Sunrise

How a Single University Project Kickstarted New Technologies

Michael Engel
https://multicores.org

SILICON VALLEY early 1980s

UC Berkeley

ATARI

LSI LOGIC

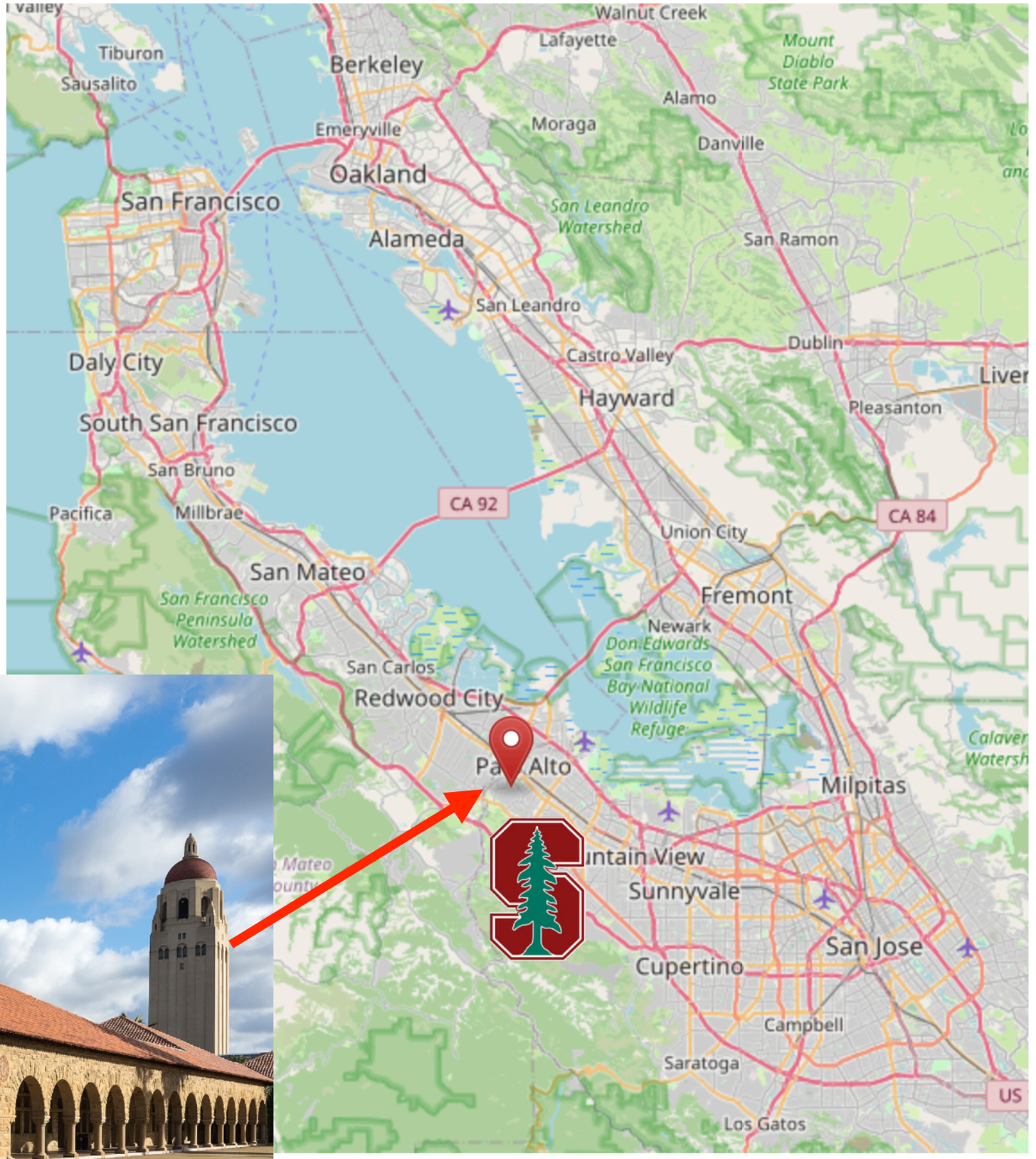
Quantum

XEROX PARC

AMD

Zilog

Stanford University
Silicon Valley
California
USA

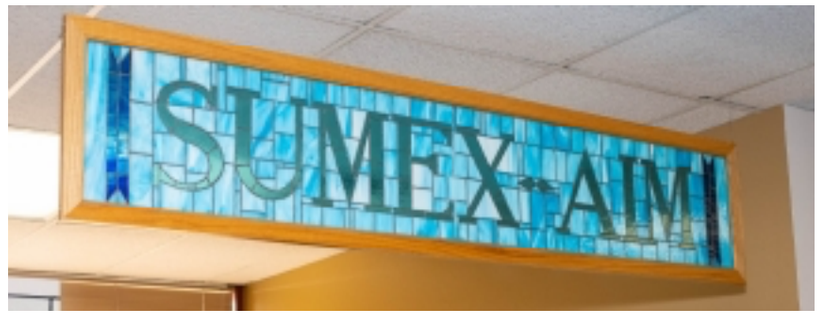




OpenStreetMap.org

CC-by-SA 4.0 by Frank Schulenburg

SUMEX-AIM and SUN



- SUMEX-AIM:
  "Stanford University Experimentation in Artificial Intelligence in Medicine"
  - Project running from 1973 to 1992
- Objectives:
  1. Promotion of applications of artificial intelligence (AI) computer science research to biological and medical problems
  2. Demonstration of network-based collaboration and computer resource sharing within a national community of health research projects
- Link the Stanford University Medical Center to the computer science and electrical engineering departments across campus: Stanford University Network **SUN**

https://exhibits.stanford.edu/cs/feature/sumex-aim

From SUN to Sun

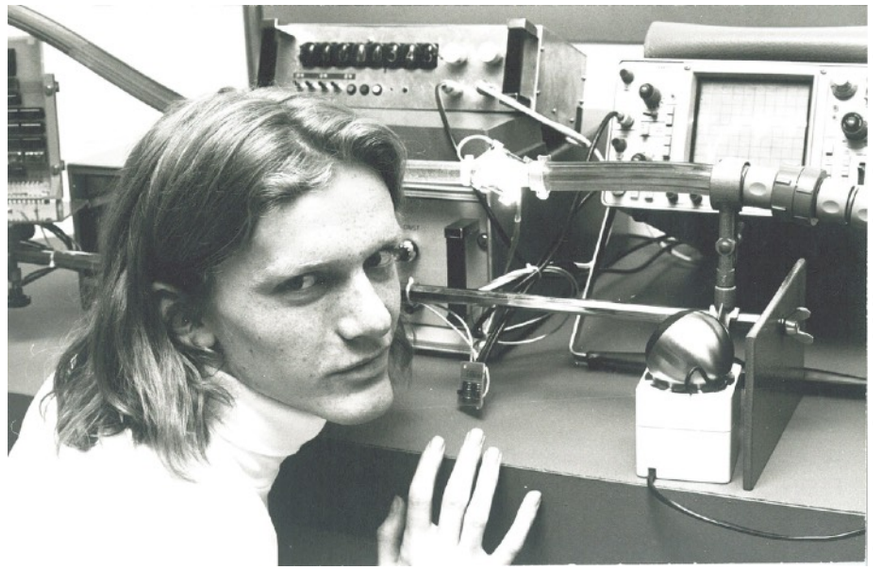
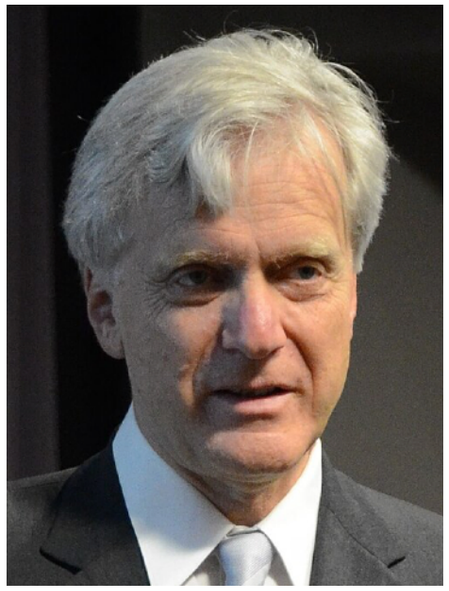


Image from Wirtschaftswoche

- SUN workstations grew out of the desire to have a display capability for the Stanford University Network
  - Detailed design of the SUN workstation in May 1980
  - First wire-wrap prototype by November 30, 1980
  - Production version demonstrated on July 3, 1981
- Created by Andy Bechtolsheim*
  - Born 1955 in Hängeberg am Ammersee, Germany
  - Designed industrial controller based on Intel 8008 at age of 16
  - Won the "Jugend forscht" physics prize in 1974
  - Master's degree in CE from Carnegie Mellon University in 1976
  - Ph.D. student at Stanford from 1977



CC-by-SA 3.0 by Norbert Stuhrmann

F. Basket, A. Bechtolsheim, W. Nowicki, and J. Seamons: The SUN Workstation: a Terminal System for the Stanford University Network, Stanford Computer Science Dep., Internal Report, March 1980

* full name: Andreas Maria Maximilian Freiherr von Mauchenheim genannt Bechtolsheim

