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Japan

ECONOMIC PLANNING AGENCY TECHNOLOGY
FORECAST TO THE YEAR 2010

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SCIENCE & TECHNOLOGY

JAPAN

ECONOMIC PLANNING AGENCY TECHNOLOGY FORECAST TO THE YEAR 2010

CONTENTS

Economic Planning Agency Technology Forecast to the Year 2010

Part I: General Report

91FE0861 Tokyo KEIZAI KIKAKUCHO SOGOKEIKAKU-KYOKU in Japanese Jul 91 pp 1-78

[Text] Members of the Council for Technology Forecast for 2010

Junichi Kikuchi (Chair)	Assistant Professor, Aoyama Gakuin University Women's Junior College
Yoshio Arai	Senior Researcher, Economic and Business Comprehensive Research Headquarters, Mitsubishi Corporation
Takashi Okawa	Director of Underground Space Development Laboratory, Technical Development Department, Technology Headquarters, Taisei Construction Company
Yasunori Omichi	Senior Researcher, Industrial Assessment Department, Long-Term Credit Bank Comprehensive Research Institute
Yutaka Kuwahara	Assistant to the Director, R&D Promotion Headquarters, Hitachi Corporation.
Satoru Kondo	Senior Researcher, Future Engineering Research Institute
Hideo Hattori	Assistant Director, Technical Control Department, Toyota Motor Company
Botaro Hirozaki	Director, Network Research Department, C&C System Laboratories, NEC Corporation
Kazuyoshi Mochizuki	Assistant Director, President's Office, Fanuc, Ltd.
Yoshifumi Fujii	Senior Researcher, Economics Department, Economics Laboratory, Electric Power Central Research Institute
Hajime Yoshida	Director, R&D Planning Room, R&D Headquarters, Kyowa Hakko Kogyo Company
Minoru Yoshinaga	Business Planning Room, Toray Corporation

(Bureau)

Director, Economic Planning Agency Planning Bureau	Shunji Tomikanehara
Chair, Planning Bureau Council	Senjuro Takahashi
Electric Power Development Official	Nobuyoshi Fujiwara
Electric Power Development Assistant Official	Kenji Yoshioka
Electric Power Development Assistant Official	Shuichiro Akazu (Jun Narige) Takumi Koyamada

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1. Scope of Research

1–1 Goal of the Council for Technology Forecast for 2010

At the Structural Adjustment Section of the Economic Council we have conducted a new review of Japan's long range economic and social prospects up to the year 2010. For this goal, we established a "Year 2010 Committee," in the section and four subcommittees on "World Economy," "Life of the Populace," "Industrial Economy," and "Social Capital" within that committee. The schedule called for the study to begin in October 1990 and the report to be compiled by June 1991.

There have been outstanding advances in technology in recent years and they have had a major impact on industry and the economy. More specifically, our country's technologies, centered mainly on industry, have reached first-rate levels in the world, and therefore we can expect that our country's technologies will have a major impact on industry and the economy in the year 2010 judging from the increases in expenditures on R&D, etc., in recent years. Moreover, global environmental problems such as global warming are being addressed throughout the world, and in a situation where there is the danger of major limitations on world growth without proper responses, a large amount of hope has been placed on technology.

However, although the Science and Technology Agency requests a technology forecast from the Future Engineering Research Institute every few years, their latest assessment report was published in 1987, and with the present outstanding progress in technology, it can no longer be considered up to date. Moreover, the only existing resources with quantitative evaluations of the impact future technologies will have on industry and the economy are scattered accounts by various think tanks on individual technologies, and these produce market forecasts of from five to ten years at the most. Thus, there have been almost no studies in the past that capture systematically the impact future technology will have on industry and the economy, and it can clearly be stated that the methodology for assessment has not been established as well.

Therefore, we have established the Council for Technology Forecast for 2010 in the Planning Bureau of the Economic Planning Agency, and we have conducted research in the Year 2010 Committee and its various subcommittees by selecting 101 technologies and products from the technologies and products that are expected to have a major impact on industry and the economy from the latter half of the 1990s up to 2010. We have not only made predictions on their practical application but also have analyzed the impact they will have on industry and the economy using new methods not used in the past.

1–2 Research Method

As mentioned above, in Japan there are almost no examples of systematic research on what kind of impact future technologies will have on industry and the economy from now on. Therefore, we have conducted our assessment based on the following methods.

First the technologies and products that will achieve practical application in the future were classified, and several items were chosen from among the technologies and products in each classification and listed in the order in which they are expected to have the greatest impact on industry and the economy. Then an analysis was conducted on their present R&D potential and the prospects for practical application of the technologies and products. This is the basis for evaluating their impact. Finally, in order to evaluate the impact on industry and the economy of each of these technologies and products, analyses were carried out on the size of the market for the technology or product, its positive impact, negative impact, etc.

The specific assessment items are as follows:

1) Summary of the new technology or product

2) Present R&D status
•Stage of R&D
•International comparisons with the US and Europe
•Rate of increase in R&D spending and number of personnel
•Rate of increase in number of patents and monographs
•Rate of increase in grants and subsidies

3) Technologies in which breakthroughs can be expected.

4) Obstacles other than technical, such as in social and government systems.
•Social limitations (government regulations, government policies, infrastructure, environment, national consciousness and values)
•Economic limitations (size of market, cost, marketing principle, lack of development funds, lack of researchers)

5) Concrete policy to promote practical application.

6) Prediction of time of application of new technology or product.
•Prediction of time of application
•Prediction of ratio of application (in 1990, 2000, and 2010)
•Effort required to achieve practical application by 2010 for technologies that are expected to begin application after 2010.

7) Size of market for new technology or product.
•Size of annual market
•Amount of annual growth
•Cost per unit at time of application
•Size of market of existing technology or product
•Rate of replacement of existing item with new technology or product
•Effort required to increase replacement rate by 10%

8) Positive impact.
•Advent of new industries and products
•Stimulation of existing industries and products
•Industries and products producing ripple effect

9) Negative impact.
•Decline of existing industries and products
•Competing industries and products
•Problems from the standpoint of technology assessment

10) Contributions of technology to society.
•Will the new technology contribute on the global level (harmony with the ecosystem, response to energy, food, or population problems), the national level (international contribution and cooperation, provide safety and security), the social and corporate

level (pursuit of abundance, assurance of regional environmental safety, measures for an aging society), or on the individual level (pursuit of leisure, pursuit of comfort)?

1–3 System of Study

The study of the above details was conducted based on the following system.

1) The Council for Technology Forecast for 2010 was established as a research council at the Planning Bureau of the Economic Planning Agency. Junichi Kikuchi, Assistant Professor at Aoyama Gakuin University Women's Junior College, was asked to serve as chairman, and after consideration of the fields of the various technologies and products, senior researchers from different think tanks, as well as research directors and researchers from representative companies were asked to serve as members.

2) The office for the research council was located in the Electric Power Development Office.

3) Data was collected by creating assessment sheets, determining a committee member to be in charge of each technology or product, and having that committee member fill in the assessment sheet based on his own knowledge.

1–4 Timetable for Study

First meeting (20 December 1990)
•Council procedures
•Organization and selection of new technologies and products
•Distribution of assessment sheet (survey form)

Second meeting (1 March 1991)
•Prediction of practical application of new technologies and products

Third meeting (12 March 1991)
•Impact on industry and the economy of new technologies and products

Fourth meeting (28 March 1991)
•Compilation of report

2 Organization and Selection of Technologies and Products

A large number of new technologies and new products exist which are expected to achieve practical application in the future. As mentioned above, in the 1987 version of the Technology Forecast Assessment, which has been conducted every few years by the Science and Technology Agency since 1971, 1071 technologies in 17 fields are analyzed. In addition, there are reports that survey such items as international comparisons of levels of technology. For example, in the "Trends and Topics in Industrial Technology" (September 1988, Ministry of International Trade and Industry), which is limited to comparative technology, 40 high-tech products and 47 basic technology fields are addressed. Further, in "Promising Advanced Technologies" (May 1990, US Department of Commerce) 12 items are considered, in "Major Technology Plans" (March 1990, US Department of Defense) 20 items are noted, and in the "US National Major Technology Report" (April 1991), 22 items in technology are listed. In consideration of time and budget limitations, in this assessment large (broad), medium, and small (narrow) categories were created using the above reports published in the past as references, and 101 technologies and products were selected, organized, and assessed in these categories.

Further, in creating the categories for technologies and products, the "Technology Forecast Assessment" (1987 edition) by the Science and Technology Agency, "Trends and Topics in Industrial Technology" (September 1988) by MITI, and "Assessment Report of Trends in Technical Development in Major Advanced Technology Fields" (May 1989) consigned by MITI were used as references.

The concept behind these categories of technologies is as follows:

1) Large Categories (4 fields)

First, the new technologies and new products were divided into three large categories—"Advanced Basic Technology, " which will bring about technical innovations to support the 21st Century, "Basic Technology to Support Industrial Activity," which is indispensable for Japan to continue to maintain competitive strength in industrial technology, and "Basic Social Technology," which is indispensable to provide leisure and abundance in the daily lives of the populace—and a fourth major category was added, "Environmental Technology," which has gained attention in recent years.

2) Medium Categories (9 fields)

Next, the Advanced Basic Technology was further divided into the three fields of "Information and Electronics," "New Materials," and "Life Sciences;" the Basic Technology to Support Industrial Activity was further divided into the two fields of "Energy," and "Automation;" and Basic Social Technology was further divided into the three fields of "Communications," "Transport and Transportation," and "Utilization of Space."

3) Small Categories (34 fields)

Then the Information and Electronics was broken down into five fields: Microelectronics, Optoelectronics, Bioelectronics, Data System Machines, and Software; New Materials was broken down into five fields: Ceramics, Semiconductors, Metals, Organic Materials, and Composite Materials; Life Sciences was broken down into three fields: New Drugs, Use of Organisms, and Biometrics; Energy was broken down into two fields: Energy Supply Technology and Technology to Improve Energy Efficiency; Automation was broken down into four fields: Robot Technology, Processing Machine Technology, CAD/CAM Technology, and CIM/HIM Technology; Communications was broken down into four fields: Satellites and Mobile Communications Technology, Image Communications Technology, Multimedia Communications Technology, and Networking Technology; Transport and Transportation was broken down into four fields: Railway Technology, Automobile Technology, Marine Shipping Technology, and Aircraft Technology; Utilization of Space was broken down into four fields: Technology to Utilize Outer Space, Technology to Utilize Terrestial Space, Technology to Utilize Space Underground, and Technology to Utilize Space Under the Sea; and Environmental Technology was broken down into three fields: Measures Against Global Warming, Measures Against Ozone Depletion, and Measures for Solid Waste Management.

4) Subjects of the Assessment (101 Technologies)

Finally, based on the small categories, several of the new technologies and new products that are expected to have the greatest impact on industry and the economy were selected from among the various categories, and the final 101 new technologies and products shown in Table 2–1 were chosen and organized to maintain overall balance.

This council has attempted to do research concerning the impact of new technologies and new products, particularly the impact on industry and the economy. Therefore, we could only address technologies that will have an impact on the daily lives of the populace in a rather limited manner. For example, we have not been able to address technologies such as functional foods, nursing care for the elderly, and those related to disaster prevention and safety.

Table 2–1a List of New Technologies and Products

Large Category	Medium Category	Small Category	Item Studied
Advanced Basic Technology	Information Electronics	(1) Microelectronics	1.Terabit memory 2. Superconductor devices 3. Super intelligent chips 4. Self-propagating chips
		(2) Optoelectronics	1. Terabyte optical files 2. Terabit optical communication devices 3. Optical computing elements and devices
		(3) Bioelectronics	1. Biosensors 2. Biocomputers
		(4) Data System Devices	1. Super parallel computers 2. Neurocomputers
		(5) Software	1. Automatic translation systems 2. Virtual reality systems 3. Self-propagating data base systems
	New Materials	(1) Ceramics	1. Superconductors 2. Ceramic gas turbine engines 3. New glass (Non-linear optic glass)
		(2) Semiconductors	1. Optical IC 2. Semiconductor superlattice elements
		(3) Metals	1. Amorphous alloys 2. Hydrogen adsorbent alloys 3. Magnetic materials
		(4) Organic Materials	1. Organic non-linear photoelectron elements 2. Optical hole burning memory 3. Molecular devices 4. Thermoplastic molecular composites
		(5) Composites	1. High performance carbon fiber reinforced plastic 2. High performance metal composite materials 3. High performance ceramic composite materials 4. High performance c/c composites
	Life Sciences	(1) New Drugs	1. Therapeutic and preventive drugs for cancer 2. Therapeutic and preventive drugs for viral diseases 3. Therapeutic and preventive drugs for symptoms of Dementia 4. Drugs for allergies and immunization
		(2) Use of Organisms	1. Bone marrow bank 2. Bioenergy
		(3) Biometrics	1. Artificial organs 2. Artificial enzymes, artificial membranes
Basic Technology to Support Industrial Activity	Energy	(1) Energy Supply Technology	1. Fuel cells 2. Solar cell technology 3. Small, independent, safe LWR technology 4. Fusion reactors 5. Fast breeder reactors
		(2) Technology to Improve Efficient Energy Use	1. High efficiency heat pump technology 2. Super conducting power storage facilities
	Automation	(1) Robot Technology	1. Intelligent robots 2. Micromachines
		(2) Machining Technology	1. AI-CNC 2. Multiple processing centers 3. Ultra-ultra precision machining devices
		(3) CAD/CAM Technology	1. Intelligent CAD 2. Product motels
		(4) CIM/HIM Technology	1. Autonomous decentralized control 2. Concurrent engineering

Table 2-1b List of New Technologies and Products

Large Category	Medium Category	Small Category	Item Studied
Basic Technology For Society	Communications	(1) Satellites, Mobile Communications Technology	1. Personal data communications devices 2. VSAT (Ultra-small land stations)/satellite data network
		(2) Image Communications Technology	1. HDTV (high-density TV) 2. CS/BS-CATV (communications satellite/broadcast satellite use cable television)
		(3) Multimedia Communications Technology	1. Television conferences 2. Television telephoning
		(4) Network Technology	1. Wide band ISDN (comprehensive digital communications net) switching devices 2. Optical subscriber systems 3. Optical LAN (Optical local area network)
	Transport & Transportation	(1) Railway Technology	1. Superconductor linear motor car 2. Next generation high temperature super conductor linear motor car 3. HSST linear motor car 4. ATCS (advanced train control system) 5. Bi-modal system (unified transport system)
		(2) Automobile Technology	1. Next generation automobiles 2. Automobiles for communications satellite use 3. Alternative fuel automobiles 4. Innovative automotive manufacturing technology
		(3) Ship Technology	1. Techno-super liner 2. Surface effect vehicle 3. Intelligent ships 4. Aquarobots
		(4) Aircraft Technology	1. Mass transport airliners 2. HST (high supersonic transports) 3. Small vertical takeoff & landing propeller aircraft 4. Small vertical takeoff & landing business jet aircraft
	Utilization of Space	(1) Technology to Use Outer Space	1. Underground test facility for weightlessness 2. Research base on moon 3. Linear motor catapult
		(2) Technology to Use Above-Ground Space	1. Super skyscrapers 2. Mammoth airdomes 3. Skyscraper disassembly technology
		(3) Technology to Use Underground Space	1. Underground distribution network 2. Deep subway and underground road facilities 3. Underground heat storage systems
		(4) Technology to Use Ocean Space	1. Artificial islands 2. Floating stations 3. Ocean "ranches" 4. Ocean amusement parks
Environment Protection Measures	Environment	(1) Global Warming	1. CO_2 catalytic fixation technology 2. CO_2 plant fixation technology 3. CO_2 disposal technology
		(2) Ozone Depletion	1. Freon gas alternatives 2. Freon recovery and processing technology
		(3) Waste Management	1. Biodegradable plastic 2. Underground general waste management systems 3. Underground storage and treatment facilities for water

3. Data Collection Method

In order to collect data concerning the long range forecasting of new technologies and products and their impact on industry and the economy, this council conducted its analysis by creating assessment sheets, having committee members, in their position as specialists, fill them in, and then organizing them. The main roles and responsibilities of each committee member are as follows:

(by field of technology or product)

Information, Electronics .... Kuwahara, Omichi
New Materials.. Omichi, Yoshinaga
Life Sciences .... Yoshida
Energy... Fujii, Okawa
Automation .... Mochizuki
Communications .... Hirozaki
Transport & Transportation.. Arai, Hattori
Utilization of Space .... Okawa
Environment... Arai, Okawa

(by field of analysis)

Technology Forecasting.. Kondo, Arai
Impact on Industry and the Economy .... Omichi, Arai

As a reference, the assessment sheets (A, B, C, & D) follow.

Long Range Forecast for Application of New Technology

Survey Sheet A Name_____________

New Technology or Product	
Summary of New Technology or Product	
R&D Status	(1) Relative Stage of R&D (Relative value with application stage = 100)____ (2) Present International Comparison Rating (Rank in Japan = 100) Japan__100__ US _______ Europe_______ (3) Rate of Increase in R&D Spending and Research Personnel Large Medium Small No Change Decrease (4) Rate of Increase in Number of Related Patents and Monographs Large Medium Small No Change Decrease (5) Rate of Increase in Grants and Subsidies Large Medium Small No Change Decrease (6) Competing Technology Methods (7) Other Relevant Information
Key Technology (Technology Required for Breakthrough)	(1) Technology Required for Breakthrough Rank 1__________________________ Rank 2__________________________ Rank 3__________________________ Rank 4__________________________ Rank 5__________________________ (2) Major Fields in Peripheral Support Technology Rank 1__________________________ Rank 2__________________________ Rank 3__________________________ Rank 4__________________________ Rank 5__________________________

<table>
<tr><td>New Technology or Product</td><td></td></tr>
<tr><td>Obstacles In Systems, etc., Other Than Technical</td><td>(1) Amount of Impact from Social Limitations Specific Details & Reasons
•System: Great Moderate Small None ( )
•Government Policy: Great Moderate Small None ( )
•Infrastructure: Great Moderate Small None ( )
•Environment: Great Moderate Small None ( )
•Value System, Understanding: Great Moderate Small None ( )

(2) Amount of Impact from Economic Limitations
•Gain of Market Share: Great Moderate Small None ( )
•Promotion of Lower Costs: Great Moderate Small None ( )
•Difficulty in Entering Market: Great Moderate Small None ( )
•Lack of R&D Funds: Great Moderate Small None ( )
•Lack of R&D Personnel: Great Moderate Small None ( )

(3) Other Limitations</td></tr>
<tr><td>Specific Policy for Breakthroughs in Key Technologies and Other Obstacles to Promote Application</td><td></td></tr>
<tr><td>Outlook for Time of Application and Rate of Replacement of Existing Item</td><td>(1) Outlook for Time of Application:
Time of Application______ 1990 2000 2010
Expectation based on present trend: Application Rate_100_ ____ _____ _____

(2) To raise replacement rate 10% over that forecast by present trend:
Rate of increase in R&D effort over present trend (+) _____%

(3) Time of application corrected to 100% application in 2010
Rate of increase in R&D effort over present trend (-, +) _____%

(4) Other Relevant Information</td></tr>
</table>

Long Range Forecast for Application of New Technology

Survey Sheet B Name____________

New Technology or Product	
Size of Market	Projected values based on present trends: Time of Application______ 1990 2000 2010 R&D Costs (¥10 million) ______ ______ ______ ______ Market Production Amount: (¥10 million) ______ ______ ______ ______ No. of Companies and Laboratories Involved ______ ______ ______ ______ Rate of Replacement (%) ______ ______ ______ ______
Positive Impact	(1) Advent of New Industries and Products Rank 1________________ Rank 2________________ Rank 3________________ Rank 4________________ Rank 5________________ (2) Activation of Existing Industries and Products Rank 1________________ Rank 2________________ Rank 3________________ Rank 4________________ Rank 5________________ (3) Industries and Products Producing Ripple Effect Rank 1________________ Rank 2________________ Rank 3________________ Rank 4________________ Rank 5________________
Negative Impact	(1) Decline of Existing Industries and Products Rank 1________________ Rank 2________________ Rank 3________________ Rank 4________________ Rank 5________________ (2) Competing Industries and Products Rank 1________________ Rank 2________________ Rank 3________________ Rank 4________________ Rank 5________________
Comments Concerning Technology Assessment	

Basis for Calculation of Data

(Assessment Sheet C)

Technology or Product Name__________________Name______________________

1. Size of Market (Calculation methods, reports referred to, etc.)

2. Price at Time of Application or Expected Price at Distribution (Calculation method, reports referred to, etc.)

3. Amount of Distribution (Calculation method, reports referred to, etc.)

4. Rate of Replacement (What kinds of technologies or products will it replace?)

Size of Market of Typical Technology or Product at Present and Cost of Major Technology or Product

(Assessment Sheet D)

Name________________

1. Size of Market of Typical Technology or Product at Present

Technology/Product Name	Annual Size of Market (¥10 million)	Date	Comments
(Example) Fine ceramics	10640	1987	
Liquid crystal display	2000	1990	

2. Cost of Major Technology or Product

Technology/Product Name	Total Cost (¥10 million)	Period	No. of Years	Annual Cost (¥10 million)	Comments
(Example) Seto Ohashi	11300	1978-1988	9.5	1189	
Liquid crystal display	2000	—	—	—	

4. Organization of Data

The data collected in the assessment sheets shown in Part 3. above were organized in the form of tables to facilitate analysis. By using the method of entering the data directly into the tables, further data was collected. However, there were some items among the new technologies and products for which data could not be collected.

Moreover, the following points should be made concerning the organization of data into tables.

Table A

(Name of Technology or Product)
The *Name of the New Technology or Product* was not listed formally for some items due to space limitations.

(Status of R&D)
The *Stage of R&D* is the present stage of progress in development of a technology toward practical application from a technical standpoint when the application stage = 100. This is a consideration only of the level of technical development, and the status of fulfillment of conditions in the application environment such as social and economic limitations is not considered.

The *International Comparison* represents the present level of technology in the US and Europe if the level in Japan = 100.

Rate of Increase in R&D Spending and Research Personnel, Rate of Increase in Number of Related Patents and Monographs, and *Rate of Increase in Grants and Subsidies* were evaluated on the following five levels.

- [3] Items showing rapid increase of several hundred percent in the past 2-3 years (for example, items in which full-fledged work on technical development has recently begun such as CO_2 fixation).
- [2] Items showing steady increase of several tens of percent in the past 2-3 years.
- [1] Items showing some increase of several percent in the past 2-3 years.
- [0] Items showing almost no change in the past 2-3 years.
- [–1] Items showing a decrease in the past 2-3 years.

(Obstacles in Systems Other Than Technical)
The *Amount of Impact from Social and Economic Limitations* was evaluated on the following five [sic] levels.

- [3] Major impact from obstacles.
- [2] Moderate impact from obstacles.
- [1] Small impact from obstacles.
- [0] No impact from obstacles.

(Outlook for Application)
The *Time of Realization* (or Application) is the time in which the first release of a new product appears on the market and commercial return is expected, based on the premise that acquisition of future profits can be expected. (For example, if a product is placed on the market when researchers view the product as only 80% complete, that will be treated as 100%.) Further, the projected application times vary considerably depending on the views of the experts, so most application times were expressed as a range of time. Here the median value or the greatest common factor was chosen for the application time.

The *Rate of Realization* takes the time of application as 100% and expresses in percent the level of realization for 1990, 2000, and 2010 after total consideration of technical, social, and economic limitations. Further, for items that are expected to achieve 100% realization by 2000, for example, a [—] mark is entered in the column for 2010.

The *Effort for Realization by 2000* indicates the extent and amount of effort that would be required in the event that technologies and products that are not expected to be realized until after 2010 would be moved forward and realized by about 2010 based on present trends. This effort includes not only the technical aspects but also the effort to overcome social and economic limitations.

- [L] Indicates realization may be possible if the present effort is increased several times.
- [M] Indicates realization may be possible if the present effort is increased several tens of percent.
- [IP] Indicates realization is impossible by 2010 regardless of extra effort.

(Size of Market)
Sizeof Market estimates the size of the market in 1990, 2000, and 2010. For those items that will have become widespread and achieved a market size by 1990 or 2000, nothing is entered in the column for the years thereafter. Further, costs for creating prototypes, etc., are considered to be included in R&D costs. If items will become widespread and create a large market even on a test basis (for example, new drugs), this is included in the "Market Size of Existing Products."

The *Size of the Market at Time of Application* indicates the expected size of the market at the time the item achieves practical application from a technical standpoint or reaches full-fledged distribution. For example, if the time of application is 2000, the same figures are entered in the 2000 column and the Time of Application column.

Table B

Breakthrough Technologies evaluates on the following two levels the importance of key technologies that will be necessary for breakthroughs to allow a certain technology or product to achieve application. This clarifies the mutual relationship of each technique in the application of a technology.

- [2] Very greatly needed
- [1] Greatly needed

Table C

Impact on Society and the Economy evaluates the positive impact a certain technology or product will have on society and the economy on the following two levels.

- [2] Very great positive impact
- [1] Great positive impact

Table D

Annual Size of Market (Units/Year) indicates the number of units distributed (the number of units sold) in a single year.

Price at Time of Application (¥100 Million/Unit) indicates the cost of the product at the time of application. Further, to calculate the market size, the *Price at Time of Application* x *Annual Distribution =Size of Market.*

Further, for items such as super skyscrapers that will require several years to construct, the total cost of construction is entered.

Expected Price at Distribution (¥100 Million/Unit) indicates what will be a good price (called the Expected Price at Distribution) for a new technology or product to become widespread and replace existing products, although major cost reductions will be necessary.

Market of Existing Product (¥100 Million) indicates the size of the market of the product (existing product) that will be replaced by the new technology or product.

Replacement Rate takes into consideration the fact that at the Time of Application (the time when the product is first released on the market) the rate of replacement will be almost zero, but that after several years the new product will replace the existing product. However, for a product that is completely original, it is expected that there will be no existing product for it to replace, so a [—] is entered.

Effort to Increase Replacement Rate 10% evaluates to what extent the present trend in R&D must be stepped up to increase by 10% the replacement rate (the rate at which the new technology or product will replace the existing product) estimated on the basis of the present trend.

Note: Because of space limitations many column headings in the tables were shortened. Moreover, Tables A–D had to be broken down to fit the format of this publication. Although headings were repeated so that each part of a table may be referred to independently, the following pattern can be used to reconstruct the entire table.

1a	1b	1c	1d
2a	2b	2c	2d
3a	3b	3c	3d
4a	4b	4c	4d

Table A–1a

Technology or Product Name	Status of R&D: R&D Stage	International Comparison: USA	International Comparison: Europe	Increase in R&D Expenditures and Researchers	Increase in Number of Patents and Monographs	Increase in Grants and Subsidies
(Information & Electronics)						
Terabit Memory	5	30	10	3	2	2
Superconductor Devices	10	50	10	3	2	2
Super Intelligent Chips	5	100	30	3	0	0
Self-propagating Chips	5	100	50	3	2	2
Terabit Optical Files	10	50	10	3	2	0
Terabit Optical Communications Devices	10	50	20	3	2	2
Optical Computing Elements/Devices	5	100	30	2	2	2
Biosensors	55	95	35	2	3	2
Biocomputers	10	100	100	2	3	3
Super Parallel Computers	20	100	30	3	2	0
Neurocomputers	5	50	10	3	2	0
Automatic Translation Systems	15	100	30	3	2	1
Virtual Reality Systems	20	150	50	3	2	3
Self-propagating Data Base Systems	10	150	50	3	2	2
Average	13	88	37	2.8	2.0	1.5
(New Materials)						
Superconductor Materials	30	80	65	0	2	1
Ceramic Gas Turbine	40	120	110	3	1	3
New Glass	0	50	—	1	1	1
Optical IC	10	100	100	2	2	2
Semiconductor Superlattice Elements	10	150	100	3	3	3
Amorphous Alloys	60	120	60	3	2	-1
Hydrogen Adsorptive Alloys	95	90	80	1	0	1
Magnetic Materials	60	80	40	0	0	0
Non-linear Photoelectronic Materials	20	150	100	2	3	3
Photochemical Hole Burning Memory	30	150	120	1	2	2
Molecular Devices	10	100	80	1	2	2
Thermoplastic Molecular Composites	30	150	50	2	2	2
High Performance CFRP	50	200	120	1	2	1
High Performance Metal Composites	10	200	150	0	0	0
High Performance Ceramic Composites	10	150	120	0	0	0
High Performance C/C Composites	10	400	200	1	2	2
Average	30	147	102	1.3	1.5	1.4

In Status of R&D: 3 = Great, 2 = Moderate, 1 = Small, 0 = No Change, -1 = Decrease

Table A–2a

Technology or Product Name	Status of R&D					
	R&D Stage	International Comparison		Increase in R&D Expenditures and Researchers	Increase in Number of Patents and Monographs	Increase in Grants and Subsidies
		USA	Europe			
(Life Sciences)						
Therapeutic Drugs for Cancer	40	130	90	1	1	-1
Therapeutic Drugs for Viral Diseases	20	200	80	2	2	2
Therapeutic Drugs for Dementia	5	100	80	3	3	3
Drugs for Allergies	50	100	80	3	3	3
Bone Marrow Bank	10	120	80	1	1	1
Bioenergy	20	100	90	1	1	1
Artificial Organs	15	100	80	2	2	2
Artificial Enzymes and Membranes	30	120	80	2	2	2
Average	24	121	83	1.9	1.9	1.6
(Energy)						
Fuel Cells	50	95	80	3	0	1
Solar Power Generation	60	80	60	0	1	0
Module Light Water Reactors	10	130	100	1	1	1
Fast Breeder Reactors	60	100	130	2	2	2
Atomic Fusion	20	120	120	2	2	2
High Efficiency Heat Pump Technology	85	80	80	2	3	2
Superconductive Power Storage Facilities	30	250	30	1	1	1
Average	45	122	86	1.6	1.4	1.3
(Automation)						
Intelligent Robots	10	95	80	2	2	
Micromachines	5	130	80	3	3	
AI-CNC	20	40	60	2	2	
Multiple Machining Center	5	80	80	2	1	
Ultra Precision Machining Equipment	10	120	120	2	1	
Intelligent CAD	10	120	120	1	1	
Product Models	30	120	120	1	1	
Decentralized Control	5	120	90	2	2	
Concurrent Engineering	20	120	120	1	1	
Average	13	105	97	1.8	1.6	

In Status of R&D: 3 = Great, 2 = Moderate, 1 = Small, 0 = No Change, -1 = Decrease

Table A–3a

Technology or Product Name	Status of R&D					
	R&D Stage	International Comparison		Increase in R&D Expenditures and Researchers	Increase in Number of Patents and Monographs	Increase in Grants and Subsidies
		USA	Europe			
(Communications)						
Personal Communication Devices	70	120	150	3	3	2
VSAT/Satellite Data Network	80	200	30	1	2	0
HDTV	60	60	70	3	3	3
BS/CS–CATV	80	150	90	2	2	2
TV Conference System	90	100	70	0	0	-1
TV Telephone	75	100	60	2	2	2
Wide Band ISDN Switchers	70	100	100	3	3	3
Optical Subscriber System	60	100	70	3	3	3
Optical LAN	70	100	70	1	2	2
Average	73	114	79	2.0	2.2	1.8
(Transport & Transportation)						
Superconductor Linear Motor Car	80	—	—	3	1	3
Next Generation Superconductor LMC	40	—	—	3	1	3
HSST Linear Motor Car	90	—	150	0	-1	0
Advanced Train Control System	30	80	120	1	1	1
Bimodal System	10	50	50	1	0	0
Next Generation Automobiles	40	90	100	3	2	1
Automobiles for Communications Satellites	80	200	70	2	2	1
Alternative Fuel Automobiles	80	150	100	3	3	3
Innovative Auto Manufacturing Technology	50	100	100	2	1	1
Techno-super Liner	40	—	—	2	1	1
Surface Effect Vehicle	80	—	200	1	0	0
Intelligent Ships	10	30	30	0	-1	-1
Aquarobots	30	300	200	2	1	1
Large Capacity Airliners	10	300	150	1	0	0
HST	10	200	150	2	1	1
Small VTOL Propeller Aircraft	20	300	150	0	0	0
Small VTOL Jet Aircraft	10	300	150	1	2	0
Average	39	175	123	1.5	0.8	0.8

In Status of R&D: 3 = Great, 2 = Moderate, 1 = Small, 0 = No Change, -1 = Decrease

Table A–4a

Technology or Product Name	Status of R&D					
	R&D Stage	International Comparison		Increase in R&D Expenditures and Researchers	Increase in Number of Patents and Monographs	Increase in Grants and Subsidies
		USA	Europe			
(Utilization of Space)						
Underground Facility for Weightlessness	50	50	50	0	0	0
Research Base on Moon	25	200	100	0	0	0
Linear Motor Catapult	30	80	—	0	0	0
Super Skyscraper	80	100	50	2	3	2
Super Air Dome	50	130	80	2	2	1
Skyscraper Disassembly Technology	90	150	80	1	1	1
Underground Distribution Network	60	80	80	2	2	1
Deep Underground Railway/Road System	80	70	70	2	2	1
Underground Heat Storage System	5	—	—	1	1	1
Artificial Islands	70	150	120	1	2	1
Floating Stations	60	200	150	0	1	1
Ocean Ranches	90	20	20	0	2	3
Ocean Amusement Parks	40	100	130	1	1	1
Average	56	111	85	0.9	1.3	1.0
(Environment)						
CO_2 Catalytic Fixation Technology	10	100	100	3	3	3
CO_2 Plant Fixation Technology	10	100	100	3	1	3
CO_2 Treatment Technology	30	150	100	3	3	3
Freon Alternative Gases	80	120	50	2	3	3
Freon Recovery & Processing Technology	90	80	50	1	1	2
Underground General Waste Management	10	100	200	1	1	1
Underground Water Storage and Treatment	10	100	100	0	0	1
Biodegradable Plastic	30	200	150	2	2	2
Average	34	119	106	1.9	1.8	2.3

In Status of R&D: 3 = Great, 2 = Moderate, 1 = Small, 0 = No Change, -1 = Decrease

Table A–1b

Technology or Product Name	Obstacles In Systems Other Than Technical				
	Social Limitations				
	Government Regulations	Government Policy	Infrastructure	Environment	Public Consciousness
(Information and Electronics)					
Terabit Memory	0	2	0	0	1
Superconductor Devices	0	2	0	0	1
Super Intelligent Chips	0	0	1	0	1
Self-propagating Chips	0	0	0	0	2
Terabit Optical Files	0	2	2	1	2
Terabit Optical Communications Devices	2	2	2	0	2
Optical Computing Elements/Devices	0	0	0	0	0
Biosensors	0	0	0	0	0
Biocomputers	0	0	1	0	1
Super Parallel Computers	0	0	0	0	0
Neurocomputers	0	0	0	0	2
Automatic Translation Systems	2	2	2	0	2
Virtual Reality Systems	0	0	2	0	2
Self-propagating Data Base Systems	0	0	0	0	2
Average	0.3	0.7	0.7	0.1	1.3
(New Materials)					
Superconductor Materials	1	1	1	2	1
Ceramic Gas Turbine	3	3	3	3	3
New Glass	0	0	0	0	3
Optical IC	1	1	1	1	1
Semiconductor Superlattice Elements	2	2	2	2	2
Amorphous Alloys	3	3	3	3	3
Hydrogen Adsorptive Alloys	3	3	3	0	0
Magnetic Materials	0	0	1	1	2
Non-linear Photoelectronic Materials	2	1	1	1	1
Photochemical Hole Burning Memory	2	1	1	1	1
Molecular Devices	2	1	1	1	1
Thermoplastic Molecular Composites	3	0	2	1	0
High Performance CFRP	2	2	2	1	1
High Performance Metal Composites	2	0	2	2	1
High Performance Ceramic Composites	3	0	2	1	0
High Performance C/C Composites	0	0	3	0	0
Average	1.8	1.1	1.8	1.3	1.3

In Obstacles in Systems other than Technical: 3 = Great, 2 = Moderate, 1 = Small, 0 = No Change, -1 = Decrease

Table A–2b

Technology or Product Name	Obstacles In Systems Other Than Technical				
	Social Limitations				
	Government Regulations	Government Policy	Infrastructure	Environment	Public Consciousness
(Life Sciences)					
Therapeutic Drugs for Cancer	3	3	1	1	3
Therapeutic Drugs for Viral Diseases	3	3	1	1	3
Therapeutic Drugs for Dementia	3	3	1	1	1
Drugs for Allergies	3	3	1	1	2
Bone Marrow Bank	3	3	3	1	2
Bioenergy	2	3	3	3	3
Artificial Organs	3	3	2	1	3
Artificial Enzymes and Membranes	1	1	1	2	2
Average	2.6	2.8	1.6	1.4	2.4
(Energy)					
Fuel Cells	2	2	1	1	2
Solar Power Generation	2	3	2	0	3
Module Light Water Reactors	3	3		2	3
Fast Breeder Reactors	2	3	3	2	3
Atomic Fusion	1	3	3	2	1
High Efficiency Heat Pump Technology	2	1	1	2	2
Superconductive Power Storage Facilities	2	3	0	2	2
Average	2.0	2.6	1.7	1.6	2.3
(Automation)					
Intelligent Robots	1	2	1	0	2
Micromachines	0	0	0	0	0
AI-CNC	0	0	3	0	3
Multiple Machining Center	0	0	2	0	2
Ultra Precision Machining Equipment	0	0	0	0	0
Intelligent CAD	0	1	1	0	1
Product Models	0	0	1	0	0
Decentralized Control	0	0	0	0	0
Concurrent Engineering	0	1	2	0	1
Average	0.1	0.4	1.1	0.0	1.0

In Obstacles in Systems other than Technical: 3 = Great, 2 = Moderate, 1 = Small, 0 = No Change, -1 = Decrease

Table A–3b

Technology or Product Name	Obstacles In Systems Other Than Technical				
	Social Limitations				
	Government Regulations	Government Policy	Infrastructure	Environment	Public Consciousness
(Communications)					
Personal Communication Devices	3	3	2	1	3
VSAT/Satellite Data Network	3	3	2	1	0
HDTV	3	3	2	0	2
BS/CS–CATV	3	3	2	0	2
TV Conference System	0	3	2	0	2
TV Telephone	1	2	2	0	2
Wide Band ISDN Switchers	1	2	2	0	2
Optical Subscriber System	3	3	2	1	2
Optical LAN	0	0	2	0	0
Average	1.9	2.4	2.0	0.3	1.7
(Transport & Transportation)					
Superconductor Linear Motor Car	0	-1	0	0	-1
Next Generation Superconductor LMC	3	3	3	2	1
HSST Linear Motor Car	0	2	2	0	0
Advanced Train Control System	3	2	3	0	0
Bimodal System	2	2	0	0	0
Next Generation Automobiles	1	1	1	1	1
Automobiles for Communications Satellites	2	3	1	1	1
Alternative Fuel Automobiles	1	3	2	3	2
Innovative Auto Manufacturing Technology	1	1	1	1	1
Techno-super Liner	3	2	2	2	1
Surface Effect Vehicle	0	2	0	2	0
Intelligent Ships	2	3	3	1	0
Aquarobots	1	0	0	0	0
Large Capacity Airliners	3	2	2	1	2
HST	3	3	3	2	2
Small VTOL Propeller Aircraft	3	3		2	0
Small VTOL Jet Aircraft	2	2	3	2	0
Average	1.9	2.1	1.7	1.3	0.7

In Obstacles in Systems other than Technical: 3 = Great, 2 = Moderate, 1 = Small, 0 = No Change, -1 = Decrease

Table A–4b

Technology or Product Name	Obstacles In Systems Other Than Technical				
	Social Limitations				
	Government Regulations	Government Policy	Infrastructure	Environment	Public Consciousness
(Utilization of Space)					
Underground Facility for Weightlessness	1	2	0	0	2
Research Base on Moon	2	3	0	0	3
Linear Motor Catapult	1	2	1	3	2
Super Skyscraper	1	0	2	2	0
Super Air Dome	2	1	3	2	1
Skyscraper Disassembly Technology	2	0	0	2	0
Underground Distribution Network	2	2	0	1	3
Deep Underground Railway/Road System	3	3	0	1	0
Underground Heat Storage System	3	3	0	0	2
Artificial Islands	2	2	1	2	2
Floating Stations	1	1	2	3	2
Ocean Ranches	3	2	1	2	3
Ocean Amusement Parks	2	2	2	2	0
Average	1.9	1.8	0.9	1.5	1.5
(Environment)					
CO_2 Catalytic Fixation Technology	0	0	2	1	0
CO_2 Plant Fixation Technology	2	2	2	2	0
CO_2 Treatment Technology	0	0	0	2	0
Freon Alternative Gases	3	3	0	3	3
Freon Recovery & Processing Technology	2	1	3	2	1
Underground General Waste Management	3	3	3	2	3
Underground Water Storage and Treatment	3	3	0	0	3
Biodegradable Plastic	2	3	0	3	3
Average	1.9	1.9	1.3	1.9	1.5

In Obstacles in Systems other than Technical: 3 = Great, 2 = Moderate, 1 = Small, 0 = No Change, -1 = Decrease

Table A–1c

Technology or Product Name	Obstacles In Systems Other Than Technical				
	Economic Limitations				
	Municipal Regulations	Cost	Municipal Principles	Lack of Dev. Funds	Lack of Personnel
(Information and Electronics)					
Terabit Memory	3	3	1	3	2
Superconductor Devices	3	3	1	3	2
Super Intelligent Chips	3	3	1	2	2
Self-propagating Chips	2	2	2	3	3
Terabit Optical Files	3	3	1	3	2
Terabit Optical Communications Devices	3	3	1	3	2
Optical Computing Elements/Devices	3	3	1	2	2
Biosensors	1	1	1	0	1
Biocomputers	1	0	1	1	1
Super Parallel Computers	3	3	1	2	2
Neurocomputers	3	3	1	2	2
Automatic Translation Systems	3	2	1	2	2
Virtual Reality Systems	3	3	0	3	3
Self-propagating Data Base Systems	3	3	0	3	2
Average	2.6	2.5	0.9	2.3	2.0
(New Materials)					
Superconductor Materials	1	2	2	1	2
Ceramic Gas Turbine	3	3	3	3	3
New Glass	2	2	0	1	2
Optical IC	3	3	2	1	1
Semiconductor Superlattice Elements	3	3	2	2	2
Amorphous Alloys	3	3	3	3	3
Hydrogen Adsorptive Alloys	3	3	0	0	3
Magnetic Materials	2	2	0	1	1
Non-linear Photoelectronic Materials	2	3	2	3	3
Photochemical Hole Burning Memory	2	3	2	3	3
Molecular Devices	3	3	2	3	3
Thermoplastic Molecular Composites	3	3	0	3	3
High Performance CFRP	3	3	0	2	2
High Performance Metal Composites	3	3	0	2	2
High Performance Ceramic Composites	3	3	0	2	2
High Performance C/C Composites	3	2	0	2	2
Average	2.6	2.8	1.1	2.0	2.3

In Obstacles in Systems other than Technical: 3 = Great, 2 = Moderate, 1 = Small, 0 = No Change, -1 = Decrease

Table A–2c

Technology or Product Name	Obstacles In Systems Other Than Technical				
	Economic Limitations				
	Municipal Regulations	Cost	Municipal Principles	Lack of Dev. Funds	Lack of Personnel
(Life Sciences)					
Therapeutic Drugs for Cancer	1	1	1	3	3
Therapeutic Drugs for Viral Diseases	1	1	2	2	2
Therapeutic Drugs for Dementia	1	1	1	3	3
Drugs for Allergies	1	1	1	1	1
Bone Marrow Bank	2	3	3	2	2
Bioenergy	1	3	2	3	2
Artificial Organs	3	3	2	2	2
Artificial Enzymes and Membranes	3	3	2	3	3
Average	1.6	2.0	1.8	2.4	2.3
(Energy)					
Fuel Cells	3	3	1	1	1
Solar Power Generation	3	3	2	1	1
Module Light Water Reactors		3	2	3	2
Fast Breeder Reactors	3	3	1	3	2
Atomic Fusion	3	3	1	3	2
High Efficiency Heat Pump Technology	1	3	1	1	1
Superconductive Power Storage Facilities	3	3	1	3	0
Average	2.7	3.0	1.3	2.1	1.3
(Automation)					
Intelligent Robots	2	3	0	2	2
Micromachines	0	1	1	2	1
AI-CNC	2	2	1	2	1
Multiple Machining Center	1	3	1	1	1
Ultra Precision Machining Equipment	2	1	1	2	2
Intelligent CAD	2	3	0	2	2
Product Models	1	1	1	2	2
Decentralized Control	1	1	1	1	1
Concurrent Engineering	1	2	1	2	2
Average	1.3	1.9	0.8	1.8	1.6

In Obstacles in Systems other than Technical: 3 = Great, 2 = Moderate, 1 = Small, 0 = No Change, -1 = Decrease

Table A–3c

Technology or Product Name	Obstacles In Systems Other Than Technical				
	Economic Limitations				
	Municipal Regulations	Cost	Municipal Principles	Lack of Dev. Funds	Lack of Personnel
(Communications)					
Personal Communication Devices	1	3	1	1	1
VSAT/Satellite Data Network	1	3	2	1	1
HDTV	3	3	0	2	2
BS/CS–CATV	2	3	1	0	1
TV Conference System	2	3	1	1	1
TV Telephone	1	3	1	2	1
Wide Band ISDN Switchers	2	2	2	3	3
Optical Subscriber System	3	3	3	2	2
Optical LAN	3	3	1	1	2
Average	2.0	2.9	1.3	1.4	1.6
(Transport & Transportation)					
Superconductor Linear Motor Car	1	2	0	1	1
Next Generation Superconductor LMC	1	2	0	1	1
HSST Linear Motor Car	0	2	0	0	0
Advanced Train Control System	0	0	0	1	0
Bimodal System	2	2	0	0	0
Next Generation Automobiles	1	2	1	2	3
Automobiles for Communications Satellites	1	1	2	2	1
Alternative Fuel Automobiles	2	2	3	2	2
Innovative Auto Manufacturing Technology	2	2	0	2	2
Techno-super Liner	1	2	0	2	2
Surface Effect Vehicle	3	2	0	1	0
Intelligent Ships	3	3	0	2	0
Aquarobots	3	2	0	1	0
Large Capacity Airliners	0	0	0	3	2
HST	0	2	1	3	1
Small VTOL Propeller Aircraft	3	1	3	2	1
Small VTOL Jet Aircraft	3	2	2	1	1
Average	1.6	1.7	0.8	1.6	1.0

In Obstacles in Systems other than Technical: 3 = Great, 2 = Moderate, 1 = Small, 0 = No Change, -1 = Decrease

Table A–4c

Technology or Product Name	Obstacles In Systems Other Than Technical				
	Economic Limitations				
	Municipal Regulations	Cost	Municipal Principles	Lack of Dev. Funds	Lack of Personnel
(Utilization of Space)					
Underground Facility for Weightlessness	1	2	3	3	2
Research Base on Moon	3	3	3	3	2
Linear Motor Catapult	2	2	3	3	2
Super Skyscraper	2	0	0	0	0
Super Air Dome	1	3	0	0	0
Skyscraper Disassembly Technology	0	0	0	1	1
Underground Distribution Network	1	1	1	1	1
Deep Underground Railway/Road System	0	0	3	2	0
Underground Heat Storage System	3	2	1	3	1
Artificial Islands	2	1	1	1	1
Floating Stations	2	1	1	3	3
Ocean Ranches	3	3	2	3	2
Ocean Amusement Parks	1	2	2	1	0
Average	1.6	1.5	1.5	1.8	1.2
(Environment)					
CO_2 Catalytic Fixation Technology	1	3	1	1	1
CO_2 Plant Fixation Technology	2	3	3	1	1
CO_2 Treatment Technology	1	3	3	1	1
Freon Alternative Gases	2	3	1	0	1
Freon Recovery & Processing Technology	3	3	3	1	3
Underground General Waste Management	1	1	3	2	2
Underground Water Storage and Treatment	0	1	1	1	2
Biodegradable Plastic	3	3	3	1	1
Average	1.6	2.5	2.3	1.0	1.5

In Obstacles in Systems other than Technical: 3 = Great, 2 = Moderate, 1 = Small, 0 = No Change, -1 = Decrease

Table A–1d

Technology or Product Name	Outlook for Date of Application: Time of Realization	Rate of Realization (%) 1990	2000	2010	Effort Needed to Realize by 2000	Size of Market at Application (¥10 mil/yr) 1990	2000	2010	Time of App.
(Information and Electronics)									
Terabit Memory	2030	3	10	20	L	-	-	-	30000
Superconductor Devices	2020	5	50	100	M	-	-	-	10000
Super Intelligent Chips	2010	20	50	100	-	-	-	10000	10000
Self-propagating Chips	2050	0	10	20	L	-	-	-	30000
Terabit Optical Files	2010	0	50	100	-	-	-	20000	20000
Terabit Optical Communications Devices	2010	0	50	100	-	-	-	30000	30000
Optical Computing Elements/Devices	2020	0	10	50	M	-	-	-	10000
Biosensors	2000	55	100	100	-	-	-	-	20000
Biocomputers	2020	0	10	50	M	-	-	-	Unclear
Super Parallel Computers	2010	0	50	100	-	-	-	20000	20000
Neurocomputers	2030	0	10	30	L	-	-	-	20000
Automatic Translation Systems	2020	5	20	50	L	-	-	-	10000
Virtual Reality Systems	2020	20	30	50	L	-	-	-	10000
Self-propagating Data Base Systems	2020	0	30	50	L	-	-	-	10000
Average	2019	8	35	66					
(New Materials)									
Superconductor Materials	2030	30	60	80	M	-	-	-	Unclear
Ceramic Gas Turbine	2000	40	95	100	-	-	-	-	Unclear
New Glass	2010	0	20	50	-	-	10	10000	10000
Optical IC	2010	10	70	100	-	-	10	20	20
Semiconductor Superlattice Elements	2010	10	40	100	-	-	-	5000	5000
Amorphous Alloys	2010	5	20	100	-	-	-	-	Unclear
Hydrogen Adsorptive Alloys	2010	10	50	100	-	-	-	-	Unclear
Magnetic Materials	2010	60	80	100	-	-	-	-	Unclear
Non-linear Photoelectronic Materials	2020	20	40	70	L	-	-	100	100
Photochemical Hole Burning Memory	2020	0	40	80	L	-	-	50	100
Molecular Devices	2040	0	1	10	L	-	-	-	100
Thermoplastic Molecular Composites	2040	0	10	20	L	-	-	-	100
High Performance CFRP	2000	50	100	100	-	-	2000	-	2000
High Performance Metal Composites	2050	0	5	10	L	-	50	300	1000
High Performance Ceramic Composites	2050	50	20	50	L	-	100	-	1000
High Performance C/C Composites	2010	5	50	100	-	-	50	-	100
Average	2020	15	44	73					

Effort to Realize by 2000: IP = Impossible, L = Extreme effort required, M = Much effort required.

