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Special report: the amazing rise of video games

DECEMBER 1982 THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC.

WHY YOU SHOULDN'T WRITE YOUR OWN SIGNAL PROCESSING SOFTWARE.

BY A.H. "STEEN" GRAY, Jr., Ph.D.
Vice President, Signal Technology, Inc.

I've been in this business long enough to know that some things never change. The "make or buy" quandary as it applies to software is a good example. "We've got some expensive programmers; let them earn their keep." How many times have you heard that when you've suggested buying a program package that seems perfectly tailored to your application?

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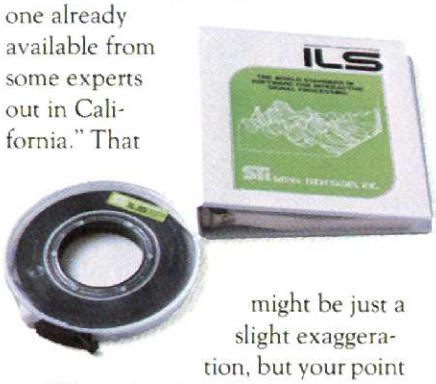

might be just a slight exaggeration, but your point would be well taken. You see, we do have the last word in interactive signal processing software. It's called ILS, and with over 200 installations worldwide, it is often referred to (and not just by us) as the "world standard."

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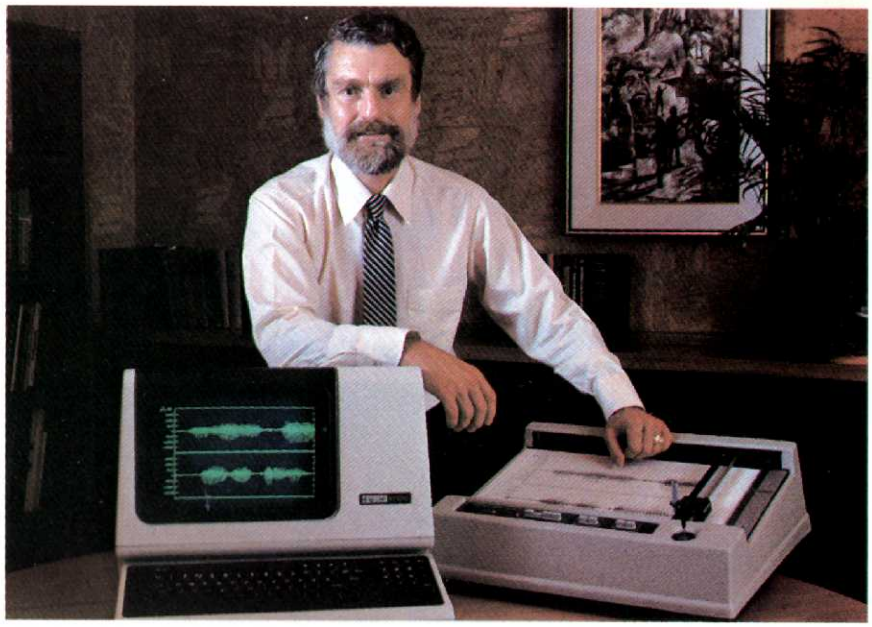
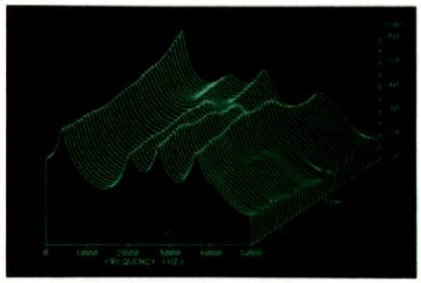
Many of our users also find DACS, our Data Acquisition and Conversion Software, and APAS, our Array Processor Application Software, of great value in their applications.



WHAT COMES OUT



With any compatible computer system and the appropriate terminals, ILS will give you: **pattern analysis—digital filtering—signal editing—3-D displays—modeling—correlation—convolution—spectral density—signal displays—coherence—** and maybe even a picture of your Aunt Sally, if that's what you want.

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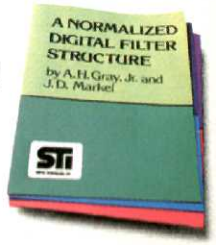
IF YOU'RE STILL WITH US

If you've read this far, you probably have some kind of interest in signal processing. I'd be delighted to send you a reprint of the series of three articles on digital filtering that I co-authored with John Markel. Write to me at the address below.



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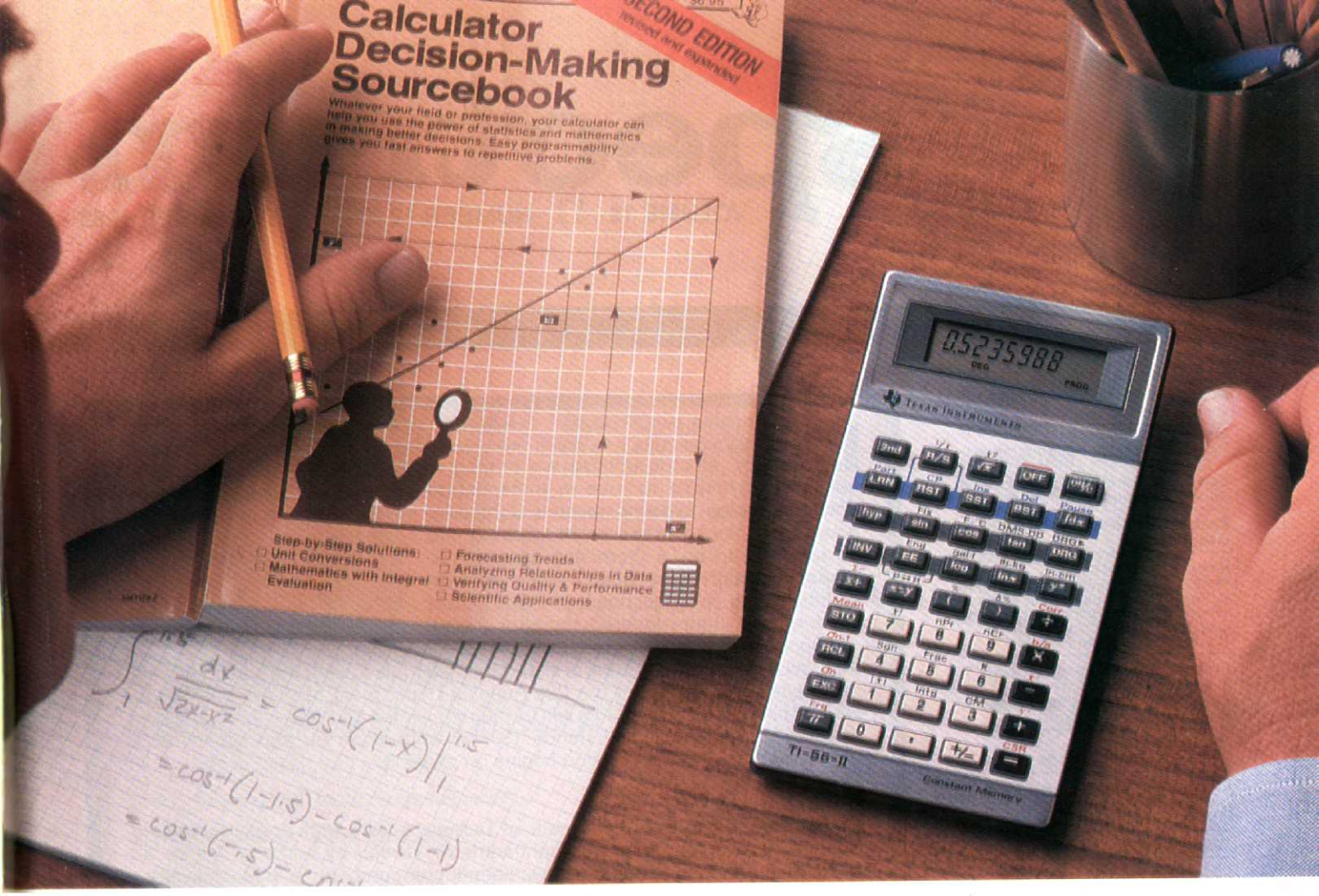

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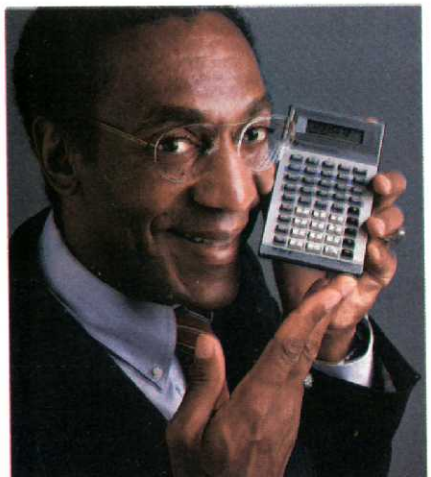

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TEXAS INSTRUMENTS

Circle No. 2

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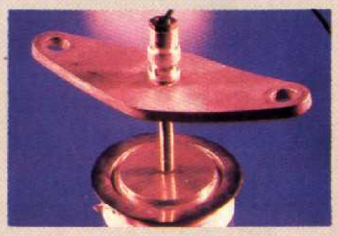
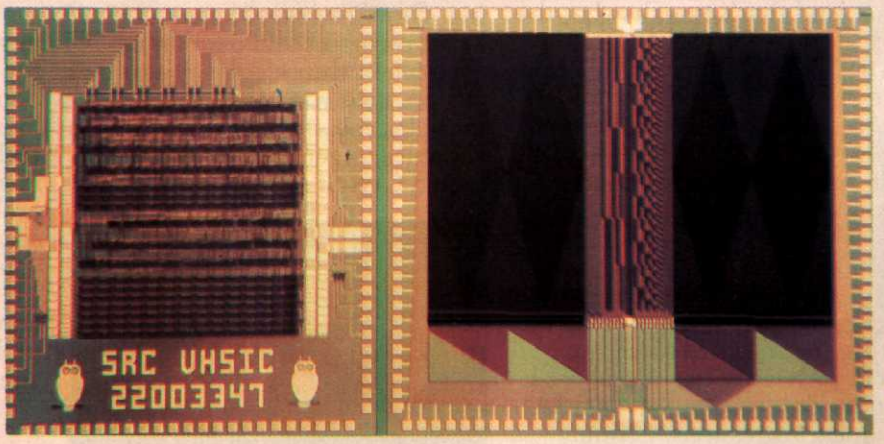


Increasingly, electric utilities are turning to advanced thyristors for use in transmission and distribution systems to control reactive power on ac lines and to convert ac power into dc and dc into ac. A promising approach to thyristor design uses light, rather than an electric signal, to trigger operation. One type of experimental light-triggered thyristor (right), developed by General Electric Co. for the Electric Power Research Institute, is slated for field trials toward the end of the year at a generating station of the Los Angeles Department of Water and Power. Several tens of these thyristors will be interconnected and then substituted for a mercury-arc valve that withstands 150 000 volts when off and passes 2000 amperes when on. A discussion begins on page 40.

In its early days, the Department of Defense's Very High-Speed Integrated Circuits (VHSIC) program was lightheartedly viewed by some critics as an inadequate reponse to Japanese semiconductor competition, a Machiavellian attempt to impose strictures on next-generation technologies or, worse yet, as an expensive way to buy esoteric chips that would never be used. VHSIC recently passed its second anniversary, and former director Larry W. Sumney reports [p. 34] that the program is on schedule and rapidly leading to a new era of silicon chips that will ensure continuing U.S. superiority in defense electronics.

