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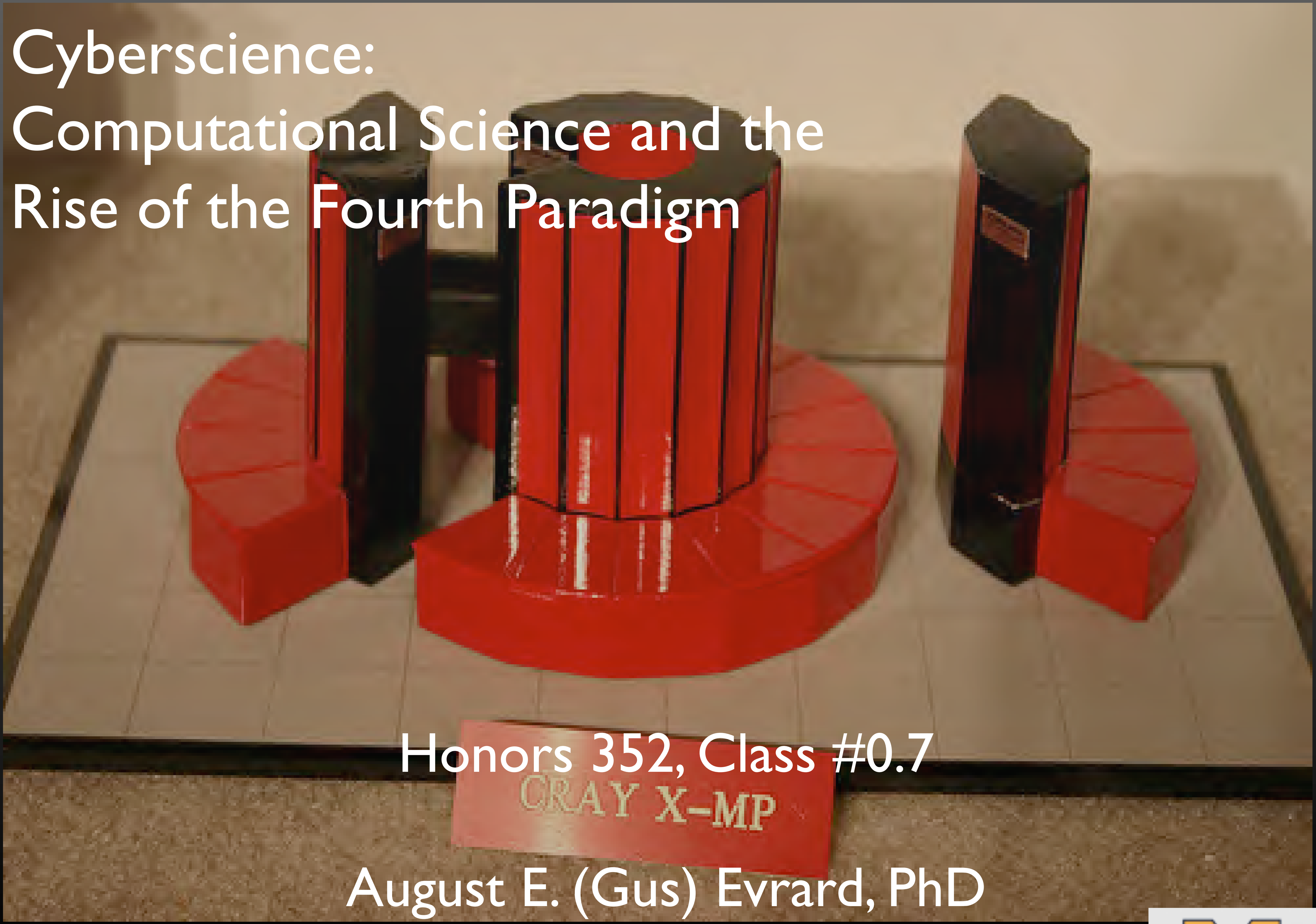
# Cyberscience: Computational Science and the Rise of the Fourth Paradigm




Honors 352, Class #0.7

August E. (Gus) Evrard, PhD



Fall 2010

University of Michigan

# today

* reading quiz online

* lecture – *from the first computers to supercomputers*
    + a personal detour on Stardent graphics supercomputer workstation

* review of v0.2 syllabus

* group project planning

Can't get enough computer history? Watch 1992 PBS 5-part video series:

***The machine that changed the world***

http://video.google.com/videoplay?docid=-7927021653651541860#

# birth of the ENIAC

[Top Secret Rosies](#)

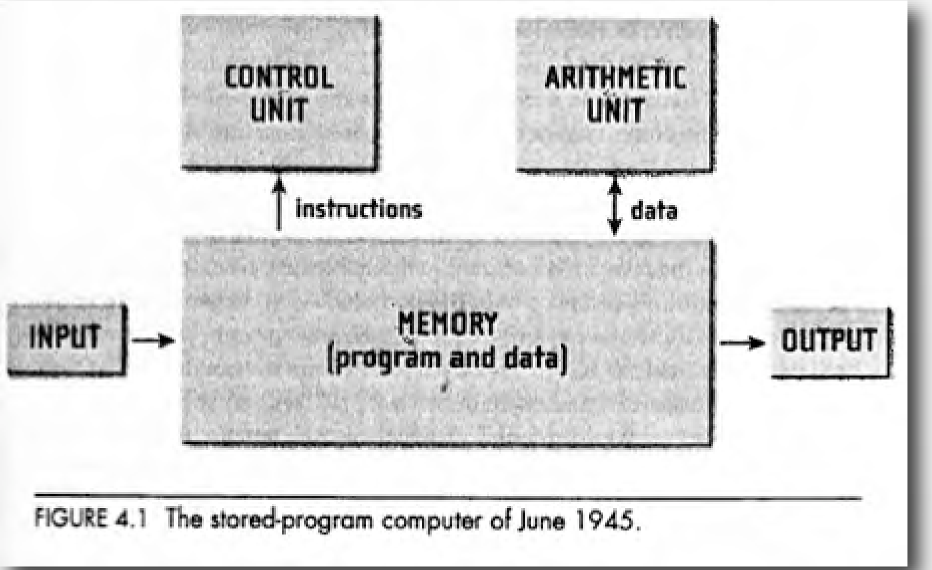

Image of *Top Secret Rosies* scene removed.

* Maryland Ballistics Research Lab uses Moore School "female computers"

* Eckert + Mauchly design, `42

* Goldstine secures Army funds, `43
~$400k (18,000 vacuum tubes!)

* von Neumann's insight, `44:
use memory for data <u>and instructions</u>
*programming is born!*

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Los Alamos wartime badge photo: John von Neumann

* binary storage + arithmetic, `45

* EDVAC report by von Neumann, June`45 creates tensions with engineers Eckert + Mauchly

* Nov 1945: ENIAC turns on!
50x30x8 feet, ~150 kilowatts

PD-GOV


Image of Movietone newsreel removed.

