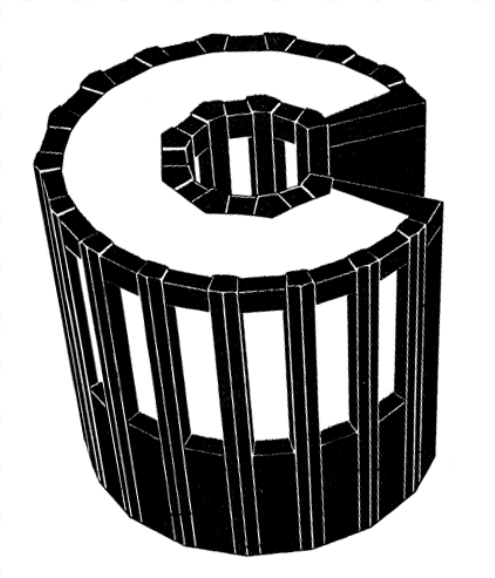


CRAY-2 MEMORIES

Clive England and David Laufer

Star Wars Day 4th May 2021

COMPUTER MUSEUM OF AMERICA
INNOVATION PAST FORWARD

Introduction – Sources & Placement in History

1. Hardware tour - What are we looking at ?
2. Software tour - Systems & Applications
3. Myths, Legends, Events Questions

Especially looking to answer Questions in yellow boxes

Sources and references

- Senior Hardware Instructor – Dan Shaw
- STCO (System Test and Check Out) on Cray-2 – Paul Gage
- Engineer in charge on site SN2008 – Tony Hatton
- Darkwavetech.com – John Kula
- Cray history co-researcher and application software expert - Alistair Mills

- Marketing and Sales literature including Cray Channels
- Cray Product familiarization training book 1987
- Cray-2 Description document Dec 1982
- HR-0200-0D CRAY-2 Computer Systems Functional Description Jun89
- The Supermen – 1997, Book by Charles J. Murray
- Darkwavetech.com – Cray-2 internals blog by John Kula
- The Internet

Cray-2 place in the museum
With David Laufer, Lonnie & Karin Mimms

Timeline of Tech History

COMPUTER MUSEUM OF AMERICA
INNOVATION PAST FORWARD

Cray-2 place in early Cray Supercomputer family

```
1972    Very Approx.  Time order    1996          (dates not to scale)

                 **T3d* --> T3e --> T3e/1200   = MPP
                 *     *
C1 -> XMP --> YMP --> C90 ----> T90             = PVP
        \       \      \
     C2  \       \      -> C90M                = Large memory
       . XMS --> ELs ---> J90 -> J90se -> SV1 = Air cooled Vector supermini
         .       APP --> SMP ---> CS6400      = Sparc Superserver
          ....... C3 --> C4                   = Cray Computer corp.
 Key :
 --> Direct architectural descendant
 \   Similar architecture but different technology
 ... Family ressemblance
 *   Hosted by
```

Cray-2
Background CPUS slightly faster than XMP,
Four of them (a single one off 8 cpu special)
Foreground/background arrangement
Much Bigger memories

Cray-2 very brief History

- Seymour Cray designed, team finished
- First Announced 1981, first delivered 1985, upgrade 1988, last one in service 1998? At NASA ???
- In media – “Hunt for Red October” mention
- Place in the Cray family just along side X-MP but up to 32 times larger main memories and 4 cpus
- Cray-2 then Cray-2s and a single 8 CPU versions
- 29+1 machines built, 27 sold at typical cost $12m .. $17m
- And then … Cray-3 & Cray-4 Started

Which one is this one ?

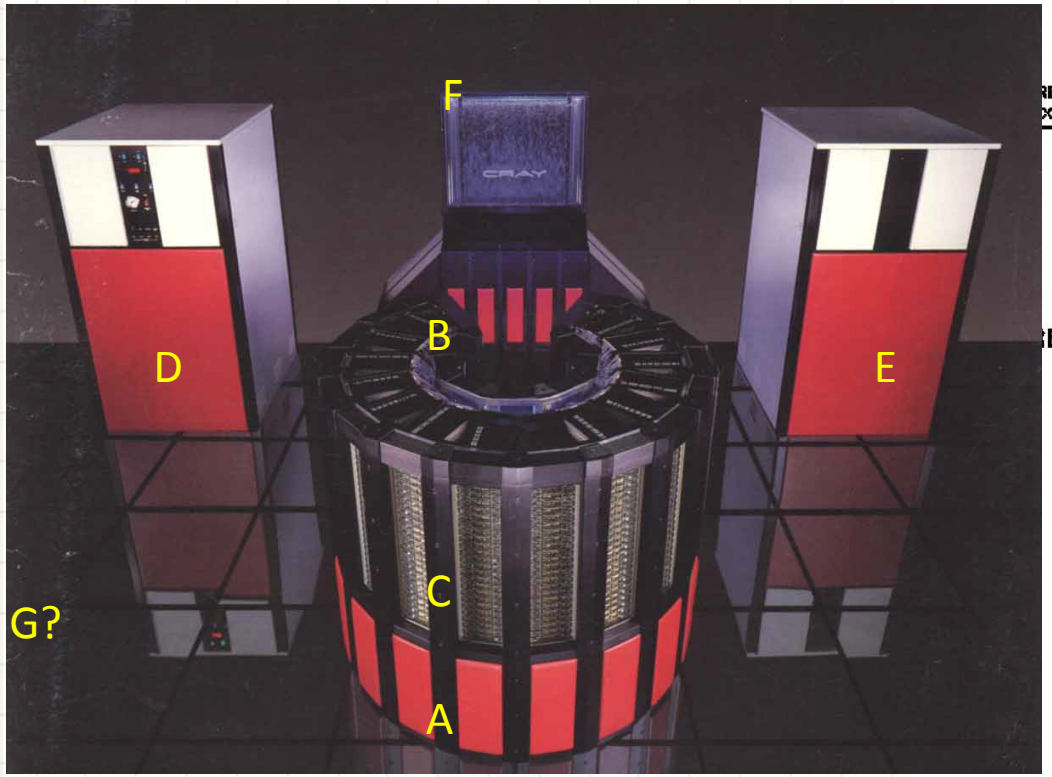
- Some conflicting sources :
  - PR came with machine has “used at NASA Langley” “has 1 billion byte memory” = 128 Mwd “Installed in 1988 used for 10 years”
  - David Reports “Our Cray 2 is number 23. NASA Langley’s data says they acquired it in 1988, and that it remained operational for 10 years.”
  - John K Reports:
    - SN:2013 went to NASA Ames Research Center, Moffett Field (4 CPU/256 MW SRAM) = 2 billion bytes
    - SN:2023 went to Livermore Advanced Research Center (4 CPU/127 MW SRAM)
- Cray Channels V08_N2_P39 has
  - “Engineers working to redesign the space shuttle orbiter' s main engine will be referring to numerical studies performed on the CRAY-2 computer system at NASA's Numerical Aerodynamic Simulation (NAS) facility at Moffett Field, California. ….. The most recent runs used over five million words of the CRAY-2 computer system's 256-millionword memory. The grid was generated with an elliptic generator widely used by the CFD community at the NASA Ames Research Center.”