Each of the six contractors is using a different integrated-circuit technology ultimately to design chips with 1.25-micrometer features. Honeywell Inc., for example, is applying bipolar technologies to develop electrooptical signal processors. Progress to date is indicated by early versions of two of the processor's components: a 2000-gate sequencer (below left) and a 96-kilobit read-only memory (bottom right). Both employ 3-micrometer integrated-Schottky-logic technology.



ARTICLES

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Large systems

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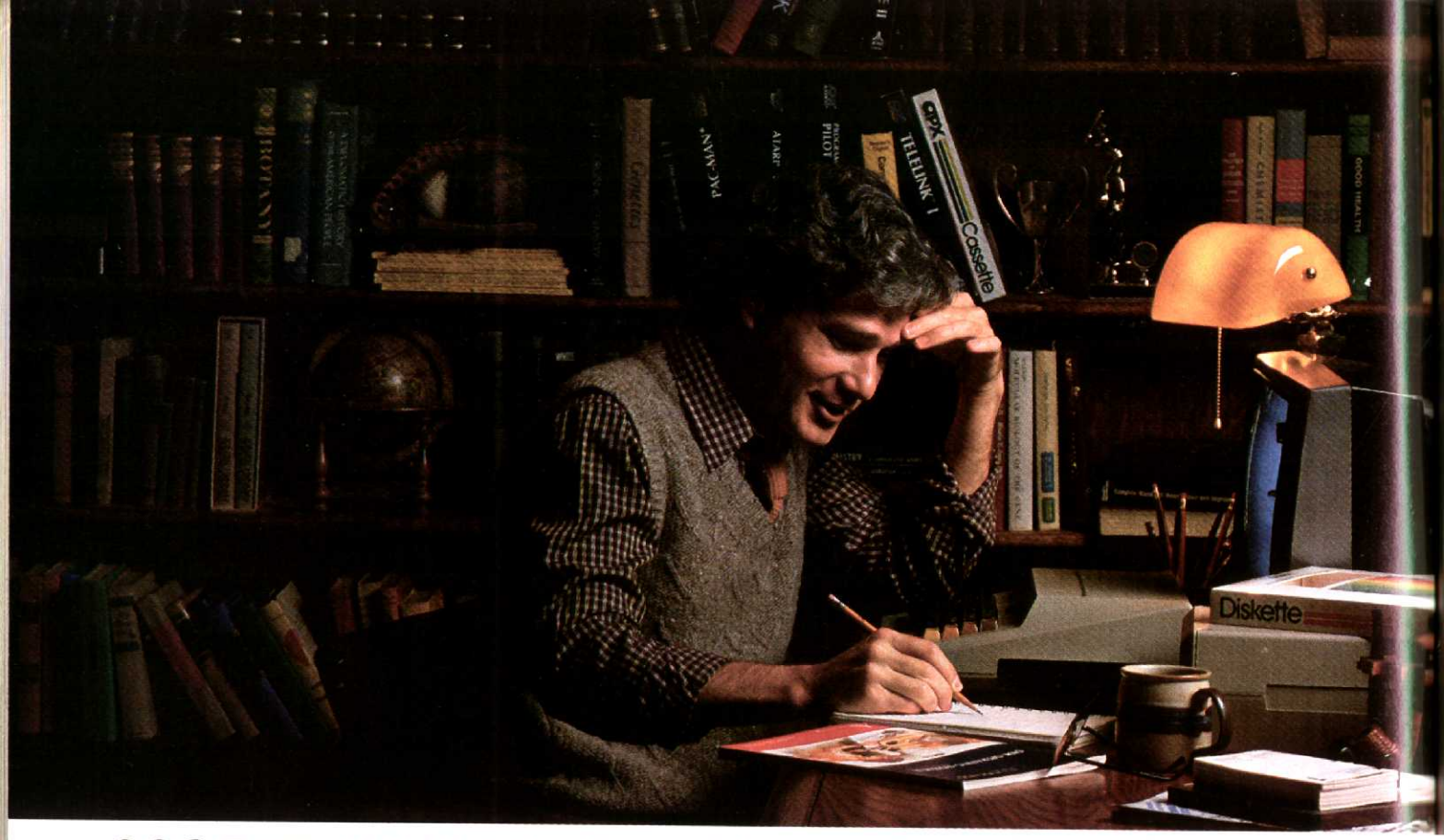
DEPARTMENTS

THE COVER

A new video game from Imagic that is played on Mattel's Intellivision home games system has just reached the market. Called Microsurgeon, it is entertaining and teaches basic anatomy. The photograph, by Imagic, illustrates outstanding graphics achieved when designers push simple hardware to its limits.
A special report on video games begins on page 20.



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Video games: the electronic big bang

The video-games industry, the design of game hardware and software, and the psychology of games are examined in this special three-part report

I. The industry: still exploding

"Hey mister, does that thing play games?" asked the nine-year-old visitor to the U.S. Patent Office's 1982 Inventors' Day show in Washington, D.C. "Well, no," apologized the representative from Westinghouse Electric Corp., demonstrating the company's advanced text-editing software for the Xerox 860 computer. "But it can teach you about English," he added hopefully. "OK," the boy decided, "tell me about that then." And for the next 20 minutes, the child sat patiently listening to a description of the program's specifications and capabilities.

Video games have accomplished what educators and personal computer companies have long attempted—they have made many children interested in computers and have introduced computerlike systems into one of every 10 households in the United States. While less than 2 million American consumers have so far been motivated to buy a personal computer, more than 10 million have purchased video-game units like the Atari video computer system (VCS).

This year U.S. consumers will buy more than 50 million game cartridges, and retailers are predicting that next year 80 or 90 million cartridges might be sold. The European market for video games, according to *Business Week*, may skyrocket from $200 million to $800 million within a year.

Responsible for this remarkable phenomenon is a relative handful of engineers and computer scientists, many fresh out of college. Called game designers, they have an uncanny knack for making costly electronics cheap and cheap electronics fun. A decade ago the first arcade game used $400 worth of hardware to execute a video game designed for a $5000 minicomputer. Today game designers are continuing that tradition of economy, using programming tricks to perform graphics wonders with the $45 worth of outdated hardware in the Atari VCS.

Only about 100 people in the United States are game designers. It takes a rare blend of talent: an artistic sense, a feel for popular trends, an ear for sounds, and, of course, engineering genius. Good game designers are in high demand by scores of companies entering the video-game industry; they are paid hefty royalties for successful games, whisked off to brainstorming sessions on remote California beaches, sometimes secreted away in hidden laboratories and sometimes promoted like rock stars, besieged by headhunters and groupies alike.

The designers are hardworking and entrepreneurial. When not putting in all-nighters in front of their CRTs or lurking around local arcades to see what the competition is doing, they can often be found plotting the start of an adventurous new company. They have shown a great predilection for leaving Atari Inc., the giant Warner Communications subsidiary in Sunnyvale, Calif., that commands more than two thirds of the video-game market.

While some of the new companies are producing arcade games and home game-playing hardware, the real money is in home software—the sale of $3 read-only memories for $20 or $30. Activision Inc., a Mountain View, Calif., software company founded in part by former Atari employees in 1979, made $13 million in profit on the sale of game cartridges last year. The Imagic Corp., another new software company in Los Gatos, Calif., has shipped 2.5 million cartridges in its first seven months of production. Some corporate giants have also entered the games software market, including such diverse companies as Coleco Industries Inc., Quaker Oats Co., and CBS. Most video-game companies also intend to produce game software for personal computers.

As competition stiffens, more creative things are being done in both software and hardware: graphics are improving; a wider variety of games is being offered to attract women; and designers are dreaming of games controlled not with a joystick, but by eye movements or brain waves. At present, low-cost phone modems are being developed to receive programs over telephone lines. New uses for games are also emerging: those like Microsurgeon [see cover] are educational; an improved version of Atari's game Battlezone has been bought by the Army to train soldiers; and games that tap particular perceptual or motor skills are being used in brain rehabilitation.

Still, video games are primarily entertainment—people play them instead of going to the movies. In fact, U.S. consumers spent twice as much this year on video games as on movies, a fact that has sent film companies rushing to Silicon Valley to get in on the action. Lucasfilm announced a joint venture with Atari this year, while MCA Inc. and Paramount Pictures Corp. opened games divisions. "Movies and games compete for the same entertainment dollar," said Albert Pepper, vice president of marketing for 20th Century-Fox's new games division, Fox Video Games, "so naturally we have to worry about them."

Movies provide good ideas for games, as well as a title that will sell. *Tron*, Disney's latest film hit, was turned into a game this year by Midway; Atari recently released a game based on *E.T.*; and other game companies are now working on translations of *Star Wars*, *Mash*, and *Nine-to-Five* (in which a player must avoid capture by her boss).

Games have a clear advantage over films—they allow the viewer to run the show. Mr. Pepper believes that the games, because they are interactive, are spearheading a new era in entertainment. The foremost reason film companies are interested in them, he said, is that "the entertainment industry is changing technologically, and we want to understand that change."

Tekla Perry, Carol Truxal, Paul Wallich
Associate Editors

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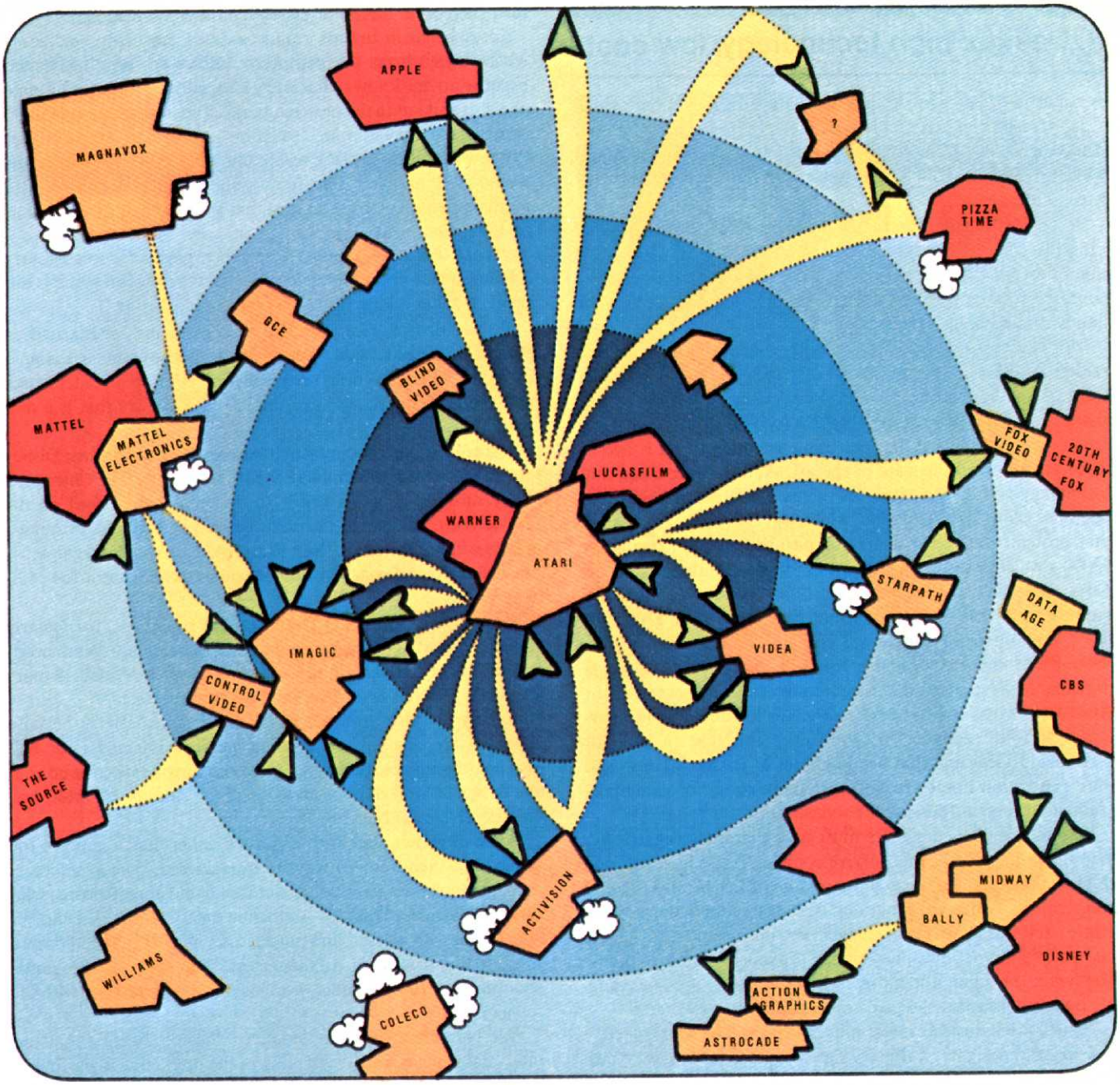


Illustration by Art Suddeth

The expanding universe of video games. *Experts calculate that the big bang occurred about 1972, and since then, the industry has grown to include dozens of companies, some of which are depicted as asteroids on the "screen" above. The size of each asteroid corresponds roughly to the size of its company. Overlapping or touching asteroids represent subsidiaries or joint endeavors; for example, Atari is a multibillion dollar subsidiary of Warner Communications and Midway worked with Disney to produce a game based on the movie* Tron.