# computing goes commercial

* Eckert + Mauchly start Electronic Control Co.
Census Bureau first customer `46

* UNIVAC = UNIVersal Automatic Computer
first use of magnetic tape storage
(replaced punch cards)
~$300k price lost money


© FAIR USE Image of UNIVAC logo

* 1948: venture capital from American Totalisator

* early 1950: EMCC approaches IBM
does not impress Tom Watson Sr./Jr.

* late 1950: Remington Rand buys EMCC

I was curious about Mauchly, whom I'd never met. He turned out to be a lanky character who dressed sloppily and liked to flout convention. Eckert, by contrast, was very neat. When they came in, Mauchly slumped down on the couch and put his feet up on the coffee table—damned if he was going to show any respect for my father. Eckert started describing what they'd accomplished. But Dad had already guessed the reason for their visit, and our lawyers had told him that buying their company was out of the question. UNIVAC was one of the few competitors we had, and antitrust law said we couldn't take them over. So Dad told Eckert, "I shouldn't allow you to go on too far. We cannot make any kind of arrangement with you, and it would be unfair to let you think we could. Legally we've been told we can't do it."

© FAIR USE Quote from the book, *Grace Hopper and the Invention of the Information Age*.

* Nov 1952: UNIVAC calls presidential election!
calls Eisenhower @8:30pm, against prior polls
accurate to ±4 in final electoral vote count

# IBM establishes *mainframe* computing

* Initially resisted 'general purpose' computing

* 1953: Model 650, ~200k
  magnetic drum calculator
  clever eduction marketing

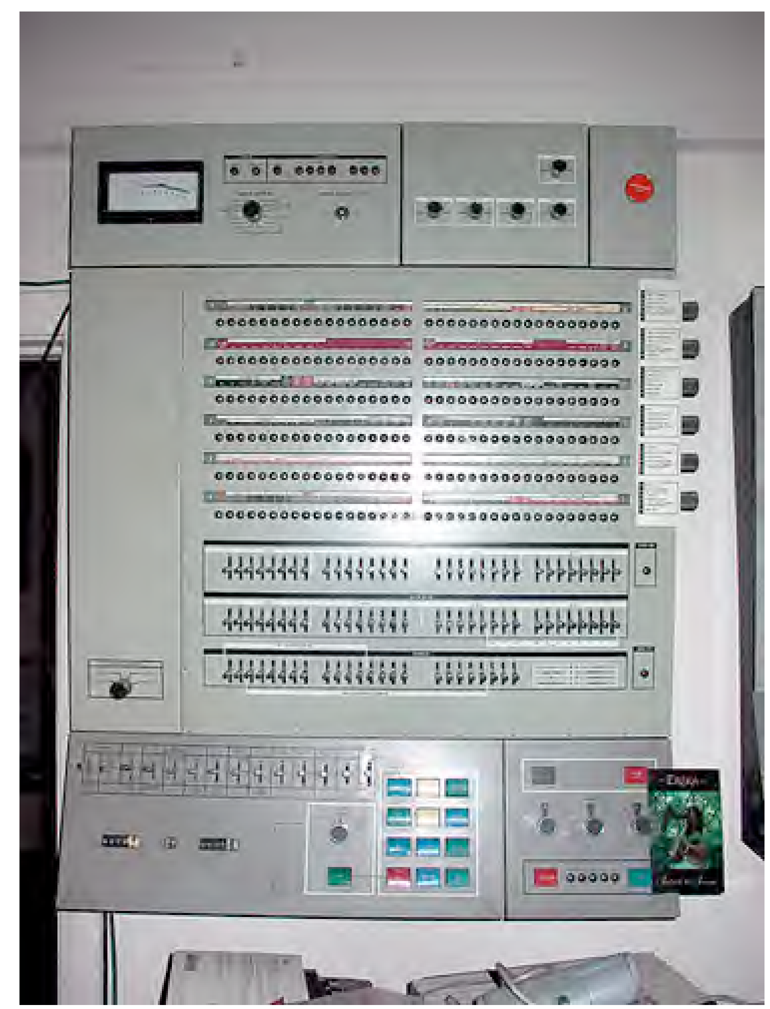
> As Watson junior observed: "While our giant, million-dollar 700 series got the publicity, the 650 became computing's 'Model T.'" With an astute understanding of marketing, IBM placed many 650s in universities and colleges, offering machines with up to a 60 percent discount provided courses were established in computing. The effect was to create a generation of programmers and computer scientists nurtured on IBM 650s, and a trained workforce for IBM's products. It was a good example of IBM's mastery of marketing, which was in many ways more important than mastery of technology.



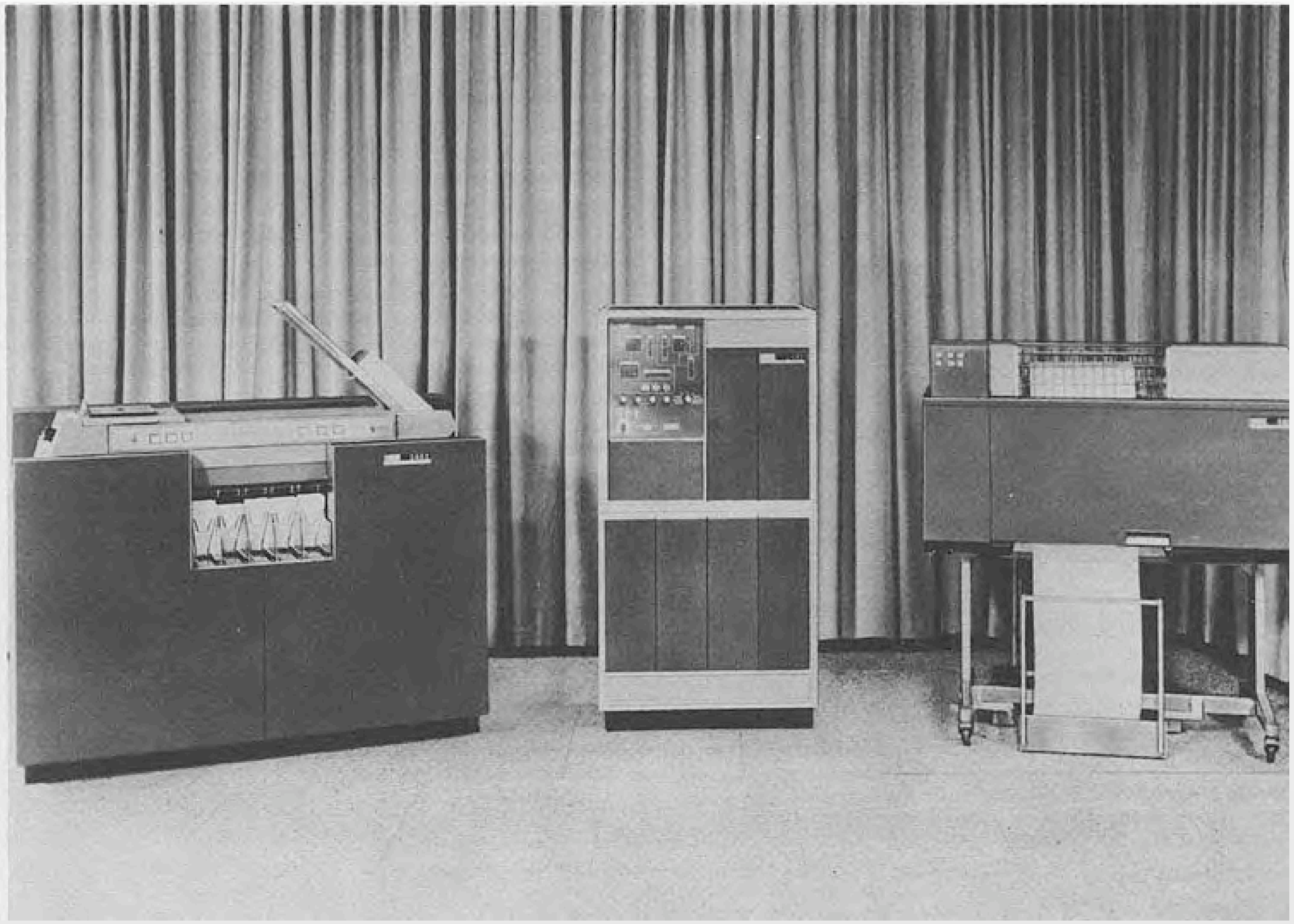
* 1953: Model 1401, ~150k
  high-speed printer (600 lines/min)
  12,000 systems produced!