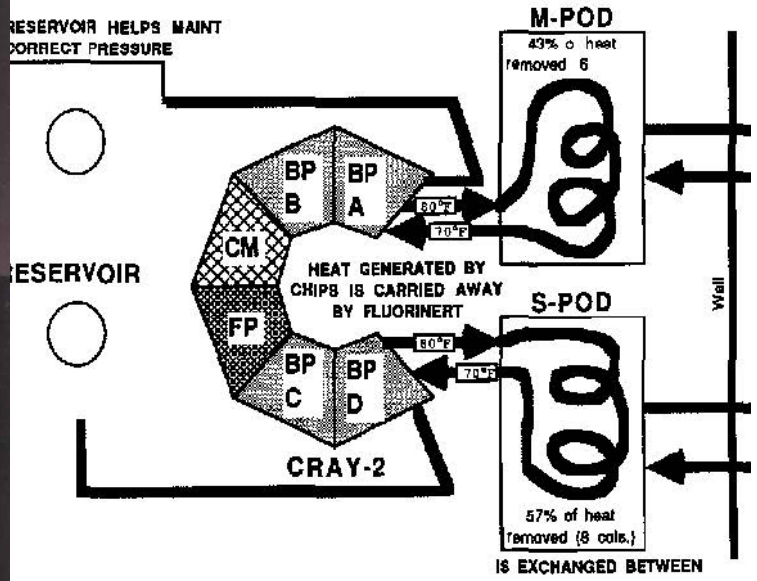
How can we tell ?
SN2023 or SN2013 ?
SRAM or DRAM ?
128Mwd or 256Mwd ?
Did NASA have more than 1 ?

CRAY-2 system configuration options

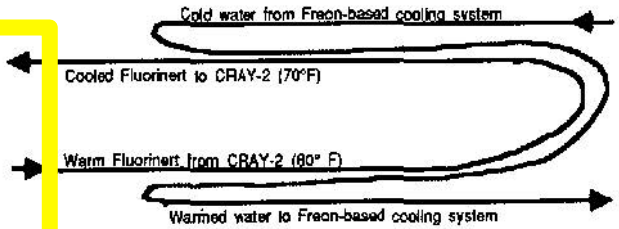
Background processors	2	2	4	4
SRAM MOS common memory (64-bit words)	64M	128M	128M	N/A
DRAM MOS common memory (64-bit words)	N/A	N/A	N/A	256M
Disk storage units	4-18	4-18	4-36	4-36
6- or 12-Mbyte/sec channels	2-8	2-8	4-16	4-16
Magnetic tape channels	0-8	0-8	0-16	0-16
100-Mbyte/sec channels	0-4	0-4	0-8	0-8

Hardware parts – main system units

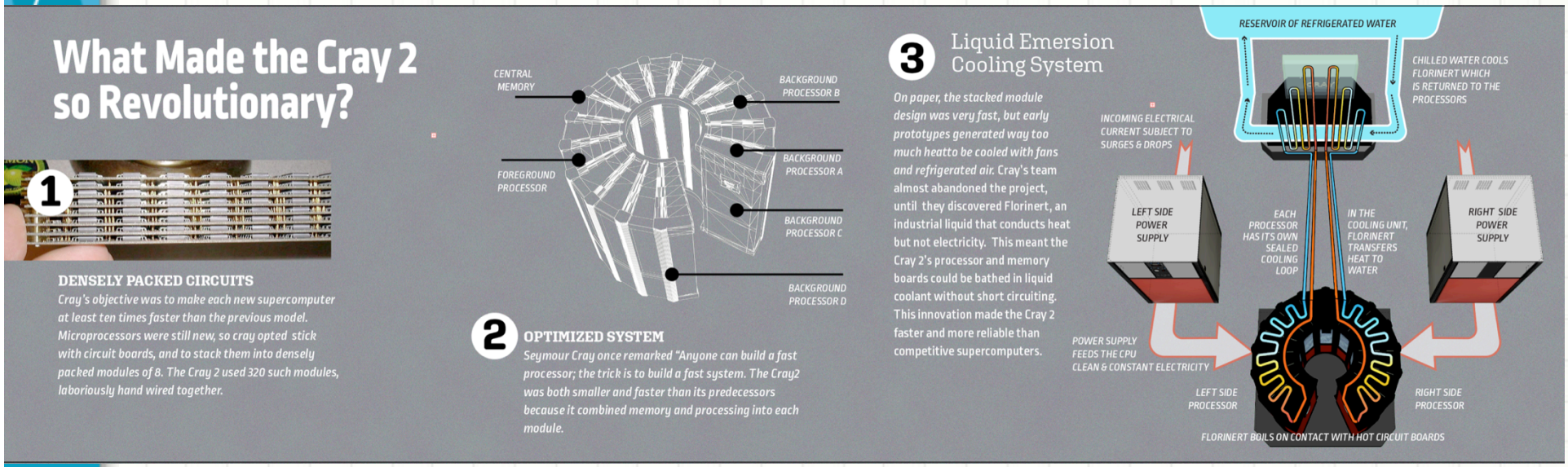




Which box does what ?
What route does the Flourinert follow ?
Two stage valveless heat transfer
Modules => Flourinert => Chilled Water
Where is Flourinert stored when machine is drained down ? Base of Fountain
How long does it take to change a module ? 20Minutes
Can areas of memory be flawed out like a bad disk drive sector ?



