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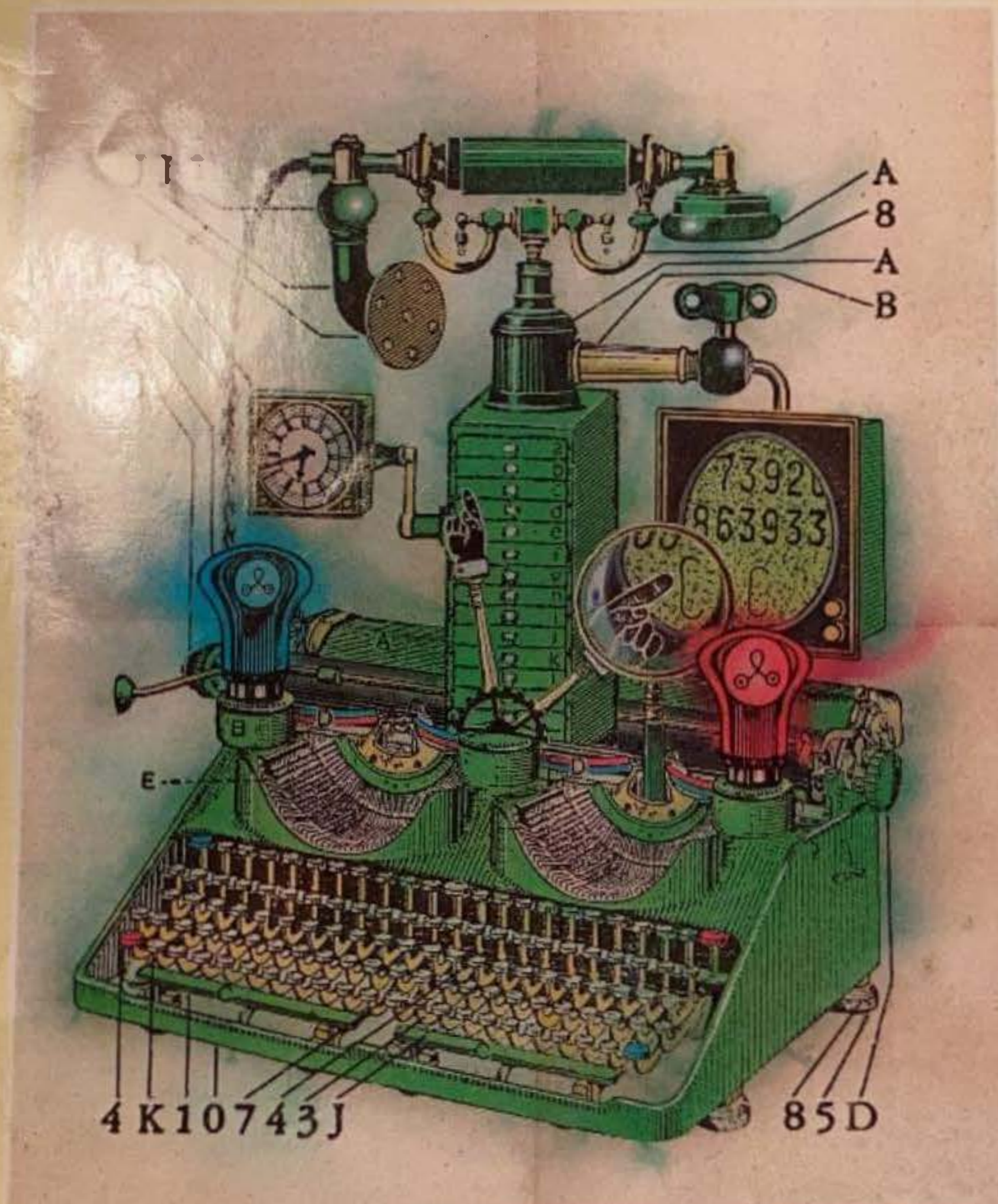

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THE CRAY 2

The Cray 2 has become a byword for computing power. **Carol Hammond** reports on her tour of inspection of the machine.