* early 1960's: System/360
  first computing 'line' with standard
  software systems
  1964: Honeywell 200 threat forces
  early release of full line-up
  $500M research cost

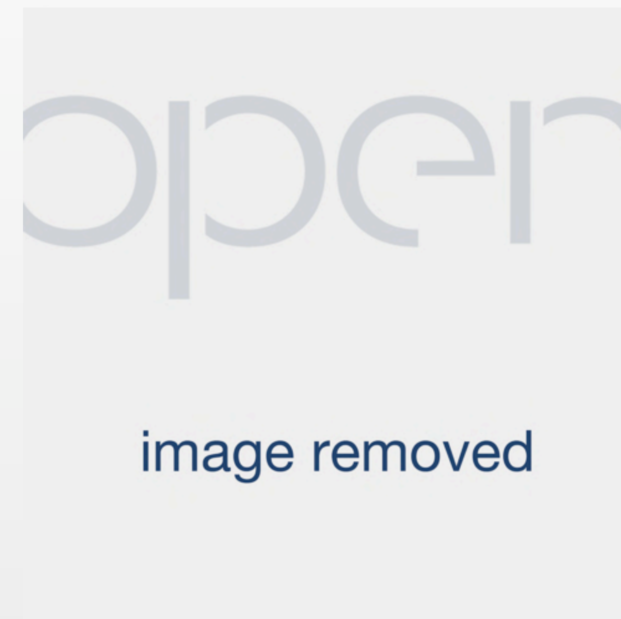
System/360 = "*The computer that IBM made, that made IBM*"



# Model 1401: Big and Blue!








Please see original image of Model 1401 at pages 12-13 of http://www.computerhistory.org/core/pdf/ibm_1401.pdf

# 1970's: *mini-computers* dethrone IBM

* late 1950's: first time-sharing computers at MIT, Dartmouth

* 1964: BASIC computer language

mer as an intermediary. Before BASIC came on the scene there were two major constituencies of computer users: computer professionals who developed applications for other people and naive computer users, such as airline reservations clerks, who operated computer terminals in a way that was entirely prescribed by the software. BASIC created a third group: users who could develop their own programs and for whom the computer was a personal information tool.

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image removed

Please see original image of Dartmouth computers at http://histoire.info.online.fr/images/dtss.jpeg

* mid-60's: utopian visions of *utility computing*

– but software not up to task (poor concurrency) and

– integrated circuits brought hardware costs down

And while it may seem odd to think of piping computing power into homes, it may not be as far-fetched as it sounds. We will speak to the computers of the future in a language simple to learn and easy to use. Our home computer console will be used to send and receive messages—like telegrams. We could check to see whether the local department store has the advertised sports shirt in stock in the desired color and size. We could ask when delivery would be guaranteed, if we ordered. The information would be up-to-the-minute and accurate. We could pay our bills and compute our taxes via the console. We would ask questions and receive answers from "information banks"—automated versions of today's libraries. We would obtain up-to-the-minute listing of all television and radio programs. We could use the computer to preserve and modify our Christmas lists. It could type out the names and addresses for our envelopes. We could store in birthdays. The computer could, itself, send a message to remind us of an impending anniversary and save us from the disastrous consequences of forgetfulness.

FAIR USE Paul Baran Rand Corp.

# France's 80's information utility service: ***minitel***


Please see original image and article of minitel at
http://www.wired.com/science/discoveries/news/2001/04/42943#

# Digital Equipment Corp PDP series

* PDP = Programmed Data Processor

    PDP-1: $125k in 1960

    Series ran into the 1990's

* mid-1960's: popular time-sharing system

    PDP-10, $500k

* precursor to successful VAX line of 1980's

    *virtual memory*: disk as memory extension

    VAX-11/780 (1977) – one MIPS (million instructions per second)


 Stefan_Kogl, Wikimedia Commons

# supercomputers and supercomputing

* terms first used in 1960's

* top end of compute power distribution (measured in flop's, MIP's)

* supercomputer = a single `machine'
- tightly-networked processors ok
- loosely-networked processors (e.g. SETI@home) not so much

* more than just fast cpu is required
- applications software
- storage devices
- programming support (high-level languages, compilers, training)

The term "supercomputer" refers to computing systems (hardware, systems software, and applications software) that provide close to the best currently achievable sustained performance on demanding computational problems. The term can refer either to the hardware/software system or to the hardware alone. Two definitions follow:

• From Landau and Fink[1]: "The class of fastest and most powerful computers available."

• From the Academic Press *Dictionary of Science and Technology*: "1. any of a category of extremely powerful, large-capacity mainframe computers that are capable of manipulating massive amounts of data in an extremely short time. 2. any computer that is one of the largest, fastest, and most powerful available at a given time."

"Supercomputing" is used to denote the various activities involved in the design, manufacturing, or use of supercomputers (e.g., "supercomputing industry" or "supercomputing applications"). Similar terms are "high-performance computing" and "high-end computing." The latter

© FAIR USE Graham, S., et al. *Getting Up to Speed: The Future of Supercomputing* (2004), pg 20.