Table A–2d

Technology or Product Name	Outlook for Date of Application					Size of Market			
	Time of Realization	Rate of Realization (%)			Effort Needed to Realize by 2000	Size of Market at Application (¥10 mil/yr)			
		1990	2000	2010		1990	2000	2010	Time of App.
(Life Sciences)									
Therapeutic Drugs for Cancer	2030	20	40	50	IP	-	-	-	4000
Therapeutic Drugs for Viral Diseases	2020	20	50	80	L	-	-	-	5000
Therapeutic Drugs for Dementia	2050	5	10	50	IP	-	-	-	2500
Drugs for Allergies	2030	30	50	70	IP	-	-	-	5000
Bone Marrow Bank	2010	10	30	100	-	-	-	-	Unclear
Bioenergy	2050	20	30	50	L	-	-	-	Unclear
Artificial Organs	2030	15	30	50	L	-	-	-	4000
Artificial Enzymes and Membranes	2020	30	60	80	M	-	-	-	Unclear
Average	2030	19	38	66					
(Energy)									
Fuel Cells	2015	10	30	90	M	60	1000	2000	2000
Solar Power Generation	2010	20	40	100	-	-	-	-	Unclear
Module Light Water Reactors	2010	0	30	80	-	-	-	200	200
Fast Breeder Reactors	2030	0	0	5	L	-	-	-	6000
Atomic Fusion	2050	0	0	0	IP	-	-	-	Unclear
High Efficiency Heat Pump Technology	1995	85	95	100	-	-	4000	-	4000
Superconductive Power Storage Facilities	2020	10	50	80	M	-	-	-	10000
Average	2019	18	35	65					
(Automation)									
Intelligent Robots	2010	10	70	100	-	-	10	500	500
Micromachines	2010	2	30	100	-	-	20	300	300
AI-CNC	2010	20	60	100	-	10	200	600	600
Multiple Machining Center	2020	5	30	60	M	-	20	150	300
Ultra Precision Machining Equipment	2020	10	30	60	M	5	20	100	105
Intelligent CAD	2020	10	30	50	L	-	50	100	300
Product Models	2010	30	50	100	-	-	50	10	100
Decentralized Control	2005	2	50	100	-	-	10	100	50
Concurrent Engineering	2010	20	50	100	-	-	100	300	300
Average	2013	12	44	86					

Effort to Realize by 2000: IP = Impossible, L = Extreme effort required, M = Much effort required.

Table A-3d

Technology or Product Name	Outlook for Date of Application					Size of Market			
	Time of Realization	Rate of Realization (%)			Effort Needed to Realize by 2000	Size of Market at Application (¥10 mil/yr)			
		1990	2000	2010		1990	2000	2010	Time of App.
(Communications)									
Personal Communication Devices	1995	70	100	100	-	-	2000	500	1600
VSAT/Satellite Data Network	1992	85	100	100	-	-	1000	200	300
HDTV	1995	60	100	100	-	-	3000	30000	1000
BS/CS–CATV	1995	80	100	100	-	-	600	1500	400
TV Conference System	1994	90	100	100	-	-	400	1000	200
TV Telephone	1994	80	100	100	-	-	200	300	100
Wide Band ISDN Switchers	1995	70	100	100	-	-	1000	2000	100
Optical Subscriber System	1995	60	100	100	-	-	2500	5000	1500
Optical LAN	1995	70	100	100	-	-	500	1000	100
Average	1994	74	100	100					
(Transport & Transportation)									
Superconductor Linear Motor Car	2010	70	90	100	-	-	-	-	Unclear
Next Generation Superconductor LMC	2030	20	30	50	L	-	-	-	10000
HSST Linear Motor Car	1995	80	100	100	-	-	500	100	100
Advanced Train Control System	2010	30	60	100	-	-	-	1000	1000
Bimodal System	2000	50	100	100	-	-	100	300	100
Next Generation Automobiles	2005	1	40	100	-	-	30000	30000	30000
Automobiles for Communications Satellites	2020	1	30	50	M	100	500	1000	1000
Alternative Fuel Automobiles	1995	1	100	100	-	5	2500	5000	5000
Innovative Auto Manufacturing Technology	2000	10	10	100	-	-	5000	5000	5000
Techno-super Liner	2010	10	70	100	-	-	-	1000	1000
Surface Effect Vehicle	1995	80	100	100	-	-	100	300	10
Intelligent Ships	2010	50	70	100	-	-	-	1000	1000
Aquarobots	2010	30	60	100	-	-	-	100	100
Large Capacity Airliners	2010	30	50	100	-	-	-	5000	5000
HST	2020	0	40	80	L	-	-	-	5000
Small VTOL Propeller Aircraft	2000	30	100	100	-	-	100	500	100
Small VTOL Jet Aircraft	2000	50	100	100	-	-	300	1000	300
Average	2007	30	66	93					

Effort to Realize by 2000: IP = Impossible, L = Extreme effort required, M = Much effort required.

Table A–4d

Technology or Product Name	Outlook for Date of Application					Size of Market			
	Time of Realization	Rate of Realization (%)			Effort Needed to Realize by 2000	Size of Market at Application (¥10 mil/yr)			
		1990	2000	2010		1990	2000	2010	Time of App.
(Utilization of Space)									
Underground Facility for Weightlessness	2005	20	100	100	-	-	-	-	100
Research Base on Moon	2020	0	10	20	M	-	-	-	5000
Linear Motor Catapult	2010	0	10	100	-	-	-	-	1000
Super Skyscraper	2000	0	100	100	-	-	-	-	2000
Super Air Dome	2005	50	90	100	-	-	-	-	1000
Skyscraper Disassembly Technology	2010	0	50	100	-	-	-	-	100
Underground Distribution Network	2010	60	80	100	-	-	-	-	5000
Deep Underground Railway/Road System	2005	5	30	100	-	-	-	-	2300
Underground Heat Storage System	2020	0	10	20	M	-	-	-	150
Artificial Islands	2000	80	100	100	-	-	-	-	500
Floating Stations	2010	60	80	100	-	-	-	-	600
Ocean Ranches	2000	10	100	100	-	-	-	-	200
Ocean Amusement Parks	2010	10	50	100	-	-	-	-	100
Average	2008	23	62	88					
(Environment)									
CO_2 Catalytic Fixation Technology	2010	10	50	100	-	-	-	3000	3000
CO_2 Plant Fixation Technology	2035	10	20	50	L	-	-	-	Unclear
CO_2 Treatment Technology	2010	10	50	100	-	-	500	1000	1000
Freon Alternative Gases	1995	20	100	100	-	-	800	800	500
Freon Recovery & Processing Technology	1995	50	100	100	-	-	1000	-	800
Underground General Waste Management	2020	0	10	30	M	-	5000	10000	50000
Underground Water Storage and Treatment	2010	10	50	100	-	-	-	-	Unclear
Biodegradable Plastic	2000	30	100	100	-	-	1000	5000	10000
Average	2009	18	60	77					

Effort to Realize by 2000: IP = Impossible, L = Extreme effort required, M = Much effort required.

Table B–1a

Technology or Product Name	Breakthrough Technologies											
	Information & Electronics						New Materials					
		Microelectronic	Optoelectronics	Bioelectronics	Systems	Software		Ceramics	Semiconductors	Metals	Organics	Composites
(Information and Electronics)												
Terabit Memory		2						1	1	1		1
Superconductor Devices		1						1	1	2		1
Super Intelligent Chips		2				1			1			
Self-propagating Chips		2				1		1	1	1		1
Terabit Optical Files			2			1						1
Terabit Optical Com. Devices			2									1
Optical Computing			2			1						1
Elements/Devices												
Biosensors												1
Biocomputers												1
Super Parallel Computers		1				1						
Neurocomputers		1				1			1			
Automatic Translation Systems												
Virtual Reality Systems		1				1						
Self-propagating Data Base Systems			2			2						
Average	0	0.7	0.5	0	0	0.6	0	0.2	0.3	0.2	0	0.5
(New Materials)												
Superconductor Materials								2				
Ceramic Gas Turbine								2				
New Glass							2					
Optical IC		2	2		2	1			2			
Semiconductor Superlattice Elements		2			2	1			2			
Amorphous Alloys										1		
Hydrogen Adsorptive Alloys										2		
Magnetic Materials										2		
Non-linear Photoelect. Materials			1		1	1			1		1	
Photochemical Hole Burning			1		1	1			1		1	
Memory			1	1	1	1			1		1	
Molecular Devices											1	
Thermoplastic Mol. Composites											1	
High Performance CFRP												1
High Performance Metal Composites										1		1
High Perform. Ceramic Composites								1				1
High Performance C/C Composites								1			1	1
Average	0	0.2	0.3	0.0	0.4	0.3	0.1	0.3	0.4	0.3	0.3	0.2

Table B–2a

Technology or Product Name	Breakthrough Technologies											
	Information & Electronics						New Materials					
		Microelectronic	Optoelectronics	Bioelectronics	Systems	Software		Ceramics	Semiconductors	Metals	Organics	Composites
(Life Sciences)												
Therapeutic Drugs for Cancer												
Therapeutic Drugs for Viral Diseases												
Therapeutic Drugs for Dementia												
Drugs for Allergies												
Bone Marrow Bank												
Bioenergy												
Artificial Organs								1		1	1	2
Artificial Enzymes and Membranes											1	1
Average	0	0	0	0	0	0	0	0.1	0	0.1	0.2	0.3
(Energy)												
Fuel Cells					2							2
Solar Power Generation					1				1			2
Module Light Water Reactors					1					2		
Fast Breeder Reactors					1					2		
Atomic Fusion					1			2		2		
High Efficiency Heat Pump					1						2	
Superconductive Power Storage								2		1		1
Average	0	0	0	0	1	0	0	0.5	0.1	1	0.2	0.7
(Automation)												
Intelligent Robots		2	1	1		2		1	1	1	1	2
Micromachines		2	1	1					1			
AI-CNC		2	1	1		2			1			
Multiple Machining Center		2	1	1		2		1		1		1
Ultra Precision Machining		2	1	1		2		1		1		1
Intelligent CAD		2	1	1	1	2						
Product Models		2	1		1	2						
Decentralized Control		2	1	1		2			1			2
Concurrent Engineering		2	1	1	1	2						
Average	0	2	0.8	0.8	0.3	1.7	0	0.3	0.4	0.3	0.1	0.6

Table B–3a

Technology or Product Name	Breakthrough Technologies: Information & Electronics	Microele-ctronic	Optoelec-tronics	Bioelec-tronics	Systems	Soft-ware	New Materials	Ceramics	Semicon-ductors	Metals	Organics	Com-posites
(Communications)												
Personal Communication Devices		1										
VSAT/Satellite Data Network												
HDTV		1										
BS/CS–CATV												
TV Conference System			1									
TV Telephone						1						
Wide Band ISDN Switchers			1									
Optical Subscriber System			1									
Optical LAN			1									
Average	0	0.2	0.4	0	0	0.1	0	0	0	0	0	0
(Transport & Transportation)												
Superconductor Linear Motor Car												
Next Gen. Superconductor LMC					2	1						
HSST Linear Motor Car												
Advanced Train Control System					2							
Bimodal System												
Next Generation Automobiles		2			2	1		1		2	2	2
Automobiles for Com. Satellites		2	1		1	1			1			
Alternative Fuel Automobiles		1			1	1				1		12
Innovative Auto Man. Technology		1	1		1	1				2	2	
Techno-super Liner										2		
Surface Effect Vehicle												
Intelligent Ships					2	2						
Aquarobots							1					
Large Capacity Airliners							1					
HST							2					
Small VTOL Propeller Aircraft							2					
Small VTOL Jet Aircraft							2					
Average	0	0.3	0.1	0	0.6	0.4	0.4	0.0	0.0	0.4	0.2	0.2

Table B–4a

Technology or Product Name	Breakthrough Technologies											
	Information & Electronics						New Materials					
		Microelectronic	Optoelectronics	Bioelectronics	Systems	Software		Ceramics	Semiconductors	Metals	Organics	Composites
(Utilization of Space)												
Facility for Weightlessness		1	1	1	1			2	1	1	1	1
Research Base on Moon								1	1	1	1	1
Linear Motor Catapult								2	1	1		
Super Skyscraper			1		1					2	1	1
Super Air Dome												1
Skyscraper Disassembly Tech.												
Underground Distribution Network												
Underground Railway/Road System												
Underground Heat Storage System												
Artificial Islands												
Floating Stations												
Ocean Ranches				1								
Ocean Amusement Parks				1								
Average	0	0.0	0.1	0.2	0.1	0	0	0.3	0.2	0.3	0.2	0.3
(Environment)												
CO_2 Catalytic Fixation Technology												
CO_2 Plant Fixation Technology												
CO_2 Treatment Technology												
Freon Alternative Gases						2						
Freon Recovery & Processing												
Underground Waste Management												
Underground Water Storage												
Biodegradable Plastic											2	
Average	0	0	0	0	0	0.2	0	0	0	0	0.2	0

Table B–1b

Technology or Product Name	Breakthrough Technologies											
	Life Sciences				Energy			Automation				
		New Drugs	Use of Organism	Bio-energy		Supply	Use		Robots	Machining	CAD CAM	CIM HIM
(Information and Electronics)												
Terabit Memory												
Superconductor Devices												
Super Intelligent Chips												
Self-propagating Chips												
Terabit Optical Files												
Terabit Optical Com. Devices												
Optical Computing												
Elements/Devices												
Biosensors			1									
Biocomputers			1									
Super Parallel Computers												
Neurocomputers												
Automatic Translation Systems												
Virtual Reality Systems												
Self-propagating Data Base Systems												
Average	0	0	0	0	0	0	0	0	0	0	0	0
(New Materials)												
Superconductor Materials												
Ceramic Gas Turbine					1							
New Glass												
Optical IC									1			1
Semiconductor Superlattice Elements									1			1
Amorphous Alloys												
Hydrogen Adsorptive Alloys												
Magnetic Materials												
Non-linear Photoelect. Materials								1			1	
Photochemical Hole Burning Mem.								1				
Molecular Devices								1			1	
Thermoplastic Mol. Composites	1							1		1		1
High Performance CFRP								1		1	1	
High Performance Metal Composites								1		1	1	
High Perform. Ceramic Composites								1		1	1	
High Perform. C/C Composites								1		1	1	
Average	0.0	0	0	0	0.0	0	0	0.5	0.1	0.3	0.3	0.1

Table B–2b

Technology or Product Name	Breakthrough Technologies											
	Life Sciences				Energy			Automation				
		New Drugs	Use of Organism	Bio-energy		Supply	Use		Robots	Machining	CAD CAM	CIM HIM
(Life Sciences)												
Therapeutic Drugs for Cancer		2	1									
Therapeutic Drugs for Viral Diseases		2	1									
Therapeutic Drugs for Dementia		2	1									
Drugs for Allergies		2	1									
Bone Marrow Bank			2									
Bioenergy												
Artificial Organs				2		1						
Artificial Enzymes and Membranes				2								
Average	0	1	0.7	0.5	0	0.1	0	0	0	0	0	0
(Energy)												
Fuel Cells						2						
Solar Power Generation						2						
Module Light Water Reactors						2			2			
Fast Breeder Reactors						2			2			
Atomic Fusion						2			1			
High Efficiency Heat Pump							2					
Superconductive Power Storage							1					
Average	0	0	0	0	0	1.4	0.4	0	0.7	0	0	0
(Automation)												
Intelligent Robots										1		
Micromachines												
AI-CNC											1	1
Multiple Machining Center											1	1
Ultra Precision Machining												
Intelligent CAD												
Product Models												
Decentralized Control												
Concurrent Engineering												
Average	0	0	0	0	0	0	0	0	0	0.1	0.2	0.2

Table B–3b

Technology or Product Name	Breakthrough Technologies											
	Life Sciences				Energy			Automation				
		New Drugs	Use of Organism	Bio-energy		Supply	Use		Robots	Machining	CAD CAM	CIM HIM
(Communications)												
Personal Communication Devices												
VSAT/Satellite Data Network												
HDTV												
BS/CS–CATV												
TV Conference System												
TV Telephone												
Wide Band ISDN Switchers												
Optical Subscriber System												
Optical LAN												
Average	0	0	0	0	0	0	0	0	0	0	0	0
(Transport & Transportation)												
Superconductor Linear Motor Car												
Next Gen. Superconductor LMC						1						
HSST Linear Motor Car												
Advanced Train Control System												
Bimodal System												
Next Generation Automobiles							1		1		1	
Automobiles for Com. Satellites												
Alternative Fuel Automobiles							2					
Innovative Auto Man. Technology							2		2	2	1	1
Techno-super Liner												
Surface Effect Vehicle												
Intelligent Ships									2			
Aquarobots									2			
Large Capacity Airliners							1					
HST												
Small VTOL Propeller Aircraft												
Small VTOL Jet Aircraft												
Average	0	0	0	0	0	0.0	0.3	0	0.4	0.1	0.1	0.0

Table B-4b

Technology or Product Name	Breakthrough Technologies											
	Life Sciences				Energy			Automation				
		New Drugs	Use of Organism	Bio-energy		Supply	Use		Robots	Machining	CAD CAM	CIM HIM
(Utilization of Space)												
Facility for Weightlessness												
Research Base on Moon				1		1	2		1			
Linear Motor Catapult												
Super Skyscraper				1		1	1		1			
Super Air Dome												
Skyscraper Disassembly Tech.												
Underground Distribution Network									2			
Underground Railway/Road System									2			
Underground Heat Storage System												
Artificial Islands							2					
Floating Stations						1						
Ocean Ranches						1			1			
Ocean Amusement Parks									1			
Average	0	0	0	0.1	0	0.3	0.3	0	0.6	0	0	0
(Environment)												
CO_2 Catalytic Fixation Technology	2											
CO_2 Plant Fixation Technology												
CO_2 Treatment Technology												
Freon Alternative Gases												
Freon Recovery & Processing												
Underground Waste Management				1					1			
Underground Water Storage				1					1			
Biodegradable Plastic	2											
Average	0.5	0	0	00.2	0	0	0	0	0.2	0	0	0

Table B–1c

Technology or Product Name	Breakthrough Technologies									
	Communications					Transportation & Transport				
		Satellite & Mobile	Images	Multimedia	Networks		Railroads	Autos	Ships	Aircraft
(Information and Electronics)										
Terabit Memory										
Superconductor Devices										
Super Intelligent Chips										
Self-propagating Chips										
Terabit Optical Files										
Terabit Optical Com. Devices										
Optical Computing Elements/Devices										
Biosensors										
Biocomputers										
Super Parallel Computers										
Neurocomputers										
Automatic Translation Systems										
Virtual Reality Systems			1							
Self-propagating Data Base Systems										
Average	0	0	0.0	0	0	0	0	0	0	0
(New Materials)										
Superconductor Materials										
Ceramic Gas Turbine								1		
New Glass										
Optical IC			1		1					
Semiconductor Superlattice Elements			1		1					
Amorphous Alloys										
Hydrogen Adsorptive Alloys										
Magnetic Materials										
Non-linear Photoelect. Materials										
Photochemical Hole Burning Mem.			1	1						
Molecular Devices										
Thermoplastic Mol. Composites										
High Performance CFRP										
High Performance Metal Composites										
High Perform. Ceramic Composites										
High Perform. C/C Composites										
Average	0	0	0.1	0.0	0.1	0	0	0.0	0	0

Table B–2c

Technology or Product Name	Breakthrough Technologies									
	Communications					Transportation & Transport				
		Satellite & Mobile	Images	Multimedia	Networks		Railroads	Autos	Ships	Aircraft
(Life Sciences)										
Therapeutic Drugs for Cancer										
Therapeutic Drugs for Viral Diseases										
Therapeutic Drugs for Dementia										
Drugs for Allergies										
Bone Marrow Bank				1						
Bioenergy										
Artificial Organs										
Artificial Enzymes and Membranes										
Average	0	0	0	0.1	0	0	0	0	0	0
(Energy)										
Fuel Cells										
Solar Power Generation										
Module Light Water Reactors										
Fast Breeder Reactors										
Atomic Fusion										
High Efficiency Heat Pump										
Superconductive Power Storage										
Average	0	0	0	0	0	0	0	0	0	0
(Automation)										
Intelligent Robots										
Micromachines										
AI-CNC	1									
Multiple Machining Center	1									
Ultra Precision Machining										
Intelligent CAD										
Product Models										
Decentralized Control										
Concurrent Engineering										
Average	0.2	0	0	0	0	0	0	0	0	0

Table B–3c

Technology or Product Name	Breakthrough Technologies									
		Communications				Transportation & Transport				
		Satellite & Mobile	Images	Multimedia	Networks		Railroads	Autos	Ships	Aircraft
(Communications)										
Personal Communication Devices		2								
VSAT/Satellite Data Network		2								
HDTV			2							
BS/CS–CATV			2							
TV Conference System				2						
TV Telephone				2						
Wide Band ISDN Switchers					2					
Optical Subscriber System					2					
Optical LAN					2					
Average	0	0.4	0.4	0.4	0.6	0	0	0	0	0
(Transport & Transportation)										
Superconductor Linear Motor Car										
Next Gen. Superconductor LMC										
HSST Linear Motor Car		2			2					
Advanced Train Control System										
Bimodal System										
Next Generation Automobiles		1		1				1		
Automobiles for Com. Satellites		1		1	1			1		
Alternative Fuel Automobiles								1		
Innovative Auto Man. Technology					1			1		
Techno-super Liner									2	
Surface Effect Vehicle									2	
Intelligent Ships										
Aquarobots										
Large Capacity Airliners										
HST									2	
Small VTOL Propeller Aircraft									2	
Small VTOL Jet Aircraft									2	
Average	0	0.2	0	0.1	0.2	0	0	0.2	0.5	0

Table B–4c

Technology or Product Name	Breakthrough Technologies									
	Communications					Transportation & Transport				
		Satellite & Mobile	Images	Multimedia	Networks		Railroads	Autos	Ships	Aircraft
(Utilization of Space)										
Facility for Weightlessness										
Research Base on Moon		1	1	1						2
Linear Motor Catapult										2
Super Skyscraper			1	1	1			1		
Super Air Dome				1						
Skyscraper Disassembly Tech.										
Underground Distribution Network							1	1		
Underground Railway/Road System							1	2		
Underground Heat Storage System										
Artificial Islands										
Floating Stations										
Ocean Ranches									1	
Ocean Amusement Parks									1	
Average	0	0.0	0.1	0.2	0.0	0	0.1	0.3	0.1	0.3
(Environment)										
CO_2 Catalytic Fixation Technology										
CO_2 Plant Fixation Technology										
CO_2 Treatment Technology										
Freon Alternative Gases										
Freon Recovery & Processing										
Underground Waste Management										
Underground Water Storage										
Biodegradable Plastic										
Average	0	0	0	0	0	0	0	0	0	0

Table B–1d

Technology or Product Name	Breakthrough Technologies									
	Utilization of Space					Environment Policy				Other
		Outer Space	Terrestial	Underground	Marine		Global Warming	Ozone Layer	Waste Mgmt.	
(Information and Electronics)										
Terabit Memory										
Superconductor Devices										
Super Intelligent Chips										
Self-propagating Chips										
Terabit Optical Files										
Terabit Optical Com. Devices										
Optical Computing Elements/Devices										
Biosensors										
Biocomputers										
Super Parallel Computers										
Neurocomputers										
Automatic Translation Systems										
Virtual Reality Systems										
Self-propagating Data Base Systems										
Average	0	0	0	0	0	0	0	0	0	0
(New Materials)										
Superconductor Materials										
Ceramic Gas Turbine										
New Glass										
Optical IC										
Semiconductor Superlattice Elements										
Amorphous Alloys										2
Hydrogen Adsorptive Alloys						1				
Magnetic Materials										
Non-linear Photoelect. Materials										
Photochemical Hole Burning Mem.										
Molecular Devices										
Thermoplastic Mol. Composites										
High Performance CFRP										
High Performance Metal Composites										
High Perform. Ceramic Composites										
High Perform. C/C Composites										
Average	0	0	0	0	0	0	0	0	0	0.125

Table B–2d

Technology or Product Name	Breakthrough Technologies									
	Utilization of Space					Environment Policy				Other
		Outer Space	Terrestial	Underground	Marine		Global Warming	Ozone Layer	Waste Mgmt.	
(Life Sciences)										
Therapeutic Drugs for Cancer										
Therapeutic Drugs for Viral Diseases										
Therapeutic Drugs for Dementia										
Drugs for Allergies										
Bone Marrow Bank										
Bioenergy										
Artificial Organs										
Artificial Enzymes and Membranes										
Average	0	0	0	0	0	0	0	0	0	0
(Energy)										
Fuel Cells										
Solar Power Generation										
Module Light Water Reactors										
Fast Breeder Reactors		1			1					
Atomic Fusion		1								
High Efficiency Heat Pump										
Superconductive Power Storage					1					
Average	0	0.2	0	0	0.2	0	0	0	0	0
(Automation)										
Intelligent Robots										
Micromachines										
AI-CNC										
Multiple Machining Center										
Ultra Precision Machining										
Intelligent CAD										
Product Models										
Decentralized Control										
Concurrent Engineering										
Average	0	0	0	0	0	0	0	0	0	0

Table B–3d

Technology or Product Name	Breakthrough Technologies									
	Utilization of Space					Environment Policy				Other
		Outer Space	Terrestial	Underground	Marine		Global Warming	Ozone Layer	Waste Mgmt.	
(Communications)										
Personal Communication Devices										
VSAT/Satellite Data Network		2								
HDTV										
BS/CS–CATV		2								
TV Conference System										
TV Telephone										
Wide Band ISDN Switchers										
Optical Subscriber System										
Optical LAN										
Average	0	0.4	0	0	0	0	0	0	0	0
(Transport & Transportation)										
Superconductor Linear Motor Car										
Next Gen. Superconductor LMC						1				
HSST Linear Motor Car										
Advanced Train Control System										
Bimodal System										
Next Generation Automobiles			1				1	1	1	
Automobiles for Com. Satellites		1	1							
Alternative Fuel Automobiles			1					1		
Innovative Auto Man. Technology			1				1		1	
Techno-super Liner										
Surface Effect Vehicle										
Intelligent Ships										
Aquarobots					2					
Large Capacity Airliners										
HST										
Small VTOL Propeller Aircraft										
Small VTOL Jet Aircraft										
Average	0	0.0	0.2	0	0.1	0.0	0.1	0.1	0.1	0

Table B–4d

Technology or Product Name	Breakthrough Technologies									
	Utilization of Space					Environment Policy				Other
		Outer Space	Terrestial	Underground	Marine		Global Warming	Ozone Layer	Waste Mgmt.	
(Utilization of Space)										
Facility for Weightlessness				2						
Research Base on Moon		2								
Linear Motor Catapult										
Super Skyscraper			1							
Super Air Dome			1							
Skyscraper Disassembly Tech.			1							
Underground Distribution Network				2						
Underground Railway/Road System				2						
Underground Heat Storage System										
Artificial Islands				2						
Floating Stations					2					
Ocean Ranches					2					
Ocean Amusement Parks					2					
Average	0	0.1	0.2	0.6	0.4	0	0	0	0	0
(Environment)										
CO_2 Catalytic Fixation Technology										
CO_2 Plant Fixation Technology										
CO_2 Treatment Technology					2					
Freon Alternative Gases										
Freon Recovery & Processing										
Underground Waste Management				2					1	
Underground Water Storage				2					1	
Biodegradable Plastic										
Average	0	0	0	0.5	0.2	0	0	0	0.2	0

Table C–1

Technology or Product Name	Global		National		Social/Corporate				Individual	
	Harmony with Eco-system	Food, Energy, Population Problems	Inter-national Cooper-ation	Safety and Security	Pursuit of Abun-dance	Safety of Environ-ment	Aging of Society	Business & Social Harmony	Pursuit of Leisure	Pursuit of Comfort
(Information and Electronics)										
Terabit Memory	2				1	1				
Superconductor Devices			1		1				1	
Super Intelligent Chips	2									
Self-propagating Chips	2									
Terabit Optical Files	2		1	1	1	1				
Terabit Optical Com. Devices			1	1		2				1
Optical Computing Elements/Devices	1		1			1				
Biosensors										
Biocomputers										
Super Parallel Computers	1		1	1	1					
Neurocomputers	2		1	1		1				
Automatic Translation Systems										
Virtual Reality Systems	1				2				1	1
Self-propagating Data Base Systems	2		1	1		1				
Average	1.07	0.00	0.50	0.36	0.43	0.50	0.00	0.00	0.14	0.14
(New Materials)										
Superconductor Materials						1				
Ceramic Gas Turbine		1				1				
New Glass		1						2		2
Optical IC								2		2
Semiconductor Superlattice Elements										1
Amorphous Alloys										
Hydrogen Adsorptive Alloys						1				
Magnetic Materials					1					
Non-linear Photoelect. Materials			1	1	1			1	1	
Photochemical Hole Burning Memory			1	1	1			1	1	
Molecular Devices			1	1	1			1	1	
Thermoplastic Mol. Composites		1	1	1	1			1		
High Performance CFRP		1	1	1	1			1	1	
High Performance Metal Composites			1	1				1	1	
High Perform. Ceramic Composites		1	1	1	1			1	1	1
High Performance C/C Composites		1	1	1				1	1	
Average	0.00	0.38	0.50	0.50	0.44	0.19	0.00	0.75	0.44	0.38

Table C-2

Technology or Product Name	Global		National		Social/Corporate				Individual	
	Harmony with Eco-system	Food, Energy, Population Problems	Inter-national Cooper-ation	Safety and Security	Pursuit of Abun-dance	Safety of Environ-ment	Aging of Society	Business & Social Harmony	Pursuit of Leisure	Pursuit of Comfort
(Life Sciences)										
Therapeutic Drugs for Cancer					2		1			2
Therapeutic Drugs for Viral Diseases					1					2
Therapeutic Drugs for Dementia					1		2		1	2
Drugs for Allergies							1			2
Bone Marrow Bank					1		2			1
Bioenergy		2				2			1	
Artificial Organs					1		2			2
Artificial Enzymes and Membranes	1	1				1			1	
Average	0.13	0.38	0.00	0.00	0.75	0.38	1.00	0.00	0.38	1.38
(Energy)										
Fuel Cells										
Solar Power Generation										
Module Light Water Reactors										
Fast Breeder Reactors										
Atomic Fusion										
High Efficiency Heat Pump										
Superconductive Power Storage										
Average	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
(Automation)										
Intelligent Robots		2			2		2	2	1	1
Micromachines		1			1					
AI-CNC		1			1		1	1		
Multiple Machining Center		2								
Ultra Precision Machining		1								
Intelligent CAD		2								
Product Models		1								
Decentralized Control		2			2		2	2	1	1
Concurrent Engineering		1								
Average	0.00	1.44	0.00	0.00	0.67	0.00	0.56	0.56	0.22	0.22

Table C–3

Technology or Product Name	Global		National		Social/Corporate				Individual	
	Harmony with Eco-system	Food, Energy, Population Problems	Inter-national Cooper-ation	Safety and Security	Pursuit of Abun-dance	Safety of Environ-ment	Aging of Society	Business & Social Harmony	Pursuit of Leisure	Pursuit of Comfort
(Communications)										
Personal Communication Devices									2	1
VSAT/Satellite Data Network					1					
HDTV					1				2	1
BS/CS–CATV					1				1	1
TV Conference System					2					
TV Telephone					1					1
Wide Band ISDN Switchers					2			1		
Optical Subscriber System					1				2	1
Optical LAN					2			1		
Average	0.00	0.00	0.00	0.00	1.10	0.00	0.00	0.20	0.70	0.50
(Transport & Transportation)										
Superconductor Linear Motor Car										
Next Gen. Superconductor LMC					2				1	2
HSST Linear Motor Car										1
Advanced Train Control System										
Bimodal System					1	1				
Next Generation Automobiles	1		1		1	1	1	1	2	2
Automobiles for Com. Satellites					1		1	1		1
Alternative Fuel Automobiles					1	2	1	1	1	1
Innovative Auto Man. Technology	1		1		1	2	1	1	1	1
Techno-super Liner									2	2
Surface Effect Vehicle					2					
Intelligent Ships									2	
Aquarobots								1		2
Large Capacity Airliners										2
HST										
Small VTOL Propeller Aircraft					2				2	
Small VTOL Jet Aircraft					2				2	
Average	0.13	0.00	0.13	0.00	0.81	0.38	0.25	0.31	0.81	0.88

Table C-4

Technology or Product Name	Global		National		Social/Corporate				Individual	
	Harmony with Eco-system	Food, Energy, Population Problems	Inter-national Cooper-ation	Safety and Security	Pursuit of Abun-dance	Safety of Environ-ment	Aging of Society	Business & Social Harmony	Pursuit of Leisure	Pursuit of Comfort
(Utilization of Space)										
Facility for Weightlessness			2		1					
Research Base on Moon	1	2	2		1	1				
Linear Motor Catapult										
Super Skyscraper					2	1		1		1
Super Air Dome					2	1			1	1
Skyscraper Disassembly Tech.					1	2		1		
Underground Distribution Network				1	1	2		1		
Underground Railway/Road System				1	1	2		1		
Underground Heat Storage System		2		1		1				
Artificial Islands		2			1	1				
Floating Stations		1			1	1				
Ocean Ranches		2								
Ocean Amusement Parks					1				2	1
Average	0.08	0.69	0.31	0.23	0.92	0.92	0.00	0.31	0.23	0.23
(Environment)										
CO_2 Catalytic Fixation Technology	2		2							
CO_2 Plant Fixation Technology	2		2							
CO_2 Treatment Technology	2		2							
Freon Alternative Gases	2		2							
Freon Recovery & Processing	2		2							
Underground Waste Management					1	2			1	1
Underground Water Storage		2		1	1					
Biodegradable Plastic	2					2		1		
Average	1.50	0.25	1.25	0.13	0.25	0.50	0.00	0.13	0.13	0.13

Table D–1a

Technology or Product Name	Size of Market					
	Annual Distribution (units/year)				Price at Time of App. (¥100 mil/unit)	Price at Time of Dist. (¥100 mil/unit)
	1990	2000	2010	Time of App.		
(Information and Electronics)						
Terabit Memory						
Superconductor Devices						
Super Intelligent Chips						
Self-propagating Chips						
Terabit Optical Files						
Terabit Optical Com. Devices						
Optical Computing Elements/Devices						
Biosensors						
Biocomputers						
Super Parallel Computers						
Neurocomputers						
Automatic Translation Systems						
Virtual Reality Systems						
Self-propagating Data Base Systems						
Average						
(New Materials)						
Superconductor Materials						
Ceramic Gas Turbine						
New Glass						
Optical IC						
Semiconductor Superlattice Elements						
Amorphous Alloys						
Hydrogen Adsorptive Alloys						
Magnetic Materials						
Non-linear Photoelect. Materials						
Photochemical Hole Burning Memory						
Molecular Devices						
Thermoplastic Mol. Composites						
High Performance CFRP						
High Performance Metal Composites						
High Perform. Ceramic Composites						
High Performance C/C Composites						
Average						

Table D–2a

Technology or Product Name	Size of Market: Annual Distribution (units/year) 1990	2000	2010	Time of App.	Price at Time of App. (¥100 mil/unit)	Price at Time of Dist. (¥100 mil/unit)
(Life Sciences)						
Therapeutic Drugs for Cancer						
Therapeutic Drugs for Viral Diseases						
Therapeutic Drugs for Dementia						
Drugs for Allergies						
Bone Marrow Bank						
Bioenergy						
Artificial Organs						
Artificial Enzymes and Membranes						
Average						
(Energy)						
Fuel Cells						
Solar Power Generation						
Module Light Water Reactors						
Fast Breeder Reactors						
Atomic Fusion						
High Efficiency Heat Pump						
Superconductive Power Storage				20	1000	1000
Average	0	0	0	4	200	200
(Automation)						
Intelligent Robots						
Micromachines						
AI-CNC						
Multiple Machining Center						
Ultra Precision Machining						
Intelligent CAD						
Product Models						
Decentralized Control						
Concurrent Engineering						
Average	0					

Table D–3a

Technology or Product Name	Size of Market: Annual Distribution (units/year) 1990	2000	2010	Time of App.	Price at Time of App. (¥100 mil/unit)	Price at Time of Dist. (¥100 mil/unit)
(Communications)						
Personal Communication Devices						
VSAT/Satellite Data Network						
HDTV						
BS/CS–CATV						
TV Conference System						
TV Telephone						
Wide Band ISDN Switchers						
Optical Subscriber System						
Optical LAN						
Average						
(Transport & Transportation)						
Superconductor Linear Motor Car						
Next Gen. Superconductor LMC				60	10	10
HSST Linear Motor Car				20	1.5	1.5
Advanced Train Control System						
Bimodal System				250	0.3	0.3
Next Generation Automobiles		1000000	1000000	2000	0.04	
Automobiles for Com. Satellites		250000	500000	2020	0.002	
Alternative Fuel Automobiles		50000	100000	1990	0.05	0.3
Innovative Auto Man. Technology						
Techno-super Liner				20	40	40
Surface Effect Vehicle				200	0.05	0.03
Intelligent Ships				10	100	100
Aquarobots				20	5	5
Large Capacity Airliners				15	350	350
HST				10	500	500
Small VTOL Propeller Aircraft				10	10	10
Small VTOL Jet Aircraft				10	30	30
Average						

Table D–4a

Technology or Product Name	Size of Market: Annual Distribution (units/year) 1990	2000	2010	Time of App.	Price at Time of App. (¥100 mil/unit)	Price at Time of Dist. (¥100 mil/unit)
(Utilization of Space)						
Facility for Weightlessness		1	4	4	250	1000
Research Base on Moon	0			1	40000	40000
Linear Motor Catapult	0	0	3	5	4000	4000
Super Skyscraper	0	1	3	5	10000	10000
Super Air Dome	0	0	2	5	5000	5000
Skyscraper Disassembly Tech.	0	0		1	1000	1000
Underground Distribution Network	0	0	1	1	100000	100000
Underground Railway/Road System	0	1	3	10	10000	10000
Underground Heat Storage System	0	0	1	10	1000	1000
Artificial Islands	0	1	2	5	10000	10000
Floating Stations	0	0	1	5	5000	5000
Ocean Ranches	0	1	2	5	1000	1000
Ocean Amusement Parks	0	0	1	3	2000	2000
Average						
(Environment)						
CO_2 Catalytic Fixation Technology				20	150	150
CO_2 Plant Fixation Technology						
CO_2 Treatment Technology				3	350	350
Freon Alternative Gases						
Freon Recovery & Processing						
Underground Waste Management	0	0	1	10	10000	10000
Underground Water Storage	0	1	5	30	2000	2000
Biodegradable Plastic						
Average						

Table D–1b

Technology or Product Name	Size of Market							
	Market of Future Product (¥100 million)				Replacement Rate (%)			Effort to Increase
	1990	2000	2010	Time of App.	1990	2000	2010	Rate 10%
(Information and Electronics)								
Terabit Memory					0	0	3	30
Superconductor Devices					0	10	30	30
Super Intelligent Chips					0	10	50	50
Self-propagating Chips					0	3	10	200
Terabit Optical Files					0	20	50	50
Terabit Optical Com. Devices					0	30	50	50
Optical Computing Elements/Devices					0	5	10	50
Biosensors					10	50		10
Biocomputers								
Super Parallel Computers					0	30	50	50
Neurocomputers					0	5	10	50
Automatic Translation Systems								
Virtual Reality Systems					5	10	20	100
Self-propagating Data Base Systems					0	10	30	100
Average					1.25	15.2	28.4	64.16
(New Materials)								
Superconductor Materials							10	
Ceramic Gas Turbine								
New Glass								
Optical IC								20
Semiconductor Superlattice Elements								
Amorphous Alloys								
Hydrogen Adsorptive Alloys								
Magnetic Materials								
Non-linear Photoelect. Materials							10	300
Photochemical Hole Burning Memory						10	30	200
Molecular Devices								1000
Thermoplastic Mol. Composites							5	300
High Performance CFRP						10	30	300
High Performance Metal Composites								300
High Perform. Ceramic Composites								500
High Performance C/C Composites								
Average						1.25	5.31	182.5

Table D–2b

Technology or Product Name	Size of Market							
	Market of Future Product (¥100 million)				Replacement Rate (%)			Effort to Increase Rate 10%
	1990	2000	2010	Time of App.	1990	2000	2010	
(Life Sciences)								
Therapeutic Drugs for Cancer	3000	3300	3500	4000	10	30	50	
Therapeutic Drugs for Viral Diseases	800	2500	3000	5000	15	40	70	
Therapeutic Drugs for Dementia	1500	1700	2000	2500	15	40	80	
Drugs for Allergies	3000	4000	4500	5000	30	50	80	
Bone Marrow Bank								
Bioenergy								
Artificial Organs	100	1000	2500	4000	5	30	60	
Artificial Enzymes and Membranes	100	800	1000	3000	10	25	30	
Average								
(Energy)								
Fuel Cells								20
Solar Power Generation								20
Module Light Water Reactors								30
Fast Breeder Reactors								
Atomic Fusion								
High Efficiency Heat Pump								10
Superconductive Power Storage	1000	1000	1000	0	0	0	0	
Average	200	200	200	0	0	0	0	16
(Automation)								
Intelligent Robots						5	20	50
Micromachines								20
AI-CNC					5	20	50	30
Multiple Machining Center					5	10	20	
Ultra Precision Machining					1	5	10	
Intelligent CAD						5	10	50
Product Models						10	30	50
Decentralized Control								20
Concurrent Engineering						10	20	50
Average					1.22	7.22	17.7	30

Table D–3b

Technology or Product Name	Size of Market: Market of Future Product (¥100 million) 1990	2000	2010	Time of App.	Replacement Rate (%) 1990	2000	2010	Effort to Increase Rate 10%
(Communications)								
Personal Communication Devices	3000					80	100	20
VSAT/Satellite Data Network	800					5	30	30
HDTV	1500					2	20	50
BS/CS–CATV	3000					10	50	50
TV Conference System						1	10	10
TV Telephone					0	5	20	50
Wide Band ISDN Switchers					0	2	20	50
Optical Subscriber System					0	1	10	50
Optical LAN					0	5	10	20
Average								
(Transport & Transportation)								
Superconductor Linear Motor Car								
Next Gen. Superconductor LMC								50
HSST Linear Motor Car							5	50
Advanced Train Control System							10	50
Bimodal System						10	30	150
Next Generation Automobiles		30000	30000	2000	0.5	5	25	20
Automobiles for Com. Satellites		500	1000	2020		2.5	5	50
Alternative Fuel Automobiles	5	2500	5000			2	5	50
Innovative Auto Man. Technology		5000	5000	2000	3	40	80	20
Techno-super Liner							10	50
Surface Effect Vehicle						10	30	50
Intelligent Ships								100
Aquarobots							10	150
Large Capacity Airliners							10	50
HST								100
Small VTOL Propeller Aircraft						10	30	200
Small VTOL Jet Aircraft						10	30	200
Average								

Table D-4b

Technology or Product Name	Size of Market							
	Market of Future Product (¥100 million)				Replacement Rate (%)			Effort to Increase Rate 10%
	1990	2000	2010	Time of App.	1990	2000	2010	
(Utilization of Space)								
Facility for Weightlessness								
Research Base on Moon								
Linear Motor Catapult								
Super Skyscraper								
Super Air Dome					30	40	50	20
Skyscraper Disassembly Tech.								
Underground Distribution Network								
Underground Railway/Road System								100
Underground Heat Storage System								50
Artificial Islands								10
Floating Stations								
Ocean Ranches								
Ocean Amusement Parks							10	10
Average								
(Environment)								
CO_2 Catalytic Fixation Technology								
CO_2 Plant Fixation Technology								
CO_2 Treatment Technology								
Freon Alternative Gases	600				0	100	100	10
Freon Recovery & Processing					50	100	100	
Underground Waste Management								100
Underground Water Storage								50
Biodegradable Plastic						10	50	30
Average								

5. Results of Data Analysis

As mentioned previously, the collected data was organized in the form of tables, and then a further, more detailed analysis was made of the data in Table A.