SUN Board Components

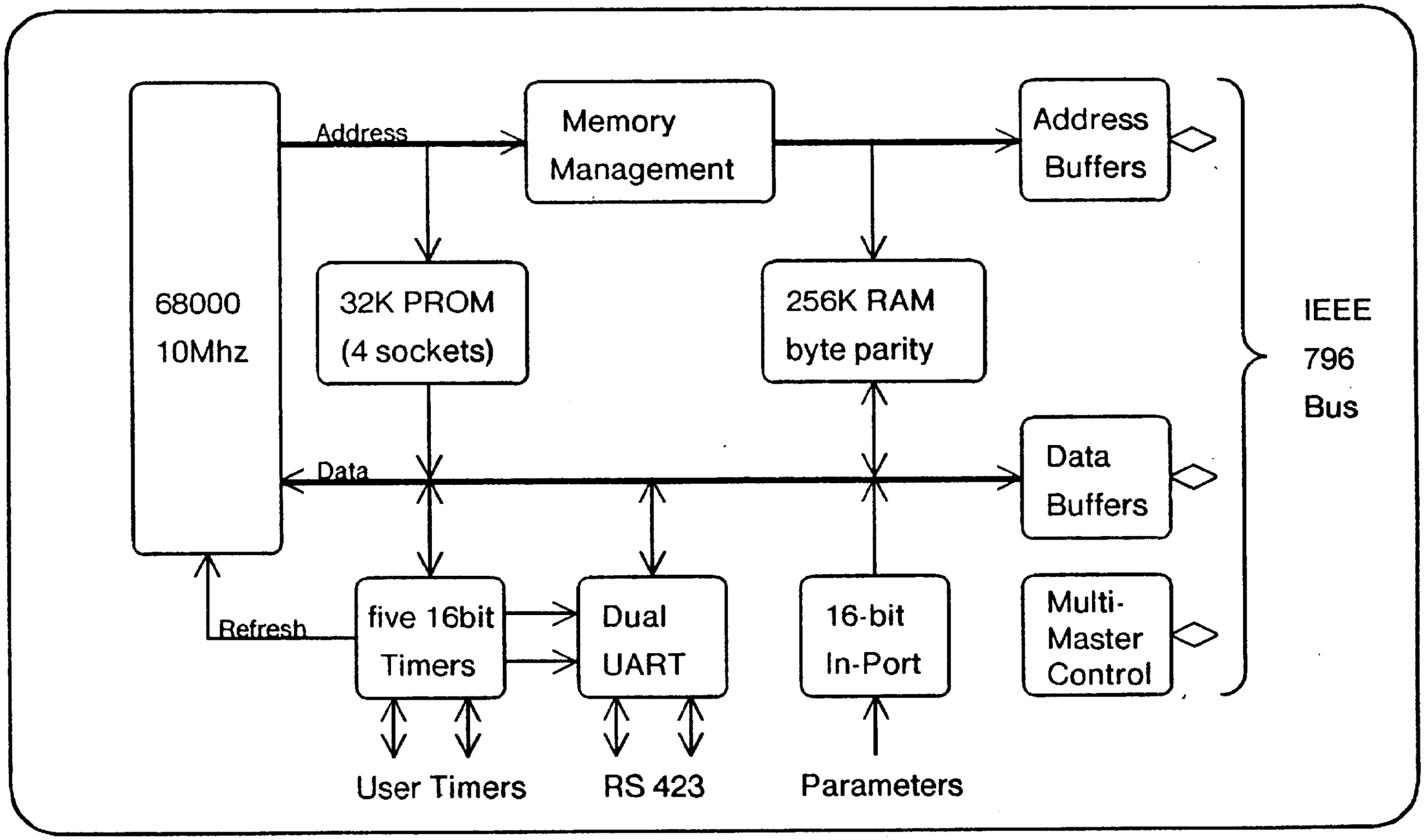


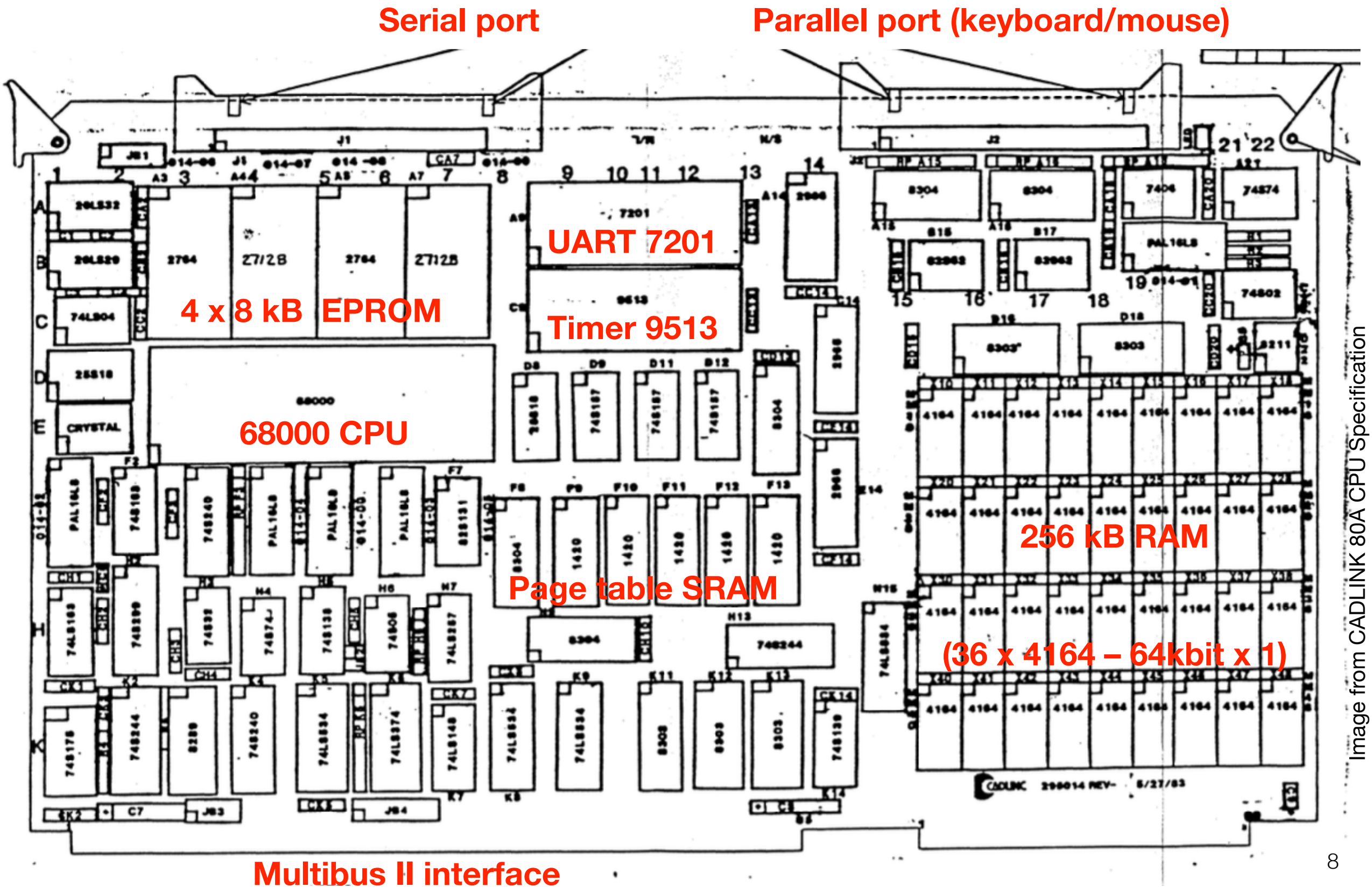
Image from SUN 68000 Board, VLSI Systems Inc. 1982

The SUN Board



Image from "SUN display", http://infolab.stanford.edu

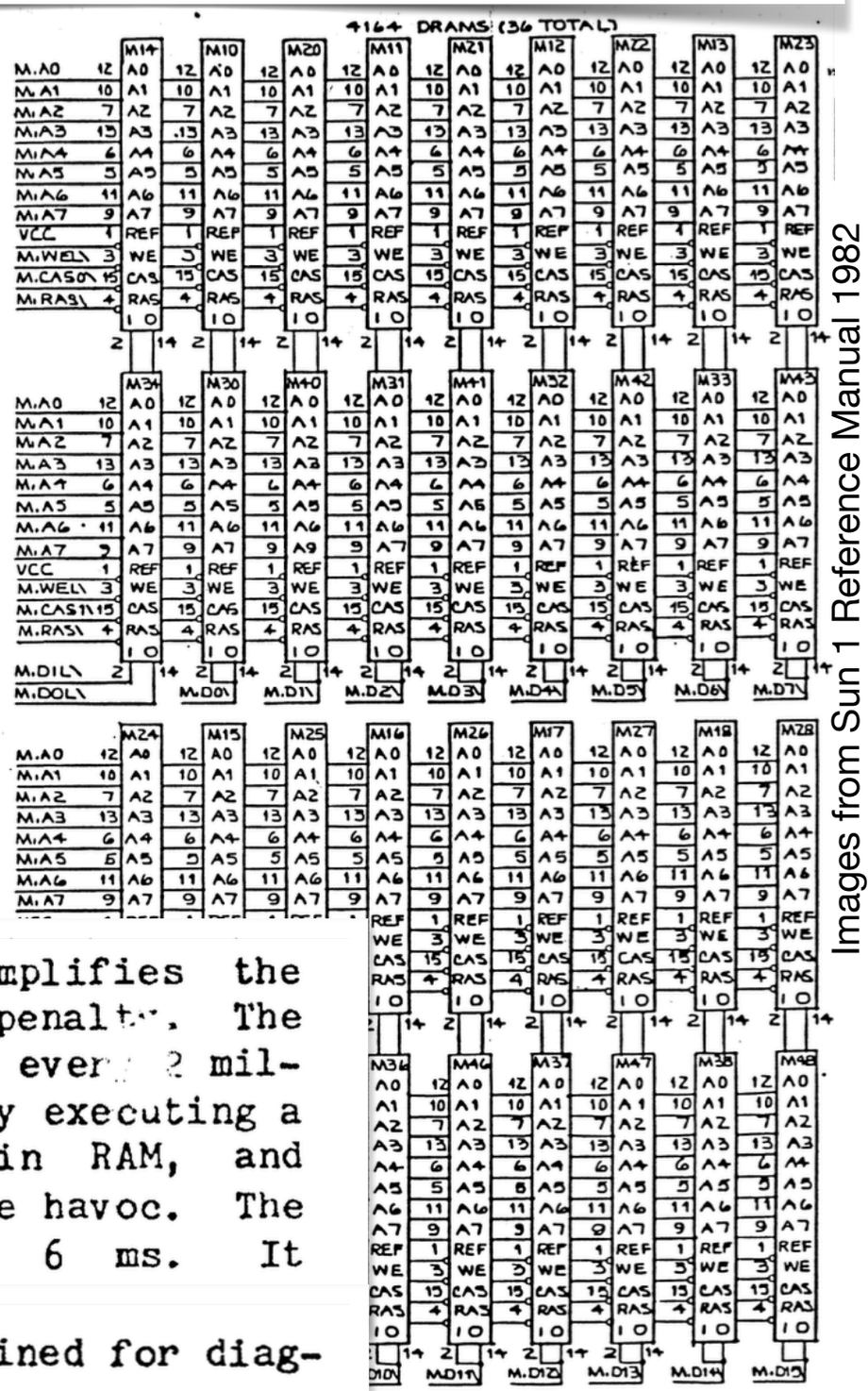
Annotated SUN Board



RAM

3	Refresh timer. OUT causes INT7.	Out=toggle, repetitive (one shot). Reset by refresh routine.	interval= 2 msec [2]

- 256 kB DRAM + parity in 36 4164 DRAMs (64 kbit)
  - later version supported 41256 DRAMs (256 kbit) → used in Cisco board
- DRAM refresh was not implemented in hardware
  - Onboard 9513 timer channel 2 set to interrupt every 2 ms

