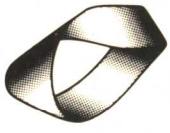
The Fourth Technology Forecast Survey of the Science and Technology Agency

FUTURE TECHNOLOGY IN JAPAN

Forecast to the Year 2015



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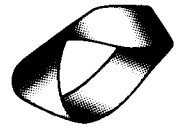

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Foreword

This report, entitled *Future Technology in Japan*, is the outgrowth of a series of surveys conducted by the Science and Technology Agency to explore from a long-term perspective the direction of future technological development.

Dramatic social and economic changes, which followed the first three surveys in 1970-71, 1974-76, and 1981-82, underscored the importance of scientific and technological development and its promotion. This point was emphasized in the 11th Recommendation of the Council for Science and Technology and the General Guidelines for Science and Technology Policy approved by the Cabinet.

Following this, the Science and Technology Promotion Policy Bureau of the Science and Technology Agency commissioned the Institute for Future Technology (IFTECH) to conduct a fourth technology forecast survey in 1985-87, the results of which are contained in this report.

Presented are the views of leading Japanese specialists on the possible directions of future advances in science and technology. The scope of the survey has expanded considerably beyond the 800 questions previously covered to 1,071.

It is our hope that the report will prove to be an incentive for further advances in science and technology.

Shoroku Kato
Director-General
Science and Technology Policy Bureau
Science and Technology Agency

Preface

Since 1970, the Science and Technology Agency has periodically completed a large-scale technology forecast survey using a Delphi method. The latest survey, the fourth of this kind, was conducted from 1985 to 1987. Its report was published in September last year. The Institute for Future Technology had the honour of playing a significant part in the survey.

In this latest survey, about 3,000 specialists in a variety of domestic sectors answered the questions about the future of scientific and technological developments.

This book is the English translation of an essential part of the above-mentioned report. It includes full texts of all the 1,071 questions used in the survey as well as statistically processed answers to them. This publication was made under the permission and advice of the Science and Technology Agency.

Because a large-scale survey of this kind seems rare worldwide, we hope that this publication would help to spur the global development in science and technology in the coming years.

Ken'ichiro Hirota
President
Institute for Future Technology

CONTENTS

Chapter 1 Outline of the Survey

1.1 Objectives

This Technology Forecast is intended to contribute to the development of future science and technology policy and to indicate guidelines for scientific and technological activities in the private sector.

1.2 Outline

1.2.1 Organizations that performed the survey

A Steering Committee was set up by the Science and Technology Agency (STA). Under the guidance of the Committee, the survey was carried out by the Institute for Future Technology (IFTECH) with 11 Working Groups composed of specialists from a variety of sectors of this country.

1.2.2 Period of the survey

The survey was conducted from September 1985 to March 1987.

1.2.3 Fields covered and number of questions asked

Field	Number of questions
1. Substances, materials, and processing	100
2. Information, electronics, and software	116
3. Life science	96
4. Outer space	39
5. Marine science	37
6. Earth science	28
7. Agriculture, forestry, and fisheries	75
8. Mineral and water resources	40
9. Energy	51
10. Production and labor	78
11. Health and medical care	103
12. Consumer lifestyles, education, and culture	87
13. Transportation	56
14. Communications	52
15. Urbanization and construction	63
16. Environment	30
17. Safety	20
Total	1,071

1.2.4 Forecast period

The forecast covers a thirty-year span from the present (circa 1985) to the year 2015.

1.2.5 Survey method

The Delphi method was used: the same questionnaire was circulated twice.

1.2.6 Survey parameters

1. Degree of importance
2. Time of realization
3. Constraints on realization (or reasons for nonrealization)
4. Methods of promoting research and development
5. Entities promoting research and development
6. Role of government (This item was included in the second round only.)

1.2.7 Questionnaire response rate and affiliations of respondents

(1) Response rate

Round	Number of questionnaires sent	Number of valid responses	Response rate
First (June 1986)	3,142	2,487	79%
Second (November 1986)	2,487	2,007	81%

(2) Respondents (second round)

Company employees	755 (38%)
Academics	663 (33%)
Civil service	379 (19%)
Industrial and professional association staff, etc.	210 (10%)

1.2.8 Comparison with the preceding surveys

	First	Second	Third	Fourth (Current survey)
Year	1971	1976	1982	1986
Number of questions	644	656	800	1,071
Number of valid responses	2,482	1,316	1,727	2,007

Chapter 2 Summary of notable findings, by field

On the following pages, characteristic findings in each of the seventeen fields are summarized in terms of the evaluation of importance, the forecast time of realization, and areas of particular future interest.

Notes: 1. The degree of importance is as defined later in 2.2, (7)-3.
2. The time of realization are expressed each in the statistical median of responses to the questionnaire.