# supercomputing: early history

* note log-linear axes imply

*exponential growth*

$$\text{Power(time)} \sim e^{\text{time}}$$

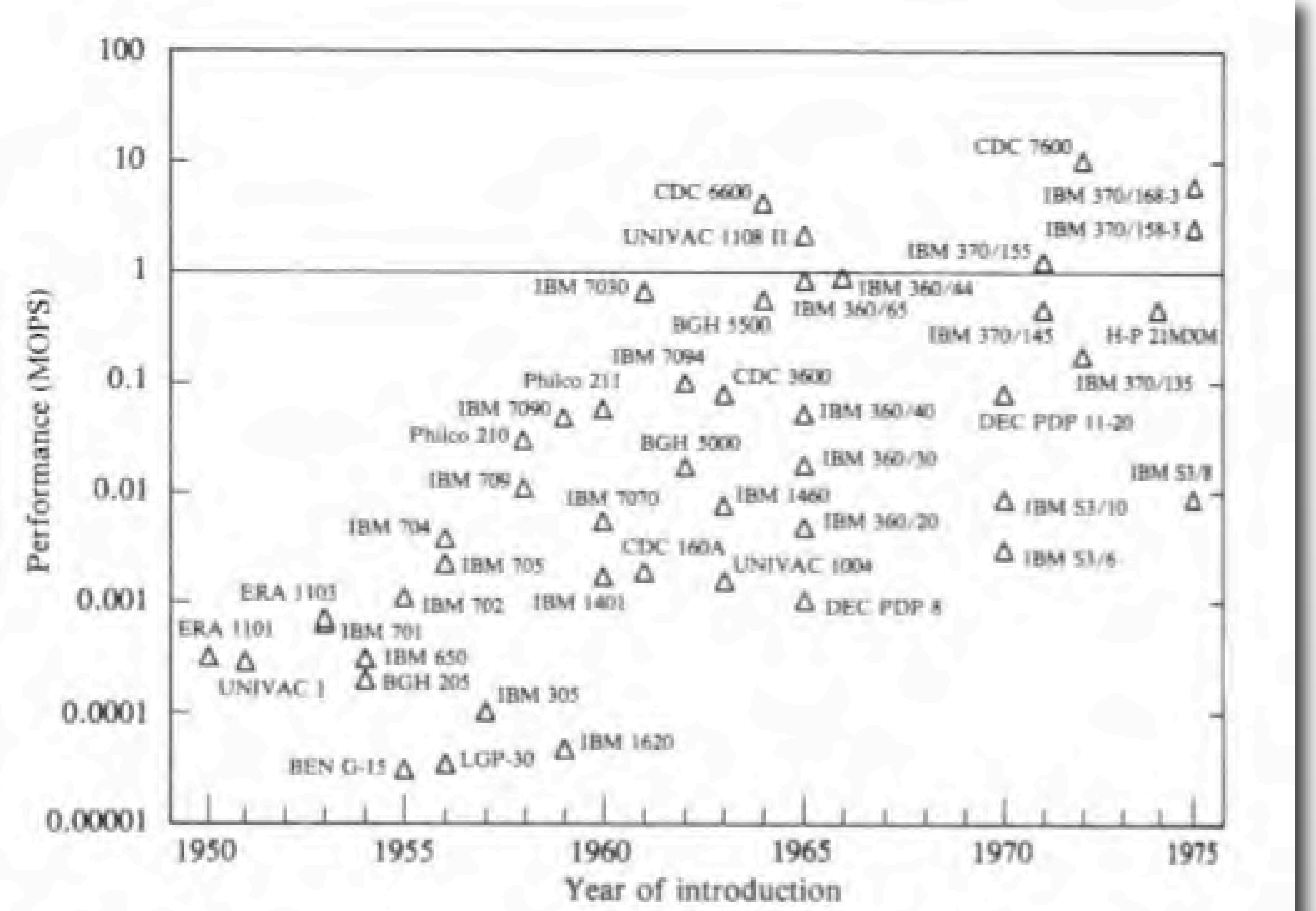



FIGURE 3.1 Early computer performance. Included in this figure are the best-performing machines according to value of installations, number of installations, and millions of operations per second (MOPS). SOURCE: Kenneth Flamm. 1988. *Creating the Computer: Government, Industry, and High Technology*. Washington, D.C.: Brookings Institution Press.