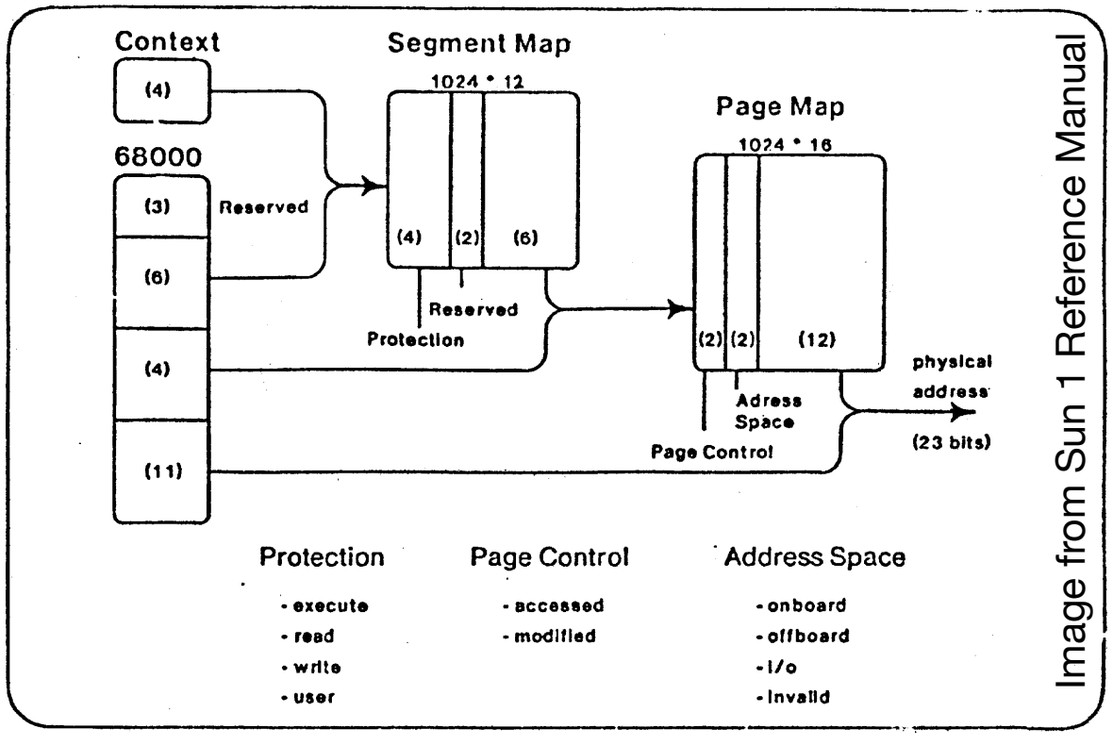


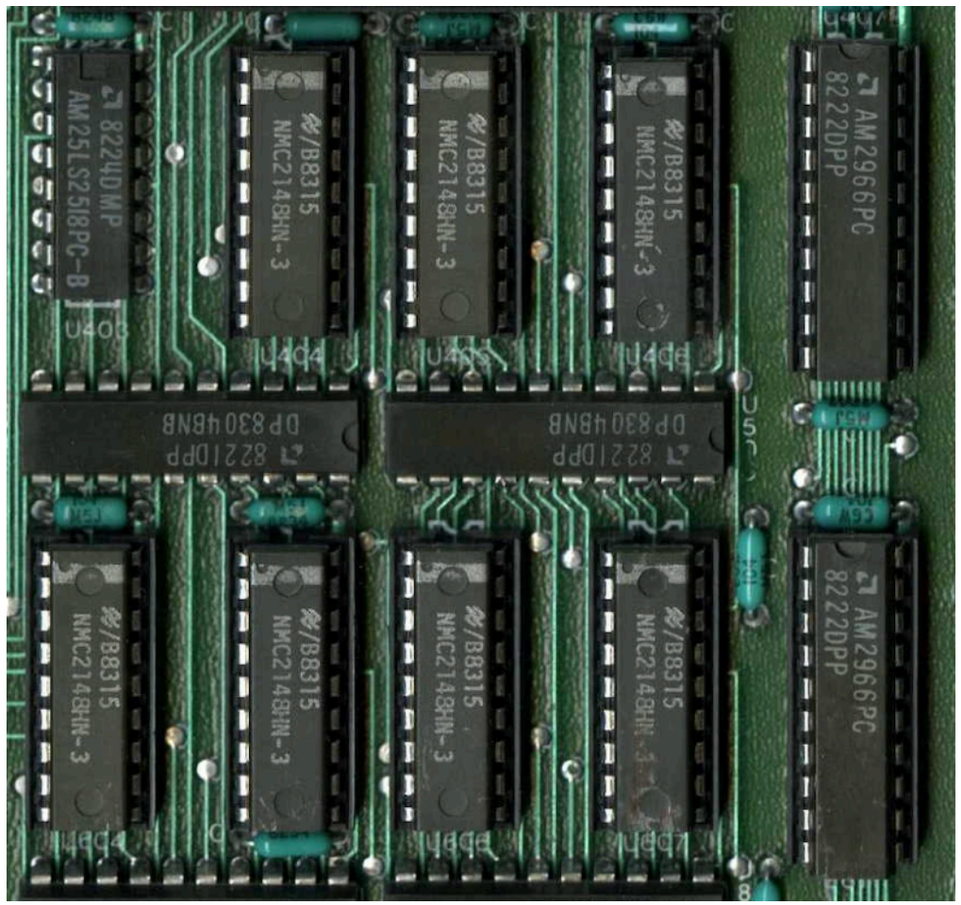
Images from Sun 1 Reference Manual 1982

Memory refresh is done by the processor because it simplifies the hardware while not incurring any significant performance penalty. The memory is refreshed by simply reading 128 consecutive words every 2 milliseconds. The reads are done as instruction fetches by executing a routine consisting mostly of NOPs. This routine is stored in RAM, and so a malfunctioning program may damage it and thus cause havoc. The watchdog timer will detect this and reset the system within 6 ms. It restores the refresh function and allows memory to be examined for diagnosis.

The SUN MMU

- Based on ideas by Stanford professor Forest Baskett (head of SUN project)
  - Virtual addresses from the 68000 are translated into intermediate addresses by the segment map and then into physical addresses by the page map
- Page size: 2048 bytes
- Segment size: 32KB, 16 pages per segment
- Up to 16 contexts can be mapped concurrently
- Maximum logical addr. space for a context: 1024 pages (2MB)
- Maximum physical addr. space that can be mapped simultaneously: 2MB
- Implemented using fast 2148 SRAMs





Forest Baskett, Pascal and Virtual Memory in a Z8000 and MC68000 based Design Station, Proc. Spring COMPCON 1980

Page Fault Handling

Full virtual memory capability is possible with the 68010 processor, the virtual-memory version of the 68000. The original 68000 processor cannot fully recover from page faults because it does not save sufficient state information to continue an aborted instruction. However, for a limited set of operations, such as load and store, recovery from aborted instructions is straightforward. With additional software assistance, recovery from more complex addressing modes appears feasible.

- Problem: 68000 didn't support restart from page faults
  - Not enough context saved on stack in case of bus errors
  - Faulting instructions could not be recovered/re-executed in all cases
- My thesis (*unconfirmed, WIP!*): *Sun solved this by using "harmless" instructions such as "tst" that did non have to be recovered*
  - Requires changes to the compiler
  - e.g. when creating a new stack frame that requires to extend the stack
- Problems solved in 68010
  - SUN board compatible with 68010 from the start, 68010 available in 1983 only!

Andreas Bechtolsheim, Forest Baskett, Vaughan Pratt, The SUN Workstation Architecture, Stanford University Technical Report 229 March 1982

Sun 1

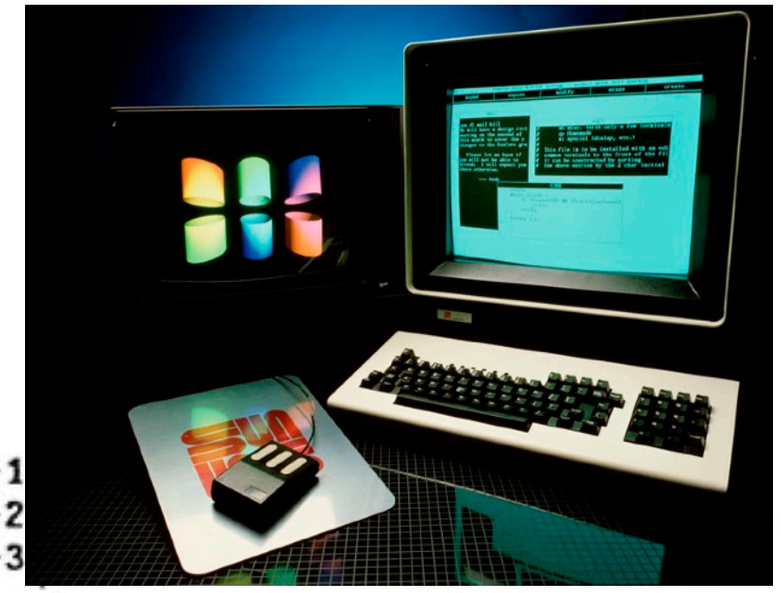


Image from ???