2.1 Substances, materials, and processing

(1) Degree of importance

Higher importance was given to topics under the heading "Materials with optical or electromagnetic properties" and "Design, synthesis, and processing technology." "Materials with optical or electromagnetic properties" attracted special interest, and included four of the five topics of this field whose degree of importance was rated "high" by 70 percent or more respondents. The degree of importance was highest in topics related to superconductive materials and semiconductor processing technology.

(2) Time of realization

Only one item was forecast to be realized within the next ten years; roughly 90 percent were forecast to be realized between 1996 and 2005. Many topics were forecast to be realized before the year 2001 in those under the heading "Materials with optical or electromagnetic properties" and "Materials with mechanical properties," whereas most under the heading "Materials with biological or chemical properties" and "Materials with thermal properties" were forecast to be realized in the year 2001 or later. All topics related to semiconductors were forecast to be realized by the year 2000.

(3) High-interest areas

- Elucidation and control at the atomic and molecular levels
- Computer-assisted design and synthesis of substances
- Evolution of intelligent devices

2.2 Information, electronics, and software

(1) Degree of importance

Under the main heading "Information and electronics," primary importance was assigned to such technologies in "Microelectronics" as those for maximizing capacity, miniaturizing, and attaining high speeds. Under the main heading "Software," a high degree of importance was generally given. Regarding "Biosoftware," in particular, five of the eight topics were rated "high" by the majority of respondents.

(2) Time of realization

Over 60 percent of topics were forecast to be realized between 1996 and 2005. Under the main heading "Information and electronics," most topics under the headings "Microelectronics," "Optoelectronics," and "Information systems and equipment" were forecast to be realized by the year 2000, whereas those under the heading "Bioelectronics" were forecast to be realized in the year 2001 or later. Under the main heading "Software," a relatively large number of topics were forecast to be realized in the year 2001 or later, but most topics related to "ease of use" (user-friendliness) were forecast to be realized by the year 2000.

(3) High-interest areas

- Assailing the limits to size and speed
- Improving the ease of use and software productivity
- Increasing intelligence
- Exploration of biological functions

2.3 Life science

(1) Degree of importance

Importance was given to topics encompassing elements of organisms--"Molecules," "Cells," and "Organs and individuals." Contrary to this, topics related to applications for systems development were given low importance ratings. The degree of importance of topics related to "Devices" tended to be especially low, indicating apparently that interest in research and development of these areas is still low, at least from the social viewpoint.

(2) Time of realization

Over 60 percent of topics were forecast to be realized between 1996 and 2005. Most topics of organism elements under the headings "Molecules" and "Cells" and topics under the heading "Production of useful substances" were forecast for realization by the year 2000. On the contrary, the realization of other topic areas is mostly expected some time in the 21st century, and a considerable number of topics, especially under the headings "Organs and individuals," and others under the "Systems" heading were regarded as very difficult to realize.

(3) High-interest areas

- High-resolution measurement and analysis of living organisms
- High-level modification of biological functions
- High-level use and simulation of biological functions
- Living-nonliving interfacing
- Design of biological functions

2.4 Outer space

(1) Degree of importance

Topics under the headings "Transportation" and "Use of space environment" were regarded as important; in terms of regions of space, the importance of topics related to low orbits was emphasized, followed by geostationary orbits. A high degree of importance was assigned to topics related to space stations and new space transport systems.

(2) Time of realization

Over 60 percent of topics were forecast to be realized between 1996 and 2005. As a general trend, realization was forecast for topics under the heading "Use of satellites" before the year 2001, for topics under the heading "Use of space environment" by 2005, and for those under the "Transportation" heading between 2001 and 2010.

(3) High-interest areas

- From the use of space locations to the use of space environments
- Development of global-scale science and technology

2.5 Marine science

(1) Degree of importance

A relatively high degree of importance was assigned to topics related to elucidating, surveying, and forecasting marine events and to the use of the sea bottom and deep sea. This means that the importance of ocean observation was emphasized, in addition to topics under the heading "Use of marine resources, energy, and space," which were fully covered first in this fourth survey.

(2) Time of realization

Ninety percent of topics were forecast to be realized between 1996 and 2005. A majority of topics under the heading "Use of marine resources, energy, and space" were forecast to be realized by the year 2000; dramatic progress is likely in this area. On the contrary, a majority of topics under the heading "Observation and forecasting" such as the practical utilization of automated observation systems, etc., are expected to be realized in the next century.

(3) High-interest areas

- Development of global-scale science and technology
- High-level use of ocean space

2.6 Earth science

(1) Degree of importance

Topics related to forecasting and advance warning of earthquakes, volcanic activity, and abnormal weather were given high ratings of importance, whereas topics under the heading "Survey of the earth's interior" were assigned relatively low importance. Very high ratings of importance were given to technologies for predicting earthquakes several days in advance and to technologies for predicting volcanic eruptions with certainty two or three days in advance, indicative of the gravity of these events.

