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EVOLUTION OF THE MICROPROCESSOR

An informal history

BY MARK GARETZ

Author's note: The evolution of the microprocessor has followed a complex and twisted path. To those of you who were actually involved in some of the following history, I apologize if my version is not exactly like yours. The opinions expressed in this article are my own and may or may not represent reality as someone else perceives it.

THE TRANSISTOR, developed at Bell Laboratories in 1947, was designed to replace the vacuum tube, to switch electronic signals on and off. (Although, at the time, vacuum tubes were used mainly as amplifiers, they were also used as switches.) The advent of the transistor made possible a digital computer that didn't require an entire room full of vacuum tubes, relays, and special air conditioning. Now a computer would take up only *half* a room and operate much more quickly.

It was not until 1959 that engineers at Texas Instruments figured out how to put more than one transistor on the same material (called the substrate) and connect them together without wires. Thus was born the integrated circuit, or IC. Today these thin flat pieces of silicon can contain millions of transistors, and we call them chips.

Integrated circuits may range from SSI (small-scale integration, containing relatively few transistors), through MSI (medium-scale integration, around 50 or more transistors), LSI (large-scale integration, with thousands of transistors), to VLSI (very-large-scale integration, which can contain millions of transistors).

In 1969, a year-old company named Intel announced a 1K-bit RAM chip. There were not yet any microcomputer chips to hook it to, but there were many other applications for the new memory chip, which was significantly larger than any that had been produced before.

About this time, the summer of 1969, Intel was approached by the Japanese calculator manufacturer Busicom to produce a set of custom chips designed by Busicom engineers for the Japanese company's new line of calculators. The calculators would have several chips, each of which would contain 3000 to 5000 transistors.

Intel designer Marcian (Ted) Hoff was assigned to assist the team of Busicom engineers that had taken up residence at Intel. Hoff looked at the Busicom design and decided it was too complex to be cost-effective. He had worked before with Digital Equipment Corporation's PDP-8 minicomputer, which had a very small instruction set. He reasoned that much of the calculator's complexity could be reduced if they used a small general-

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ILLUSTRATED BY WILLIAM LOW

purpose processor. Such a design, using software rather than electronics to do the calculating, would greatly increase the memory requirements of the calculator—but then, Intel was in the memory business. Hoff also realized that this processor could be put to other applications and he sold the idea to Intel management.

The Busicom engineers were still pursuing their original design when Hoff and his group started work on their alternative design. And although the Busicom engineers had simplified their design, each chip still had over 2000 transistors, and it would take 12 chips to make a working calculator. Hoff's team figured it would take 1900 transistors to build their processor.

Hoff's general-purpose processor design was chosen over the Busicom design, and Intel got a contract from Busicom to produce the chip that later became known as the 4004.

Actually making the chip proved to be difficult until Federico Faggin (who later founded Zilog) joined Intel in early 1970. He took the chip from concept to silicon in just nine months. At first Intel sold the 4004 exclusively to Busicom, but in the summer of 1971, it gained the right to sell the chip set to other manufacturers.

In November 1971 Intel advertised the 4004 as a four-bit processor that performed 60,000 operations per second. By February 1972 Intel had sold $85,000 worth of chip sets.

THE BIRTH OF 8-BITS

At the same time the 4004 was being developed, CTC (Computer Technology Corporation, now Datapoint) asked both Intel and Texas Instruments to design LSI chips for a new intelligent terminal. Both companies proposed an 8-bit general-purpose processor. Note the pattern developing: 4-bits for calculators because they work in BCD (binary-coded decimal) and 8-bits for terminals because they deal with ASCII characters.

Interestingly, CTC chose neither solution; it built its terminal with standard logic ICs. But TI and Intel went ahead with their projects anyway. TI eventually got a patent on its chip design and the project at Intel gave birth to the 8008.

The 8008, introduced in April 1972, was the first 8-bit microprocessor on the market. It required at least 20 support chips, but it had 45 instructions that it executed at 300,000 instructions per second, and it adddressed a whopping 16K bytes of memory. That was a lot of memory then, and the 8008 was a considerable upgrade of the 4004.

The documentation for the 4004 and 8008 was cryptic (at least it seemed so to me; I didn't have a computer background at the time). The documentation assumed that you knew what everything was before you started reading it (a still-common failing of technical literature).

Intel's primary goal with the 4004 and 8008 was to replace "random logic"—another way of saying "lots of SSI and MSI wired together." Few people thought that these chips were suitable for general-purpose computing. But a few visionaries were intrigued by the possibility of owning a computer that could actually *do* something. True, computer kits had been offered previously, but they were more useful for demonstrating computer principles than for doing computing tasks. The availability of the 8008 changed all that.

In 1973 Scelbi Computer Consulting Inc. announced the first general-purpose microcomputer based on the 8008. This was followed by the RGS-008 from RGS Electronics. Then, in July 1974, *Radio-Electronics* magazine introduced Jonathan Titus's Mark-8 in a series of construction articles.

Until then, all computer articles and ads had been confined to amateur-radio publications. The Mark-8 was the first computer to hit a general-interest electronics magazine. These early microcomputers were still more demonstration tools than useful, but the small-computer revolution had begun.

THE MIGHTY 8080

In April 1974 Intel changed the way we think about computers forever. They announced the 8080, a significant upgrade to the 8008 that required only six support chips, had 75 instructions and a tenfold increase in throughput over the 8008, and addressed 64K bytes of memory. (No program, most people thought, could ever be *that* large!)

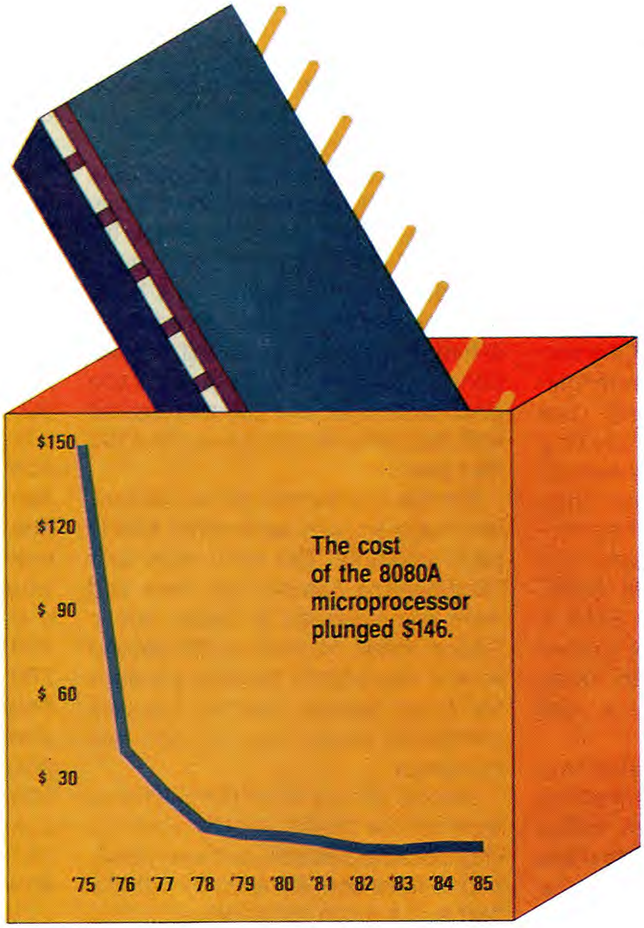
The 8080 design was proposed by Faggin, but the design team was headed by Masatoshi Shima, a young engineer Intel had wooed away from Busicom. Having learned from the limitations of the 4004 and 8008, the designers made improvements to make their new chip a truly useful computing engine. The 8080, the first microprocessor not aimed at logic replacement, looked much more like a computer than anything that had come before it, and it was much easier to use from a hardware standpoint.

The January 1975 *Popular Electronics* magazine featured the first in a series of construction articles on the Altair 8800, a so-called "minicomputer" based on the 8080. The Altair was designed by MITS (Micro Instrumentation and Telemetry Systems), which was founded by Ed Roberts as a vehicle for supporting his experiments in electronics. The whole Altair kit, including the 8080 processor, motherboard, power supply, front panel with lots of lights, and 256 bytes (*not* 256K bytes) of memory sold for $395.