5–1 Forecasts Concerning Application

The data was organized based on the Time of Application (Realization) shown in Table A. Table 5–1 shows these data arranged in order of Time of Application beginning with the earliest, and classified into three time periods: 1990–2000, 2000–2010, and after 2011. Table 5–2 organizes these data based on their medium-sized categories. Table 5–3 gives the totals in each of these categories, and Table 5–4 expresses these in percentages.

[Key Points in Analysis Results]

•Concerning the forecast for the Time of Application, in past reports the time of application has been given as a range because there is the chance that a technological breakthrough will occur suddenly, and the social and economic situations at the time of the study are greatly influenced by the political climate, so in this study we have adopted the median value or the greatest common factor as the Time of Application. For example, in the case of "Fast Breeder Reactors," both people in the government and experts expect the time of application to be 2020–2030, so the median value of 2025 was chosen in this study. Therefore, in looking at Table 5–1 and 5–2, it is necessary to look at the Time of Application with the understanding that for these items, particularly for the items after 2020, there is already a large range in years both before and after.

•There are 101 new technologies and products analyzed. There are 26 items expected to be realized by 2000, 39 items expected from 2001–2010, and 36 items expected after the year 2011.

•From the standpoint of the medium-sized categories, all 9 of the Communications items are expected to be realized in the 1990s. In the areas of Transportation and Transport, Utilization of Space, and Environmental Measures about 80–90%, and in Automation and New Materials roughly 60% are expected to be realized by 2010. Further, in Information and Electronics, and in Energy only about 40%, and in Life Sciences only about 10% will be realized by 2010.

•In other words, based on the fact that the majority of new technologies and products that will reach application between 2001 and 2010 are expected to be realized close to 2010, about 80–90% of the Advanced Basic Technologies, such as Information and Electronics, New Materials, and Life Sciences, and of the Basic Technologies to Support Industrial Activity, such as Energy and Automation, can be expected to be realized after 2010.

•In this study most of the times of application are rather late in comparison to other technological forecasting reports because our ranking does not merely indicate the point at which a technological breakthrough occurs and prototype products can be made, but it fixes the Time of Application as the time in which a product can be expected to be competing with existing products and yielding a return on a commercial basis.

Table 5–1

Technology and Product by Time of Application

1990–2000	Time	2001–2010	Time	After 2011	Time
VSAT/Satellite Network	1992	Autonomous Control Systems	2005	Fuel Cells	2015
TV Conference System	1994	Weightlessness Facility	2005	Artificial Enzymes/Membranes	2020
TV Telephone	1994	Super Air Dome	2005	Anti-Viral Drugs	2020
Surface Effect Vehicle	1995	Deep Underground Road & Railway	2005	Multiple Processing Center	2020
Freon Alternative Gases	1995	Next Generation Autos	2005	Intelligent CAD	2020
Freon Recovery & Processes	1995	Underground Heat Storage	2005	Automatic Translation System	2020
Optical Subscription System	1995	Aquarobots	2010	Superconductive Devices	2020
Personal Communication Devices	1995	Magnetic Materials	2010	Non-linear Photoelectronic Mat.	2020
Gasoline Alternative Autos	1995	Hydrogen Adsorbing Alloys	2010	Virtual Reality Systems	2020
CS/BS–CATV	1995	AI–CNC	2010	Optical Computing Elements	2020
Optical LAN	1995	Optical IC	2010	Self Propagating Data Base	2020
High Efficiency Heat Pump	1995	Micromachines	2010	Superconductive Power Storage	2020
Wide Band ISDN Switchers	1995	Floating System	2010	HST	2020
HDTV	1995	Product Models	2010	Moon Base	2020
HSST Linear Motor Car	1995	Advanced Control Systems	2010	Underground Waste Mgmt.	2020
Biodegradable Plastics	2000	Concurrent Engineering	2010	Comm. Satellite Vehicles	2020
High Performance CFRP	2000	Semiconductor Superlattice Elements	2010	Photochemical Hole Burning	2020
Artificial Islands	2000	Super Parallel Computers	2010	Biocomputer	2020
Bimodal System	2000	Solar Photoelectric Generators	2010	Ultra Precision Processing	2020
Super Skyscrapers	2000	Underground Water Store=age	2010	Fast Breeder Reactors	2025
Marine Ranch	2000	Underground Distribution System	2010	Anti-Cancer Drugs	2030
Biosensors	2000	New Glass	2010	Neurocomputers	2030
Ceramic Gas Turbine	2000	Skyscraper Disassembly Technology	2010	Next Gen. Superconductor LMC	2030
Small VTOL Propeller Craft	2000	CO_2 Catalysis Fixation Technology	2010	Artificial Organs	2030
Innovative Auto Mfg. Technology	2000	Module Light Water Reactors	2010	Superconductive Materials	2030
Small VTOL Jet Craft	2000	Ocean Amusement Parks	2010	Allergy & Immunization Drugs	2030
		Techno-Super Liner	2010	Terabit Memory	2030
		Superconductor Linear Motor Car	2010	CO_2 Plant Fixation Technology	2035
		Terabit Optical Files	2010	Thermoplastic Mol. Composites	2040
		Amorphous Alloys	2010	Molecular Devices	2040
		Bone Marrow Bank	2010	Drugs for Dementia	2050
		Intelligent Ships	2010	Bioenergy	2050
		CO_2 Processing Technology	2010	Self Propagating Chips	2050
		High Performance C/C Composites	2010	High Perf. Ceramic Composites	2050
		Super Intelligent Chip	2010	High Perf. Metal Composites	2050
		Terabit Optical Communication Device	2010	Nuclear Fusion	2050
		Linear Motor Catapult	2010		
		Intelligent Robots	2010		
		Large Capacity Transport Airliners	2010		
			2010		
	26		39		36

Table 5–2a

		1990–2000	Time	2001–2010	Time	After 2011	Time
Advanced Basic Technology	Information and Electronics	Biosensors	2000	Super Parallel Computer	2010	Automatic Translation System	2020
				Terabit Optical File	2010	Superconductor Devices	2020
				Super Intelligent Chip	2010	Virtual Reality System	2020
				Terabit Optical Comm. Device	2010	Optical Computing Elements	2020
						Self Propagating Data Base	2020
						Biocomputer	2020
						Neurocomputer	2030
						Terabit Memory	2030
						Self Propagating Chip	2050
	14		1		4		9
	New Materials	High Performance CFRP	2000	Magnetic Materials	2010	Non-linear Photoelectronic	2020
		Ceramic Gas Turbine	2000	Hydrogen Adsorbing Alloys	2010	Photochemical Hole Burning	2020
				Optical IC	2010	Superconductor Material	2030
				Semiconductor Superlattice	2010	Thermoplastic Mol. Comp.	2040
				New Glass	2010	Molecular Devices	2040
				Amorphous Alloys	2010	High Perf. Ceramic Compos.	2050
				High Perf. C/C Composites	2010	High Perf. Metal Composites	2050
	16		2		7		7
	Life Sciences			Bone Marrow Bank	2010	Artificial Enzymes/Membranes	2020
						Anti-viral Drugs	2020
						Anti-Cancer Drugs	2030
						Artificial Organs	2030
						Allergy/Immunization Drugs	2030
						Drugs for Dementia	2050
						Bioenergy	2050
	8		0		1		7
Basic Technology to Support Industrial Activity	Energy	High Efficiency Heat Pump	1995	Solar Photoelectric Power	2010	Fuel Cells	2015
				Module Light Water Reactor	2010	Superconductor Power Storage	2020
						Fast Breeder Reactors	2025
						Atomic Fusion	2050
	7		1		2		4
	Automation			Autonomous Control	2005	Multiple Processing Center	2020
				AI–CNC	2010	Intelligent CAD	2020
				Micromachines	2010	Ultra Precision Processing	2020
				Product Models	2010		
				Concurrent Engineering	2010		
				Intelligent Robots	2010		
	9		0		6		3

Table 5–2b

		1990–2000	Time	2001–2010	Time	After 2011	Time
Social Basic Technology	Commui-cations	VSAT/Satellite Network	1992				
		TV Conference System	1994				
		TV Telephone	1994				
		Optical Subscription System	1995				
		Personal Comm. Devices	1995				
		CS/BS–CATV	1995				
		Optical LAN	1995				
		Wide Band ISDN Switchers	1995				
		HDTV	1995				
	9		9		0		0
	Transpor-tation and Transport	Surface Effect Vehicle	1995	Next Generation Autos	2005	HST	2020
		Gasoline Alternative Autos	1995	Aquarobots	2010	Comm. Satellite Vehicles	2020
		HSST Linear Motor Car	1995	Advanced Control Systems	2010	Next Generation LMC	2030
		Bimodal System	2000	Techno-Super Liner	2010		
		Small VTOL Prop. Craft	2000	Intelligent Ships	2010		
		Innovative Auto Mfg. Tech.	2000	Large Transport Airliners	2010		
		Small VTOL Jet Craft	2000	Superconductor LMC	2010		
	17		7		7		3
	Utilization of Space	Artificial Islands	2000	Super Air Dome	2005	Moon Base	2020
		Super Skyscrapers	2000	Underground Road & Rail	2005		
		Marine Ranches	2000	Underground Heat Storage	2005		
				Weightlessness Facility	2005		
				Floating System	2010		
				Underground Distribution Net	2010		
				Skyscraper Disassembly Tech	2010.		
				Marine Amusement Park	2010		
				Linear Motor Catapult	2010		
	13		3		9		1
	Environ-ment	Freon Alternative Gases	1995	Underground Water Storage	2010	Underground Waste Mgmt.	2020
		Freon Recovery & Processing	1995	CO_2 Catalyst Fixation Tech	2010	CO_2 Plant Fixation Tech	2035
		Biodegradable Plastics	2000	CO_2 Treatment Technology	2010		
	8		3		3		2
	101		26		39		36

Table 5–3

Time of Application by Technology/Product Category (Number)

	1990-2000	2001-2010	After 2011	Total
Electronics	1	4	9	14
New Materials	2	7	7	16
Life Sciences	0	1	7	8
Energy	1	2	4	7
Automation	0	6	3	9
Communications	9	0	0	9
Transportation & Transport	7	7	3	17
Utilization of Space	3	9	1	13
Environment	3	3	2	8
Total	26	39	36	101

Table 5–4

Time of Application by Technology/Product Category (%)

	1990-2000	2001-2010	After 2011
Electronics	7	29	64
New Materials	13	44	44
Life Sciences	0	13	88
Energy	14	29	57
Automation	0	67	33
Communications	100	0	0
Transportation & Transport	41	41	18
Utilization of Space	23	69	8
Environment	38	38	25
Total	26	39	36

Table 5–5

Time of Application (Average)

Electronics	2019
New Materials	2020
Life Sciences	2030
Energy	2018
Automation	2013
Communications	1994
Transportation & Transport	2007
Utilization of Space	2008
Environment	2009
Total	2013

Figure 5–1 Time of Application by Technology/Product Category (Number)

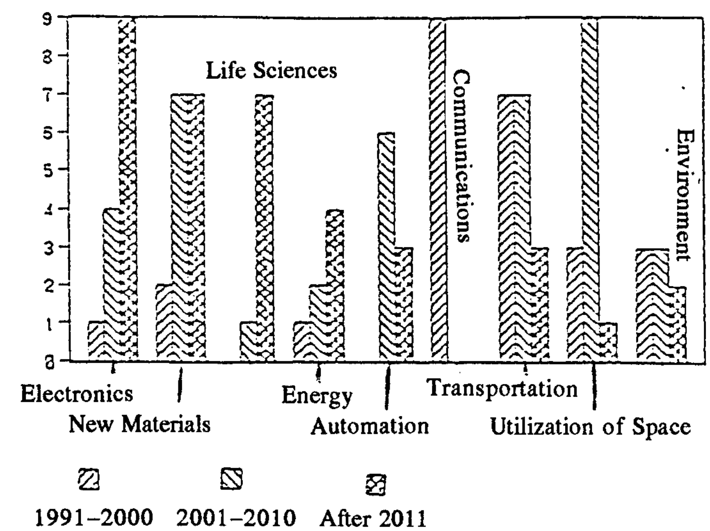


Figure 5–2 Time of Application by Technology/Product Category (%)

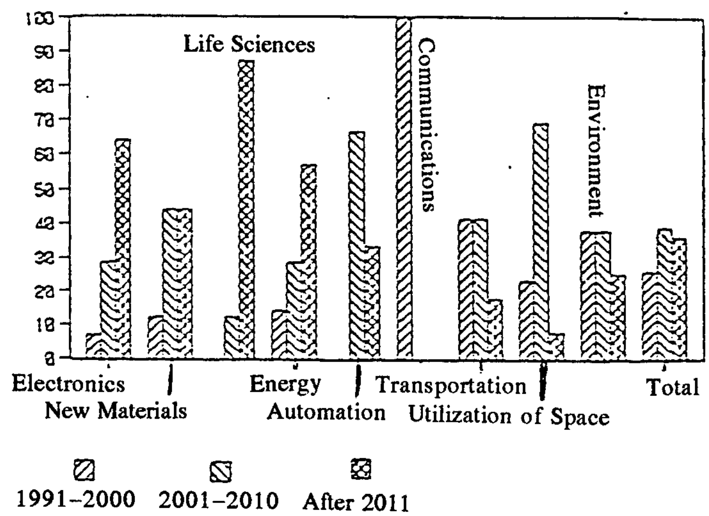
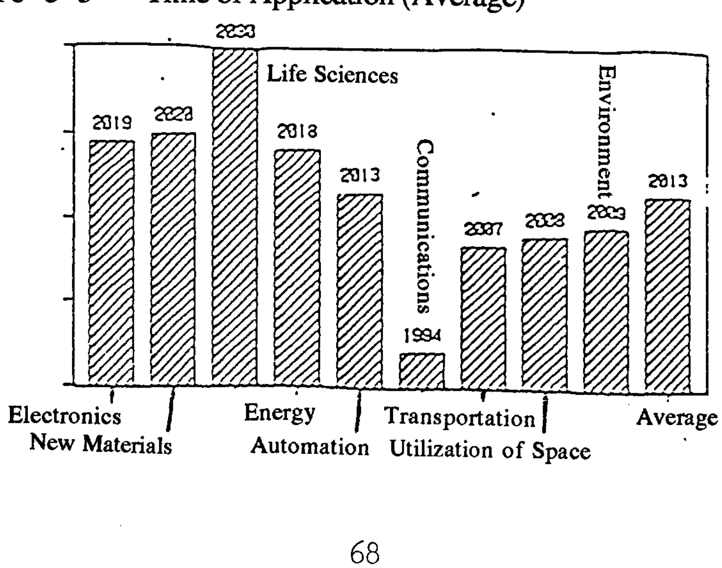


Figure 5–3 Time of Application (Average)



5–2 Size of Market

Next an analysis of the size of the market for the new technologies and products was made. The Size of Market corresponds to a 1 year period.

In the case of the Size of Market, data were successfully compiled for 86 of the 101 new technologies and products. In the analysis, the largest figure for the Size of Market listed in Table A was chosen.

Table 5–6 shows the Size of Market in descending order. Table 5–7 rearranges the items into their small categories. Table 5–8 notes the number of items in each medium-sized category, and Table 5–9 expresses this as a percentage.

Resources concerning the size of the markets for existing technologies and products at present were used as references in this study, so they are included in the Appendix.

[Key Points in Analysis Results]

- In making the forecast for the Size of the Market, a trial calculation was made based on certain assumptions about each new technology or product. These assumptions differ considerably depending on which expert makes these calculations, but this study presents a clear-cut figure rather than a range. Therefore, it is necessary to look at the Size of the Market with the understanding that there is a range of several multiples in both directions of the figures in question.

- Based on Table 5–8 and 5–9, 17 items will have an annual market of ¥1 trillion or more, 37 items will range between ¥100 billion and ¥1 trillion, and 32 will lie between ¥10 billion and ¥100 billion.

- Based on the medium-sized categories, we can see that the Size of Market for all 13 items in Information and Electronics will surpass ¥1 trillion. Thus, compared with the other categories, it is overwhelmingly large. This is because if products are realized that have much higher performance than existing products, there is a chance that they will replace the existing products in a comparatively short period of time. The only other items with a Size of Market over ¥1 trillion are New Glass under New Materials, HDTV under Communications, and Next Generation Automobiles and Next Generation High Temperature Superconductor Linear Motor Cars under Transport and Transportation.

- Looking at items in the range between ¥100 billion and ¥1 trillion, we can see that there are many technologies and products that will have a Size of Market at this level, with Automation being the only exception: Four of the 10 items under New Materials, all 5 under Life Sciences, 4 of the 5 under Energy, 5 of the 9 under Communications, 9 of the 16 under Transport and Transportation, 6 of the 13 under Utilization of Space and 4 of the 6 under Environmental Measures.

Table 5–6

Size of Market by Technology/Product Category

¥1 Trillion or More	¥Billion/yr.	¥100 Billion	¥Billion/yr	¥10 Billion	¥Billion/yr
Terabit Optical Comm. Device	3000	Fast Breeder Reactors	600	Freon Alternative Gases	80
Terabit Memory	3000	Underground Distribution Net	500	AI–CNC	60
Self Propagating Chips	3000	Large Transport Airliners	500	Floating System	60
HDTV	3000	Gasoline Alternative Autos	500	Small VTOL Prop. Craft	50
Next Generation Autos	3000	Innovative Auto Manufacturing	500	Artificial Islands	50
Neurocomputers	2000	Allergy & Immunization Drugs	500	Intelligent jRobots	50
Super Parallel Computers	2000	Semiconductor Superlattice Ele.	500	Optical LAN	30
Terabit Optical Files	2000	Biodegradable Plastics	500	Micromachines	30
Biosensors	2000	Anti-viral Drugs	500	VSAT/Satellite Data Network	30
Automatic Translation	1000	HST	500	Surface Effect Vehicle	30
Next Gen. Superconduct. LMC	1000	Optical Subscription Systems	500	Multiple Processing Center	30
Superconductor Devices	1000	Moon Research Base	500	Intelligent CAD	30
Super Intelligent Chips	1000	High Efficiency Heat Pump	400	Concurrent Engineering	30
Virtual Reality Systems	1000	Anti-Cancer Drugs	400	Underground Waste Mgmt.	30
Optical Computing Elements	1000	Artificial Organs	400	Weightlessness Facility	20
Self Propagating Data Bases	1000	CO_2 Catalyst Fixation	300	Module LWR	20
New Glass	1000	Drugs for Dementia	250	Marine Ranches	20
		Deep Underground Road/Rail	230	Ultra Precision Processing	15
		High Performance CFRP	200	Underground Heat Storage	15
		Wide Band ISDN Switchers	200	Marine Amusement Park	10
		Fuel Cells	200	High Perform. C/C Composites	10
		Super Skyscrapers	200	Bimodal System	10
		Personal Communication Devices	160	Thermoplastic Mol. Composites	10
		CS/BS–CATV	150	TV Telephone	10
		Superconductor Power Storage	150	Molecular Devices	10
		Small VTOL Jet Craft	100	Product Model	10
		High Perform. Metal Composites	100	Photochemical Hole Burning	10
		CO_2 Processing Technology	100	HSST LMC	10
		TV Conference System	100	Aquarobots	10
		Advanced Control System	100	Autonomous Control	10
		Super Air Dome	100	Non-linear Photoelectronic Mat.	10
		Comm. Satellite Vehicles	100	Skyscraper Disassembly	10
		Freon Recovery & Processing	100		
		Techno-Super Liner	100		
		Intelligent Ships	100		
		High Perform. Ceramic Composites	100		
		Linear Motor Catapult	100		
	17		37		32

Table 5–7a

		¥1 Trillion or More	¥Bil/yr	¥100 Billion	¥Bil/yr	¥10 Billion	¥Bil/yr
Advanced Basic Technology	Information and Electronics	Terabit Optical Systems	3000				
		Terabit Memory	3000				
		Self Propagating Chips	3000				
		Biosensors	2000				
		Terabit Optical Files	2000				
		Super Parallel Computers	2000				
		Neurocomputers	2000				
		Self Propagating Data Bases	1000				
		Super Intelligent Chips	1000				
		Superconductor Devices	1000				
		Virtual Reality Systems	1000				
		Optical Computing Element	1000				
		Automatic Translation	1000				
	13		13		0		0
	New Materials	New Glass	1000	Semiconductor Superlattice	500	Photochemical Hole Burning	10
				High Performance CFRP	200	High Perf. C/C Composites	10
				High Perf. Metal Composites	100	Molecular Devices	10
				High Perf. Ceram. Composites	100	Thermoplastic Mol. Comp.	10
						Non-linear Photoelectronics	10
	10		1		4		5
	Life Sciences			Anti-Viral Drugs	500		
				Allergy & Immunization	500		
				Anti-Cancer Drugs	400		
				Artificial Organs	400		
				Drugs for Dementia	250		
	5		0		5		0
Basic Technology to Support Industrial Activity	Energy			Fast Breeder Reactors	600	Module LWR	20
				High Efficiency Heat Pump	400		
				Fuel Cells	200		
				Superconductor Power Storage	150		
	5		0		4		1
	Automation					AI–CNC	60
						Intelligent Robots	50
						Concurrent Engineering	30
						Intelligent CAD	30
						Multiple Processing Center	30
						Micromachines	30
						Ultra Precision Processing	15
						Autonomous Control	10
						Product Models	10
	9		0		0		9

Table 5–7b

		¥1 Trillion or More	¥Bil/yr	¥100 Billion	¥Bil/yr	¥10 Billion	¥Bil/yr
Social Basic Technology	Communi-cations	HDTV	3000	Optical Subscription	500	VSAT/Satellite Network	30
				Wide Band ISDN Switchers	200	Optical LAN	30
				Personal Comm. Devices	160	TV Telephone	10
				CS/BS–CATV	150		
				TV Conference System	100		
	9		1		5		3
	Transpor-tation and Transport	Next Generation Autos	3000	Large Transport Airliners	500	Small VTOL Prop. Craft	50
		Next Generation High Temperature Semiconductor		HST	500	Surface Effect Vehicle	30
				Gasoline Alternative Autos	500	Aquarobots	10
		LMC	1000	Innovative Auto Mfg.	500	HSST Linear Motor Car	10
				Intelligent Ships	100	Bimodal Systems	10
				Comm. Satellite Vehicles	100		
				Techno-Super Liner	100		
				Advanced Control Systems	100		
				Small VTOL Jet Craft	100		
	16		2		9		5
	Utilization of Space			Underground Distribution Net	500	Floating System	60
				Moon Research Base	500	Artificial Islands	50
				Underground Road & Rail Net	230	Marine Ranches	20
				Super Skyscrapers	200	Weightlessness Facility	20
				Linear Motor Catapult	100	Underground Heat Storage	15
				Super Air Dome	100	Skyscraper Disassembly Tech.	10
						Marine Amusement Parks	10
	13		0		6		7
	Environ-ment			Biodegradable Plastic	500	Freon Alternative Gases	80
				CO_2 Catalyst Fixation	300	Underground Waste Mgmt.	30
				Freon Recovery & Processing	100		
				CO_2 Processing Technology	100		
	6		0		4		2
	85		17		37		32

Table 5-8

Size of Market by Technology/Product Category (Number)

	¥1 Trillion or More	¥100 Billion	¥10 Billion	Total
Electronics	13	0	0	13
New Materials	1	4	5	10
Life Sciences	0	5	0	5
Energy	0	4	1	5
Automation	0	0	9	9
Communications	1	5	3	9
Transportation & Transport	2	9	5	16
Utilization of Space	0	6	7	13
Environment	0	4	2	6
Total	17	37	32	86

Table 5-9

Size of Market by Technology/Product Category (%)

	¥1 Trillion or More	¥100 Billion	¥10 Billion
Electronics	100	0	0
New Materials	10	40	50
Life Sciences	0	100	0
Energy	0	80	20
Automation	0	0	100
Communications	11	56	33
Transportation & Transport	13	56	31
Utilization of Space	0	46	54
Environment	0	67	33
Total	20	43	37

Figure 5–4 Size of Market by Technology/Product Category (Number)

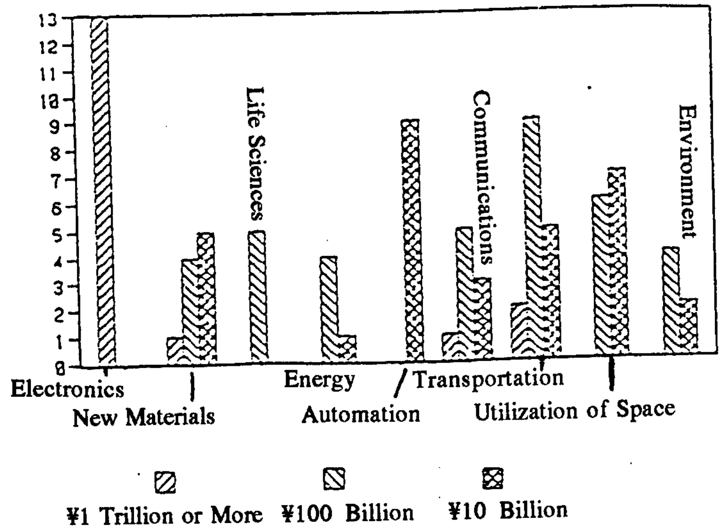
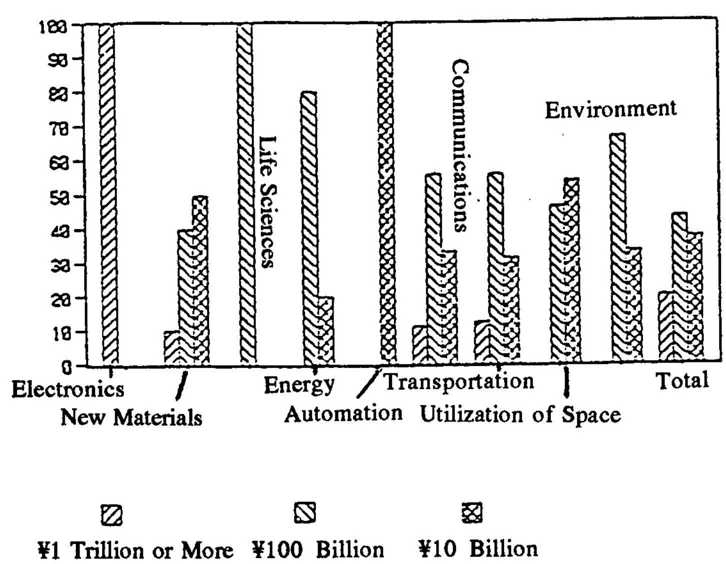


Figure 5–5 Size of Market by Technology/Product Category (%)



5–3 Stage of R&D and International Comparison

The Stage of R&D takes the level of technology at the time of application as 100 and expresses to what extent the present level of technology has progressed. This indicates purely the level of technology without including social or economic limitations.

International Comparison takes the level of technology in Japan as 100 and expresses the present levels of technology in the US and Europe.

In the case of the international comparison of levels of technology, studies were recently undertaken by both the US and Japanese governments. A comparison of the levels of technology in Japan, the US and Europe was made in the report published in September 1988 by the Ministry of International Trade and Industry entitled "Trends and Topics in Industrial Technology," and this is included in the Appendix.

[Key Points in Analysis Results]

- Concerning the Stage of R&D, as shown in Table 5–10 and Figure 5–6, items in the 10% range are Information and Electronics, and Automation; in the 20% range is Life Sciences; in the 30% range are New Materials, Transport and Transportation, and Environmental Measures; in the 40% range is Energy, in the 50% range is Utilization of Space, and in the 70% range is Communications. The average is 36%.

- In the case of the international comparison of the present levels of technology, as shown in Table 5–10 and Figure 5–7, when Japan is compared with the US, Japan is slightly ahead in Information and Electronics, but Japan is far behind in Transport and Transportation and in New Materials. In Life Sciences, Energy, Communications, Utilization of Space and Environmental Measures, Japan is slightly behind the US. Automation is roughly at the same level.

- When Japan is compared with Europe, Japan is far ahead of Europe in the field of Electronics, and is slightly ahead in Life Sciences, Energy, Communications, and Utilization of Space. The levels are roughly the same in New Materials, Automation and Environmental Measures, and Japan is behind in Transport and Transportation.

- When we look at individual technologies, as shown in Figure 5–8, between Japan and the US, the US is ahead in 43%, Japan is ahead in 33% and about 25% are roughly the same. Between Japan and Europe, Europe is ahead in 26%, Japan is ahead in 60% and about 14% are roughly the same.

Table 5–10

	Items in R&D Stage	International Comparison	
		US	Europe
Electronics	13	88	37
New Materials	30	147	102
Life Sciences	24	121	83
Energy	45	122	86
Automation	13	105	97
Communications	73	114	79
Transportation & Transport	39	175	123
Utilization of Space	56	111	85
Environment	34	119	106
Total	36	122	88

Figure 5–6

Present R&D Stage
(Level at Time of Application = 100)

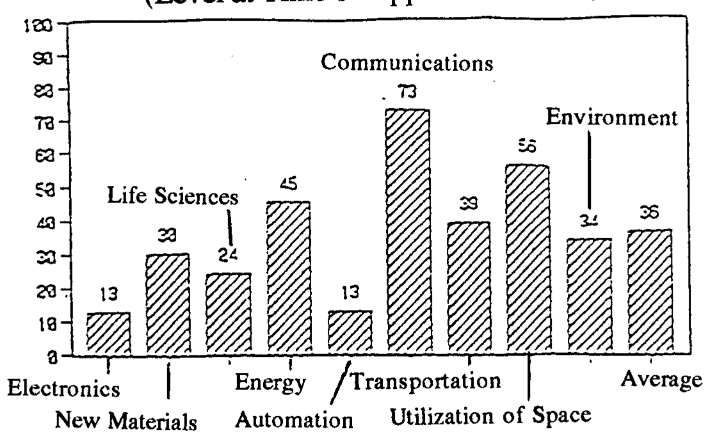


Figure 5–7 International Comparison of Level of Technology
(Japan = 100)

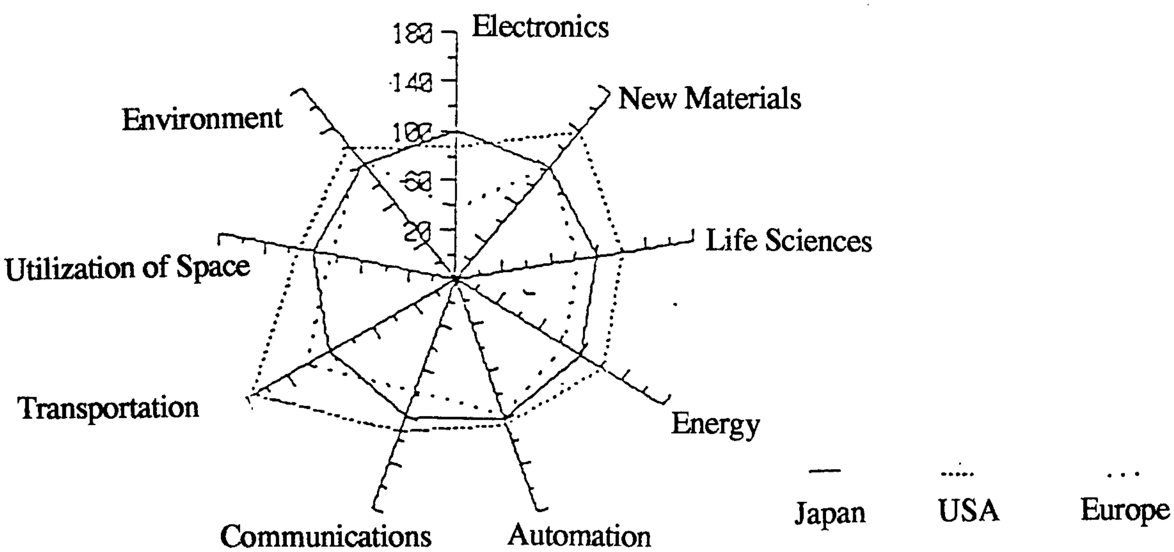


Table 5–11

Comparison of Level of Technology in Japan, US, and Europe

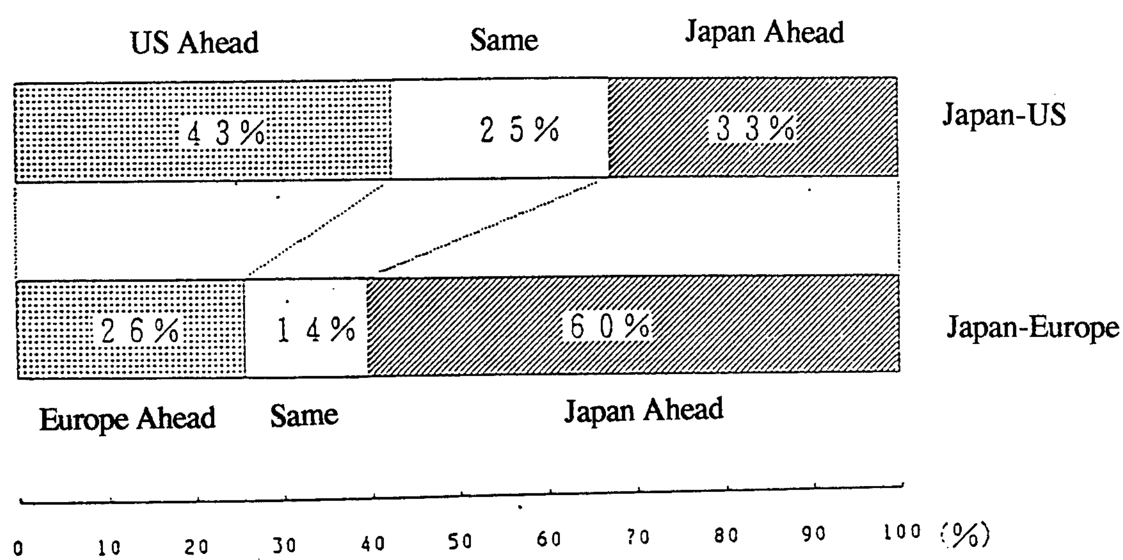
Japan Alone in 1st	Japan Tied for 1st	Japan 2nd	Japan 3rd
Terabit Memory	Super Intelligent Chips	Virtual Reality System	Ceramic Gas turbine
Superconductor Devices	Self Propagating Chips	Self Propagating Data Base System	Photochemical Hole Burning Mem.
Terabit Optical Files	Optical Computing Element Device	Semiconductor Superlattice Element	High Performance CFRP
Terabit Optical Communications	Biocomputers	Amorphous Alloys	High Perf. Metal Composites
Biosensors	Super Parallel Computers	Non-linear Photoelectronic Material	High Perf. Ceramic Composites
Neurocomputers	Automatic Translation System	Thermoplastic Mol. Composites	High Perf. C/C Composites
Superconductor Materials	Optical IC	Anti-Cancer Drugs	Nuclear Fusion
New Glass	Molecular Devices	Anti-Viral Drugs	Ultra Precision Processing
Hydrogen Adsorbing Alloys	Drugs for Dementia	Bone Marrow Bank	Intelligent CAD
Magenetic Materials	Allergy and Immunization Drugs	Artificial Enzymes/Membranes	Product Model
Fuel Cells	Bioenergy	Module Light Water Reactors	Concurrent engineering
Solar Photoelectric Power	Artificial Organs	Fast Breeder Reactors	Personal Comm. Devices
High Efficiency Heat Pump	TV Conference System	Superconductor Power Storage	Aquarobots
Intelligent Robots	TV Telephone	Micromachines	Large Transport Airliners
AI–CNC	Wide Band ISDN Switchers	Autonomous Control	HST
Multiple Processing Center	Optical Subscription System	VSAT/Satellite Data Network	Small VTOL Propeller Craft
HDTV	Optical LAN	BS/CS–CATV	Small VTOL Jet Craft
Superconductor Linear Motor Car	Next Generation Autos	HSST Linear Motor Car	Artificial Islands
Next Gen. Superconductor LMC	Innovative Auto Manufacturing	Advanced Control Systems	Floating Systems
Bimodal Systems	Super Skyscrapers	Comm. Satellite Vehicles	Biodegradable Plastics
Techno-Super Liner	Marine Amusement Parks	Gasoline Alternative Autos	
Intelligent Ships	CO_2 Catalyst Fixation Technology	Surface Effect Vechicle	
Weightlessness Facility	CO_2 Plant Fixation Technology	Moon Research Base	
Linear Motor Catapult	Underground Water Storage Facility	Super Air Dome	
Underground Distribution Net		Skyscraper Disassembly Tech.	
Deep Underground Road & Rail		CO_2 Processing	
Underground Heat Storage		Freon Alternative Gases	
Marine Ranches		Underground Waste Mgmt.	
Freon Recovery & Processing			
29	24	28	20

Table 5–12

Comparison of Level of Technology in Japan, US, and Europe

	Japan–US Comparison			Japan–Europe Comparison		
	Same	US	Japan	Same	Europe	Japan
Electronics	6	2	6	1	0	13
New Materials	2	10	4	3	6	7
Life Sciences	4	4	0	0	0	8
Energy	1	3	3	1	2	4
Automation	0	6	3	0	4	5
Communications	5	3	1	1	1	7
Transportation	1	7	9	3	8	6
Utilization of Space	2	5	6	1	3	9
Environment	4	3	1	4	2	2
Total	25	43	33	14	26	61
Ratio (%)	24.8	42.6	32.7	13.9	25.7	60.4

Figure 5–8



Comparison of Levels of Technology in Japan, US, and Europe

5–4 R&D Potential

The R&D Potential was estimated by looking at the present extent of activity in R&D of new technologies and products. The rates of increase in three major areas–rate of increase in R&D spending and number of research personnel, rate of increase in number of patents and monographs, and rate of increase in grants and subsidies–were categorized as large, moderate, small, no change, or reduced. In the analysis, large was given 3 points, moderate 2 points, small 1 point, no change 0 points, and reduced –1 point for purposes of quantification and averaging.

[Key Points in Analysis Results]

- When a comparison is made in the averages of these three major items, as shown in Figure 5–9, it is clear that R&D in Information and Electronics, Communications and Environmental Measures is extremely active. R&D in New Materials, Life Sciences, Energy, and Automation is rather active. On the other hand, R&D in Transport and Transportation and in Utilization of Space is not as active as in other items, but steady progress is being made.

Table 5–13

	Rate of Increase in R&D Spending and Personnel	Rate of Increase in Number of Patents and Monographs	Rate of Increase in Grants and Subsidies	Average of R&D Potential
Electronics	2.8	2.0	1.5	2.1
New Materials	1.3	1.5	1.4	1.4
Life Sciences	1.9	1.9	1.6	1.8
Energy	1.6	1.4	1.3	1.4
Automation	1.8	1.6	1.6	1.6
Communications	2.0	2.2	1.8	2.0
Transportation & Transport	1.5	0.8	0.8	1.0
Utilization of Space	0.9	1.3	1.0	1.1
Environment	1.9	1.8	2.3	2.0
Total	1.7	1.6	1.5	1.6

Figure 5–9 Rate of Increase In Present R&D Potential (Total of 3 Items)

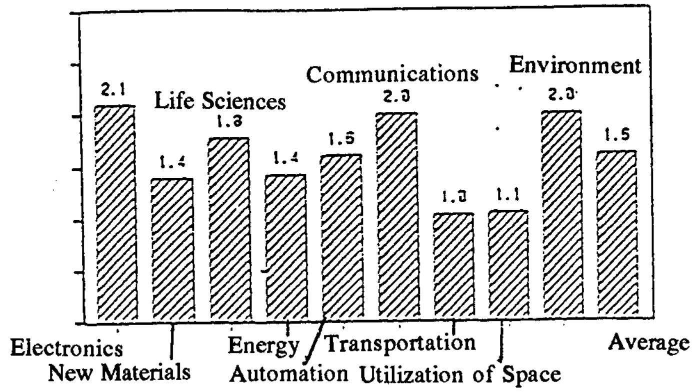


Figure 5–10 Rate of Increase in Present R&D Potential

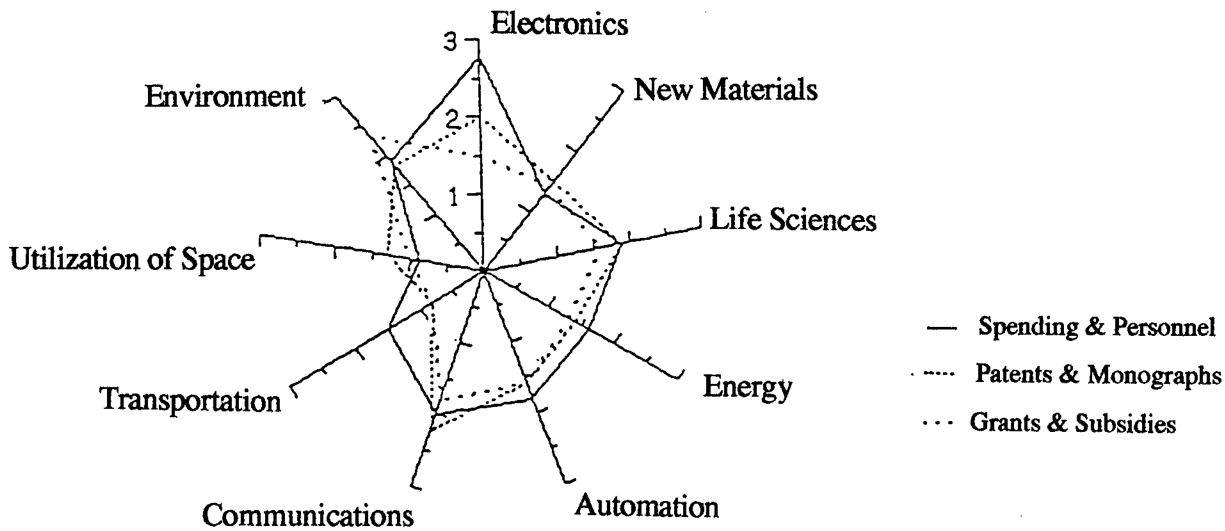
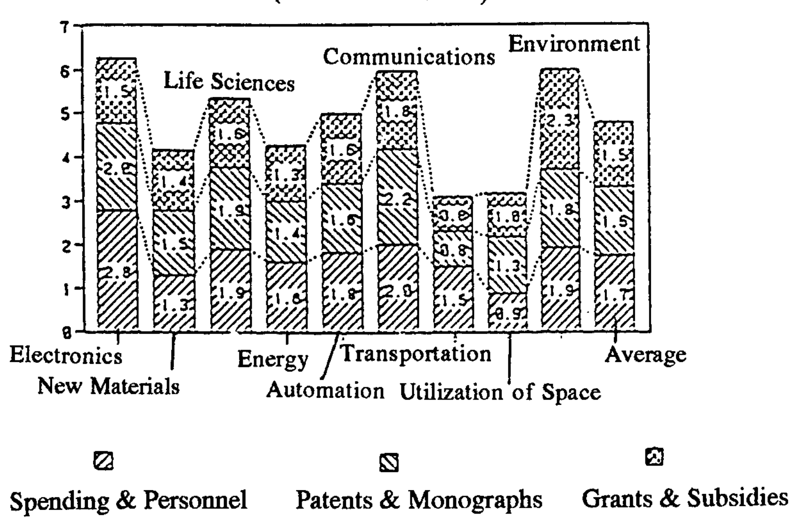


Figure 5–11

Breakdown of Rate of Increase of Present R&D Potential (Total of 3 Items)



5–5 Social and Economic Limitations

Not only technical problems affect the application of new technologies. In many cases, social and economic limitations are major factors. Here, Social Limitations were considered with respect to 5 aspects–the System (government regulations), Government Policy (government promotional policies), Infrastructure of the Society, Environment, and Consciousness and Values of the People. The Economic Limitations were considered with respect to 5 aspects–Acquisition of Market, Progress toward Reduced Costs, Difficulty in Introducing Marketing Principle, Lack of R&D Funds, and Difficulty of Acquiring R&D Personnel. The effect of each aspect was categorized as large, moderate, small or none, and in the analysis, large was given 3 points, moderate 2 points, small 1 point, and none 0 points. The average values were then compared.

Among these limitations, items closely linked to government policies are the System (regulations made by the government) and Government Policy (government policy toward promoting R&D) under the Social Limitations. Figure 5–15 shows these in the form of a graph.

Below are several concrete examples of how these affect application.

(1) For the development and spread of solar photoelectric power generation, under the present regulations in the Electrical Utility Act, to set up a privately owned power generating device it is necessary to have an electrical technician in charge of each generator. In order to promote the installation of solar cells at various households and businesses, the relevant laws must be revised. Further, in order to promote installation, an appropriate fee system and installation subsidies will be needed.

(2) For the development of artificial islands and marine amusement parks, because the laws that will apply are unclear, corporations cannot actively engage in R&D until these points are clarified. Therefore, the relevant laws must be revised.

(3) For the development of a techno-super liner (a large, high-speed ship), because technical standards for ship construction are specified under regulations such as the Ship Safety Law, new technical standards must be completed to promote a techno-super liner that will make wide use of new technologies and materials. Further, at the time of application, revisions in relevant laws must be made for high-speed navigation and navigation at night, and harbor facility capabilities must be improved.

(4) In the case of the development of new drugs, to obtain approval as a drug for therapeutic use under the Pharmaceutical Affairs Law, an extremely long waiting period and large amounts of research expenditures are necessary. Further, the cost of new drugs will be determined by the drug pricing system of National Health Insurance, and because the price of the drug will be reduced every two to three years, in the future it will be extremely difficult to recover the large R&D expenditures under the present system. Therefore, without reducing evaluation of drug effectiveness and safety, it is necessary to shorten the waiting period in order to promote R&D,to prioritize reviews for approval, and set up an appropriate pricing system.

(5) Concerning the development of HDTV, although technically it is approaching the point right before practical application, Japan, the US, and Europe are each insisting on their own technical standards in order to acquire leadership in the development and commercialization of HDTV. Therefore, the practical application of HDTV will be greatly delayed. At present, an international unified standard has not been established, and because the two

systems in Japan and the EC are not interchangeable, each country will choose one or the other based on its own judgement. Therefore, corporations must carry out HDTV technical development and establish distribution routes for both systems, and from the viewpoint of technical development, this represents a doubling of investment in technical resources.

[Key Points in Analysis Results]

•Looking at Figure 5–13, Social Limitations are extremely low for Information and Electronics and for Automation at 0.5–0.6. Further the values for Life Sciences and Energy are 2.0 or more, so there are great social limitations in these categories. It is clear that the remaining items have moderate social limitations with values of 1.5–1.8.

•Next, looking at Figure 5–14, those lying in the 2 point range for Economic Limitations are Information and Electronics, New Materials, Life Sciences and Energy at 2.0–2.2. All the others are in the 1 point range from 1.5–1.8. This means that all the new technologies and products will have rather large economic limitations.

•According to Figure 5–15, there are few obstacles to application in the System and Government Policy for Information and Electronics and for Automation, but it appears that this area will affect all other items very strongly.