Atari's growth over the past 10 years has been impressive—from a $500 investment in 1971 to a company controlling 70 percent of the $10 billion video games market—but perhaps more remarkable still has been the rate at which it has spawned other game companies. Former Atari employees have founded such companies as Activision, Imagic, and Videa; on the screen, those companies that split off earliest have naturally "traveled" farther from Atari than those formed recently.

Each spaceship in the drawing represents a video-game designer or executive whom Spectrum *discusses in this special report. Spaceship trails show the person's movement from company to company. For example, one ship flying from Atari to Activision and back to Atari represents designer Larry Kaplan; flying from Atari to the edge of the screen but turning back is designer Allan Alcorn.*

The tendency of spaceships and their cargo of ideas to shuttle from asteroid to asteroid has displeased many an asteroidal satrap, leading to the barrage of lawsuits and accusations represented here by puffs of smoke. Of course, some designers have left the industry completely, as shown by the ships leaving the "screen" for hyperspace.

Companies represented by light-colored asteroids are involved primarily in video games, whereas darker asteroids show companies with other main missions. The asteroid marked with a "?" represents the company that Joe Keenan, Nolan Bushnell, and Mr. Alcorn, three of the founding figures of Atari, intend to form when their contract not to compete with their former company expires in October 1983.

II. Design: high technology, low cost

A roomful of engineers watch the flight of a rocket on a small video screen. They control it with the help of a supercomputer. The year is 1969. The experience was to cost the United States $300 million. The goal was to put a man on the moon—money was no object.

A roomful of engineers watch the flight of a rocket on a small video screen. They control it with the help of a 6502 microprocessor. The year is 1979. The experience was to cost the consumer 25 cents. The goal was to put a vector generator in the hands of the public—cheap.

This latter group of engineers are video-game designers. They, said Ed Rotberg, vice president of Videa Inc. in Sunnyvale, Calif., "are finding new ways of doing things for a little money that other people have been able to do for a lot of money." They are not state of the art; they are using technology that is two or three years behind the state of the art. And they are using that technology within very tight cost constraints. An average coin-operated game, like Asteroids, which was one of the first games that brought the vector generator into the arcades, retails for $3000—which means, according to industry standards, that the parts, including all the electronics, the wooden cabinet, TV monitor, and coin safe, should not cost much over $1000. At most, coin-operated games will contain two microprocessors, some ROM and RAM, and a few TTL parts. The home programmable video game that has become an industry classic, the Atari VCS, costs $50 to make and retails for about $149. It requires software designers to write programs that fit in 4- or 8-kilobyte ROMs and that use 128 bytes of RAM. Second- and third-generation home systems have more room for game programs, but they introduce other constraints.

Besides low cost, designers must also guarantee ruggedness. Will the home video game survive a sibling battle in which one child yanks out a cartridge in the middle of her brother's game and slams in a different program? Arcade environments are not gentle to electronics either. Teenagers and businessmen have been known to pummel machines whose "invaders" destroy them. The better the game, the more excited the player becomes, and the more punishment the game must endure.

"There are industrial specs, military specs, and Atari specs," said an Atari designer. "Military specs would never survive Atari players."

But rather than stifle the industry, constraints have stimulated it. Giving a person constraints forces him to become creative, says Allan Alcorn, one of Atari's original employees and, at 35, a "grandfather" in the video-game industry. "You get more juice out of a lemon when you squeeze it," he said.

For a decade now, video-game designers have been squeezing electronics technology, and they have created a multimillion-dollar industry in the process. They are shocking engineers outside the industry by repeatedly doing what formerly could not be done. Since the first video-game company, Atari, was incorporated in 1972, the industry has proved a fertile field for entrepreneurship, and now established companies are getting into the act—companies like 20th Century-Fox and Quaker Oats. But the great majority of video-game companies were started by engineers—very young engineers.

The video-game industry is a test bed for engineering design in which there is no cookbook to design from and the research-and-development cycle must be kept short—under six months. Designs are personal. Designers admit they sometimes cannot read each other's code or even each other's schematics.

Ideas begin in brainstorming sessions, normally held somewhere away from the company. No idea is too farfetched, because no one knows what crazy idea will set off sparks in someone else and ignite the next hit game. "We talk about a Halley's comet game, for example," said Siu Kuen Lee, an Atari designer, "that would show a black screen and once every 76 years a light would flash across." This may sound farfetched, but so did a multisegmented worm—an idea that led to one of the top games of 1982, Centipede.

"Ideas can also come from other games," noted Larry Kaplan, a vice president at Atari. "To write a good game is difficult. It takes a long time, a lot of test marketing."

Robert Brown, vice president of engineering for Starpath in Santa Clara, Calif., said, "One way we choose games to design is by seeing what categories are popular in coin-op (arcade) games and trying to develop something in that category that is a new twist."

Game ideas also come from movies—directly, as when Disney got in touch with the Midway Manufacturing Co. of Chicago, a Bally subsidiary, and asked it to design a game based on the movie *Tron*. "It gets to the point where you can't get through a movie without thinking, 'Boy, that would make a good game,' " observed Bill Adams, director of games development for Midway.

Game ideas also come from real-life situations, particularly sports. "Sports games are easier to do," said Bob Whitehead, cofounder of Activision, "because they are well defined. A more original game has to evolve, so it takes more time."

Reality can also present a pitfall for a game designer because mistakes are obvious. At Atari a game nicknamed Foul Ball reached the market testing stage before anyone discovered that the designer, who did not understand the rules of baseball, was treating strikes as balls.

Some designers start with a picture rather than a concept for game play, then think of ways to interact with their graphics.

"I got interested in drawing pictures," said John Perkins, who designed Artillery Duel for Astrocade Inc., Columbus, Ohio. "I started out with a desert and put cactuses all over it, then I drew a hill and put rocks on it, then trees. The idea for the game, shooting over the mountain, evolved as a way to interact with the scenery."

One complaint of game designers who left Atari is that too many game ideas were originating in the marketing department. "A video game is a creative thing, like an artist with a palette full of colors," said Mr. Alcorn, who is still under contract to Atari but on the inactive roster. "The artist has control of the medium. I can smear paints on a canvas, and it's not going to look like a picture. Take a marketing guy, someone who is nontechnical and doesn't understand the medium. He tries to design a game, and it's inefficient."

One example of a marketer's idea for a game, Mr. Kaplan says, is Polo, designed by Carol Shaw, a former Atari designer who is now with Activision. Mr. Kaplan related, "Ray Kassar [president of Atari] was into cosmetics. 'Hey,' he said, 'cosmetics is a $4 billion industry. Why can't we get a piece of that with video games?' Warner commissioned clothing designer Ralph Lauren to come up with a perfume and put his name on it and call it Polo. They had a line of cosmetics and wanted this Polo cartridge as a come-on in the stores." The perfume was not a hit on the market. The video game was not sold.

If marketing people cannot always identify a good game, engineers are quick to admit that they cannot either. Engineers often love games that the public hates and are bored by

Pong: an exercise that started an industry

In 1971 video games were played in computer science laboratories when the professors were not looking—and in very few other places. In 1973 millions of people in the United States and millions of others around the world had seen at least one video game in action. That game was Pong.

Two electrical engineers were responsible for putting this game in the hands of the public—Nolan Bushnell and Allan Alcorn, both of whom, with Ted Dabny, started Atari Inc. in Sunnyvale, Calif. Mr. Bushnell told Mr. Alcorn that Atari had a contract from General Electric Co. to design a consumer product. Mr. Bushnell suggested a Ping-Pong game with a ball, two paddles, and a score, that could be played on a television.

"There was no big contract," Mr. Alcorn said recently. "Nolan just wanted to motivate me to do a good job. It was really a design exercise; he was giving me the simplest game he could think of to get me to play with the technology."

The key piece of technology he had to toy with, he explained, was a motion circuit designed by Mr. Bushnell a year earlier as an employee of Nutting Associates. Mr. Bushnell first used the circuit in an arcade game called Computer Space, which he produced after forming Atari. It sold 2000 units but was never a hit.

In the 1960s Mr. Bushnell had worked at an amusement park and had also played space games on a PDP-10 at college. He divided the cost of a computer by the amount of money an average arcade game made and promptly dropped the idea, because the economics did not make sense.

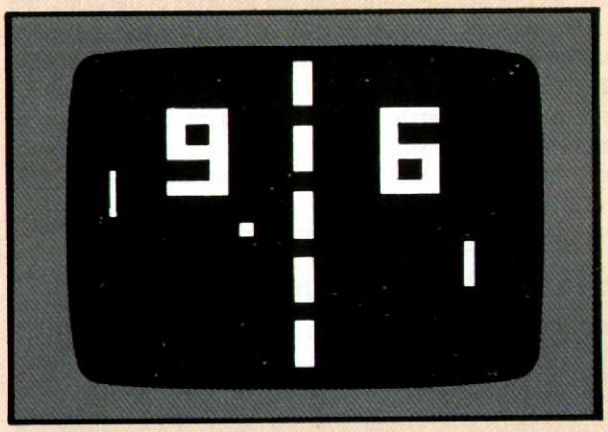
Then in 1971 he saw a Data General computer advertised for $5000 and determined that a computer game played on six terminals hooked up to that computer could be profitable. He began designing a space game to run on such a timeshared system, but because game action occurs in real time, the computer was too slow. Mr. Bushnell began trying to take the load off the central computer by making the terminals smarter, adding a sync generator in each, then circuits to display a star field, until the computer did nothing but keep track of where the player was. Then, Mr. Bushnell said, he realized he did not need the central computer at all—the terminals could stand alone.

"He actually had the order for the computers completed, but his wife forgot to mail it," Mr. Alcorn said, adding, "We would have been bankrupt if she had."

Mr. Bushnell said, "The economics were no longer a $6000 computer plus all the hardware in the monitors; they became a $400 computer hooked up to a $100 monitor and put in a $100 cabinet. The ice water thawed in my veins."

Computer Space appealed only to sophisticated game players—those who were familiar with space games on mainframe computers, or those who frequent the arcades today. It was well before its time. Pong, on the other hand, was too simple for an EE like Mr. Bushnell to consider designing it as a real game—and that is why it was a success.