# dramatic cost/performance reduction

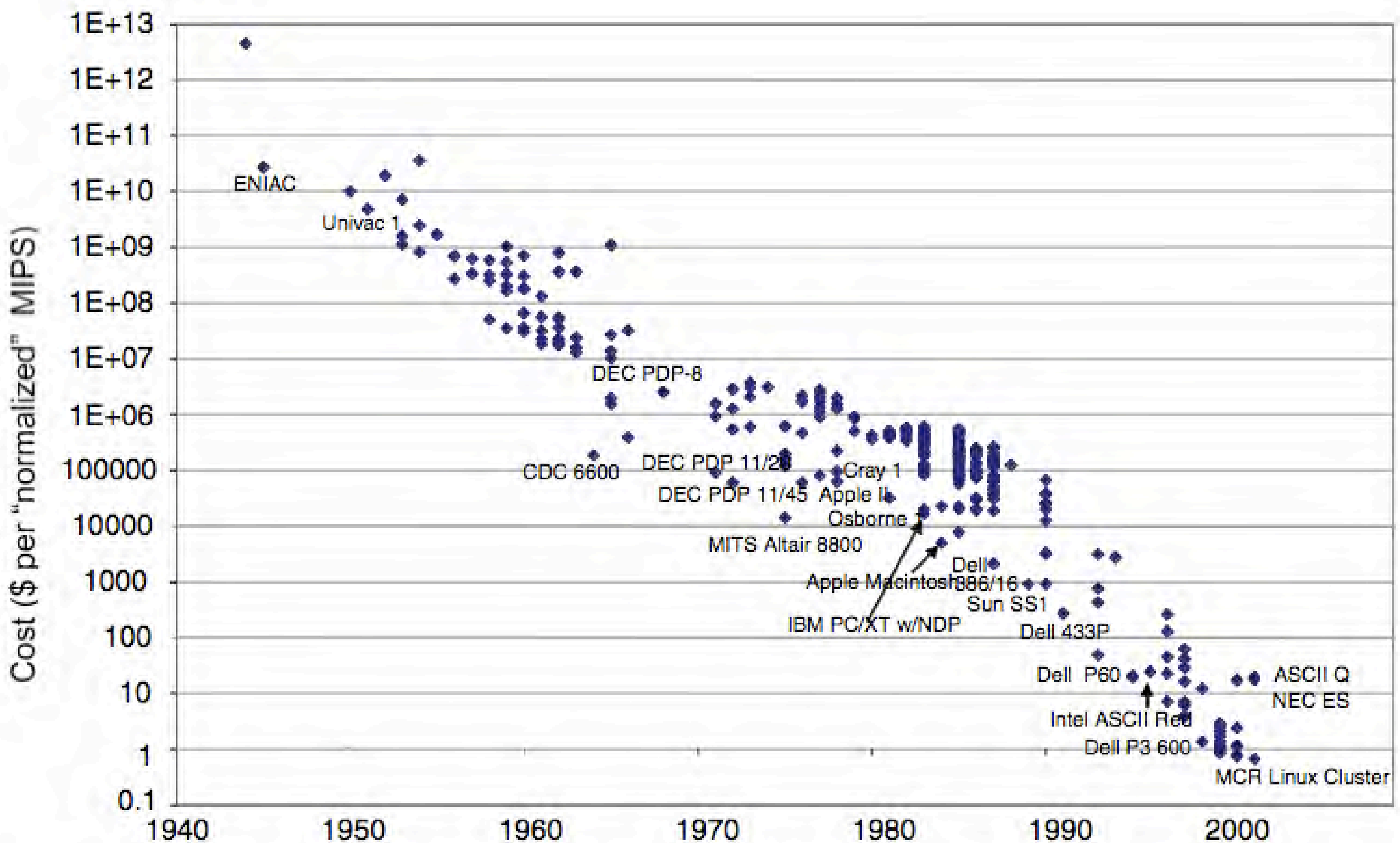



FIGURE 3.2 Cost/performance over time. Based on data collected by John McCallum at <http://www.jcmit.com/cpu-performance.htm>. NEC Earth Simulator cost corrected from $350 million to $500 million. Note that "normalized" MIPS (millions of instructions per second) is constructed by combining a variety of benchmarks run on these machines over this 50-year period, using scores on multiple benchmarks run on a single machine to do the normalization.

# supercomputing flavors

* **capability** computing
  – explore new problems or expose new realms of solution
    (e.g., finer resolution or add new physical processes to a simulation)

* **capacity** computing
  – construct solutions in `bulk', typically following capability phase
    (e.g., parametric studies of processes in a simulation)

* cpu design flavors
  – serial (pre-1970's) : one processor does it all
– vector (1970's-90's) : multiple computations per clock cycle
– parallel (late 80's-) : link many (multi-core) processors over network
– gpu/cell hybrid (2000's-) : parallel with special processor assist

# the Stardent Titan!

* late 80's ***graphics supercomputer workstation***


Image of Biere Titan poster removed.


Please see original image of the Stardent Titan at
http://www.computerhistory.org/collections/accession/X1570.98A


Please see original image of the Stardent Titan at
http://ricm.museum.com/collections/ardent/ardent.html

# Stardent Titan: a `vector supercomputer'

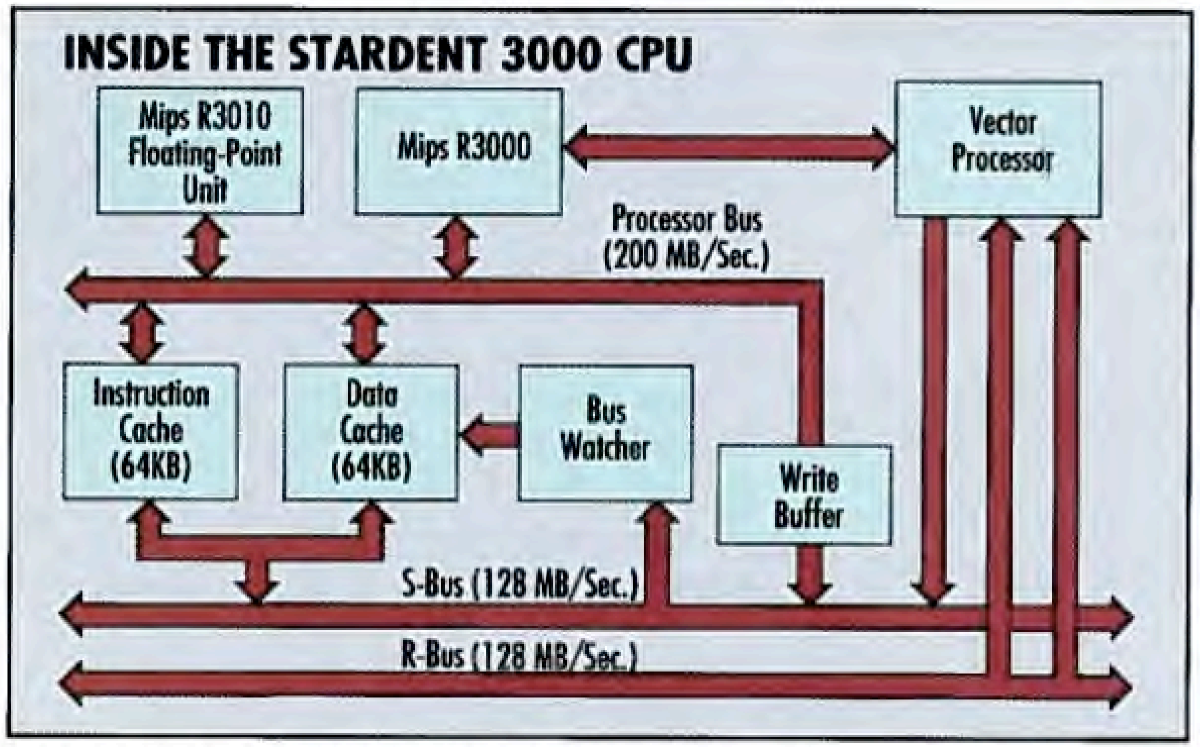



**FIGURE 3:** *Each Stardent 3000 CPU includes both a scalar and a vector processor. The scalar processor is a Mips R3000 chip running at 32MHz, accompanied by a R3010 floating-point co-processor, and the vector processor is proprietary to Stardent. The scalar processor handles all integer and almost all floating-point scalar operations, and during graphics operations functions as the scene database transverser. There are two independent 64KB direct-mapped caches—instruction and data—and four-deep write buffers. The vector unit performs all vector operations, and during graphics processing serves as the geometry engine.*



