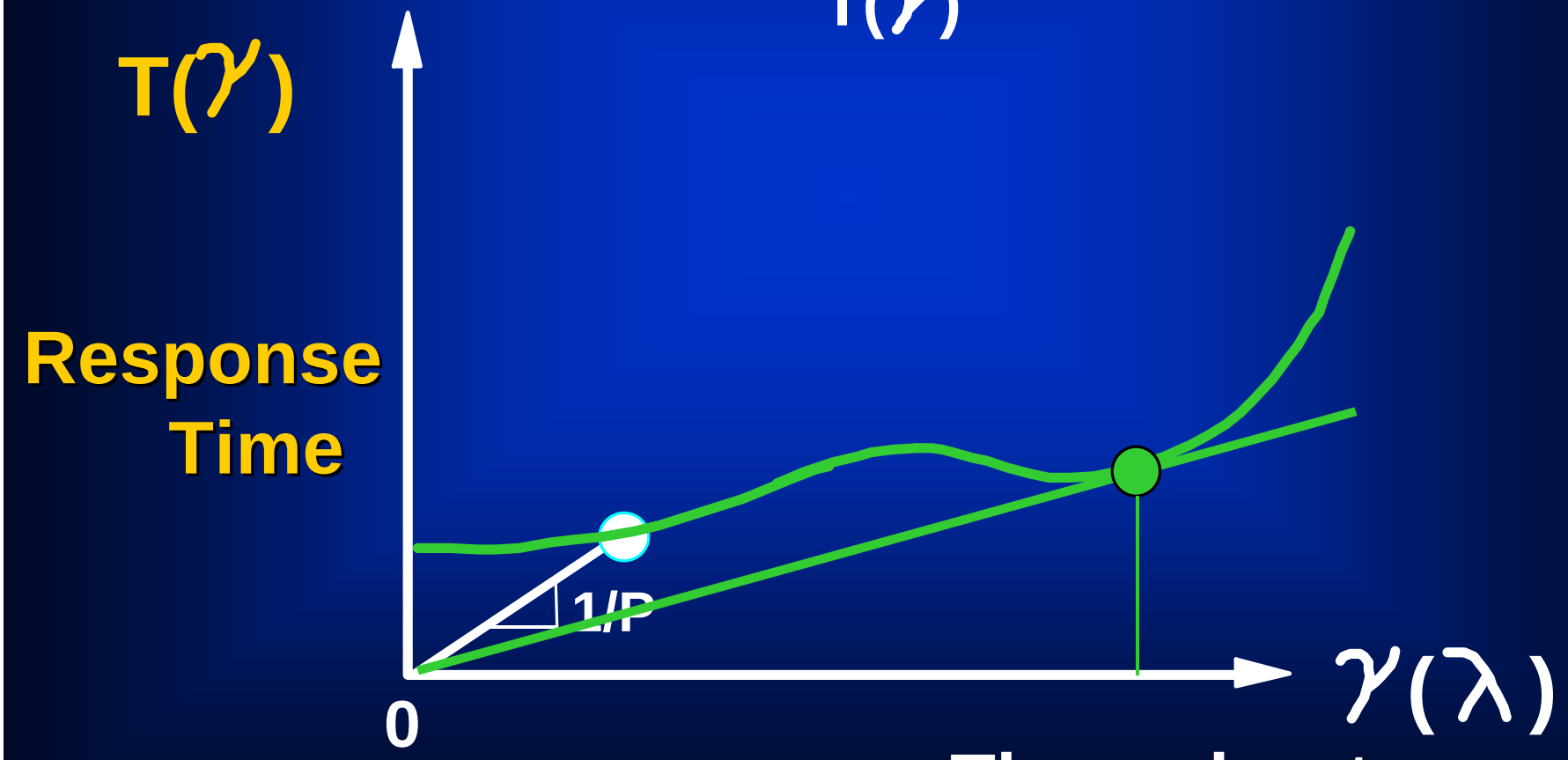

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