THE FIFTH GENERATION

# APPROACHING

第五代

Calligraphy by Kyoko Okamoto

FIRST OF THREE ARTICLES

*Transliteration for the three Japanese characters – or kanji – above is* dai go dai, *and means "fifth generation."*

By JANET RALOFF

The president of Jifuji Ltd. in Tokyo punches a button on his desk console and barks: "Send a letter to Landy in New York alerting him that delivery problems with that new 64K chip will delay the terminals he ordered for at least another two months. Include apologies. You know the rest. Copies to me, the file and accounting. And rush it." A robot-like voice answers back, "Hai."

Four minutes later a soothing bell tone announces the availability of a draft to be read off a desk display screen. Although all the executive's commands have been given in Japanese, the letter addressed to Ross Landy of Rokow Enterprises appears on the screen in conversational American English. Crafted in a personal yet businesslike style, this computer-generated letter includes identification of the terminals Landy ordered with their order numbers, acknowledges the date of the order and even mentions the week the units may now be expected to arrive.

Satisfied that the letter needs no corrections, the Jifuji executive presses a "translate" button and watches as a Japanese version of the same message appears on the screen. Seeing that this version is also error-free, he presses a button marked "execute." Immediately, print-out terminals in his outer office, the filing center and accounting all begin typing dual copies of the letter, one in English, the other in Japanese. Some eight minutes later, Landy's own copy begins printing on a terminal in his office — in Brooklyn, half a globe away.

This scene is, of course, fiction. No machine exists today that can interpret such complicated, non-explicit oral commands, much less translate within minutes between Japanese and English. Yet the development of just such a personal, automated work station — to become as ubiquitous and interconnected as are telephones today — is among explicitly stated goals directing Japan's "fifth-generation" computer project.

It epitomizes, in fact, the many "user friendly" applications the Japanese hope will result from such next-generation technology: specifically, the ability to "hear" and comprehend spoken, conversational language; the ability to translate between languages nearly as quickly as they are spoken or read; the ability to "see" and comprehend the meaning of visual data such as maps, photographs or handwritten script; the ability to search for and retrieve requested data from stores of knowledge filed locally or in some distant library — data that may only have been referred to casually; and finally the ability to solve problems even when details about the problem are still somewhat sketchy.

Not only is that a lot to ask of any computer system, but the Japanese have given themselves a mere 10-year agenda — which helps explain why the fifth-generation project is considered unquestionably the most ambitious research venture Japan has ever undertaken. More important, this program, first unveiled at a Tokyo conference in October 1981, stands to be among Japan's most strategic gambles for economic security. Subscribing to the idea that knowledge is a valuable economic commodity, Japan intends to use fifth-generation technology to market that resource.

Ironically, most of the advanced-generation computer technologies the Japanese hope to draw from have been developed by U.S. university researchers under Defense Department funding, notes Robert Cooper, director of the department's Advanced Research Projects Agency (DARPA).

Most researchers who have evaluated the Japanese goals and progress to date believe the United States still leads the world in most research aimed at fifth-generation systems. What has made the Japanese project so threatening, however, is the fact that it is not only well focused, but also directed at producing well-engineered products — something that has certainly not charac-

# THE AGE OF REASON

## Spearheading the coming information revolution is Japan's 'fifth-generation computer'—a substantial departure from its honorable ancestors

terized the U.S. research effort. There is a growing fear throughout the computer industry that if the United States continues to foster fifth-generation research — but not products—the Japanese could end up dominating commercial markets for knowledge engineering much as they have recently come to dominate in electronics.

This concern has fostered a number of targeted responses to the Japanese project. Last October, for example, DARPA began coordinating the broadest fifth-generation development thrust in the United States (see related story). The Microelectronics and Computer Technology Corp. (MCC), a consortium of U.S. computer companies, has also launched an unprecedented joint research venture. Even the Europeans have jumped on the bandwagon. The European Economic Community (EEC), for example, is in the process of setting up its own 10-year $2.6 billion program called ESPRIT (for European Strategic Program for Research and Development in Information Technology). To qualify for 50-percent funding of research, at least two basic research laboratories from different EEC member states must collaborate on joint projects. Moreover, at least one of the research partners must be "commercially oriented." Acknowledging that its fifth-generation work has been "badly fragmented," Britain has also initiated a five-year $300 million domestic program sponsoring up to 50 percent of the cost of collaborative research between university and industry scientists. More recently, the West German and French governments have also announced domestic research programs to complement their involvement in ESPRIT.

