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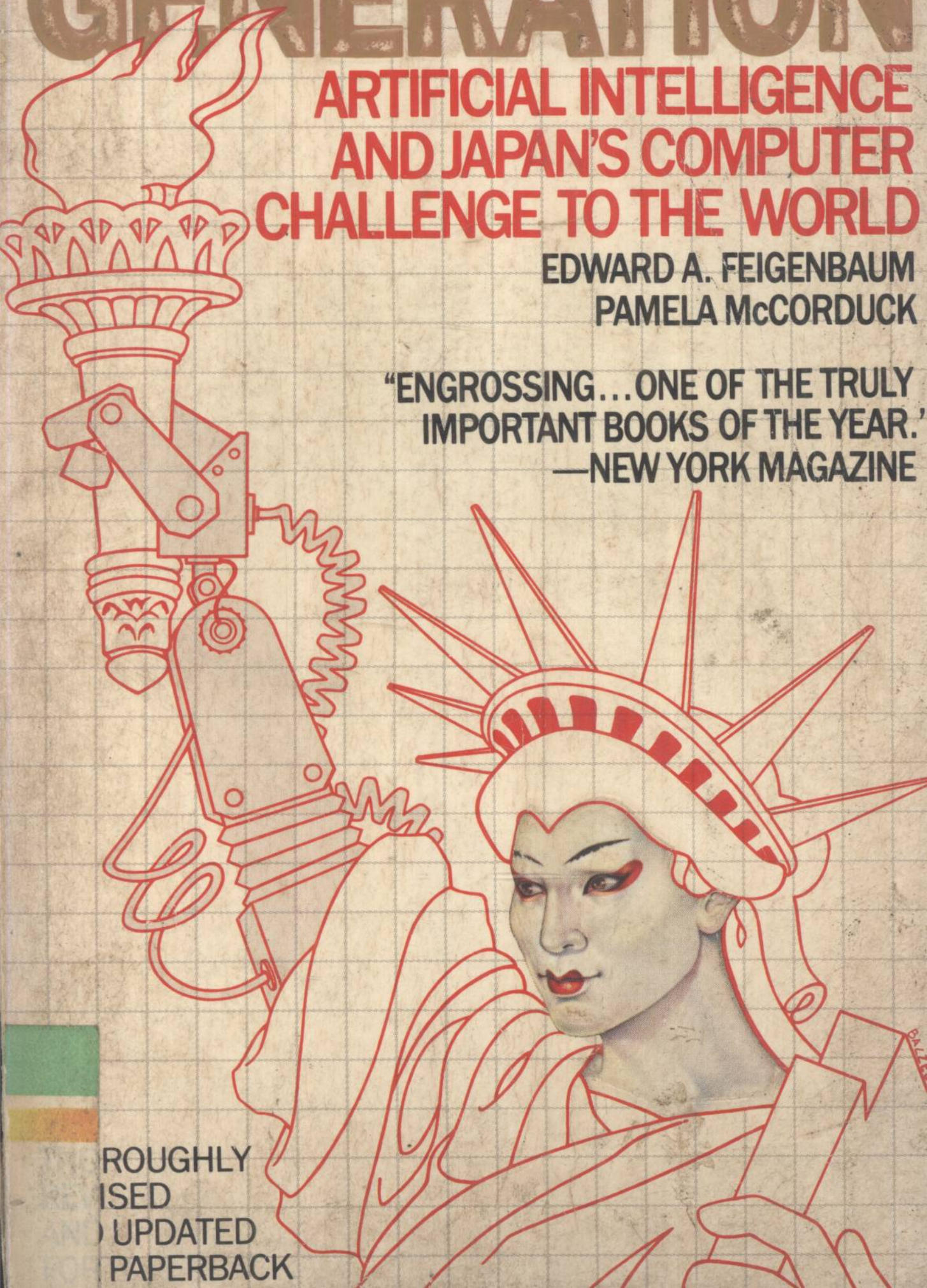
THE FIFTH GENERATION

ARTIFICIAL INTELLIGENCE AND JAPAN'S COMPUTER CHALLENGE TO THE WORLD

EDWARD A. FEIGENBAUM
PAMELA McCORDUCK

"ENGROSSING...ONE OF THE TRULY IMPORTANT BOOKS OF THE YEAR."
—NEW YORK MAGAZINE



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Artificial Intelligence and Japan's Computer Challenge to the World

Edward A. Feigenbaum
and
Pamela McCorduck

Revised and Updated

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"AN URGENT, ENGROSSING AND LITERATE REPORT OF THE DIZZYING FUTURE OF THE COMPUTER REVOLUTION."—*San Francisco Chronicle.*