Mr. Bushnell had developed the motion circuit in his attempt to make the Computer Space terminals smarter, but Mr.



Alcorn could not read his schematics and had to redesign it. Mr. Alcorn was trying to get the price down into the range of an average consumer product, which took a lot of ingenuity and some tradeoffs.

"There was no real bulk memory available in 1972," he said. "We were faced with having a ball move into any of the spots in a 200-by-200 array without being able to store a move. We did it with about 10 off-the-shelf TTL parts by making sync generators that were set one or two lines per frame off register."

Thus, the ball would move in relation to the screen, both vertically and horizontally, just as a misadjusted television picture may roll. Mr. Alcorn recalled that he originally used a chip from Fairchild to generate the display for the score, but it cost $5, and he could do the same thing for $3 using TTL parts, though the score was cruder.

The ball in Pong is square—another tradeoff. Considering the amount of circuitry a round ball would require, Mr. Alcorn asked, "who is going to pay an extra quarter for a round ball?"

Sound was also a point of contention at Atari. Mr. Bushnell wanted the roar of approval of a crowd of thousands; Mr. Dabny wanted the crowd booing.

"How do you do that with digital stuff?" Mr. Alcorn asked. "I told them I didn't have enough parts to do that, so I just poked around inside the vertical sync generator for the appropriate tones and made the cheapest sound possible."

The hardware design of Pong took three months, and Mr. Alcorn's finished prototype had 73 ICs, which, at 50 cents a chip, added up to $30 to $40 worth of parts. "That's a long way from a consumer product, not including the package, and I was depressed, but Nolan said 'Yeah, well, not bad.'"

They set the Pong 2 prototype up in a bar and got a call the next day to take it out because it was not working. When they arrived, the problem was obvious: the coin box was jammed full of quarters. —*T.P.*

games—like Pac-Man—that the public loves.

After ideas are generated and a priority list is drawn up, designers choose or are assigned an idea from the list. Perhaps half of the ideas are eventually attempted as games, says Lyle Rains, an Atari vice president for coin-op. Half of those or less are completed, he says, and half again are produced.

Graphics artists become involved, doing story boards for game ideas and working with designers to develop the graphics that will be put up on the screen. In the early days, artists were not necessary—paddles and a ball did not take much artistic ingenuity—but game graphics today have much more detail. Some programmers are artistically talented and will design their own graphics, and this can work very well because they know the limitations of the system. But Roger Hector, president of Videa and a graphics artist, says it is difficult to find people who are both technically competent and artistically creative. The solution lies in a team approach.

The first wave of attack: programming

While the artist is working on the graphics, the designer thinks about how the game will play and how the program will be written. Good designers don't jump right in and begin programming.

"A fellow started a 3-D game when I started Battlezone," Mr. Rotberg said. "He jumped in and started programming; I sat around and thought about how to organize the data. He had a lot of stuff on the screen and code generated before I did, but even-

tually he had to take it apart and rewrite it, using a lot of routines I used for Battlezone, because he ran into a brick wall; it couldn't do what he needed it to do."

After a game designer thinks out the elements of the game, the programming begins. This may take several months—of nights, usually, as game designers tend to be night people.

"The days are hard to work in," Ms. Lee at Atari said, "because it's wild, there's a lot of energy, a lot of socializing. At night people settle down to work."

Designers play one another's games during development, giving advice and also taking it if it will improve the game, even if it means throwing out four or five months of work.

In the early days of the video-game industry, companies raced to get a game—any game—into the arcades and did not take time for serious market research. Today some game companies may be leaning too far in the opposite direction. Some companies

Breakout: a video breakthrough in games

Breakout was the best video game ever invented, many designers say, because it was the first true video game. Before Breakout, all were games like Pong—imitations of real life. With Breakout, a single paddle was used to direct a ball at a wall of colored bricks. Contact made a brick vanish and the ball change speed. The game could never exist in any medium other than video.

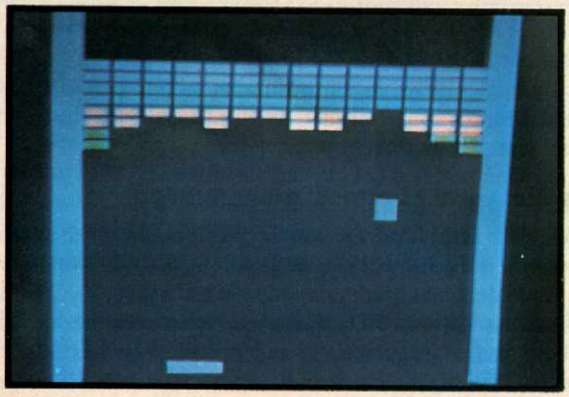
Like Pong, the specifications for Breakout—its look and game rules—were defined by Nolan Bushnell at Atari Inc., Sunnyvale, Calif. But along with the specs came an engineering challenge in 1975: design the game with less than 50 chips, and the designer would receive $700; design the game with less than 40 chips, and the designer would receive $1000. Most games at that time contained over 100 chips. Steven Jobs, now president of Apple Computer, Santa Clara, Calif., was hanging around Atari at that time. "He was dirt poor," recalled Allan Alcorn, who joined Atari at its formation. Atari's design offer was "good cash"—to Mr. Jobs. Mr. Alcorn remembered that Mr. Jobs quickly designed the game with fewer than 50 chips. He had help. He called on his friend, Steven Wozniak, who later designed the Apple computer.

Mr. Jobs had to make a trip to Oregon, Mr. Wozniak related, "so we just had four days." Mr. Wozniak went to his regular job at Hewlett-Packard during the day and joined Mr. Jobs at Atari at night. "We got it down to 45 chips, and got the bugs out, but after four days we wouldn't have done anything to get it down further," Mr. Wozniak said.

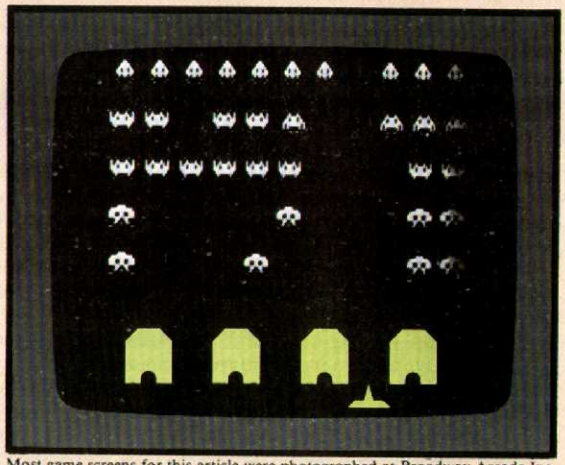
They got their bonus, but, Mr. Alcorn recalled, the game used such minimized logic it was impossible to repair.

Larry Kaplan, a designer who was also at Atari at that time, explained: "What Woz or Jobs liked to do was to design things that were parallel sequential, so at a given point in time this chip was used in one part of the circuit, and three microseconds later it was used in a different part of the circuit. It's a dream, but it's impossible to debug or produce."

Breakout sat in the Atari lab for eight months. Then the same design was reworked with 100 ICs before it was put into production. —*T.P.*



Space Invaders: the sound of success



Most game screens for this article were photographed at Broadway Arcade Inc., New York, N.Y.

While the sound of footsteps slowly growing louder may be a sure sign of impending doom in any horror film, the pulse of video game players quickens to a different beat: the drumming of approaching space invaders.

"My heart used to beat in time to that sound," says one fan of the 1978 hit game, Space Invaders. So, apparently, did many others. In Japan, where Space Invaders was invented by engineers from Taito Inc., people became so addicted to stuffing the game with coins that the government reportedly faced a yen shortage. Within a year after Space Invaders was introduced in the United States, the game could be found behind a crowd of people in arcades and bars across the land.

Designers can only speculate on why players found Space Invaders so engaging. Perhaps it was the predictable march of the aliens; if a player was annihilated, he could not blame bad luck—only himself. Next time, he swore, he would do better. Or perhaps Space Invaders was a hit because it was among the first games with "character"—a player did not just move blocks around; rather he was on the screen, a lone earthling besieged by approaching aliens.

Most gripping, however, was the sound. The more aliens a player shot, the faster they approached; their drumbeat quickened, the tension mounted. Ironically, says Bill Adams, director of game development for Midway Manufacturing Co., of Chicago, Ill., which licensed Space Invaders for sale in the United States, these features of the game were accidental.

"The speeding up of the space invaders was just a function of the way the machine worked," he explained. "The hardware had a limitation—it could only move 24 objects efficiently. Once some of the invaders got shot, the hardware did not have as many objects to move, and the remaining invaders sped up. And the designer happened to put out a sound whenever the invaders moved, so when they sped up, so did the tone."

Accident or not, the game worked. As of mid-1981, according to Steve Bloom, author of the book *Video Invaders*, more than 4 billion quarters had been dropped into Space Invaders games around the world—"which roughly adds up to one game per earthling." —*C.T.*

"field-test a game to death," Mr. Rotberg said. "They are so unwilling to let a game go that the timing of its release is all screwed up," he said. Minimum testing of three months is obligatory, he said, "but it can go to nine months—or years. At some point you have to say, 'I'm done with this; it may work or it may not, but I'm not going to put any more into it.' "

Coin-operated games are most often tested on location, and the bottom line is simple: people vote with quarters. Designers and marketing experts watch people play the game and ask them what they like or do not like, then send the game back to the laboratory for changes based on those comments. They watch the timing of the game—arcade games are geared to take the average player 90 seconds to complete. If players lose too quickly or can play too long, the timing is changed. They watch to make sure the player understands the game.

For example, in Tron a joystick controls the movement of the cycles, and a trigger that would normally fire a missile controls the speed. Watching it in the first field test, Bill Adams of Midway said they noticed that people did not realize the control was for speed, so they added a series of instructions in text. "We were fun and there was time to do them, Mr. Rotberg said.

"Early in the game there is a lack of a sense of urgency," he noted. "You can stroll around and blow tanks up or not. A modification would be to give you a goal other than blowing up tanks."

If he had the game to do over again with today's technology, Mr. Rotberg said, he would change it even more: instead of a monochrome display, a color vector display could be used, and newer microprocessors and cheaper memory could add realism and complexity.

Mr. Rotberg did do a version of Battlezone with added realism and complexity, but only under duress. It is called Army Battlezone, and it features a rolling landscape and images of U.S. and Soviet tanks. A company under contract to the Army to find training uses for video games approached Atari just as Battlezone was going into production, Mr. Rotberg said. He related:

"They had no idea it existed, saw it in the lobby, and said, 'That's what we want.' And someone at Atari said, 'We could make it just what you want.' This was in December. They said the Army was having a meeting of the training centers in March, could Atari make it to their specifications by then?

"I said I didn't want anything to do with the project. I was vehemently against it, but it became readily apparent that there was no one else familiar enough with the software in Battlezone to make the modifications by March. We had a formal brainstorming session, and I got into a loud shouting match with Joe Robbins, then president of Atari's coin-op division, about Army Battlezone. I felt one of the reasons engineers worked for Atari instead of working for the Government or for a corporation doing Government contracts was that it (military) is not the kind of work we want to be doing. And with talk about games being violent and molding the minds of children, it couldn't possibly be good press.

"I ended up losing three months of my life, spending every waking minute at Atari, coming home at 1 a.m., going in at 6 a.m. The game got done." —*P.W.*

Battlezone: war in 3-D

Three-dimensional displays first appeared on computer screens in the 1960s, and very large machines could manipulate those images in real time, but it was not until 1980 that a video-game player could maneuver at will through an imaginary landscape, wreaking havoc until brought to an untimely end by enemy tanks. Battlezone, a first-person tank game, was made possible by a vector display unit used by Atari Inc. Sunnyvale, Calif., in Asteroids, which came out the previous year.