In the past, computer "generations" have tended to be differentiated by the hardware technology that gave them a competitive advantage over their predecessors—starting with vacuum tubes and advancing on to transistors, integrated circuits, and finally to very-large-scale integration (microminiaturization). Even most supercomputers still on the drawing board are considered "fourth generation" because of their reliance on advances in conventional hardware to achieve their greater speed in number crunching. But for the fifth generation, innovations in software (programming) are expected to be as essential and integral to performance as the requisite innovations in hardware. The fifth generation will also change the way knowledge is used and valued.

Today computing is generally referred to as data processing. What's processed are the abstract information bits that a machine can store and manipulate as electrical impulses. By themselves, these are facts, items or numbers without context or perspective. Knowledge is what makes data useful and gives them meaning. For instance, the words Ronald and Reagan are data until knowledge is applied to associate them with the man elected President of the United States. A primary factor differentiating the fifth generation from earlier computing systems will be its use of knowledge instead of data as basic units to be processed.

Moreover, whereas the first four generations performed calculations of a fundamentally numerical—that is, arithmetic—nature, the fifth generation will base its calculations on symbols or logic. Its tasks will not be to calculate so much as to infer, reason, hypothesize or learn. Often thought of as the first potentially "intelligent" computers, these machines will be asked "to calculate the truth or falsehood of propositions, or to make logical inferences—and to perform billions of such calculations at high speed," explains DARPA's Cooper.

Propelling this evolution from counting machines to inference engines is the realization that most of the world's problems do not call for mathematical solutions, explains Edward Feigenbaum, a Stanford University pioneer in artificial intelligence. As he and computer historian Pamela McCorduck explain in their book,

**Whoever has a controlling hand in the information revolution has a controlling hand on geopolitical resources.**

*The Fifth Generation* (Addison-Wesley, 1983), "Even in such 'hard' sciences as chemistry, most thinking is done by inference, not calculation. The same is true of biology, most of medicine, and all of law... In short, almost all the thinking that professionals do is done by reasoning." And it is this ability to reason with logic—deducing answers from comparisons of pictures, verbal statements, sound intensities and a range of sensory inputs other than simple numbers — that most notably differentiates the coming generation of computers from their predecessors.

This is also what promises to make the fifth-generation machines so powerful. "The greatest asset of a computer is heuristic," Feigenbaum says. Heuristics are generally those rules-of-thumb or pieces of empirical knowledge that help to narrow a focus or search. Development of knowledge bases and programs to query them offers to put the working heuristic knowledge and textbook-derived knowledge of experts into the hands of nonexperts. Not surprisingly, the Japanese have placed a high priority on developing such "expert systems" to initially tap the deductive powers of fifth-generation machine reasoning.

In the book *Fifth Generation Computer Systems* (North Holland, 1982), Tohru Moto-oka, chairman of Japan's program committee on such systems, explains some of the factors that led Japan's leaders to pursue this technology so vigorously. "Suffering from a shortage of land and natural resources, it is impossible for Japan to be fully self-sufficient in food, and her ability to supply her own energy and oil is the lowest among the developed countries," he writes. "On the other hand, we do have one precious asset" — the nation's labor force. By developing this resource, Moto-oka says, Japan intends "to cultivate information itself as a new resource comparable to food and energy."

This attempt to anchor its economy with the fifth-generation project is an economically brilliant gambit, according to Michael Dertouzos, director of the Massachusetts Institute of Technology's Laboratory for Computer Science in Cambridge. "Oil is exhaustible, bits are not. Therefore Japan, with no natural resources, is an ideal match to the information revolution" — a revolution that he maintains is well underway. It won't be long, he says, before the entire developed world finds itself part of "this gigantic information marketplace where information is peddled as a fundamental commodity." And what the Japanese have so wisely anticipated, Dertouzos says, is that "whoever has a controlling hand in the information revolution has a controlling hand on geopolitical influences."

**We cannot ignore the Japanese challenge.**

Good intentions aside, can the Japanese pull this ambitious project off? Initially there was some considerable doubt among many of the world's computer design leaders. Though it was the computer industry's dream to develop all those technologies and applications now being discussed in the context of Japan's 10-year project, nobody in 1981 had any idea what it would take to achieve them. What's more, the Japanese were notorious for being weak in innovation. Since the Japanese couldn't continue to piggyback their computer-development program on foreign research (SN: 11/6/82, p. 296) and still hope to meet their timetable, there was serious doubt expressed about whether this project might not be a little too ambitious.

Such smugness soon gave way to sweaty palms, however, as Western computer experts gave the Japanese agenda a closer look. Scrutiny showed that the Japanese had done their homework very well before embarking on the fifth generation's development. Very specific development targets, to be evaluated yearly, had been set in 26 different research areas—including "logic" programming, "machine logic," and advanced computer-architecture concepts aimed at boosting computational speed by parallel processing (tackling multiple portions of a problem simultaneously instead of in a series of sequential operations). At least as important, the Japanese, acknowledging their relatively lackluster reputation in the world's science community, decided to engineer an about-face.