Hardware parts – Infographic

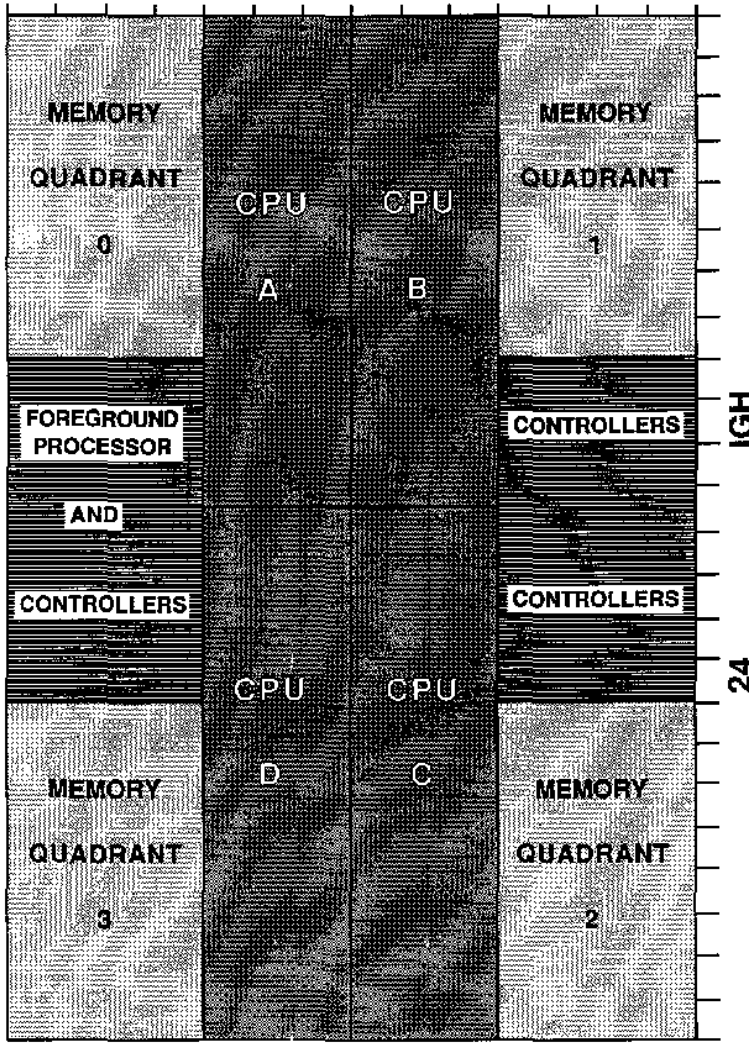


Review cooling circuit and other information
To be revised….

Hardware modules locations 4-CPU

From the above modules a variety of CRAY-2 systems can be assembled. Below is a module layout for a 4-CPU model, in this case serial number 2001.

		QUAD 0				CPU A			CPU B			QUAD 1					
		A	B	C	D	E	F	G	H	I	J	K	L	M	N		
Channel 0	A	SB	SB	SB	SB	FA	AR	EA	EA	AR	FA	SB	SB	SB	SB	A	Channel 1
	B	SB	SB	SB	SB	FB	AM	EB	EB	AR	FB	SB	SB	SB	SB	B	
	C	SB	SB	SB	SB	FC	VR	JA	JA	VR	FC	SB	SB	SB	SB	C	
	D	SB	SB	SB	SB	GB	VR	JC	JC	VR	GB	SB	SB	SB	SB	D	
	E	SB	SB	SB	SB	GA	VR	JC	JC	VR	GA	SB	SB	SB	SB	E	
	F	SB	SB	SB	SB	VA	VR	JB	JB	VR	VA	SB	SB	SB	SB	F	
	G	SB	SB	SB	SB	VB	WA	IA	IA	WA	VB	SB	SB	SB	SB	G	
	H	SB	SB	SB	SB	VL	VR	IB	IB	VR	VL	SB	SB	SB	SB	H	
	I	--	DA	DA	DA	ME	VR	TB	TB	VR	ME	DA	DA	--	--	I	
	J	--	DB	KA	DB	RA	VR	TC	TC	VR	RA	DB	DB	--	--	J	
	K	--	DA	KB	MD	MA	VR	TA	TA	VR	MA	MD	DA	--	--	K	
	L	--	DA	KC	MC	MB	QB	TD	TD	QB	MB	MC	DA	--	--	L	
Channel 3	M	--	--	DA	MC	MB	QB	TD	TD	QB	MB	MC	DA	--	--	M	Channel 2
	N	--	--	DA	MD	MA	VR	TA	TA	VR	MA	MD	DA	--	--	N	
	O	--	--	DB	DB	RA	VR	TC	TC	VR	RA	DB	DB	--	--	O	
	P	--	--	DA	DA	ME	VR	TB	TB	VR	ME	DA	DA	--	--	P	
	Q	SB	SB	SB	SB	VL	VR	IB	IB	VR	VL	SB	SB	SB	SB	Q	
	R	SB	SB	SB	SB	VB	WA	IA	IA	WA	VB	SB	SB	SB	SB	R	
	S	SB	SB	SB	SB	VA	VR	JB	JB	VR	VA	SB	SB	SB	SB	S	
	T	SB	SB	SB	SB	GA	VR	JC	JC	VR	GA	SB	SB	SB	SB	T	
	U	SB	SB	SB	SB	GB	VR	JC	JC	VR	GB	SB	SB	SB	SB	U	
	V	SB	SB	SB	SB	FC	VR	JA	JA	VR	FC	SB	SB	SB	SB	V	
	W	SB	SB	SB	SB	FB	AM	EB	EB	AM	FB	SB	SB	SB	SB	W	
	X	SB	SB	SB	SB	FA	AR	EA	EA	AR	FA	SB	SB	SB	SB	X	
		A	B	C	D	E	F	G	H	I	J	K	L	M	N		
		QUAD 3				CPU D			CPU C			QUAD 2					



4 cpu module map Credit: Darkwavetech.com
See notes for Module Key
This could be wrapped like wallpaper round the machine
To show the module types/locations (see key)

4 CPU system
24 modules high
14 columns
Product famiz doc

Hardware modules key 4-CPU

From the above modules a variety of CRAY-2 systems can be assembled. Below is a module layout for a 4-CPU model, in this case serial number 2001.