People thought it was a misprint. The 8080 chip, introduced just nine months before, had been selling for $360 all by itself. But MITS had made a special deal with Intel, and the price of the Altair was real. MITS sold more computers in the first day than it had hoped to sell during the whole life of the product.

The Altair played a significant role in the success of the 8080, largely because programmers now had a reason (and a good excuse) to write software for a microcomputer chip. Also, the Altair's open bus architecture (an improved version of which later became the S-100/IEEE 696 bus) allowed people to begin making peripherals for the computer.

One such peripheral was a disk controller from Digital Microsystems that featured the use of a new operating



The cost of the popular 8080A microprocessor from 1975 to 1985. Note that in 1975 only the 8080 microprocessor was available.

system for the 8080 called CP/M (Control Program for Microcomputers.) CP/M, brainchild of Naval Postgraduate School instructor Gary Kildall, sold for $70 and played a major role in the success of the 8080 and its architecture. As a result, a large portion of the microcomputer software in use today either runs on the 8080 instruction set or is a direct upgrade of a product that did.

The Motorola Family

In response to the 8080's success, Motorola began work on the 6800, which was designed by Chuck Peddle. Motorola was the first company to introduce a line of peripheral chips designed specifically to go with its microprocessor. These chips included parallel (6820) and serial (6850) I/O functions and made the integration of these functions into a system simple for system designers.

Motorola produced one other significant "peripheral": a huge microprocessor applications manual, bigger than all other microprocessor documentation put together. And it was almost readable! Hackers and system designers like myself rushed out and bought them at $25 each. True, the manual was still oriented toward logic replacement, and you needed a minicomputer and expensive cross-assemblers to write software. No one had yet written anything that really explained these new chips to people who had no idea what they really were inside, or who had no computer experience. But we read the Motorola manual anyway. . . it was all we had.

Chuck Peddle left Motorola to join MOS Technology (not to be confused with Mostek, the subsidiary of United Technologies), a leader in the scientific-calculator-chip field. In June or July 1975, MOS Technology ads appeared in the electronics trade journals claiming that the company would be introducing and delivering a $20 microprocessor at the WESCON show that September. The so-called 6501 was to be pin-for-pin plug-compatible with the Motorola 6800—you could unplug the 6800 from a circuit board and plug the 6501 right into the same socket and it would work—although the software would also need changing because of differences in the architecture and instruction set. MOS was also planning a version of the chip with the complex clock circuitry required by other microprocessors built in. This would be the 6502 and would cost $25.

The industry went into an uproar. At this time, Intel's 8080 and Motorola's 6800 were both selling for $179 in single-piece quantity. I remember standing in the lobby (actually a living room) of E-Mu Systems with Scott Wedge and Dave Rossum, who had just designed some 8080s into their synthesizers. We were talking with an Intel salesperson who dismissed the ad as a hoax. He said Intel had assured him that MOS couldn't possibly do it at that price, and that either the ad was a publicity stunt or MOS Technology was quoting the million-piece price. I said that there was no reason that microprocessor chips wouldn't go the same way as scientific calculator chips had—originally hundreds of dollars, now just a few dollars. He said that the chips would never go below $100.

The salesperson's attitude was nearly universal in Silicon Valley—but MOS Technology was on the East Coast. I called them up, and they insisted that they were serious and that yes, that was the single-piece price. I, and the rest of the valley, would have to wait for WESCON to find out.

WESCON finally came and there was the MOS Technology booth—but no chips. The company had discovered when it got there that exhibitors weren't allowed to sell anything on the show floor. The chips, company representatives said, were available in their hospitality suite in a nearby hotel.

I went to the suite that evening, and it was packed. The chips were in two large fishbowls. MOS also had hardware and software manuals available for $5 each. Ray Stevens, who owned RGS Electronics and had designed the RGS-008, was tending bar. Steve Wozniak, was there, along with a lot of other people including Chuck Peddle,

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who was happy to talk about his new processors.

I sat down on the couch and looked at the two manuals. They were written in English and they made sense!

MOS was also showing one more innovation in the suite that night—the first multifunction peripheral chips. The company had put RAM, ROM, timer, and I/O on one chip. One version was called the TIM (terminal-interface monitor) chip and contained a complete monitor for talking to a serial terminal. The other was the KIM (keyboard-input monitor) chip, and it was designed into a microcomputer board that had a keyboard, central processor, display, ROM, RAM, and parallel I/O, and sold for $245. It was a complete system. No other microprocessor vendor had done anything like this before. It was impressive.

I went home that evening clutching my $25 6502 microprocessor and two manuals. At the time I didn't realize I would spend another $300 to make a working system, not counting the ASR-33 Teletype I used as a terminal.

That first day of WESCON, Intel and Motorola lowered the price on their chips to $69.95. The revolution was in full swing. The industry would never be the same.

The 6501 was short-lived. Motorola sued MOS Technology charging that Chuck Peddle had stolen the technology from Motorola and that the 6501 infringed because it was plug-compatible. MOS Technology agreed to drop the 6501.

However, the many computers that were developed around the 6502 are now legend: MOS Technology's own KIM-1, the Apple I and II, the Atari models, and the Commodore PET and VIC-20, among others. Actually, the future of the 6502 was still questionable when fledgling Apple Computer Inc. produced the Apple I. Steve Wozniak put in a jumper connection that could be changed to allow the 6800 to be used instead of the 6502.

ENTER THE Z80

Sometime in late 1975 or early 1976, Federico Faggin left Intel and formed his own company, Zilog Inc. He took Masatoshi Shima with him. Their goal was to build a super 8080.

In 1976, Zilog announced the Z80, a significantly enhanced 8080 that ran almost all of the programs written for the 8080. The company claimed it would have parts that ran at 4 MHz, twice as fast as the 8080. In addition it had many more powerful instructions—a total of 176. It sounded too good to be true; the Z80 was treated with the same skepticism as the 6502 had been.

But the Z80 turned out to be real, and there actually were some 4-MHz parts available. The early ones said "Engineering Sample" on them and were manufactured in Dallas, not in Silicon Valley. Mostek, a Z80 second source, was actually building the chips for Zilog. Nobody minded because everybody wanted one for their own computer.

Several Z80 cards for the S-100 bus were on the market shortly after the chip became available, and everybody had to have one. But even though the Z80 was a much more powerful chip than the 8080 in terms of its instruction set, very few people were writing software to take advantage of the Z80's extra instructions. The reason was simple: The majority of the machines installed at that time were 8080-based, and if you wrote code that only ran on a Z80, your market would be considerably smaller. This problem plagues the Z80 even today.

However, designers stopped using the 8080 in new computers. The Z80 was a far easier chip to use, requiring no support ICs and only a single-voltage power supply. And it was much faster, even if you didn't use the extra instructions.

The Z80 introduced one other new concept to microcomputer chips: built-in support for refreshing dynamic RAMs. Dynamic RAMs have always cost about four times less per bit than their static counterparts, and that made them very attractive to use. However, because you have to refresh them (or else they forget their data), they are extremely difficult to use, and early system designers viewed them with some distrust. The Z80 gave the designer 90 percent of the solution and made it possible to build systems that were significantly cheaper than before. Computers such as Radio Shack's original TRS-80, designed by Steve Leininger, took advantage of this fact.

INTEL STRIKES BACK

Meanwhile, Intel had realized that the 8080 needed upgrading. In 1976 Intel announced the 8085. It had all the 8080 instructions, plus a few more. But Zilog had taken Intel by surprise. The enhancements that the 8085 had over the 8080 were nowhere near as extensive as those of the Z80. From a purely hardware standpoint, the 8085 was a much nicer chip than the Z80, but the Z80 had mass appeal because it was faster. When introduced, the 8085 ran at 3 MHz, as opposed to the 4-MHz chip that Zilog was already shipping. Intel had to come up with something else—a 16-bit processor seemed like the answer.