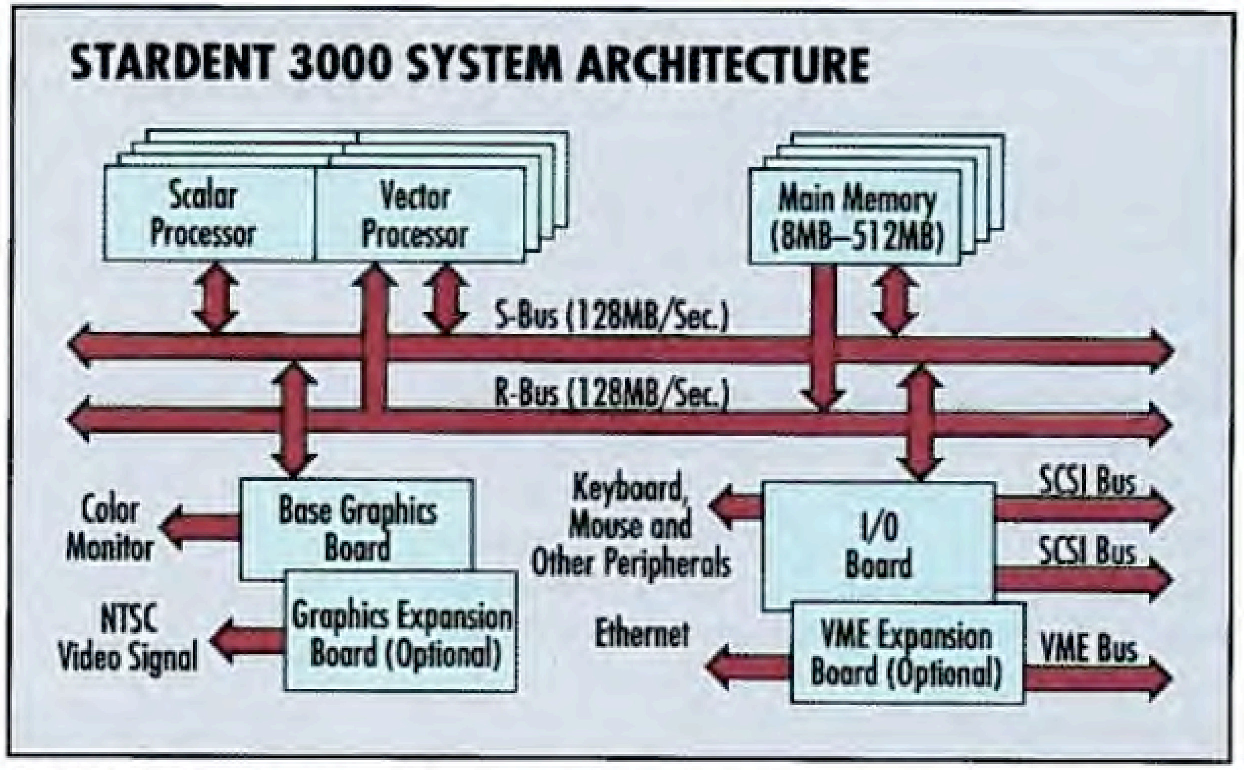



**FIGURE 4:** *The Stardent 3000 uses two buses for communication between the CPUs, memory, I/O subsystem and graphics subsystem. The buses carry 32-bit addresses and 64-bit data and operate at 16MHz; they are rated at 128MB per second each. The R-bus is dedicated to data transfers from memory to the vector processor and the S-bus handles all other transfers. The system can support a maximum of 512MB of memory.*

# Stardent Titan: a graphics workstation

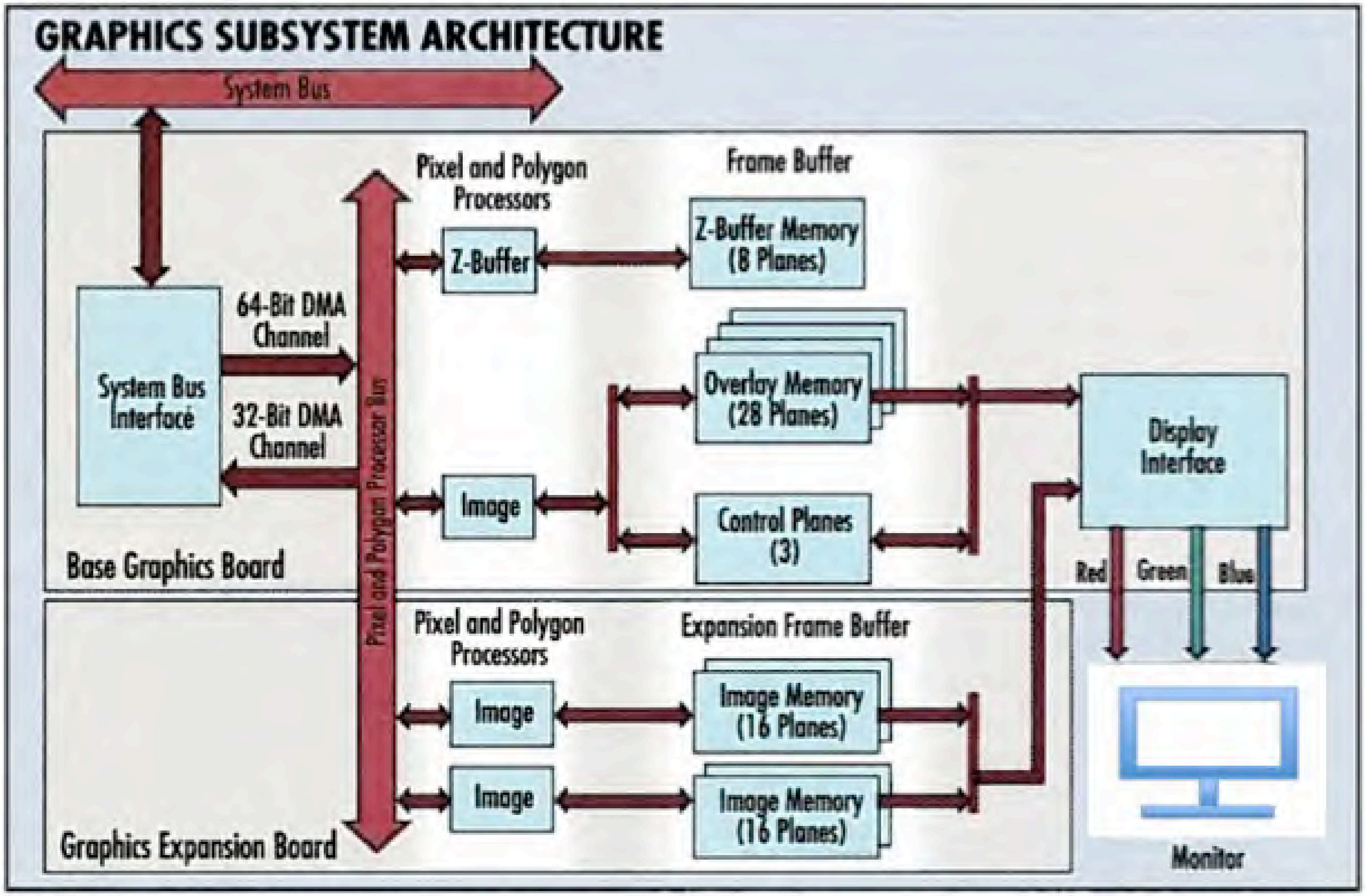
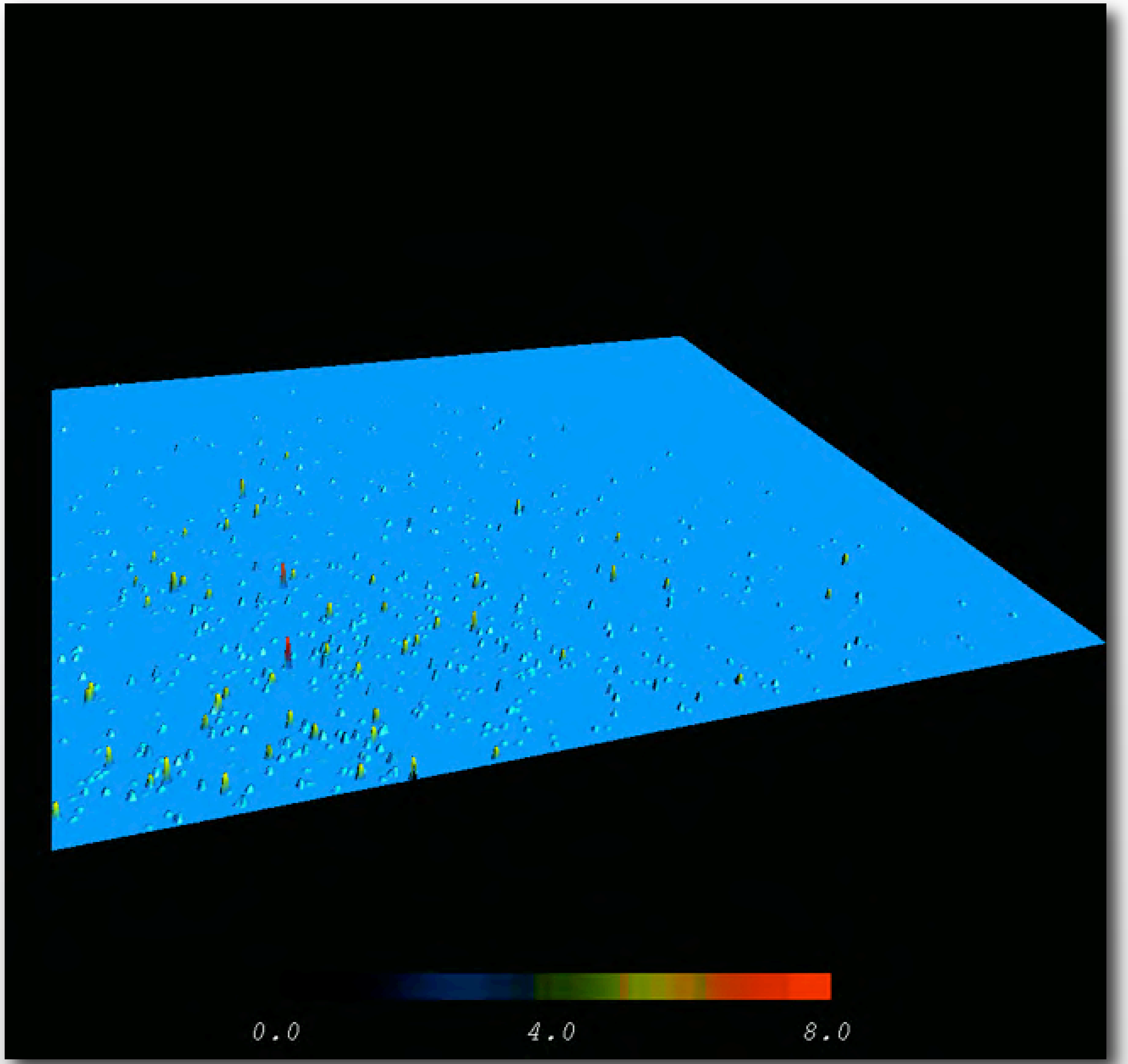