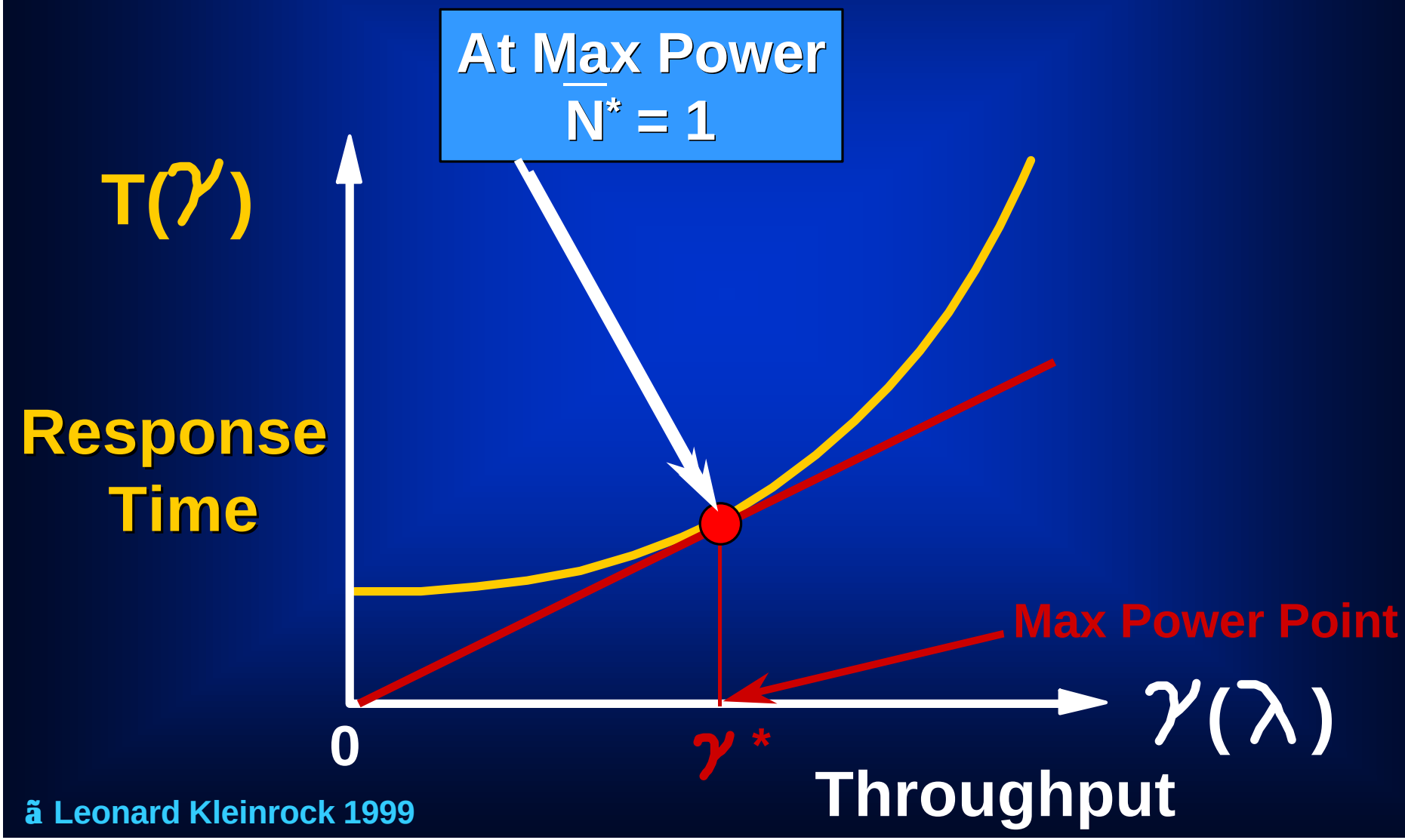