To look at the Cray 2 is like being beamed up to the bridge of the *Starship Enterprise*. The horseshoe-shaped main unit stands nearly four feet high and is more than four feet in diameter. At its outer edge can be seen row upon row of silver- and gold-coloured circuit boards stacked several layers high. Viewed from its inner edge it appears to be crammed full of blue and white wiring. Closer inspection reveals that the whole unit is full of a gently bubbling clear liquid, giving the impression of a high-tech cauldron.

The Cray 2 is a product of Cray Research Inc. The company was founded in 1972 by Seymour Cray, and by 1986 it had gained a 64 percent share of the supercomputer market. Over 10 percent of all Cray machines are installed in the UK — nearly twice as many as in any other country apart from the US.

The machine we saw was installed in March of this year at the Harwell Laboratory of the UK Atomic Energy Authority. It is valued at £13 million. Crays are not new to Harwell. It bought a Cray 1 in 1981, and upgraded it to a Cray 1S in 1982. This was followed by a Cray X-MP in 1986 and finally the Cray 2 in 1987.

The Cray 2's main unit is accompanied by two free-standing support cabinets for the power-supply control unit and a cooling unit, along with a number of Perspex standpipe towers down which liquid coolant cascades. The towers of the Harwell machine are bathed in blue light, further enhancing the futuristic look.

If you want to run a Cray 2 you do not simply plug it into the mains. The machine consumes several hundred kilowatts of electrical power, and motor generators are needed to provide it with the 400Hz supply that it requires. Apparently the higher frequency is necesary to give sufficiently smooth d.c. supply.

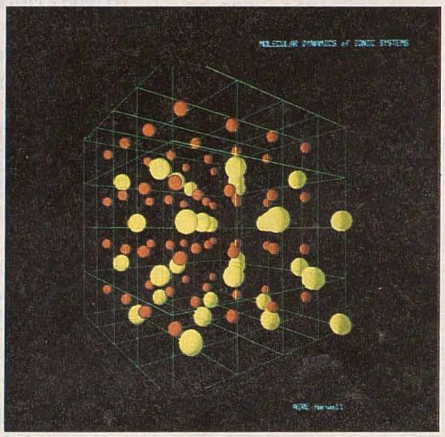
The Cray 2 at Harwell has 12 DD-49 disc drives. Each one provides 1,200Mbyte of storage, giving a total of 14.4Gbyte. It is possible to have up to 36 disc drives on a Cray 2 though as yet no one does — even Nasa restricts itself to 34. The drives run at a sustained rate of 9.6Mbyte per second. A modified AT&T PC serves as an elaborate on/off switch, acting as a system-control console to stop and start the main machine.

The main unit of the Cray 2 is built up from 14 columns like slices of a pie. The upper part of each column contains a stack of circuit-board modules, while the lower part contains power supplies for each column. Up to 320 circuit-board modules can be accommodated. Each one contains about 750 integrated circuits to give the Cray 2 a total of around 240,000 components, of which 75,000 are memory chips. Each module is made up of eight circuit boards. The chips on the modules we saw were Japanese, but Cray Research now has its own chip-making facility at Chippewa Falls, Wisconsin, where all the hardware is assembled.

Circuit interconnections are made in all three dimensions within the module. In a supercomputer, component packing is important because one of the main constraints on speed is the time required for signals to pass from point to point within the machine. It takes about a nanosecond for electrical pulses to travel 10cm. through ordinary wiring. The distance that electrical signals have to travel along the data path is therefore crucial to the performance of the machine. The longest wire in a Cray 2 is 25in., with 10in. being the average length. About 36,000 pairs of wires are hand wired into the machine.

The problem with such a compact design is that the power consumption of the machine is huge in relation to its size. The Cray 2 is rated at 195kW, which is of the order of 1,000 times the power consumption of a PC. Nearly all of this energy ends up as heat, which is carried away by the 200 gallons of coolant that bathes the machine's components.