Even with the vector generator, according to Videa's Ed Rotberg, who wrote computer code for the game, Battlezone required three microprocessors: a 6502 to control the game play, a custom processor for the display, and another, built from 2901 bit-slice processors, for the mathematics. The display generator and the game microprocessor operated in parallel, communicating by instructions left in a common memory area, and the math processor operated either in parallel or in sequence with the others.

"It was pretty fast," said Mr. Rotberg. "Quite often it wasn't worth going off and doing something else—you just waited for the math box to finish."

What the math box in Battlezone does is to solve the matrix equations for vanishing-point perspective for all of the objects on the screen. To bring the problem within reach, the game is restricted to movement on a horizontal plane, reducing the matrix from 4 by 4 to 2 by 2. Much of the early work in designing Battlezone, Mr. Rotberg said, was involved in "figuring out how to organize the data."

Because Battlezone is a vector game, objects consist simply of points connected by lines, rather than entire filled regions, as a raster game would have. Even so, controlling the number of objects on the screen stretched the abilities of the three microprocessors, and Mr. Rotberg had to go to his graphic designer, Roger Hector, who also helped define the game play, to ask: "Could you do the same thing in less lines, less vertices?"

Although Battlezone does not deal with the hidden-line problem, it does use diminished brightness to indicate distance, and, like any vector-drawing system, it must cope with the problems of clipping—that is, deciding what objects are on the screen and what to do about objects that are partly on the screen and partly off.

"We did an end run around the problem," said Mr. Rotberg. "The hardware lets you draw about half a screen off each side, which helps considerably. You calculate where the center points are and determine whether or not you're going to display an object, and if you are, you draw all its lines regardless of whether or not they'll be on the screen."

There is only one problem with this approach: if an object is very close, it may suddenly disappear from the screen, because its center point has moved off screen, even though some lines should still remain on the screen. But, noted Mr. Rotberg, "if we didn't do it that way we'd be instructing the vector generator to draw lines past where it could, and it would go off into the ozone."

Battlezone took 15 months to develop, from the beginning of design to production. Some features, like an erupting volcano on the horizon, went into the game because they

generally don't like to use text," said John Pasierb, vice president of engineering at Midway. "Ideally we want someone to just be able to walk up and know how to play the game."

Some coin-operated games and some home games are tested among what marketing people call focus groups. For test subjects, game companies call on consumers who mailed in the guarantee cards that were enclosed with home games, or company representatives simply walk into arcades and offer children and adults $10 to accompany them to the company's offices to test a new game. The subjects play the games and are watched by designers, then they are asked in a group what was fun and what was not.

"You watch the kids' reaction to the whole game," Ms. Lee said. "And their response to the controls, whether they understand the movement, how they react, how fast," added Carla Meninsky, an Atari designer.

Games are also tested informally among the children of the designer's friends and family. One problem is testing the game at high scores. Many designers do not have the skill or patience to play the game for eight hours, so they must rely on a willing child to find the bugs that crop up at 900 000 points.

Designers test one another's games. Rick Maurer, who designed the home version of Space Invaders for Atari, was good at the game Missile Command and was asked to demonstrate it at a trade show. "I got the highest score I ever got," he recalled, "eight hundred and something thousand, and I found that there was a bug at 812 000—with all these operators watching. No one had ever gotten that high."

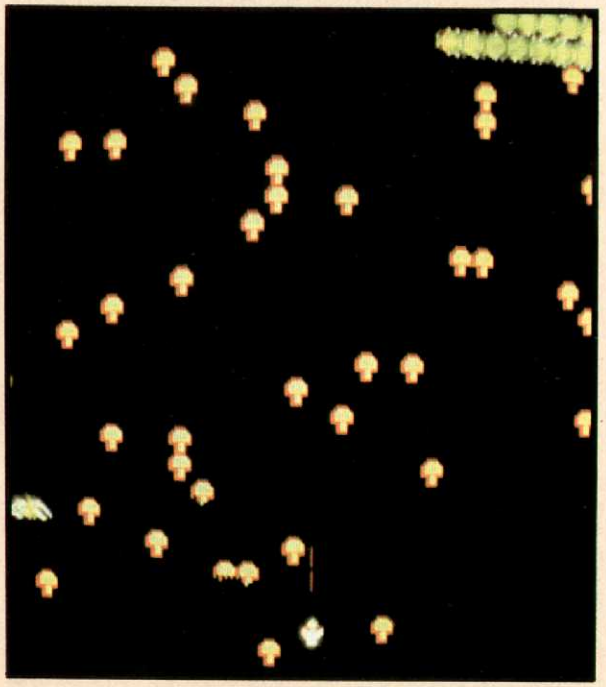
Centipede: the worm that turned a trend

Dona Bailey, who recently left Atari and joined Videa Inc., is apparently the only woman who designs coin-operated games in the United States today, though a few other women design home games. Centipede was her first attempt, and it was a smashing success. She attributes it to beginner's luck, a series of accidents, and intution.

"When I got to Atari, everyone was doing a space game or a war game," she said. "I didn't want to do either. I thought games could be more attractive, but I didn't know what to do, so I didn't say anything. I was supposed to do a laser game, and I didn't want to do it.

"Atari kept a notebook of game ideas, and there was one sentence—a multisegmented worm comes out, gets shot at, and breaks into pieces—that I kept coming back to. It wasn't that a worm was attractive, but it was the only different idea in the whole book. So when a few people said maybe we shouldn't do another laser game, I said, 'Did you see that worm?' "

"Designing Centipede—it was always called Centipede—was a logical progression; nothing got taken out once it got put in, which is rare. For example, I wanted to make sure I was turning the centipede in the right places as it moved across the screen, so I put some visual markers in to help me program—just little dots. People came in and said the dots were really dumb, and I should make them rocks. I never intended to leave them in, but it made the screen a maze, and it was better. I didn't like the idea of rocks, so I started fooling around with graph paper and came up with the mushrooms.



"Then I wanted something that was more threatening to the player, something that came closer to the bottom of the screen. I thought of a spider, because I've always been scared of spiders—when I see a spider I think it's coming to get me. I did the spider over the Thanksgiving holidays. And I fooled around trying a bunch of different movements for a week.

"They were all crummy. Then I hit on the idea of making the spider bounce up and down—it looked like bouncing on one thread of a web. I was so happy."

Except for the spider, the sounds of Centipede were done by Ed Logg, a designer at Atari. "All the sounds were deep," Ms. Bailey said. "I wanted something higher-pitched so I did it."

Reviews of the game Centipede focus on the "incredible colors" that stand out; they are different from anything in arcades. "At first Centipede was black and white," Ms. Bailey recalled, "but Missile Command came out eight months earlier, and it had colors, so I wanted colors. I argued for a long time and finally got the eight standard primary colors. I said that wasn't enough. I wanted more colors, like purple, because there was a fashion craze then for purple, and I was always wearing purple and brightly colored clothes. They never had a female programmer before, and they teased me as if I were from a different planet.

"I kept asking for different colors, and only my technician would listen. He came up with a different set of really bright colors, but I wanted some pastels. One day he was standing behind the cabinet, tweaking the resistors, and by accident he hit on an astounding set of colors. I said, 'Stop!' He hated the colors and wanted to change them back, but I wouldn't let him. For days I sat around playing with new color combinations. People would come look and say, 'Blah!' Even after it did well, the other designers kept saying 'Blah!' but women tell me they like the colors."

Another thing reviewers like is the simple trackball control used to play Centipede. "They didn't want me to use a trackball," Ms. Bailey explained. "Ed was really big on buttons. He thought if you give people enough buttons to keep their hands busy, they'll be happy. I thought that with all those buttons, I wasn't going to be able to play it—I never could play Missile Command or Defender—and I had to play it to program it. On top of that, people who looked at the game thought I might be designing a little kids' game—and little kids can't handle a lot of buttons.

"For a while it had a joystick, but that was awkward, and I think controls should be natural. I finally convinced them to try a trackball, just so I could use it while I was working—the game was produced with a trackball.

"Since Centipede did so well, Atari has started seeking designers who are into things other than space and war." —*T.P.*

One of the great challenges for the video-game designer is to program something that has never been done before. Compared with more mature industries, there is still far more revolution here than evolution. Limited to relatively tiny amounts of memory and processor time, the designer turns to ingenious ways of "scrunching."

Beating the hardware: the tricks

In hardware design, scrunching usually means designing a system without flexibility. "You tailor to your end product," Mr. Rotberg noted. "You make as many assumptions [about how the end product will operate] as you can to reduce the amount of work you have to do and the amount of work your hardware and software have to do."

His partner at Videa, Howard Delman, said, "You accept certain quirks and certain restrictions that—if it's designed right—won't show up in the game. If you have an idea what the end product is, you don't need to make it any faster than it has to be or add any more RAM than you have to have. And you can decide what you can live without."

Using this method, Mr. Delman, when he worked for Atari, designed a black and white vector generator that cost, Mr. Alcorn says, $150 to make at a time when the cheapest commercial vector generators cost $2000 to $3000. Mr. Delman used only a discrete microcode processor made of TTL and some hi-fi operational amplifiers to control the electron beam on the screen. The "scrunched" generator ran at 50 kilohertz, compared with 4 megahertz for commercial-grade components, but it still drew enough vectors for video games. The first game programmed in this system was Lunar Lander, in which a player attempts to guide a lunar module to the surface of the moon without crashing. The next became the hit of 1979—Asteroids, in which a player controls a spaceship and tries to blow up asteroids without getting hit.

The most popular method of cutting the costs of game hardware is to transfer functions to software. This has been possible since 1976, when the first microprocessor-based game was produced. The best examples of software virtuosity are not in coin-operated games, where a programmer can bargain for more capable hardware, but in home games, where 4 kilobytes of code must wring wonders from a chip set designed only to support Pong, Tank, and Jet Fighter games.

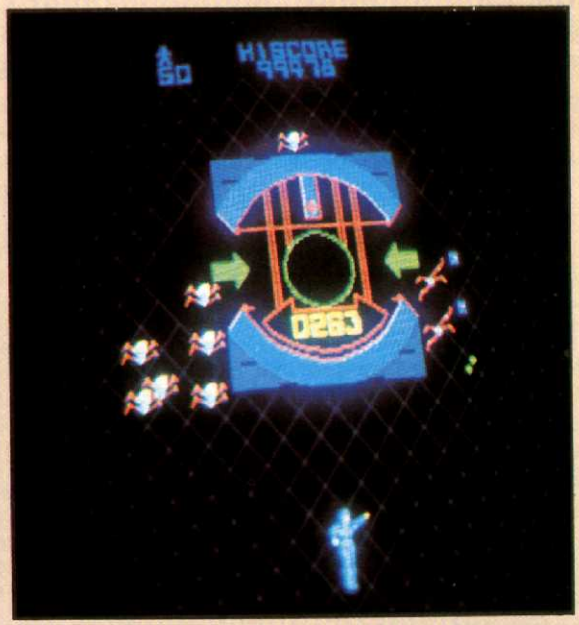
Home-game programmers are pushing the hardware beyond the wildest dreams of those who designed it. The Atari VCS has done 25 times as many games as its designers ever expected it to do, and programmers say they have only gone about 80 percent of the way toward fully exploiting the hidden capabilities of the hardware.

Different systems have different tricks. Microsurgeon, the game for the Intellivision home system produced by Mattel Inc. of Los Angeles, Calif., displays the internal workings of a human body and puts more detail on the home screen than seen previously [see cover photo]. The designer of Microsurgeon, Rick Levine of Imagic in Los Gatos, Calif., developed an algorithm to compact the screen information for 10 entirely different frames that move smoothly from one to another.