		QUAD 0				CPU A			CPU B			QUAD 1					
		A	B	C	D	E	F	G	H	I	J	K	L	M	N		
Channel 0	A	SB	SB	SB	SB	FA	AR	EA	EA	AR	FA	SB	SB	SB	SB	A	Channel 1
	B	SB	SB	SB	SB	FB	AM	EB	EB	AR	FB	SB	SB	SB	SB	B	
	C	SB	SB	SB	SB	FC	VR	JA	JA	VR	FC	SB	SB	SB	SB	C	
	D	SB	SB	SB	SB	GB	VR	JC	JC	VR	GB	SB	SB	SB	SB	D	
	E	SB	SB	SB	SB	GA	VR	JC	JC	VR	GA	SB	SB	SB	SB	E	
	F	SB	SB	SB	SB	VA	VR	JB	JB	VR	VA	SB	SB	SB	SB	F	
	G	SB	SB	SB	SB	VB	WA	IA	IA	WA	VB	SB	SB	SB	SB	G	
	H	SB	SB	SB	SB	VL	VR	IB	IB	VR	VL	SB	SB	SB	SB	H	
	I	--	DA	DA	DA	ME	VR	TB	TB	VR	ME	DA	DA	--	--	I	
	J	--	DB	KA	DB	RA	VR	TC	TC	VR	RA	DB	DB	--	--	J	
	K	--	DA	KB	MD	MA	VR	TA	TA	VR	MA	MD	DA	--	--	K	
	L	--	DA	KC	MC	MB	QB	TD	TD	QB	MB	MC	DA	--	--	L	
Channel 3	M	--	--	DA	MC	MB	QB	TD	TD	QB	MB	MC	DA	--	--	M	Channel 2
	N	--	--	DA	MD	MA	VR	TA	TA	VR	MA	MD	DA	--	--	N	
	O	--	--	DB	DB	RA	VR	TC	TC	VR	RA	DB	DB	--	--	O	
	P	--	--	DA	DA	ME	VR	TB	TB	VR	ME	DA	DA	--	--	P	
	Q	SB	SB	SB	SB	VL	VR	IB	IB	VR	VL	SB	SB	SB	SB	Q	
	R	SB	SB	SB	SB	VB	WA	IA	IA	WA	VB	SB	SB	SB	SB	R	
	S	SB	SB	SB	SB	VA	VR	JB	JB	VR	VA	SB	SB	SB	SB	S	
	T	SB	SB	SB	SB	GA	VR	JC	JC	VR	GA	SB	SB	SB	SB	T	
	U	SB	SB	SB	SB	GB	VR	JC	JC	VR	GB	SB	SB	SB	SB	U	
	V	SB	SB	SB	SB	FC	VR	JA	JA	VR	FC	SB	SB	SB	SB	V	
	W	SB	SB	SB	SB	FB	AM	EB	EB	AM	FB	SB	SB	SB	SB	W	
	X	SB	SB	SB	SB	FA	AR	EA	EA	AR	FA	SB	SB	SB	SB	X	
		A	B	C	D	E	F	G	H	I	J	K	L	M	N		
		QUAD 3				CPU D			CPU C			QUAD 2					

4 CPU system
24 modules high
14 columns
Product famiz doc

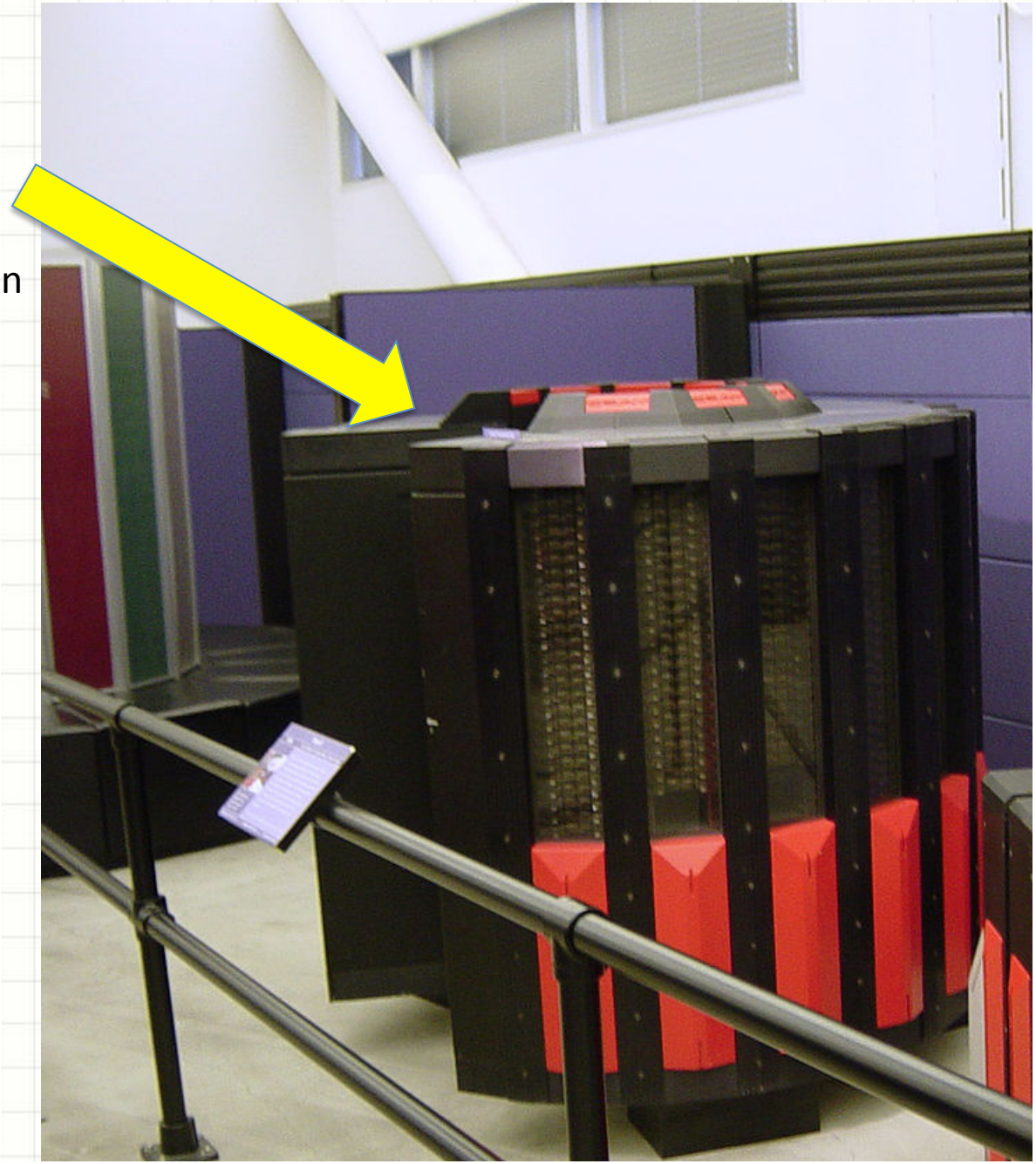
Module Key
AM Address multiply
AR Address registers
EA Foreground processor port
EB Foreground processor port
- Channel Function Decodes, - Foreground Access Register
- Interrupt Address Register, - Data Buffer
- Length Register, - Status Register
- Common Memory Error Address , - I/O Memory Reference Control
- Common Memory Address Register