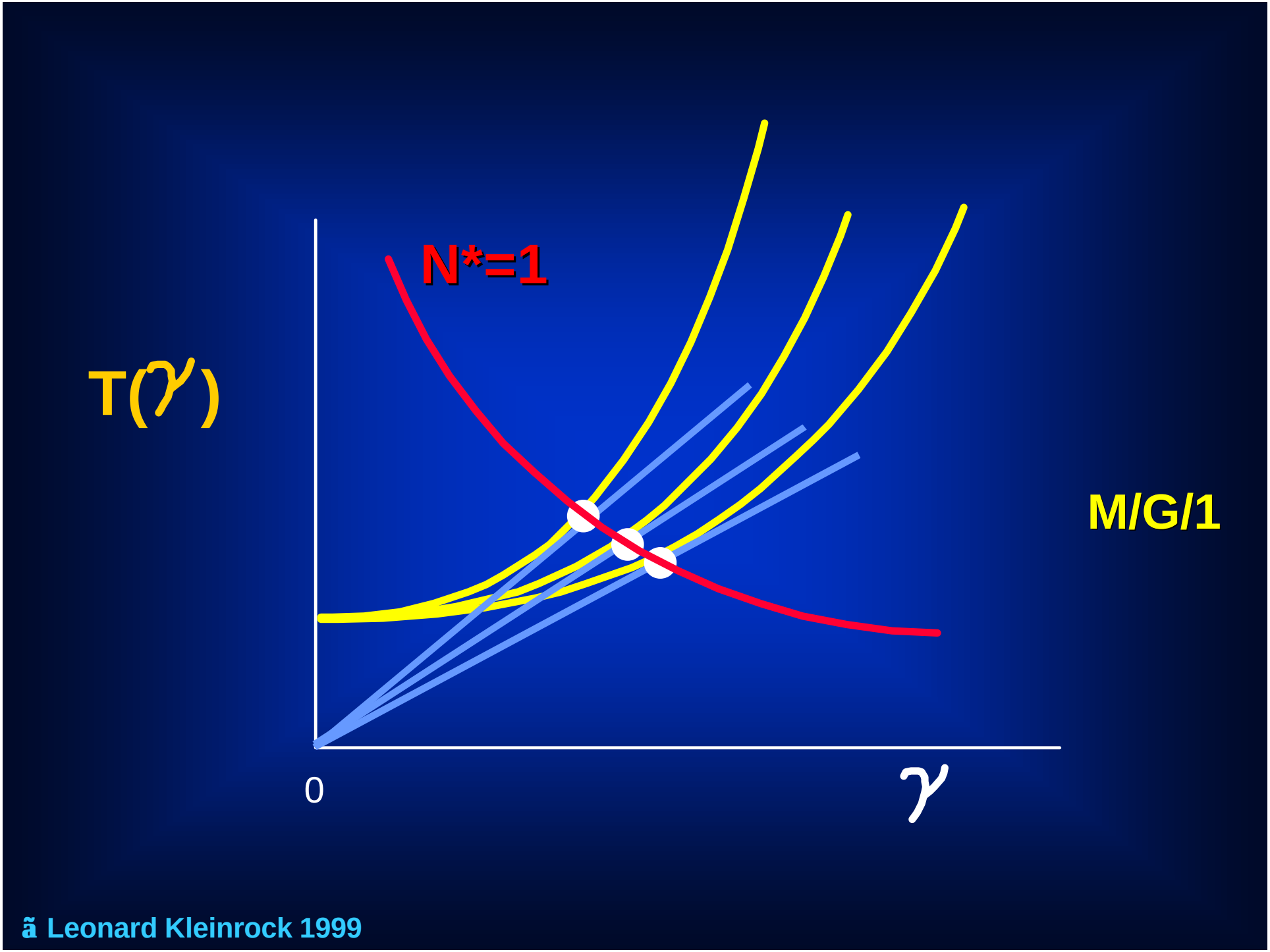
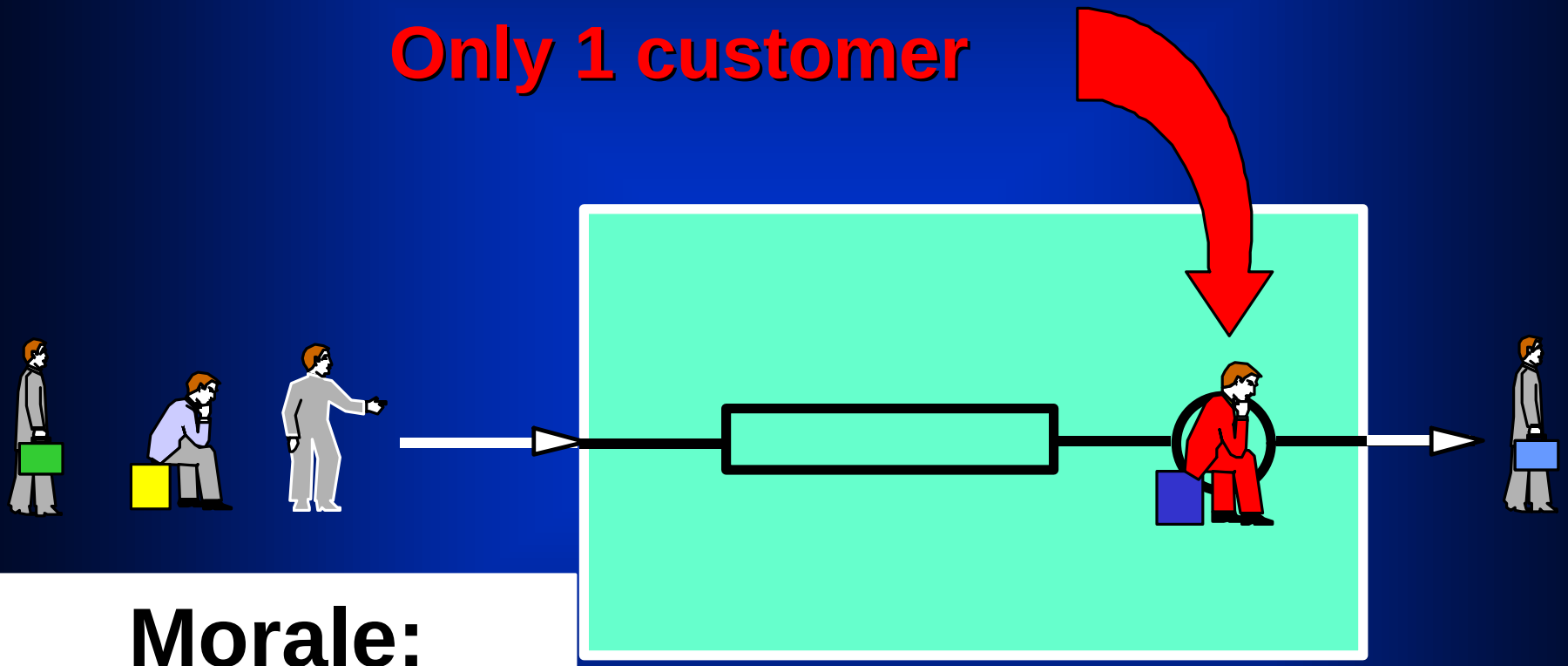