Sixteen-bit processors had been tried before. National Semiconductor had started work on the IMP-16 chip set as early as 1972. The company reduced it to one chip called the Pace, and Bill Godbout Electronics announced a Pace-based computer, designed by George Morrow, in mid-1975. The unnamed system, a full-blown 16-bit computer with RAM and a built-in cassette interface, was advertised in the first issue of BYTE. They actually built one, but it never got to market. Bill Godbout said that the market wasn't ready for a 16-bit computer, and he was probably right. After all, the Altair was only a few months old itself. Neither the Pace chip nor the computer was ever a hit.

Other 16-bit chips included General Automation's LSI-16, a microprocessor version of its SPC-16 minicomputer; DEC's LSI-11, which was manufactured by Western Digital and included the PDP-11 instruction set; Western Digital's own WD-11, which was only one instruction different from the LSI-11; General Instrument's CP1600; and Texas Instruments'

TMS9900, which went into their home computer, making it the first mass-market 16-bit computer.

Interestingly, the first literature released by MOS Technology on the 6502 showed some little dashed lines where the 16-bit extensions to their registers would go in their 16-bit version of the 6502, the 6516. But the 6516 was never marketed, and the little dashed lines soon disappeared. The existence of such a part was rumored for years, but it never surfaced. Not until December 1983 did the Western Design Center (not the same as Western Digital) announce a 16-bit version of the 6502.

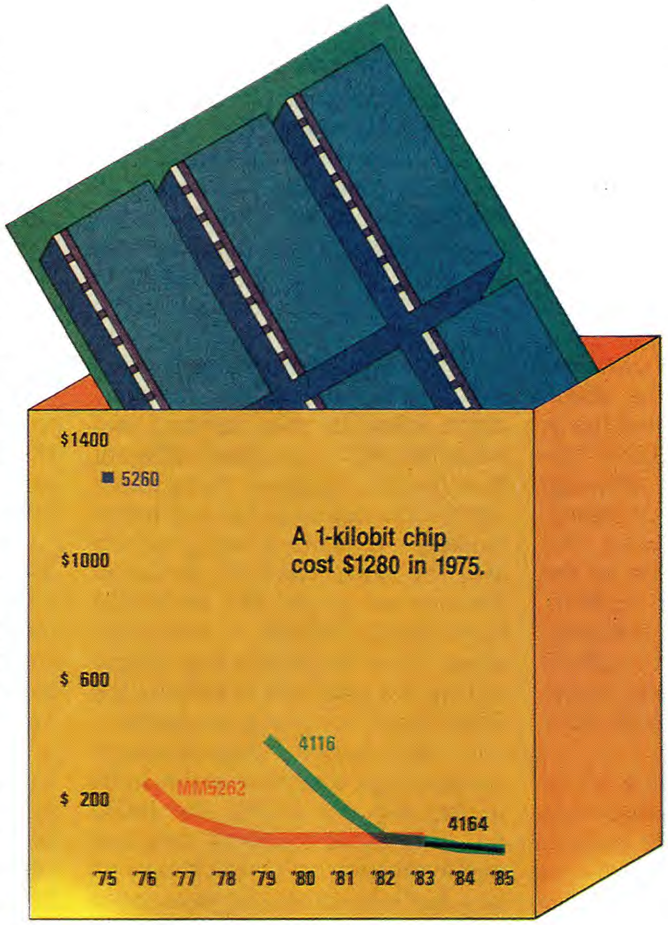
Again, Intel needed something to compete with the Z80. The company figured that most previous 16-bit designs were flops because they had no existing software base that could easily be migrated to it—they were all the first microprocessor offerings from their respective companies.

But Intel had an edge: the growing base of 8080 software. The company decided that its 16-bit processor would be a direct enhancement of the 8080. In 1976 Intel started work on the 8086. Unfortunately, the designers did not preserve direct compatibilty with 8080 code, but at least each 8080 register had its 8086 counterpart, which made 8080-to-8086 code translators possible and gave programmers a familiar starting point. This was a big factor in the success of the 8086, which was announced to the world in 1978.

Then someone at Intel had an inspiration. Why not make the hardware almost as easy to migrate as the software? Thus was born the 8088. The 8088 is an 8086 on the inside but has an 8-bit data bus on the outside. When the processor wants to fetch 16 bits of data, it first gets 1 byte, then the second. The programmer doesn't have to worry about it, it all happens automatically in the hardware. The actual signals coming out of the 8088 look similar to the 8085, a chip that designers were already familiar with. Thus, it was easy to upgrade an existing 8-bit design to 16 bits.

You might think that by doing this the processor would run at half its potential. But Intel had been clever when they designed the 8086. Internally it consisted of two different but linked processors. One was the execution unit, the part that actually processes the data or executes the instructions. The other was called the bus-interface unit (BIU). The BIU handles all communications with the outside world and is in charge of generating addresses and storing and retrieving data from the system. Inside the BIU is a queue. While the execution unit is busy crunching data, the BIU is out on the bus getting the next instruction and putting it in the queue. The 8086 BIU can stay up to 6 bytes ahead of the execution unit by keeping those bytes in its queue. Because of the queue, the 8088 performance only suffers an average of 20 percent compared to an 8086. (See "Benchmarking the Intel 8086 and 8088" by Gregg Williams, July 1983 BYTE, page 147.) The 8086/8088 processors were the first to use a queue mechanism.

Intel also introduced another new concept with its 8086 family—coprocessing. The idea was to hang another processor right on the bus of the main processor to extend its functions. The most significant of these coprocessors was the 8087, a math coprocessor that added a whole set of floating-point instructions to the 8086/8088. Since the 8087 was built solely to do math, it could do so very quickly.



The cost of 64K bytes of RAM from 1975 to 1985, as found on the pages of BYTE magazine. Prices shown are for 512 of the 1-kilobit 5260 chip, 256 of the 2-kilobit MM5262 chip, 32 of the 2K-byte 4116 chip, and 8 of the 8K-byte 4164 chip.

THE MC68000

In 1977, designers at Motorola were working on a new processor for the 16-bit market but vowing to keep it 32 bits internally. They also wanted to eliminate any special-purpose instructions and allow the processor to perform all operations, on all registers, on all data types, and in all addressing modes. This is called *orthogonality*. Programmers like

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orthogonality because it means they don't have to memorize a bunch of exceptions to the instruction set. The fruit of Motorola's effort was the 1979 release of the MC68000.

The MC68000 is one of those chips that some people love and others hate. There is very little middle ground. Compared to the 8086/8088, it required a massive software effort to get it to do anything. But UNIX was becoming popular, and the 68000 looked like a good UNIX machine. A number of 68000-based UNIX machines were announced, although hardly any of them were successful.

Motorola also announced the 68008, an 8-bit-bus version of the 68000, similar in concept to the 8088. However, the 68000 had no real queuing, and that meant that the 68008 ran half as fast as the 68000. Unfortunately, this made the 8088 look even better.

Internally, the 68000 was a microcoded chip, which means that internal functional elements are general-purpose. A ROM (which contains the microcode) controls what the chip does. The processor's response to each instruction is controlled by the ROM. If an instruction doesn't do the right thing, you can usually fix it in the ROM and, within limits, you can even change the instruction set of the microprocessor if you want to. (IBM's add-in processor for the XT/370 is essentially a 68000 with custom microcode.)

Up until this time, all other processors were generally random-logic designs that had a little bit of circuitry to perform each specialized function within the central processor. There are advantages and disadvantages to both types of microprocessor design—microcoding offers flexibility at the expense of speed, while a random-logic design offers speed at the expense of flexibility. It is also difficult to fix errors in a random-logic design—especially when the designer of the chip leaves the company.