FA Floating Point Addition
FB Floating Point Addition
FC Floating Point Addition
GA Scalar Integer Add, Scalar Population Count, and Scalar Leading Zero Count
GB Scalar shift
IE Instruction buffers
IF Instruction buffers
JA Main issue module
JB Main issue module (CPU issue logic that could not fit on JA)
JC Main issue module - Each JC controls 4 VR modules
(each VR is 8 bits of the Vector registers, S registers and some of the vector and Scalar logical operations. There are 2 JC modules.)
KA Foreground CPU
KB Foreground CPU
KC Foreground CPU
MA Floating multiply, reciprocal, reciprocal square root
MB Floating multiply, reciprocal, reciprocal square root
MC Floating multiply, reciprocal, reciprocal square root
MD Floating multiply, reciprocal, reciprocal square root
ME Floating multiply, reciprocal, reciprocal square root
Qx* Memory access control
RA Look up for reciprocal and reciprocal square root
Sx* Memory module
TA Memory interface modules, packetize address and data, SECDED
TB Memory interface modules, packetize address and data, SECDED
TC Memory interface modules, packetize address and data, SECDED
TD Memory interface modules, packetize address and data, SECDED
VA Vector integer adder
VB Vector shift
VL Vector Logical, Real-time counter, vector mask register
VR Scalar Logical, Scaler Register, Vector registers, 8 modules each with 8 bits
WA Local memory:1

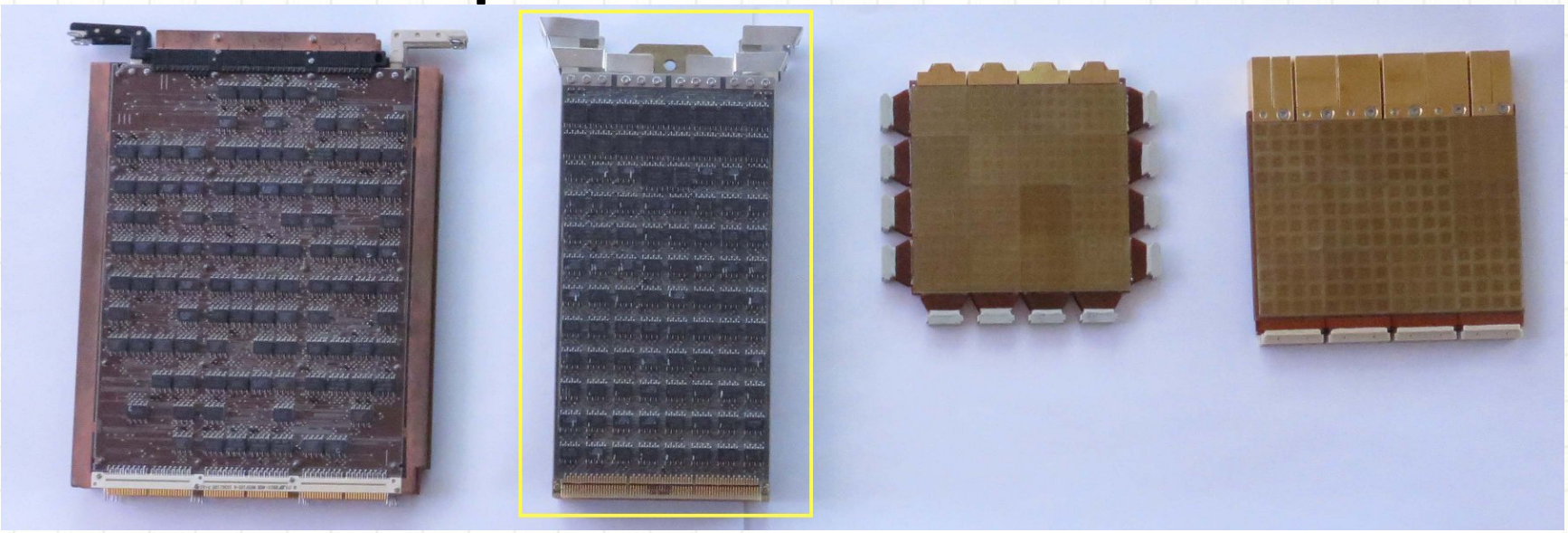
Question

Q: What's this lump on top ?
Others are flat.
A: Just design feature only seen on SN2101 the 8 CPU Cray-2