The coolant used is a colourless, non-toxic, non-flammable fluorocarbon liquid called Fluorinert, made by 3M. It is a g electrical insulator, has high ther stability and good heat-transfer proper It circulates up one column of the main and then down the next in direct con with the integrated-circuit boards power-supply components.



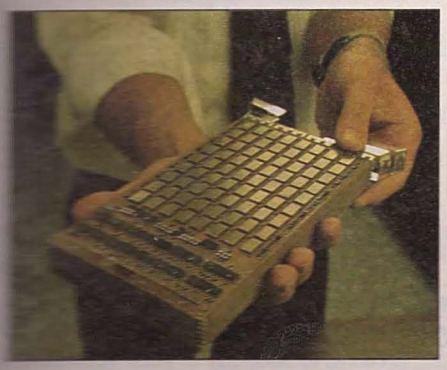
The Cray is capable of modelling the dynamics of a crystal lattice.

Placing the coolant in direct contact the components to be cooled helps stabilise the operating temperature, improves the reliability of the system by venting chips getting hot. The liquid en the main unit at a temperature of aro 70F and leaves at about 80F.

If a module fails, diagnostic softw isolates the problem to the failing mod or, in the worst case, to two or th modules. Indicator panels on the top of machine display information about status of key components. Before defec modules are removed the coolant must pumped up into the standpipe towers. then pumped back into the machine aft replacement module has been fitted. C claims that the operation only takes a minutes.

Faulty modules are diagnosed and paired by on-site maintenance staff. Wh a fault can be pinned down to a partic chip it is removed from the board, repa or replaced and then soldered back on. I preventive-maintenance scheme Cray search stresses the machine outside its mal operating limits to expose any incipi faults.

Above: The Cray 2's main unit, with the standpipes for the coolant visible in the background.
Below: Each module contains eight circuit boards and around 750 ICs.



To achieve its high processing rates the Cray 2 uses scalar and vector processing and a large common memory in a multi-processing environment. The scalar processing used by conventional computers handles information sequentially. Supercomputers attain their increased speeds by handling data which has been assembled in vectors or arrays. Vectors are expressed in a computer as a string of 64-bit numbers that can be processed in parallel as a single entity. A special set of instructions is used to process vectors, and only one instruction need be issued to carry out the processing of the entire vector.

Each Cray 2 has four identical CPUs which run at 1,700 million floating-point operations (1.7Gflops) per second. The common memory holds 256 million 64-bit words and there is an integral I/O controller and a maintenance control console. Each of the four CPUs contains registers and functional units to perform vector and scalar operations. The I/O controller controls I/O devices like disc drives and the front-end interfaces. The large size of the common memory allows users to run programs that would be too large to run on other systems, and it allows several jobs to reside concurrently in memory.

The Cray 2 comes with an operating system called Unicos, based on AT&T Unix System V. Fortran is the main language used, though Cray also offers an automatic vectorising Fortran compiler and a C compiler. A large number of applications packages are available from third-party suppliers.

The Cray 2 at Harwell is connected to IBM and DEC machines as well as various work stations, including Sun and Apollo units. The IBMs are linked via a front-end interface which acts as a channel-to-channel connector and sorts out the differences between Cray and IBM channels. The Vaxes are linked via a Network Systems Corporation Hyperchannel, which also links to one of the work stations and an IBM. The work stations also use one of the Vaxes as an Ethernet gateway.

The high cost and small market for supercomputers has meant they have hitherto been the domain of government, research and military establishments. But their number-crunching prowess and real-time computing ability has taken them into other fields. Harwell's Cray 2 is used for applications in aerospace, computational physics and structural analysis.

Harwell hires out time on the Cray 2 at around £1,000 per hour. If this seems expensive it is worth bearing in mind that a problem which could be solved in an hour on the Cray 2 would take something like a month on a DEC Vax 11/780. Put another way, 10 days' worth of calculation on an IBM PC would be completed in just one minute on the Cray. PC