**FIGURE 2:** *A full graphics subsystem consists of two boards that are tightly coupled to both the CPUs and memory. These boards incorporate rasterizers (pixel and polygon processors), frame buffers, Z buffer, and additional overlay and control planes. The subsystem is coupled to main memory with a 64-bit DMA channel that transfers data from memory to the graphics subsystem and a 32-bit DMA channel that transfers data in the reverse direction.*

# AVS on ~1998 HP 735 workstation

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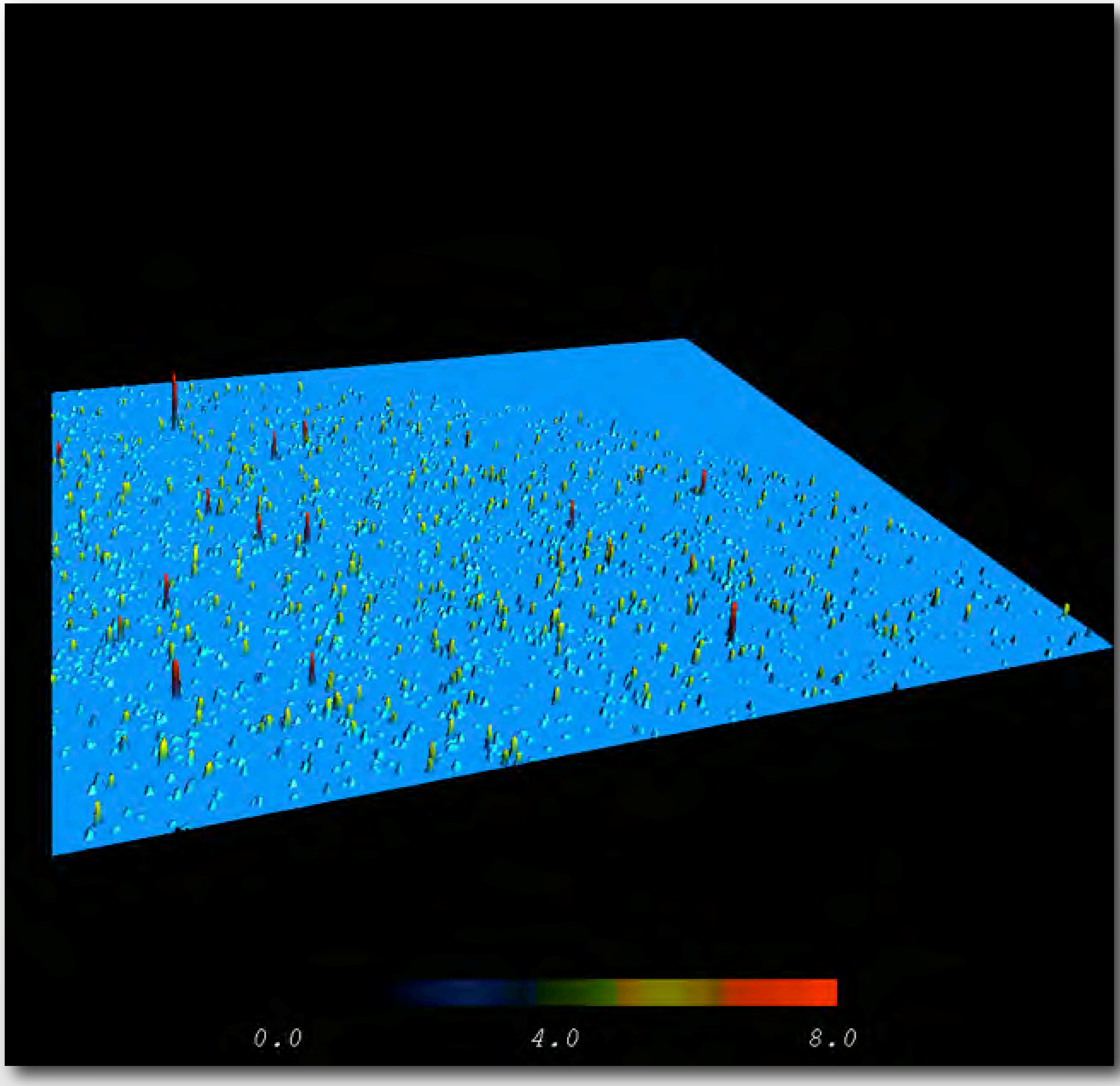