A Cray-2 and its Fluorinert-cooling "waterfall", formerly serial number 2101, the only 8-processor system ever made, for NERSC

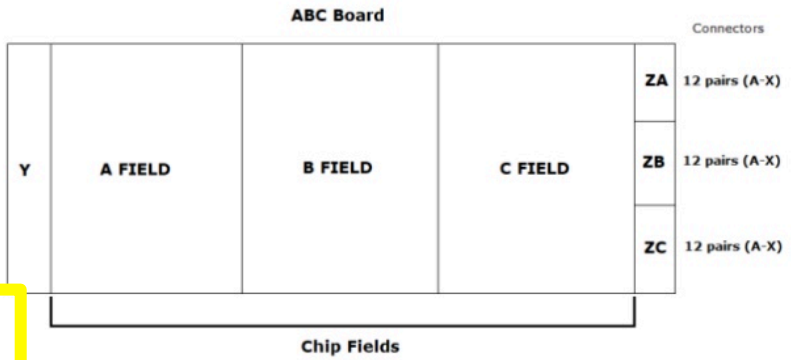


Hardware parts – A Module



Fields of a Cray-2 Module Printed Circuit Board

Each board of an eight board module is divided into fields. The majority of the area of a board is allocated for three fields of gate array chips. A single letter defines each chip field. This letter corresponds to the letter that was used to define the board of the module. These chip fields contain gate array chips, termination resistors, and inter-board jumper pins. The second type of field, labeled the Y field, is located on the power bus end of each board. The Y field is used exclusively for inter-board jumper pins. The third field is located on the connector end of each board. This field is labeled the Z field. The Z field is where the connector is attached.



Each Module :

- 8 interconnect boards
- 8 * 4 inches
- 6 layers

Which worked best on modules pins or holes ?

Credit: Darkwavetech.com

CPU – internals block diagram

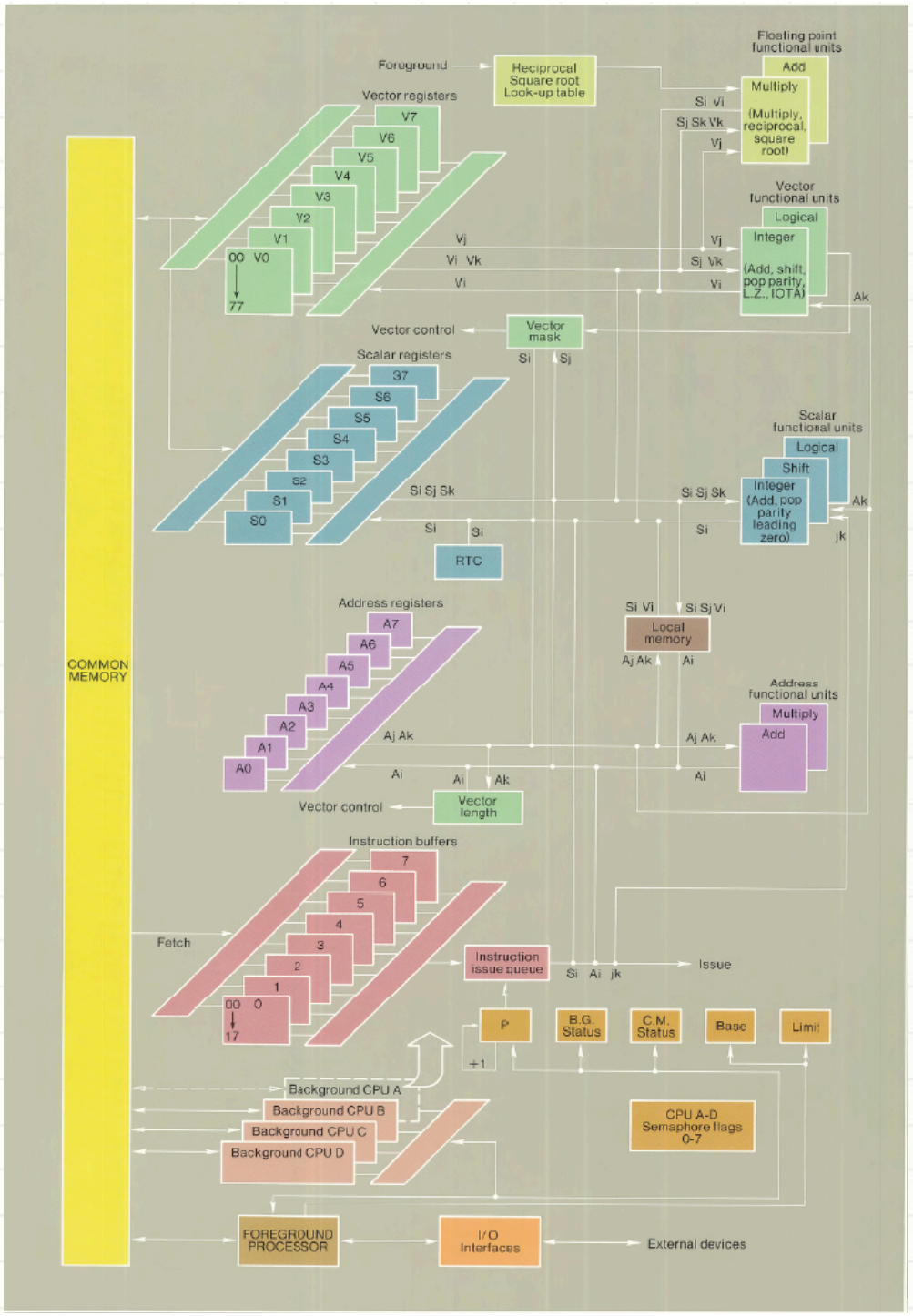
The heart of the machine was a combination of 1 controlling foreground processor that orchestrated the up to 4 workhorse background processors and all the peripheral devices.