Table 5–14

	Social Limitations Average	Economic Limitations Average	Social Limitations: System	Govt. Policy	Infra-structure	Environ-ment	National Consci-ousness	Economic Limitations: Market Size	Cost	Marketing Principle	Lack of Dev. Funds	Lack of Research Personnel
Electronics	0.6	2.1	0.3	0.7	0.7	0.1	1.3	2.6	2.5	0.9	2.3	2.0
New Materials	1.4	2.2	1.8	1.1	1.8	1.3	1.3	2.6	2.8	1.1	2.0	2.3
Life Sciences	2.2	2.0	2.6	2.8	1.6	1.4	2.4	1.6	2.0	1.8	2.4	2.3
Energy	2.0	2.1	2.0	2.6	1.7	1.6	2.3	2.7	3.0	1.3	2.1	1.3
Automation	0.5	1.5	0.1	0.4	1.1	0.0	1.0	1.3	1.9	0.8	1.8	1.5
Communications	1.7	1.8	1.9	2.4	2.0	0.3	1.7	2.0	2.9	1.3	1.4	1.6
Transportation	1.5	1.3	1.9	2.1	1.7	1.3	0.7	1.6	1.7	0.8	1.6	1.0
Space Utilization	1.5	1.5	1.9	1.8	0.9	1.5	1.5	1.6	1.5	1.5	1.8	1.2
Environment	1.7	1.8	1.9	1.9	1.3	1.9	1.6	1.6	2.5	2.3	1.0	1.5

Figure 5–12 Effect of Social & Economic Limitations (Evaluation of 3 Separate Items)

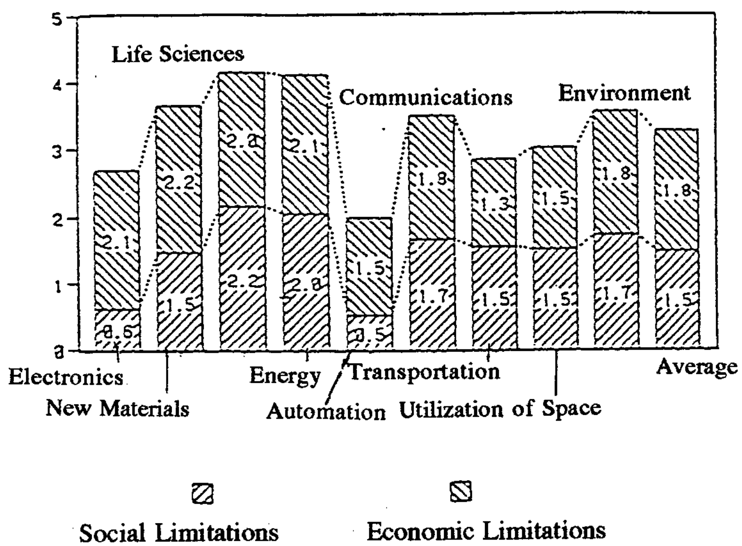


Figure 5–13 Details of Social Limitations (Evaluation of 3 Separate Items)

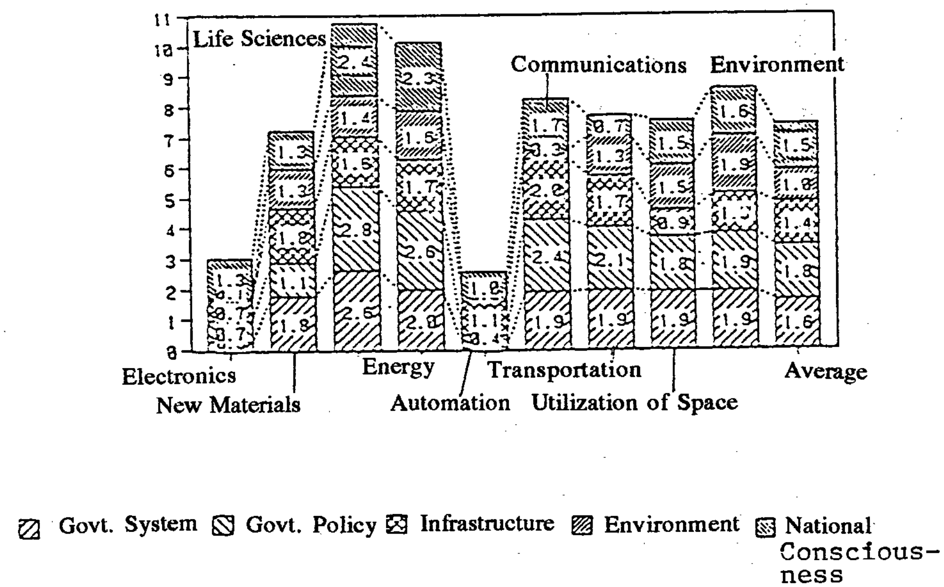


Figure 5–14

Details of Economic Limitations
(Evaluation of 3 Separate Items)

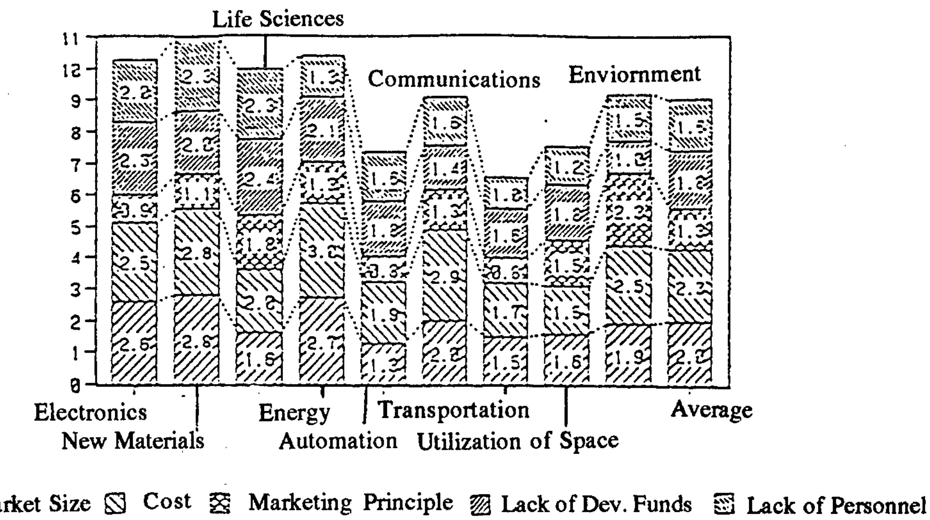
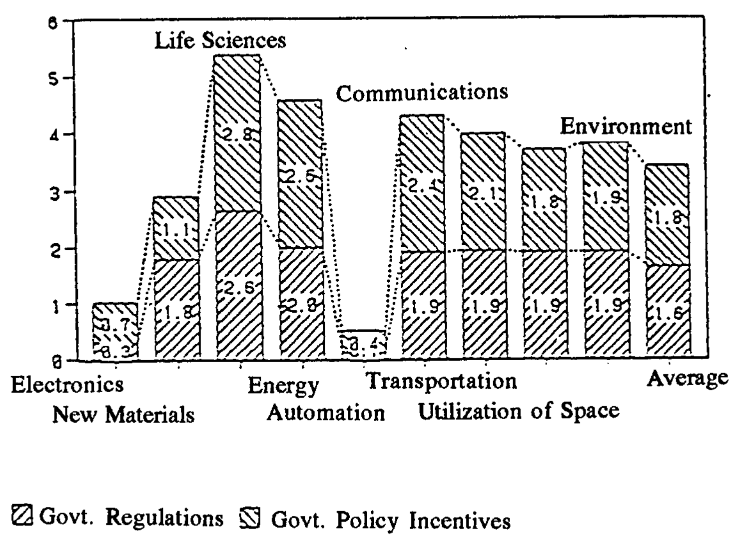


Figure 5–15

Social Limitations (Govt. Regulations & Policy Incentives)
(Evaluation of 3 Separate Items)



5–6 Rate of Realization

The Rate of Realization

The Rate of Realization takes the rate of realization at the time of application as 100% and expresses its projected level in 1990, 2000 and 2010 in light of the total technical, social and economic limitations. It is important to note, particularly in the Rate of Realization for 1990, that because social and economic limitations are taken into consideration, these figures have a different meaning from the figures for the Stage of R&D. The difference between the two can be roughly estimated by the size of present social and economic limitations.

[Key Points in Analysis Results]

•As shown in Table 5–15, Communications will be 100% realized by the year 2000, but Information and Electronics, Life Sciences, and Energy will be in the 30% range, New Materials and Automation will be in the 40% range, and Transport and Transportation, Utilization of Space, and Environmental Measures will be in the 60% range of realization.

•Looking at the year 2010, Information and Electronics, Life Sciences, and Energy are expected to reach the 60% range, New Materials and Environmental Measures will reach the 70% range, Automation and Utilization of Space will reach the 80% range, and Transport and Transportation will reach the 90% range.

Table 5–15

	Rate of Realization		
	1990	2000	2010
Electronics	8	35	66
New Materials	15	44	73
Life Sciences	19	38	66
Energy	18	35	65
Automation	12	44	86
Communications	74	100	100
Transportation & Transport	30	66	93
Utilization of Space	23	62	88
Environment	18	60	77
Average	24	54	79

Figure 5–16

Rate of Realization
(Realization at Application = 100)

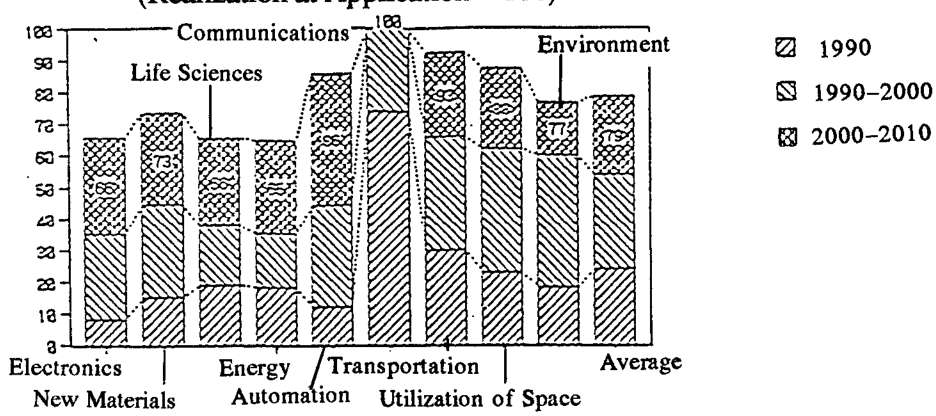
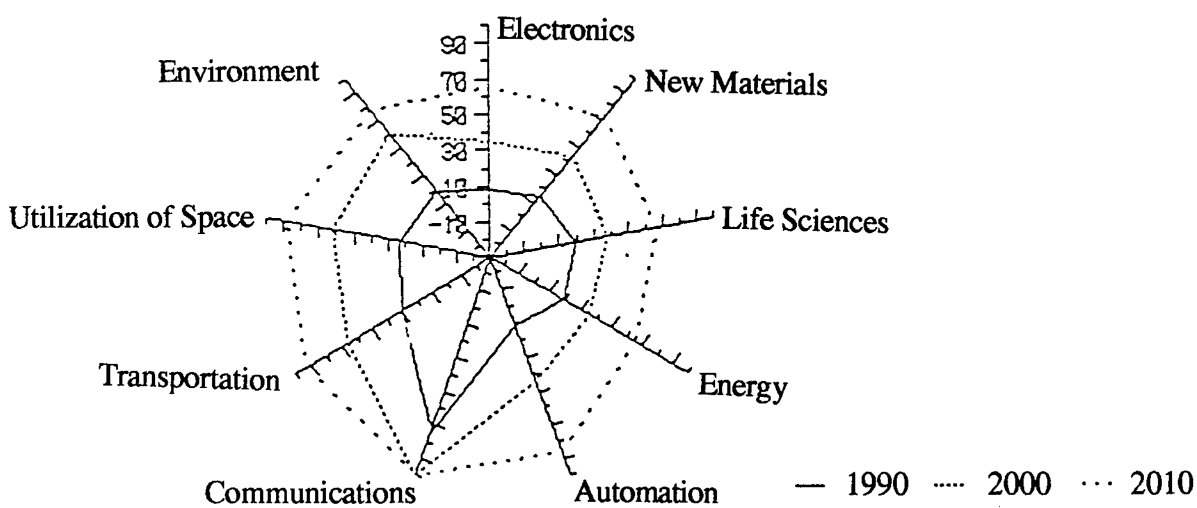


Figure 5–17 Rate of Realization (by Year)



5–7 Contributions to Society and the Economy

Table C is a study of what kinds of contributions new technologies and products will make in social and economic areas. The areas were categorized as Global Level, National Level, Social and Corporate Level, and Individual Level. The Global Level was subdivided into Harmony with the Ecosystem, and Measures for Food, Energy, and Population Problems; the National Level was subdivided into International Contributions and Cooperation, and Safety and Security; the Social and Corporate Level was subdivided into Pursuit of Abundance, Regional Environmental Safety, Measures for an Aging Society, and Harmony between Business and Society; and the individual level was subdivided into Pursuit of Leisure and Pursuit of Comfort. In making these classifications, reference was made to the Demand Matrix,which has been based on Maslow's Demand Matrix, that was created by the Japan Productivity Headquarters Research Institute.

Safety and Security on the National Level is strictly limited to economic security such as safety and security of energy supplies, and it does not include military safety and security.

Items with an extremely large positive impact were given a 2, and those with a rather large positive impact were given a 1. These results are arranged in Table 5–16.

[Key Points in Analysis Results]

•Technologies and products in their medium-sized categories were organized according to the field to which they will contribute, and these results are shown in Figures 5–18 through 5–26.

The averages for these data are shown in Figure 5–27. According to these data, the 101 new technologies and products in this study will make particularly great contributions on the Global Level to Harmony with the Ecosystem and to Food, Energy and Population Problems; on the National Level to International Contributions and Cooperation; and on the Social and Corporate Level to Pursuit of Abundance and Regional Environmental Safety.

Table 5–16

	Global		National		Social/Corporate				Individual	
	Harmony with Eco-system	Food, Energy, Population Problems	Inter-national Cooper-ation	Safety and Security	Pursuit of Abun-dance	Safety of Environ-ment	Aging of Society	Business & Social Harmony	Pursuit of Leisure	Pursuit of Comfort
Electronics	1.07	0.00	0.50	0.36	0.43	0.50	0.00	0.00	0.14	0.14
New Materials	0.00	0.38	0.50	0.50	0.44	0.19	0.00	0.75	0.44	0.38
Life Sciences	0.13	0.38	0.00	0.00	0.75	0.38	1.00	0.00	0.38	1.38
Energy	1.20	2.60	1.80	1.40	0.00	1.40	0.00	0.00	0.00	0.00
Automation	0.00	1.44	0.00	0.00	0.67	0.00	0.56	0.56	0.22	0.22
Communications	0.00	0.00	0.00	0.00	1.10	0.00	0.00	0.20	0.70	0.50
Transportation & Transport	0.13	0.00	0.13	0.00	0.81	0.38	0.25	0.31	0.81	0.88
Utilization of Space	0.08	0.69	0.31	0.23	0.92	0.92	0.00	0.31	0.23	0.23
Environment	1.50	0.25	1.25	0.13	0.25	0.50	0.00	0.13	0.13	0.13
Average	0.46	0.64	0.50	0.29	0.60	0.47	0.20	0.25	0.34	0.43

Figure 5–18

Contributions to Society and the Economy (Information & Electronics)

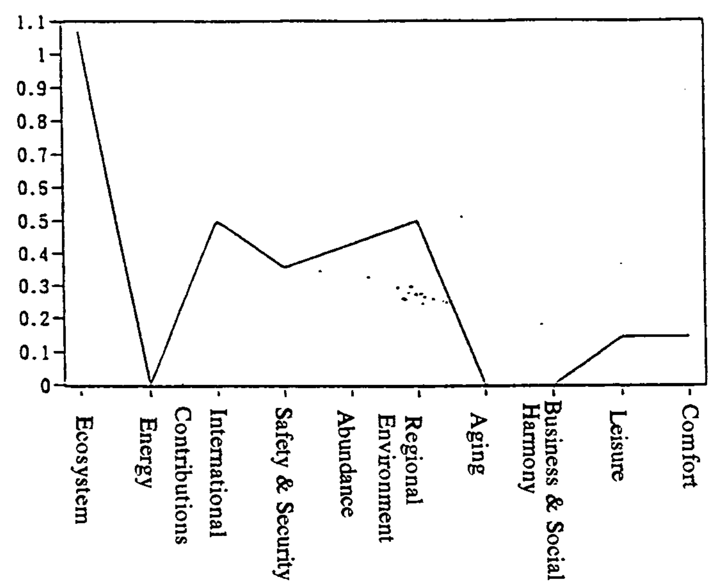


Figure 5–19

Contributions to Society and the Economy (New Materials)

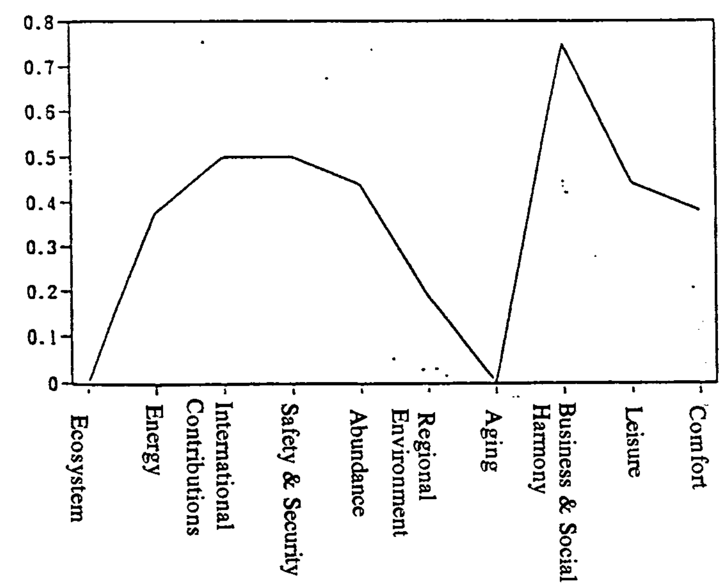


Figure 5–20 Contributions to Society and the Economy (Life Sciences)

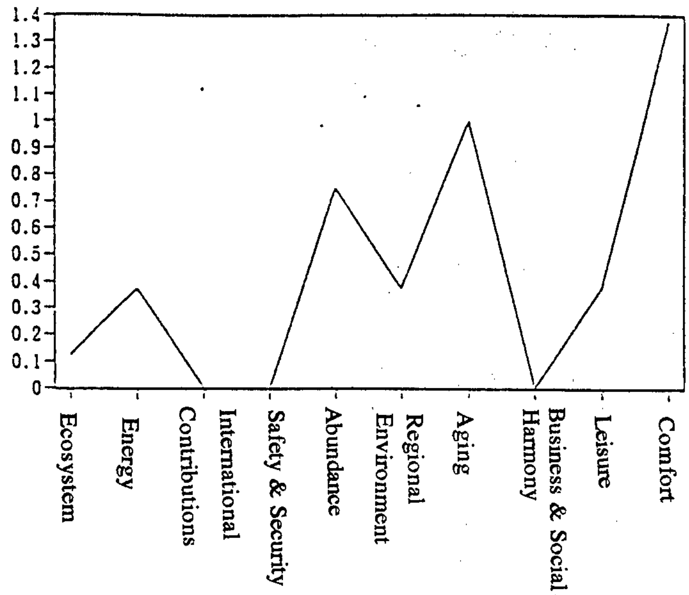


Figure 5–21 Contributions to Society and the Economy (Energy)

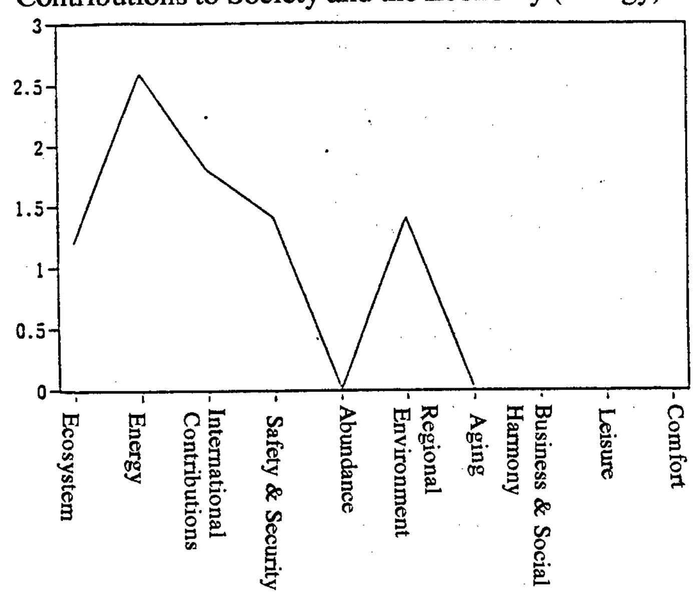


Figure 5–22 Contributions to Society and the Economy (Automation)

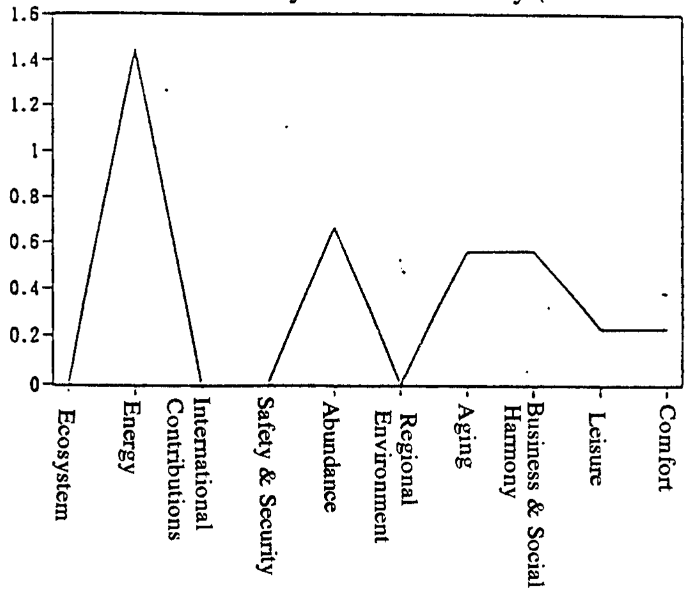


Figure 5–23 Contributions to Society and the Economy (Communications)

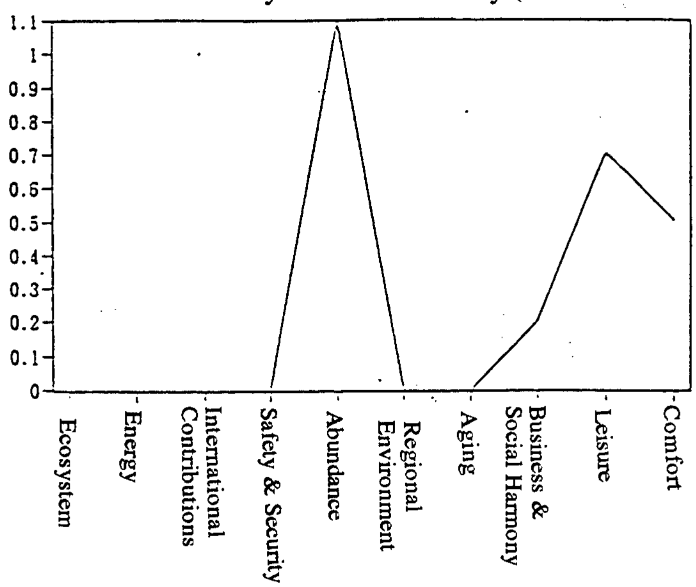


Figure 5–24 Contributions to Society and the Economy (Transport and Transportation)

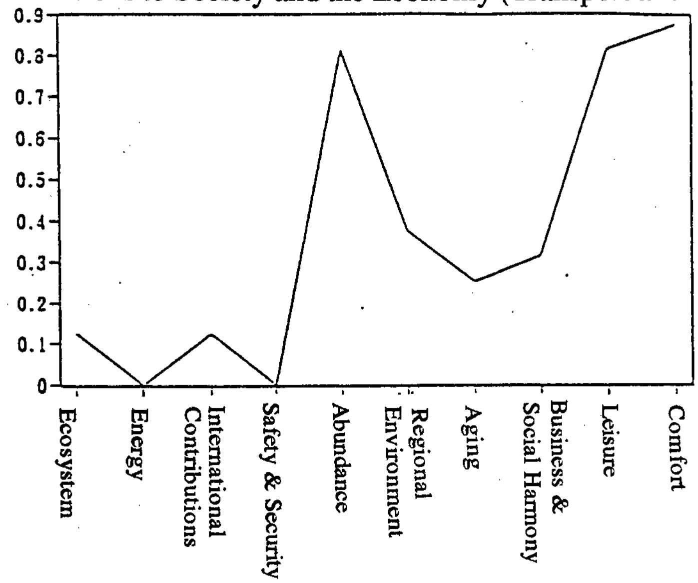


Figure 5–25 Contributions to Society and the Economy (Utilization of Space)

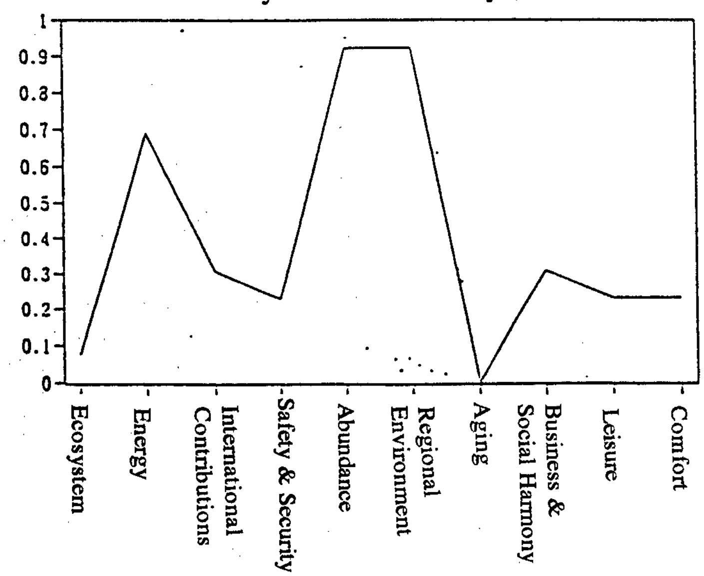


Figure 5–26

Contributions to Society and the Economy (Environmental Measures)

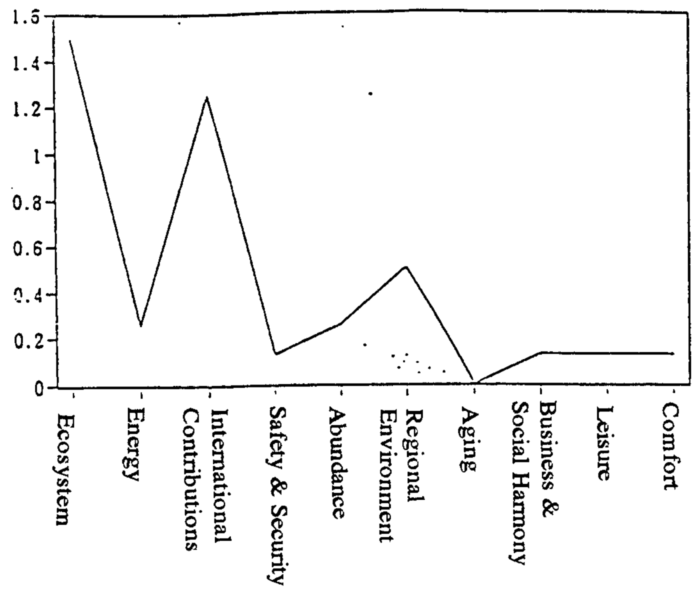
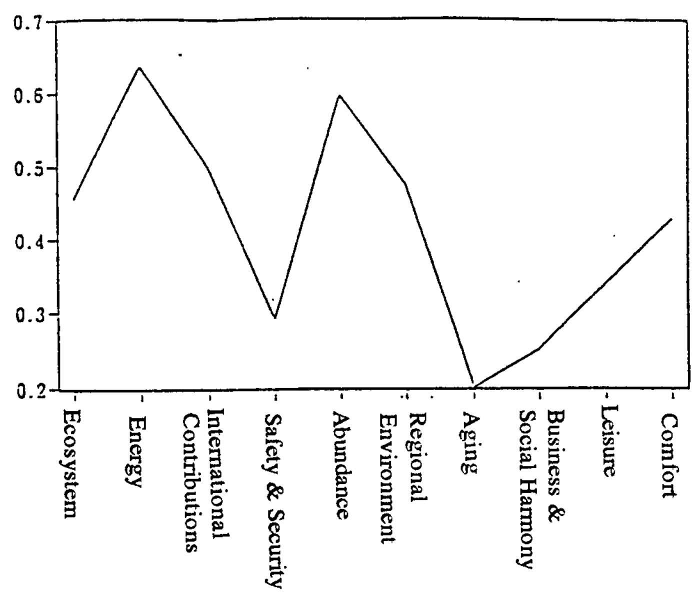


Figure 5–27

Contributions to Society and the Economy (Average)



6. Summary

As can be seen from the above analysis, 101 items were selected from among technologies and products presently in the R&D process that have been called the "future technologies" which are expected to have a major impact on industry and the economy, and these items were evaluated according to their time of application, size of market, impact on industry and the economy, etc. A summary of the key points in the analysis results follows.

Concerning the Time of Application, the time when future technologies will compete with existing products and yield returns on a commercial basis, that is, the time when future technologies will have somewhat of an impact on industry and the economy, is much more distant in the future than previously predicted. The reason is because even if application is attained on the technical front, social and economic limitations will become an obstacle, so a considerable amount of time will elapse before its impact on industry and the economy will be felt. More specifically, government policies, such as the regulations imposed by government and government incentives, will have a great effect on progress in development and practical application in most fields. Therefore, in order to promote the application of technology, it is extremely important for the government to reconsider the need for some of its existing regulations and systems, and to carry out appropriate governmental measures such as the establishment of development goals. Further, this forecast was made based on the major increases in corporate R&D spending in recent years, but depending on the trends of future R&D spending, there is some concern that the times of application may be delayed even longer.

Concerning Size of Market, it was learned that when and if these future technologies reach application, among the 86 items surveyed, 17 items (20%) led by the field of Information and Electronics will have a market of ¥1 trillion or more, and among all fields except automation, 54 items (63%) will have a market of ¥100 billion or more (including the 17 items with a market of ¥1 trillion or more). Because these estimates were made based on some bold assumptions, there is a rather large margin of error, but it can be said that when they reach application, there is a good chance these future technologies will have a major impact on industry and the economy.

Concerning the International Comparisons of the levels of technology in Japan, the US, and Europe, Japan stands alone in first place in 29 items (29%), Japan is tied for first place in 24 items (24%), Japan is in second place in 28 items (28%) and Japan is in third place in 20 items (20%). When this is compared with the 1987-88 survey conducted by the Ministry of International Trade and Industry's Agency of Industrial Science and Technology, if we look at the total (87 items) in their categories of High-Tech Products (40 items) and Basic Technologies (47 items), which most nearly approaches the 101 future technologies in this study, Japan stands first in 11 items (13%), is tied for first in 31 items (36%), and is lagging behind (second or third) in 45 items (52%). Although a direct comparison cannot be made because the technologies in the two studies differ, generally speaking we can say that in regard to the levels of research in future technologies over the past few years Japan has widened the gap with the US and Europe in areas where she holds the lead, and that Japan is closing the gap in areas where she lags behind.

These 101 future technologies were selected based on the view that these, among the many future technologies presently in the R&D process, will have the greatest impact on industry and the economy. These future technologies will play an important role from now on in dealing with environmental, energy and population problems on a global scale, in responding to a reduced labor force and the rapid aging of society on a national level, and in realizing an abundant and humane lifestyle for our people as Japan approaches the year

2010. Therefore, it is hoped that these future technologies can reach application even sooner through the aggressive promotion of appropriate government policies and of R&D in the private sector not only in the present but also in the future.

Appendix 1

Summary of "Technology Forecast Assessment" from the Science and Technology Agency

This has been conducted every five years since 1971 to determine the direction of Japan's technical growth. It assesses the importance, time of realization, method of advancing R&D, etc., of technical items that are expected to be advanced over the following 30 years. It makes the assessment through surveys of experts (the same survey is repeatedly sent to several people and the opinions of the respondents are converged using the Delphi method).

In *The Fourth Technology Forecast Assessment* 1071 items that are expected to be realized by roughly 2015 were surveyed.

(1) Importance

Fields considered high in importance were biologically related items such as Life Science, and Heath and Medical Care, and global items such as Space and The Earth. Further, items that were considered high in importance among all fields were Cancer, Superconductors, Earthquake Forecasting, Atomic Energy, and High Level Information Processing. Especially, Cancer occupied 4 items among the top 5, indicating that it is an important topic for research not only in the minds of the people but for researchers as well.

(2) Time of Realization

Overall, more than half the items are those expected to be realized roughly within the next 20 years. Many that will be realized relatively early fall under Information, Electronics and Software and under Communications, while many that are expected to be realized in the more distant future fall under Life Sciences and Energy.

(3) Limitations on Realization (Non-realization)

Generally speaking, the great majority of items have Technical Limitations, and this stands out in fields such as Life Sciences, and Substances, Materials and Processing.

Next comes Economic Limitations, and in this field we find items requiring large scale research expenditures such as Space and Energy. Major items under Social Limitations are in the field of Safety and The Environment.

(4) Methods for Advancing R&D

The methods for advancing R&D are divided into three major categories–Autonomous Technical Development, International Cooperative Development, and Introduction of Technology.

1. Autonomous Technical Development

    Overall about 70% of the topics fall under advancing R&D by Autonomous Technical Development. More specifically, there are many items in fields such as Cities and Construction, and Communications that are related to the improvement of the economic and social infrastructure, and in the field of Substances, Materials and Processing that have have elements of strong advanced and basic research.

2. Development by International Cooperation

   Concerning advancing R&D through international cooperation, most topics were in such areas as Life Sciences and Health and Medical Care that are related to biology, and generally speaking, this category has increased with each successive assessment.

3. Introduction of Technology

   A great majority of respondents indicated no topic in which R&D will be advanced by introduction of technology.

(5) Main Bodies Advancing R&D

The Main Bodies Advancing R&D were divided into three categories–National and Regional Public Agencies, National and Regional Public Agencies together with the Private Sector, and The Private Sector.

1. National and Regional Public Agencies

   There were relatively many items where it is desirable for R&D to be advanced by national and regional public agencies among the topics concerned with the whole world such as The Earth, Space, and The Environment.

2. National and Regional Public Agencies together with the Private Sector

   The largest number of items at roughly 70% were those where it is desirable for R&D to be advanced by national and regional public agencies together with the private sector. This trend is particularly strong in fields such as Health and Medical Care, Life Sciences, and Substances, Materials and Processing.

3. Private Sector

   There were relatively many fields where it is desirable for R&D to be advanced by the private sector included in those intended to improve life in society such as Transport, and Production and Labor.

(6) Policy as a Nation

With respect to the various national policies that are greatly desired in all items and particularly in the field of Space, there is a great expectation for funding.

It appears there are also many expectations concerning The Environment based on improving the system of operations, and many concerning Life Sciences with respect to human resources.

Issued by Future Engineering Research Institute *Technology in Japan (4th Science and Technology Agency Forecast Assessment).*

Average Time of Realization for Various Items

Field	No. of Items	Average Time of Realization
Substances, Materials & Processing	8	2002
Information, Electronics & Software	24	2001
Life Sciences	11	2001
Space	7	2007
Seacoast	5	2001
The Earth	2	2000
Agriculture, Forestry & Fisheries	18	2003
Mining and Water Resources	4	2002
Energy	9	2008
Production & Labor	22	2003
Health and Medical Care	18	2005
Lifestyle, Education & Culture	7	1998
Transport	12	2000
Communications	5	2000
Cities and Construction	18	2002
The Environment	14	1999
Safety	5	1999

Source: Future Technologies of Japan '87 (Diamond Publishing Co.)

Fields with Major Limitations (Top 3)

Type	Field	Ratio of Responses*
Technical Limitations	Life Sciences	96%
	Substances, Materials & Processing	87
	Information, Electronics & Software	83
	Health & Medical Care	83
Social Limitations	Safety	15
	The Environment	13
	Production & Labor	9
Economic Limitations	Space	51
	Energy	43
	Mining & Water Resources	43

*Indicates the percentage of topics in which a large majority of responses showed a certain limitation would be great.

Fields With Great Expectations from Main Bodies Advancing R&D (Top 3)		
Type	Field	Ratio of Responses*
National & Regional Public Agencies	The Earth	89
	Space	44
	The Environment	37
National & Regional Public Agencies together with the Private Sector	Health & Medical Care	99
	Life Sciences	96
	Substances, Materials & Processing	94
The Private Sector	Transport	34
	Lifestyle, Education & Culture	32
	Production & Labor	31
	Communications	31

*Indicates items in which large majority of responses expect advancement by each type.

Fields With Great Expectations from Various Government Policies (Top 3)		
Type	Field	Ratio of Responses*
Funding	Space	100
	Substances, Materials & Processing	94
	Mining & Water Resources	93
Human Resources	Life Sciences	15
	Information, Electronics & Software	11
	Agriculture, Forestry & Fisheries	7
System	The Enviornment	50
	Lifestyle, Education & Culture	36
	Cities & Construction	30
	Safety	30

*Indicates items in which large majority of responses expect advancement by national policies.

Appendix 2

Classification of Separate Technological Fields by Assessment of the Direction of Advanced Technological Development

Large Classification	Medium Classification	
New Materials	Performance & Function	High performance, High elastic modulus Resistance to extreme environments Optical functions Conductive functions Chemical functions Isolation functions Mechanical functions Ecologically compatible functions
	Processing & Evaluation	Structure control tech. (molecular level) Structure control tech.(aggregate level) Thin film forming technology Ultra-fine drawing and particle forming Evaluation technology
Biotechnology	Search for new useful genetic resources Luminescence Biochemical utilization technology Plant & animal cell engineering Biodegradable plastics Comprehensive therapy for hepatitis Food, nutrition, health, disease prevention with aging Toxicity tests that do not use animals	
Devices	High integration High speed High capability	
Computers	Architecture System Technology Element Technology Basic Technology Input/Output Technology	
Software	Programming Languages Super parallel calculation models Parallel calculation OS Robotics Intelligent Data Bases Software Engineering Ultra-high speed memory processor Interfaces	
Aeronautics and Space	Aeronautics Space	
Energy & Quantum Engineering	New Energy Energy Utilization Application of Quantum Engineering (Quantum development technology, quantum beam utilization)	

Source: Assessment Report of Trends in Technical Development in Major Advanced Technology Fields (May 1989) consigned by MITI.

Appendix 3

White House National Major Technology List
US National Major Technology Report (April 1991)

Field	Major Technology
Materials	Technology for synthesis and processing of materials Electronic & optical materials (including superconductors) Ceramics Composites High performance metals & alloys
Manufacturing Technology	Integrated production technology through computers Intelligent processing equipment (including robots) Micro & nano processing System control technology
Information & Communications	Software Microelectronics & optical electronics High performance computers & networks High resolution image processing and display Sensor and signal processing Data storage and peripheral processing Computer simulation and modelling
Bio-engineering & Life Sciences	Applied molecular biology Medical technology
Aeronautics & Transport	Aeronautic technology Land transport technology (intelligent automobiles, etc.)
Energy & the Environment	Energy Technology Pollution prevention & recovery technology; waste management

In the National Major Technology Report that the White House submitted to Congress, there is a list of 22 technologies that are strongly needed by the US both from the standpoint of national security and economic competitiveness.

This report was created by a special advisory group formed within the White House based on the 1990 Defense Authority Act. It not only deals with technologies that the US and Japan are in close competition over such as super computers and high resolution image processing, but also places emphasis on manufacturing technology, such as computer integrated manufacturing (CIM), where the US is considered weak.

As shown in the above table, the technologies are divided into six categories, and the majority overlap with the lists compiled by the Defense and Commerce Departments, but the striking aspect is that it includes four items from manufacturing technology such as CIM, in which steps from product planning and design through production and distribution are controlled in an integrated fashion by computers, as well as robots, and ultrafine processing technology (nano technology and micromachines), which MITI will be aiming for in its next major technical development project.

Source: Asahi Shimbun, 26 April 1991.

Appendix 4

US Department of Defense 1991 Major Technology List

1. Semiconductor materials
2. Software engineering
3. High capability computers
4. Intelligent machines; robotics
5. Computer simulation and modelling
6. Optics technology
7. High sensitivity sensors
8. High sensitivity radar
9. Signal and image processing
10. Marker control
11. Environmentally suited weapons systems
12. Data fusion
13. Fluid dynamics using computers
14. Jet propulsion (fuel efficiency types)
15. Pulse input
16. Ultra high speed firing
17. High energy integration elements
18. Composite materials
19. Super conductors
20. Biotechnology
21. Flexible manufacturing technology

In the 1991 edition of the US Department of Defense's "Major Technology Plan," 21 types of major technologies are listed whose development should be emphatically addressed in the future from the standpoint of US national security.

In this report, in addition to an increase in plans for the development of technology over the previous two reports, flexible manufacturing (multiple product, small volume production) technology has been added. The report indicates that Japan leads the US in 5 of these fields such as semiconductors, biotechnology and superconductors, and Japan is in a position to partially lead the world in 6 areas such as high sensitivity sensors, high sensitivity radar, etc., but in the other areas the US is somewhat ahead of Japan.

This report considers 15 of these 21 technologies (except for 6 specially designated for military use) as "dual use technologies" that can be applied in both civilian and military fields, and it points out that in areas such as semiconductors and intelligent machines, the degree of dependence on imports from countries such as Japan will increase.

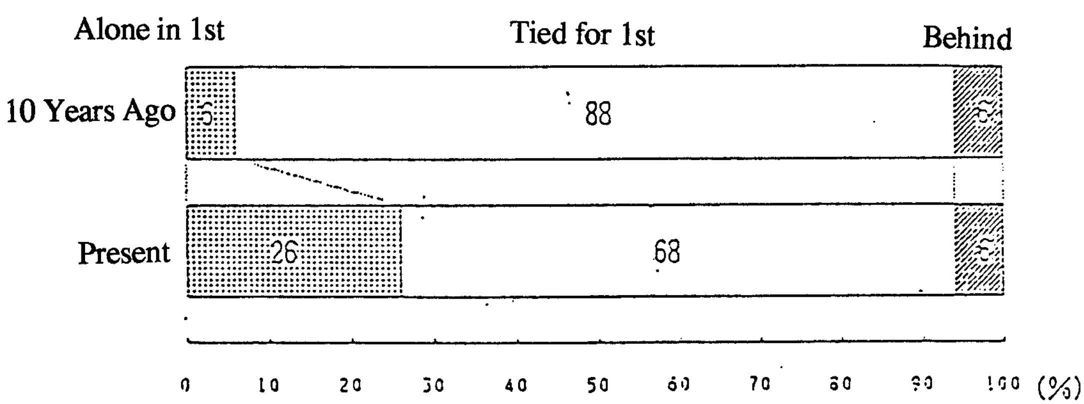
Source: Nihon Keizai Shimbun, 8 May 1991.

Appendix 5

Comparison of Levels of Technology in Japan, USA and Europe

(1) Existing products–Top level internationally in almost all product fields.

Industry	Type	Product Field
Basic Materials Industries	1) Steel	Conventional Steel
	2) Chemicals	Synthetic fibers, synthetic resins, fertilizers, Industrial drugs (organic intermediates), synthetic rubber, dyes, cosmetics, surface active agents, medicines, pesticides, film
	3) Other basic material industries	Girders, beams, vats (steel), aluminum products, aluminum smelting, electric wires, petroleum refining, tires, glass, cement
Processing and Assembly Industries	1) General machine industries	Motors, boilers, processing machines, environmental machines construction machines, wind & water powered machines, plants (steel mills, chemical and petroleum refining plants, etc.), machine parts (seals, valves, bearings, pistons, etc.)
	2) Electric machine industries	Nuclear power devices, electric power devices, electric devices for industry, general use electric devices, music and movie devices, home appliances (refrigerators, washers, etc.), medical devices
	3) Auto industry	Passenger vehicles, trucks
	4) Other machine industries	conventional ships, special commercial ships, railroad cars and rail systems, cameras, watches, measuring instruments, office equipment
Consumer Industries	1) Fiber industry	Natural fibers
	2) Other consumer industries	Foods
Mining Industry		Petroleum, natural gas
Construction Industry		Construction, lumber

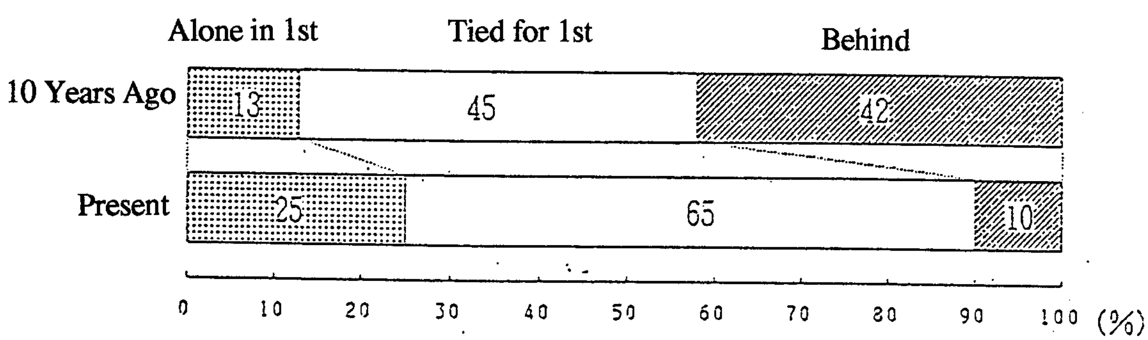


Change in Level of Technology of Existing Products (Comparison with US & Europe)

(2) High-Tech Products

The level of technology in Japan has increased in recent years, and many technologies are at a top level internationally, or at a level near the top. However, items requiring comprehensive system technology, etc., are inferior in comparison to the top levels in the world.

Field	Product	
Raw Materials	•High tensile steel •Superconductors (liquid helium temperatures) •Fine ceramics •Polymer isolation membranes	•Composite materials •Amorphous alloys •New glass •Engineering plastics
Parts	•Optic fiber •CCD •Microprocessor •Servo motors	•Semiconductor lasers •Semiconductor memory elements •Ball screws •Hydraulic control valves
Final Products & Systems	•Optical & magnetic disks •Computers •CAD/CAM •D–PBX •Laser processing machines •Accelerators •Aircraft engines •Artificial organs •Plant bio products •Light water reactors •Rockets to launch satellites •Marine construction materials	•1/2" household VCRs •Data bases •Copiers •Assembly robots •Laser printers •Spectrum analyzers •MRI •Bio products from animal cells •Bio products from microorganisms •Solar photoelectric power •Communications satellites •Skyscrapers

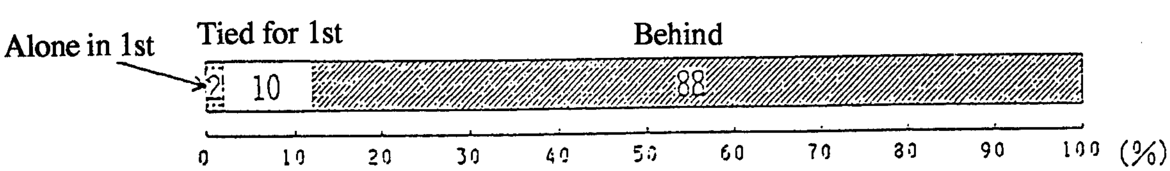


Change in Level of Technology of High-Tech Products (Comparison with US & Europe)

(3) Basic Technologies

Although the level of research in Japan appears to be at a top level internationally in part, it is somewhat behind the level of the US in existing products and in high-tech products.