Kazuhiro Fuchi was among those who thought it time Japan began leading the world in science as it had recently come to lead in design and engineering. How Japan could not only achieve respect but also preeminence in research was a favorite discussion topic for him. And in April 1982 he got his chance to put theory to test when Japan's Ministry of International Trade and Industry made him director of the new Institute for New Generation Computer Technology (ICOT) in Tokyo.

Aside from Fuchi, ICOT's staff is comprised of young (under 35 year old) scientists on three-year loans from eight of Japan's leading — and competing — computer companies. Their mission is to brainstorm, create, test and evaluate in an intensive cooperative research setting.

Alexander Williman of Rockwell International Corp. in Anaheim, Calif., recently completed a year-long study of the Japanese fifth-generation plan and U.S. responses to it. After talking extensively with U.S. scientists working on next-generation computer technology, he says, he found that "the thing that shook everyone up is the way Japan approached the fifth-generation area by setting up this research center under Fuchi." Within the next year ICOT's graduates should begin returning to the company from which they were loaned, immediately transferring state-of-the-art technology developments to their firms' design engineers. "With the eight companies involved," Williman notes, "they can have products out in a pretty broad range of hardware and software areas" even before ICOT's initial 10-year program is completed.

ICOT's program ought to shake up the U.S. computer community, Dertouzos believes, because "it strikes at the heart of our technological leadership. In blunt terms, it forces us to ask whether we would like to see 10 years from now our computer industry in the same shape as today's Detroit," he says. "If we lose our lead in this area we will suffer serious if not grave economic consequences. In short, we cannot ignore the Japanese challenge."

And the U.S. computer industry is not. One of the first and most visible responses was creation of the Microelectronics and Computer Technology Corp. (MCC) (SN: 10/16/82, p. 247) — the U.S. industry's version of ICOT. According to MCC president and board chairman Admiral Bobby Inman, by this past February research had finally begun in two of the four areas initially targeted by the consortium's members—computer-aided design and data-base management.

"The climate to create and the talent to do it is already visibly coming into place," Inman told SCIENCE NEWS. "What is far from established is whether that technology that we create gets transferred to and used by the investors. There is the challenge and I think there is the ultimate yardstick" of MCC's success. What's more, he says, even if the investors use the technology MCC develops, "they've still got to be better than they've been in the past at their own engineering, quality control and production" if they hope to compete successfully in world markets against the Japanese.

Representing 3 percent of the gross national product, information processing is already more than an $88 billion per year industry in the United States alone. "And what's motivated [Japan's] effort is the prospect that it's one of the fastest, if not the fastest, growing business sectors visible out over the next 10 to 15 years," Inman points out. Moreover, Feigenbaum would add, the Japanese need be only partially successful in their fifth-generation efforts to jeopardize the United States' computing preeminence. According to Inman, the U.S. computer industry knows that. □

***Next: Logic programming***

# DOD Targets Fifth Generation Too

Last October the Department of Defense (DOD) jumped into the race to build a fifth-generation computing system with a massive new "strategic computing initiative" (SN: 6/18/84, p. 390) to be carried out through its Advanced Research Projects Agency (DARPA). A report describing this program characterizes DOD's goals as focusing on three applications: autonomous navigation for military vehicles (from cruise missiles to automated battle-supply convoys); an intelligent fighter-pilot's assistant to handle routine tasks, thereby freeing up the pilot for more critical activities; and a battle-management analyst to not only alert commanders of pending problems, but also to generate a range of responses, evaluate risks associated with each, and then to aid in executing whatever options are selected.

To get some idea of the complexities involved, the report notes that an "expert system" to guide an autonomous land vehicle moving at 60 kilometers per hour would probably require 6,500 rules firing at a rate of 7,000 rules per second. (A rule might be: *If* a large solid object obstructs the intended path ahead, *then* the vehicle must divert from the path. The firing of a single such rule could require execution of tens of thousands of computer instructions.) Current expert systems generally contain only about 2,000 rules and fire at rates of only 50 to 100 rules per second. Even the vision (image understanding) system that would interpret sensor data to help the vehicle navigate would itself require computational abilities on the order of 10 billion to 100 billion instructions per second—at least two orders of magnitude better than the fastest that can be offered by the computers of today.

In explaining the genesis of the new strategic-computing initiative to the House science and technology committee last year, DARPA director Robert Cooper denied that the program had sprung from concern that the Japanese project might jeopardize U.S. supremacy in computer technology. DARPA's program evolved "independently," he said. Its motivation was solely "to retain our national security lead over the Soviet Union against the substantial threats that we see off in the distant future," and to capitalize on a 20-year investment in related research.