Scalar, Vector and Address registers along with Instruction buffers hold the CPU data.

Each background processor also had 16k of local working memory and access to shared semaphore flags.

A huge central shared memory was directly accessible from any processor.

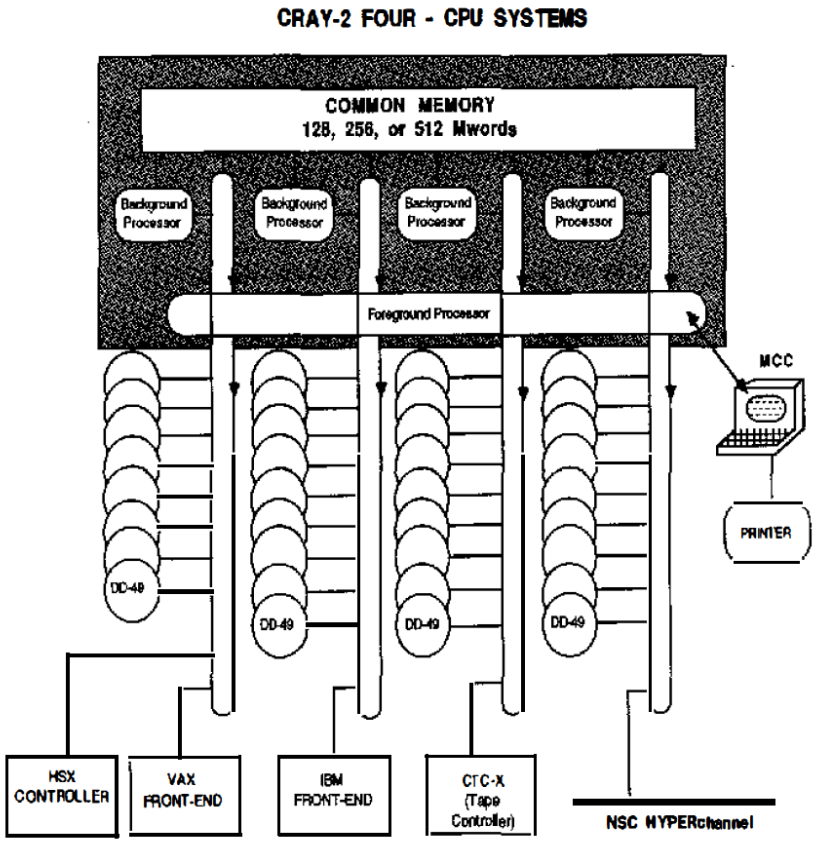
I/O all controlled by Foreground processor. (The 8p special had 2 foreground processors)



Hardware parts – peripherals & Network

Cray-2 Four CPU machine
UP TO 40 PERIPHERAL DEVICES INCLUDING:
UP TO 9 DS-40 SUBSYSTEMS TOTALING 36 DD-40 DISKS
STORAGE UNITS (72 WITH SHADOWING)
UP TO 36 DD-49 DISK DRIVES
UP TO 8 HIGH-SPEED EXTERNAL 100 Mbyte/s CHANNELS (HSX-1) CONTROLLERS
UP TO 16 EXTERNAL I/O CONTROLLERS SUCH AS:
FRONT-END INTERFACES (FEI)
CRAY-2 TAPE CONTROLLERS (CTC)
OR HYPERchannel ADAPTORS (A 130)

Cray-2 Two CPU machine
UP TO 20 PERIPHERAL DEVICES INCLUDING:
UP TO 4 DS-40 DISK SUBSYSTEMS TOTALLING 16 DD-40
DISK STORAGE UNITS **(32** WITH SHADOWING)
UP TO 18 DD-49 DISK DRIVES
UP TO 4 HIGH-SPEED EXTERNAL 100 Mbyte/s CHANNEL
(HSX-1) CONTROLLERS
UP TO 8 EXTERNAL 110 CONTROLLERS SUCH AS:
FRONT-END INTERFACES (FEI)
CRAY-2 TAPE CONTROLLERS (CTC)
OR HYPERchannel ADAPTORS (A130)



Any strange device hookups ?
Mostly just comms devices

Software tour - System

Unicos – 1.0 - First Cray System to use Unix.
No need for Station software or managed front end as Unicos has TCP/IP. Batch job entry via frontends still used.

Language compilers
CFT2 based on Cray Fortran CFT
CFT77 ANSI Leading edge in compiler development
Pascal and Cray C
Assembler language
Micro and Macro tasking

NQS, Interactive Shells

Maintenance Control Console MCC
Thought to be a Compac or similar Pc
What did this do ?
Run diagnostics, bootstrap the machine, load software, login to machine,

Software tour – Applications & notable customers

Kings Cross Underground station disaster – Understanding How Fire spreads Analysis
From CC Astronomy, CAD visualizations, Lots of CFD eg. Hull and Wing design,
Helicopter and Turbine blade design

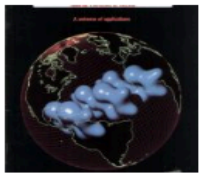
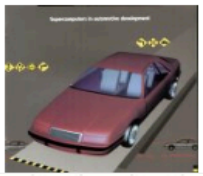
SN2010 went to NTT (4 CPU/256 MW SRAM) – Japan Telecoms
SN2011 went to AFSCC (4 CPU/128 MW SRAM) – US Air Force Kirkland
SN2013 went to NASA Ames Research Center, Moffett Field (4 CPU/256 MW SRAM)
SN2015 went to Falcon AFB (NBT) (4 CPU/127 MW SRAM) – US Air Force Falcon
SN2023 went to Livermore Advanced Research Center (4 CPU/127 MW SRAM)
SN2027 went to CNRM (Centre National de Recherches Meteorologiques) Toulouse (4 CPU/256 MW SRAM)

Who got the 8 CPU version ? NERSC

What other Applications and Sites used Cray-2 ?

What problems were solved and what new scientific ground was broken using this and other Cray hardware ?