- Sun Microsystems workstation:
  - SUN CPU board
  - Graphics, screen, kbd, mouse
  - Ethernet
  - *Optional* disk controller
    - Interphase SMD 2180

Product:

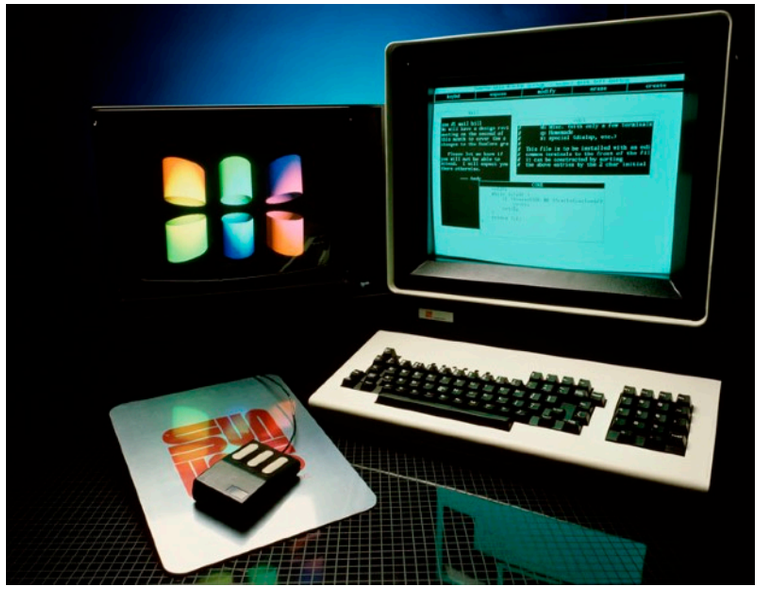
SUN-1
SUN-2
SUN-3

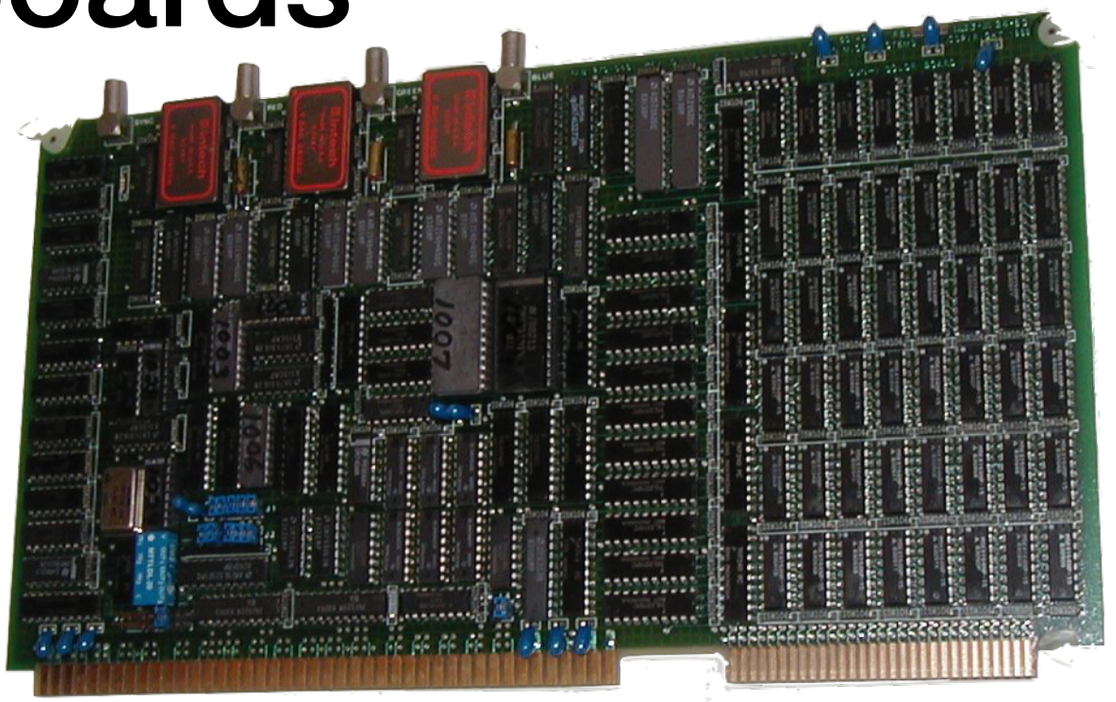
Direct Material Costs (qty 1000/year):

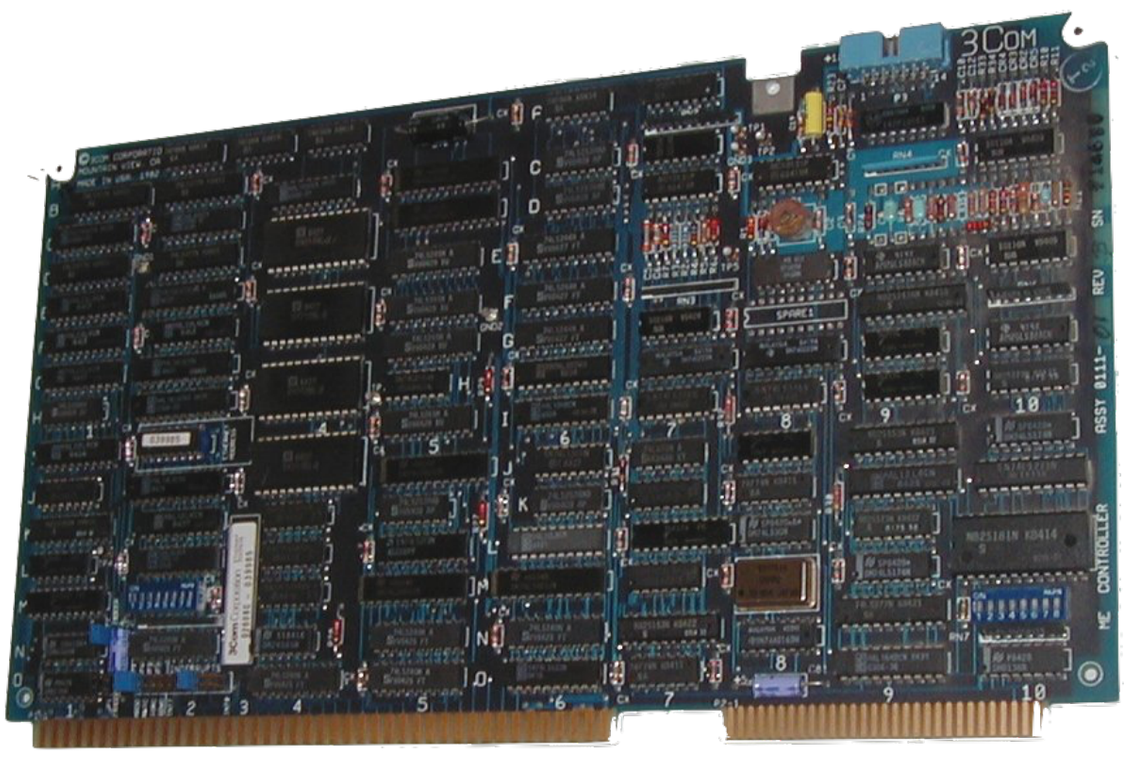
	SUN-1	SUN-2	SUN-3
Electronics (ICs):	$1100	$1000	$800
Other Parts:			
Monitor:	$400	$350	$300
Keyboard	$120	$100	$70
Mouse	$180	$100	$80
Power Supply	$100	$50	$50
Packaging	$600	$300	$200
Subtotal	$1400	$800	$700
Total Material Cost:	$2500	$1800	$1500
Direct Labor (10%)	$250	$180	$150
Indirect Labor (10%)	$250	$180	$150
Total Manuf. Cost	$3000	$2240	$1800
Average Selling Price:	$7000	$5000	$4000

- "Sun shipped about a thousand of these, then replaced them all (at a price) with a redesigned 68010-based board so that it would not be necessary to support both a vm and a non-vm unix." [Vaughan Pratt]

Sun 1 Boards







- Graphics board + 17" monitor
  - 1024×1024 pixels monochrome
    - only 1024×800 displayed
    - includes hardware to accelerate raster operations
      - screen fill in 64 milliseconds
    - later optional 640x480 8-bit color
- Ethernet
  - 3 Mbps (Xerox)
  - 10 Mbps (3Com)

Both images: CC-by-SA 2.5 by Robert Harker

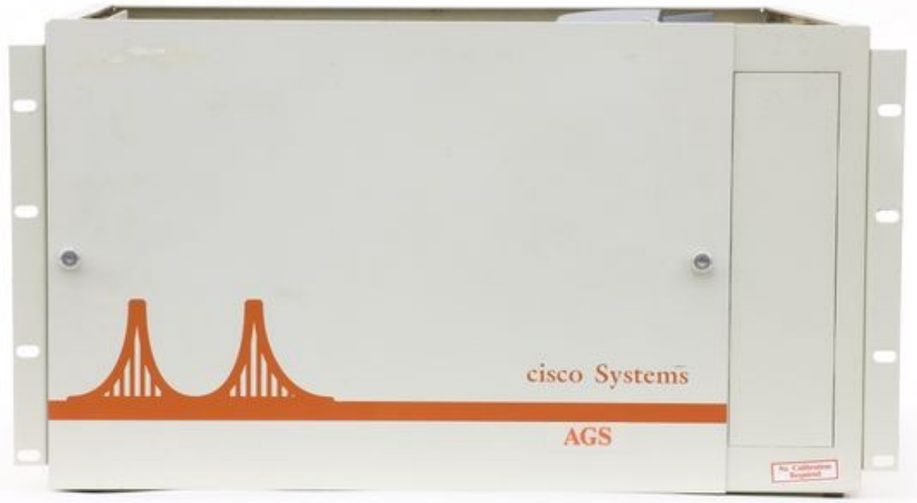
SUMEX-AIM and SUN



- Link the Stanford University Medical Center to the computer science and electrical engineering departments across campus
- Initial router code written by Bill Yeager for PDP11s
- Switch to SUN 68000 board starting in 1981
  - Prototypes used 3 Mbps Ethernet
- Blue box prototype built by the CS dept. (also 10 Mbps)

The Origins of the Stanford University SUMEX-AIM Router Technology – An Historical and Technical Overview by William James Yeager
https://exhibits.stanford.edu/cs/feature/sumex-aim