Use Your Intuition

Only 1 customer

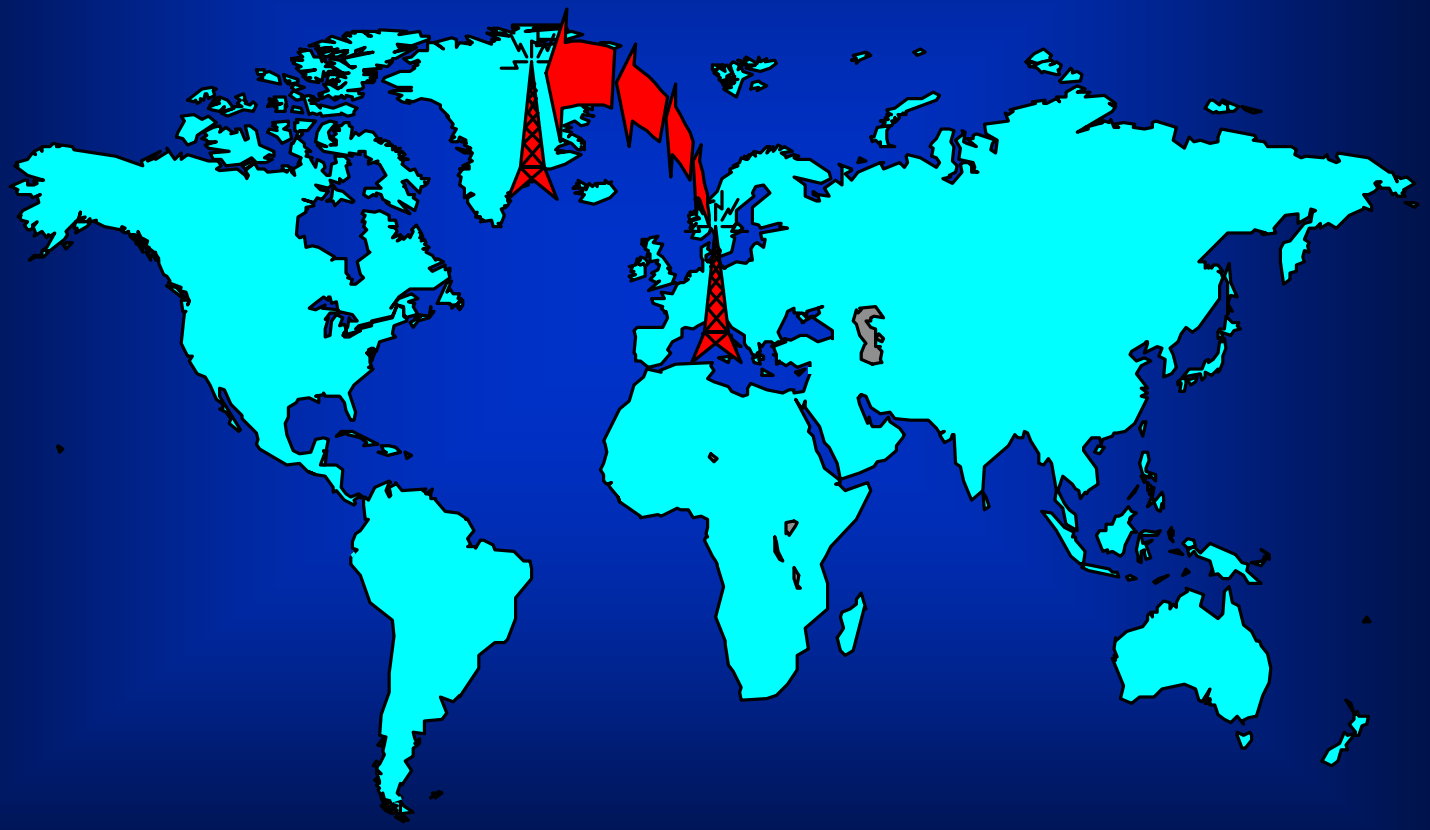


Morale:
Just keep the pipe full!

T = Min
Eff = Max

A Brief History of Radio