At Zilog, for example, Masatoshi Shima had begun work on a 16-bit processor, the Z8000, using random logic. Random logic worked fine for the 8080 and Z80 but, in hindsight, it is unfortunate that Shima designed the Z8000 that way. After the first Z8000 silicon was produced, but before his team had had worked all the bugs out of the chip, Shima left Zilog to return to Intel. Zilog never did get all the bugs out of the Z8000. In addition, Zilog had set a standard by allowing the Z80 to run all the software for the previous-generation 8080. Unfortunately, the company didn't follow its own standard and made the Z8000 completely different from the Z80. Zilog was trying to put a minicomputer on a chip and, unfortunately, it didn't do a very good job of it. The Z8000's lack of a similar instruction set to the Z80, its built-in bugs, and its sacrifice in instruction power due to its random-logic nature all played a great role in keeping the Z8000 from becoming successful.

In 1981, National Semiconductor made a second attempt at the 16-bit market with the 16032. The 16032 was to be a 32-bit (internal data bus) microprocessor with a 16-bit external bus. Since Motorola had never been able to produce their promised math coprocessor, and Intel's 8087 so far couldn't break the 5-MHz speed barrier, everyone was impressed when National announced its math coprocessor, which would run at 10 MHz, giving it twice the performance of Intel's 8087.

Unfortunately, National became the first microprocessor company to ship all its peripheral chips 100 percent functional before the processor was available. Today the 16032 still has a few bugs in it. But programmers like its instruction set, which reminds them of a VAX (a series of high-performance DEC superminicomputers). Because the VAX has been so successful as an engine for running UNIX, the 16032 may be a natural successor as the base for a UNIX computer. There may be some life left in it yet.

In 1982, Intel one-upped the semiconductor industry again. They announced the iAPX 286. This new product was a vastly upgraded 8086 architecture that included built-in virtual memory management and many other features designed expressly for supporting a multitasking, multiuser environment. It has a mode that runs all 8086 code directly, and Intel has significantly sped up its throughput. Also, true built-in memory management is something that no other microprocessor has to this day. The main advantage to having memory management built in is that it can work much faster than processors that require external memory managers. The IBM PC AT's use of the 80286 has ensured the success of this processor for at least the next few years.

32-BIT CHIPS

In spite of problems with the 16032, National Semiconductor was the first company to announce and ship a full-blown 32-bit microprocessor. The 32032, which used to be the 16032, is code-compatible with the 32016. It's still early to tell how the 32032 will fare, but the popularity of UNIX will probably be a major factor in its success, if indeed all the projections of the 32000 family being the ideal UNIX engine are true.

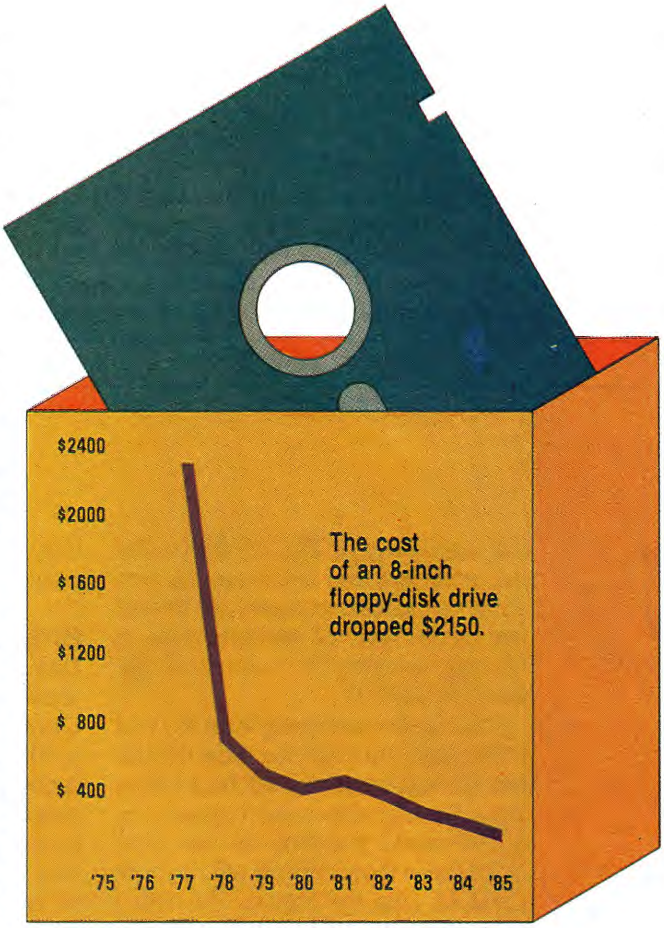
Motorola is now sampling its full 32-bit extension to the 68000, the 68020, which looks promising. It has one new feature that will probably get it into lots of designs early. Remember that the 8088 was successful because it allowed an easy migration path due to its 8-bit external data bus. The 68020 lets you dynamically choose the bus size you want—8, 16, or 32 bits. Supposedly, it is able to run all 68000 code, and it's fast. One of the things that gives it great speed is its cache—the logical extension of the queue used in the 8086/8088/80286 processors.

The cache in the 68020 is 256 bytes deep and works a little differently from a queue. If a jump occurs to a point in the queue, the queue is flushed and reloaded. But the cache looks just like memory, so a jump to a point in the cache would not cause the cache to be dumped and reloaded. If loops are small enough, they can execute directly from the cache. The advantage is that the processor can access the cache much faster than it can access external memory, so programs run faster if they stay mostly in the cache. As with the 32032, it's still early to tell what the eventual success of the 68020 will be.

National has also announced the 32132 (not yet available), which is to have multiple caches and something the company calls a look-aside buffer.

Zilog had announced a product called the Z800, a 16-bit upgrade to the Z80 that was to be code-compatible with it. The company was never able to produce working silicon, however. Instead, it is trying to get the Z80 to work at 10 MHz. Zilog has also announced the Z80000, a 32-bit version of the Z8000 that I call the "kitchen-sink processor" because it will have everything, including code compatibility with the Z8000, which is the right idea but the wrong processor.

Intel has been talking for some time about the coming 80386, its 32-bit version of the 80286, but to date it hasn't released any hard data on it. Intel said it will be 80286-compatible, and that probably means IBM will use it.



The cost of an 8-inch single-sided double-density floppy-disk drive from 1977 to 1985. Note that such drives were not available in 1975 and 1976.

FASTER OR SMARTER?

I can't end my discussion of microprocessors without mentioning a few bizarre approaches. There is still a debate raging on whether microprocessor instruction sets should evolve toward more complex and high-level instructions, or whether they should be getting much simpler but much faster. So far, high-level instruction sets have not been winners. One ill-fated attempt was Western Digital's Pascal Microengine, which executed Pascal pseudocode (the output of all loyal Pascal compilers) directly. Unfortunately, Pascal compilers that put out native 8080 code beat it handily.

Similar in concept is the new FORTH processor from Novix, developed under the direction of FORTH inventor Charles Moore. Instead of executing the output of a compiler directly, this FORTH chip runs threaded FORTH code directly—its instruction set is FORTH. It's supposed to be very fast, and if you like FORTH it's great.

The FORTH engine is a custom version of a chip from National Cash Register called the NCR 32. It is a microcode-executing 32-bit engine on two chips; a third chip is required to contain the microcode. Essentially you can "roll your own" instruction set, which is what the developers of the FORTH engine did. This technique opens up a whole realm of possibilities, such as being able to emulate different computers on the fly by downloading different instruction sets. The speed at which this will be accomplished, however, will be limited by the fact that microcoding is hard work.

The Intel iAPX 432, probably the first 32-bit microprocessor available, was designed with very-high-level instructions to support the U.S. Department of Defense's Ada language.

Opposite the high-level instructions' team are those who think that a small set of simple but extremely fast instructions can outperform large and complex (slow) instructions. Such are the RISC (reduced instruction set computer) fans. A RISC machine was successfully implemented in silicon at Berkeley, amazingly on the first pass. They are currently working on speeding up the chip, which has a 32-bit architecture. Hewlett-Packard is also rumored to be working on several RISC machines.

Last is a unique device just about to be sampled from INMOS called the Transputer (see "The Transputer" by Paul Walker, May BYTE, page 219). It is designed to perform parallel processing. It will take many more years of software development and sophistication to take full advantage of the Transputer, but the possibilities are fascinating.