Field	Product	
New Materials	•High temperature semiconductors •Strongly magnetic materials •Ultra environmentally resistant advanced composites •New alloys and metal compounds •Ultra pure polymer materials •New microelectronic materials	•Non-linear photoelectronic materials •Molecular functional materials •Fine ceramics with new functions •Glass (non crystalline) materials with new functions •Silicon chemical materials
Electronics	•Superconductor devices •Power electronics elements •Optical elements with new functions	•Elements with quantum functions •Large surface area circuit elements
Biotechnology	•Manufacture of high capability enzymes and biological substances •Plant & animal cell optics •Construction of bio data bank	•Finding and isolating new microorganisms, plants and animals as useful genetic resources •New genetic optics •High level utilization of in vivo reactions
Technology Common to New Materials & Electronics	•Atomic precision control tech. •Molecular precision alignment control technology •Design & simulation tech. •Photoreactive process technology	•Metal & inorganic material processing technology •Evaluation, analysis, measurement technology •Extreme environment mfg. tech.
Technology Common to Biotechnology & Electronics	•Protein handling (alignment) technology •Development of bio-related analysis and evaluation systems	•Techniques utilizing biological membranes
Tech. Common to Biotech & New Materials	•Materials simulating biological functions •Techniques utilizing biochemistry	•Biologically compatible materials •Bioprocess separation and refining technology
Software Systemization	•Autonomous integrated data processing devices •Autonomous data processing devices with neural structures •Super parallel architecture •Software compatibility development techniques •Disaster prediction technology	•Human technology •Resource & energy technology •Integrated software to control machines •Environmental management technology •High performance robot technology



Present Level of Technology in Basic Technical Fields (Comparison with US & Europe)

Source: Trends and Topics in Industrial Technology, September 1989, MITI

Appendix 6

Market Size of Present Typical Technologies & Products and the Cost of Major Technologies & Products

(1) Size of Market of Present Typical Technologies & Products

Field	Technology or Product	Annual Size of Market	Date of Survey	Notes
Communi- cations	Station switching devices	¥287 billion	1990	
	PBX	¥83 billion	1989	
	Multimedia multiplex eqpmt.	¥48 billion	1989	
	Optical transmission system	¥233 billion	1990	
	CATV	¥33.3 billion	1989	VATV terminals only
	TV conference system	¥4.8 billion	1989	
	Satellite communications	¥81.5 billion	1990	Satellites ¥23 billion Ground eqpt. ¥58.5 billion
	Car telephone	¥76.4 billion	1989	Includes portable telephones
	Telephones (includes multifunctional devices)	¥123.7 billion	1989	Includes cordless telephones
Energy	Air conditioner (home use)	¥820 billion	89-90	Number shipped from mfr.
Data & Electronics	Biosensors	¥5.5 billion	1988	
	Semiconductor multiplexing	¥3000 billion	1990	
Composite Materials	(US)Fiber reinforced plastic	¥733 billion	1989	Business Communication Co.
	(Japan) Fiber reinforced plastic	¥489 billion		MITI New Material Comm.
	(US) Fiber reinforced metal	¥10 billion	1989	Business Communication Co.
	(Japan) Fiber reinforced metal	¥100 million	1987	MITI New Material Comm
	(US) Fiber reinforced ceramic	¥30 billion	1989	Business Communication Co.
	(US) Ceramic engine	¥500 billion		from newspaper (in 2000)
	(Japan) Fiber reinf. ceramic	¥100 million +	1987	MITI New Material Comm.
	(Japan) Carbon fiber	¥40 billion	1987	MITI New Material Comm.
	(Japan) C/C Composite	¥100 million +	1987	MITI New Material Comm.
Organic Materials	Semiconductor elements	¥3594.1 trillion	1989	MITI Production Statistics
	Microprocessors	¥250 billion	1989	Data Quest
	Optical disks	¥115 billion	1990	Optics Industry Society
	Photoelements and parts	¥150 billion	1989	Optics Industry Society
	Engineering plastics	¥320 billion	1987	MITI New Materials Comm.
	FRP	¥489 billion	1987	MITI New Materials Comm.

(2) Present Cost of Major Technologies and Products

Field	Technology or Product	Total Cost	Time Period	No. of Years	Annual Cost
Energy	Tokyo Electric Kashiwasaki Karihane #2 Atomic Power Plant (1.1 million kW)	¥301 billion	10/1971–9/1990	19.1	¥15.8 billion
	Kyushu Electric Matsuura #1 Coal Power Plant (1.1 million kW)	¥277 billion	4/1978–6/1990	12.2	¥15.8 billion
Environment	Large scale environmental equipment (acid rain processors)	¥5–10 billion	—	—	—
Transport	20,000 ton tanker	¥15 billion	—	—	—
	Jumbo jet	¥20 billion	—	—	—
Utilization of Space	Seto Bridge	¥1130 billion	1978–1988	9.5	¥118.9 billion

Appendix 7

Demand Matrix
(Relation Between Level and Subject of Demand)

	The Earth for the Sake of Humanity	Nation	Society	Corporation	Individual
5		Utopia	Utopia	Realization of Corporate Principles	Self Realization
4		Leadership	Abundance (cultural)	Top-notch Corporation	Esteem (interests)
3	Harmony with Ecosystem	International Harmony	Abundance (physical & economic)	Recognition from Society (member of group)	Belonging (leisure, convenience)
2	Environmental Safety	Security (peace)	Safety & Stability	Intermediate-term Survival	Safety (avoidance of discomfort and difficulties)
1	Energy Problems, Food Problems, Population Problems	Survival (acquisition of food, acquisition of resources)	Survival	Short-term Survival	Physiological Functions (food, clothing, shelter) (minimum needs)

Source: Report entitled "Trends in Japan's Technical Development Viewed from Needs and Wants of Society and the Individual" by Japan Productivity Headquarters

Part II: Individual Reports

91FE0863 Tokyo KEIZAI KIKAKUCHO SOGOKEIKAKU-KYOKU in Japanese Jul 91 pp 1-94

[Text] Contents

Terabit Memory

1. Outline of Technology and Products

The (10*12)-bit memory chip, which utilizes such technology as super-electric power device based on a new concept, will be attainable around the year 2030. The 1-gigabit random access memory chip is expected to materialize by the year 2000. The 1-terabit chip device, which possesses 1000 times the capacity of the 1 gigabit device, on the other hand, is generally considered unattainable by the mere extension of silicon technology.

2. Long-range Prediction For Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then the current juncture in the R&D stage relatively-speaking would be assigned a numeric value of 5, which means that the practical application of the terabit chip will be realized around the year 2030.

Comparison of various international R&D efforts in this field indicates that only Japan at present has a firm grasp of the concept of the terabit memory capacity which approaches that of the human brain.

Key technologies requiring breakthroughs include the super-electric motor devices (including the high-temperature super-electric motor), super high-density circuit integration/control, measurement, and processing technologies.

Social constraints likely to affect the implementation of the terabit memory technology will be weak governmental aid policies for the development of super electric motor technology and the effects of the general public's awareness and value systems with respect to the new technology. Effects of economic restrictions would include the difficulties involved in securing an adequate market scale, effecting low costs, application of marketing principles, inadequate market development funds available, and in securing adequate R&D manpower.

3. Impacts on Industrial Economy

It is estimated that the market scale of terabit memory will reach approximately the 3 trillion-yen level. The number of related industrial research laboratories will increase to approximately five.

The following products and industries will be positively impacted by the terabit memory: advanced-function computers, advanced-function laptop computers/word processors, intelligent home electronics, information input systems, communication systems, and social infra-systems; the automobile industries; and the space and defense industries.

Negative impacts will be felt by existing the computers, information systems, and home electronics industries. In all probability, the more significant the role of memory become, the greater the adverse effects suffered by existing equipment industries will be.

From the viewpoint of technological assessment, the question of human dignity and of the assignment of roles to machines and to humans will become an important issue.

Superconductive Device

1. Outline of Technology and Products

Constructed with superconductive transistors, the Josephson device, the quantum magnetic flux parametron, etc., the superconductive device is superior to the VLSI achieved by current semiconductor technology by 10^3 x 3-102 2 x 7, namely, in terms of a product of electrical-energy consumption timed by switching time. This is a new device founded on the concept of "quantum effect." The quantum magnetic flux parametron, especially, has an excellent potential in terms of achieving an integrated circuit which, in principle, approaches the capacity of the human brain.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then the numeric value assigned to the current juncture relative to that R&D stage would be one of 10. The period of its practical utilization, therefore, will begin around the year 2020.

Comparison of advanced industrial nations' R&D efforts in the field at this point indicates that very few of them are working on the concept of the superconductive device based on the series of "quantum effect" as a major future research undertaking. Japan's cutting-edge electronic industry firms, however, already have been seriously grappling with this problem.

Breakthroughs are required in the following key technologies: (1) VLSI/measurement/control technologies in the superelectric drive state (includes high temperature superconduction); (2) VLSI packaging technology; and (3) VLSI process/design technologies.

As for the social barriers deterring the practical utilization of this technology, the governmental assistance policy for development of the superconductive technology and the effects of the general public's strong feelings and value systems concerning the emergence of a device which could rival human capability as does the superconductive device. Effects of economic restrictions include difficulties involved in securing adequate market scale (due to demands for advanced-function and high-performance devices), realizing low-cost products (necessary to successfully compete with the conventional-type device), and in introducing marketing principles (this is not a big factor), as well as inadequate R&D appropriations (trade-off with insufficient funds), and difficulties associated with securing R&D manpower (which will become even more severe).

3. Impacts On Industrial Economy

It is estimated that the scale of the superconductive device market will reach approximately the 1 trillion-yen level. This will increase the number of related corporate research laboratories to five.

Positive impacts which will be created by the superconductive device upon the industrial economy are dramatic improvement in the performance and functions of supercomputers, rapid expansion of their application fields (large-scale simulations), emergence of high function computers equipped with the ability to make judgments, i.e., artificial intelligence, a full-fledged robotic translation machine, and vitalization of database and social infrastructure industries.

Among discernable negative impacts will be the factor that existing computer systems and Si and GaAs devices gradually will be eased out as they are being replaced by new devices. However, since application areas of information processing equipment and system are quite extensive, it probably will take some additional time before old devices are completely replaced by the new.

From the standpoint of technological assessment, it is estimated that at a relatively gradual pace, this device will assume the major technological role. On the other hand, a dramatic increase in functions and capabilities of the new device will generate debates on the question of superiority of man over machine. The question of man's dignity and of the separate roles to be assigned to man and machine will become an important issue.

Super-Intelligent Chip

1. Outline of Technology and Products

In comparison with the present semiconductor chip, the functions of the super-intelligent chip is some 1000 times more powerful in terms of its intelligence. As a basic element of a system capable of high-level judgment, it is an effective chip. It is also useful as a memory or processor chip. As the demand for intelligent electronic equipment rises, the super-intelligent chip will play a significant role in providing intelligent judgmental functions in equipment.

2. Long-Range Prediction for Practical Utilization

If a numeric value of 100 were to be assigned to the practical utilization stage, then the relative value assigned to the present juncture of the R&D stage would be one of 5, which means that the practical implementation will take place around the year 2010.

Comparison of advanced industrial nations' R&D efforts at this point indicates that those which are specifically working on the development of a series of "intelligent device" are Japan's cutting-edge electronics industrial companies and the U.S.'s semiconductor makers. The United States is ahead of Japan in processor chip technology.

Key technologies requiring breakthroughs are the VLSI/packaging technology, intelligent software technology, and intelligent file technology.

Social barriers which will impede practical application of super-intelligent devices will include aspects of social infrastructures such as the protection of privacy and accurate recognition of the division of roles to be played by artificial intelligence and by humans. Economic constraints will be found in the areas of (1) securing market scale which involves the parallel expansion of application fields, (2) realization of low costs through developmental and production efficiency, (3) introduction of the marketing principle (not a big factor), (4) R&D funding level eroded by the need for large scale equipment (the trade-off which must be considered due to inadequate funding in recent years), and (5) difficulties associated with securing R&D manpower (Increasingly, the effectiveness of education will be questioned.).

3. Impacts On Industrial Economy

The super-intelligent chip market is estimated to reach approximately the 1 trillion-yen level. The number of related corporate research laboratories, accompanying this, will be increased to around five.

Positive impacts created by the super-intelligent chip on the industrial economy in terms of new industries and products will be advanced computers, neural networks, and artificial intelligence industries. Among the industries and products which will be vitalized by the super-intelligent chips are the social infrastructure industry, communication systems, and the automobile industry. Among the secondary effect industries and products will be the space industry, resource exploration, and the defense industry.

Negative impacts will be felt by the conventional type computer systems, devices, and home electronics.

From the viewpoint of technological assessment, we can foresee a rapid increase in the use of super-intelligent chips in all types of equipment. On the other hand, a dramatic expansion of machinery functions and capabilities will ferment "man vs. machine" debates designed to determine which has the superior capabilities. The question of human dignity and distinct roles to be played by man and machine will emerge as an important issue.

Self-Reproducing Chip

1. Outline of Technology and Products

Unlike currently existing semiconductor chips, whose functional definition and behavioral control are handled by a so-called, "external command," the functions and behavior of a "self-reproducing chip" are determined internally. In other words, it possesses a self-organizing function. As an example of the internal architecture of this new type of semiconductor chip, a "neural computing" structure may be considered.

The intelligent function of this kind of chip is as much as 1000 to 10 million times more powerful than those associated with maximum function chips currently available; and, as such, the new chip is a basic device which will prove effective either as a system memory capable of advanced-level decision making or as a processor. In the future, when we see a rise in demand for electronic equipment with an advanced-decision making function, the self-reproducing chip will play an essential role in the realization of such equipment.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then the current juncture in the R&D stage, relatively-speaking, would be 5. This means that it will be sometime around the year 2050 when practical utilization of the chip will be realized.

Comparison of various countries' R&D efforts in the field at this point indicates that those pursuing basic research in an effort to create the concept of the "self-producing chip" are just a few of Japan's pioneering electronic industrial firms and some limited segments of the U.S. electronic industry.

Key technologies requiring breakthroughs will include self-organizing-type technology, self-learning architecture and software technology utilizing knowledge acquisition, and hyper-parallel computing technology, and VLSI technology which realizes self-learning.

Social barriers which will impede practical application of self-reproducing chips have to do with accurate recognition of the difference in roles to be played by machines and humans respectively. The major effects of economic restrictions will be the lack of R&D funds, this being attributable to large-scale of investment required and the difficulties associated with securing R&D manpower in this field.

3. Impacts on Industrial Economy

The self-reproducing chip market is estimated to reach approximately 3 trillion-yen level. Accompanying this will be an increase in the number of corporate research laboratories of related industries to around five.

A positive impact created by the self-reproducing chip on the industrial economy in terms of the new industries and products emerging is the possible emergence of a so-called "computer with reasoning power" equipped with a self-reproducing function.

Those which may be negatively impacted are the "non-thinking" computer systems whose actions are triggered by conventional type instructions generated by humans, similar electronic devices, and electronic equipment.

From the viewpoint of technological assessment, we can foresee use of self-producing chips in many types of equipment. It is reasonable to assume that this would trigger many "man vs. machine" debates, designed to determine which one possesses the superior capability. Re-examination of the question of human dignity and of the distinction between man's role and that of the machine will emerge as an important issue.

Terabyte Optical File

1. Outline of Technology and Products

Any file system which contains more than 10^{12} bytes per system, of necessity, must incorporate optic file disks. These disks must be a read-write type. As it will be necessary to access on real time a file containing massive memory at high speed, the memory probably will have a multi-layered hierarchical structure composed of a fast main memory and a buffer memory.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then the current juncture in the R&D stage in relative terms would be one of 10, which means that it will be sometime around the year 2010 when practical application of the terabyte optical file will be realized.

Comparison of various countries' R&D efforts in the field at this point indicates that Japan's cutting-edge electronic companies and a few European and U.S. companies are working on file systems constructed around optical disks and that Japan clearly is substantially ahead of the rest of the world in this field at present.

Key technologies requiring breakthroughs are the ultra-high density optic disk technology (read/write type), ultra large capacity filing system structure/retrieval technology, and peripheral support technologies, viz., laser technology (optic source and beam) and ultra high density disk design technology.

Social barriers which will tend to impede implementation of the terabyte optical file technology are governmental policies concerning social data base construction, harmony between the new technology and the social infrastructure, and the general public's awareness and value systems with respect to databases containing knowledge and culture. Economic restrictions will affect business's efforts to secure a market scale based on social demand for ultra-large volume files and to achieve lower per-bit costs. Also affected will be the R&D funding level, which will be reduced as a result of the large-scale investment required for equipment purchases. The R&D staffing level will also be reduced.

3. Impacts on Industrial Economy

It is estimated that the terabyte optic file market scale will reach the approximately 2-trillion-yen level. Accompanying this will an increase in the number of corporate research laboratories to around five.

The positive impact created by the self-reproducing chips on the industrial economy will be the rise of a massive-size database industry.

Its negative impacts will be felt by the conventional low-intelligence systems and equipment manufacturing industries, which will begin to decline. Currently-produced optic and magnetic disks will be competing with the new terabyte files for a while, thus allowing the old and the new to coexist during that period.

Terabit Optic Communication Device

1. Outline of Technology and Products

The optic device, which will achieve ultra high-speed communication even faster than the 10^{12} bit system, is a key component of system configuration in the age of the full-fledged B-ISDM. This kind of speed is attainable only by ultra-coherent optic control.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then the current juncture in the R&D in relative terms would be 10. This means that it will be sometime around the year 2010 when practical application of the terabit optical device actually will be realized.

Comparison of worldwide R&D efforts in the field of ultra high-speed optic communication technology at this point indicates that there is a substantial gap between Japan's efforts and those of the United States and Europe. In other words, Japan's cutting-edge electronic companies are well ahead of European and U.S. companies. This situation probably will continue.

Key technologies requiring breakthroughs are the ultra-coherent optic control technology, ultra high-density optic device design technology, and ultra-wideband B-ISDN technology.

Social barriers which will tend to impede implementation of the terabit optic communication device are the public policy governing optic communication, especially the B-ISDN, coordination of social infrastructure regarding wide-band area communication, and the general public's awareness and value systems with respect to the importance of large capacity communication. Economic restrictions will affect industry's efforts to secure an appropriate market scale based on social demand for ultra large volume communication, to achieve low per-bit-cost, R&D funding level which will be reduced as a result of the large-scale investments required for large-scale equipment purchases, and the R&D staffing level.

3. Impacts on Industrial Economy

It is estimated that the market scale of terabit optic-file will reach approximately 3-trillion-yen level. Accompanying this will be an increase in the number of corporate research laboratories of the related industries to anywhere between five and seven.

Positive impacts created by terabit optic-communication devices on the industrial economy will be the further growth of the moving-image communication industry (for instance, the entertainment industry). The B-ISDN communication industry, as a result, will expand. Moreover, the technology's secondary effects will be felt by industries related to automobiles, social infrastructure systems, and energy explorations.

Its negative impacts will be felt by the conventional-type communication systems, devices, and media industries, and those electronic equipment industries which do not stress communication. These industries will have no alternative than to cease growing or to decline.

From the viewpoint of technological assessment, we can foresee many fundamental problems which must be dealt with in order to realize the terabit optic communication. Those, however, can be overcome. Moreover, if such ultra high-speed communication can be achieved, then the sharing of data and knowledge on a truly global scale, as well as achieving close global cooperation, will become feasible. We, then, will see the advent of an age in which the phrase, "the world is one," literally will have become a truism.

Optic Computing Device/Equipment

1. Outline of Technology and Products

In order to improve computer performance by more than 1000 times the current capabilities, a computer system will be designed using optical technology which is free of electromagnetic effects. The technology consists of optic device processors chiefly engaged in parallel processing, optic high-speed data communication paths, and optic memories. It goes without saying that partial substitution among these will be a possibility. From the standpoint of principles, what is involved is precision control of optical second and third harmonics.

2. Long-Range Prediction for Practical Utilization

if the practical utilization stage were to be assigned a numeric value of 100, then the current juncture in the R&D stage in relative terms would be assigned a numeric value of 5. This means that it will be sometime around the year 2020 when practical application of the optic computing device and equipment actually will be realized.

Comparison of various countries' R&D efforts in the field of optic computing at this point indicates that Japan and the United States are about equal in terms of progress thus far made. It has been reported that in Europe, also, basic and theoretical research has been undertaken at several universities. The present situation is expected to continue for sometime to come. Strong possibility of global cooperation leading to substantial development in the field exists.

Key technologies requiring breakthroughs are ultra-precision optic control technology for SHG and THG and the miniature structure ultra-precision optic device design technology.

No social barriers to prevent practical utilization of the optic computing appear to exist. Economic restrictions will affect the industry's effort to secure an appropriate market scale based on social needs for optic and all other high-performance computers, demand for ultra large volume communication, pursuit of low-cost factors in production overcoming ever-increasing developmental costs, R&D funding level, the cut in which is necessitated by the industry's need for more complex and large-scale equipment, and the R&D staffing level involving researchers knowledgeable both in optic and computing technologies.

3. Impacts on Industrial Economy

It is estimated that the optic computing, device, and equipment market scale will reach approximately the 3-trillion-yen level. As a consequence, the number of related industrial research laboratories will be increased to somewhere between seven and ten.

Positive impacts created by the optic computing, device, and equipment on industrial economy will be the emergence of full-fledged super performance workstations (whose capability ranges from several hundred megaflops to in the gigaflops). We will also see dramatic advances made in software technology, enabling computers to perform processing with near-human intelligence, to carry out machine translations, and to perform large-scale simulations. Moreover, their secondary effects will have beneficial effects in the fields of weather forecasting, space/earth explorations, earthquake prediction, environment, energy, the social infrastructure, and architecture, contributing to their advancement.

Their negative impacts will be felt by the conventional-type computer system industries whose growth will be stunted. However, since this will not take place immediately, there will be a period during which time the new and the old types of computer systems will coexist.

From the viewpoint of technological assessment, we foresee many fundamental problems which must be dealt with in order to realize the potentials of optic computing, optic devices, and optic equipment. In order to overcome these problems, a global cooperative R&D setup will be found to be both necessary and effective.

Biosensor

1. Outline of Technology and Products

A biosensor is designed to make micro-quantity measurements through the combined use of biomolecular identification materials (such as enzymes, microorganisms, antigens, antibodies, ligand receptors, DNA, and RNA/DNA probes) with physical chemistry methodology. It already is being put to practical use in the fields of clinical analysis, industrial process, and environmental measurement. Currently, research aimed at development of ultra-high degree of sensitivity, expansion of categories of measurable items, and development of ultra-compact size instrument is in progress.

2. Long-Range Prediction for Commercialization

If the commercialization were to be assigned a numeric value of 100, then the current juncture in the R&D stage could be assigned the numeric values, ranging from 50 to 60. This means that it will be sometime around the year 2000 when the commercialization of biosensors actually will be realized.

Comparison of various countries' R&D efforts in the biosensor field indicates that if Japanese efforts were to be given a score of 100 points, then the United States would score 95 and Europe 85, indicating that at present Japan is slightly ahead of the rest of the world.

Key technologies requiring breakthroughs are development of a stable and high-sensitivity element as well as of chemiluminescent materials.

No social barriers, whether system-wise or government policy-wise, stand in the way of commercialization of the biosensor technology; however, the industry's efforts to secure market scale, to achieve low prices, and to ensure an adequate R&D staffing level will be affected, to some degree, by economic constraints.

In order to solve these problems, it will be necessary to realize low pricing, increased stability and mass production through stepping up R&D efforts.

3. Impacts on Industrial Economy

Positive impacts created by the biosensor on the industrial economy will include the emergence of a new taste sensor, of olfactory sensor, and of a freshness sensor, which will provide substantial growth for the sensor market and will accelerate the development of such products as home electronics.

Moreover, the biosensor is expected greatly to vitalize medical fields. This will be especially evident in the field of artificial organs, in which technological innovations will occur rapidly. Use of biosensor technology is expected to raise diagnostic medicine to yet another level.

Its negative impacts will be felt by the autoanalyzer makers, who will face a shrinking market even as they begin to compete with biosensor makers.

Development of biosensor element technology already has been progressing in many fields. The point now is that the industry must explore future needs and find ways in which the technology will be utilized, as these two factors will be the key to its commercialization.

Biocomputer

1. Outline of Technology and Products

A biocomputer is a computer featuring biological characteristics. Although no definite concept has yet to have been formulated, we are being made to understand that it is a product capable of performing the kind of information processing which existing computers are unable to accomplish. Its research currently is in progress. Although its concrete technological image has yet to be formed, its characteristics are listed as follows: (1) high density integration of devices; (2) parallel architecture; (3) bidirectionality of one-dimensional and three-dimensional computing; (4) developmental capabilities, such as learning functions and evolution; and (5) kind to environment.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then, the current juncture in the R&D stage would be assigned 10, which means that it will be sometime around the year 2020 when commercialization of biocomputers actually will be realized.

Comparison of various countries' R&D efforts in the biocomputer field indicates that if Japan were to score 100 points, then both the United States and Europe also would have a score of 100, indicating that all of them currently are at the same stage of development. At present, the biocomputer must be approached from both the life science and computing fields, as all biocomputer R&D projects are very much in their beginning stages. In Japan, leading manufacturers and, in the United States, venture capital businesses are primarily involved in R&D.

Key technologies requiring breakthroughs are development of biochips, neurochips, and other new devices; parallel computers; and such new logic methods as learning/memory. Also required is research into optic computers, brain/nervous systems, and developmental biology, which will serve as peripheral technologies.

Although no social constraints, whether in terms of system or of government policy, are standing in the way of practical utilization of the biosensor technology, still effects of economic constraints will be felt to some degree in the areas of securing new markets, of inadequate R&D funds, and of securing R&D personnel. For these reasons, it will be necessary to increase R&D budgets and manpower and to promote cooperation between computer scientists and life scientists, as well as among governmental, academic, and industrial sectors in carrying out research.

3. Impacts on Industrial Economy

The biocomputer market scale cannot be ascertained at this point. Currently, there are twenty related industrial research laboratories, which number is expected to increase.

Positive impacts created by the biocomputer on industrial economy will be the part it will play in advancing the present information processing and information communication fields. It is also expected to vitalize existing computer, home electronics, medical equipment, and machine tool industries. Its secondary effects will be felt by financial institutions' information processing segments.

Its negative impacts will be felt by manufacturers of conventional home electronic products, conventional-type medical equipment, and machine tools.

Super-Parallel Computer

1. Outline of Technology and Products

Imagine a computer system which houses from in excess of 20,000 to a few million computer elements in a single computer! The system will be designed to extract problems which can be autonomously processed from those requiring processing. The computer will be designed to minimize total processing time through maximum parallel processing. In other words, this is the computer which will come after the next generation of computers, with its architecture designed to maximize total throughput by internal paralleling. This computer appears to offer a great deal of promise for mainframes and workstations. It aims at performance from a few hundred- to a few million-times more powerful than conventional computers. In other words, in terms of supercomputers, it achieves computing performance in the region of teraflops (execute more than 1 trillion floating point operations a second). By designing a computer system using optic technology which is free of electromagnetic field effects, for example, we believe it will be possible to achieve this performance goal.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then, relatively speaking, the current juncture in the R&D stage would be 20, which means that it will be sometime around the year 2010 when practical application of superparallel computers actually will be realized.

Comparison of various countries' R&D efforts indicates that all Japanese computer manufacturers are seriously pursuing research in the superparallel computer field; and, that in the United States, also, several companies and universities are involved in the superparallel computer research. In Europe, although there is a report of theoretical research conducted at several universities, not much has been reported on the industrial projects. In this field, also, a great deal can be achieved by global cooperation.

Key technologies requiring breakthroughs are the inter-superparallel communication mechanism, the OS (operating system) software designed for superparallel processing, parallel linkage structure of application and process, technologies related to optic computing, viz., SHG, THG, and similar ultra-precision optic control technology,. Also considered important are ultra-fine structural precision optic device design technology.

Although no social constraints appear to stand in the way of practical utilization of the superparallel computer technology, nevertheless, economic constraints will deter, to some degree, business's efforts (1) to secure appropriate market scale based on social needs for high performance computers, (2) to reduce costs so that ever-increasing development costs (the cost of building one prototype machine reportedly will exceed 20 billion yen) can be overcome, thus allowing the industry to manufacture computers, (3) to prevent erosion of R&D funding levels caused by the increased complexity and enlarged scale of systems, and (4) to secure R&D personnel who "can see a total picture" (especially in OS software development).

3. Impacts on Industrial Economy

The superparallel computer market scale is estimated to reach approximately the 2 trillion-yen level. As a result the number of related industry's research laboratories may increase to around five.

A positive impact created by the superparallel computer on the industrial economy is the possibility of emergence of the considerator, equipped with near-human functions--not as a theoretical product but as an actual product approximating human functions. In other words, computers currently in use are several hundred million times inferior to the human brain in the areas of processing characterized distinctly human (recognition, grasping, understanding, sensitivity, etc.). For this reason, computers whose capabilities come close to humans' do not exist at the present time. Emergence of the superparallel computer, however, will provide at least a partial solution to this problem.

Neurocomputer

1. Outline of Technology and Products

A neurocomputer possesses an internal structure which approximates that of the human brain; and, as such, is capable of achieving the kind of processing which existing computer systems find extremely difficult to execute in that it requires the abilities to "use judgment," to "estimate," and to "grasp the total picture," normally attributed to human thought and behavior.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then, in relative terms, the current juncture in the R&D stage would be one of 5, which means that it will be sometime around the year 2030 when the practical utilization of neurocomputers actually will be realized.

Comparison of various countries' R&D efforts at the present juncture appears to indicate that all of the Japanese computer manufacturers are giving serious efforts to the field of neurocomputer research. Such endeavors have produced both a prototype machine for testing and partial development of software. Also, in the United States and Europe, several companies and universities have undertaken research projects; however, these latter still are in their theoretical stages. We can safely state that Japan is ahead of the rest of the world in this field. However, since the structure of the neurocomputer basically is extremely complex, containing such an element as "self-organization," the future of the research itself still is an unknown factor. Global cooperation will definitely contribute to rapid progress and development.

Key technologies requiring breakthroughs are those designed to develop the architecture which approximates the human brain, the relevant computing structure and the structure of its linkage to memory devices, and the high-performance processing device which achieves these. As a support technology, cooperative action between the five senses (viz., sensory perceptions) and the computer, superparallel processing, and optic computing are also important.

A social barrier standing in the way of practical utilization of the neurocomputer is the serious question posed by the respective roles to be assigned to the computer and to man, which, in turn, will affect the general public's awareness and value systems concerning the technology. Economic constraints will deter the business's efforts to establish applicable markets based on social needs for the neurocomputer, to bring production costs down by recovering huge developmental costs, to remove chronic shortages in R&D funds experienced by most pioneering businesses, something unavoidable in the "Age of Research Industry", and to securing adequate R&D staffing levels.

3. Impacts on Industrial Economy

The neurocomputer market scale is estimated to reach approximately a 2-trillion yen level. As a result the number of research laboratories in related manufacturing firms will increase to around five.

Positive impacts created by the neurocomputer on the industrial economy will be spectacular growth experienced by such industries as the robotic industry, which manufactures machines capable of carrying out tasks in an almost-human-like fashion. It goes without saying that the computer and database industries also will emerge as growth industries. Negative impacts, however, will be experienced by the conventional-type computer industry, which will rapidly decline.

From the viewpoint of technological assessment, we foresee rapid developments in hardware, software, and file systems, which will realize the development of neurocomputer technology, during the next 20 to 30 years. We can reasonably expect realization of the neurocomputer by integrating all of these components, and by doing so, we will come close to achieving the Fourth Industrial Revolution.

Automatic Translation/Interpreting System

1. Outline of Technology and Products

A system which performs sequential and simultaneous translation/interpreting--this system will produce accurate transfer of sentences into Japanese or into foreign languages in an acceptable form. Basically this is accomplished by software. However, the end product will be a system configuration involving a VLSI high performance chip and an ultra-small, massive file subsystem, on which a large-scale translation/interpreting software will be mounted.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then, in relative terms, the current juncture in the

R&D stage would be 15, which means that it will be sometime around the year 2020 when practical application of the automatic translation/interpreting system actually will be realized.

Comparisons of various countries' R&D efforts at the present juncture in R&D of "automated translation/interpreting systems," indicates that both Japan and the United States are actively pursuing research and development. In the United States, for instance, Carnegie-Mellon University is conducting basic research in knowledge acquisition and self-learning, as well as the testing of concrete prototype systems developed. In Japan, several pioneering electronics manufacturing companies are grappling with research problems while converting some of their findings into finished products.

Key technologies requiring breakthroughs include a language conversion technology which can deal with the semantics of sentences involved, hardware and system architecture component technologies, designed for online, realtime high-speed processing; inter-multilingual conversion technology; knowledge-base and expert system construction/reconstruction/operation technology; and knowledge-acquisition/self-learning/self-organizing technologies.

A social constraint standing in the way of practical utilization of the automated translation/interpreting system will be the relatively strong influence exerted by societal systems and by governmental policies, as well as the close connection which it inevitably will have with the social infrastructure. Moreover, the effects of the system's relationship with language and culture, as well as value judgment to which the software will be subjected, cannot be ignored. Effects of economic constraints will be reflected in the need for firmly securing the large-scale market expected to emerge (although this will depend on the quality of translation involved in the mutual exchanges of technical documents between the U.S. and Japan). The ability to secure a large market share will have a definite bearing on future technological and product development. Also important in this connection is the push for low cost. In the area of software development, shortage in R&D funds caused by the large-scale investment required in terms of manpower resources and the tremendous difficulties associated with recruiting R&D personnel will create some adverse effects.

3. Impacts on Industrial Economy

The automatic translation/interpreting system market scale is estimated to reach approximately 1 trillion-yen level.

Accompanying this market will be an increase in the number of related industrial research laboratories to 20. Software application fields will witness vigorous R&D activity, involving a relatively large number of research organizations.

Positive impacts created by the automatic translation/interpreting system industry will include emergence of a computer-based translation/interpreting industry, and the revitalization of the computer software-house, of the computer industry, and of the robotic industry. Those which will be affected by the secondary effect will be the publishing industry, newspaper/magazine firms, and broadcasting industry (television, radio, etc.).

Negative impacts will be experienced by the conventional-type translation/interpreting businesses which will suffer either from non-growth or from declining business.

From the viewpoint of technological assessment, we foresee many opportunities on an international level and application of automated translation/interpreting systems in various fields.

Virtual Reality System

1. Outline of Technology and Products

A technology designed to create a kind of pseudo-virtual world using computer technology is designated as "virtual reality" technology. The "virtual reality system" is a system which generates this pseudo-virtual world. For instance, using large-screen images and sounds, or simply by moving a chair in concert with screen images, a system can create various kinds of experiences for users as if they actually are in an airplane or in a space ship.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then, in relative terms, the current juncture in the R&D stage would be 20, which means that it will be sometime around the year 2020 when practical application of the virtual reality system actually will be realized.

Regarding the comparison of various countries' R&D efforts at the present juncture in the "virtual reality system" field, both Japan and the United States are actively working on research and development of the system. At this particular point, however, the United States is more actively pursuing the system research. In the United States, for instance, the aerospace industry's R&D projects and national level projects in support of the industry, are conducting truly large-scale simulations and are constructing excellent databases.

Key technologies requiring breakthroughs will be those used in development of three-dimensional simulation models, the super-computer application technology, and the self-growth-type database technology.

One form of social constraint standing in the way of practical utilization of the virtual reality system will be the effects of its possible application to transportation systems as a part of the social infrastructure. Moreover, it will be influenced by the general public's perception and value judgments regarding the system. Economic constraints will affect the business's attempt to establish a market and to drive costs down. Moreover, the need for making large-scale investments centering around costs of securing technical specialists in the software development field and the resultant shortage in R&D funds, as well as other difficulties involved in recruiting R&D personnel must be dealt with.

3. Impacts on Industrial Economy

The virtual reality system market scale is estimated as reaching approximately the 1 trillion-yen level. Accompanying this market, there will be an increase in the number of related industrial firms' research laboratories to as many as 100. Software application fields will be extensive, and a large number of R&D divisions will be pursuing product research and development targeted for various social strata.

Positive impacts created by the virtual reality system on the industrial economy will include the emergence of the new simulation industry (which probably will maintain supercomputers), and revitalization of computer software-houses, computer industries, the entertainment industry, and the aerospace industry. The secondary effects will be experienced by the information industry, the general communication-related industry, the publishing industry, newspaper and magazine businesses, and by television and radio broadcasting industry.

Negative impacts will be felt by industries which have tended to hold on to hardware-oriented products.

Self-Reproducing Database System

1. Outline of Technology and Products

A self-reproducing database constantly updates and maintains itself by generating new data and provides timely revision of old data based upon its own judgment. In addition, the database, equipped with learning capabilities, increases necessary knowledge in an organized fashion. There is an urgent demand for such a database by today's society. Especially in the future when the amount of data will be further increased and every aspect of human activities and products of those activities (not only in the area of technology but also in the cultural domain as well) will be stored in a database (it may be more correct to designate it as a culture base), the "self-reproducing database" will become an essential tool and will have an important role to play.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then, relatively speaking, the current juncture in the R&D stage would be assigned 10. This means that it will be sometime around the year 2020 when practical utilization of the self-reproducing database will be realized.

Comparison of various countries' R&D efforts in the field at this point indicates that those pursuing basic research in an effort to create the concept of the "self-producing database system" are prominent industrial and academic research institutes in the United States and a few of Japan's cutting-edge electronic firms.

Key technologies requiring breakthroughs are the automatic knowledge acquisition technology, the self-organizing technology, the self-learning technology, the knowledge filing software, as well architectural technology including both neural computing and superparallel computing.

Social constraints impeding practical application of the self-reproducing database system, in our opinion, would be the lack of accurate recognition of the division of roles to be assigned to machines and humans. The economic constraints would adversely affect business's need to secure an adequate market scale, efforts to bring costs down, and the R&D funding levels (because of the need to make large-scale investments), creating difficulties in the recruitment of R&D personnel.

3. Impacts on Industrial Economy

The self-reproducing database system market is estimated as one reaching approximately the 1 trillion-yen level. This probably would require establishment of approximately 20 more related industrial research laboratories.

A positive impact created by the self-reproducing database system on the industrial economy in terms of new industries and products would be the emergence of a self-reproducing database industry, specifically, a full-fledged knowledge-base industry.

Those negatively impacted would be the "non-reproducing-type" computer systems which work only by blindly following the conventional-type human instructions.

From the viewpoint of technological assessment, we can foresee the use of self-producing database systems in all areas of society. The system will control and organize a flood of data (whose volume otherwise would inundate society), thereby maintaining social order.

Superconductive Material: (High-Temperature Superconductive Coil)

1. Outline of Technology and Products

Superconductive material is a certain type of metal or oxide ceramic which possesses zero electric resistance below a certain temperature called the critical temperature. The highest critical temperature at which the metal displayed its superconductivity was at 23 degrees absolute temperature(-250 degrees). However, in 1986, oxide ceramic superconductive material with the critical temperature of 238 degrees was discovered, thus bringing superconductive technology one step closer to practical application.

Coils made of this material exhibits zero electric resistance when energized, making it possible to provide a permanent flow of current without wasting any electricity. For this reason, if applications to transmission cables, electric generators' power systems, linear motor cars, and Josephson devices are put to practical use, the economic, technical, and social effects of this material will be immeasurable.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then, relative progress thus far made to bring R&D to the current juncture would be 30. This means that it will be sometime around the year 2030 when practical utilization of the superconductive material will be realized.

In comparing various countries' R&D efforts in the field at this point, if Japanese efforts were to score 100 points, the United States would score 80 points, and Europe around 65 points. Japan, therefore, is ahead of the rest of the world in this field.

However, Japan has not stepped up its spending in R&D and research manpower. The availability of research aid and supplementary funding, moreover, does not look particularly promising at present. In the United States, on the other hand, system-related research is making progress, and in Europe, basic research has been advancing.

Key technologies requiring breakthroughs are the advanced technology designed to improve stability and durability of long electric coils, efficiency of wiring, and grain boundary quality; also required is a push for discovery of new materials. Important peripheral support technology includes larger-scale and higher-efficiency refrigeration, and improvement in coil technology and in handling technology designed to deal with fragile wire materials.

Social constraints impeding practical application of the superconductive material in terms both of systems and governmental policy are negligible. However, there is a possibility that the industry very well may have to face the emerging problems of standardization and environmental pollution. These will greatly limit the industry's efforts to lower costs and to introduce the market principles, and will present difficulties in its attempt to secure R&D personal. Moreover, the technology's impact on environments and recycling problems will have limiting effects. In order to solve these problems, it will be necessary to strengthen a setup in which matters of cooperation among researchers and other R&D personnel, funding, and facility exchanges can be carried out smoothly.

Ceramics Gas Turbine Engine

1. Outline of Technology and Products

The ceramic gas turbine engine is a new type of engine based on operating principles which are a complete departure from those of the conventional reciprocating-type engine. By using ceramics as materials in the gas turbine engine, it will become possible to produce an ideal engine characterized by high efficiency, a low environmental pollution factor, and the ability to use various kinds of fuel.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then, relative progress thus far made to bring R&D to the current juncture would be 40. This means that it will be sometime around the year 2000 when practical utilization of the ceramics gas turbine will be realized.

In comparing various countries' R&D efforts in the field of the ceramics gas turbine engine at this point, if Japanese achievements thus far made were to be given 100 points, the United States would earn 120 points, and Europe around 110. Japan is, therefore, lagging behind the United States and Europe. However, Japan has embarked on the national R&D project participated by three auto manufacturers in 1990. Since R&D funding and research manpower recently have been bolstered, together with an anticipated increase in research aid and supplementary funding, Japan's R&D is expected to take off.

Key technologies requiring breakthroughs are those designed to improve durability and reliability of ceramics, to achieve an improved exhaust system, and to effect cost reduction. As for peripheral support technologies, development of ceramic processing technology and design technology will be extremely important.

Among social constraints impeding practical application of the ceramics gas turbine engine, those related to systems, governmental policies, and the environment loom large. Very much in evidence, also, are economic restrictions affecting the business's efforts to secure adequate market scale, lower costs, and adequate R&D funding and R&D staffing levels. Moreover, even if the practical utilization of the engine should be realized and the desired widespread distribution stage reached, problems of training maintenance technicians and of setting up supply systems geared to use various types of fuels will remain.

In order to solve these problems and develop ceramics material technology, it will be necessary to strengthen the cooperative relationship among auto manufacturers and material makers, and, at the same time, to strengthen the social foundation of multi-fuel supply systems under public administration guidance.

3. Impacts on Industrial Economy

The market scale of the ceramic gas turbine engine is not clear. Positive impacts created by the ceramics gas turbine engine on industrial economy would be reflected in the tremendous revitalization of the ceramic industry and emergence of such new fuel as methanol. The secondary effects, moreover, will appear in the field of high-speed rotation generators, as well as in environmental measures developed to deal with automobile gas exhaust.

Negative impacts will be felt by the automobile radiator industry which will have to compete with the new technology and may suffer from possible ill effects on its growth.

New Glass (Nonlinear Optic Glass)

1. Outline of Technology and Products

Although not defined in any specific way, the new glass means "glass equipped with specified functions, or amorphous material, or a material which performs thermal and chemical processing," covering a very broad area. This report deals with nonlinear optic glass. The nonlinear optic glass is a high-speed light switching device which can be driven by light and realizes massive volume super-speed processing. Moreover, it brings us closer to realization of optic computer.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then, relative progress thus far made to bring R&D in new glass to the current point would be 0. However, we can estimate that it will be sometime around the year 2010 when practical utilization of the new glass will be realized.

In comparing various countries' R&D efforts in the field of the new glass at this point, if Japan were to be given a score of 100 points for its achievements, then the United States would score 50, and Europe 0. Japan, therefore, is substantially ahead of the rest of the world. However, since Japan currently is suffering from the lack of R&D funds and personnel, it will have to rely on its future R&D efforts.

Key technologies requiring breakthroughs are those involved in development of materials, optical modules, and optic capacity.

Although system and public policy factors will not be social constraints impeding practical application of the new glass, economic restrictions will deter the industry's efforts to secure an adequate market scale, to promote low costs, and to recruit R&D personnel.

3. Impact on Industrial Economy

Although the market scale of the nonlinear optic glass currently is almost non-existent, it is expected to grow into a huge market reaching the 1-billion-yen level in the year 2000 and the 1-trillion-yen level in the year 2010. As a result, related business research laboratories will be increased from the present 10 companies to 30 in the year 2000 and in the year 2010, as many as 50 companies. Moreover, although the current R&D funding level is 1 billion yen, in the year 2000, it will have climbed to the 1-billion-yen level, and in the year 2010, to a 10-billion-yen level.

Positive impacts created by the nonlinear optic glass on the industrial economy would be the appearance of new products, such as photoswitch, optic memory, and optic computers, on the market, and revitalization of the fields of optic communication and fiber optics. Although, the current R&D funding is no more than 100 million yen, in the year 2000, this will have been increased to 1 billion yen, and, by the year 2020, to 10 billion yen.

Negative impacts will be felt by the conventional computer industry; since the nonlinear optic glass will compete with electronic circuits, the latter may experience possible decline in ability to grow.

Optic IC

1. Outline of Technology and Products

Optic IC is an integrated circuit board on which optic and electronic functional characteristics have been aggregated, and for its chemical semiconductor, GaAs is used. Currently, its use is limited to a single-unit device, such as a semiconductor laser and a photoreceptor. Unlike the silicon IC, fabrication of an IC using semiconductor optic devices presents some extremely difficult technical problems.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then, the relative degree of progress made in optic IC R&D to bring it to the current point would amount to no more than 10, which means that optic IC probably could be put to practical use around the year 2010.

In comparing various countries' R&D efforts in the field of the optic IC, if Japan's efforts were to score 100 points, both the United States and Europe also would score 100 points, placing all three on an equal footing. At present, both R&D funding and research staffing levels are being raised, with the prospect of research aid and supplementary funding also increasing. Moreover, the numbers of patents and research paper publications also are increasing, generating expectations of still further advances in future R&D.

Key technologies requiring breakthroughs are the dry etching technology and the selective crystal-growth technology.

As for factors barring practical utilization of the optic IC, we perceive no social constraints insofar as systems and public policies are concerned. Economic constraints affecting the industry's efforts to secure an acceptable market scale and to reduce costs, however, will be quite substantial.

For this reason, the fabrication of a full-fledged prototype IC device will be an extremely important factor. At the present stage of development, validation of various functions is being conducted, although none, as yet, have gone beyond the initial stage at this time.