- Marconi 1890's



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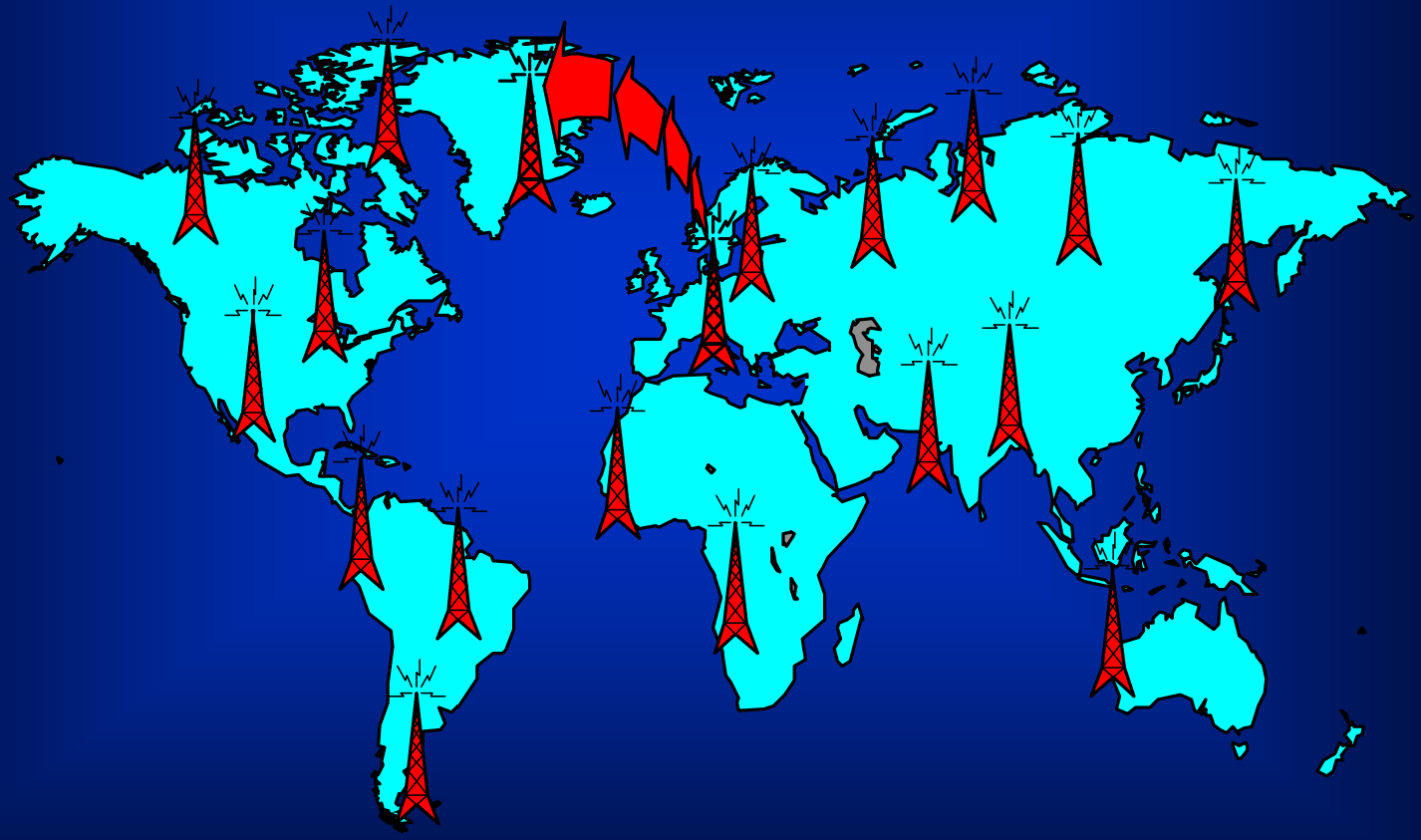
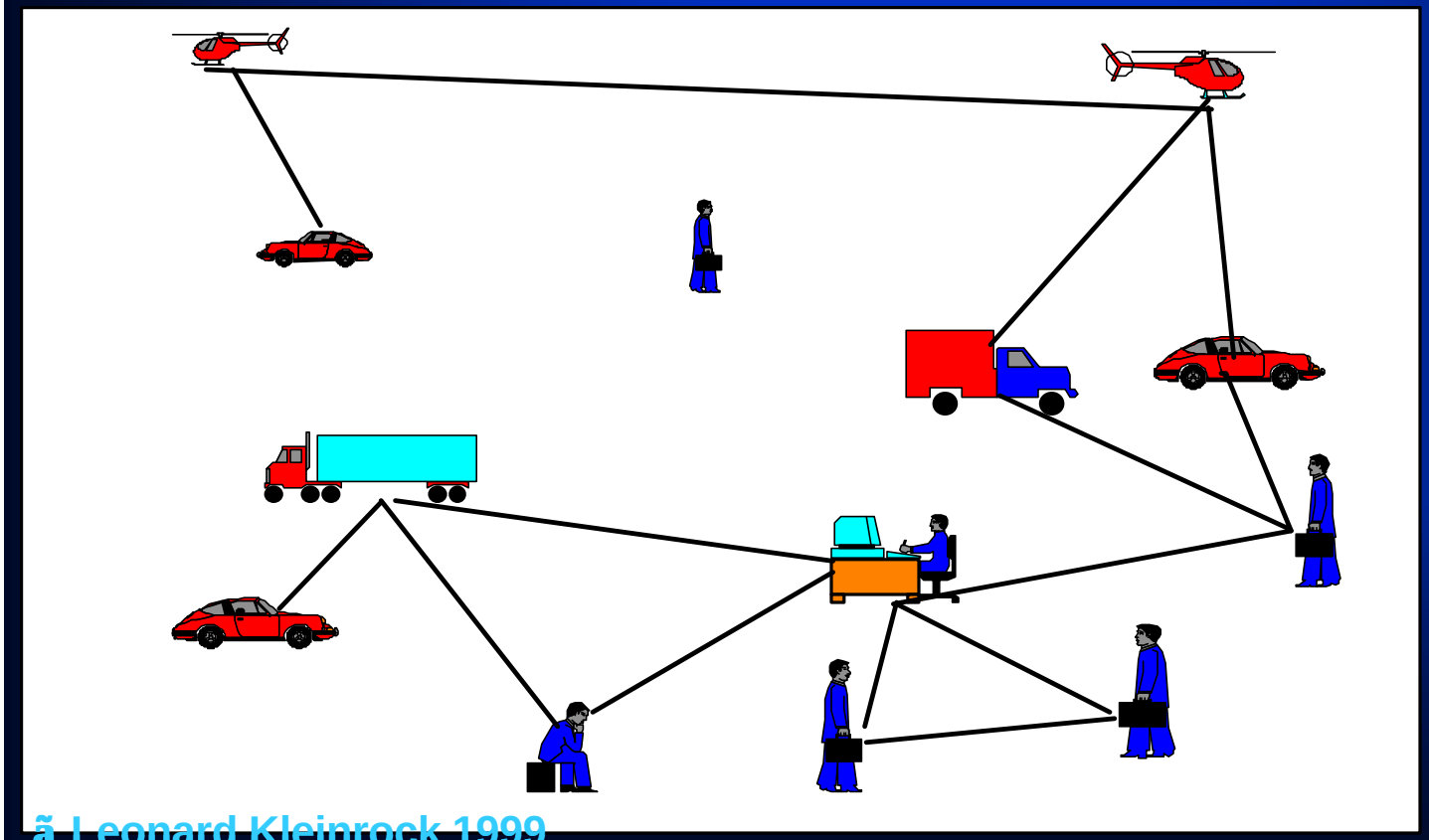