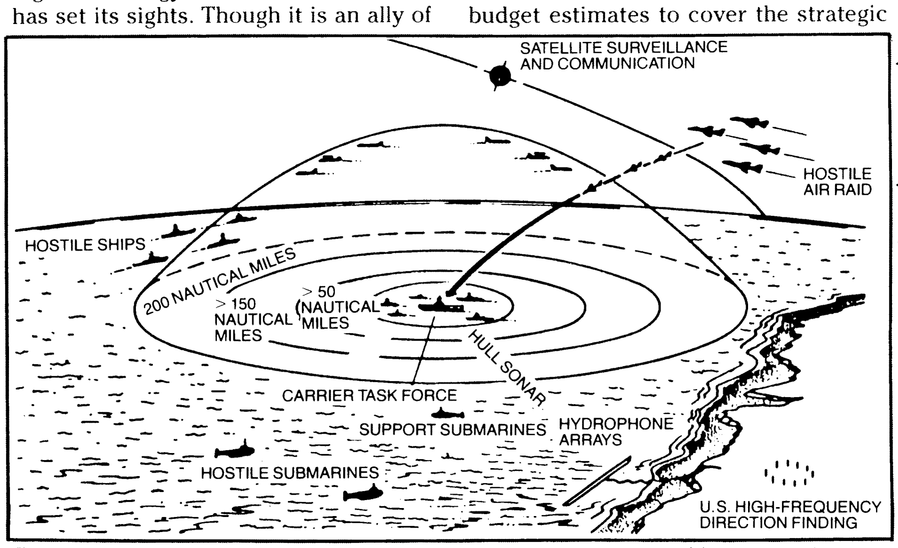
Alexander Williman describes DOD's interest a little differently. He headed a team that recently completed a year-long analysis of the Japanese fifth-generation effort and U.S. "counter thrusts" for the Defense Electronics Operations division of Rockwell International Corp. in Anaheim, Calif. In addition to visiting a number of universities, companies and laboratories conducting research aimed at fifth-generation capabilities, he told SCIENCE NEWS, "We tied in heavily to DARPA—to Cooper and [Robert] Kahn." The latter directs DARPA's fifth-generation work.

DARPA has two primary concerns, Williman says. First, that "the U.S. cannot get into a position where we have to lean on a foreign country for basic technology. And they [at DARPA] feel that it could get to that point" with Japan, considering that nation's recent and impressive history in quickly dominating most of the high-technology industries on which it has set its sights. Though it is an ally of the United States, Williman says "Japan will trade with anybody in the world," including the Soviets. And DARPA has no intention of letting Japan get into a position where it could call the shots on whether the United States maintains technological superiority over the Soviets in defense, he believes.

Secondly, Williman says, "DARPA feels there is going to be a major shift away from strong, heavy industries to information-processing industries." If the United States loses its advantage in these business arenas early, Williman says, it could find itself unable to compete later on—as happened in the video-cassette-recorder industry.

Williman sees a third reason for DARPA's interest, one that mirrors that of his own company (which makes, among other things, the B-1 bomber). The defense community's reliance on data from a growing network of ground-, sea- and space-based sensors has led to an exponential increase in the data on which important military decisions turn. At the same time, the greater delivery speed being built into weapons systems is reducing the time available to analyze and profit from that sensor data. That's why, he says, it's possible that defense systems may be the first to truly need fifth-generation capabilities.

In any event, DARPA's fifth-generation involvement is serious. Preliminary budget estimates to cover the strategic computing initiative's first five years of operation are $600 million. By contrast, Japan's entire joint government-industry fifth-generation project has only been slated to receive $850 million—and that for its first 10 years. A poll by the Institute of Electrical and Electronics Engineers' magazine SPECTRUM, reported last November, turned up at least 98 university projects already receiving DARPA funding in areas related to fifth-generation technology development. That work is concentrated, however; Stanford University in Palo Alto, Calif., received DARPA funding in 33 fifth-generation related areas, the University of California, Berkeley in 29. —*J. Raloff*



Adapted from IEEE Spectrum, Oct. 1982

*This drawing of a hypothetical battle scene helps illustrate why DOD is so anxious to develop fifth-generation computing capabilities. Already the wealth of data available from air-, land- and sea-based sensors have reached bewildering proportions. But a fleet commander can't risk bewilderment if a battle is likely or even underway. The goal is to have computers that process knowledge information read meaning out of the steady influx of data — as in forecasts of hostile-fleet movements or likely air sorties against the "friendly" aircraft-carrier group. Through this lightning-quick inference engine, the commander would tap sensors for the data needed to plan and revise tactics and contingencies.*