Meanwhile, a 4004 microprocessor still controls a traffic light near my office. It tends to put all the whizzy new things in perspective, doesn't it? ■

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A MICROCOMPUTING TIMELINE

PHOTOGRAPHED BY PAUL AVIS

What follows is a modest and, we hope, correct timeline of personal computing. If the number of entries per year is any indication, then the most active years of personal computing were 1975, 1976, and 1977 and 1982, 1983, and 1984.

Although the roots of personal computing go back further, the excitement really started in January 1975, with the publication of Popular Electronics' *cover story on the* Altair 8800. *A slogan printed on the cover of the first three issues of* BYTE *said it all: "Computers—The World's Greatest Toy." The slogan expressed the ideal that lured many, but few of us had the stamina and consuming fanaticism needed to make it happen; you had to design and build* everything *yourself, hardware and software. Most of you also had to learn electronics, mathematics, and the art of deciphering arcane, poorly written spec sheets—the phrase "by your bootstraps" took on new meaning.*

By 1978, things were different; you could buy microcomputers and they would usually work, but it wasn't the same. Prior to 1978, the excitement was in saying "Look, my design works!" But when you took it for granted that it worked, the question became "What can you do with it?"; however, the answer was "Not all that much." Most systems lacked a disk drive and had 32K bytes of memory or less. The years between 1978 and 1982 were slow, evolutionary years—not too exciting, but necessary.

By late 1981, the industry was poised for growth, and IBM's introduction into the marketplace catalyzed that growth into a bumpy, breathtaking ride that shows no signs of slowing (though it did take about a year to get started, that is, to produce a significant number of IBM-related products). Personal computers finally could perform and were affordable enough to be used by people who weren't just hobbyists; that progress continues to build as computers become simultaneously cheaper and more capable.

BYTE *has kept a close watch on the computer industry's growth, and we felt the need to annotate this timeline. When dates have been difficult to pinpoint, we've approximated them. In general, it has been an active and interesting first ten years.*

—Gregg Williams and Mark Welch

***JULY 1974* RADIO-ELECTRONICS' COVER STORY IS ON THE MARK-8.**

1948
The Transistor
is invented
at
Bell
Industries

Pre-1975

1948 John Bardeen, Walter Brattain, and William Shockley of Bell Laboratories invent the transistor.
1959 Texas Instruments unveils the first integrated circuit.
1964 John G. Kemeny and Thomas E. Kurtz develop the BASIC programming language at Dartmouth College.
Digital Equipment Corp. advertises the PDP-8 minicomputer, which, at $16,200, is "a full, general-purpose computer that scientists can afford—but it gets personal."
1970 OCTOBER *Scientific American* publishes Martin Gardner's first "Mathematical Recreations" column on John Conway's game of Life.
1971 Intel Corp. puts the 4-bit 4004 microprocessor on a single chip. Its initial price is $200.
1972 NOVEMBER Intel Corp. introduces the 8008, their first 8-bit microprocessor.
Nolan Bushnell founds Atari and ships the Pong video game.
1973 Scelbi Computer Consulting offers the 8008-based Scelbi-8H computer kit ($565 with 1K byte of memory).
FALL Intel Corp. announces the improved 8080 8-bit microprocessor.
SEPTEMBER *Radio-Electronics* magazine publishes Don Lancaster's TVT-1 computer terminal project.
1974 Brian W. Kernighan and Dennis M. Ritchie develop the C programming language.
SUMMER Gary Kildall develops the CP/M operating system.
JULY *Radio-Electronics'* cover story is "Build the Mark-8: Your Personal Minicomputer."
SEPTEMBER *Creative Computing* magazine founded.

NOVEMBER 1971 INTEL'S FIRST AD FOR THE 4004 MICROPROCESSOR IN ELECTRONIC NEWS.

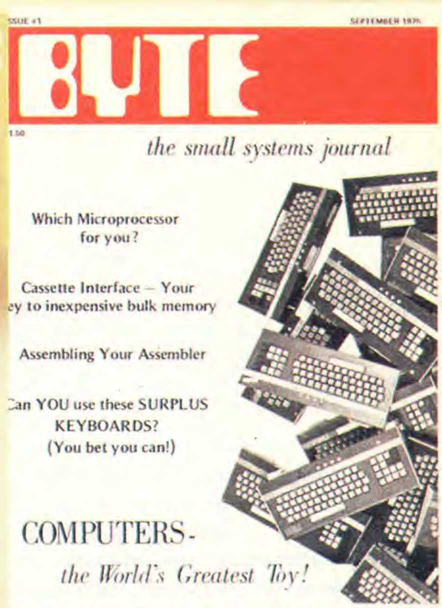
1975

WINTER Zilog Inc. develops the Z80 microprocessor, whose instruction set is a superset of the 8080's.
JANUARY Carl Helmers founds *Experimenters' Computer System* (ECS), which lasts for five issues before he moves to BYTE.
JANUARY *Popular Electronics'* cover story is "World's First Minicomputer Kit to Rival Commercial Models...Altair 8800." The Altair 8800 kit, with an Intel 8080 microprocessor, 256 bytes of memory, and a toggle-switch-and-LED front panel, sells for $395.
MARCH Homebrew Computer Club founded.
MAY Amateur Computer Group of New Jersey founded.
SUMMER IMS International announces the IMSAI computer, which is essentially an improved clone of the Altair 8800.
SUMMER MOS Technology announces the MC6501 at $20 and the MC6502 at $25; at this point, the 8080 costs about $150.
FALL MITS (the company that sells the Altair 8800) announces 4K-byte and 8K-byte BASIC (from Microsoft's founders Bill Gates and Paul Allen) for $350 and $500, respectively ($60 and $75 for purchasers of complete Altair systems).
FALL Dennis Allison publishes Tiny BASIC—later enhanced by many, including Tom Pittman and Li-Chen Wang.
FALL Sphere Corp. offers the Sphere I computer kit (6800, 4K bytes of RAM, ROM monitor, keyboard, video interface, for $650).
FALL MOS Technology announces the KIM-1 microcomputer, an assembled single-board computer (6502, 1K byte of RAM, 2K-byte monitor in ROM, keypad, LED readout, cassette and serial interfaces, for $245).
SEPTEMBER IBM announces the IBM 5100, the first briefcase-size computer (with BASIC, 16K bytes, and a tape cartridge storage system, for about $9000.
SEPTEMBER BYTE publishes its first issue.
SEPTEMBER Godbout advertises the Pace kit in BYTE with "7 segment readouts for easy octal debugging."
NOVEMBER Southwest Technical Products Co. advertises the M6800 computer kit (6800, serial interface to terminal, monitor in ROM, for $450). Unlike the Altair, it has *no* front-panel switches!
DECEMBER MITS unveils the Altair 680 kit (6800, 1K byte of RAM, serial interface, for $293).
DECEMBER Microcomputer Associates Inc. offers the JOLT kit (6502, 512 bytes of RAM, serial interface to terminal, monitor in ROM, for $249).
DECEMBER Robert Tinney's first BYTE cover.