(2) Time of realization

About 90 percent of topics were forecast to be realized between 1996 and 2005. A majority of topics related to observation of and forecasting events on the surface of the earth and in the atmosphere were forecast to be realized by the year 2000. Contrary to this, topics of forecasting phenomena such as earthquakes caused by changes in the crust of the earth and volcanic eruptions related to the state of subsurface magma were forecast to be realized after 2000.

(3) High-interest areas

- New developments in the earth sciences
- Advances from macroscopic to local observations

2.7 Agriculture, forestry, and fisheries

(1) Degree of importance

Relative importance was assigned to topics under the heading "Breeding" in the area of agriculture, "Cultivation and rearing" in the area of livestock raising, and "Environmental assessment and management" in the areas of forestry and fisheries. Particular importance was given to production technology using biotechnology and to forestry (including tropical-forest) resource management technology.

(2) Time of realization

Whereas most topics under the headings "Storage, distribution, and processing" and "Cultivation and rearing" were forecast to be realized by 2000, most topics under the heading "Environmental assessment and management" were forecast to be realized after 2000. Under the heading "Breeding," the times of realization were diversified. For example, topic number 14, "Establishment of technologies for the long-term storage of in vitro fertilized ova from domestic animals," was forecast to be realized at a relatively early date (1995), whereas topic number 3, "Creation of crop varieties with 1.5 times the photosynthetic ability of C_4 plants (for example maize)" was forecast at a relatively late date (2009).

(3) High-interest areas

- Utilization of advanced biotechnologies
- Responses to the need for environmental management and conservation
- Advances in food science and technology

2.8 Mineral and water resources

(1) Degree of importance

Under the main heading "Mineral resources," topics related to "Mining and extraction" of petroleum, LNG, and other resources were regarded as relatively important. Under the main heading "Water resources," the topics of "Water quality improvement technology" and "Water resource development technology," both related to dams, lakes, rivers, and underground water, were regarded as important. A particularly high degree of importance was assigned to topics related to water resources and seabed mineral resources.

(2) Time of realization

Ninety percent of topics were forecast to be realized between 1996 and 2005. Under the main heading "Mineral resources," all topics were forecast for realization by the year 2010, and 50 percent of them were forecast to be realized by the year 2000. Analyzed by process, topics related to "Transportation," "Application development" and "Transformation into resources" were forecast to be realized at relatively early dates. Under the main heading "Water resources," all topics are expected to be realized between 1996 and 2005.

(3) High-interest areas

- Robotization and other forms of labor saving and automation of heavy and dangerous tasks
- Identifying reserves through development of prospecting technology

2.9 Energy

(1) Degree of importance

Importance was assigned to topics related to energy conversion and electric power generation of large nuclear reactors and to fossil fuel electric power generation. In particular, seven out of eight topics related to nuclear power were given "high" importance by the majority of respondents. An especially high degree of importance was given to topics related to fast breeder reactors and nuclear fusion, including the processing of wastes and the nuclear fuel cycle.

(2) Time of realization

Only six topics were forecast to be realized by the year 2000, and more than 80 percent of topics were forecast to be realized between 2001 and 2015. All topics related to transport and storage and to probes were forecast to be realized after 2000, and all topics related to nuclear electric power generation and the active use of solar energy and other natural energy sources were forecast to be realized after 2010.

(3) High-interest areas

- Responses to energy needs
- Advances in diversification of energy sources and their effective uses

2.10 Production and labor

(1) Degree of importance

More detailed coverage than in previous surveys was given in this survey to the areas "Use and simulation of living organisms" and "Human sciences," and topics related to these areas received higher ratings of importance. On the other hand, topics related to manufacturing systems and social systems also received higher ratings.

(2) Time of realization

Approximately 80 percent of topics were forecast to be realized between 1996 and 2005. By objective, the realization of most topics under the headings "(production of) Substances and materials" and "Full and partial automation" was forecast by the year 2000, and many of the remaining topics after 2000.

(3) High-interest areas

- Increasing fusion of different technologies and knowhows (construction of high value-added intelligent production systems)
- Advanced technology for security systems and better human interface

2.11 Health and medical care

(1) Degree of importance

A high degree of importance was assigned to topics related to cancer, aging, and other diseases for which no prevention or therapeutic measures yet exist. Of these, there was a relative increase in the ratings of importance given to topics related to "Basics," "Elucidation of mechanisms of disease onset, and improvement of methods for prevention," which were covered in more detail in this survey than in the past surveys. The perceived importance of "Systematization" and other applications was relatively low. Emphases were put upon topics related to neoplasms, diseases of the brain and nervous