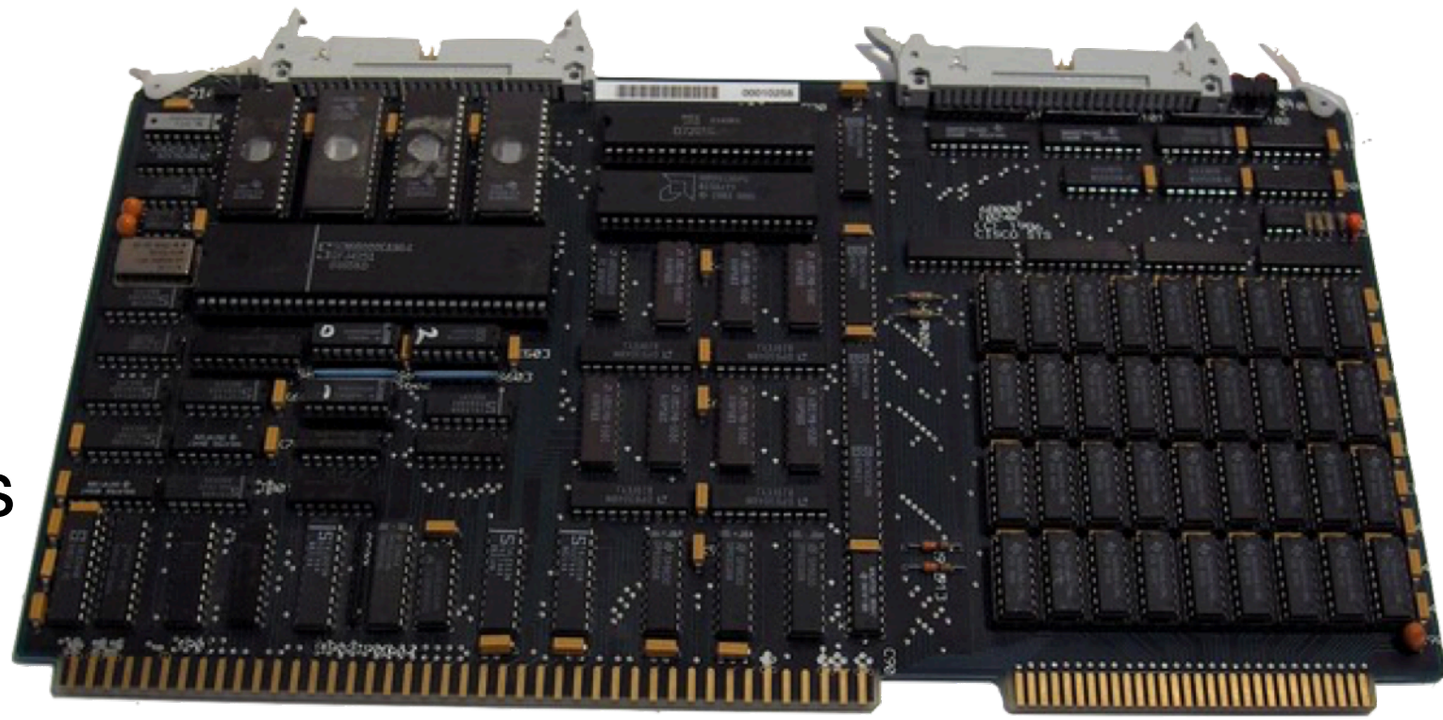
CISCO



- Len Bosack, Sandy Lerner, and Kirk Lougheed (at Stanford)
  - Gained access to Bill Yeager's router source code in 1985
    - Promised to continue development of the system
    - Founded Cisco Systems the year before, *planned to rewrite and copyright the sources as Cisco Systems' intellectual property*
      - In 1985 Cisco sold its first product, a network interface card for Digital Equipment Corporation's computers
  - Code officially licensed by Bosack and Lerner on behalf of Cisco Systems in 1986
- Bluebox prototype was basis for Cisco's first router: AGS "Advanced Gateway Server"

Bill Yeager, The Software that Launched Cisco Systems, IEEE Internet Computing January/February 2005

CISCO



- Original Cisco CPU was a slightly upgraded 68000 SUN board
- Andy Bechtolsheim was asked to modify the SUN board to accept 256 kbit RAM chips
- *"I handed Andy a pencil and the schematics and he scribbled the mods on it. I took the mods, and with exacto knife and jumpers, modified a sun board for the 256k chips. Len Bosack then took the mods and relaid out the PC. That board was the first cisco cpu, and was also produced internally to Stanford."* [bjork@rahul.net]

SEAGATE

- More network systems created in the SUMEX project
- Bill Croft created an Stanford Ethernet–AppleTalk Gateway (SEAGATE)
- SUN 68000 board
- 3 Mbps Ethernet
- Self-built Multibus card with Zilog Z8530 SCC + transceivers (same as in Mac/Lisa)

```
Date: 29 Apr 1985 0946-PDT (Monday)
From: Bill Croft <croft@safe>
To: info-applebus@mit-xx
Reply-To: croft@sumex
Subject: appletalk programs from SUMEX

Ralph,

Here is what you can get from SUMEX.  Since this stuff is fairly
large, I recommend just posting this note as a 'pointer' and let
folks pick it up by FTPing directly to SUMEX.

(1) a cross development environment (SUMACC) that allows Mac
C programs to be developed on UNIX.  After the executable module
is produced, it can either be downloaded to the Mac or simply
'executed' remotely via the Mac file server below.  [released
in Nov 84].

(2) a 'gateway' between ethernet and AppleTalk (SEAGATE).  This allows
UNIX to provide servers for Mac AppleTalk applications.  [released
in Feb 85].
```

```
Subject: Re:  North Sea Gate
Actual-Sender: Stephen Lewis

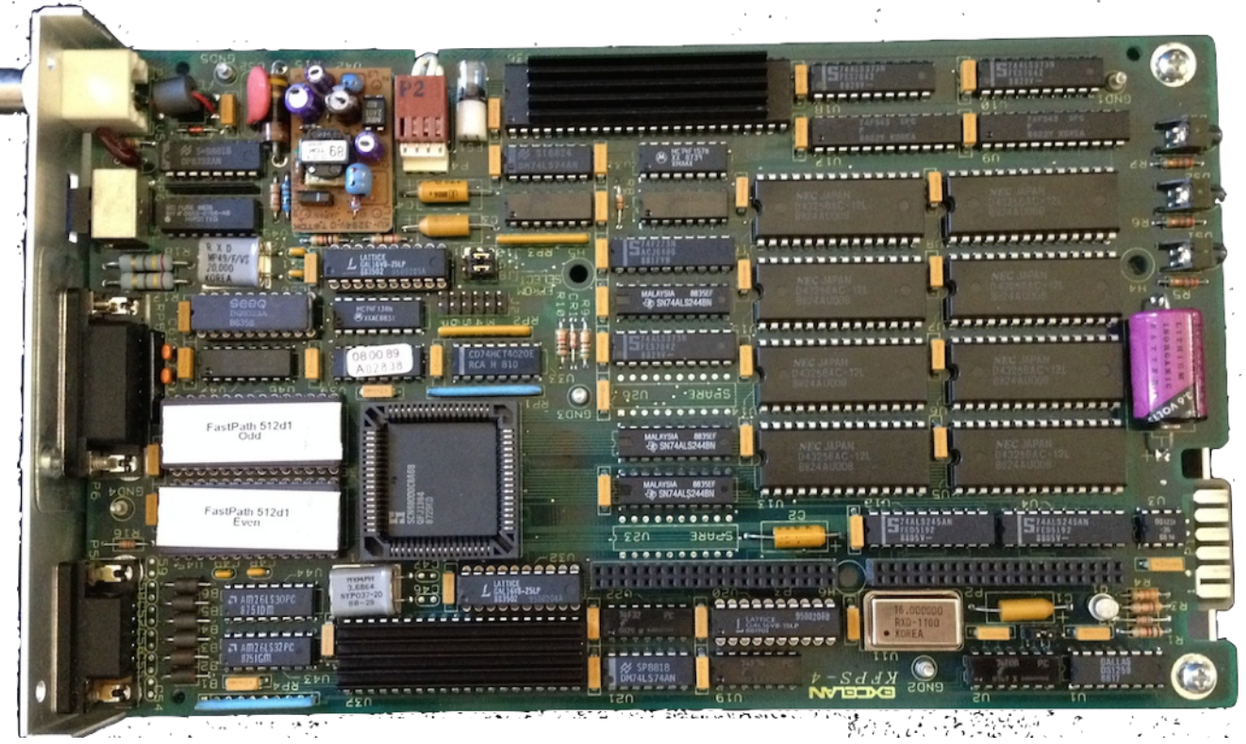
       Sorry for late answer. Re Kinetics' Mac/Ether Bridge.
Yes I am working on a single board version. Details follow.

Status: Wire wrap prototype about to be built. PC version after bugs
        fixed (maybe 2 mos).

Spec: 68008 CPU (running 8Mhz), Z8530, 82586, sockets for 8 memory
        chips which can be any of:
        8k*8 RAM; 8k*8 up to 32k*8 ROM or 2k*8 EEPROM each.
        Final config not fixed yet (maybe 40k RAM, 32k ROM, 2k EEPROM)
        parallel port to bus which can be Multibus or Q-bus.
        Operates stand-alone with single 5v supply as a gateway or
        in a card cage as a gateway or in a cage as Applebus interface
        or in a cage as poor man's Ethernet interface or combinations.
        DB15 connector for Applebus - 16pin transceiver cable
        connector for Ethernet (with cable - you need transceiver).
        All RAM is *static* (no refresh!) and all shared between
        82586 and 68008 on a 2Mbyte/s bus.
```

SEAGATE code available at https://bitsavers.org/bits/Stanford/SEAGATE/

Kinetics/Shiva FastPath



- SEAGATE commercialized by Kinetics (later Shiva) as "FastPath"
  - DRAM replaced by SRAM
- Updated versions of the SEAGATE code "KIP" available from Phil Budne (ex-Shiva/Kinetics)



Image by jake18125 (68kmla) By Douglas Finn, http://www.walshcomptech.com/fastpath5