1976

JANUARY *Dr. Dobb's Journal of Computer Calisthenics and Orthodontia (Running Light Without Overbyte)*, a homebrew hardware and software magazine, publishes its first issue.
MARCH David Bunnell of MITS organizes the First World Altair Computer Convention in Albuquerque, New Mexico.
SPRING Texas Instruments announces its TMS9000, the first 16-bit microprocessor.
APRIL Apple Computer Inc. formed.
APRIL Cromemco Inc. advertises the Dazzler TV interface board—the first color display for a microcomputer.
SUMMER Keuffel and Esser (K&E) ceases its production of slide rules and donates its last one to the Smithsonian.
JUNE SwTPC M6800 ad promises "SOFTWARE—The flood is near. Editor and assembler now available. BASIC and more games right away. Yours for the cost of copying. WE DON'T SELL SOFTWARE—WE GIVE IT TO YOU. ENJOY IT, COPY IT, WE WON'T COMPLAIN..."
JUNE Scelbi releases SCELBAL, a BASIC-like language for $49 (includes source); it runs in 8K bytes of memory or more.
AUGUST First floppy-disk-drive ad in BYTE (iCOM Frugal Floppy, 8-inch, for $1195 [single quantity]).
AUGUST John Dilkes organizes the Personal Computing Festival in Atlantic City; it is the first microcomputer show of national scope.
AUGUST First portable computer: STM Systems' "BABY!" (6502, 2K bytes of RAM, bootstrap program in ROM, system software on tape, for $850 assembled).
FALL Steve Wozniak proposes that Hewlett-Packard Co. create a personal computer; Steve Jobs proposes the same to Atari—both are rejected.
SEPTEMBER Ohio Scientific Instruments advertises OSI 400 (6502, 6572, or 6800, parallel and serial ports, 1K byte of RAM, 512 bytes of PROM, kit prices—$140 and up).
OCTOBER Cromemco Inc. offers 4-MHz Z80 board for Altairs and other S-100 systems ($395 kit, with a monitor program on paper tape).
OCTOBER PolyMorphic Systems advertises the S-100—based POLY 88 (8080A, 512 bytes of RAM, video/keyboard interface board, 1K byte of ROM, cassette interface, for $685 in kit form).
NOVEMBER Steve Ciarcia's first article (not Circuit Cellar).
DECEMBER Processor Technology advertises the Sol computer (8080, S-100 bus, 1K byte of RAM, 1K byte of PROM, 1K byte of video RAM, keyboard, cassette, serial, and parallel interfaces, BASIC-5 on cassette—kit, $995; with dual 8-inch drives and operating system, $1895; an assembly-language TREK-80 game, PT 8K BASIC, and 8080 FOCAL are also available). The machine was invented by Lee Felsenstein.
DECEMBER Michael Shrayer writes Electric Pencil, the first popular word-processing program for microcomputers.
DECEMBER Shugart announces its 5¼-inch "minifloppy" disk drive for $390.

***FALL 1975* THE SPHERE 1 COMPUTER KIT**

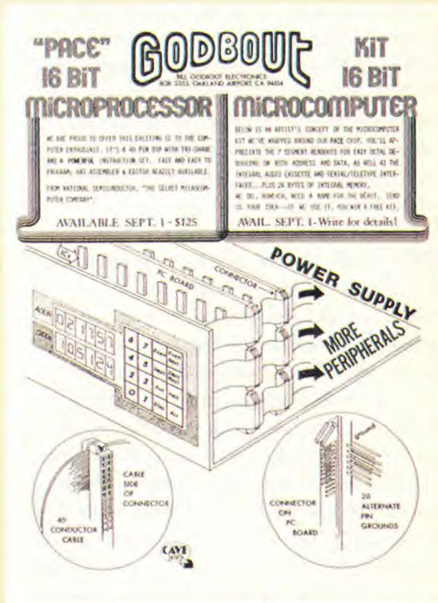


APRIL 1976 APPLE I BOARD

SEPTEMBER 1975 BYTE'S DEBUT

JUNE 1976 SWTPC SOFTWARE AD

AUGUST 1976 ICOM'S FRUGAL FLOPPY AD



SEPTEMBER 1975 GODBOUT PACE KIT AD

JANUARY 1975 POPULAR ELECTRONICS' FEATURES THE ALTAIR 8800

FALL 1975 THE KIM-1

JANUARY 1975 THE ALTAIR 8800

1977

WINTER Ohio Scientific Instruments offers the first microcomputer with Microsoft (floating-point) BASIC in ROM; it is also the fastest.
JANUARY *Kilobaud* (which later changed its name to *Microcomputing*) publishes its first issue.
FEBRUARY Computer Shack (which later changes its name to ComputerLand) opens its first store.
APRIL Jim Warren organizes the 1st West Coast Computer Faire in San Francisco. The Apple II and Commodore PET (see below) are introduced there.
APRIL Commodore Business Machines Inc. unveils its PET computer (6502, 4K bytes of RAM, 14K bytes of ROM, keyboard, display, tape drive, for $595 assembled). Its all-in-one packaging and 8K bytes of Microsoft BASIC were innovative. Its calculator-pad keyboard was (unfortunately) the precedent for later microcomputers.
JUNE Camp Retupmoc, the first week-long computer camp, is held in Terre Haute, Indiana.
JUNE Apple Computer Inc. runs its first ad in BYTE (6502, 4K bytes of RAM, Integer ROM and monitor in 16K bytes of ROM, keyboard, cassette interface, 8-slot motherboard, game paddles, graphics/text interface to color display, for $1298; with maximum 48K bytes of RAM, $2638).
AUGUST SwTPC offers a two-drive 6800 system with terminal, monitor, and computer for $1999.
AUGUST Microcomputers become more widely available (service does, too) through Radio Shack: their TRS-80 Model I (Z80, 4K bytes of RAM, 4K bytes of ROM [Level I BASIC], keyboard, display, cassette interface, and recorder) costs $599.95.
OCTOBER North Star Computers announces its Horizon computer (Z80A, 16K bytes of RAM, one 5¼-inch floppy drive, 12-slot S-100 motherboard, serial interface to terminal, $1599 kit, $1999 assembled).
NOVEMBER Ciarcia's Circuit Cellar begins.

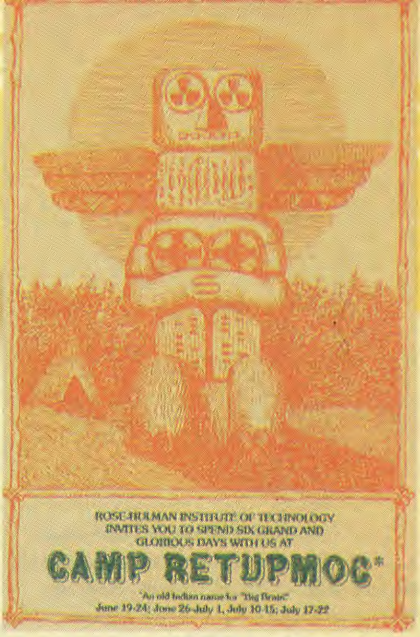
1978

FEBRUARY Ward Christensen and Randy Seuss create the Computerized Hobbyist Bulletin Board System, the first major CBBS running on a microcomputer.
MARCH Kathe and Dan Spraklen's Sargon wins the 2nd West Coast Computer Faire chess tournament. (The 3rd takes place in Los Angeles in November.)
APRIL The Digital Group advertises the Bytemaster, a sewing-machine-size computer housing a display, keyboard, and disk drive. Never very popular, it predates the Osborne 1.
MAY Ken Bowles first describes the machine-independent UCSD Pascal language/operating system in BYTE.
JUNE Exidy unveils the Sorcerer (Z80, 8K bytes of RAM, 12K bytes of ROM, keyboard, parallel, serial, and cassette interfaces, $895). The machine's innovations are its user-definable characters and its optional software on plug-in ROM cartridges.
AUGUST MicroPro International unveils Word-Master, the precursor of the ubiquitous WordStar word processor (which appears in mid-1979).
DECEMBER Epson America Inc. announces the MX-80 dot-matrix printer; its high performance and low price stun competitors and force competition and lower prices in the printer market.
DECEMBER Atari announces the Atari 400 and 800. The 800 has a full keyboard, 8K bytes of RAM (expandable to 48K via memory slots), two ROM cartridge slots, and custom graphics and sound chips designed by Jay Miner (who later designs the Amiga custom chips); it originally costs $1000. The machines do not become available until late 1979. A derivative machine (now costing under $100) is still on the market, and its graphics are unsurpassed in the 8-bit market.