"ONE OF THE TRULY IMPORTANT BOOKS OF THE YEAR . . . not only delivers an important message but provides a comprehensive introduction to artificial intelligence . . . with a flair that will keep readers engrossed."—*New York Magazine*

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"HIGHLY RECOMMENDED . . . SHOULD BE READ BY EVERYONE INTERESTED IN THE ECONOMIC AND TECHNICAL FUTURE OF AMERICA."
—*Library Journal*

EDWARD A. FEIGENBAUM, Professor of Computer Science at Stanford University, is a founding father of artificial intelligence and one of the originators of the concept of knowledge-based systems—computers that use stored knowledge to make decisions that would normally be made by human experts. Feigenbaum is the author of scores of scientific papers and has edited and coauthored several books, most recently *The Handbook of Artificial Intelligence.* He helped found TeKnowledge, Inc., the first knowledge engineering company, and IntelliCorp, Inc., a consulting firm. Both firms are in Palo Alto, where Feigenbaum lives.

PAMELA McCORDUCK published two novels before she undertook a groundbreaking history of artificial intelligence, which has become a standard reference in the field. She recently wrote the script for the theme film of the United States Pavilion at the 1985 World's Fair in Japan, and has published nearly three dozen articles in specialized and popular magazines. She has been a lecturer at Columbia University since 1980, where she originated a workshop that aims to bring the same kind of critical intelligence to science that scholars have traditionally brought to literature and art.

To H.P.N. and J.F.T.

ACKNOWLEDGMENTS

We wish to acknowledge several people who were helpful in the writing of this book. First are all those at Japan's Institute for New Generation Computer Technology (ICOT) who were frank in their discussions and generous in their hospitality when we visited Japan. We would also like to thank our hosts at the industrial laboratories we visited: Fujitsu, Hitachi, Nippon Electric Corporation, and the Musashino Laboratories of Nippon Telegraph and Telephone Corporation. In exchange for their candor, we have honored their requests for anonymity. In the U.S. members of the Microelectronics and Computer Corporation (MCC) have been helpful, especially Gordon Bell and Bruce Delagi. Robert Kahn and Joseph Traub read early drafts of the manuscript and made useful suggestions.

Following the example of Henry Adams, we appear here as characters in our own book. Since one of us, Feigenbaum, has played an active role in the story we tell, and since both of us represent distinct though concordant points of view, to efface ourselves would not only have blurred those distinctions but might have hidden from the reader our special interests in the whole topic. We are decidedly not disinterested observers.

In the matter of Japanese names we have been inconsistent, but our inconsistency has a purpose. We have simply chosen the form that most Westerners are likely to be familiar with: thus the novelist Murasaki Shikibu appears with her surname first, whereas our contemporaries, like Kazuhiro Fuchi, appear with surnames last.

E.A.F. and P.M.
January 1983

Preface to the Signet Edition

Readers familiar with the first edition of this book will find substantial revisions in this edition. The computer field is a rapidly changing one, and the ground shifts beneath us even as we write. Some of the new information came too late for us to include in the first edition; other revisions mend errors made in haste. But the major revisions are a result of the world's taking serious notice of the Japanese Fifth Generation Project. Optimists will be pleased with some of the news; pessimists will find news to confirm their gloomiest expectations.

To optimists we can report that an American response, having both industrial and governmental components, to the Japanese Fifth Generation is emerging. To pessimists we are compelled to report that while a response in the United States *is* emerging, it is in its nascent state, and appears in some aspects to be dangerously diffuse, responding not only to the challenge of the Fifth Generation, but also to the challenge from other Japanese national projects, such as the Superspeed Computing Project and the Robotics Project. By attempting to meet all challenges, we may end by meeting none.

Meanwhile, Japan makes steady progress toward its goals, not only on the Fifth Generation project, but also on

related projects, such as supercomputers. Once upon a time—in the distant past of two years ago when we wrote the first edition of this book—supercomputers were an American exclusive. Today, Japanese firms are offering machines that challenge, and in some ways exceed, the performance of those American machines. There is every reason to believe that other Japanese goals in computing will be met, from microcomputers to artificial intelligence. Intermediate goals are being met precisely on schedule.

A good friend has scolded us for presenting this as a zero-sum game. When artificial intelligence becomes everyone's, he reminded us, quoting Alice, "all shall be winners, all shall have a prize." We agree and take great comfort in that. But if we may, in turn, quote Orwell, some prizes will be more equal than others.

In a recent talk to an American audience, Kazuhiro Fuchi, director of the Japanese Fifth Generation Project, likened this all to scaling Mount Everest: there are many paths to the summit and different routes should be investigated by climbers with differing skills. Implicit in Fuchi's metaphor is the undeniable prize of mountaineering, reaching the summit first. In the case of the Fifth Generation, it is not mere chauvinism that makes us persist in believing that whoever achieves this summit first will gain important economic, scientific, military and cultural advantages for their nation. It is the evidence of human history.