3. Impact on Industrial Economy

The optic IC market scale is estimated to reach the 1 billion-yen level in the year 2000 and the 2-billion-yen level in the year 2010. As a result, the number of related business research laboratories is expected to increase from the present 20 to 25 companies by the year 2000 and to 30 by the year 2010.

The optic IC is expected to contribute substantially to the revitalization of optic industries such as the optic communications industry. Advances made in the semiconductor laser technology will dramatically increase communication density, facilitating image communication and improving such factors as cost, reliability, and ease of maintenance. This also would generate substantial secondary effects stimulating the information-communication industry. Moreover, we probably will see such new products as a modulator-attached semiconductor laser, a multi-wavelength laser array, OEIC, and a photoswitch appearing on the market.

Negative impacts will be felt by the microwave communication industry which must compete with these new technologies, and some segments of the industry may face a business slump.

Semiconductor Super-Lattice Device

1. Outline of Technology and Products

The semiconductor super-lattice device is a super-speed ultra-high frequency device which utilizes semiconductor quantum effect. It achieves the speed of 1 PS and the frequency of 100 GHz. It is a new functional and multi-value logic device, equipped with memory and with advanced computational functions.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then, the relative progress made thus far to bring R&D in the semiconductor superlattice device the present point would be set at 10, which means that it will be sometime after the year 2010 when practical utilization of the device would be realized.

Comparison of various countries' R&D efforts in the field of the semiconductor superlattice device at this point indicates that if Japan's achievement in the field were to be given a score of 100 points, the United States would score 150 and Europe 100. The United States is the most advanced in the field while Japan and Europe are considered as being about par. Japan, however, has undertaken several large national projects, viz., the large-scale Ministry of Education Project, MITI's Device Association Project, and the STA project. Since both the public and private sectors are greatly increasing their R&D funding and their research manpower levels, advances in the field most likely will follow.

Key technologies requiring breakthroughs are developments of an element device with new functions, the invention of an element device based on a new operational principle, and a technology which show quantum effect at room temperatures or at 77K+ temperatures.

As for peripheral support technology, micro-processing technology, ultra-low-noise measurement technology, and a new functional element device design/systematization technology will be required.

Social constraints in the areas of system, public policy, and environment will have some adverse effects on the practical implementation of the semiconductor superlattice device. Economic constraints, however, will have greater effects, especially in the areas of securing appropriate market scale and of achieving low costs. Lack of sufficient R&D fundings and the difficulty encountered in securing R&D personnel will also be restricting factors.

In order to resolve these problems, it will be necessary to develop an extra-fine processing technology, a new operational principle which will capture the market, and to invent and develop an element device with new functions.

3. Impact on Industrial Economy

The semiconductor superlattice element device market scale is expected to reach a 500 billion-yen level by the year 2010. As a result, the number of related industry's research laboratories is expected to increase from eight companies at preset to ten in the 2000s.

Positive impacts created by the semiconductor superlattice element device on the industrial economy would be the acceleration of technological innovations in the semiconductor industry as well as vitalization of fields which utilize semiconductors. Achievement of a superspeed semiconductor will greatly affect the computer industry. New products which will appear on the market in the future and generate a great deal of expectation will include a digital IC, a superspeed analog IC, and microwave/milliwave band active element devices.

Amorphous Alloys

1. Outline of Technology and Products

Amorphous alloys are produced by quickly cooling melted metals to prevent the formation of a crystalline nucleus, and are characterized by tensile strength, toughness, and excellent magnetic properties.

The amorphous alloys may be divided into the Fe and the Co groups. The Fe group, characterized by high saturation magnetic flux density and relatively non-rigid good magnetic properties, can be used in pole transformers. Because of its non-rigid magnetic property, the Co group can be used in the switching of electric sources and sensors.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then, the relative progress made thus far to bring the amorphous alloy R&D to its current point of development would be 60. Comparison of various countries' current R&D efforts in this field indicates that if the score of 100 points were to be accorded Japanese efforts, then the United States would score 120 and Europe 60. Thus, in this field, the United States has the most advanced technology, followed by Japan. Use of the amorphous alloy in pole transformers was the topic of discussion at the U.S.-Japan Structural Initiative meeting. Although the United States leads Japan in R&D, the two countries are about even in practical utilization of the amorphous alloy in electric sources switching.

Key technologies requiring breakthroughs would be those of its mass production and insulation/coiling. As peripheral support technologies, a new type of insulation material for transformers and a high-frequency compact-size packaging design technology for use in switching electric sources will be required.

Social constraints created by the public system, public policy, and social infrastructure considerations will adversely affect practical utilization of the amorphous alloys. Economic factors restricting such practical utilization are evidenced in the areas of securing an adequate market scale and reducing costs, in insufficient R&D fundings, and in the shortage of research personnel.

The most immediate steps to be taken in resolving these problems will be to eliminate the political tensions existing between the United States and Japan. It is important, also, to work on reducing iron core loss and cost reduction through mass production.

3. Impact on Industrial Economy

The scale of the amorphous alloy market cannot be determined at this time. However, since operational energy loss is extremely small, if prices are reduced, power companies, no doubt, will use the material for their transformers. Expansion of the market scale, therefore, can be predicted for the future.

Positive impacts created by the amorphous alloys would be revitalization of the transformer industry resulting from their application to the transformer iron core. Secondary effects may appear in the storage battery field.

Moreover, since their power loss is so small, use of the amorphous alloys promises substantial power savings. Expectations of the substantial effects such energy saving would generate are high.

Hydrogen Absorbing Amorphous Alloys

1. Outline of Technology and Products

Hydrogen absorbing alloys, which can both absorb and (reversing its process) release hydrogen, produces metal hydride through a metal-hydrogen reaction by increasing pressure and lowering temperatures. They can store an amount of hydrogen equivalent to the capacity of a milk bottle per 1 g. alloy at 0<deg>C, 1atm.

Its capacity is larger than that of the NiCd battery, currently considered a leading secondary battery. Since hydrogen absorbing alloys can be used as a substitution, it is used in a nickel-hydrogen battery, Its application is not limited simply to batteries. Currently, researchers are working on its application to heat pumps.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then relative progress thus far made to bring the hydrogen absorbing alloy R&D to the current point would be 0. However, it is estimated that the practical utilization stage would be reached by the year 2010.

Comparison of various countries' current R&D efforts in this field indicates that if the score of 100 points were to be given to Japanese efforts, then the United States would score 90 and Europe 80, indicating that Japan is slightly ahead.

Key technologies requiring breakthroughs would be those designed to increase hydrogen absorbing capacity, to reduce hysterisis loss, and to improve the plateau characteristic; also required is establishment of mass production technology aimed at reducing prices. As for peripheral support technology, development of filter and activation technology will be considered important.

Social constraints created by system and public policy considerations will adversely affect the practical utilization of the hydrogen absorbing amorphous alloys to a certain degree. Economic constraints, however, will be more serious, undermining the industry's efforts to secure adequate market scale and to effect cost reduction.

3. Impact on Industrial Economy

The scale of the hydrogen absorbing amorphous alloy market cannot be determined at this time. A positive impact the hydrogen absorbing amorphous alloys will have on the industrial economy will be revitalization of the electric manufacturing industry resulting from product innovations involving batteries and heat pumps. Industrial and home refrigerators, also, are expected to change.

Moreover, the hydrogen absorbing amorphous alloys will replace lead batteries. Since batteries made of hydrogen absorbing amorphous will offer compact size together with large capacity and are free of harmful substances, there is a very good chance that they will bring electric automobiles to the practical utilization stage much faster than previously had been thought possible. Moreover, they are directly linked to the compact size and light weight of portable items, such as personal computers, OA equipment, and cameras.

Negative impacts arise from the fact that they will be competing with NiCd and lithium batteries, thus adversely affecting growth of the existing battery market.

Moreover, since their power loss is so small, use of the amorphous alloys batteries promises substantial power savings. Expectations are high for the tremendous effects such energy savings would generate.

Magnetic Material

1. Outline of Technology and Products

The magnetic material consists of (1) "soft material" (material exhibiting high magnetic ratio), which is easily magnetized by an external magnetic field and whose magnetization can be reversed by inversion of the magnetic field, and (2) a hard material whose coercive force resists reversal of its magnetization. A soft magnetic material is used in the magnetic core of transformers, electric generators, and electric motors, and so, sometimes, it is designated as magnetic-core material. Electromagnetic iron plate, soft ferrite, and permalloy are soft magnetic materials. A hard magnetic material is used in permanent magnets, audio and video tapes, and computer disks.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then, the relative progress thus far made to bring the magnetic material R&D to its current point would be around 60.

Comparison of various countries' current R&D efforts in this field indicates that if a score of 100 points were to be given to Japanese efforts, then the United States would score 80 and Europe around 40, indicating that Japan is slightly ahead.

No new development has taken place recently in the magnetic metal field. However, in application areas, practical use of rare metallic thin films in optico-magnetic media almost has been established. Other than that, we know of no new applications in either of the groups, soft or hard.

Key technologies requiring breakthroughs would be those designed to achieve high-magnetic flux density and high coercive force. Also required will be development of new materials with emphasis on low-priced materials and technology using a metallic superlattice. As for peripheral support technology, development of a computer support program in material design will be required.

As an obstacle to practical implementation of the technology, weakened foundations of basic research in academic institutions may be cited. Economic constraints undermining the business's efforts to secure adequate market scale and to effect low costs will be substantial.

In order to resolve these problems, it will be necessary to strengthen basic research at universities and to develop mass production, realizing low costs.

3. Impact on Industrial Economy

The scale of the magnetic materials market cannot be ascertained at this time. Positive impacts created by the magnetic materials on the industrial economy would be the revitalization of the FA industry, which includes the robotic industry; and of electric/electronic industries which use printers, facsimiles, CD, and other compact motors. Their secondary effects will be felt by the automobile industry.

Negative impacts arise from the fact that they may compete with such an oxide magnet as the ferrite magnet because of its price factor, and this will have adverse effects on its market.

From the standpoint of technological assessment, the reuse of rare metallic elements and methods of recovery will become important factors.

Organic Nonlinear Photoelectronic Element

1. Outline of Technology and Products

The organic nonlinear photoelectric's refraction index changes in response to the photointensity of input light. By applying this characteristic and through the use of the super-speed and low-energy consumption full-luminous-type photo-switch and photo-modulator (products which will revolutionize the information communication field), as well as an optic amplifier, the organic nonlinear photoelectronic element can become the mainstay material of optic computers whose performance will be far superior to those of semiconductor-based computers.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then, the relative progress made thus far to bring the organic nonlinear photoelectronic element R&D to its current point would be set at around 20. This means that practical utilization would be achieved at sometime in the year 2020.

Comparison of various countries' current R&D efforts in this field indicates that the United States, where a government-sponsored large-scale project is in progress, is ahead of the rest of the world. In Europe, also, an R&D project involving the entire EC, is being undertaken. In terms of progress made thus far, this project is about on a par with MITI's next generation technology research project which includes this field as one of its research themes.

Key technologies requiring breakthroughs would be the evaluation technology which clarifies nonlinear photoelectronic material's super-speed phenomenon and molecular design technology which determines the optimal molecular structure generating the largest nonlinearity and which optimally arranges those molecules. Also required would be the molecular-arrangement control technology, various miniaturization technologies (for instance, thin-film preparation technology), and the inorganic-organic junction technology.

As obstacles to practical implementation of the technologies, social system constraints may affect standardization of the material. Economic constraints may result in the lack of R&D funding and difficulties involved in securing R&D personnel. Moreover, the organic nonlinear photoelectronic materials may face stiff competition from such inorganic group materials as compound semiconductor and semiconductor doped glass, or an MQW (quantum well) element and bioelements.

The key point of practical utilization of the organic nonlinear photoelectronic element is that it is essential to develop a material which satisfies the degree of photo-nonlinearity (established by MITI's Next Generation Research Theme), or super-speed response characteristics. In our present situation, we have yet to reach the stage of effective material design based on the understanding of this phenomenon. Further effort to bolster our capability in that connection and to accelerate the necessary research through information exchanges with the United States and Europe will be producing results.

3. Impact on Industrial Economy

The organic nonlinear photoelectronic material market is estimated to reach the 10 billion yen-level by 2020, the year in which its practical utilization would be realized. As a result, the number of research laboratories of related industries probably will be increased to around 40 companies.

Positive impacts which the nonlinear photoelectronic element will have on the industrial economy would be the emergence of new products, such as optic computers, optical amplifiers, super-speed photo switches, and optic modulators. Existing products such as optic fibers and lasers will be greatly revitalized. As a consequence, we should be able to expect revitalization of the optical information processing industry, which manufactures and markets these products, and of the optic communication industry in general.

Photochemical Hole-Burning Memory

1. Outline of Technology and Products

This is an optic memory device designed to utilizes changes in the molecular energy state caused by light. By using variable wavelength laser beam focused on its boundaries, it can record not only two-dimensional information but also wavelength-dimensional information on one recording spot as well, achieving a recording density approximately 1000 times that of currently available optic disks. Since it is possible to store a large volume of information, it can be applied to the parallel processing of data in time sequence as well as to arithmetic operations.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then, the relative progress thus far made to bring photochemical hole burning memory R&D to the current point would be set at around 30. This means that the practical utilization would be achieved at sometime in the year 2020.

Comparison of various countries' current R&D efforts in this field indicates that none have yet to advance beyond the basic research stage. The United States (IBM and others), first to pay attention to application of the photochemical hole burning phenomenon to memory technology, however, is ahead of the rest. In Europe, both universities and industries are actively engaged in research, and they appear to be slightly ahead of Japan where MITI's Next Generation Research Themes Project is in progress.

Key technologies requiring breakthroughs would include molecular design and molecular arrangement control technologies, aimed at designing optimal host and guest and at working out the optimal molecular arrangement so that recording density may be greatly increased and high-temperature functionality achieved. Also required would be the evaluation technology, designed to assess memory in terms of its life-span and its reliability. As a peripheral technology aimed at effective use of optical memory, we also should include the technology designed for the advanced use of laser, viz., development of a recording and reading laser; low-temperature technology; and parallel information I/O technology.

As for obstacles to practical implementation of the technology, social system constraints may deter standardization of material. Economic constraints may cause the lack of R&D funding and thus create difficulties in securing R&D personnel. As for competing memories, the extent to which per-bit cost may be reduced will be the major factor in determining how the optical memory market will fare. Moreover, in the area of high-density memory, the opto-magnetic memory, phase-change utilization molecular memory, and the photocromic molecular memory will be the major competitors.

In order to resolve these problems, it will be essential to strengthen and accelerate the pace of research conducted under one of MITI's Next Generation Research Themes, in a section entitled, "optical reaction material," and in the basic research involving development of materials and systems.

3. Impact on Industrial Economy

The photochemical hole burning memory market is estimated to reach the 10 billion-yen level by 2020, the year in which its practical utilization would be realized. As a result, the number of related industries' research laboratories probably will be increased to around twenty companies. As positive impacts created by the photochemical hole burning memory on the industrial economy, we can cite revitalization of the optic information processing and optic communication industries which manufacture optical computers, optic fibers, and lasers.

Molecular Device

1. Outline of Technology and Products

This is a device fabricated by assembling molecules rather than by relying on the ultra-precision processing method. It is characterized by a high degree of integration, exceeding current VLSI. Moreover, because it is a high-speed, low-energy consumption-type device, it will replace today's VLSI memory and will be used as a mainstay device in super-speed computers.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then, relative progress thus far made to bring molecular device R&D to its current point would be placed at about 10. This means that the advent of the practical utilization period would take place in the year 2020.

Comparison of various countries' current R&D efforts in this field indicates that none has yet to have advanced beyond the basic research stage. The research level of the United States and Japan are about equal, while Europe may be slightly behind.

Of key technologies requiring breakthroughs, a tool designed to perform molecular-level assembly and formulation of methodological theory will be considered the most important. For instance, there now is an urgent need for a breakthrough in the accurate assembly of from twenty to three hundreds A domains (molecular assembly technology and thin-film preparation technology) and the wiring technology (inorganic/organic combination technology) designed to link them. Also considered important would be the evaluation technology designed to assess reliability and life span of the device.

As for obstacles to practical implementation of the technology, social system constraints will deter standardization of the material. Economic constraints may interfere with securing of an adequate market scale and with realizing low costs, as well as creating a lack of R&D funding and difficulties in securing R&D personnel. As for sensors, we tend to believe that the molecular device can be achieved at a relatively early time, in which event, they will be competing with semiconductors and ferroelectric substance.

In order to resolve these problems, it is essential that intensified efforts in developing a nano-scale structural control technology, a molecular design technology, and a molecular-arrangement technology be mounted as part of a national project jointly undertaken by the public, academic, and private sectors.

3. Impact on Industrial Economy

The scale of the molecular device market is estimated to reach the 10 billion-yen level by 2020, the year in which its practical utilization would be realized. As a result, the number of research laboratories of related industries probably will be increased to approximately 20 companies.

As positive impacts created by the molecular device on the industrial economy, we can cite emergence of such new products as molecular memory, molecular processors, and molecular sensors, which will revitalize the information and communication industries.

It also will create new industries which manufacture materials used in molecular devices or intelligent materials into which molecular devices are incorporated. Negative impacts would be felt by the conventional semiconductor and computer industries.

Thermoplastic Molecular Complexes

1. Outline of Technology and Products

Characterized by high heat resistance and high elasticity modulus, comparable to those possessed by metals, thermoplastic molecular complexes are light-weight organic polymers, easy to mold because of their thermoplasticity. Unlike the FRP (fiber reinforced plastics), their constituent resin contains reinforced molecular framework, thereby eliminating the brittleness found in the reinforced fiber-matrix resin interface, characterizing the FRP. The possibility of its widespread use as a substitute for light metals and FRP is great.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then, the relative progress thus far made to bring thermoplastic molecular complexes R&D to the current point would be placed at approximately 30. This means that its industrial implementation would be realized at sometime in the year 2040.

Comparison of various countries' current R&D efforts in this field indicates that the United States, which is pursuing research in nano-scale self-assembly molecular complexes, is leading the world in this field. In Japan, basic high-polymer research is progressing well.

Key technologies requiring breakthroughs will include the technology for design and synthesis of thermotropic liquid crystal and other advanced-function high liquid crystal polymers, the polymer alloy technology which achieves structural design and assembly at a molecular level, the resin molding fabrication technology, and the reliability assessment technology.

As for obstacles to practical implementation of the technology, social constraints would be laws and regulations governing new materials and the current trends in waste recovery and recycling. In terms of economic constraints, although these depend on material costs and the extent of environmental problem, the foremost problem may be the small scale of the metal market (according to the current estimate) which the new materials will be replacing.

In order to solve these problems, it is important to intensify joint efforts, involving public, academic, and industrial sectors, to carry out research and development of uses of the new material together with in-depth basic research in three-dimensional high durability/elasticity polymers and in nano-scale self-assembly molecular design technology.

3. Impact on Industrial Economy

At this point, the future potentials of thermoplasticity molecular complexes in terms of quality, performance, and cost are unknown. The extent of impact of the new material on the industrial economy ultimately will depend on the extent to which it can replace the use of metals and FRP. If we were to hypothesize that the thermoplasticity molecular complexes can achieve the quality and cost comparable to those of light metals, then the industries which would be positively impacted and revitalized would be the liquid crystal and other high polymer industries and the vehicle/shipbuilding industries. In such cases, negative impact will be felt by the light metal and FRP industries. From the standpoint of technological assessment, since it does not belong to the composite material group, recycling would be relative easy. However, the problems of plastic waste management and recycling will remain, pointing to the importance of government-sponsored coordinated systems to deal with these problems.

High Performance Carbon Fiber Reinforced Plastics

1. Outline of Technology and Products

Because of its excellent mechanical property, the high performance carbon fiber-reinforced plastic is widely used as a metal substitute in the structures of airplanes, automobiles, and vehicles. For this reason, it will be necessary to (1) improve performance, (2) lower costs, and (3) enhance reliability. Currently in progress are the development of three-dimensional reinforcement of reinforced materials, the increase of resin's toughness, improving its environment-resistant characteristics, prevention of defects in molding, development of molding technology suited to mass production, development of a non-destructive quality assurance test method, and the construction of a design database.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then, the value of the relative progress thus far made to bring the high performance carbon fiber reinforced plastic R&D to its current point would be set at approximately 50. This means that its industrial implementation would be realized sometime in the year 2000.

Comparison of various countries' current R&D efforts in this field indicates that in terms of overall achievement the United States ranks at the top. In terms of productive and technical capabilities of carbon fiber as a reinforced material, however, Japan's achievement is considered as being at top level.

Key technologies requiring breakthroughs will include the mass production molding technology and the advanced-function fiber/resin, and the preform/optimal component material design technologies.

As for obstacles confronting practical implementation of the technology, social constraints would be laws and regulations governing use of new materials, inadequate educational programs offered by universities and colleges, recycling problems, and the current code regulating industrial waste management. Key economic constraints would be those deterring the expansion of the market (backed by reliability) and efforts to lower material costs.

In order to resolve these problems, we should consider establishment of a development organization, such as the Advanced Composite Material Development Association, bringing government, academics, and industry together to pursue the development of light-weight structures (for instance, airplanes, automobiles, and linear motor car vehicles).

3. Impact on Industrial Economy

It is estimated that the scale of the advanced performance carbon fiber reinforced plastic market will have reached approximately the 200 billion-yen by the year 2000. The growth would center around the aircraft industry in which the need for light-weight material is most keenly felt. Consequently, its positive impacts on the industrial economy would be the revitalization of the composite material manufacturing segment of the materials industry, the aircraft manufacturing industry, automobile manufacturers, and of production machinery manufacturers. The beneficiaries of the secondary effect most likely would be the defense industry and construction businesses.

Negative impacts would be felt by the non-metal industry in areas in which it will compete with the high-performance carbon fiber reinforced plastic industry. However, since each material has its own niche (in terms of its use), based on its unique characteristics, the degree of competition would be small.

From the standpoint of technological assessment, the problems of material recycling and waste management must be mentioned. It will be necessary, moreover, to examine the new material from the standpoint of resources savings, comparing it with metals from the standpoints of consumption and of recovery of total energy.

Advanced Metallic Composite Material

1. Outline of Technology and Products

As development of faster aircraft and man's exploration of space gather momentum, needs for composite materials, such as metallic matrix silicon carbide fiber, boron fiber, and whisker-reinforced materials, will increase. Especially in the aerospace industry, there is a strong need for materials which can withstand actions of atomic oxygen. Since resin composite materials have short lifespan and are not sufficiently heat-resistant, the metallic composite materials, which combine light weight, high elasticity modulus with acid resistant and heat-resistant characteristics, are considered a better candidate.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned the numeric value of 100, then, the value of relative progress thus far made to bring the advanced performance metallic group composite materials R&D to its current point would be about 10. This means that its industrial implementation would be realized sometime in the year 2050.

Comparison of various countries' current R&D efforts in this field indicates that the United States, which already has begun investigation of practical utilizations of the material in space craft, is leading the world both in basic and application research.

Key technologies requiring breakthroughs will include fabrication technology for large structural units and reenforced materials(including whisker); low-cost technology for the production of metallic composite materials, and reliability assessment technology.

As for obstacles to practical implementation of the technology, social constraints would be laws regulating the use of new materials and environmental safety measures which will deal with effects of whisker filaments on the human body. Economic barriers would be the limited scale of the market, lagging efforts being made to promote utilization and marketing, and factors blocking the expansion of a market backed by reliability and efforts to lower material costs.

In order to resolve these problems effectively, we should work together to further the Next Generation Material Basic Research Program under MITI's guidance, so that emphasis will be shifted instead toward manufacturing technology, performance evaluation, and utilization development.

3. Impact on Industrial Economy

As has been stated before, the field to which the advanced FRM can be applied is pretty much limited. The scale of the advanced metallic composite materials market, therefore, can be estimated as reaching from a 50 billion yen to a 100 billion-yen level by the year 2050. However, the development of this material will be the key to the extensive space development program. We believe, therefore, that the material will generate a great deal of expectation for the role it will play in the distant future.

Positive impacts created by the advanced metallic composite material on the industrial economy would include revitalization of the metal-processing industry, the aerospace industry, the production machinery industry, and the metal-fiber manufacturing industry. As for industries which may be impacted negatively, we cannot think of any at this time.

From the standpoint of technological assessment, environmental problems caused by whisker filaments and recycling problems involving advanced metallic composite materials, although quantitatively negligible, should be investigated.

Advanced Ceramic Group Composite Materials

1. Outline of Technology and Products

As a substitute for heat-resistant metals, ceramic composite materials are being used in mechanical parts, such those used in jet engines. Oxide/carbide/nitride group ceramics are mixed with ceramic fiber and reinforced, thereby substantially improving their fracture-resistant toughness. Low-priced ceramic composite materials consist of carbon fiber and uninflammable matrix (glass, cement, etc.). The non-combustible, light weight, high-elasticity, and highly durable materials are used in the construction of super high-rise buildings, in deep underground construction, and in overpass construction materials.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then, the value of relative progress thus far made to bring the advanced ceramic composite materials R&D to its current point would be set at about 10, which means that its industrial implementation would be realized sometime in the year 2050.

Comparison of various countries' current R&D efforts in this field indicates that the United States and Europe, which wasted no time in embarking on research aimed at turbine energy savings, are ahead of Japan.

As the key technologies requiring breakthroughs, we suggest composite processing technology designed to improve the toughness of ceramic composite materials, themselves; mass production technology for large structural units; and development of low-cost advanced reinforced fibers.

As for barriers impeding practical utilization of the new advanced material, social restrictions would be the Building Standard Laws, the Fire Law, and other regulations controlling the use of new materials, as well as the inadequate educational programs being offered by schools. Economic barriers would have a relatively limited bearing and the insignificant scale of the market at this point (the jet engine market is very limited in Japan), which, in turn, limits the opportunity for product validity testing designed to improve product reliability. In addition, lagging efforts in establishing a well-coordinated setup for R&D and their practical implementation may be suggested.

In order to resolve these problems effectively, it will be necessary to establish a well-coordinated R&D setup integrating public, academic, and private sectors and to have such an organizational setup merge with MITI's Next Generation Environmental Resistant Material Development Program currently in progress. This will widen the scope of the target field. Additionally, development and application of new materials can be advanced at a greater speed by enlarging the Franco-Japanese Friendship Monument Program and by establishing a Super High-Rise Building Construction Research Association and Promotion of Underground Utilization Research Association under the leadership of the Ministry of Construction.

3. Impact on Industrial Economy

The present scale of the advanced ceramics market centering around electronics worldwide reportedly is approximately 1.3 trillion yen. The field of ceramic engines, around which an advanced ceramic-group composite material market will be built, is expected to grow rapidly in the United States and, to a lesser extent, in other countries. Reportedly, the scale of its market is expected to reach the 100 billion-yen level by the year 2010.

Positive impacts created by the advanced ceramic composite materials on the industrial economy, generating a great deal of expectation, are the revitalization of aircraft industries, construction business, and the machinery industries. As for possible competition with metal industries, since application fields of these two types of materials differ, it is thought that each will find its own niche.

Advanced C/C Composite

1. Outline of Technology and Products

Use of a 100-percent C/C composite in structural component materials used in the equipment of the kinds subjected to extremely high temperatures, namely, those used in space craft, supersonic planes, missile rockets, and nuclear fusion reactors, is making headway. The C/C composite's anti-oxidation properties are further improved through surface plasma processing, so that it can be used under extremely high temperature of around 1700°C.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then, the numeric value of relative progress thus far made to bring the advanced ceramic composite material R&D to the current juncture would be placed at about 10, which means that its practical utilization would be realized at sometime in the year 2050.

Comparison of various countries' current R&D efforts in this field appears to indicate that the United States and France are the countries in which, stimulated by robust demand for advanced aircraft and missile rockets, R&D has been progressing most vigorously, to the extent that the material, in part, is now being used in aircraft brakes.

With respect to key technologies requiring breakthroughs, the technology designed to improve toughness of materials themselves, composite processing technology, mass-production technology, and surface- processing technology designed to improve heat-resistant properties, may be mentioned.

As for barriers deterring practical utilization of the new advanced material, social restrictions would be a factor. Economic constraints would be the reason for Japan's weak aerospace and defense industries. Since demand, per se, is small, manufacturers hardly have any opportunity to conduct the kind of validation tests necessary to improve product reliability; and the private sector's lagging R&D efforts simply invite increases in material costs.

In order to resolve these problems, it will be helpful to expand the scope of MITI's goals for the Next Generation's Heat-Resistant Material Development Program, currently in progress, through a well-coordinated undertaking of the next generation's aerospace-related technology development under government guidance and by getting together with the United States and Europe in conducting joint research.

3. Impact on Industrial Economy

In quantitative terms, a segment of the general industries to which the advanced C/C composite can contribute will not be large one (the market scale will be around 10 billion yen in the year 2010). However, its impact on the development of super-high-speed space craft and on nuclear fusion reactors will be substantial. Industries which will be positively impacted and revitalized will be chemical industries, aerospace industries, and satellite rocket manufacturers, while negative impacts on other industries will be practically nil.

From the viewpoint of technological assessment, although they may appear small in terms of quantity, it will be necessary to give careful consideration to the problems of recycling and waste management.

Cancer Treatment (Prevention) Drugs

1. Outline of Technology and Products

Various types of drugs are being developed as anti-cancer or cancer-control agents. However, with the advancement of basic research in (1) cancer suppression genes and prevention of carcinogenesis, (2) cellular information transmission mechanisms and carcinogenesis mechanisms, (3) immune surveillance mechanisms and carcinogenesis, and (4) transfer mechanisms, R&D projects dealing with cancer treatment drugs based on new effect mechanisms have begun to make headway. Unfortunately, however, the chances of developing any "all-cure" drugs which will work on all types of cancers, especially the terminal-stage cancer, are extremely slim. Consequently, research efforts probably will be devoted to each specific type of cancer, so that treatment drugs will be made more effective, one by one. Cancer-treatment drugs which will be developed in the future clearly will have recognizable effects in prolonging life and, at the same time, in improving the quality of remaining life for patients.

2. Long-Range Prediction for Practical Utilization

Development of cancer-treatment drugs based on the new concept of a medicine which exhibits the distinct effect of prolonging a patient's life while, at the same time, improving the quality of that life, makes many approaches to the disease possible as basic research into causes and symptoms of cancer progresses. Although cancer-treatment medicine based on a new mechanism is pursued as soon as discovered, it will be around the year 2030 before we should be able to see any spectacular results.

Key technologies requiring breakthroughs would include further developments in basic research in cancer genes, cancer repression genes, intra-cellular information transmission mechanisms, transfer devices, and clarification of immune surveillance mechanisms. At the same time, a breakthrough will be needed in the development of anti-cancer/cancer-control assessment systems which will work effectively.

Factors obstructing timely marketing of drugs are the huge amount of time and the R&D costs involved in securing a license permitting manufacturers to produce drugs for medical use in accordance with the pharmaceutical laws. From the standpoint of assessing effectiveness and safety of drugs, we realize the necessity of development test currently in effect. However, what we need above all is a more effective setup which will make much-needed drugs available as soon as possible by shortening the processing period and by priority ranking of drugs slated for examination.

Economic restrictions include the drug-pricing system based on the health insurance system. In Japan, a country which offers a universal insurance system, unless drugs are part of that health insurance system and appear on its drug-price list, they will not have a chance of succeeding commercially. Consequently, their economic values will differ greatly depending on how well they are priced. Moreover, in most cases, prices are changed once every two to three years, downward, by from 10 to 15 percent, making recovery of the huge amounts spent in R&D increasingly more difficult. This year (1990), the cancer drug market already has exceeded the 300 billion-yen mark; however, as long as cancer-treatment drugs remain supplementary to surgery and radiation treatment, any substantial market expansion cannot be expected, due to the measures which are effected in order to curb overall medical costs. This means that there is a distinct possibility that the market, for the most part, will consist of just two activities, viz., price reduction of existing drugs and replacement of existing drugs by new drugs. It is predicted, therefore, that the market at its practical utilization period is likely to expand only 50 percent.

3. Impacts on Industrial Economy

Although direct impacts created by the development of cancer-treatment drugs on the economic world will not be substantial, still, improved quality of life in an aging society and preventing loss of the working population through realization of pleasant working conditions will indirectly affect the industrial economy.

Viral Disease Treatment (Prevention) Drugs

1. Outline of Technology and Products

Although viral-disease treatment and prevention drugs, such as interferon, influenza virus vaccine, and hepatitis-B vaccine, already have been developed, a genuinely effective drug or vaccine for retrovirus, represented by AIDS, has yet to be developed. Utilizing our knowledge of virus infection and multiplication mechanisms, medical researchers currently are pursuing R&D of anti-virus drugs and vaccines. One by one, a vaccination will be developed for each particular virus and made available for the general public. Each time a new type of virus appears on the horizon or disease-causing virus is discovered, research will be undertaken and a vaccine drug developed.

2. Long-Range Prediction for Practical Utilization

Drugs for treatment or prevention of viral diseases currently available consist of synthetic drugs represented by ACT (azidothymidine), the BRM drug, represented by interferon; and vaccine agents. The most effective in treatment and prevention of viral diseases are the vaccines. As a result, focus in the development of virus treatment drugs, including artificial antigens, will be the development of vaccines. How to produce effective vaccines against viruses with weak antigenicity or with strong mutability is the foremost problem which must be dealt with. At the present time, no effective vaccine is available for retrovirus, which encompasses AIDS and hepatitis C viruses currently receiving a great deal of attention. However, intense efforts are being mounted in basic research on retrovirus, which will make it possible to have, by the year 2020, treatment and prevention drugs for viruses currently creating numerous problems.

Factors barring commercialization are the huge amount of time and R&D costs involved in securing a license permitting manufacturers to produce drugs for medical use in conformity to the pharmaceutical laws. From the standpoint of assessing effectiveness and safety of drugs, we fully realize the necessity for the development test currently in effect. However, what we need above all is a more effective setup which will make much needed drugs available as soon as possible by shortening the processing period and by priority ranking of drugs slated for examination.

Economic restrictions include the pricing of drugs established by the health insurance system. In Japan, a country which offers a universal insurance system, unless drugs are part of that health insurance system and listed on its drug-price list, they will not have a chance of succeeding commercially. Consequently, their economic values differ greatly depending on how well they have been priced. Moreover, in most cases, prices are changed once every two to three years downward, by from 10 to 15 percent, making recovery of the huge investment made in R&D increasingly more difficult.

Moreover, even if virus vaccines are developed, in most cases, the vaccination shots will provide life-time immunity. Consequently, even if there is a huge demand, it will be a one-time occurrence, shattering any hope of establishing a long-term market of any substantial scale.

The present virus vaccine market is valued at 30 billion yen, and even that of the total virus treatment drug market amounts to no more than 50 billion yen. In the practical utilization stage, the total virus-treatment and prevention drug market will reach the 500 billion-yen level. Depending on trends, the market scale will differ greatly.

3. Impacts on Industrial Economy

Although direct impacts created by the development of cancer-treatment drugs on the economic world will not be substantial, since the diseases triggered by viruses reportedly will be more in number than expected, if these viral diseases can be completely prevented or effectively treated, their impact on social life will be tremendous.

Senile Dementia Treatment/Prevention Drugs

1. Outline of Technology and Products

Although no drugs for the treatment or prevention of senile dementia, as such, are available at present, drugs for improving brain circulation do exist, and are enjoying a 60 billion-yen market. When the brain suffers from localized tissue anemia, these drugs activate the neurocirculation, and, therefore, work effectively on the brain's ischemic dementia. However, they are useless for treatment/prevention of another type of senile dementia currently receiving a great deal of attention, namely, Alzheimer's Disease.

Since basic research in the Alzheimer-type (combination type) of senile dementia is being vigorously carried out, drugs for treatment and prevention of Alzheimer's Disease will be developed in due time.

2. Long-Range Prediction for Practical Utilization

Since causes of Alzheimer's Disease currently are unknown, much research effort is being devoted to discovering possible causes. Researchers are now advancing to the level of development at which an explanation of causes at the genetic level is being explored. However, they have not advanced beyond the basic research stage. It will be some time before current research findings can be put to any actual use in the production of drugs for treatment and prevention of the disease. At this point, it would be difficult to predict when that might come, but practical utilization of any truly effective drug for treatment will not be realized perhaps until the year 2050.

Key technologies requiring breakthroughs will that of basic research aimed at shedding light on the causes of Alzheimer Disease as well as on the cerebral nervous system and memory mechanisms, and also essential will be a construction of experimental model animals.

Factors obstructing the timely marketing of drugs are the huge amount of time and R&D expenditures which must be spent in securing a license permitting manufacturers to produce drugs for medical use in accordance with the pharmaceutical law. From the standpoint of assessing effectiveness and safety of drugs, we realize the necessity for development test currently in effect. However, what we need above all will be an improved setup which will make much needed drugs available as soon as possible by shortening the processing period and by priority ranking of drugs slated for examination.

Economic restrictions include drug pricing system established by the health insurance system. In Japan, a country which offers a universal insurance system, unless drugs are part of that health insurance system and listed on its drug price list, they will have little chance of succeeding commercially. Consequently, their economic values differ greatly depending on how well they have been priced. Moreover, in most cases, prices are changed once every two to three years downward, by from 10 to 15 percent, making recovery of a huge investment made in R&D increasingly more difficult.

As population grows older, the probable number of patients is estimated as reaching 2 million, which will create at least the 250 billion-yen market.

3. Impacts on Industrial Economy

Impacts generated by the development of drugs on the quality, enrichment, and comfort of life for the aged population are extremely large. They are beneficial not only for the aged themselves but also for their families, psychologically and physically. Freed from the care of the aged, young people can return to work of their own, thereby receiving economic benefits as well.

Entertainment and other industries geared to the aged population may be revitalized; however, the industry producing paper diapers and other items previously required by the aged population may be impacted negatively.

(Auto)Immune Disease/Allergy Treatment Drug

1. Outline of Technology and Products

Currently (1990) a large number of immune-disease and allergy-treatment drugs, principally, antihistamines, anti-rheumatism, and steroid drugs are being sold. As the causes and mechanisms of diseases become identified, based on these findings, research in new types of anti-allergy drugs and autoimmune disease drugs are pursued, and new drugs are in the process of being developed, one after another. For the future, we can expect the development of effective autoimmune disease drugs which will not be based on the necessity of treatment for disease.

2. Long-Range Prediction for Practical Utilization

Allergy-type diseases, such as represented by those caused by pollen, have been spreading widely, with the number of patients growing dramatically in recent years--so much so that it is now designated as modern illness. Many of the hard-to-cure types are the (auto)immune diseases. In recent years, spectacular advances have been made in basic research dealing with mechanisms for triggering allergy disease/immune diseases and mediators, enabling researchers to develop new approaches for development and use of treatment drugs. More effective anti-allergy drugs based on new mechanisms will be put to practical use one after another by the year 2010. As for the autoimmune disease treatment drugs, their practical utilization is expected to arrive by the year 2030. Since the number of patients is expected to increase, the market scale will be expanded, and by the time they reach the practical utilization stage, the market scale is expected to have reached the 500 billion yen level.

Key technologies requiring breakthroughs would include development of basic research including explication of disease-triggering mechanisms and intra-cellular information transmission mechanism, as well as of cellular immunology (Cell-Cell interaction). Also required will be the establishment of an experiment assessment system, such as a model animal system in vitro.

Factors obstructing timely marketing of drugs are the huge amount of time and R&D costs involved in securing a license permitting manufacturers to produce drugs for medical use in conformity to the pharmaceutical laws. From the standpoint of assessing effectiveness and safety of drugs, we do realize the necessity for the development tests currently in effect. However, what we need above all is a more effective setup which will make much needed drugs available as soon as possible by shortening the processing period and by priority ranking of drugs slated for examination.

Economic restrictions include a drug-pricing system based on health insurance systems. In Japan, a country which offers a universal insurance system, unless drugs are part of that health insurance system and appear on its drug-price list, they will have little chance of succeeding commercially. Consequently, their economic values tend to differ greatly, depending on how well they have been priced. Moreover, in most cases, prices are changed once every two to three years, ranging from 10 to 15 percent downwards, making recovery of the huge amount spent in R&D increasingly more difficult.

3. Impacts on Industrial Economy

Although direct impacts created by the development of allergy/autoimmune disease treatment drugs on the economic field will not be substantial, we should point out that expectations are high regarding impacts created on social life through the improved quality and comfort of life.

Bone Marrow Bank

1. Outline of Technology and Products

A bone marrow bank is an enterprise set up to collect, for a fee, myeloid cells from those who registered at the bank under normal physical conditions. The myeloid cells are maintained at freezing temperatures; and, whenever need arises, the bank will fuse and propagate these cells for use.

Technological features consist of a safe and relatively painless sterilized method of collecting myeloid stem cells, a technology designed to maintain these cells at freezing temperatures over a long period of time, myeloid stem cell propagation technology, a system which responds quickly whenever need arises, and networking.

2. Long-Range Prediction for Practical Utilization

Bone-marrow transplantation is an extremely effective method of treating leukemia. However, when the situation calls for use of the bone marrow of others, a patient will discover that because of the problem of histocompatibility, only his parents, or at least, a very limited range of people can be a donor. Since a patient's bone marrow cells contain leukemia cells, naturally they cannot be transplanted exactly as they are. There is a strong possibility of bone marrow transplantation becoming an effective method of treating not only leukemia but also cancers and some immune diseases as well. This is an important technology offering wide areas of application.

Consequently, it is extremely convenient if a healthy individual's myeloid cells can be collected and preserved so that they can be used whenever need arises. The bone marrow bank is a business which collects, preserves, and supplies myeloid cells. It appears that by the year 2010, it will have been be established as a business serving the general public.

Key technologies requiring breakthroughs will include those of collecting myeloid cells without inflicting a great deal of physical pain, a method for the sterilized long-term preservation of the bone marrow, and of a method of propagating myeloid stem cells. At present, myeloid cells are collected through surgical punctures inflicted on the breast bone or the intestinal bone. Since this method causes the individuals concerned so much pain on that the number of those willing to go through this procedure is very limited. It has been confirmed recently that capillaries contain myeloid stem cells in a small quantity, which means that if a propagation method is developed, then the rest will be taken care of through the collection of blood. Use of the bone marrow bank by the general public, then, will become widespread. In addition to these technologies, establishment of a computer system designed to manage deposited myeloid cells and a system of fast delivery to sites requiring bone marrow cells will be necessary.

Although these technical problems will obstruct practical implementation of the bone marrow bank, the problem of the general public's perception of this insurance-like setup of the bone marrow bank where myeloid cells are being deposited for future use, as well as of the system and policy generated by this setup, will constitute far greater constraints.

Problems which will be affected by economic restrictions will be many. Among them, the question of pricing, the length of preservation period, methods of guaranteeing preservation, the question of whether an individual should pay total costs, and of whether health insurance can be applied, which will determine the extent to which the bank will be utilized and the scale of the market to be established. At this point, it will be difficult to predict what the market scale will be like when the practical utilization stage is reached.

3. Impacts on Industrial Economy

Impacts created by the bone marrow bank on the industrial economy will be seen in the freezing equipment/container industries, the computer-related industries (networking), and in myeloid stem cell propagation factors, which will not necessarily be large. However, in terms of the peace of mind and comfort which it will bring to an aging society, its impact on quality and revitalization of life is indeed great. Moreover, if the bone marrow bank were to succeed as a business, it might very well open the way for the establishment of organ transplants banks.

Bioenergy

1. Summary of Technology and Products

As bioenergy, we already have biomass alcohol and methane fermentation, which, technically, already have reached the stage of practical utilization. Indeed, they are being used, now at least in part, in practical situations. In economic terms, however, they are not necessarily paying off. Currently, research in the production of hydrogen which generates the cleanest and the most thermo-efficient energy through biomass is being pursued. If hydrogen can be mass-produced and offered at low cost, we can expect a huge market to spring up.

2. Long-Range Prediction for Practical Utilization

As a result of today's problems of dwindling earth resources, together with global environmental problems, energy, easily is the biggest issue confronting mankind. If hydrogen can be produced in massive quantities at low cost as bioenergy, its value to us will be immeasurable. At present, research in the production of hydrogen,using photosynthetic bacteria, chemical synthetic bacteria, or bioreactor for immobilizing them is being pursued. How these highly productive bacteria can be screened and generated is an important question which must be answered. The timing of commercial availability of the bioenergy is difficult to predict, as it involves not only technical problems but also economic problems involving a competing form of energy (petroleum). Our guess is that it will become applicable in a practical way around the year 2050.

It will be difficult to predict the scale of market for this product when commercialization becomes feasible.

Technologies requiring breakthroughs, first of all, would be those designed to find photosynthetic bacteria and chemical synthetic bacteria through screening. At the same time, it will be necessary (1) to pursue basic research in photosynthetic bacteria's photosynthesis-related organelle and oxygen and (2) to obtain hydrogen high-productivity mutation stock from photosynthetic (chemical synthesis) bacteria. It will be necessary, moreover, to examine, as peripheral technologies, photo-condensation and photo-induction technologies, and artificial biomembrane technology.

Competition with existing forms of energy will deter commercialization of bioenergy. Ultimately, the economic factor (cost) will decide the outcome. However, even if it can compete with existing forms of energy on equal terms or better, because of global environmental problems, still there is the possibility that, for policy reasons, bioenergy may be selected.

3. Impacts on Industrial Economy

If bioenergy can replace existing energy products on commercial markets, its impact on the industrial economy will be huge. Typically, automobile gasoline engines will be replaced by hydrogen engines, and since electricity can be supplied at very low cost, it is most likely that machinery and home electronic industries will be revitalized. Moreover, since it is a clean form of energy, it will have considerable impacts on global environments.

Artificial Organs

1. Outline of Technology and Products

As artificial internal organs, wound-coating materials, large-diameter artificial blood vessels, supplementary artificial hearts, artificial bones, and the artificial dialysis equipment are put to practical use. Moreover, for the future, it is expected that artificial skin, small-diameter blood vessels, the artificial heart, the artificial kidney, the artificial pancreas, the artificial liver, and the artificial lung will be developed and commercialized.

2. Long-range Prediction for Practical Utilization

At the present time, with the exception of the artificial bone, all commercialized artificial organs are either of supplementary or temporary types, with the market scale for the year 1990 at the 10 billion yen level. It will be around the year 2030 when all artificial organs as substitutes for the main organs will have become available on the market. At that point, it is anticipated that the market for the total organs will reach around the 400 billion-yen level. Its breakdown is as follows: artificial hearts, 100 billion yen; artificial kidneys, 80 billion yen; artificial pancreas, 56 billion yen; artificial liver, 40 billion yen; artificial skin, 4 billion yen; artificial blood vessels, 40 billion yen; and other organs, 80 billion yen.

Technologies requiring breakthroughs will be those involved in the development of materials with high-level safety, biocompatibility, antithrombosis, and with high durability. Secondly, it will be necessary to develop a compact-size motor (driver system) with low-level heat generation, featuring energy-saving and excellent durability, and equipped with a computer (control system).

Factors which may deter commercialization will be the problem of licensing under the Pharmaceutical Laws. In developing a material with a high degree of biocompatibility and excellent durability, conducting safety tests are essential. Time and cost factors involved in such tests and R&D are costly. Moreover, if high polymer compounds are to be used as materials, various problems associated with decomposition, as well as those of safety and validation method must be dealt with.