Cray Channels stories

Link cc_v03_n2_OCRNew.pdf#page=14		**V03_N2 1981 ?** Cray announces breakthrough in computer development Cray-2 Prototype photo Also Org chnages of Cray stepping back.
Link cc_v07_n2_OCRNew.pdf#page=4		**V07_N2** Summer 85 Introducing the Cray-2 Architecture and design overview.
Link cc_v08_n1_OCRNew.pdf#page=35		**V08_N1** **CRAY-2 computer renders architecture in 3-D** Computer-generated images such as these views of the Minnesota state capitol can be valuable design and marketing tools for architects and developers
Link cc_v08_n2_OCRNew.pdf#page=41		**V08_N2** **NASA-Ames** CRAY-2 computer system takes a slice out of pi CRAY-2 computer system aids shuttle engine design
Link cc_v10_n2_OCRNew.pdf#page=42		**V10_N2** CRAY-2 system performs star search The sky is no limit for a team of as astronomers at the University of Minnesota. By linking the university's CRAY-2 computer system and a high-speed measuring machine used to scan photographic plates, they are analyzing the sky statistically
Link cc_v10_n4_OCRNew.pdf#page=6		Larger memory and better performance make the new **CRAY-2/4-512** computer system an exciting addition to the CRAY-2 series of computer systems.

Alistair and Clive working on building a Cray Channels web index reference system

Myths, Legends and factoids

- Cooling First reservoir design was tubes later a rectangle reservoir was used because of crazing problems with the Acrylic tubes
- Cray-2 was first Cray system to use Unix derived operating system Unicos.
- Unicos allowed direct interactive access to machine from remotely connected users using tcp/ip (did not need a front end station) ARPANET
- Wire lengths – 5.6 miles of blue and white twisted pairs.
- Cooling liquid flows at 1 inch a second across modules
- Four background processors running with a clock period of 4.1 nanoseconds offer an effective throughput six to twelve times that of the original CRAY-1.
- A single 8 CPU system SN2101 was built for NERSC

- Technicians could test individual modules in a flourinert bath test fixture. The probes had marks like a ruler so they could tell how far into the module they were probing.
- There were two "Quads". They were ¼ of a full chassis. One was used for software development in the twin cities, the other was used in STCO for module screening (and doing my homework for a programming class).

What can you add here ?

Four best features of the Cray-2

- Density of electronics, it's a very small machine compared to contemporaries.
- Speed of processor using a 4 nano second clock − way ahead of it time
- Size of main memory − up to 30 times size of Cray-1 & XMP − could run problems that would bog down on other systems. Very good at CFD codes.
- First Cray with direct interactive access for users along side batch work. Due to using Unix as base for Unicos operating system

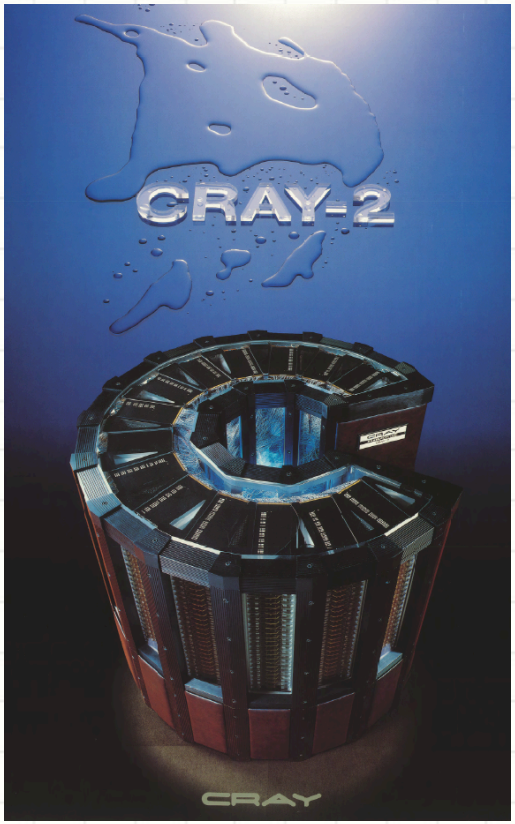
Darkwavetech.com

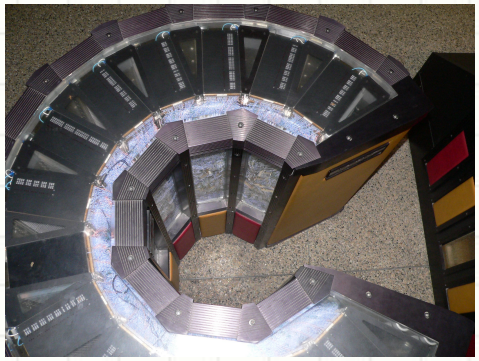
You may be interested in the information about a Cray-2 logic emulation project and recreation along with a detailed description of Cray-2 modules and systems

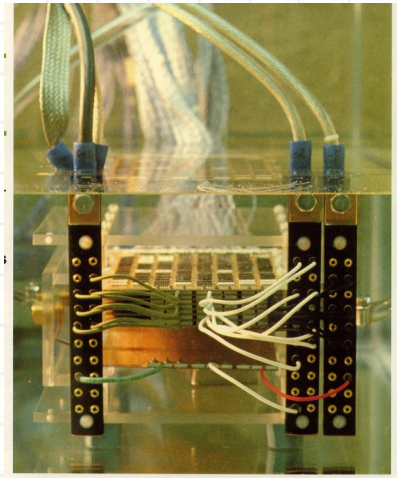
By John Kula

https://www.darkwavetech.com/index.php/cray2blog/

Final Picture Gallery







Seymour Cray (l.) and John Rollwagen pose with a module of the prototype CRAY-2 computer at Cray's laboratory in Chippewa Falls, Wisconsin.

Cray announces breakthrough in computer development

CRAY-2 computer. As in previous products, Cray has found an "obvious" answer to a complex problem. Said company president John Rollwagen, "When we explain the

Lee Friedlander Picture Gallery

Wrap-up

- Thank you for your time and contributions.
- Presentation will be updated with your contributions and re-shared/reused.
- Let us know if you are interested in similar occasional meetings based around other Cray systems in the museum.

- Follow-up to
  - Clive@spikynorman.net
  - davidl@brandbook.us