"I'd say I shaved off about 60 percent of what it would have taken without the algorithm," Mr. Levine said. He "cheated" in two ways: he spent a month working with an artist to design a character set to represent the different parts of the body, such as one character for brain cells and one for lung tissue. (One character, he says, has his name in it.) Then he assembled tables with multiple cross-references so that the characters for each screen could be stored in compacted form. He envisions using this same type of logic for future games, perhaps for geographic representations, with no two sections of a map alike, but some figures, like mountains and lakes, repeated in different places.

While designers have a stack of programming tricks to work from, they must be good magicians to pull them off. Pac-Man, while the biggest hit in the history of arcade video games, is widely considered to be the worst implementation in the history of home video games. The noticeable flicker of the ghosts that chase Pac-Man in Atari's version for the home is particularly disturbing. The arcade game uses entirely different hardware that can

Tron: the master control program takes over



In the Walt Disney film *Tron*, an evil Master Control Program schemes to take over the Pentagon and the Kremlin, telling its human henchman that it can run them 900 to 1200 times more efficiently. In the Midway Manufacturing Co.'s Tron arcade game, a master control program, known as the executives, makes more efficient use of game programmers' time by taking care of all the routine functions of accepting quarters, recording game scores, switching between players, and displaying messages on the screen.

Before the standardized executive was developed, programmers would write the computer code for each game from scratch. The executive allows them to concentrate on writing the code for the game play, which is unique to each game.

While the executive must be altered somewhat for each game, it still saves a great deal of time. For example, when a new weakness is discovered in arcade games, it only needs to be dealt with once, according to John Pasierb, vice president for engineering at Midway.

"We were having a problem where if someone tampered with the game by turning the power switch on and off really quickly, our battery backup didn't maintain the information," noted Bill Adams, Midway's manager of software development. "Normally you can turn one of our games off, come back two weeks later, and it will still remember all the high scores.

The solution was to change the software, Mr. Pasierb said, adding, "We did this in the executive, and that solved the problem in all the games."

The same executive was used by Midway in one game before Tron, and it is now being used for all arcade games the company has in production. Copies of the code have also been distributed to freelance programmers who develop games for Midway. —*P.W.*

display multiple objects, without resorting to software tricks like flicker. The arcade game costs more, of course—$3000 retail versus $30.

In using the flicker, the Atari designer was applying—clumsily, other designers say—one of the older tricks in the industry. The VCS is designed to display two players, two missiles, and a ball, but programmers learned early that twice as many objects could be displayed by showing different objects on alternating frames. Taking out every other frame in a movie makes the picture flicker. The same is true in video games, but doubling the number of objects permitted games that were not possible before, so sacrificing a little clarity was worth it. With flicker, games like the first consumer version of video baseball, Home Run, became possible.

Since Home Run, a refinement of the flicker technique has been developed that allows four, six, or more objects to be displayed on a screen without flickering: Carla Meninsky, a designer at Atari, showed four objects on the screen in her game Warlords by restricting their movements within a given area. "But it was difficult to design," she commented. "It took six months." Pac-Man, other designers say, was done in a few months.

"He took the lazy route," Mr. Kaplan said of the designer who was assigned to convert Pac-Man from an arcade game into software for Atari's VCS. The Pac-Man designer used one of the VCS's player objects as Pac-Man and the other as the four ghosts. Each ghost is displayed only once every four frames, and so the flicker is very noticeable—and disturbing.

Improving design scores: the tools

Besides their own ingenuity, game designers have a few tools that they can use. First, there are the development systems, which allow programmers to write complex game software. A small

The game designer: an artist-engineer

There are only about 100 game designers in the United States, according to most estimates, and perhaps 20 are truly creative state-of-the-art designers. The video-game companies search constantly for more talented designers. What makes a good one?

"You have to be a good engineer," said William Grubb, president of Imagic Corp. of Los Gatos, Calif. "You have to have specific knowledge of that microprocessor you're working with, and that comes from formal education and experience; it takes time to learn the idiosyncrasies of the system. And you have to be able to combine art with engineering, to be able to understand what is fun, what will titillate your market. Not every engineer, used to thinking logically, has that ability."

Dona Bailey, who designed Centipede for Atari Inc., Sunnyvale, Calif., agreed, saying, "There's a lot of trendiness and pop culture that goes into games. Many programmers have trouble with that, so they can't do games."

According to an Atari promotional video tape, a designer has to be an engineer who is also an artist and a musician. "You can't do games if you are a scientist type; you have to think artistically of what the computer can do," one Atari designer said. "I'm creating a world in which my game will live."

People move into the games industry from many engineering places—automotive, electronics, instrumentation, large computer systems, defense, and semiconductors, to name a few. Many engineers join the industry straight out of college.

Game designers are difficult to stereotype. "This industry takes all kinds," said Allan Alcorn, one of Atari's first employees. "You must have the ability to work with some very perverse people, because the best take strange forms."

On one end, he said, are people like Steven Jobs, now president of Apple Computer. "He showed up on our doorstep, and the personnel lady said we should either call the police or hire him because he's brilliant," Mr. Alcorn recalled.

Harold Lee, who designed the first game on a single chip for Atari, "came out of the hills of Los Gatos dressed in leather like a Hell's Angel and said he was going to work with us," Mr. Alcorn continued. "He drove a chopper to work and drank Ripple wine."

On the other end of the spectrum are people like Robert Brown, a former Atari employee who is now executive vice president of Starpath. He "has a Ph.D., is bespectacled and a very straight guy," Mr. Alcorn noted.

Once designers get into the games industry, it is hard to imagine them doing anything else. Brian Johnston, a designer with Fox Video Games, San Jose, Calif., said, "I've thought it might be fun to come back in the next life as a rock 'n' roll singer, and video games seem as close as I'll get to that in this lifetime."

Are video-game designers the new generation of pop stars? There is no consensus in the industry. Activision Inc., Mountain View, Calif., promotes its designers heavily, with names and pictures attached to anything associated with their games. The company's president, Jim Levy, a former record company executive, said he considers game designers "rock stars."

Atari, on the other hand, never willingly releases the names of its game designers, some say for fear that they will be hired by another company. The Atari designers would like a little recognition, so they often bury their names in their games. It takes work and may use memory that could have been used for additional game features, but they consider themselves artists, and artists sign their creations. Atari used to review games and take the signatures out; they have stopped that policy. Designers learned to hide their tracks and beat the censors anyway.

Larry Kaplan, Atari vice president of product development, says he signed Superbreakout for the Atari 800. After a certain sequence of keys the screen displays "I love Suzie and Benji too." He lists other signed games for the Atari VCS: Adventure, with Warren Robinett's signature in a secret room; Yar's Revenge, with Howard S. Warshaw's initials appearing at one point and ending the game; Defender, with the attackers turning briefly into Bob Polaro's initials very late in the game; and Missile Command, with Rob Fulop's initials appearing if the player loses the game immediately in game 13.

Most designers prefer the way Imagic Corp., Los Gatos, Calif., handles designer publicity: the designer's name is on

Ray Kassar, president of Atari, once told reporters his engineers were "high-strung primadonnas," but he knew how to deal with them. The engineers answered with a T-shirt, displayed by Allan Alcorn.

company called Future data, which was absorbed by GenRad in Los Angeles, Calif., manufactures a development system for the 6502 microprocessor in the VCS. This development system is used by Imagic and some other companies that make VCS-compatible software. The system is considered to be vastly better than the VCS development system used at Atari and Activision. Imagic reverse-engineered the Intellivision system and produced a development system called the Merlin.

Some companies do not have many tools besides the development system. "Atari is in the Stone Age," Ms. Meninsky quipped. "They give us a chisel."

Some other companies have more tools. At Imagic, one game designer, Dave Durran, specializes in sounds; he designed and built a sound development system to make his job easier. At Videa the designers have created their own graphics painting system to create displays that can be implemented in game hardware. At Midway the programmers have developed a series of programming codes that, with adaptation, can be used in a number of games. Few other companies have any systematic way for programmers to reuse code, though designers say they will flatter another designer by admiring a certain effect, then ask to borrow a piece of code.

At one point an attempt was made to develop a game language. Brian Johnston, a designer at Fox Video Games in San Jose, Calif., once worked for a company that was developing games for a number of coin-operated game companies; he decided that a game language might increase productivity. It would not get away from the assembly language that commercial games are written in completely, he says, but it would deal with portions of the code that are not time-dependent.

"Because each game was so individual, it didn't end up being practical," he said, "and we spent as much time writing assembly language code as ever. I'm not sure it will ever work because as fast as processors get, programmers are going to be pushing the state of the art to the limit to get spiffy effects, and that takes it out of the language of the everyday."

The next game: better graphics

As game designers eye the future, they see no limits, but rather steadily improving technology that will allow better and better arcade games for the same quarter a play. The games of the future, they say, will allow the player to create his own environment, his own monster, his own playfield—to make his own game because no two players are alike. It will involve the player's entire body. Richard Maurer, a designer at Blind Video in Mountain View, Calif., envisions a gladiator game, in which the player uses a sword to fight a lifelike gladiator that is electronically generated, perhaps holographically—one that watches your moves, analyzes them, and fights back.

The designers list new technologies that will be used in future video games. One possibility is a hybrid of color vectors and raster scans, with vectors doing fast-moving objects and raster graphics filling in the background. A vector generator can render a line drawing of an object, given end points. A raster display uses scan lines, like a television. This setup is envisioned by Cliff Perry of GCE Vectrex in Santa Monica, Calif.

High-resolution video monitors and declining memory costs will lead to high-resolution games, Mr. Rotberg said. Video disks represent a big potential in games, he adds, though right now they are too expensive and difficult to produce.

Mr. Alcorn said that video-disk players are poorly engineered for real-time access but that in time an industrial video disk, with reasonable access time, will find its way into video games. In fact, he says, Atari is working on something like that now, although "it probably won't admit it." At a recent trade show in Japan, Sega Enterprises of Los Angeles demonstrated a video-disk-game prototype.

Robert Ogden, president of Action Graphics in Cary, Ill., does not see a future in video-disk games; he predicts that high-resolution, real-time video animation will become cheap enough to replace video disks except for some static image storage. "You create the image with video cameras and then digitize it," he said. "Then you can take people beyond a couple of stick figures running around and into a fantasy world, where they can really get involved."

Some designers think the geometry engine, being designed by James Clark at Stanford University, is going to make a big impact on video games. The engine provides so much power for the generation of graphics that a game could contain solid raster 3-D instead of vector 3-D. The engine is being designed for ultimate

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the box and the cartridge, but representations of game characters, rather than the designers' names, appear in the advertisements. Mr. Fulop, who left Atari for Imagic, said, "I signed my games at Atari, but I don't anymore. My name is on the box. I don't have to put it in the game." At Imagic, Mr. Fulop designed Demon Attack. It was named Game of the Year for 1982 in the Arcade Alley awards, the game industry's Emmy.

Not many women design video games—perhaps four or five in the United States. Imagic, among others, is actively seeking women designers, however.

Siu Kuen Lee, a woman designer at Atari, theorized, "Until recently, designing video games was not thought of as a 'real job.' Women in technical fields work very hard to be taken seriously, so perhaps that is why they don't apply."

She also said Atari management has trouble hiring women because they have a hard time believing that women really like video games. Dona Bailey, a game designer who recently left Atari for Videa, agreed. "When I went to Atari at first," she said, "I don't think they really believed I like games. They kept asking me, 'Are you sure you want to do games?' and I kept saying, 'Why else would I be here?' "

Engineers who would like to try their hands at video-game design but do not want to apply formally at a games company can break into the industry as freelancers. Game programs written on a home computer can be submitted to established companies for consideration [see 'To probe further" for addresses]. If the company chooses to market the game, the freelancer gets royalties of 10 to 15 percent. Most companies will do no more than help polish a finished game and then market it, but one company, Action Graphics in Cary, Ill. goes further.