KIP code available at https://ftp.ultimate.com/FastPath/shiva-ftp/

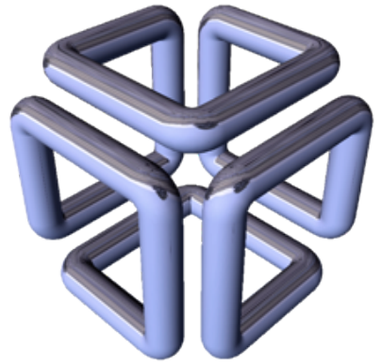
SGI

- Geometry Engine by James Clark (Stanford professor) and Marc Hannah
  - first very-large-scale integration (VLSI) implementation of a geometry pipeline
  - specialized hardware that accelerated the "inner-loop" geometric computations needed to display three-dimensional images
  - capable of multiplying two four-element vectors every 15 microseconds
- SGI (Silicon Graphics, Inc.) founded Nov. 1981 in Mountain View
- Iris-1000 und 1200
  - Graphics terminals
  - Based on SUN board
- Iris-1400
  - First standalone workstation
  - Unix from Unisoft (again)



James H. Clark, The Geometry Engine: A VLSI Geometry System for Graphics, ACM SIGGRAPH Computer Graphics, Volume 16, Issue 3, 1982

SGI



- Iris 1000 and 1200 based on SGI's PM1 ("Processor Module 1")
  - Clone of the original SUN board with 68000
- Later machines (Iris 1400, 2000, 3000) used PM2 board with 68010 CPU (later "Turbo" 68020 on "IP2" board:"Internal Processor")
- Switch to MIPS in 1987
  - SGI 4D60
- SGI engineers founded ArtX, base of ATI/AMD GPUs

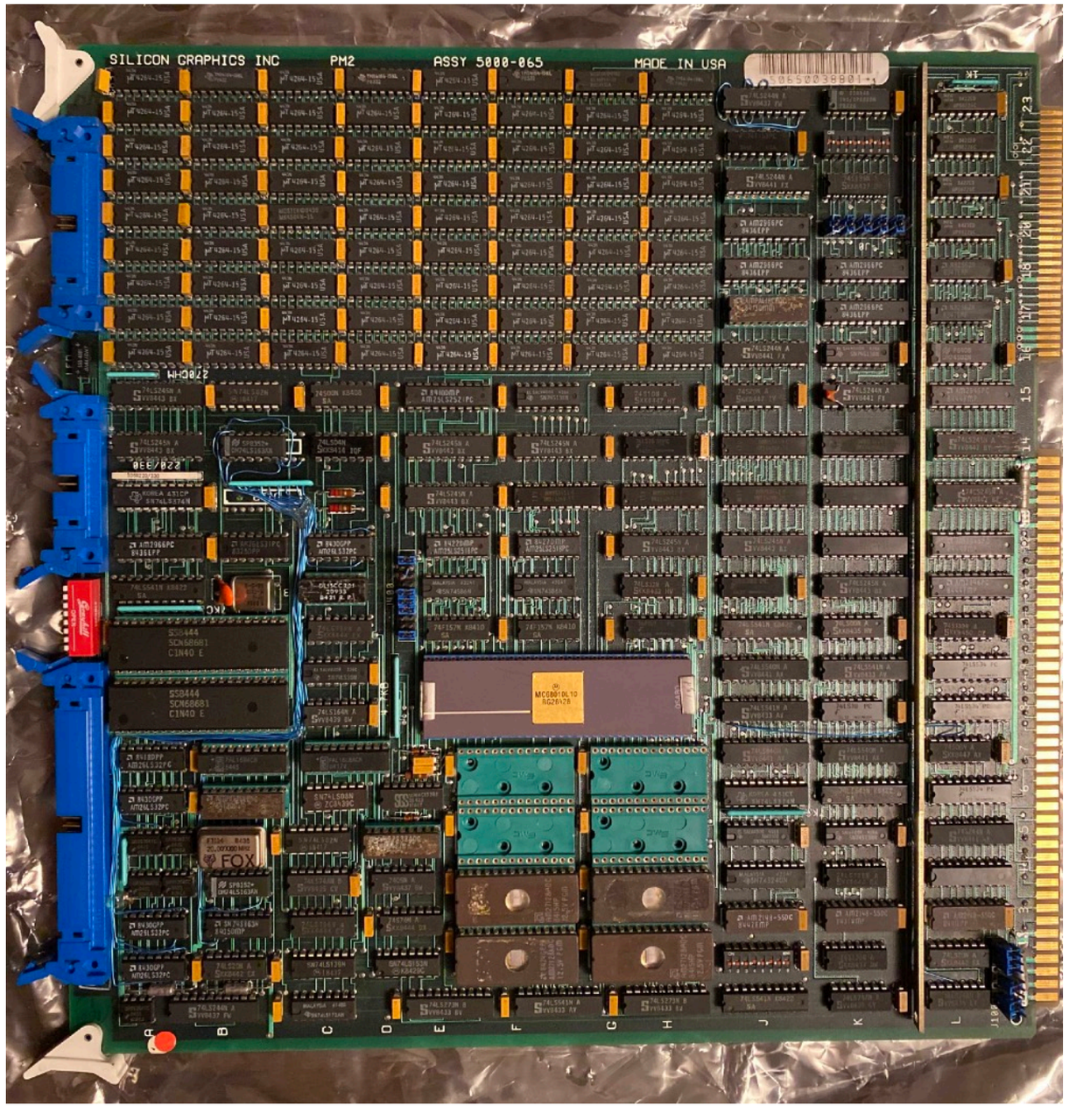


Image from ???

Many others…

- Cadlinc (Mountain View)



- Callan Data Systems (Westlake Village, CA) -> Pacific PM68k
- Codata (Sunnyvale)



- Forward



- Imagen
- Pacific Microcomputer (Cardiff, CA)

Codata

- Contel Codata Codata-3300
  - 320 kB RAM (?)
    - up to 1.5 MB
- 12 MB, 33 MB or 84 MB hard drive
- Floppy drive
- priced from £8,900/ $9,600 in the US
- distributed in the UK by Cambridge Micro Computers

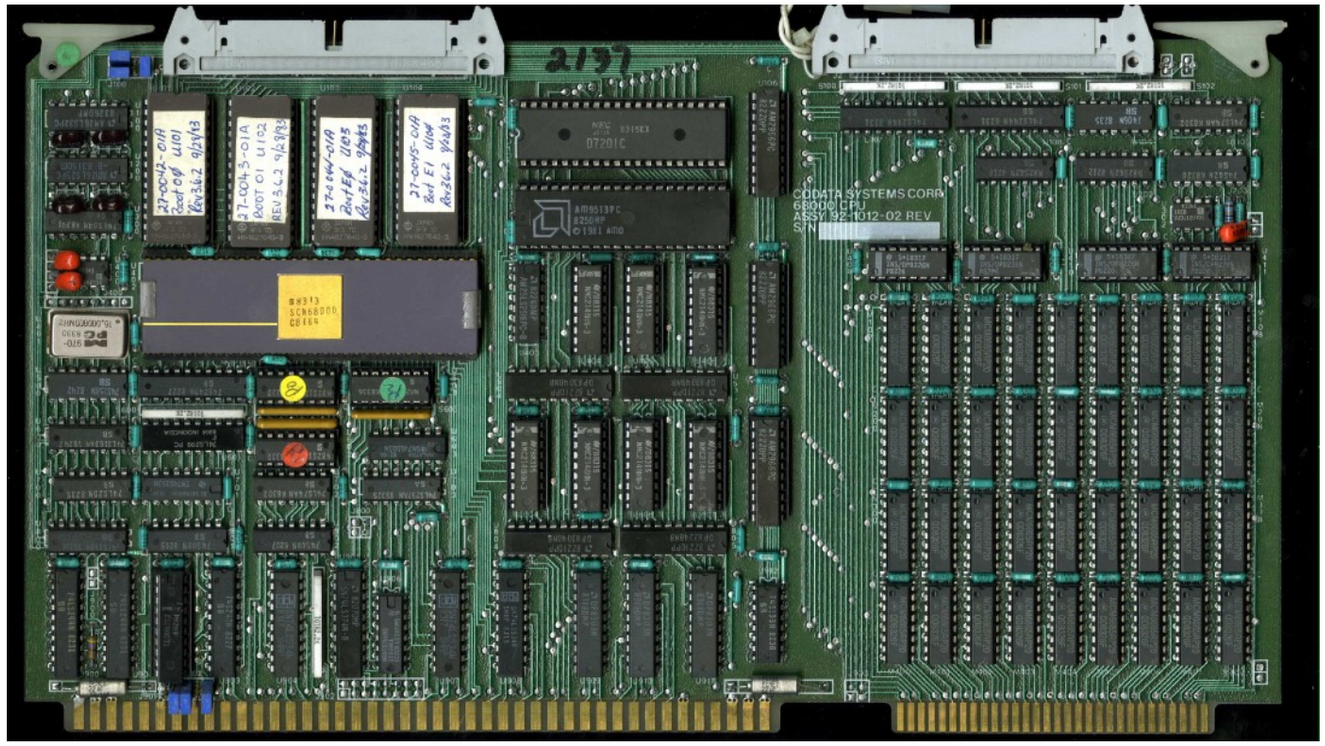


Image from bitsavers

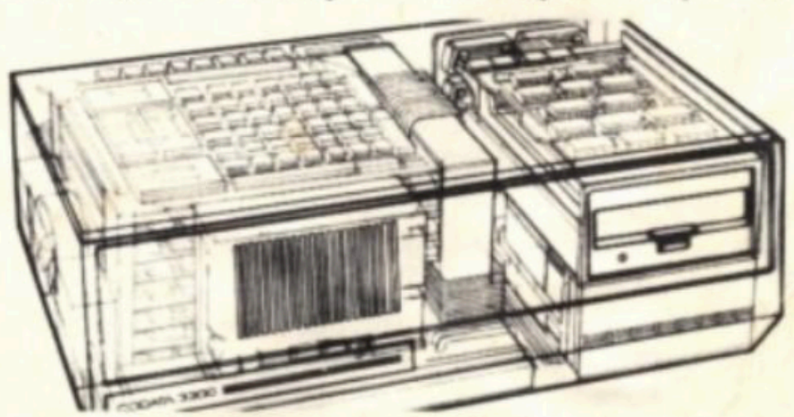
Codata 3300 tackles micro big league

Last week saw the launch of a new supermicro in the same class as the Sage and the Tandy Model 16.