Moreover, artificial organs will be competing with organ transplants, and in addition to technical and cost problems, the general public's stand on ethical issues, including those of brain death and organ donations, is expected to affect the commercialization of artificial organs.

In economic terms, as in the case of drugs for medical and home use, they will be affected by the health insurance systems and pricing systems, with their market scale and profitability greatly influenced by pricing.

3. Impacts on Industrial Economy

Commercialization of artificial organs is expected to impact the material, computer, and motor industries to a certain extent. However, the impact on a patient's quality of life and his ability to return to work, thereby contributing to the solution of the labor shortage problem, will be far greater.

Artificial Enzymes and Artificial Biomembranes

1. Outline of Technology and Products

Artificial enzymes and artificial biomembranes themselves can be commercialized not only as reagent and bulk products but they can also can be used in diagnostic drug kits, various types of bioreactors, biosensors and in many other kinds of products. More important from an industrial point of view, however, will be the use of artificial enzymes as a catalyst in the production of chemical compounds, of artificial biomembranes in the separation of membranes, and in energy production.

2. Long-range Prediction for Practical Utilization

Artificial enzymes are produced in a wide variety of forms, ranging from the natural enzyme whose characteristics have been changed by a protein engineering method, the artificial protein designed to express a certain catalytic activity, the artificial RNA (artificial ribozyme) designed for catalytic activity, the monoclonal antibody (abzyme) selected so as to have catalytic activity, to such low molecule compounds as cyclodextrin and crown ether. Research in these fields encompasses a wide range of activities, from basic work to commercialized application research. Because of the intensity which characterizes enzyme activities and their cost factor, the major part of research has yet to reach the practical application stage. Types of artificial enzymes with well-defined uses will be improved through research, and by the year 2020, a fair number of them will be put to practical use.

The artificial biomembranes, also, come in a wide variety, ranging from artificial lipid membranes (ribosome), artificial cellular membranes made of artificial lipid membranes into which functional protein is imbedded, silicon membranes, to high polymer membranes, all of which currently are being investigated. Functions sought in the biomembranes also vary widely, ranging from simple structural support, separation, transport, stimulation reception, to energy conversion. The biomembrane equipped with a simple support function is already in the practical application stage. At present, use of the ribosome membrane in the drug delivery system (DDS), in bioreactors, in purification of membrane separators, and in biosensors, as well as in the fields of separation, transport, and stimulus reception, is about to enter the practical application stage. Research in membranes equipped with photosynthesis membranes and other energy conversion functions will flourish, and by the year 2020, practical utilization on a partial basis may be possible. At this point, it is difficult to predict what the scale of the market will be at the point when the practical utilization is completely achieved.

In order to achieve technological breakthroughs, basic research in enzyme engineering dealing with enzyme's higher-order structural analysis and activity-centered analysis, as well as a structural and functional analysis of biomembrane, must be undertaken. More specifically, with respect to artificial enzymes, the foremost challenge is that of being able to supply at low cost highly active artificial enzymes whose characteristics (substance specificity, stability, the optimum pH zone, and catalytic activity in organic solvent) are superior to those of natural enzymes. As for the artificial biomembranes, the development of materials with excellent stability and functionality, as well as of a technology designed to achieve efficient immobilization of functional molecules in membrane materials and integration technology will be required.

The foremost barrier to practical utilization is related to technical problems. Other obstacles lie in difficulties involved in establishing a market scale proportionate to R&D spending level for each product, a problem which must be resolved if artificial enzymes and artificial biomembranes are to be marketed as products; on the other hand, if they are to be used as chemical reaction catalysts, it will be necessary to be able to sell them at low cost. Either way, these are big economic constraints.

3. Impact on the Industrial Economy

Both the artificial enzymes and the artificial biomembranes have wide application areas. Since they require high-temperature and high-pressure equipment, there is a possibility that their commercialization may completely change the face of the chemical industry, which, in fact, is an equipment industry. Moreover, they may make it possible to manufacture new and useful high-value-added chemicals previously considered impossible to produce. Impacts created by the artificial enzyme and the biomembrane, therefore, will be huge. If they are used in solving energy problems, their impact on the industrial economy will be immeasurable. Their contribution to global environmental problems also will be tremendous.

Fuel Cells

1. Outline of Technology and Products

The fuel cells are the result of a technology designed to convert chemical energy, generated by natural gas, methanol, or coal fuels into electricity without going through the combustion process. Its high-energy-conversion-efficiency and low environmental-pollution factor are generating high expectations. A phosphoric acid type of fuel cell already has been developed; and R&D projects dealing with molten carbonate and solid-electrolyte type fuel cells are in progress.

These new types of fuel cells are generating a great deal of expectation because they provide compact power sources which can be constructed in the centers of cities; they are also attracting attention as a kind of technology which saves energy through the use of heat.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then, the relative degree of progress thus far made to bring R&D of phosphoric acid fuel cell to the current juncture would be assigned 50. This means that sometime around the year 2015, it will be in a position to compete with the peak electric source currently in use.

Although the United States has been ahead in the development of the fuel cell's main body, Japan now is more energetically developing the fuel cells, and even may have overtaken the United States in this field.

Technical themes are mostly focused on reducing costs, as evidenced in the development of low-cost catalysts and extending the life-spans of power generation systems. Moreover, high-performance molten carbonate and solid electrolyte cells still have many elements requiring further research, among them, development of heat resistant materials (for all types), element technology concerned with CO_2 circulation (molten carbonate); and development of stable thin-film electrolytes (solid electrolyte).

Although development of the phosphoric acid fuel cell already has been undertaken by the private sector, the biggest obstacle to its practical utilization would be the need for cost-cutting. As the success of fuel cells depends to a 100 percent on mass-production-based skills, it is extremely important that a considerable demand for the products exists. For this reason, the demand sector's decision-making will be the foremost factor in the promotion and sale of fuel cell.

3. Impact on Industrial Economy

The fuel cell, which is creating high expectations as the most promising distributed-type power source, will impact (1) the structure of the energy market, (2) the cost structure of electric utility industry whose operations have been based on a large-scale network-type supply system as its axis, and (3) heat and electricity supply systems in metropolitan areas.

Photovoltaic Power Generation

1. Outline of Technology and Products

This is a system based on the solar cell, whose use in such specialized areas as electronic calculators, disaster prevention measures, and space development already have been put to practical use. An area requiring future efforts will be the development of applications to other fields. MITI's Sunshine Project, whose main goal is to reduce the cost of energy down to the 20-30 yen/KWH level, a level which enables solar energy to compete with existing electric energy, is working on the development of a mass-production technology in order to achieve the solar cell production cost level of 100-200 yen/W by the year 2000.

2. Long-Range Prediction for Practical Utilization

If a numeric value of 100 were to be assigned to the practical utilization stage, then the relative value assigned to the present juncture of the R&D stage would be one of 60, which means that its practical utilization will be achieved sometime in the year 2010.

Comparison of various countries' R&D efforts at this point indicates that, if Japan's achievement were to earn 100 points, then the United States would score 80 points and Europe around 60 points.

Key technologies which will require breakthroughs in achieving practical utilization will be those aimed at development of a new material with high-conversion efficiency and low-cost batteries/invertors, low-cost manufacturing technology, and a degradation prevention technology.

Non-technical constraints and problems in the area of social systems are those concerned with regulations imposed by the Electric Utility Business Law. Economic constraints include difficulties associated with securing adequate market scale and the reduction of costs, and the latter, especially, is extremely difficult. In order to realize its early commercialization, therefore, a favored state should be accorded the solar cell for the reason that it is a type of energy which does not emit CO_2. This measure is certain to promote development and widespread use of the solar cell. Moreover, a type of public relations work designed to make the general public understand the necessity for imposition of higher electric bills as a necessary cost of introduction of a solar power system.

3. Impacts on Industrial Economy

It is difficult to estimate the scale of the solar power system market at this time. According to some reports, it will reach the 200 billion-500 billion yen level. R&D funding at this point is approximately 15 billion yen; by the year 2000, it is estimated that it will reach the 200 billion yen level.

Positive impacts which the solar power system will create on the industrial economy will be in the revitalization of the electric equipment industries (cell, invertor, battery) and the nonferrous metal industry (silicon processing).

Negative impacts will be created in the existing petroleum and coal thermal power plant manufacturing industry, which will begin to decline.

Small Light Water Reactor Technology With Built-in Safety

1. Outline of Technology and Products

This is a small light water reactor, equipped with built-in safety and designed to reduce costs as a result of expert skills made possible through unit operation and standardization rather than economies achieved through large-scale plant operation. It maintains simplicity and static safety by utilizing such laws of natural physics as gravity and natural convection/pressure accumulation.

Nuclear power generation technology in the United States no longer is economically viable when the uncertainty factor created by changes in demand and amount of construction time necessary are considered. Development of small reactors for use in developing nations appear promising. For this reason, the United States is pursuing research aimed at reducing unit construction cost and construction time, and facilitating operational maintenance. It is planning to obtain a design certificate for a small experimental reactor to be developed by the Electric Power Research Institute sometime between 1995 and 1998.

2. Long-Rage Prediction for Practical Utilization

At this point, the United States is most definitely ahead of the rest of the world in this field. In Japan, because of the competition represented by the improved standardization of a large light water reactor, as well as by other developments, including FBR (fast breeder) and use of plutonium, the light water reactor technology has not been receiving government attention. Manufacturers have just begun to prepare for its conceptual design. If a numeric value of 100 were to be assigned to the commercialization stage, then relative value assigned to the current status of research would be 10. However, once research acquires an official status, its development will take a relatively shorter time in comparison with those of other types of reactors since a great deal of experience already has been accumulated in the field of the light water reactor.

Technologically, the focus will be on safety assessment of static system aimed at system simplicity and on a design technology which achieves economy (resulting from system simplification) and safety.

The biggest obstacle to practical utilization of the light water reactor, from the social standpoint, will be the building restrictions imposed on nuclear reactor sites stemming from concern for safety, and the small size of a reactor, alone, will not solve this problem. There is an opinion to the effect that "The small type makes it all the more necessary to look for a site, which in return makes PR even more difficult," indicating that those involved in the introduction of the light-water reactor are not necessarily prepared to be aggressive in pursuing this problem.

Moreover, from the standpoint of R&D, because of the monopoly presently existing in the development of nuclear power technology in terms of both sellers and buyers, the market structure is quite simple. Consequently, unless it is certified by government or by the utility industry, it will not be likely that any high-risk development will be undertaken. For this reason, the position taken by government policy will be an important factor. Moreover, it will be necessary to deal with the system which regulates site selection and safety factors in order for the small reactor to have any chance of commercial success.

3. Impacts on Industrial Economy

The small light water reactor is a replacement for a large-sized one. In the process of development, however, they have similar electric and transport machineries forming the nucleus, and it is inconceivable, therefore, that related parts and construction and maintenance inspection sectors in both sizes of reactors will differ significantly. However, with small light water reactor, most manufacturing processes will be performed at plants and its system simplification will reduce the level of demand for system-related service.

Moreover, if the small light water reactor were to be installed as a distributed-type electric source or were to compete with thermal and other types of electric sources, then it would greatly impact system operation of the electric utility industry.

Nuclear Fusion Reactor

1. Outline of Technology and Products

This is a type of equipment which generates electricity using energy generated by nuclear fusion of deuterium or tritium. Nuclear fusion reaction consists of (1) the D-D reaction which fuses deuteriums and (2) the D-T reaction in which deuterium and tritium are fused. When technically more difficult D-D reaction nuclear fusion reactor is put to practical use, since it uses deuterium found in seawater in infinite quantity (every 1 m^3 of seawater contains 34 g deuterium: this 1 g is equal to several tons of petroleum) as a fuel, mankind will be forever freed from the worry that energy may dry up some day.

2. Long-Range Prediction for Practical Utilization

If a numeric value of 100 were to be assigned to the practical utilization stage, then the relative value assigned to the current stage of research would be approximately 20, which means that the practical utilization stage most likely will be realized at sometime in the mid-21st century. At present, in Japan, R&D aimed at achieving critical plasma conditions using the critical plasma test facility JT-60 is being carried out. After this has been completed, it will be necessary to construct large-scale facility for the next phase aimed at achieving self-igniting conditions and long combustion time. Since the construction of this equipment reportedly will cost approximately 1 trillion yen, the need for international cooperation involving Japan, the United States, the EC, and the Soviet Union in this project is under study.

Comparison of various countries' R&D efforts at this point indicates that if Japanese efforts were to be rated as 100 points, then both the United States and Europe would merit a rating of 120 in this field.

Key technologies requiring breakthroughs in order to reach the practical utilization stage will be those developing superconductive magnet, plasma heating equipment, reactor structural material which can withstand neutron irradiation, technology for handling the radioactive substance, tritium, and the blanket technology which extracts nuclear fusion energy.

Because of the enormity of the technical problems, non-technical obstacles and problems are not attracting a great deal of attention. However, due to the extremely high cost of constructing test facility, there is a real danger of economic constraints, such as the lack of R&D funds, which may well have devastating effects.

3. Impact on Industrial Economy

As the nuclear fusion reactor is put to practical use and becomes the main source of energy, the energy industry's structural changes will negatively affect some industries. From the standpoint of the good of mankind, however, we can see it as the best means of capturing infinite source of energy, thus positively impacting not only the industrial economy but also the entire human race.

Fast Breeder

1. Outline of Technology and Products

A fast breeder is an epoch-making atomic reactor designed to produce nuclear fuel in excess of the amount consumed in generating electric power. If put to practical use, this atomic reactor will have the effect of increasing uranium resources by several tens of times over.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then the current juncture at the relative R&D stage would be assigned the level of 60, which means that the industry will achieve practical utilization sometime in the year 2050. More specifically, in Japan, an experimental reactor, the "Joyo" (thermal power output 100,000 kW) has been in operation without a hitch since 1977, and a prototype reactor, the "Monju" (electric power output 280,000 kW), is under construction with completion scheduled for 1992. The development of a demonstration reactor following this is in a planning stage, with the second half of the 1990's set up as the starting date. By constructing and operating multiple reactors designed for initial commercialization, the industry will attempt to realize full-fledged practical utilization at sometime between the years 2020 and 2030.

Comparison of various countries' R&D efforts in the field indicates that if Japan were to be given 100 points for its achievements in the field, then the United States, also, would merit the level of 100 and Europe that of 130. In France, a validation reactor (electric output 1.2 million kW), "Superphenix," has been operating since 1976, and currently, France, Germany, and Great Britain are developing jointly the next series of the fast breeder validation reactor.

As for key technologies, it is fairly accurate to say that a fair number of problems already have been solved. For the future, based on experience gained over the years in R&D, the industry will work on improving validation, skills, and performance as part of plant technology and to establish cost effectiveness.

As for obstacles and problems in non-technical areas, social constraints will come from difficulties associated with making a certain segment of the general public understand that nuclear power generation is safe. Economic constraints will be the extreme difficulties encountered in obtaining R&D and construction funds and in reducing construction and operational costs.

3. Impacts on Industrial Economy

Although it is extremely difficult to predict the scale of the market for the fast breeder, if it should become the "main stream" of nuclear power generation and its construction should proceed accordingly, then a several hundred billion yen market could be predicted.

Positive impact on the industrial economy would be the revitalization of nuclear power-related industry which has been suffering from stagnation in recent years, stabilization of the energy supply in Japan, and control of the CO_2 exhaust. The fossil-fuel power generation-related industry will be adversely affected and gradually will decline.

High Efficiency Heat Pump

1. Outline of Technology and Products

This is a heat pump whose coefficient of performance is rated as 8; in other words, its heating/cooling, hot water supply, and processing/heating capabilities are double those of conventional heat pumps. Since 1984, aiming at practical utilization in 1992, its development has been continuing at NEDO. Since power-generation efficiency is barely 40 percent, if HOP is less than 2.5 in electric-power conversion, increases in the electric power share will lead to increases in primary energy. For this reason, the high-efficiency heat pump is considered extremely important, playing a key technological role in energy saving.

2. Long-Range Prediction for Practical Utilization

R&D aimed at commercialization of the high-efficiency heat pump has been making progress. A thermo-type already has achieved the performance coefficient of 7.7. If a numeric value of 100 were to be assigned to the practical utilization stage, the current juncture in the R&D stage would be around 85. By the year 2000, it will also become cost effective.

On the international scene, IEA (International Energy Agency) is developing an improved type HP. Japanese technology is considered most advanced in this field.

As future development themes, in addition to validation with use of a large-scale pump, development of fleon substitution and cost effectiveness will be pursued. The fleon substitute, especially, can be considered a key technology because of its effects both on efficiency and on economic factors.

Based on the results obtained by the research union, business-based development and commercialization are already moving forward. Although obstacles to practical implementation are by no means formidable, cost reductions and sensitivity to the general public's reactions will be necessary. Rebates by an electric utility company rewarding customers' energy saving efforts and economical night-time use of electricity are two examples of how the industry is handling the latter problem. Moreover, a combined use of large-scale heating/cooling equipment (inside office buildings) and thermal storage equipment designed to reduce peak-time power use is an example of an important development theme of systematization.

3. Impact on Industrial Economy

If the super-heat pump will satisfy demands for heating/cooling and hot water supply and, at the same time, increase power generation efficiency, even with a practical application COP of 5, the super-heat pump will require less than half of the primary energy required by conventional-type non-electric heating/cooling and air-conditioning equipment. For this reason, the super heat pump goes beyond being merely substitute of existing energy-use equipment, as it contributes to the development of energy substitution (expanded energy saving and use of equipment). However, manufacturing of equipment, per se, belongs to the machinery division, and, therefore, drastic structural changes cannot be readily considered.

What we will see in the industrial division will be that conventional dryers and low-temperature heaters increasingly will be replaced by the newer types and, in the food industry and other light industries, the super-heat pump will replace boilers.

Moreover, in the energy industry, unless the gas companies (main suppliers of cooling/heating system and hot water supply) and medium- and small-size petroleum product distribution companies develop gas (petroleum)-engine heat pumps, they will not be impacted significantly.

Superconductive Power Storage Facilities

1. Outline of Technology and Products

Superconductive power storage facilities store electric energy itself by installing, underground large coils which generate superconduction phenomena when electric resistance sinks to zero under extreme low temperature conditions. Although at present pumped-storage hydraulic power stations and compressed air storage gas turbine power facilities are being developed for use as a power source-leveling facility for storage of a supply of electricity. Building site codes restrict development of these facilities. The superconductive power storage facilities, therefore, will emerge as the main facilities for highly efficient electric source leveling.

2. Long-Range Prediction for Practical Utilization

If the relevant practical utilization stage were to be assigned a numeric value of 100, then the current stage in R&D would be evaluated as 30, which means that the practical utilization of superconductive power storage facility would be realized in the year 2020.

Comparison of advanced industrial nations' R&D efforts at this point indicates that if Japan's achievement were to be given the score of 100 points, then the United States would score 250, and Europe, around 30. The United States, therefore, is ahead of Japan in this field.

Key technologies requiring breakthroughs will be those used in developing economic coils, high temperature superconductive equipment, and cold-insulation systems, as well as in the establishment of safety measures technology at facilities.

Social constraints deterring practical implementation of the technology would be in the area of energy policy and a government-led development setup. At present, although industrial and academic R&D are displaying a great deal of vitality, the total R&D systems under the setup mentioned above will be highly desirable.

In order to solve these problems, it will be essential that the clarification of the following policy aimed at for promoting practical utilization be made: superconductive power storage is a system which can be realized only when new technologies of various fields are integrated. For this reason, the government must be a driving force to further validation tests by validations plants and to promote research in the total system and assessment of safety measures.

3. Impacts on Industrial Economy

It is estimated that the scale of the superconductive power storage facility market will reach the 1 trillion-yen level. The number of related company's research laboratories will be increased to 100.

Positive impacts created by the superconductive power storage facility industry on the industrial economy will be the emergence of such new industries as the parts industry which manufactures superconductive coils, cold insulation equipment manufacturers and an engineering industry which deals with extremely low temperatures even reaching at below -100<deg>C. At the same time, such existing industries as the heavy electric equipment industry, the metal industry, and the construction industry will be revitalized.

Negative impacts will be felt by industries involved in the pumped storage power stations.

From the standpoint of technological assessment, effects of magnetic fields on living things and on underground water substances, as well as extremely low heat sources on the ground must be considered.

Intelligent Robots

1. Outline of Technology and Products

Robots currently used in practical situations and not limited to industrial usage, require detailed programming of their actions by programmers, thus producing the ironic situation in which a great deal of human labor is involved so that labor saving device can be installed. This fact is preventing more widespread use of robots, especially in small- and medium-sized businesses.

In order to solve this problem, robots which can perform work without detailed instructions to guide them must be developed. As long as an outline of the work to be accomplished is given, such a type of robot can perform the level of work equivalent to that performed by skilled human workers. This type of robot is called an intelligent robot.

The intelligent robot which will be seen first at production sites probably will be an all-purpose assembly robot. A custodian robot and a hard, dirty, and dangerous workplace robot, such as a garbage processing robot, may be possibilities.

2. Long-Range Prediction for Practical Utilization

As stated previously, programming problems are not necessarily limited to the field of robots. They are problems common to all Neumann-type computers currently in use. As a key to the solution of this kind of problem, research in artificial intelligence (AI) has been carried out for sometime now. However, we have not gone beyond the realization of more than just a segment of expert systems. Moreover, although fuzzy logic and neurocomputing are included in this, neither has the capability of solving this problem in its totality.

Since this is a problem which should be resolved by going back to the basics of the programming methodology, it is unlikely that we will be able to achieve a quick solution.

In that sense, therefore, this may be the problem on which all the industrial countries should work together.

If the numeric value of 100 were to be assigned to the practical implementation of this technology, then the current stage reached in R&D would be assigned the level of 10, which means that it would be in the year 2050 when practical utilization of this technology can be realized.

Comparison of advanced industrial nations' R&D efforts at this point indicates that the United States, which had exhibited overwhelming strength in this field in the past, now has been overtaken by Japan, and Europe lagging behind both the United States and Japan.

Both social and economic constraints are few and far between. It is the technological constraints which are deterring practical implementation. As stated before, the problem is still a very basic one. Researchers must return to the basics of programming theory and restudy it. Development of autonomous control, learning control, and of the three-dimensional visual sensor will be required.

3. Impacts on Industrial Economy

Impacts created by this technology will be tremendous from the standpoint of its ability to solve most of the current labor-shortage problems. Most of these will be positive impacts.

Negative impacts have to do with the enormous amount of time required in ascertaining to what extent robots, equipped with the ability to make decisions on their own, can act safely in time of emergency.

Micromachine

1. Outline of Technology and Products

Recently use of the IC fabrication process in the field of machining mechanical parts was suggested, and an experiment in this connection has begun. Micromachine combines both of these two categories of processing. At present, interest is focused on its uses in the medical field. In time, application of similar machines on manufacturing floors will be realized. If this should occur, we may very well see (1) an automatic machine, no bigger than from 2 or 3 centimeters to around 10 cm, designed to perform spot-checking and repair, (2) a micromachine tool designed to perform machining of miniaturized parts, (3) a micro-manipulator, and (4) a small machine manufacturing system composed of a carrier and inspection devices of about the same size.

2. Long-Range Prediction for Practical Utilization

The micromachine presently being made public is in the development stage, and researchers have succeeded in fabricating a static motor on a silicon. The question of how this power can be extracted, or the problem of frictions and durability, have yet to be resolved.

Moreover, if materials other than silicon are to be used, in the case of a micromachine tool, the questions of what to do with a cutting tool or the methods of assembly, measurement, and inspection of these miniature parts will have to be resolved.

However, since this is a field thus far left untouched by any other type of development, at one point in time, a sudden burst of development may take place. We have heard that its development will be incorporated into MITI's Large-Scale Project next time. This may very well serve as a triggering mechanism for the filed's development.

Since the initial idea came from the United States, U.S. research in this field is the most advanced. Japan's research activity has been picking up in recent years. Europe is lagging behind the United States and Japan.

If the practical implementation stage were to be assigned a numeric value of 100, then the present juncture in terms of progress made in R&D would be assigned less than 10, which means that it would be around the year 2010 when practical use of micromachines would be realized.

Neither social constraints nor economic constraints are evidenced.

3. Impact on Industrial Economy

We cannot imagine that, with a single swoop, the micromachine will create a big impact on the industrial economy. Its impacts will be gradual and cummulative, instead.

There will be no negative impact because of the complete novelty of the micromachine. There is nothing existing either now or in the past which can be replaced by this technology.

AI-CNC

1. Outline of Technology and Products

When a finished shape of a part and its precision level are input, the machining process will be automatically generated by pre-input specifications of a plant's machining and finishing tools. After machining has been completed, the shape will be automatically measured and the finishing process automatically performed, and the specified precision rate will be output.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100 and the present stage one of 20, then the practical use of AI-CNC would be realized at sometime in the year of 2010.

It will be necessary to increase the speeds of microprocessors and memory devices in data processing by 100 times. Moreover, since the size of software will have become enormous, it will be necessary to increase software development efficiency by 10 times, and, at the same time, to establish a method of software development which will not require maintenance.

In addition, on-machine measurement, generation of three-dimensional models, recognition of work forms, and automatic generation of machining and measurement processes will be required.

At present, Japan technologically is the most advanced in this field, followed by Europe. The United States is lagging behind the two.

3. Impact on Industrial Economy

CNC machine tool will increasingly become widespread, and, with it, a decrease in the use of general-purpose machine tools will set in.

At the same time, since CNC functions will include a small-scale CAD system, the AI-CNC will compete with low-priced CAD systems for use in machine design.

Combined Machining Center

1. Outline of Technology and Products

Using data input on the finished shape of a product, the combined machining center will automatically perform a several kinds of work, ranging from material processing to assembly; more specifically, cutting of materials, machining, assembly, cementing, and welding.

2. Long-Range Prediction of Practical Implementation

If the practical implementation stage of the above were to be assigned a numeric value of 100, the present juncture in R&D would be assigned a level 5, which means that practical implementation of the combined machining center will be sometime realized around the year 2020.

Required technologies will include those designed to determine (1) the shape of a part from a product form, (2) material form from the finished shape of a part, (3) the machining process, (4) machining and cutting tools to be used, as well as automatic procedures to be followed by machine tools and compensation processing to be performed.

At present, Japan is slightly ahead of the United States and Europe.

For the future, the combination of lathe, machining center, and grinding, as well as development of assembly robots, will be required.

3. Impact on the Industrial Economy

Since machining and assembly costs will come down, total demand will increase, as a result of which, the demand for NC machine tools as a unit of this combined machining center will increase. However, demand for single-function NC lathes and industrial robots may decrease.

Ultra Precision Machine Tools

1. Outline of Technology and Products

This is an automatic machining tool, which, using the shapes of various finished products, analyzes various causes for errors and performs compensatory processing so that form precision within the margin of 1 nm can be achieved with ease.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then the present juncture in R&D would be assigned a level of 10, which means that the practical utilization of the ultra-super precision machine tools would be achieved around the year 2020.

At present, the United States and Europe are a few steps ahead of Japan in this field.

It will be necessary to establish a super-ultra-precision measurement method and to accumulate experience in the ultra-precision machining so that analysis of the causes of errors can be analyzed automatically and, at the same time, automatic establishment of machining conditions and compensation to achieve precision accomplished. In order to achieve these, technology to determine positioning of an object with high precision, ultra-precision measurement technology, and error analysis technology will be required.

3. Impact on Industrial Economy

Prices of today's costly products (laser equipment) because of the high precision requirement will come down. There will be no negative impact of which we are aware.

Intelligent CAD

1. Outline of Technology and Products

This is a CAD system which can perform detailed designing if the concept of the item to be designed, its use, its rough shape, and the type of material to be used are provided.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned the numeric value of 100, the present juncture in R&D would be assigned a level of 10, which means that practical utilization of the intelligent CAD would be around the year 2020.

At present, Japan is slightly ahead of the United States and Europe in this field.

Although it is still unclear to what extent human creativity can be given to computers, nevertheless, by developing new technology, there should be room for improving computer creativity.

At present, the essential part of design work is being left to human creativity, and most relatively simple, cut and dry work will be delegated to computers. By increasing design efficiency, the computer gradually will be able to take on more work. We do not believe, however, that the part carried out by humans will be reduced to the stage of zero. It will be design speed and accuracy in which we will see dramatic improvement.

Regardless, the work which designers are performing consciously and subconsciously must be analyzed in detail and described objectively. Moreover, it will be necessary to make a clear statement of what human creativity "is all about."

Moreover, the problems of geometric inference, intelligent user interfaces, a solid modeler, and concept design must be resolved.

3. Impact on Industrial Economy

Impacts created by the shortened cycle of new product development can be treated as either positive or negative impacts.

However, shortening of development cycle itself is a good thing, and whether this merit can be used to advantage or to abandon it is a problem of the social system and not one to be settled by technicians. In that sense, it might be viewed as a kind of social constraint.

Product Model

1. Outline of Technology and Products

Information required in manufacturing a product is generated by simulation of its manufacturing process, using a solid product model constructed inside a computer.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, the present technological stage would be assigned a level 30, which means that practical utilization of the product model would be realized around the year 2010.

At present, the United States and Europe are ahead of Japan in this field.

Since presently existing solid models cannot process all types of forms, it will be necessary to develop, for example, a non-variable solid modeler, which can be used to display any kind of form, which is equipped with robust form change operation, and which, at the same time, provides fast-processing speed.

In addition, a simulator for manufacturing process will be required.

3. Impacts on Industrial Economy

Impacts of the product model will be approximately the same as those of the intelligent CAD.

Autonomous Distribution Control

1. Outline of Technology and Products

This is an autonomous distribution system of a group of robots, designed to use a multiple number of robots in moving a heavy object which cannot be transported by a single robot, or to assign a number of robots to carry out a series of tasks in order to improve operational efficiency and reliability.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage of the above were to be assigned a numeric value of 100, then the current juncture in R&D would be at a level of 5, which means that the practical use of a simple system would be around the year 2005.

At this point, the United States is slightly ahead of Japan, and Europe is lagging behind Japan.

Since frequent exchange of data among robots will be necessary, a data communication system technology will be essential. Control technology, designed to coordinate the actions of a group of robots, moreover, must be developed. Also required will be a robotic sensor and force control technology.

3. Impacts on Industrial Economy

The system will be used in machine manufacturing and assembling. It will be possible also to use it in shipping, construction, and engineering work sites. The problem of 3K workplace, which currently is attracting attention, may be solved by substituting human workers with robots.

As for negative impacts, we unable to come up with any.

Concurrent Engineering

1. Outline of Technology and Products

Concurrent engineering aims at achieving streamlined production by effectively utilizing various resources related to production. This is accomplished by carrying out technical activities, ranging from product planning to manufacturing, which hitherto have been performed serially, in parallel progression, by installing new computers and a shared data base.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then the current juncture in R&D would be assigned a level of 10, which means that practical implementation of concurrent engineering would be realized around the year 2010.

At present, the United States and Europe are slightly ahead of Japan in this field.

Object-oriented software will need to be incorporated into the existing database management system. Moreover, the kind of technology designed to clarify the precision-cost relationship which, at present, is mostly maintained by the production floors, so that a computer will be able to determine automatically dimensional tolerance of parts from the specifications of a final product.

3. Impacts on Industrial Economy

Impacts, probably, will be similar to those created by the intelligent CAD and the product model.

Personal Information Communication Equipment

1. Outline of Technology and Products

This is information and communication terminal equipment which is prerequisite to the maintenance, on a personal base either at work or at home, of digital car phones, digital portable phones, or on-the-premises cordless/wireless personal computers, equipped with dramatically increased number of connections over those of analog communication method currently in use.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, the current point in the R&D stage would be at 70, which means that practical use of this technology would be realized around the year 1995.

Comparison of various countries' R&D efforts at this point indicates that if a score of 100 points were to be accorded to Japanese efforts, the United States would score 120 and Europe 150.

Key technologies requiring breakthroughs will include the compact and light-weight battery technology, the system control technology, the coding technology, and the packing technology.

Obstacles to practical implementation of the technology in terms of system and government policy would be the radio wave frequency allocation, radio wave management, and, in terms of the general public's perception and value systems, the problem of public acceptance, viz., the question of to what extent changes in personal culture brought about by this equipment will be accepted by the general public. For this reason, in order to put personal information communication equipment to practical use, a review of government policy regarding frequency allocation and radio wave management will be necessary.

3. Impacts on Industrial Economy

It is estimated that the scale of personal information communication equipment market will reach the 160 billion yen level by 1995, when practical utilization of the equipment will be achieved (the market scale for existing equipment in 1990 is approximately 100 billion yen), increasing approximately 200 billion yen by the year 2000, and approximately 500 billion yen by the year 2010.

Positive impacts created by the personal information communication equipment on the industrial economy will be the establishment of a new voice database industry and the revitalization of existing first class and the second class communication businesses, the database industry, and the battery industry.

Negative impact will strike the existing-type telephone industry which will begin to decline.

VSAT (Very Small Aperture Terminals)/Satellite Data Network

1. Outline of Technology and Products

The VSAT system is a satellite data system configured with a large number of distributed VSATs revolving around one or more hub stations (parent station). It is a multiple-address type of high-speed data communication systems, designed to transmit product information, for instance, to dealers scattered throughout the country, or to send the latest medical information to hospitals nationwide. Furthermore, the system is equipped with inter-LAN linkage and image transmission capabilities.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then the current juncture of its R&D stage would be assigned the level of 80, which means that practical utilization of the VSAT/Satellite data network would be realized at sometime in the first half of the 1990s.

Comparison of various countries' R&D efforts at this point indicates that if Japan were to score 100 points for its achievements in this field, the United States's score would be 200 and Europe approximately 30.

Key technologies requiring breakthroughs will include preamble-less technology, high speed multi-access technology, and multi-access protocol technology. As an important support technology, security technology must also be included.

An obstacle to practical implementation would be the severity of frequency resource management. The key to achieving the practical implementation of the VSAT/satellite data system will be its system technology, which will be more important than each individual technology. The problem of adjusting and augmenting the communication protocols (which take advantage of the multiple accessibility of satellite systems) to existing ISDN and OSI must be dealt with.

3. Impacts on Industrial Economy

It is estimated that the scale of the VSAT/Satellite data system market will reach the 30 billion-yen level at sometime in the first half of the 1990s (when practical implementation will be realized), the 100 billion-yen in the year 2000, and the 200 billion-yen level in the year 2010.

Positive impacts created by the VSAT/satellite data system on the industrial economy would be the emergence of new satellite education industry and the low-priced navigation system and the revitalization of the imaging equipment and database industries.

HDTV (high quality image television)

1. Outline of Technology and Products

HDTV (High Definition TV) is a high-quality television characterized by a degree of high resolution not attained in existing televisions (in terms of information volume, approximately a few times higher). Currently it is a focus of intense competition being waged among Japan, the United States, and Europe in their effort to develop a model which can be put to use in practical situations. HDTV is roughly divided into two categories in terms of its of use: (1) those designed for home use (mainly broadcasting) and (2) those designed for business use (demonstrations, teleconferences, and telelectures, etc.). For the future, it will be applied to multimedia information terminals. Technically, it can be classified as technology concerned with studios' technical standards, transmission technology, and receiving technology, including displays, camera technology, and storage technology.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numerical value of 100, then the current stage of R&D would be 60, which means that the practical use of home HDTV will be achieved sometime in the year 1995.

Comparison of various countries' R&D efforts at this point indicates that if Japanese were to be given 100 points for its achievements in this field, the United States would have a score 60 and Europe one of around 70.

Key technologies requiring breakthroughs will include transmission technology, image processing technology, and display technology. Of the peripheral support technologies, camera technology and storage technology are considered important.

Obstacles of a non-technical nature will include, systemwise, a radio wave allocation system in the case of wireless broadcasting and a tariff structure in the case of wire broadcasting; government policy-wise, technical standardization policy; and social infrastructure-wise, wide-band communication network coordination; and from the standpoint of the general public's perception, the question of whether a virtual reality as presented by the high-resolution TV will be accepted by society. From the economic standpoint, improvement in the rates of recovery of equipment investments and of lowering costs will be the key points. Moreover, bolstering the industry's ability to supply advanced HDTV software will be essential to popularization of HDTV. For this reason, large R&D investments to further research and a sound aid policy for a software center will be necessary.

3. Impacts on Industrial Economy

It is estimated that the scale of the HDTV market will reach the 20 billion yen level in 1995, 300 billion yen-level in the year 2000, and 3 trillion yen-level in the year 2010. The R&D funding level will be increased from the level of 200 billion yen (1990) to the level of 300 billion yen in 1995.

Positive impacts created by HDTV on the industrial economy will be the emergence of a large wall-hanging-type TV industry, of an HDTV specialized software industry, and of a new electronic publishing industry. Moreover, we also will see revitalization of the existing PC-WC industry, imaging industry, and the semiconductor industry.

The existing motion picture industry will be impacted negatively, and as a result, will begin to decline.

CS/BS-CATV (Communication Satellite/Broadcast Satellite-Based Cable Television)

1. Outline of Technology and Products

Broadcasting which utilizes a communication satellite (CS), a broadcasting satellite (BS), and CATV have a symbiotic relationship of the competition and dependency. Trends indicate that a rapid rise of a metropolitan-type CATV is expected, and that if it will continue to incorporate advanced functions (directional functions and optic CATV), then CS, BS, and CATV can be integrated to offer a wide variety of information services, such as, for example, electronic publishing and the electronic library.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then the present juncture in the R&D development, in relative terms, would be assigned the level of 80, which means that if we are to assume that optic CATV will be implemented at the practical utilization stage, it will be around 1995 when this will be achieved.

Comparison of various countries' R&D efforts at this point indicate that if Japan were to be given a score of 100 points for its achievements, then the United States would score 150 points and Europe 90 points.

Key technologies requiring breakthroughs will include the multibeam satellite technology, the optic CATV technology, and the low-priced optic circuit technology. As important support technology will be the scramble technology (secrecy method).

Non-technical obstacles to practical implementation will be social constraints which will seriously affect the regulations governing the framework structured on the radio wave policy and the Communication and Broadcasting Laws. Reduction of costs, moreover, must be pushed. The question of whether society will accept the new electronic media, CS/BS-CATV, positioned between the boundaries of communication and broadcasting, will become an important point.

3. Impacts on Industrial Economy

It is estimated that the scale of the CS/BS-CATV market will reach the 40 billion-yen level in 1995, when practical utilization will be realized, the 60 billion yen level in the year 2000, and the 140 billion yen level in the year 2010. The R&D funding level was estimated at 5 billion yen; this trend will continue until the year 2000.

Positive impacts created by CS/BS-CATV on the industrial economy would include the newly emerging electronic publishing industry, and revitalization of the old industries, such as the second class communication business and the CATV industry. The secondary effect will be felt by the satellite industry and by optic fiber manufacturers.

The existing ground broadcasting and video rental businesses will be impacted negatively, as a result of which factor their decline will set in.

TV Conference System

1. Outline of Technology and Products

This is a TV conference system designed to transmit images and voices through high-speed dedicated circuits and a communication satellite, making it possible to hold a conference participated in not only by speakers at two sites, a method currently in use, but also at a large number of sites as well.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then the present juncture in the relative R&D stage would be one of 90. This means that practical utilization of the TV conference system will be realized in 1994.

Key technologies requiring breakthroughs will include image band compression technology and high quality voice signal processing. Important support technologies will be the communication protocol and the acoustic processing technologies.

Non-technical obstacles to practical implementation of the TV conference system will be the policy of establishing the basis for rates, viz., the speeds of circuits, distances, etc., and difficulties involved in lowering costs. The key point will be the revision of the tariff policy. From the standpoint of the general public's perception and value systems, if general public should be slow in recognizing the virtual reality, the resulting delay may very well deter practical implementation.

3. Impact on Industrial Economy

It is estimated that the scale of the TV conference system market will reach the 20 billion yen level in the practical utilization stage (1994), the 40 billion-yen level in the year 2000, and the 200 billion-yen level in the year 2010. The current R&D funding level is 10 billion yen; it is estimated to reach the 20 billion-yen level in the year 2000 and will shrink to a 10 billion-yen level in the year 2010.

Positive impacts created by the TV conference system on the industrial economy will include the formation of a new TV conference image and picture database business and revitalization of existing image industries and of the communication industry. The secondary effects, moreover, will extend to the semiconductor industry.

TV Telephone

1. Outline of Technology and Products

This is a moving picture TV telephone which utilizes ISDN (64 Kpbs). The emergence of a moving picture TV phone based on the B-ISDN (150 Mbps. 600 Mbps) is expected in the future. It will begin with the installation of the equipment priced at more than 1 million yen primarily for business use, followed by reductions in prices, at which point, the TV phone will begin to enjoy widespread use.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then the present juncture in the R&D stage would be 80. This means that practical utilization will be achieved around 1994.

Comparison of various countries' R&D efforts in the field indicates that if Japan were to be given a score of 100 points, the United States also would score 100 points and Europe approximately 60 points.

Key technologies requiring breakthroughs will include image-band-compression technology and that of image-processing processor. Important support technologies will be the high-density packaging and the AD/DA circuit technologies.

Non-technical obstacles and problems to be anticipated would be, from the standpoint of policy, revision of the telephone rate system; and, from the social infrastructure, adjustment and improvement of the wideband area communication infrastructure. From the standpoint of the general public's perceptions and value systems, it will take some time before people become accustomed to having face-to-face telephone conversations. Low cost will be an essential factor in putting the TV telephone to practical use. For this reason, it will be necessary to come up with popularization promotion measures for ISDN-related equipment, including TV phones.

3. Impacts on Industrial Economy

It is expected that the scale of the TV phone market will reach the 10 billion yen level at the practical implementation stage, the 20 billion-yen level in the year 2000, and the 30 billion-yen level in the year 2010. R&D funding, at this point, is around 3 billion yen and will remain at about this level before and after the practical implementation stage.

As for impacts created by the TV phone on the industrial economy, as in the case of the TV conference system, we will see the emergence of the voice and image database business, as well as revitalization of the existing communication industry. The secondary effect will spread to the semiconductor industry.

Wideband ISDN (Integrated System Digital Network) Exchange

1. Outline of Technology and Products

This is an ATM (asynchronous transmission mode)-based wideband switchboard, through which the maximum of 150 Mbps, or up to 600 Mbps, of voice, data, and image can be communicated in wideband at a speed of one's own choice. Moreover, it can be used in fast dedicated line service, as well as in LAN linked lines.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then the present juncture viewed from the total R&D project would be at a level of 70, which means that practical use of the wideband ISDN exchange will be achieved in 1995.

Comparison of various countries' R&D efforts at this point indicates that if Japan were to score 100 points in this field, then both the United States and Europe would score 100 points, also.

Key technologies requiring breakthroughs will include high-speed LSI technology, circuit control technology, optic subscriber circuit technology, and communication protocol technology. The high-density packaging technology will be considered as an important support technology.

Constraints of non-technical nature which are especially damaging will be inadequate levels of R&D funding and staffing. High-speed LSI and large-scale software developments will require vast amounts of funds as well as a large number of engineers with R&D capabilities in the fields of system, software, and LSI technologies. For this reason, a timely aid policy designed to bolster R&D equipment investment will be essential. It will be necessary, moreover, to make appropriate use of rate policies and to increase the general public's receptiveness toward multimedia information.

3. Impacts on Industrial Economy

It is estimated that the scale of the wideband ISDN exchange market will reach the 10 billion-yen level at the time of practical implementation of the technology, the 100 billion yen level in the year 2000, and the 200 billion-yen level in the year 2010. R&D expenditure at this point is approximately 20 billion yen. This will be increased to 50 billion yen at the practical implementation stage and will continue at that level.

Impacts created by the wideband ISDN exchange will include the newly emerging image and picture database business and the electronic publishing industry, as well as the revitalization of the existing communication industry. Secondary effects will be felt by the personal computer and workstations industries.

Optic Subscriber System

1. Outline of Technology and Products

The optic subscriber system is a system which forms a subscriber access subsystem in the wideband ISDN, integrating and providing multimedia communication and broadcasting services through optic fibers extended to link the switching center with each subscriber's home or with a specified point in the vicinity of a subscriber's home.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then the present juncture in the R&D project would be at a level of 60, which means that practical utilization would be realized approximately the year 1995.

Comparison of advanced industrial countries' current R&D efforts indicates that if the score of 100 points were to be given to Japan's achievement in this field, the United States would also score 100 and Europe about 70.

Key technologies requiring breakthroughs will include wave multiplexing technology, low-priced optic circuit technology, and network management technology. Important support technologies are the simplified photo-operation technology and the supplied-power technology.

Constraints of a non-technical nature especially damaging from the system and policy standpoints will be the integration of communication and broadcasting. Economic constraints will deter business's efforts to secure adequate market scale, low costs, and the introduction of market principles. For these reasons, it will be essential to have a policy to aid research efforts aimed at the development of highly reliable and low-cost optic devices and optic circuits.

3. Impacts on Industrial Economy

It is estimated that the market scale of optic subscriber system will reach the 150 billion-yen level at the practical implementation stage, the 250 billion-yen level in 2000, and will be increased to the 500 billion-yen level in 2010.

Positive impacts created by the optic subscriber system will include the emergence of new home-banking and shopping services and revitalization of the existing opto-electronics industry, and the CATV and communication business.

Optic LAN (Optic Local Area Network)

1. Outline of Technology and Products

This is a gigabit-class optic LAN, installed in factories, office buildings, or campuses, and providing access to multimedia databases as well as linkage among supercomputers. This is an expanded future version of the FDDI-LAN now under implementation.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then the present stage in the totality of R&D project would be 70, which means that practical implementation is expected to take place in the year 1995.

Comparison of advanced industrial nations' current R&D efforts in the field indicate that if 100 points were given to Japanese achievements, then the United States would also score 100 points and Europe about 70.

Key technologies requiring breakthroughs include high-speed communication protocol technology, low-priced optic circuit technology, and network management technology. Important peripheral technologies are the high-speed data terminal and multimedia DB technologies.

From the technical standpoint, we perceive no social constraints which would create obstacles or problems. From the economic standpoint, however, difficulties involved in securing adequate market scale and in realizing low costs should be mentioned. In the United States, development of the optic LAN is being conducted under government leadership. It is expected that Japan will come up with a similar policy to assist in the development of high reliability-low cost optic devices and optic circuits.

3. Impacts on Industrial Economy

It is expected that the scale of the optic local area network will reach the 5-billion yen level in the practical implementation stage, the 20 billion-yen level in the year 2000, and the 30 billion yen level in the year 2010. R&D funding, which currently is at the 2.5 billion yen level will be increased to 5 billion yen during the practical implementation stage, and to around the 10 billion-yen level in the year 2000.

Positive impacts created by the optic local area network on the industrial economy will be the emergence of new unmanned farms and factories and the revitalization of the existing distributed processing system industry, the personal computer workstation industry, and the opto-electronics industry.

Superconductive Linear Motor Car: the Next Generation High Temperature Superconductive Linear Motor Car

1. Outline of Technology and Products

The superconductive linear motor car is a rail car which uses a superconductive magnet for levitation and periodic switching of magnetic polarity for propulsion. Its super-speed reduces the traveling time between Tokyo and Osaka to just an hour. Moreover, it not only is free of noise and vibration but also saves energy. It has the great potential of becoming the transportation of the 21st century. The superconductive linear motor car currently under development uses a regular electrostatic magnet and aims at achieving the speed of 500km/hour. The maximum speed of 700 km/hour will be achieved by the next generation of linear motor cars which will use a high-temperature superconductive magnet.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned the numeric value of 100, the relative numeric value of the present juncture in terms of the progress made in R&D would be 80. This means that practical utilization of the superconductive linear motor car currently under development will be achieved in the year 2010 and of the next generation of the linear motor car, in the year 2030.