"We provide a creative center," said Robert Ogden, president of Action Graphics. People show Mr. Ogden a game they have created on a home computer. He looks at the concept, its polish, professional touches, attention to detail, and programming style. Everything must be tight and efficient. If he spots talent, he discusses potential game ideas with the programmer, agrees on a concept, sets the programmer up with a development system, pays him an advance against royalties, and handles his medical benefits and insurance.

Games in progress travel via phone lines to Action Graphics' computers, where other designers play them and provide feedback and graphics. Sound specialists add their talents. When the game is complete, Action Graphics handles production and marketing.

"Many times a creative engineer can't live in a corporate environment," Mr. Ogden said. "We allow the designer to choose his or her own environment. It is my responsibility to make sure that the person out there is totally serviced, has all needs provided, and gets the creative feedback necessary to make a product. —*T..P.*

graphics at a cost of over $3000. But designers are sure there are ways to do circuit boards cheaper and predict someone in the game industry will bring down the cost of the geometry engine.

Mr. Hector at Videa pointed to infinity optics as a technology that also will be feasible but not for a long time. "It's really expensive to create a large, precise, spherical mirror you can manufacture in quantity," he said. "The cost-effectiveness tradeoff has been a barrier so far. I'm convinced it will happen, but somebody is going to have to be really clever to get around that barrier."

Controls are not expected to change too much, as people understand familiar controls best, and because of the environment the game must exist in, very sophisticated controls would likely fail. An arcade is noisy, so voice inputs are difficult, though they have been done. Touch-sensitive screens would have to endure the pounding of a frustrated player.

Currently, many in the industry look to Videa as the expected mother of innovation. Another possible birthplace of the next generation of games has not been created yet—but will be in existence a year from now. Three of the key figures in Atari's remarkable success—Nolan Bushnell, Allan Alcorn, and Joe Keenan—left Atari under contract not to work on video games for five years. That contract expires in October 1983. "There will be a new video game company formed with certain people," according to Mr. Alcorn. "We're thinking of calling it Irata, which is Atari spelled backwards."

Mr. Bushnell declined to comment on the future of video games because, he said, "I'm going to make a lot of money on it." But he and Mr. Alcorn both talked about the wide-open possibilities of computer simulation and believe that the economics of a realistic flight simulator merged with a video game are feasible. At least one Federal Aviation Administration official has already expressed interest. In a few years pilots-in-training may be able to log some of their training time in an arcade.

And then there is Atari, still the biggest and wealthiest company in the industry. It has not done much in the way of innovation in the last few years, observers say, because its experienced designers have left. But during those years a young staff of designers has been getting experience; they may play key roles in the future of video games. In addition, Larry Kaplan, part of the first wave of Atari designers who left in 1979 to form Activision, has returned to Atari as vice president. He said that Atari's recent problems, basically the managing of creativity, are not much worse than problems in the rest of the industry. Atari has empowered him to make some major changes, Mr. Kaplan said—and that could put Atari solidly back in the game.

III. Psychology: mind and matter

The attraction video games have for some players borders on addiction: What are the psychological factors that incite people to play video games, and what may be the implications of widespread game play?

"Some well-designed research is needed to evaluate this, and to my knowledge, it's not being done," said Randall Weingarten, a psychiatrist in Palo Alto, Calif., who has begun researching the psychological basis and possible effects of video-game playing. He notes that some projects are under way using video games to treat brain-injured patients [see "Video games aid the brain-injured," p. 32], to help diagnose depression, and to measure the effects of certain drugs on the central nervous system and the brain. Some companies do motivational research as part of the market testing of video games, but controlled studies on video games are lacking, according to Dr. Weingarten.

Video-game designers have some ideas about what attracts people to games. The most basic one was expressed long ago by Mr. Bushnell, who helped found the industry: video games should be easy to learn and hard to master. Novices should be able to walk up to a game, drop in a quarter, and get some gratification, and experts should walk away knowing that next time they will do better.

"What makes a game addictive," according to Ms. Meninsky of Atari, "is that your own stupidity got you and you could do better next time."

Good video games provide continuing satisfaction with a learning schedule—a series of discoveries and strategies that evolve as one plays, said designer Roger Hector, president of Videa. Learning also comes subliminally because patterns are built into games, explains Brian Johnston, a senior game designer at Fox Video Games Inc., San Jose, Calif. "The patterns may not be obvious," he said, "but you begin to develop a feel for what is going to happen next because there is a pattern that may be complex, but you begin to understand it, to anticipate the movement. It's not totally random; it's learnable, and people delight in that. There are so few places in the world where you can see yourself making progress and learning something new."

The increasing rewards of learning strategies for game play bring with them increasing difficulty and tension. Tension comes from increasing speed, from sounds, and from factors that people cannot define—but know when they see them.

Games can also give you that rare sense of beating a computer. Before 1979, two-player games were popular, pointed out designer Ed Rotberg of Videa, but since then they have died out. "When you beat your buddy, it's only as exciting as the abilities of your buddy. It's not the same as when you beat a machine."

"We philosophically want to max life," theorized Larry Kaplan, now a vice president at Atari, "but we can't. You can max a computer game; you can get a perfect score."

The primal attraction

Video games also attract people because of their visual effects. "A light source, such as a video monitor, is inherently more fascinating than any source of reflected light," according to Tim Skelly, a freelance arcade designer currently under contract to D. Gottlieb & Co. "There's something primitive there; it's like looking into a fire."

Different games present different symbolic motifs, said Dr. Weingarten, and preferences for particular games may be tied to an individual's needs to work out particular problems. The overriding motif in most games is aggression: players shoot, ram, disintegrate, and otherwise destroy other characters on the screen while trying to avoid a similar fate.

"Most of us get conflicting ideas from society," claimed Mr. Johnston of Fox Video. "There are times when you can be aggressive and times when you can't, and that's an area of conflict for most people. In video games you get freedom to release your aggressive nature, and any way you react is OK."

Some critics have expressed concern that aggression in video games might carry over into real life, just as it has been suggested that watching television violence may incite violent acts in the real world. Others suggest, however, that aggression expressed in video games is defused rather than released on the player's family and friends.

Many of the motifs in the newer arcade games are much more specific than simple aggression. Dr. Weingarten noted an example in the game Donkey Kong, in which the player must climb a

building while avoiding objects hurled by an angry gorilla that has captured a fair damsel.

"On a very basic level," Dr. Weingarten said, "the protagonist ascends through various obstacles and ordeals until he has to confront the negative figure and rescue the maiden or precious figure. You could say that is a beautiful symbolic expressive motif of what is meant by the Oedipus complex, and also of quest myths in general."

Some designers play on prevalent phobias such as fears of spiders, insects, or snakes to lend tension to their games [see "Centipede: the worm that turned a trend," p. 26]. Video games may furnish a way for people to confront these phobias and deal with them in a nonthreatening environment, according to Mr. Johnston.

Male versus female games

Another popular arcade game, Pac-Man, involves eating opponents rather than shooting them. Coincidentally, perhaps, the game is as popular with women as it is with men. A number of people in the games industry have speculated that women are attracted to the game because they have been socialized to avoid violence in the real world.

But female designers suggest that the popularity with women of games such as Pac-Man has less to do with stereotypes of game play or theme than with a game's overall popularity. Only when a game becomes popular enough to be installed in locations outside the arcades do women feel comfortable playing it, claimed Ms. Bailey, Ms. Meninsky, and Ms.Lee, three of the industry's five female designers. Ms. Meninsky and Ms. Lee said that they seldom go into arcades because the atmosphere is uncomfortable for women.

Gregory Fritz, director of the consultant-liaison service at Children's Hospital in Stanford, Calif., has suggested that the atmosphere of an arcade resembles that of "boys' locker rooms," enforcing gender separation, and Dr. Weingarten speculated that "it may be that girls are fighting space invaders just as enthusiastically as boys—but in the confines of the home."

Cultural differences also affect video-game preference. Japan, for example, has as intense a video-game culture as does the United States, but different kinds of games are popular there. Pac-Man developed, according to a spokesman for Taito Inc., Tokyo, when players in Japan grew bored with space games and designers decided to try a comic game. Later comic games include Donkey Kong and Crazy Climber, in which a human fly attempts to climb office buildings while dodging flower pots thrown from windows.

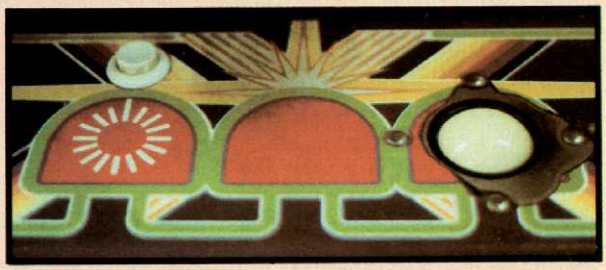
Adolescents play video games that many adults avoid. This may be due in part to their faster reflexes and extended hours of practice—even game designers are unable to play their own games at the highest levels and must call in young players to check for bugs at the higher scores. But it may relate to the special need of adolescents to develop self-esteem without risking ridicule. The recording of high scores by arcade machines allows for recognition, and poor play is more anonymous than in sports

Controls: easy to learn, hard to destroy

In video-game design, ruggedness is a key to survival. "Godzilla plays our games," quipped Allan Alcorn, one of the first designers at Atari Inc., Sunnyvale, Calif., and now temporarily inactive though still under contract to Atari.

Designing video controls that are simple to use and that last a long time has been a problem ever since Computer Space, the first arcade video game, went on location in a Sears store and had its joystick torn off by the end of the first day. The game was finally produced with a four-button controller—"which was a bad human interface, but at least they stayed on," Mr. Alcorn observed.

Defender's five buttons and joystick confuse novices.



Centipede's simple controls—a trackball and one button.

Since Godzilla does not read, game controls, in addition to being indestructible, must also be obvious to use. The paddle control knobs on Pong are an example: they rotate to move paddles up and down on the screen, and the instructions on the game simply say: "Avoid missing ball for high score."

Although the controls may be simple, sometimes they must also operate quite differently from their analogues in the real world. "The steering wheel on our driving games doesn't work at all like the steering wheel in a car," said Mr. Alcorn. "We tried it that way, but you couldn't drive a straight line. Now, when you turn the wheel, the car turns; when you stop turning, it goes straight ahead. It's transparent to the player, but a real car doesn't work that way."

In the 10 years that video games have existed, players have become more sophisticated, and so more complex controllers are acceptable. The arcade game Defender has a joystick and five buttons, which may be why novice players usually survive only for seconds. On the other hand, simple controllers, like the trackball, have also been developed. This is simply an enclosed ball that is rolled in the direction one wants to go on the screen.

The trackball also has this advantage, according to Mr. Alcorn: "If you pour a bottle of beer over it, it'll run better because the ball will stick better to the shafts. It's just optical, and the electronics are elsewhere." The trackball design was tested, Mr. Alcorn said, by finding a 6-foot-6-inch, 300-pound engineer to stand on the ball and work it with his feet.

There have been some failures along the way in designing controls. One notorious example, according to Joe Decuir, hardware designer for Atari's video computer system (VCS), was the control for Fairchild's Channel F. "The handle had a little triangular thing on the top," he said. "You could push it down, pull it up, turn it right, turn it left, push it forward, push it back, push it right, push it left. And playing that machine was like patting your head and rubbing your stomach at the same time." —*P.W.*

or other group activities. The machine, observed Mr. Kaplan of Atari, "is a perfect opponent. It doesn't scream and say, 'Hey, look at this stupid mistake over here!'"