The Codata 3300, made by Codata Systems Corporation of California and distributed in the UK by Cambridge Micro Computers, Cambridge, is based on the 8MHz 68000 processor and runs the full implementation of the Unix Version 7.0 operating system.

At £8,900 for the basic system consisting of microprocessor, 320K RAM, 12Mb Winchester and 1Mb floppy disk drive, the micro uses the multibus standard bus system and can accommodate ten or more users.

Its 320K memory is upgradable to 1.5 Mb, and 12,33 or 84 Mb of storage are available on high speed Winchesters. It also takes 5¼in floppies, cartridges or magnetic tapes, and hardware expansion options.



Cadlinc

- Cadlinc CAD systems
  - Sun-1 with 10 Mbps Ethernet
  - Systems for engineering applications with numeric control
- Switched to only providing software for Sun machines



Images from The Jim Austin Computer Collection

Imagen

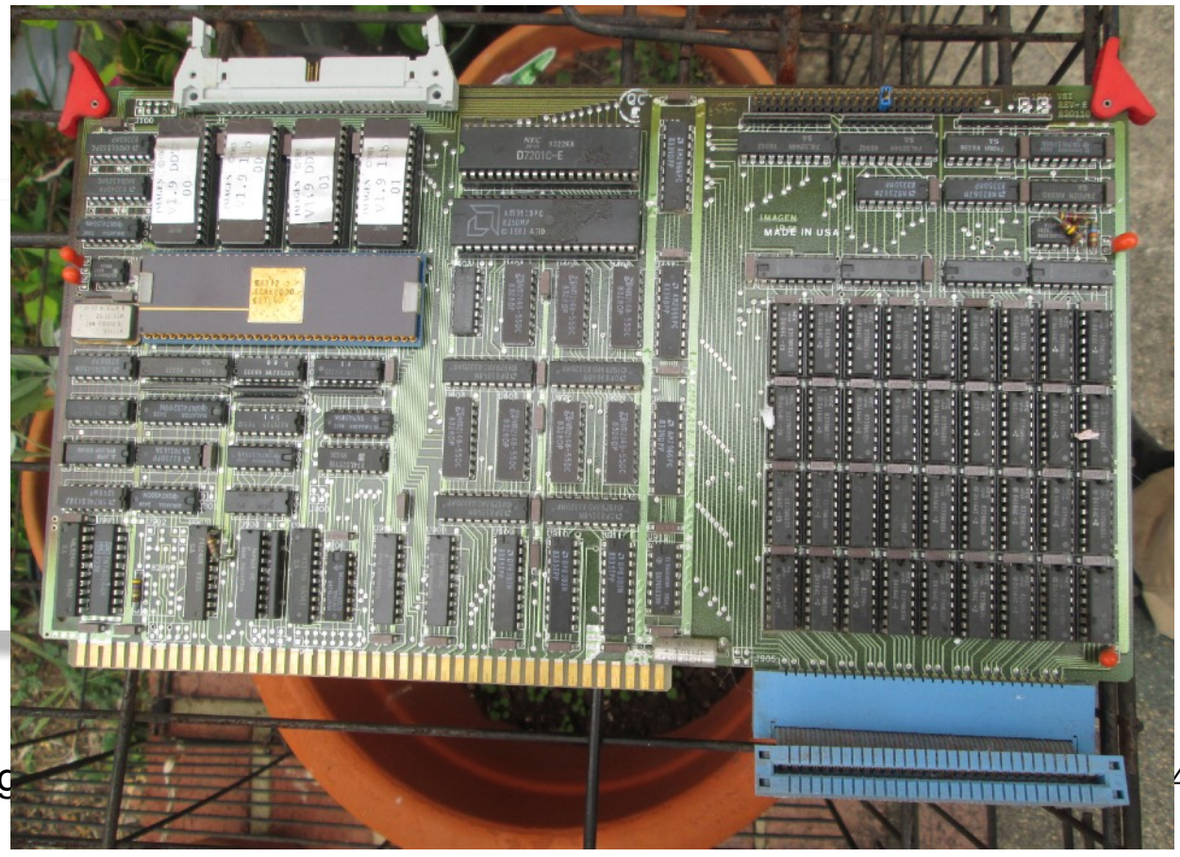


- Luis Trabb Pardo and Les Earnest spun off Imagen as a start-up from the **TeX project at Stanford** 1980
- Productized laser printer prototype Luis and Kok Chen built for the TeX project ($20k)
  - Donald Knuth: Luis was his “right hand man” for the development of TeX78
- Based on (1982) LBP-10 "wet process" lasers from Canon, later dry-toner 300 dpi Canon LBP-CX engine (also used in HP LaserJet and Apple LaserWriter)