A Brief History of Pkt Radio

- 1970's: ARPA



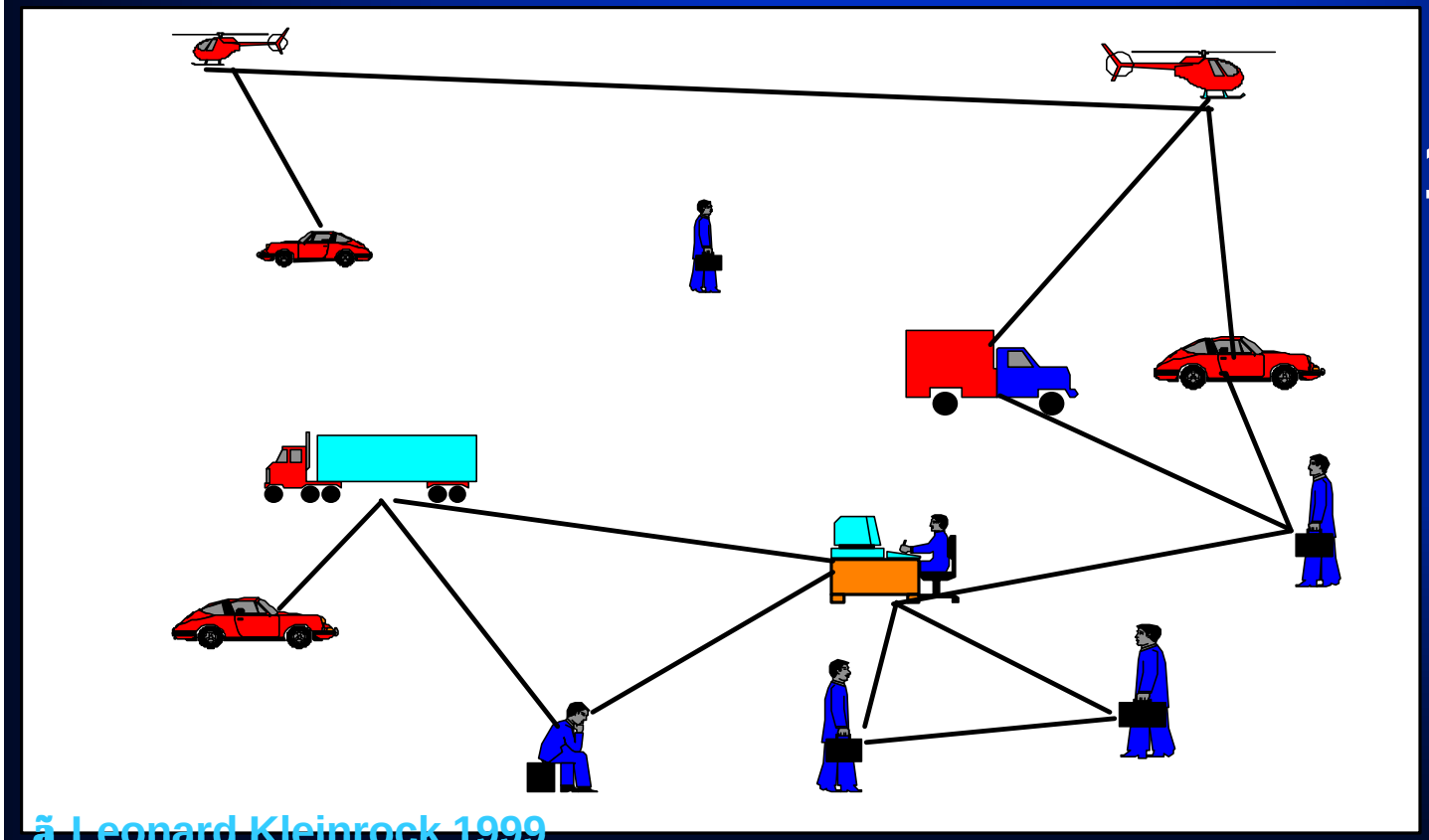
250 cu in

25 watts

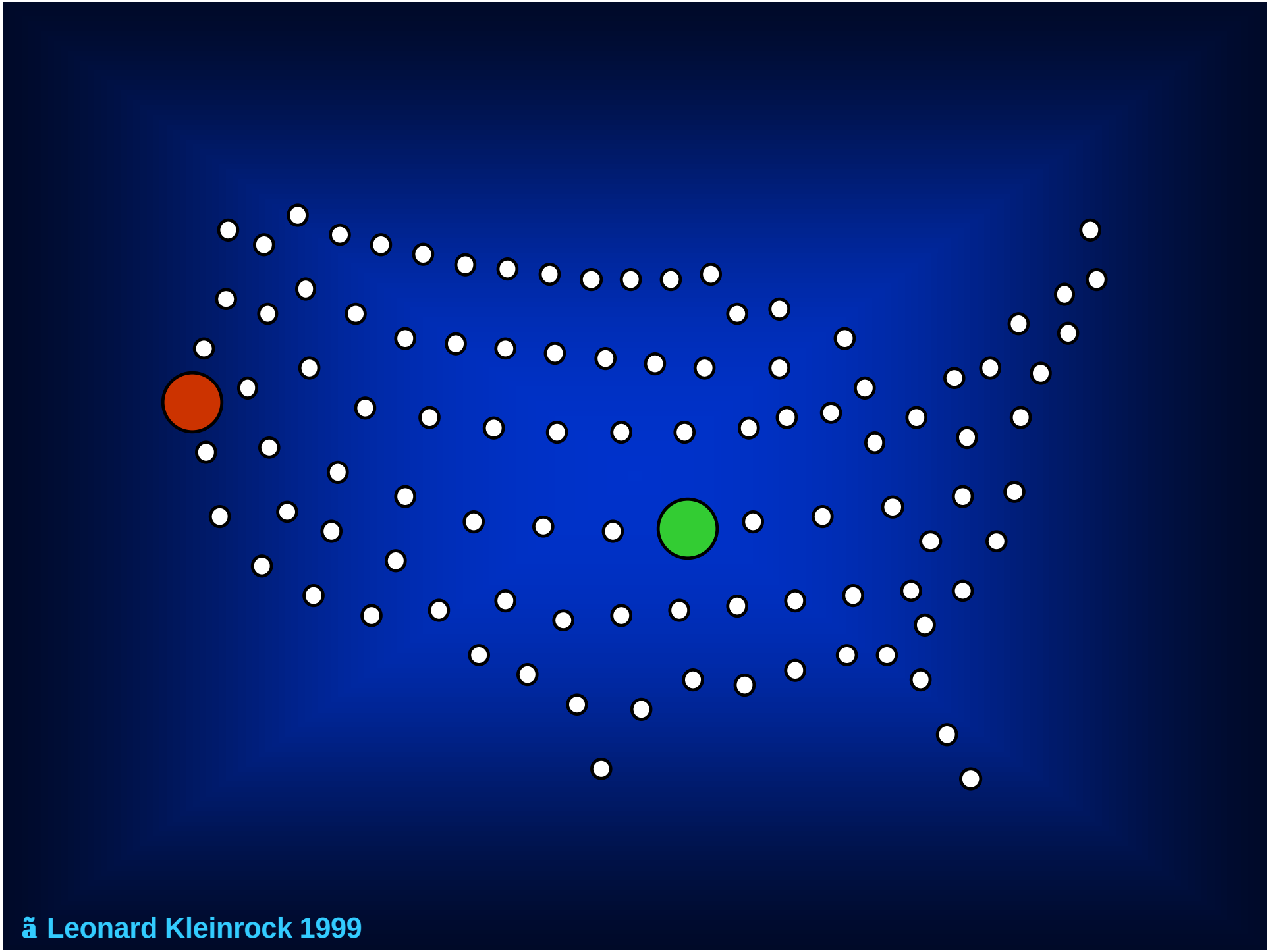
25 pounds

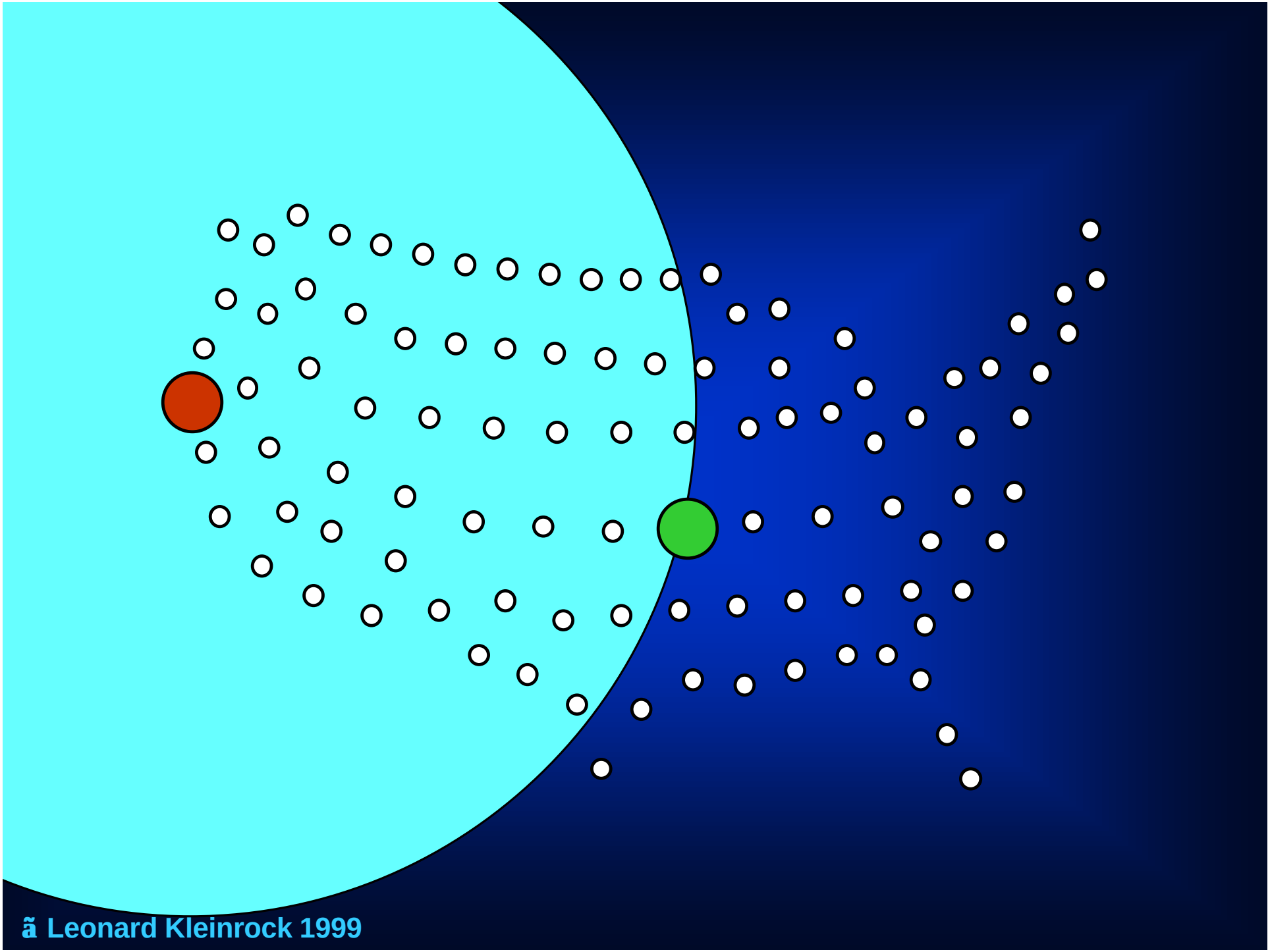
A Brief History of Pkt Radio

- 1990's: ARPA



10 cu in
1 watt
1 pound