1979

SPRING CompuServe, a telecommunications utility, founded.
MAY Dan Bricklin and Bob Frankston of Software Arts Inc. show the VisiCalc spreadsheet program at the 4th West Coast Computer Faire. This program caused many to take microcomputers seriously for the first time. VisiCalc was originally marketed by Personal Software (which later changed its name to VisiCorp), but Software Arts regained the rights to VisiCalc in September 1984. (VisiCorp merged with Paladin in late 1984, and Software Arts merged with Lotus in April 1985.)
MAY The FORTH Interest Group distributes the first public-domain version of fig-FORTH, which begins the eventual widespread availability of the language on microcomputers.
JUNE The Source telecommunications utility founded.
JUNE Texas Instruments unveils the TI-99/4, which originally sold for $1150 (which included a color monitor). The machine is slow (even though it uses TI's TMS9900 16-bit processor), the button-style keyboard is oddly laid out, and TI discouraged third-party software. The revised TI-99/4A solved some problems, but TI finally discontinued the computer in late 1983; its closeout price went as low as $50.
SUMMER Magic Wand becomes the first serious competitor to WordStar; it was just as powerful and easier to use.
SUMMER Wayne Ratliff develops the Vulcan database program (Ashton-Tate later markets it as dBASE II).

JUNE 1977 APPLE'S FIRST AD IN BYTE



JUNE 1977 THE FIRST COMPUTER CAMP

JUNE 1979 THE TI-99/4A

DECEMBER 1978 THE EPSON MX-80

APRIL 1978 THE BYTEMASTER

DECEMBER 1978 THE ATARI 800

DECEMBER 1978 THE ATARI 400

AUGUST 1977 THE TRS-80 MODEL I

APRIL 1977 THE COMMODORE PET

FEBRUARY 1980 **THE SINCLAIR ZX80**

1980

FEBRUARY *InfoWorld* publishes its first issue.

FEBRUARY Sinclair Research announces its ZX80 computer (Z80A, 1K byte of RAM, 4K integer BASIC in ROM, plastic membrane keyboard, $199). Its successor, the ZX81, was later marketed by Timex for under $100 before Timex left the microcomputer market.

MARCH Microsoft Corp. shows its first hardware product, the Z80 SoftCard for the Apple II at the 5th West Coast Computer Faire. The sudden availability of CP/M business software for the Apple contributes greatly to Apple Computer Inc.'s success.

MAY Apple Computer Inc. announces the Apple III, which is delivered a year late and has, at first, a high failure rate. The machine never becomes the replacement for the Apple II that Apple Computer wanted it to be.

JUNE Shugart begins selling 5¼-inch Winchester hard-disk drives.

JUNE Commodore Business Machines unveils the VIC-20 (6502A, 5K bytes of RAM, BASIC in ROM, serial, cassette, and modem interfaces, ROM cartridge slot, color display, for $299).

SUMMER Radio Shack announces its TRS-80 Color Computer (6809E, "chicklet"-style keyboard, 4K bytes of RAM, BASIC in ROM, color display, serial and cassette interfaces, for $399). They also announce the TRS-80 Model III, which replaced and improved their original Model I.

SUMMER "Zork, the Great Underground Empire" is first distributed by Personal Software Co. and later by Infocom, its creators. Infocom changed the nature of adventure games by allowing full-sentence input.

JULY Jerry Pournelle's "The User's Column" begins in BYTE.

MAY 1980 **THE APPLE III**

NOVEMBER 1981 **THE EPSON HX-20**

JUNE 1980 **THE COMMODORE VIC-20**

AUGUST 1981 **THE IBM PC**

SUMMER 1980
ZORK—AN EARLY ADVENTURE GAME

APRIL 1981 **THE OSBORNE I**

SUMMER 1981
THE HAYES SMARTMODEM 300

1981

WINTER Tracy Kidder's *The Soul of a New Machine* (New York: Avon Books) glorifies the inner workings of the computer industry and becomes a national bestseller.

FEBRUARY Steve Wozniak, principal designer of the Apple II, crashes the airplane he was flying. After recovering from injuries and amnesia, he moves to non-Apple tasks such as returning to the University of California at Berkeley for his undergraduate degree and (in September of 1982 and 1983) sponsoring music/technology weekends called US Festivals.

APRIL Adam Osborne, publisher of microprocessor books, surprises the industry with the $1795 portable Osborne 1 (Z80, 5-inch display, 64K bytes of RAM, keyboard and keypad, two serial interfaces, and two 5¼-inch disk drives). He also includes an impressive collection of bundled software whose list prices total more than the cost of the machine. The Osborne 1 had some flaws—low-density disk drives and a kludgy 52-character display—but it was a good machine for the money, and it caused competitors to produce similar computers at a lower cost than was common at the time.

MAY Xerox Corp. unveils the Star (later called the 8010). This is Xerox's first commercial product derived from over a decade of work at Xerox PARC (Palo Alto Research Center). Costing over $50,000 for the smallest usable configuration, the computer has little direct effect; however, its use of icons, the "desktop metaphor," and the mouse pointing device begin to influence the microcomputer market in 1983 (with Apple Computer Inc.'s announcement of the Lisa computer).

SUMMER Hayes Microcomputer Products Inc. advertises the Smartmodem 300, which becomes the industry standard.

AUGUST IBM introduces the IBM Personal Computer (PC) (8088, 64K bytes of RAM, 40K bytes of ROM, one 5¼-inch disk drive, $3005), which legitimized the microcomputer industry to the rest of the world and established the preeminence of the Intel 8086-family processor and the Microsoft MS-DOS operating system.

SEPTEMBER BYTE publishes "A High-Level Language Benchmark" by Jim Gilbreath. This article makes the Sieve of Eratosthenes benchmark program infamous; it is later used to test hundreds of computer/language combinations.

NOVEMBER Epson America Inc. shows the HX-20, the first laptop computer, at COMDEX. The unit weighs less than 3 pounds and runs a CMOS (complementary metal-oxide semiconductor) equivalent of the 6801 and 16K bytes of RAM on internal batteries. Its 20-character by 4-line display, however, reduces its usefulness.

SUMMER 1982 ***THE COMMODORE 64***

1982

JANUARY Radio Shack announces the TRS-80 Model 16 (68000 and Z80, 128K bytes of RAM, one 8-inch disk drive, for $4999).

APRIL BYTE's Famous Programmer's School ad.

APRIL Non-Linear Systems (later named Kaypro Corp.) announces the Kaycomp II (later named Kaypro II), a portable computer with a full 9-inch screen and considerable bundled software, meant to compete with the Osborne at $1795.

APRIL GRiD Systems announces the Compass, a futuristic briefcase-size portable computer with an electroluminescent display, for $8150. Despite several price cuts and feature changes, the computer never becomes popular. (GRiD was to announce a new product line in the summer of 1985.)

APRIL Xedex Corp. builds the Baby Blue card (a Z80 coprocessor card) to ease the lack of software for the 9-month-old IBM PC.

SPRING Franklin Computer Corp. unveils the Ace 100, the first legal Apple II clone.

JUNE Columbia Data Products Inc. advertises the MPC, the first IBM PC clone. Compaq Computer Corp. follows in November, and IBM PC cloning and claimed compatibility become a way of life in the industry.

SUMMER Commodore Business Machines Inc. announces the Commodore 64 (6510, 64K bytes of RAM, 20K bytes of ROM [including Microsoft BASIC], custom sound chip, color graphics, serial interface, for $595). During 1983, its price drops to around $200 and it eventually takes the market away from the Atari 800-series computers.

SUMMER The Logo programming language becomes readily available for several computers, most notably the Apple II and the TI-99/4A.

JULY Motorola Inc. and Hitachi America Ltd. release preliminary specifications for 256K-bit chips (they become available in late 1983).

JULY Intel Corp. announces the 80186 and 80286, more powerful processors that are compatible with the 8086 and 8088.

FALL U.S. Customs refuses to allow the custom chess-playing computer Belle to be taken to Moscow to play in exhibition. Ken Thompson, its inventor, notes that the only way it might be used as a weapon would be "to drop it out of an airplane. You might kill somebody that way."

OCTOBER Lotus Development Corp. announces 1-2-3, a fast spreadsheet/graphing program with some list-handling capability for the IBM PC. Its speed and capabilities allow it to replace VisiCalc as the industry standard, and its combination of several functions into one program starts the "integrated software" movement in microcomputers.

DECEMBER Volition Systems announces the first implementation of the Modula-2 language. It runs on an Apple II under the Softech p-System.

AUGUST 1984 **THE IBM PC AT**

1983

JANUARY Commodore Business Machines Inc. sells its one-millionth VIC-20.