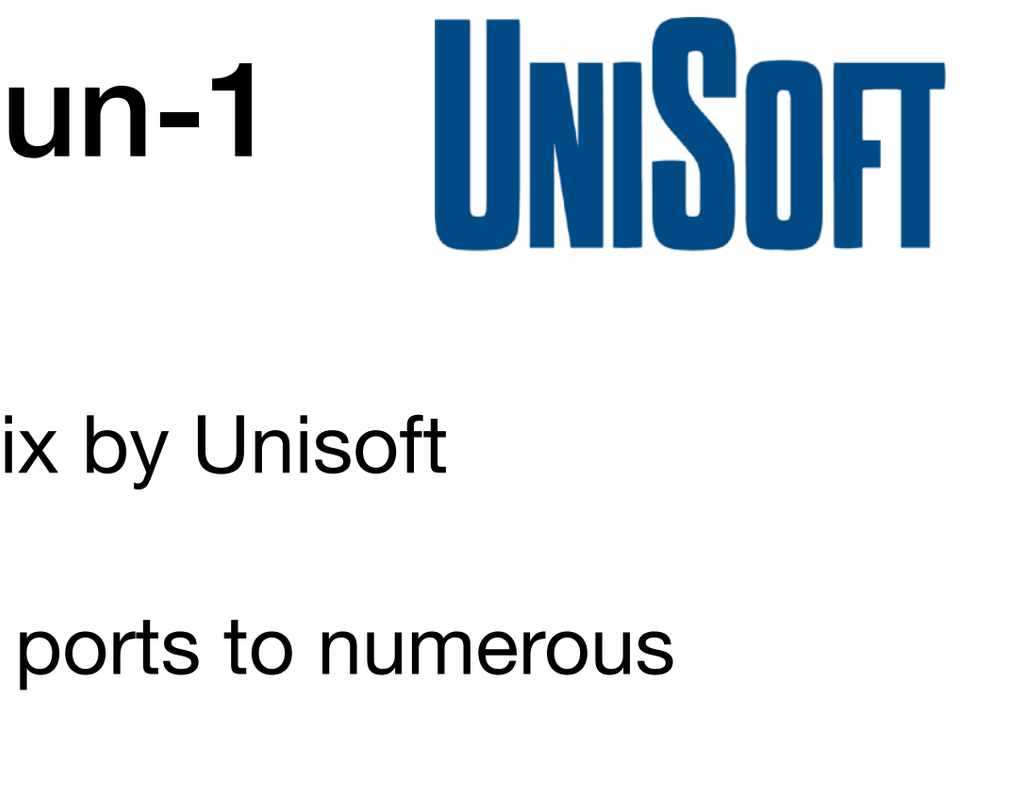
https://www.retrotechnology.com/herbs_stuff/s_intel.html

```
>From C70:daemon Sun Oct 18 17:22:53 1981
Imagen Corporation sells a Canon LBP-10 with MC68000 and controller
in a multibus.  You can connect via serial line (now), or 3MBit or
10MBit Ethernet (later).  It prints 240 points per inch, with all the
"Computer Modern" Fonts created by Don Knuth.  We have written Unix
software to allow "line printer" emulation, complete with a queue
manager (a superset of lpr), a set of programs to print troff output
(such as the entire Unix Programmer's manual), and, of course,
TEX.  For more information contact Lester Earnest (les at sail),
at (415) 949-1580.
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```



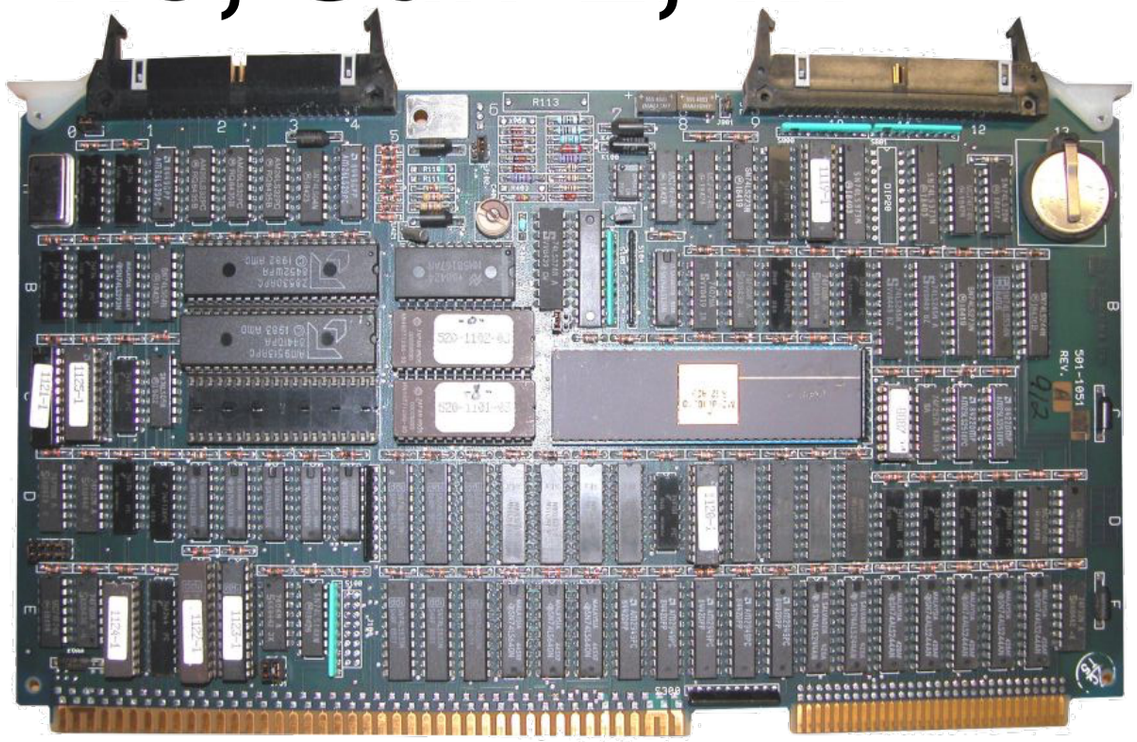
Unix for the Sun-1

- Original Unix: port of 7th Edition Unix by Unisoft
  - Unisoft completed over 225 Unix ports to numerous CPU architectures
    - e.g., Lisa Unix, A/UX, …
- Paging MMU, but swapping kernel
  - V7 did not support paging
- No windowing system



Followup – Sun-1.5, Sun-2, …

- Upgrade to 68010 CPU
  - Paging!
  - Same MMU used
  - Still provided parallel interfaces for keyboard and mouse
- Sun-2 systems
  - Multibus-2 68010 board (2/1[27]0)
  - Switch to VME for 2/50, 2/1[36]0
  - Serial keyboard and mouse



CC-by-SA 2.5 by Sun-collector



CC-by-SA 2.5 by Michael Thompson



Joy to the Sun!

UC Berkeley

The June 1982 issue of *;login:* carried the following:

Interesting Developments

Bill Joy of UCB Moving to Sun Microsystems

Bill Joy has decided to become involved with a new startup company and will be phasing out of the Computer Systems Research Group at Berkeley over the next few months. He will be joining Sun Microsystems, Inc., a company whose founders include Andy Bechtolsheim, the designer of the Sun workstation. SMI is one of a small number of companies which plan to offer microprocessor-based networked workstations running 4.2BSD software ...

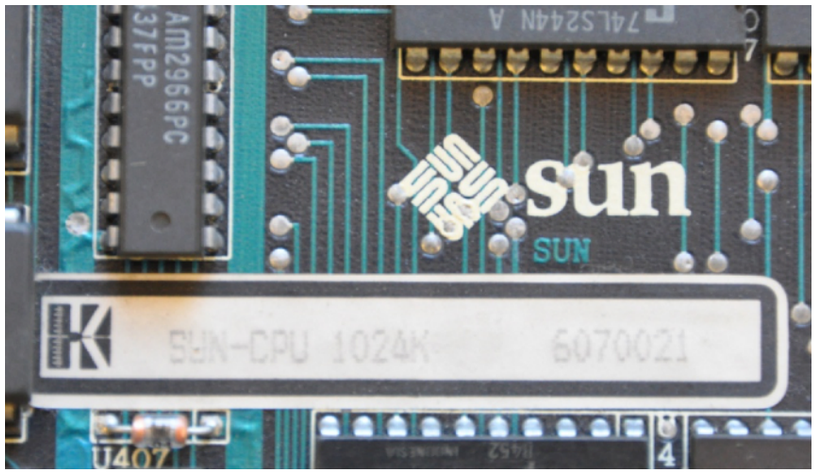
While SMI may need to develop proprietary software in certain specialized areas, Bill expects fixes to the shared base of 4.2BSD programs which are made at SMI can be distributed by Berkeley. The current cooperative efforts between CSRG and various industrial groups are seen as a model for the relationship....

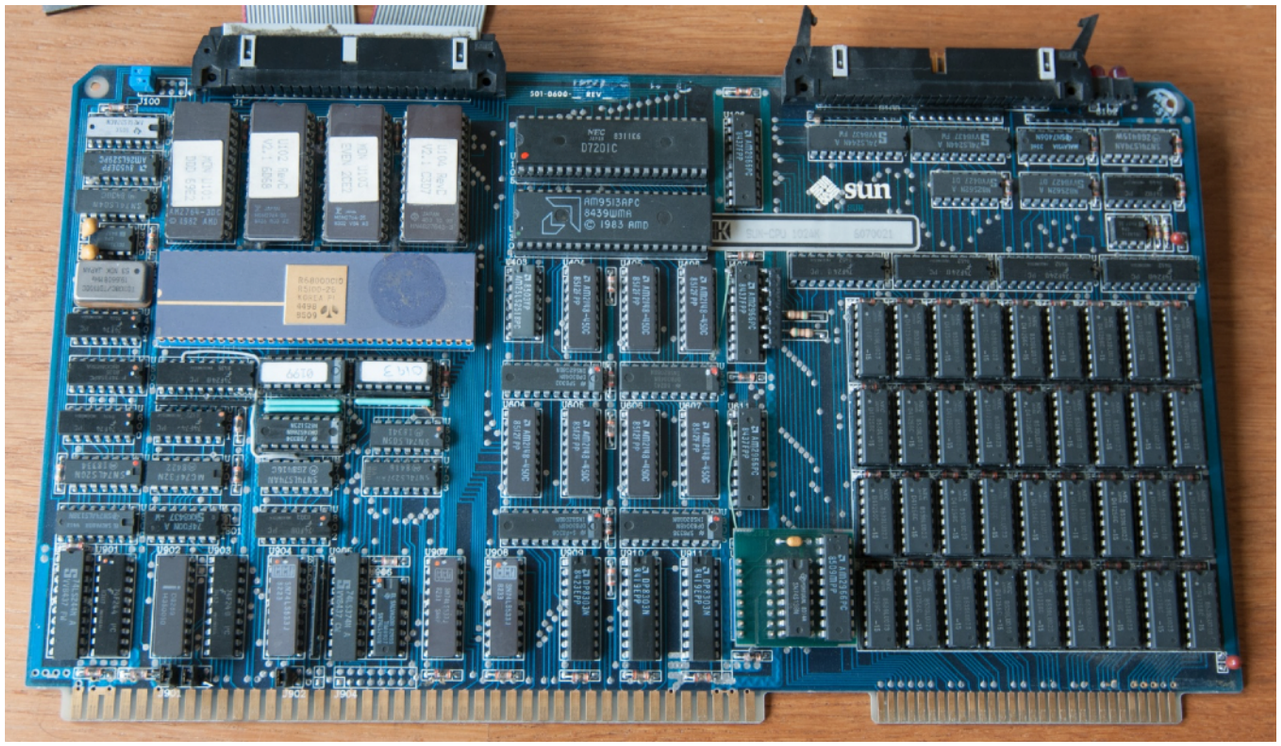




…he's also the inventor of vi!

Afterlife…





- Kontron PSI Ψ 9068 server
- Kontron bought old Sun-1 boards that came back from customers upgrading to Sun-1.5 boards





KONTRON PSI 9068

Der Abteilungs-rechner

Sowohl für den kommerziellen als auch für den technisch-wissenschaftlichen Bereich und für Programmentwicklungen bietet sich dieses moderne Multiprozessor-Timesharing-System an, mit dem bis zu 12 Anwender ohne Leistungseinbußen gleichzeitig arbeiten können. Auf große Datenmengen kann man über die eingebaute 20 MB-Festplatte als Massenspeicher oder die 616 KB Floppy Disk zugreifen.

Das Betriebssystem Unix läßt eine Programmstruktur zu, die komplexe Programmsysteme übersichtlich gestaltet. Die große Anzahl von Dienstprogrammen schließt zum Beispiel auch eine Mail-Box ein. Als Kommandointerpreter von Unix ist die C-Shell und die Bourne-Shell vorhanden. Über 100 Dienstprogramme sind im Unix-Lieferumfang enthalten. Viele davon können in Form von Pipelines aneinandergehängt werden und so zu komplexen Funktionen werden.

Sprachen sind C, Fortran 77, Pascal, SMC-Basic, Basic Plus, RM-Cobol etc. Ein Anschluß für KOBUS, das lokale Netzwerk von Kontron, ist vorgesehen. Das Multiprozessor-System beinhaltet eine Doppelbus Architektur, die 16/32 Bit CPU 68000 und den 8-Bit-Prozessor Z 80 A.

Leserdienst 575

PRODUKTNAME: PSI 9068
PRODUZENT: Kontron
IMPORTEUR: Kontron
URSPRUNGSLAND: BRD
ERSTPRÄSENTATION (in Österr.): 1984
LISTENPREIS: k.A.
GARANTIE: k.A.
PROZESSOR: MC 68000 mit 10 MHz.
RAM: 256 KB bis 2 MB
ROM: 16 KB
TASTATUR: Abhängig von Arbeitsplatzausstattung
BILDSCHIRM: Mehrplatzsystem, je nach Arbeitsplatz
LAUFWERKE: 5 1/4 Zoll Floppys a 616 KB, 20 MB Festplatte; Option: Wechselplatte für Backup 5 oder 10 MB; weiter Festplatten
SCHNITTSTELLEN: 1x Centronics-parallel, 4x RS-232C (für Terminals)
ERWEITERUNGSSTECKPLÄTZE: 3 Erweiterungsmoduln, 8 Schnittstellen, max. 12 User
BETRIEBSSYSTEM: Unix Version 7
SPRACHEN: Assembler, C, Basic, Pascal, Cobol
STANDARDPROGRAMME: Auf Unix Basis
BRANCHENLÖSUNGEN: Auf Anfrage

Monitor Extra 113

Pictures by Walter Belgers

Two universities

–

one project

–

many different industries

- Unix workstations
  - Sun Microsystems
  - Silicon Graphics
  - many smaller vendors

- Multi-protocol network routers
  - Cisco
  - Kinetics/Shiva

- High-end 3D graphics
  - Silicon Graphics

- Laser printer raster languages
  - Imagen



OpenStreetMap.org

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To Be Done…

- Recreate source code of original Sun UniSoft V7 Unix
  - UniSoft kernel source is available for the Apple Lisa
- Try to confirm suspected approach to page fault handling
  - Identify required changes in kernel, compiler, runtime
- Build a Sun-1 emulator (user + system mode)
  - + FPGA implementation, original component replica…



The August 2026 eclipse in Copenhagen (own picture)