ã Leonard Kleinrock 1999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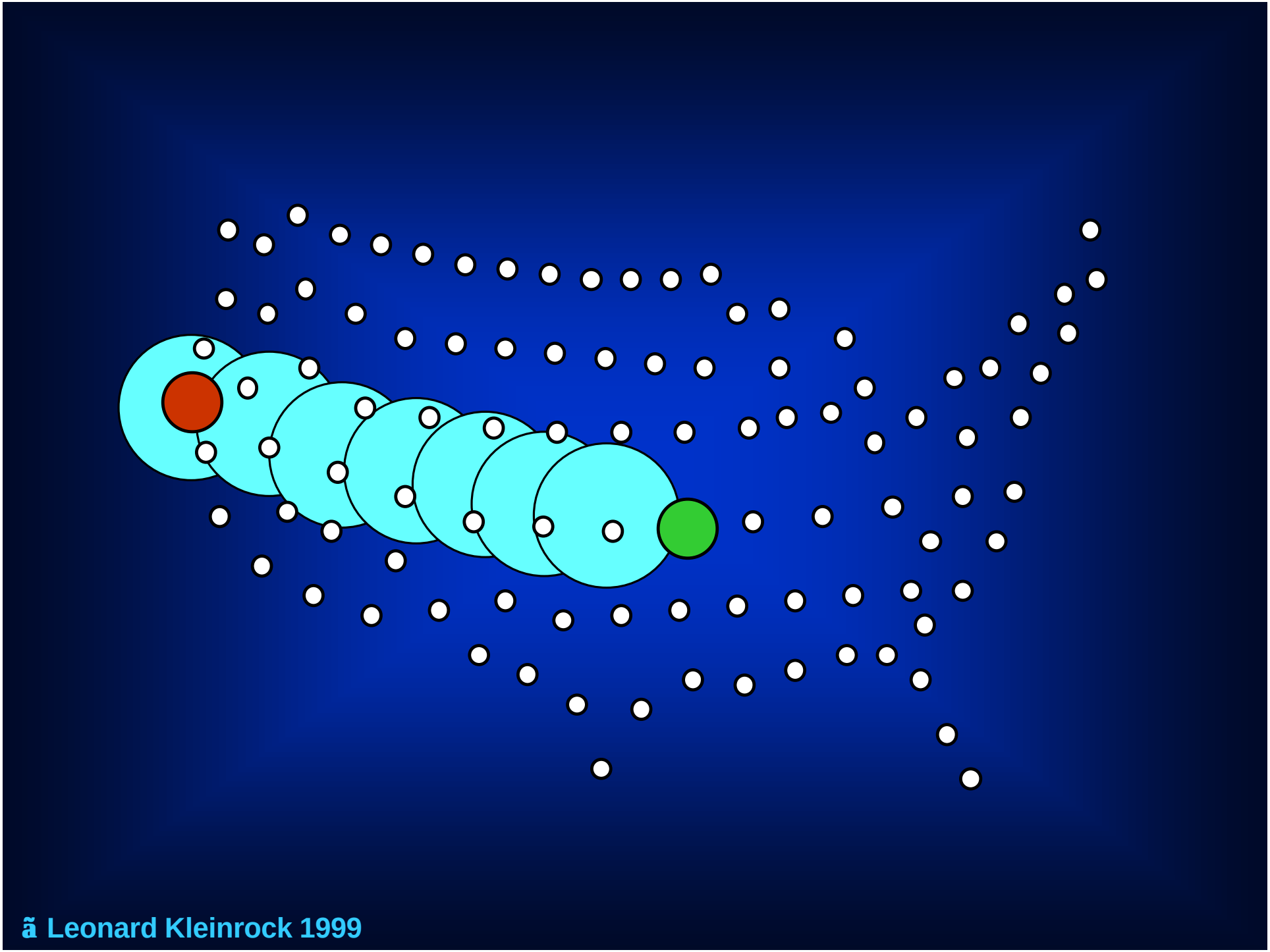
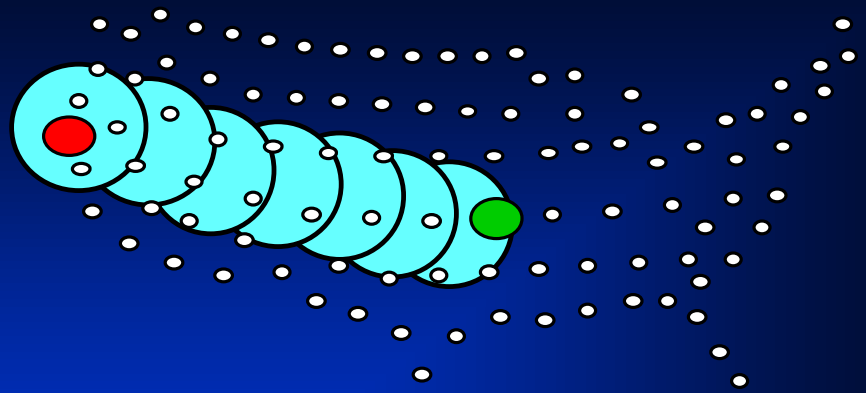
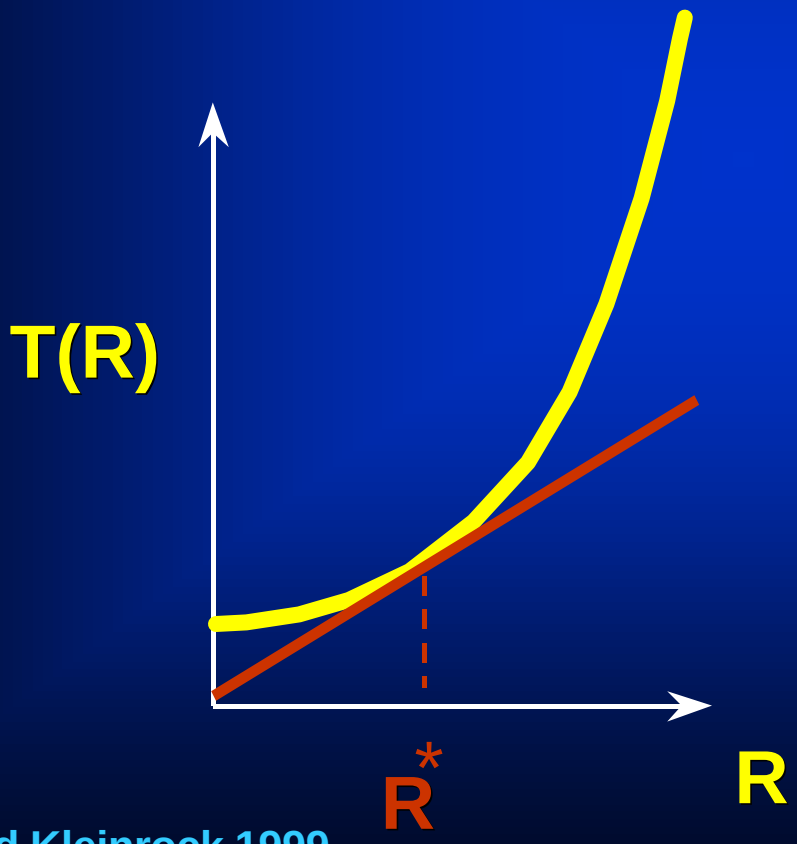

ã Leonard Kleinrock 1999

Giant Stepping
in Packet Radio

- Multihop
- Each hop covers distance R (Tx Radius)
- Total distance to cover is D (D>>R)
- Big R, more interference, fewer hops
- Small R, less interference, more hops
- Total Delay = T(R)[D/R]
- Choose $R=R^*$ to minimize total delay
- dT(R)/dR = T(R)/R optimality condition



$$dT(R)/dR = T/R$$



Thank You

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