Arcade problems

Though video games may allow young players to build self-esteem and avoid ridicule, some of the behavior patterns developed in the arcades may not be beneficial. In addition to the sexual segregation of arcades themselves, many games may promote ethnic or other stereotypes. Dr. Weingarten commented that one game involves passing through a perilous jungle to "confront some rather scary tribal figures and rescue missionaries who are being boiled."

And, of course, the very presence of arcades devoted to video games has created what some communities see as behavioral problems. A number of towns have attempted to restrict arcade hours or ban them altogether. Many arcade operators have voluntarily restricted access by school-age children during school hours, but some in the industry feel that video games and arcades are not the real issue.

Video games aid the brain-injured

Odie Bracy treats patients whom other psychologists consider hopeless. The 11-year-old girl who walked into his office at the Community Hospital of Indianapolis had suffered a brain injury four years earlier that left her with difficulties in organizing her thoughts, planning simple strategies, and maintaining hand-eye coordination. Her IQ had plummeted from 130 to 70. She had tried traditional brain rehabilitation therapy, but when it no longer seemed to help, she dropped out. Her parents brought her to Dr. Bracy as a last resort.

Dr. Bracy is one of a handful of psychologists and physicians in the United States who are using video games and gamelike computer programs to treat brain-injured people. After examining his young patient, he wrote a number of programs tailored to her weaknesses. In one, she had to keep her player inside a square that continuously moved around the computer screen. In another, she had to watch two squares change colors, and react when either square turned a particular shade.

She practiced the programs daily at home, and each week Dr. Bracy gauged her progress. When appropriate, he introduced more challenging programs. Today, after about a year of computer therapy, the girl's IQ has risen 16 to 17 points and Dr. Bracy claims she has shown an increase in all the standard diagnostic tests used in brain rehabilitation.

Why such therapy should work, no one knows. Perhaps, when an injured brain is challenged to perform certain tasks, it begins to reorganize, so that healthy tissue takes over the job of the damaged tissue. Whatever the reason, Dr. Bracy reports that almost all of his patients using computers in therapy have progressed. He is now providing the programs to other clinicians across the country.

One psychologist taking advantage of these programs and standard video games is William Lynch, director of the brain-injury rehabilitation program at the Veterans Administration Medical Center in Palo Alto, Calif. About half of Dr. Lynch's patients have suffered brain damage from accidents or strokes, the others from diseases such as multiple sclerosis or tumors. "All these patients typically have a problem with attention," he said, "and unless we deal with that problem, other areas of rehabilitation are not going to be successful." Dr. Lynch has discovered that Space Invaders is good exercise for attention, for it demands the player's concentration for increasing lengths of time. Similarly, a team of New York researchers recently reported that Pong may increase alertness in senile patients.

Many questions about video game therapy remain to be answered. Do the games really cause mental improvements, or merely reflect them? Do skills perfected in video games carry over to other life tasks? Even if video games are not therapeutic, Dr. Lynch believes, they have a place in rehabilitation programs.

"For one thing, they're fun," he said, "and that's important in a place like this, where there's so much frustration. Even if a patient is paralyzed and can only move one arm, games give him a chance to act on his environment, improve his skills, and feel good about himself."

Computer games can also be a fast, cheap way of diagnosing a patient's abilities. Prior to microcomputers, diagnostic equipment such as reaction-time monitors could cost thousands of dollars. Many clinics were forced to rely instead on paper and pencil tests, reminiscent of exercises from children's books and hardly motivating to adult patients. Therapists could also use their subject impressions to gauge a patient's progress, but this was apt to be discouraging. Week-to-week progress is often so slight as to be unnoticeable—unless measured by scores on computer games.

William Lynch, head of the brain-injury rehabilitation program at the Veterans Administration Medical Center in Palo Alto, Calif., explains to a colleague how video games can benefit patients. Breakout, shown on the screen, may help brain-injured patients with concentration and hand-eye coordination.

Computer diagnosis can be as helpful to the patient as it is to the therapist, notes Rosamond Gianutsos, a psychologist at Adelphi University in Long Island, N.Y. She cites the case of a man who, because of a stroke, was left with a large gap in the lower left-hand corner of his field of vision. The man did not believe the gap was there, however, because his brain reconstructed the sights that were missing. Dr. Gianutsos spent hours trying to convince her patient that the gap existed, and that it would therefore be unsafe to, say, drive a car. He was unpersuaded. Finally, she presented him with a computer task in which he had to react as quickly as possible to numbers flashing on the screen. He played several rounds with ease, but when the numbers started to appear in the lower left portion of the screen, his score plummeted. Dr. Gianutsos reports that, on looking at that score, the patient's first response was, "My God, that could have been somebody's kid."

Researchers are also using computer games to diagnose temporary brain impairments caused by drugs. According to Jared Tinklenberg, a psychiatrist at Stanford University, driving games, computer memory tests, and reaction-time tasks can reveal whether a person's psychomotor skills have been hampered by sleeping pills or hypertensive drugs. If so, the patient can ask for a different medication, or, at the least, avoid such tasks as driving until the drug wears off.

In fact, people who insist on driving while drugged or intoxicated may someday find computer games their nemesis: a pharmacist at Purdue Univeristy in West Lafayette, Ind., has proposed that police officers be equipped with pocket "video games" to test drivers suspected of being under the influence.

—*C.T.*

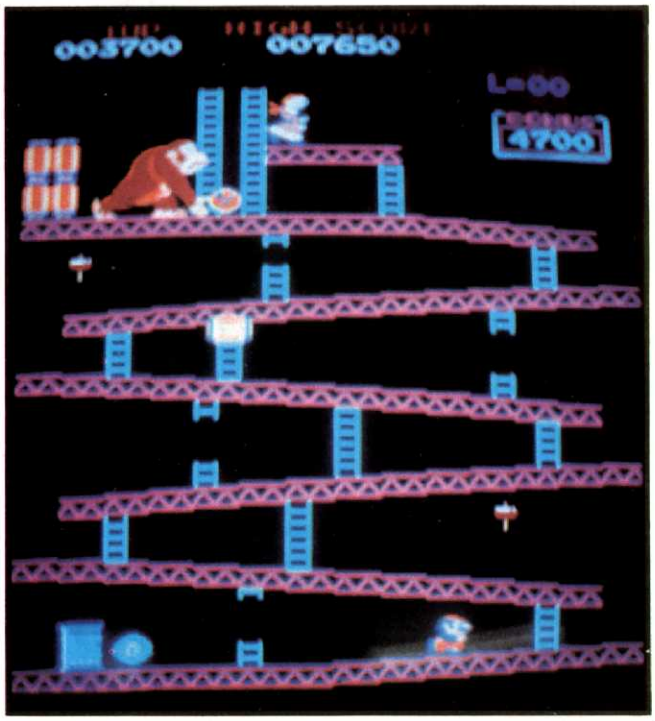
"A big fear of the arcades is the fear that whenever a group of kids is in one place something bad is going to happen," asserted Mr. Delman of Videa. "That's a problem not with the arcade but with adults and the way children are brought up. Ultimately parents are not afraid of arcades: they're afraid of teenagers."

His colleague, Ed Rotberg, agreed: "Any time you have adolescents becoming very visible to adults, there is an uneasiness," he said. But arcades are only a sign of the problem, said Mr. Delman: "The fallacy is that when you close the arcades, the kids do not disappear. They're going to be somewhere on Saturday night, and it's unlikely that they'll go from the arcade to staying at home."

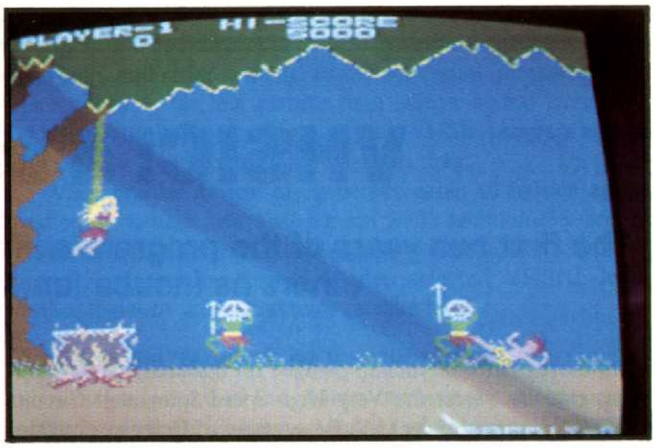
In addition to fears that video games will transform otherwise healthy children into juvenile delinquents, there are also concerns that the games may be causing physical harm. One 18-year-old player in Illinois died of a heart attack while putting a quarter into a video game, and studies at the University of Nebraska Medical Center have revealed significant increases in blood pressure and pulse rate during game play.

Attacks of epilepsy brought on by the flashing lights of video games and hand-held electronic games have also been reported in the *New England Journal of Medicine* and elsewhere, and many agree that game playing is stressful. "People will have heart attacks while playing video games," said Mr. Rotberg, "but how many people die each year from heart attacks from having sex? More people have sex than play video games to this day, which is a good thing. I hope that never changes."

Mr. Alcorn recalled that a heart surgeon once wrote to the chairman of Warner Communications, Atari's parent company, complaining that video games were reducing the amount of exercise that Americans got and asking whether there might not be a way to couple games with exercise machines so that cardiovascular conditioning would be combined with game play. The letter was forwarded to Mr. Alcorn, who said, "I wrote back saying that Pong and other video games were designed as a way



The hero of Donkey Kong must climb past many dangers to subdue an evil gorilla and win back his love. Some may play the game to work out Oedipal problems.



The hero and rescuee of Jungle King are Aryan; the evil figures are Blacks. One psychiatrist worries that the game may perpetuate cultural stereotypes.

that someone could participate in sports while maintaining a firm grip on a can of beer."

Benefits of game play

Whatever the effects of current games, Dr. Weingarten sees potential benefits that could accrue from future games. "I would like a game to have elements of hopefulness in it," he said, "I would like a game that enabled kids to have some empathy for figures and activities, to move away from self-absorption to looking at something that was going on out there, to being able to balance awareness of one's own self-interest with a genuine awareness of others."

Some video games may be moving in that direction. One arcade game, Wizard of Wor, designed at Midway Manufacturing Co. by Bob Ogden, David Nutting, Thomas McHugh, David Armstrong, and Scot Norris, can be played by two players who cooperate to earn points instead of competing as in earlier two-player games. And Swords and Serpents, a new game designed by Brian Dougherty at Imagic for Mattel's Intellivision system, is set up so that the ultimate treasure in it can only be retrieved by two players working together: a knight, who can fight but is illiterate, and a wizard, who can read and cast spells but can't fight. Dr. Weingarten said that he is encouraged by such games.

Games in which players take on particular roles and characters require programs of complexity more often seen in small computers than in arcade games, but at least one designer in the industry may be thinking along those lines. "I'd like to see games that would allow the player to create his own environment, his own monster, his own playfield—make his own game," said Mr. Alcorn, whose contract not to compete with Atari expires in October 1983. "It would just take new software."

To probe further

Video Invaders by Steve Bloom gives a quick and relatively complete history of the industry (Arco Publishing Inc., New York, 1982) and that history is updated bimonthly in *Video Games* magazine (Pumpkin Press Inc., New York).

The following companies will consider games software written on home computers for distribution as a video game: Action Graphics, 812 W. Main, Cary, Ill. 60013; Muse Software, 347 N. Charles St., Baltimore, Md. 21201; and Atari Program Exchange, 1265 Borregas Ave., Sunnyvale, Calif. 94086.

Try "Amusements" in the local telephone directory for the arcade nearest you. ◆

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