E.A.F. and P.M.

Prolog

Time magazine's "Man of the Year" for 1982 was not a man at all, but a machine—the computer. The computer revolution has barely begun, but already we see a startling penetration of computers in most forms of work people do, their gadgets and machinery, and their entertainment. The economists tell us that we have become a nation of knowledge workers: more than half of us are engaged in the various forms of knowledge and information processing. The computer is the knowledge worker's tool, as the planting and harvesting machines are to the farmer and the heavy industrial machines are to the manufacturing worker. The ascendancy of the knowledge worker is reflected in the ascendancy of the tool—the computer. It has been a long time since a child of technology has had such a profound effect upon our lives and our society.

Knowledge is power, and the computer is an amplifier of that power. We are now at the dawn of a new computer revolution. *Business Week* featured it as "the second computer age." We view it as the important computer revolution, the transition from information processing to knowledge processing, from computers that calculate and store data to computers that reason and inform. Artificial intelligence is emerging from the laboratory and is beginning to

take its place in human affairs. Professor Allen Newell of Carnegie-Mellon University, a pioneer of artificial intelligence, once wrote that "computer technology offers the possibility of incorporating intelligent behavior in all the nooks and crannies of our world." The nooks and crannies are right now being filled with computers, and the intelligent behavior is following quickly along.

The American computer industry has been innovative, vital, and successful. It is, in a way, the ideal industry. It creates value by transforming the brainpower of the knowledge workers, with little consumption of energy and raw materials. Today we dominate the world's ideas and markets in this most important of all modern technologies. But what about tomorrow?

The Japanese have seen gold on distant hills and have begun to move out. Japanese planners view the computer industry as vital to their nation's economic future and have audaciously made it a national goal to become number one in this industry by the latter half of the 1990s. They aim not only to dominate the traditional forms of the computer industry but to establish a "knowledge industry" in which knowledge will be a salable commodity like food and oil. Knowledge itself is to become the new wealth of nations.

To implement this vision the Japanese have both strategy and tactics. Their strategy is simple and wise: to avoid a head-on confrontation in the marketplace with the currently dominant American firms; instead to look out into the 1990s to find an arena of great economic potential that is currently being overlooked by the more shortsighted and perhaps complacent American firms; to move rapidly now to build major strength in that arena. The tactics are set forth in a major and impressive national plan of the Ministry of International Trade and Industry (MITI) called Fifth Generation Computer Systems. The plan documents a carefully staged ten-year research and development program on Knowledge Information Processing Systems. The implementation began in April 1982 with the formation of the Institute for New Generation Computer Technology (ICOT) and coordinated laboratories of the major Japanese firms in the computer industry.

The Japanese plan is bold and dramatically forward-looking. It is unlikely to be completely successful in the ten-year period. But to view it therefore as "a lot of smoke,"

as some American industry leaders have done, is a serious mistake. Even partially realized concepts that are superbly engineered can have great economic value, preempt the market, and give the Japanese the dominant position they seek.

We now regret our complacency in other technologies. Who in the 1960s took seriously the Japanese initiative in small cars? Who in 1970 took seriously the Japanese national goal to become number one in consumer electronics in ten years? (Have you seen an American VCR that isn't Japanese on the inside?) In 1972, when the Japanese had yet to produce their first commercial microelectronic chip but announced their national plans in this vital "made in America" technology, who would have thought that in ten years they would have half of the world's market for the most advanced memory chips? Are we about to blow it again? The consequences of complacency, of our spirited attention to the near-in at the expense of the long view, will be devastating to the economic health of our most important industry. Even more important than its direct effect on the computing industry, present complacency will have serious economic effects on all industries. Since computing is the technology that drives all other technologies, a second-rate computing industry will also mean impaired industrial design and manufacturing, and enfeebled management and planning. The Japanese could thereby become the dominant industrial power in the world.

We are writing this book because we are worried. But we are also basically optimistic. Americans invented this technology! If only we could focus our efforts, we should have little trouble dominating the second computer age as we dominated the first. We have a two- or three-year lead; that's large in the world of high technology. But we are squandering our lead at the rate of one day per day.

America needs a national plan of action, a kind of space shuttle program for the knowledge systems of the future. In this book we have tried to explain this new knowledge technology, its roots in American and British research, and the Japanese Fifth Generation plan for extending and commercializing it. We have also outlined America's weak, almost nonexistent response to this remarkable Japanese

challenge. The stakes are high. In the trade wars, this may be the crucial challenge. Will we rise to it? If not, we may consign our nation to the role of the first great postindustrial agrarian society.

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