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Renderings of galaxy cluster temperatures within a thin slice of simulated sky in two different cosmological models: dark matter–dominated (left) and vacuum energy–dominated (right). The virtual Milky Way (i.e., here and now) is located at the near corner of each image, and the depth is approx. 10 billion light-years (redshift, z~1). The color scale is the thermal energy of each cluster, kT, in kilo-electron volts. From ~2000.

# published version of the previous slide

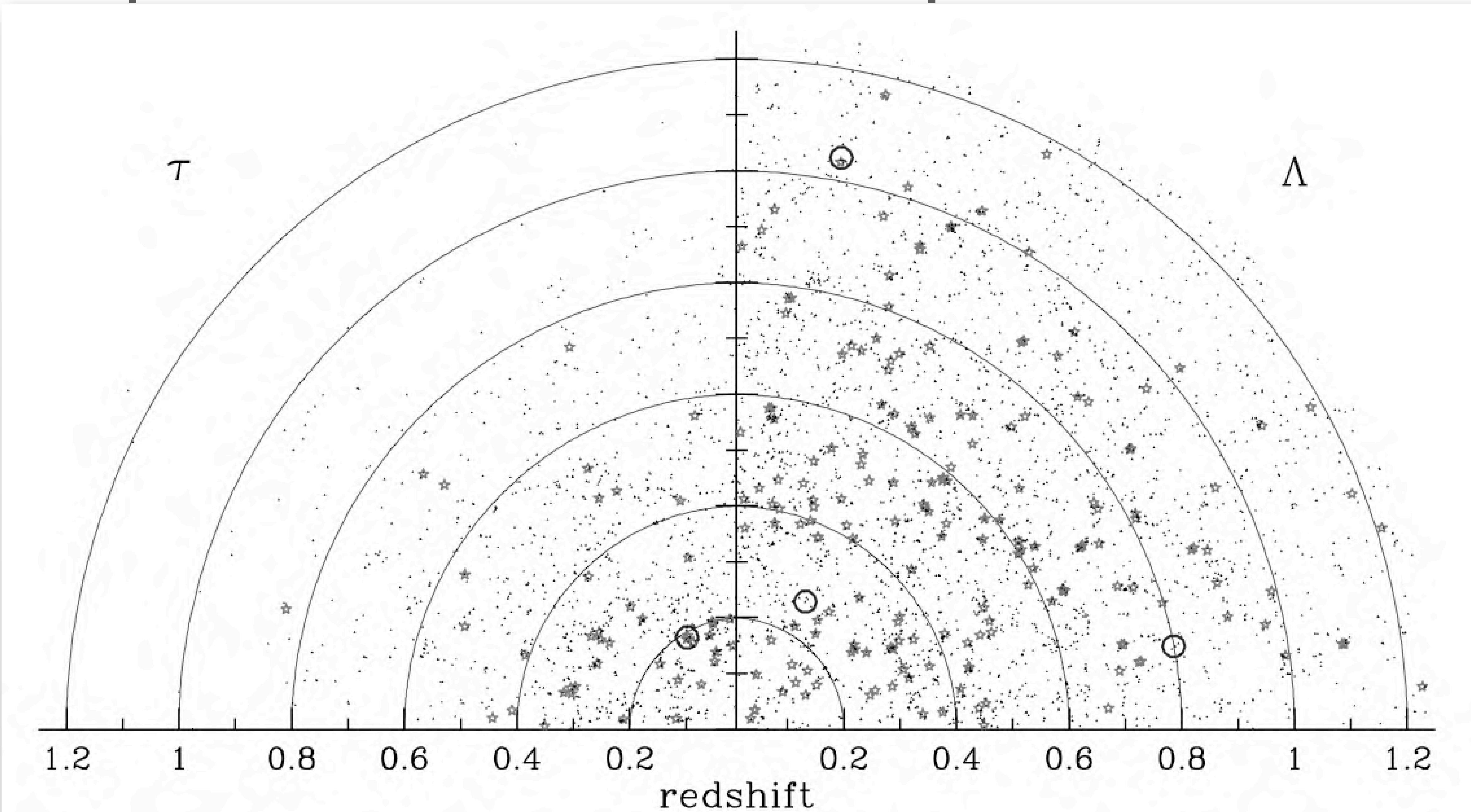


FIG. 6.—Maps of clusters in $90^\circ \times 3^\circ$ slices extending to $z = 1.25$, derived from the octant sky surveys of the $\tau$CDM (*left*) and $\Lambda$CDM (*right*) models. Symbols shows clusters of different masses: $hM_{200}/M_\odot > 10^{15}$ (*open circles*), $\in 10^{14.5}$–$10^{15}$ (*stars*), and $\in 10^{14}$–$10^{14.5}$ (*dots*). Numbers of clusters in these mass ranges are 1, 50, and 1071 ($\tau$CDM) and 3, 185, and 2896 ($\Lambda$CDM). [*See the electronic edition of the Journal for a color version of this figure.*]

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Evrard et al. "Galaxy Clusters in Hubble Volume Simulations: Cosmological Constraints from Sky Survey Populations," The Astrophysical Journal, 573: 7-36.


THE ASTROPHYSICAL JOURNAL, 573:7–36, 2002 July 1



GALAXY CLUSTERS IN HUBBLE VOLUME SIMULATIONS: COSMOLOGICAL CONSTRAINTS FROM SKY SURVEY POPULATIONS


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(THE VIRGO CONSORTIUM)


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Slide 9, Image 1 (top): Please see original image of Dartmouth computers at http://histoire.info.online.fr/images/dtss.jpeg
Slide 9, Image 2 (middle): Quote regarding BASIC.
Slide 9, Image 3 (bottom): Paul Baran Rand Corp.

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Slide 12: Graham, S., et al. *Getting Up to Speed: The Future of Supercomputing* (2004), pg 20.

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Slide 14: Source Undetermined

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