JANUARY Ill-fated computers: Atari unveils the 1200XL, and Mattel belatedly announces the Aquarius. Both are later discontinued, and Mattel gets out of electronic products entirely.

JANUARY *Time* magazine selects the Computer as its "Man" of the Year.

JANUARY Apple Computer Inc. unveils the Lisa computer at its annual stockholders' meeting. The machine is slow but innovative. It originally costs $9995, but its price goes as low as $4495 (with a 5-megabyte hard disk). By this time, however, the Macintosh is in the news.

FEBRUARY IBM announces the IBM PC XT. It adds a 10-megabyte hard disk, three extra slots, and a serial interface to the basic IBM PC design. With 128K bytes of RAM and one disk drive, it costs $4995.

MARCH Radio Shack announces the TRS-80 Model 100, its first laptop. The unit weighs almost 4 pounds and has an 40-character by 8-line LCD (liquid-crystal display). It becomes very popular with journalists and businesspeople because of its built-in text editor and modem.

APRIL Microsoft Corp. announces Multi-Tool Word (later shortened to "Word").

MAY AT&T Information Systems announces the UNIX System V operating system.

JUNE Microsoft Corp. and numerous Japanese companies announce the MSX standard for low-cost Z80-based computers. It enjoys considerable success in Japan but none in the U.S..

JUNE Coleco announces the Adam, a Z80-based computer with a daisy-wheel printer, 64K bytes of RAM, and a tape-cartridge mass-storage device, for $600. Coleco delivers late, raises the system's price, repairs many defective units, and discontinues the product by the end of 1984.

JUNE Apple Computer Inc. ships its one-millionth computer.

SEPTEMBER Hewlett-Packard Company announces the HP 150, later renamed the Touchscreen.

SEPTEMBER Osborne Computer Corp. files for protection from creditors under Chapter 11.

OCTOBER IBM announces the IBM PCjr. The 128K-byte floppy-disk version first sold for $1269 and was crippled by lack of expansion and a cheap "chicklet"-style keyboard. Though these problems were fixed, IBM discontinued the PCjr in March 1985.

JANUARY 1983 **THE LISA**

JANUARY 1984 **THE MACINTOSH**

OCTOBER 1983 **THE IBM PCJR**

MARCH 1984 **THE AT&T 3B2/300**

SEPTEMBER 1983 **THE HP 150**

MAY 1984 **THE HP 110**

The computer has finally arrived, to be named "Man of the Year" 1983

OCTOBER Western Design Center introduces the 65802 and the 65816, both 16-bit versions of the popular 6502 chip. These chips were still not available in early 1985.

OCTOBER Shugart Corp. announces a $7600 1-gigabyte write-once optical-disc drive.

OCTOBER In Japan, Canon displays an under-$2000 300-dot-per-inch laser printer for OEM (original equipment manufacturer) use.

OCTOBER Borland International Inc. advertises Turbo Pascal for CP/M and 8086-based computers. Its quality, speed, and low price make it a de facto standard, especially in the IBM PC world.

OCTOBER Ovation Technologies announces Ovation, an ambitious integrated IBM PC software package that gets shown at several conventions but never gets shipped—the term "vaporware" is coined to describe it and similar products.

NOVEMBER Microsoft Corp. announces Windows, its multiple-window software product for the IBM PC, a package that became available in summer of 1985.

DECEMBER Tandy (Radio Shack's parent) announces the Tandy Model 2000, a $2999 IBM PC clone with enhanced features and an 80186 processor.

1984

JANUARY Apple Computer Inc. introduces the Macintosh. At $2495 for a computer that needs considerable expansion for many applications, it's hardly "the computer for the rest of us," but its innovations (which draw considerably from its ancestors, the Xerox 8010 and the Apple Lisa) continue to influence many other microcomputer products.

JANUARY Seiko Instruments U.S.A. Inc. displays the first wristwatch computer; it has a 10-character by 4-line LCD, 2K bytes of CMOS RAM, and 6K bytes of ROM.

JANUARY Sinclair Research announces the Sinclair QL (68008, 128K bytes of RAM, two cassette-loop mass-storage drives, bundled software, and other features) for £399 in the U.K. The computer is not made available in the U.S.

FEBRUARY Lotus announces Symphony, its $695 spreadsheet-oriented integrated package whose complexity limits its success.

MARCH AT&T unveils its 3B2/300 UNIX-based supermicrocomputer for $9950; the computer uses the Western Electric 32000 CMOS processor.

MARCH Ashton-Tate announces Framework, its word-processor-oriented $695 competitor to Symphony.

APRIL Mindset Corp. announces the Mindset PC, a graphics-oriented microcomputer with custom graphics chips and some IBM PC compatibility. Although its enclosure won a design award that put it in the Museum of Modern Art's design collection, the microcomputer market in 1984 was not able to support a new computer.

MAY Apple Computer Inc. unveils the Apple IIc with a morning-to-night publicity extravaganza that sets a new standard for such things in the industry.

MAY Hewlett-Packard Co. announces the HP 110, a 9-pound $2995 portable that includes Lotus's 1-2-3 in ROM.

JUNE Motorola Inc. adds the 68020 32-bit processor to its 68000 family.

JUNE Tom Jennings releases the Fido computerized bulletin-board system, which runs on many MS-DOS microcomputers, into the public domain. By 1985 there are over 300 Fido "nodes" in the U.S.

JULY Jack Tramiel (formerly head of Commodore Business Machines Inc.) buys Atari from Warner Communications.

AUGUST Commodore Business Machines Inc. buys Amiga Corp. and its graphics-intensive 68000 computer design.

AUGUST IBM announces the IBM PC AT (80286, 256K bytes of RAM, one 1.2-megabyte floppy-disk drive, and other items—minimum working system, $5469) and its PC Network local-area network.

FALL Digital Research Inc. announces its GEM icon/desktop user interface for 8086-based computers. (GEM is later used by Atari in its $395 68000-based "Jackintosh.")

OCTOBER Data General Corp. announces the DG/One, a 10-pound, $2895 battery-powered portable computer with most of the features of a fully configured IBM PC. The machine is criticized for an LCD that is hard to read, a point that DG corrects to some extent in a later model.

DECEMBER IBM acquires Rolm Corp., a communications equipment company; this gives IBM a competitive edge against AT&T, which has entered the computer market.

DECEMBER Osborne Computer Corp. emerges from bankruptcy proceedings with the Vixen, a $1298 Z80-based, two-drive portable with bundled software.

NOTABLE QUOTES

"What peripheral device most often describes the home hacker's ultimate system? It is, if course, the floppy disk."

—Ira Rampil, December 1977 BYTE

"In less than eight months, more than five thousand people have proudly purchased WordStar. . . ."

—a MicroPro ad, April 1980 BYTE

"The sin of inefficiency is venial compared to the mortal sin of "user-unfriendliness." I'd buy an operating system any day that takes a long time to run a given program but which makes me more productive by communicating with me in useful ways."

—Chris Morgan, June 1981 BYTE

"The current personal computer market is about the same size as the total potato-chip market. Next year it will be about half the size of the pet-food market and is fast approaching the total worldwide sales of panty hose."

—James Finke, President, Commodore International Ltd., February 1982 BYTE

"CP/M 2.2. is extremely important, and the Z80 chip will live forever because of it."

—Portia Isaacson, Future Computing Inc., May 1982 BYTE

"To be a real hacker means to dedicate a substantial part of your life to the advancement of some application of a technology. It means going behind the backs of stuffed-shirt administrators who think that, despite their inability to do the technical work, they have royal prerogatives to push the technologists this way and that to satisfy obscure, largely symbolic organizational needs.

"To be a real hacker means to make a magnificent obsession of creating some effect previously unknown, especially when others say you cannot or may not do it. You will impoverish yourself, devote your whole being to the task, and go far beyond the limits that reasonable people place on unremunerative effort."

—Lee Felsenstein, 1985

A decade of personal computer development displayed at The Computer Museum in Boston.

PHOTOGRAPHED BY PAUL AVIS