Comparison of R&D efforts of various countries at this point indicates that Japan is the only country which is developing a superconductive linear motor car.

Key technologies requiring breakthroughs will be those required in developing high-temperature superconductive materials, explication of the aerodynamic characteristics displayed by a car when it thrusts its way into a tunnel, in development of magnetic shield technology, and in development of train control systems.

In order to overcome obstacles to practical implementation, from the social standpoint, there is a need for strengthening the R&D development setup, augmentation of the system for technological advances, and a sufficiently large sum of money to support well-coordinated main rail lines. From the economic standpoint, since there is a sufficient number of potential users, it is essential that the kind of fares which can compete with those of airlines and the shinkansen currently in operation be established. Currently Japan Railways is working on producing faster trains on Shinkansen Line (350 km/hour), which will give stiff competition to the current model of linear motor cars.

In order to solve these problems, it will be essential that the country approach this problem with the determination to develop and install the next generation of high-temperature superconductive linear motor cars. Moreover, in order to compete with the high-speed Shinkansen trains, it will be necessary to increase the presently planned speed of 500 km/hour to 700 km/hour.

3. Impacts on Industrial economy

It is estimated that the market scale of the superconductive linear motor cars will reach the 1 trillion-yen level, including construction costs. The number of related industries' research laboratories will increase to 50 companies. Positive impacts created by the superconductive linear motor cars will be the formation of new industries, such as the vehicle manufacturing industry which will manufacture the superconductive motor cars and the parts industry, which will manufacture coils for tracks and other parts. Revitalization of such existing industries as the rail car industry, the metallic material industry, the construction industry, and the electric-electronic equipment industry, is anticipated.

Negative impacts will be felt by the hotel and inn industry, the airline industry, and the existing high-speed rail car manufacturing industry.

From the viewpoint of technological assessment, effects of noise and magnetism on living things are factors which must be examined carefully.

HSST Linear Motor Car

1. Outline of Technology and Products

This is a rail car which is propelled by the regular conductive magnet which levitates it approximately 1 cm above the rail. Its target speed, aimed at medium distances, ranges from 120 km/hour to 300 km/hour. While the superconductive linear motor car is designed for long-distance travel, the HSST linear motor is designed strictly for mid-distance travel. It is free of noise and vibration, and, its low construction costs may catapult it to the position of being the main conveyance for inner city travel.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then the present juncture in R&D would be 90, which means that practical implementation would take place sometime in 1995.

Comparison of advanced industrial nations' current R&D efforts indicates that West Germany already has achieved a regular conductive magnet method transbit at 500 km/hour, with a permit for commercialization already secured. In England, the normal conduction linear motor car, the "People Mover," similar to the HSST, is being operated between Birmingham Airport and Birmingham Train Station, covering a distance of 640 m.

We cannot think of any obstacles which would bar practical implementation of the HSST linear motor car. The HSST(corporation)'s commercial operation appears to indicate that the development of the technology for its practical use is in its final stage. In connection with social constraints, we must mention the need for assistance from national or regional government and organizations to bring the technology to the practical implementation stage. There are no serious problems of which we know which are caused by economic constraints. Since this method can be applied to constructing a high-suspension monorail system, as to lines serving suburbs, it has a much brighter future than other modes of transportation..

3. Impact on Industrial Economy

In the early part of practical utilization, which will be realized in 1995, the market scale is estimated as reaching approximately the 10 billion-yen level, including construction costs.

Positive impacts created by the HSST linear motor car on the industrial economy will be the formation of new industries such as the magnetic materials industry and the parts industry(i.e., manufacturing of coil tracks) as well as revitalization of the existing rail car industry which manufactures HSST linear motor cars, metallic materials industry, the construction industry, and the electric power equipment industry.

Negative impacts will be felt by the bus transportation industry and conventional rail car manufacturers.

From the viewpoint of technological assessment, we cannot think of any large problems which should be mentioned.

ATCS (Advanced Train Control System)

1. Outline of Technology and Products

Use of a satellite communication system enables this system (1) to recognize the distance between two trains and the one preceding them, (2) compute a safe speed which can stop the train before a collision occurs, (3) to control a train's speed, and (4) to run the train at a maximum speed which narrows the distance between two trains nearing the edge of the safety limit but preserves a safe distance. It is an independent operating system made possible by a mechanism which switches controls from a centralized to a distributed individualized control.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then the current juncture of the R&D stage would be assigned a value level of 30, which means that practical utilization would be achieved at sometime in the year 2010.

Comparison of various countries' current R&D efforts in the field indicates that only slight difference separates Japan, the United States, and Europe. Japan is slightly ahead of Europe, while the United States is slightly ahead of Japan.

Key technologies requiring breakthroughs will be system technology, designed for verification of a train's position and maintaining an awareness of its running conditions, as well as a technology which will develop a fail-safe safety device.

Obstacles to practical implementation in terms of social constraints will be deterrents to the easing of regulations, support by the national development organizational setup, and to funding of communication satellite launching. Economic constraints present no serious problems. Securing funds for research and development, however, will remain very important.

Support not only by railway companies but also by the national government, will be the key to solving these problems.

3. Impacts on Industrial Economy

It is estimated that the market scale of the Advanced Train Control System, mounted in each train with its own electronic communication controls system, communication information networks, and system construction, will reach the 100 billion-yen level (with the cost of satellite launching excluded).

Positive impacts created on the industrial economy will be the revitalization of electronic-electric machinery industry, which manufactures computer equipment, communication equipment, and communication satellite products. The electronic-electric industry also will be revitalized.

None of the existing industries will be negatively impacted, nor do we perceive any particular problems arising from the technological assessment standpoint.

Bimodal System (Integrated Transportation Method)

1. Outline of Technology and Products

This method enables a carriage to be connected to a trailer, so that they can be operated both on rail and on road. It is a transportation system which can fully realize the advantage of large volume high speed transportation on rails and that of automobile transportation which allows a greater number of accesses to various locations. It is a system which can solve congested traffic problems, and, as such, has an essential role to play in the transportation system of the future.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then the current juncture in R&D would be one of 10, which means that it will be around the year 2000 when practical utilization will be realized.

Comparison of advanced industrial nations' current R&D efforts indicate that Japan is leading the way in this field. Levels of the U.S. and Europe's technologies are about equal.

Key technologies requiring breakthroughs will be those used in developing (1) efficient connect/disconnect mechanisms; (2) connectors which link two trailers, or a trailer with an incoming freight car and a locomotive; and (3) light-weight vehicle material.

Obstacles to practical implementation in terms of social constraints will be those which will undermining the easing of regulations concerning railways and roads as well as support from the national government. Economic constraints will be those problems associated with the mass production of vehicles and the realization of low costs involved therein.

In order to solve these problems, the easing of regulations concerning roads and rails and support from the national government will be essential.

3. Impacts on Industrial Economy

The scale of the bimodal system market is estimated to reach the 10 billion-yen level in the early part of the practical implementation stage.

A positive impact created by the bimodal system will be the revitalization of that part of the vehicle industry which manufactures railroad carriages for use with trailers. The bimodal transportation system will make easier for various local industries to become part of the national distribution network, which, in turn, will revitalize those industries.

Negative impacts will be felt to a degree by the automobile industry.

From the technological viewpoint, improved efficiency in transforation will reduce the number of operating trucks, thus reducing gas exhaust.

Next Generation of Automobiles

1. Outline of Technology and Products

Although its basic structure is an extended version of those of gasoline-engine automobiles currently in use, the next generation of automobiles will be safer (in terms of collision prevention), kinder to the environments, economical, and enjoyable both to ride in and to drive. In the future, when these advantages are realized, its widespread use will follow.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then that of the current juncture in R&D would be 40, which means that it will be around the year 2005 when practical utilization will be realized.

Comparison of advanced industrial nations' efforts in R&D at this point indicates that automobile manufacturers throughout the world are pursuing R&D of the next generation automobiles as they fully understand the its importance.

Key technologies requiring breakthroughs will be those related to collision safety, prevention measures for safety, environmental measures, low energy consumption, integrated vehicle controls, and improved comfort and ease in driving.

As for obstacles which may deter practical implementation of the new automobile, few social constraints in terms of public attitudes, government policy, the social infrastructure, and the environment, appear to exist.

As for economic constraints, these include (1) labor shortages, (2) high wages making the business's efforts to achieve low-cost products difficult, (3) the vast amount of R&D funds required, and (4) the lack of research personnel in the electronics field.
In order to solve these problems, substantial levels of research funding and personnel will be necessary. Moreover, depending on the particular research field involved, joint projects, more than ever, will become necessary. Government assistance policies designed to aide in the advancement of research will be essential in the area of basic research.

3. Impacts on Industrial Economy

It is essential that the scale of the next generation automobile market will reach the 3-trillion-yen level in the year 2000. The number of related manufacturers' research laboratories, as a consequence, will be increased to approximately 300, including those related to parts-manufacturing industries.

Positive impacts which the next generation automobile will have on the industrial economy will be the revitalization of automobile parts industries, which manufacture air bag systems, various types of sensors, and recyclable plastics. Revitalization of the technology industries, such as simulation and software package industry, is also a possibility.

Negative impacts will be felt by the existing automobile industry which will suffer a big blow.

From the technological assessment standpoint, it will be important to pursue a macro-energy-saving policy as viewed from the vantage point of the low energy consumption technology and to attempt to ease the traffic congestions of main roads through reexamination of traffic systems.

Satellite-Communication-System-Equipped Automobile

1. Outline of Technology and Products

This is a new type of an automobile equipped with a high-performance phone, FAX, and a navigation system, designed to improve the automobile's occupants' ability to communicate with the outside world. At this time, some automobiles equipped with the basic system are available on the market, and those equipped with the high-performance system are currently under development.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then the current juncture in R&D would be assigned a numeric value of 80, which means that practical utilization of the high-tech automobile will be realized at some time around the year 2020.

Comparison of advanced nations' R&D efforts at this point indicates that in this field the United States is substantially ahead of Japan.

Key technologies requiring breakthroughs will include the simultaneous bidirectional communication technology involving a large number of automobiles, the voice synthesis technology, and the high-density packaging technology.

As for obstacles to practical implementation, international constraints concerning the use of a radio-wave resource will constitute a major social constraint. Adjustment of the social infrastructure accommodating the launching of many satellites and of installation of ground communication stations will be essential.

Economic constraints will be the shortage of electronic technicians and the R&D funds, which must be dealt with as the field has great growth potential if the problems of low cost equipment and the establishment of strategic usage rates can be worked out.

In order to solve these problems, strong government leadership at international conferences concerned with use of radio wave resources will be required. Also required will be an agreement with respect to government investment to augment the social infrastructure.

3. Impacts on Industrial Economy

It is estimated that the market scale for automobiles which use communication satellites will reach the 100 billion-yen level in the year 2000. The number of related companies' research laboratories will increase to approximately 50, including those of parts manufacturers.

Positive impacts which satellite-communication-system-equipped automobiles will have on the industrial economy will include the emergence of a new industry which will manufacture automobile-mounted telephone equipment and navigation systems, as well as the revitalization of existing information software industry, electronics industry, antenna manufacturing, and functional glass manufacturing industries. Moreover, a small communication-facility manufacturing industry which uses satellite-communication-system-equipped automobiles may be included in this group of revitalized industries.

A negative impact will be felt by the publishing business which publishes road maps and guides.

From the standpoint of technological assessment, prevention of accidents and disasters caused by the breakdown of the launched communication satellite which then collides with a ground station would be a preventive measure, something which requires looking into.

Gasoline Substitute Fuel Automobile

1. Outline of Technology and Products

Among many candidates for automobile designs which use substitute fuels are an electric car, an alcohol-fuel car, and a hydrogen-fuel car. A recent estimate indicates that an electric automobile is the most promising type gasoline substitute-fuel automobile. Although the electric car had the disadvantage of being able to run for only a short distance between recharges, it is now predicted that this problem will be solved by the development of a gas and electric hybrid engine. After the year 2000, when a fuel battery will become available on the market, its use will gather momentum.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then the present juncture of R&D would be assigned a numeric value of 80, which means that practical implementation of electric cars will be realized sometime in 1995.

Comparison of advanced industrial nations' R&D efforts at this point indicates that the United States is substantially ahead of Japan in the development of an electric car.

Technologies requiring breakthroughs will be those of the secondary battery, fuel battery, hybrid system, and "wheel motor" system technologies.

As for obstacles to the practical implementation, the social, infrastructure, and environment constraints will undermine a strong environmental policy, networks of recharge stands and the coordination of services, and the reduction of costs which must be born by each individual, respectively. Economic constraints will include the higher price of electric cars compared with that gasoline-fuel cars, their limited use, and the shortage of electric engineers who must take on the technical development as well as that constituted by limited R&D fundings.

In order to solve these problems, undertaking of projects on a national scale, designed to develop small and light-weight secondary batteries and of new materials, will be necessary.

3. Impacts on Industrial Economy

It is expected that the scale of the gasoline substitute fuel automobiles will reach the 100 billion-yen level by the year 2000. The number of related industries' research laboratories, as a result, will be increased to approximately 50 companies, including those in the auto-parts industry.

Positive impacts which will be created by the gasoline substitute fuel automobiles in the industrial economy will be the formation of a new industry which manufactures recharge stands and equipment. Vitalization of battery and motor control equipment industries will be a possibility. Negative impacts will be felt by existing gasoline stands in regions where gasoline substitute fuel automobiles will be heavily used.

From the standpoint of technological assessment, examination of a system of which battery recycle technology is an integral part must be conducted.

Revolutionary Automobile Manufacturing Technology

1. Outline of Technology and Products

This is a revolutionary type of automobile-assembly-manufacturing technology, designed to solve a multitude of problems facing automakers in recent years, such as those of energy saving, of environmental measures, of recycling problems, of labor shortages, as well as the need to improve assembly capabilities.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then the present juncture in the R&D stage would be assigned a numeric value of 50, which means that practical utilization of the technology will be realized at some time around the year 2000.

Comparison of advanced industrial nations' R&D efforts at this point indicates that auto makers throughout the world, being aware of the crucial nature of this revolutionary automobile assembly manufacturing technology, are devoting considerable effort in R&D in this technology. Not much technological difference, therefore, exists among them.

Key technologies requiring breakthroughs will include the automatic assembly technology, the part utilization technology, the component technology, the next generation CAD/CAM technology, and the robotic technology designed to develop assembly and processing robots.

As for obstacles to the practical implementation, in terms of social constraints, we perceive few which will be damaging. Of the element technologies considered the key to development of the revolutionary automobile manufacturing technology, those requiring advanced technological R&D must be pursued as part of a large-scale government project. As for economic constraints, since this assembly technology will be put to practical use as a production tool in automobile plants, it will tend to be influenced by economic changes. If prices for assembly robots should escalate, then practical implementation will face a hurdle.

In order to solve these problems, research in practical use of assembly robots must be pursued as part of a large-scale national development project.

3. Impacts on Industrial Economy

TIt is estimated that the market for totally automated assembly lines and automated assembly robots, achieved by the revolutionary automobile assembly manufacturing technology, will reach the 500 billion-yen level in the year 2000. The number of related companies' research laboratories, as a result, will increase to approximately 100, including those of parts manufacturers.

Positive impacts which the revolutionary automobile assembly manufacturing technology will have on the industrial economy will be the revitalization of industries manufacturing the totally-automated assembly lines, automatic assembly robots, electronics and mechatronics products, and computer software.

The assembly robots are used in automated lines in various types of manufacturing industries, contributing to greatly improved productivity. Moreover, unitization and componentization of parts will facilitate the recycling of automobile parts and materials.

Negative impacts will be increases in R&D costs resulting from automobile unitization and componentization, which, in turn, will expand the technological areas under the control of auto parts makers.

From the standpoint of technological assessment, since research will be conducted in an automobile development system which encompasses a broad scope of technological fields, ranging from the planning and design stages to that of automatic assembly, the results of future research will be extremely fruitful.

Techno Superliner

1. Outline of Technology and Products

In addition to its own buoyancy, the Techno Superliner has a support structure of a hydrofoil lift and a hover craft's air pressure system skillfully combined. This is a new technical concept on which the Techno Superliner is constructed. Techno Superliner, with its load capacity of 1000 tons and speed of 50 knots, is a seaworthy liner designed for ocean voyages, capable of sailing without any difficulty in a rough weather even when waves are from 4 to 6 meters high.

Because of its high speed, its use in the 21st century as a high-speed liner linking the Far East/Southeast Asia and Japan, and as a means of high-speed transportation for domestic use, replacing trucks, for example, or as a high-speed ferry, is expected. It is considered as one of the major means of transportation for the future.

2. Long-Range prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then the present juncture in the Techno superliner R&D would be assigned a numeric value of 40, which means that practical utilization would be realized at some time around the year 2010.

Comparison of advanced industrial nations' R&D efforts at this point indicates that although Japan has been conducting a large-scale R&D project since 1989, aimed at building a reduced scale model ship within 5 years, no such development activity is seen either in the United States or Europe.

Key technologies requiring breakthroughs will be those aiming for the development of a combined-support type of ship-model propulsion system, with hull attitude control, and using weather-resistant hull materials.

As obstacles to practical utilization, social constraints will deter the easing of navigation regulations, the enhancement of harbor facility functions, and the ensuring of safe night-time navigation. Economic constraints will deter establishment of the reasonable fares which will be essential if the Techno Superliner is to emerge as one of the future's major modes of transportation, given the high potential needs for this type of transportation.

The key to the solution of these problems lies in the extent the to which government is willing to support this technology by resolving existing legal problems and improving harbor facilities.

3. Impacts on Industrial Economy

It is estimated that the scale of the Techno Superliner market will reach the 100 billion-yen level at sometime around the year 2010, when its practical utilization will be realized according to present forecasting. Positive impacts will be experienced in shipbuilding and construction businesses. In addition, revitalization of the perishable foodstuff imports, transportation, and travel industries is expected.

From the technological assessment standpoint, since the Techno Superliner is a high-speed navigation vessel, it will be important to insure navigational safety of the vessel.

Surface-Effect Vehicle

1. Outline of Technology and Products

A launch, with a wing designed for gliding, will be lifted to 20 or 30 centimeters above the water by air pressure when the ship's speed exceeds a predefined limit. It, then, will glide above the water at a speed from 70 to 80 km an hour.Its use, under consideration, is as a leisure boat with a few-passengers capacity, or a sight-seeing ship with a passenger capacity of 20 to 30. As a future high-speed tour or leisure ship, the surface-effect vehicle is generating a great deal of expectation.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then the current juncture in R&D would be assigned a numeric value of 80, which means that practical utilization will be realized at some time around the year 1995. (for a 2-passenger leisure ship, practical utilization can be achieved a year or two earlier)

International comparison of R&D efforts at this point indicates that West Germany already has commercialized a 20 - 30 passenger ship. No examples of R&D in this field have been found in the United States. In Japan, also, a large 20 - 30 passenger ship is currently under development and its future looks promising.

Key technologies requiring breakthroughs will be those used in construction of lighter-weight ships, low noise engines, high output and light-weight engines, and of larger ships.

As for obstacles to practical implementation, a social constraint will be concentrated in the area of securing government's assistance in funding; and, there will be an environmental constraint, in the area of establishing measures for dealing with noise. Economic constraints will be in the areas of usage-development, mass production, and the lowering of costs.

In order to solve these problems, if a government support is available, development of new markets will be carried out smoothly.

3. Impacts on Industrial Economy

It is expected that the scale of the surface-effect vehicle market will reach the 10 billion-yen level in 1995 (the initial period of the practical utilization stage), which is not a large market; however, it will grow, and by the year 2010, it is estimated that it will reach the 30 billion-yen level.

Positive impacts will be the formation of the surface-effect vehicle manufacturing industry, and the vitalization of the leisure tour industry, a segment of the users of these surface-effect vehicles.

Negative impacts will be few; it is possible that motor-boat and hover-craft industries may be partially affected.

From the technological assessment viewpoint, since it is a high-speed launch, the problems of disaster at sea or of noise should be examined.

Intelligent Ship

1. Outline of Technology and Products

This is a ship's navigation system, designed to perform integrated sea and land operations through the processes of analysis and assessment of navigation-related information. Supporting these processes is an AI knowledge base containing support information obtained from land, various information available on shipboard, and a veteran sea captain's practical knowledge which have been formalized for incorporation into the knowledge base. This system eliminates the need for a navigation expert on board ship.

2. Long-Range Prediction For Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then the current juncture in the R&D would be assigned a numeric value of 10. This means that practical utilization of the intelligent ship would be around the year 2010.

Comparison of various countries' related R&D efforts at this point indicates that Japan appears to be substantially ahead of the rest of the world. The United States and Europe are at the same level.

Technologies requiring breakthroughs will be those used in the development of advanced artificial intelligence, advanced automatic driving systems, advanced satellite communication systems, integrated navigation support systems, shipboard work robots, and weather forecasting technology.

As obstacles to practical implementation, social constraints deterring funding system support, coordination of a development execution setup, and the construction of a navigation system, including overseas systems, may be mentioned. Economic constraints may affect deepening labor shortages in the future, although at present, the needs are not that urgent. Moreover, since the project requires construction of a large-scale system, substantial funding will be required for the undertaking of R&D projects. In order to solve these problems, it will be essential that the government provide strong support to achieve practical utilization of the intelligent navigation system, while considering the possibility of some kind of organizational setup designed to secure international cooperation.

3. Impacts on Industrial Economy

It is estimated that the scale of the intelligent ship market will reach the 100 billion-yen level (excluding system construction spending).

Positive impacts created by the intelligent ship on the industrial economy will be the formation of a new industry manufacturing advanced ship's navigation system, which will be engaged in R&D and production of advanced AI systems and satellite communication systems for intelligent ships. Another possibility will be the revitalization of the electric industry and of the communication equipment industry.

Negative impacts will be negligible. From the standpoint of technological assessment, we feel it is important to stress and ensure the safety factor.

Aqua Robots

1. Outline of Technology and Products

Designed to meet needs arising from the recent off-shore development of ports, harbors, and ocean, and future submarine-resources developments, an aqua robot has the capability to work in the depths of the ocean. It will become a technology which will be essential to the 21st century's ocean development.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then the current juncture in the R&D stage would be assigned a numeric value of 30. The United States, substantially ahead of Japan, will be the first to achieve practical utilization of this technology, followed by Europe, which also is more advanced technologically than Japan in this field.

Key technologies requiring breakthroughs will be those designed to remove such obstacles as underwater plants, for example, and to develop remote control technology, underwater walking, and underwater-power sources. Important support technologies will include underwater hot-wire communication, underwater measurement systems, and virtual reality systems.

As for obstacles to the practical implementation of the aqua robot, social constraints may tend to work against institutionalized financial support, while economic constraints, per se, include the need to promote R&D under present conditions and to reduce costs, although future needs will grow substantially.

In order to solve these problems, government support in achieving practical utilization of the technology or government orders for purchase of aqua robots will be essential.

3. Impacts on Industrial Economy

It is estimated that the scale of the aqua robot market will reach the 10 billion-yen level during the initial period of its practical utilization stage.

Positive impacts created by the aqua robotic technology on the industrial economy will be the establishment of an electric machinery industry which will manufacture tele-existence equipment, underwater communication equipment, and underwater measurement instruments, and also the revitalization of the robotic industry which manufactures aqua robots. The ocean resources industry, and construction and materials industries, also, will benefit.

We can think of no negative impacts which will affect the industrial economy. From the standpoint of technological assessment, we must ensure that oceanic developments will not disturb environmental harmony. In order to achieve this, random developments likely to follow commercialization of aqua robots must be avoided.

Massive Transport Passenger Planes

1. Outline of Technology and Products

A large-scale transport jet with the capacity to transport from 800 to 1000 passengers has the potential of becoming the major form of international transportation machinery in the 21st century, which is being characterized as "the age of massive movement."

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then the present juncture in the R&D stage would be assigned a numeric value of 10, which means that practical utilization will be realized at sometime around the year 2010.

Comparison of advanced nations' R&D efforts in the field of massive passenger transport planes at this point indicates that the United States has the most advanced technology and that Europe, also, is ahead of Japan in this field.

Key technologies requiring breakthroughs will be high output engines and light-weight airframe materials technologies. The main support technologies will include those of safe navigation systems, as well as search systems to be used in the event of disasters.

Obstacles to the practical implementation of this technology, in terms of social constraints, will be the difficulties faced by companies single-handedly undertaking R&D projects, which fact points to the need for international cooperation and for governmental aid in the form of financial support. Anticipated economic constraints point to the need for substantial R&D funding and to the importance of an international cooperative setup in R&D projects and in securing of research personnel.

In order to solve these problems, a strong national will, determined to pursue R&D in the international cooperative setup, will be essential.

3. Impacts on Industrial Economy

It is estimated that the scale of the massive transport passenger plane market will reach the 500 billion-yen level by the time practical utilization begins in the year 2010.

As positive impacts on the industrial economy, we suggest the revitalization of the aircraft industry manufacturing massive transport passenger planes, the aircraft-related equipment material industry, and construction industry which will be involved in the construction of airports.

Negative impacts will be felt by some segments of the existing high-speed railway system or the railway companies involved in future operation of high-tech trains currently under development.

From the standpoint of technological assessment, safety of the massive transport planes, as well as effects of the noise produced by their large output engines must be considered.

HST (Hypersonic Transport)

1. Outline of Technology and Products

The hypersonic transport, which can fly at ultrasonic speeds of above 4 - 6 mach, covers the distance between Tokyo and Los Angeles within from two to three hours and has the capacity ranging from 200 to 300 passengers. This new plane has the potential of becoming the major form transportation of the 21st century.

2. Long-range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then the present juncture in the R&D stage would be assigned a numeric value of 10, which means that practical utilization of the HST would be realized at some time around the year 2020.

Comparison of advanced industrial nations' R&D efforts at this point indicates that the U.S.'s technology in this field already has reached the most advanced stage, followed by those of Europe and Japan.

Key technologies requiring breakthroughs will include new-type engines, heat-resistant materials, development of light-weight airframe materials, and resolution of the sonic boom problems.

Obstacles to the practical utilization of HST from the social standpoint will be the lack of any national organizational setup for pursuing research, the fact that an international cooperative setup has yet to be established, and the fact that it is not possible for HST to utilize existing airport constructions. Economic constraints (although there will be a sufficient number of potential users) will consist of (1) poor prospects of establishing low fares and (2) the need for huge R&D funds.

In order to solve these problems, a strong national will to develop and to implement HST will be necessary.

3. Impacts on Industrial Economy

It is estimated that the scale of the HST market will reach the 500 billion-yen level at the time practical utilization is achieved. Positive impacts created by HST on the industrial economy will be the revitalization of the portion of the aircraft industry which will manufacture the HST and of the construction industry which will be engaged in airport construction. Secondary effects will be felt by the materials and the electronic communication industries. There hardly will be any negative impacts to speak of. From the standpoint of technological assessment, noise factors and the destruction of the ozone layers can be mentioned. Moreover, it is expected that the need for a giant airport will lead to construction of a marine airport in Japan.

Small Vertical Take-Off and Landing Propeller Aircraft

1. Outline of Technology and Products

A small VTOL aircraft equipped with propeller or duct fan, featuring either the TILT WING (a method whereby a wing attached to the propeller rotates horizontally and vertically) or the TILT ROTER(a method whereby a wing installed on a propeller rotates horizontally and vertically). It can accommodate anywhere between a few to as many as 12 or 13 crew members.

Since the aircraft employs vertical takeoff and landing methods, a small empty lot in an urban area can be used for the purpose of take-off and landing. It has the potential of becoming the 21st century's major form of inter-city business transportation, especially in Japan lying on a narrow strip of land.

2. Long-range Prediction for Practical Utilization

If the practical utilization were to be assigned a numeric value of 100, the present juncture in the R&D stage would be assigned numeric value of 20, which means that practical utilization would be realized at some tome around the year 2000.

Comparison of advanced industrial nations' R&D efforts at this point indicates that the United States is substantially ahead, followed by Europe.

Key technologies requiring breakthroughs will be the development of TILT mechanisms, reduction in engine noise, and development of a lighter-weight airframe.

Obstacles to the practical utilization of the aircraft, from the standpoint of social constraints, exist in the areas of augmentations of airport facilities for the handling of light planes, securing government aid for technological development/production, and in public measures for noise control. Economic constraints will be the deterrents against constructing well-coordinated infrastructures and the training of pilots.

3. Impacts on Industrial Economy

It is expected that the scale of the small-VTOL-propeller-plane market will reach the 10 billion-yen level in the initial period of the practical implementation stage, which will be around the year 2000, and will reach the 50 billion-yen level during the year 2010.

Positive impacts created by the small VTOL propeller plane will be the revitalization of the aircraft industry and of the transport business. Secondary effects will enliven the construction business and the pilot-training businesses.

Negative impacts may be felt by the helicopter manufacturers.

From the standpoint of technological assessment, the importance of successful anti-noise measures for cities and of the safety factor must be emphasized.

Small Vertical Take-Off and Landing Business Jet Plane

1. Outline of Technology and Products

This is a small vertical take-off-and-landing jet plane, whose vertical-ascendance and horizontal-propulsion fans, assembled into horizontal wings are operated by a jet engine. Its passenger capacity ranges from a few to thirteen people.

Although its vertical-landing-and-take-off capabilities allow the use of even a small city lot for this purpose, because of the noise factor created by the jet engine, it will be necessary to construct an airport in a suburban lot.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, the current juncture in the R&D stage would be assigned a numeric value of 10, which means that practical utilization would be realized at some time around the year 2000.

Comparison of advanced industrial nations' R&D efforts at this point indicates that the United States is ahead in this field, followed by Europe.

Key technologies requiring breakthroughs will be hovercraft technology and the development of a small light-weight engine.

Obstacles to the practical utilization of the small VTOL business jet, from the standpoint of social constraints, will be in the area of augmentation of a cooperative setup for public and private sectors, joint international developments, automation of commuter airport facilities, and of noise-control measures. Economic constraints will include deterrents to securing an international market and to the development of low-priced planes.

In order to solve these problems, a government support system designed to augment and coordinate the infrastructure and an organizational setup for securing international cooperation must be in place.

3. Impacts on Industrial Economy

It is estimated that the scale of the small VTOL business jet market will reach the 30 billion-yen level in the year 2000, the initial period of the practical utilization stage, and the 100 billion-yen level during the year 2010. Its positive impacts on the industrial economy will include the formation of new industries, such as the part of the aircraft industry which manufactures the small VTOL business jet planes, the aircraft rental/lease business and the aircraft maintenance businesses; and at the same time we will see the revitalization of the conventional aircraft industry and construction business.

Negative impacts may be seen partially in the helicopter industry.

From the technological assessment standpoint, it will be important to have both noise control and safety measures in place.

Underground Facility for Weightlessness Experiment

1. Outline of Technology and Products

By allowing a capsule to free-fall, using its weightlessness state while falling, various types of experiments can be conducted at a weightlessness-experiment underground facility. In order to obtain valid weightlessness time, it will be necessary to have an underground shaft with a depth of more than 500 meters. The capsule which falls inside a shaft will be controlled by a linear motor.

Included in these experiments are the inspection of equipment to be used in space, observations of the physical phenomena, and experiments in the dissolution and coagulation of materials. The experimental facility constructed with the assumption that it will be used in space serves an important function as a preparatory experimental facility for a production setup.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then the present juncture of the R&D stage would be assigned a numeric value of 50, which means that practical utilization of the underground weightlessness experiment facility will be realized at sometime around the year 2005.

Comparison of advanced industrial nations' R&D efforts at this point indicates that if Japanese efforts in this field were to merit 100 points, then both the United States and Europe would merit a score of 50. It appears, therefore, that Japan is well ahead of the other two.

Key technologies requiring breakthroughs will include a technology designed for the vertical use of the superconductive linear motor, a linear motor control technology, and a shaft environment control technology.

Obstacles to the practical utilization of the underground facility for weightlessness experiments, from the standpoint of social systems, will be the lack of clarity in the application of laws when deserted mining shafts are to be used as experimental sites and, from the standpoint of government policy, the weakness evidenced in organizational setup established to further space development. Construction of experimental facilities currently in progress at Kamisunagawa in Hokkaido and at Toki-shi in Gifu-keen indicates that these problems are gradually being overcome.

Economic constraints include the small amount of private investments in R&D, attributable to the small scale of the market. In order to solve this problem, it will be necessary to obtain a national consensus concerning use of space, to establish an organizational setup for space development, and to clarify the purpose of using the available underground facilities to conduct weightlessness experiments.

3. Impacts on Industrial Economy

It is estimated that the scale of the market for the weightlessness experiment underground facility will reach approximately the 10 billion-yen level, which is not as large as it should be. The construction of such an experimental facility will have positive impacts on the construction industry, the superconductive material-related industry, and the linear motor-related industry. We can think of no specific industry which will be adversely affected.

Use of such a facility will produce rapid progress in various types of R&D, thus positively, if indirectly, impacting the facility. Industries which will be the beneficiaries are the metallic materials manufacturing industry, the bio-related industry, other types of materials industries, and the electronic equipment industry.

From the standpoint of technological assessment, effects of the facility on the quality of underground water must be brought to our attention.

Lunar Research Base

1. Outline of Technology and Products

The lunar research base, aimed at scientific exploratory experiments and observation and resource development on the moon, is structured mainly with spheres and cylinders made of the aluminum group alloy. The internal part of the base is maintained at 1 barometric pressure, and all foodstuff and materials are being transported from the earth. As for gas and water, only if the need for them cannot be satisfied by facility will supplies be transported from Earth.

At the lunar base, exploration of the moon's surface will be conducted by the revolving moon observation equipment and the unmanned lunar vehicle. Preparation for the construction of the base will be performed by robots, subsequent to which, after a brief period of human occupancy, the construction of the lunar base with human occupancy on a regular basis, will be completed.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, the present juncture in the R&D stage would be assigned the numeric value of 25, which means that the practical utilization of the lunar research base would be realized in the year 2020.

Comparison of advanced industrial nations' R&D efforts at this point indicates that if Japan would merit a score of 100 points, then the United States would score 200 points and Europe 100 points. Japan is lagging substantially behind the United States in this field.

Key technologies requiring breakthroughs are as follows: since the moon's surface is a super vacuum, with its gravity measuring only one-sixth that of the earth gravity and with temperatures ranging from -170°C to 120°C, and since it is an environment showered by cosmic rays, it is suited for the development of materials which offer excellent cosmic-ray-shielding capability, excellent adiabatic characteristics, and quick response to temperature changes. The lunar research base is also suited for the development of unmanned devices (such as advanced construction robot), and rockets/space planes (as an efficient means of space transport). The following technologies, in addition, need to be developed: (1) those for the maintenance of the lunar base environment, (2) automated electric power and thermal control technologies, and (3) efficient communication technology between the earth and the moon.

As for obstacles to the practical utilization of the lunar research base, social constraints will be encountered in the areas of international agreement concerning the development of the moon and, policy-wise, the industry's effort to establish a national organizational setup to pursue the lunar development after the national consensus has been formed on the subject.

In order to solve these problems, an international agreement on the purpose of lunar development and the awareness and determination on the part of people to pursue the development.

3. Impact on the Industrial Economy

It is expected that the scale of the market for the construction of the lunar research base will reach approximately the 4 trillion-yen level (500 billion yen annually). The number of related industries' research laboratories, as a consequence, will be increased to approximately 100.

Positive impacts created on the industrial economy by the lunar research base construction will be the revitalization of the materials industry which produces the structural materials for the base, of the operational machinery industry which manufactures the construction work robots, and of the air-conditioning-related industry which will control the base's environment and which manufactures water processing equipment.

Moreover, the technologies which will be developed on the moon will offer (1) application possibilities to the nuclear power industry which requires a shielding material for the nuclear power, (2) use in the global environmental problem-related industry as the CO_2 fixing technology, (3) use in various types of work robots designed to perform under extremely severe working conditions, and (4) offering a wide variety of use in broad areas of industrial fields.

No industry will be negatively impacted.

From the standpoint of technological assessment, effects of materials which are showered by a large quantity of cosmic rays must be examined.

Linear Motor Catapult

1. Outline of Technology and Products

This is an economical and safe space launching system, with a superconductive linear motor installed in its orbit. The system is designed to catapult a shuttle into space by accelerating the carriage (on which the shuttle is placed) using a linear motor, thereby providing the initial speed and height required for a shuttle take-off into space.

The space shuttle, accelerated to the speed of 630km/hour at the 1,600-meter-high take-off point, will be separated from the carriage and catapulted into space, propelled by the same force used in rocket take-offs. Use of this system in space shuttle launching will result in a fuel saving of approximately 300 t.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then the present juncture in the R&D stage would be assigned a numeric value of 30, which means that it will be around the year 2010 when practical utilization of this technology will be realized.

Comparison of advanced industrial nations' R&D efforts at this point indicates that if Japanese efforts were score 100 points, the United States would score 80 points and Europe 0. Japan, therefore, appears to be ahead of the rest of the world.

Key technological developments requiring breakthroughs will include (1) a large superconductive linear motor technology, (2) a large-scale solar power system to serve as its power source, (3) power storage systems, and (4) construction technology and light-weight, strong materials required to build large-scale structures.

Obstacles to the practical utilization of the linear motor catapult, from the standpoint of social constraints, will be the general public's lack of interest in the subject of space development and the fact that no organizational setup for advancing the cause exists at the present time. Element technologies especially required in the construction of this facility are currently under development in R&D projects aimed at use for other purposes. For this reason, it will be necessary to establish an organizational setup designed to further R&D projects on system technology along with the development of element technologies.

Economic constraints will deter the industry's effort to realize low launching costs, lower than those of existing space craft launcher, including construction costs.

In order to solve these problems, it will be necessary to grips with the problem of space development viewed as a national undertaking. It will be especially important to clearly present the goals of space development and the means of achieving them, and to establish the concept of space shuttle and the basic specifications involved, after which the basic specifications of the linear motor catapult as a launching facility should be decided upon. It is essential that research and development efforts be integrated into a space development project.

3. Impacts on Industrial Economy

It is expected that the linear motor catapult market will reach approximately the 100 billion-yen level, and accompanying this development will be an increase in the number of related companies to 50.

Positive impacts which the linear motor catapult will have on the industrial economy possibly will be revitalization of the heavy electric industry which will manufacture the linear motors, the materials industry which will develop and manufacture light-weight and tough materials, the electric and electronic equipment industry which will produce solar batteries, and, finally, the construction industry.

We can think of no industry which will be negatively impacted.

From the standpoint of negative assessment, effects of noise and magnetic fields on living things must be considered.

Super High-rise Building

1. Outline of Technology and Products

This is a high-rise construction, with height ranging from 500 meters to 4,000 meters and with total area ranging from 35 ha to 7,000 ha; it can be used either as a residence or an office building, accommodating from 20,000 to 70,000 people. A high-rise building with such a large number of occupants already can be considered, in a sense, a city, and, as such, it has the need for functions similar to a conventional city's. Part of its infrastructure will be facilities for energy supply, high- and intermediate-grade water supply, waste water treatment, garbage service, and information and communication processing. Requirements of most of these facilities will be that they should be autonomous and should work efficiently.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage of a 500-meter-high building (100 stories) were to be assigned a numeric value of 100, then the present juncture in the R&D stage would be assigned a numeric value of 80, which means that it would be around the year 2000 when it would be put to practical use. With respect to a 4,000-meter high building (800 stories), if its practical utilization stage were to be assigned a numeric value of 100, then the numeric value of 20 would be assigned to the present juncture in the R&D stage, which means that it would be at sometime around 2050 when it could be put to practical use.

Comparison of advanced industrial nations' R&D efforts at this point indicates that if Japanese efforts in this field were to be given a score of 100 points, the United States also would be given 100 points and Europe 80 points, showing only a small degree of disparity.

Development of key technologies requiring breakthroughs will be in (1) aseismatic and control structures (height and scale will differ depending on structure), (2) materials with high level of strength and durability, (3) high-efficiency distribution-type thermal energy systems, (4) a water system with a step recycling-device aimed at achieving savings in water resources, (5) waste-transport and waste-management systems, (6) a new heavy-load-lifting system with a main road laid inside the building, and (7) disaster-prevention systems.

Obstacles to practical utilization of the super high-rise buildings from the standpoint of social constraints will be the problem of harmony, viz., whether they would blend in with the existing urban space and facilities. Viewed from the standpoint of the already existing city, a high-energy density and traffic/distribution density spots will emerge as a result. These effects, therefore, must be given adequate consideration. Economic constraints include the possibility of competition arising between the new and existing high-rise buildings.

In order to solve these problems, it is essential that a super high-rise building be incorporated into city planning as a kind of three-dimensional city within a city. Moreover, in order to improve its business opportunities, development of a module construction method and system will be necessary.

3. Impacts on Industrial Economy

It requires an expenditure of approximately 400 billion yen and a five years' time to construct a 500 meter-high super high-rise building (100 stories high) offering a total floor space of 35 ha. If such a building were to be built on the one-wing-every-two-year kind of construction schedule, it is estimated that the scale of the market will reach approximately the 200 billion-yen per year. The number of related industrial research laboratories, as a result, will increase to 30, including those of general construction companies, equipment and machinery manufacturers, as well as those of material manufacturers.

Positive impacts directly created by the super high-rise building on the industrial economy will be the revitalization of the existing construction industry, the metallic material industry, the equipment and machinery industry, and the electric and electronic equipment industry; and, also, indirectly, the revitalization of a wide variety of industries ranging from furniture to electric manufacturers.

The existing commercial office areas will be negatively impacted.

From the technological assessment standpoint, the effects of dry weather, wind, and radio-wave disturbances, as well as sociological effects on building users are factors to be considered.

Super Air Dome

1. Outline of Technology and Products

The air dome is a construction with a roof mainly built of film-type material; in other words, it is a kind of air-film architecture in which internal pressure is maintained at high level by external atmospheric pressure. The Tokyo Dome Baseball Stadium is a typical example of this type of a building. The "super air dome" would be a building containing huge amount space, covering the entire region stretching as long as 1 km, large enough to accommodate 30 Tokyo Domes inside.

For instance, if a sea surface of 1,000 m x 900 m were covered by an air film of 130 meters, and if a natural sea surface and sandy shore are brought into the center of the dome, with hotels with various leisure facilities arranged around them, then it can be used as an all-weather-type resort in all seasons. Use of this type of resort can be considered in a desert area or in a region of high rainfall, thus offering the possibility of a living environment quite different from those existing before.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then the present juncture in the R&D would be assigned a numeric value of 50, which means that it would be around the year 2020 when practical utilization of the super air dome will be realized. However, a super air dome with an area of 5 ha, approximately several times the size of the present baseball stadium, may be put to practical use around the year 2005.

Comparison of advanced industrial nations' R&D efforts at this point indicates that if Japan's achievements in this field were to be given a score of 100 points, the United States would merit a score of 130 and Europe one of approximately 80.

Key technologies requiring breakthroughs will be those designed to develop (1) light-weight but extremely strong cables and film materials, (2) methods of comprehending and forecasting various types of external environments, (3) massive pressurized blast technology, and (4) environmental design technology suitable for a wide variety of regions.

Obstacles to practical utilization from the standpoint of social constraints will be the difficulty encountered by one segment of the private sector pursuing this kind of development on its own, inasmuch as the more extensive the space, the larger the regional development elements and the more urgent the needs will become for infrastructural accuracy of pleasure space. As for economic constraints, recognition of the need to pay the costs of pleasure space is yet to be developed; therefore, additional time will be required for this type of demand to surface.

Factors which will be necessary in order to solve these problems, will include the strong will of the industry to develop the super air dome, gambling, in a sense, on future changes in the general public's perception of leisure and on increased use of leisure space, as well as government cooperation in the enterprise.

3. Impacts on Industrial Economy

It is expected that the scale of the super air dome market around the year 2005 will reach the 100 billion-yen level. Accompanying this market will be an increase in the number of the related industrial research laboratories to the level of 30.

Positive impacts created by the super air dome in the industrial economy will be the revitalization of construction industry, the material industry which will produce cables and films, the electric machinery industry, and including large forced blast equipment manufacturers, the leisure industry which will use the super air domes, and the real estate industry.

Conventional types of leisure industry and the real-estate industries may be negatively impacted.

From the standpoint of technological assessment, effects of this proposed huge artificial facility on the water systems and air temperatures of surrounding environments outside the dome should be considered.

Demolition Technology for Super High-Rise Building

1. Outline of Technology and Products

The demolition technology, when applied to the monolithic construction, is a technology designed to demolish a building, safely, with the use of explosion; and, when applied to the prefab construction, it is an automated disassembling technology with use of robots.

Demand for demolition of high-rise buildings is generated by aging building functions or when use of an area is altered by redevelopment.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then the present juncture in the R&D stage would be assigned the numeric value of 19. This means that practical utilization of the super high-rise demolition technology will be achieved by the year 2010.

Comparison of advanced industrial nations' R&D efforts at this point indicates that if Japan's achievements would merit a score of 100 points, then the United States' score would be 150 points and Europe's approximately 80. The United States, therefore, is ahead of the rest of the world.

Key technologies requiring breakthroughs will include safety measure technology designed to protect surrounding areas against effects of blast, universal robotic technology required in automatic disassembly, a technology designed to sort various disassembled materials, and a recycling technology for disassembled materials.

Obstacles to practical utilization from the standpoint of social constraints would be in the area of revision of legal system to deal with blast demolitions and the need for pursuing that field's R&D in which the government will act as a driving force in dealing with the problem of developing an adequate method for treatment of disassembled waste and of securing dumping sites.

Economic constraints will affect the industry's effort to deal with the question of how the demolition costs can be incorporated into land-use plans following demolition.

In order to solve these problems, it will be necessary to elucidate the concept of the use of urban space in a way which will be more in tune with changing city functions; it also will be necessary to allow the demolition demands to come to the surface. In discussing one of the effective methods for dealing with developments and changes taking place in cities, it is important to have an understanding of the regional redevelopment method and to secure financial assistance from national or local government.

3. Impacts on Industrial Economy

It is expected that the scale of the super high-rise building demolition market will reach approximately the 10 billion level, although much will depend upon the extent of demand for regional redevelopment. Along with this factor will be an increase in the number of related company research laboratories to 20.

Positive impacts created by super high-rise building demolition will be the new formation of the high-rise building demolition industry and the revitalization of the explosive devices industry, the resources recycle industry, the portion of the construction machinery industry which manufactures disassembling robot, and the particular portion of the chemical industry which will develop a concrete degradation solvent.

The conventional construction materials industry and the design consultant industry will be impacted negatively as demands for super high-rise buildings, constructed with demolition in mind, increases. Also on the rise will be needs for materials and designs which will be geared to demolition and devices employed in accomplishing demolition.

From the standpoint of technological assessment, disaster prevention measures designed for protection of residents in surrounding areas and the securing of waste-treatment sites will be the factors requiring consideration.

Underground Distribution Network

1. Outline of Technology and Products

A distribution system, aimed at easing traffic congestion on large cities' roads and achieving labor savings in the transport industry, employs a network of underground tunnels and is equipped with underground the distribution centers, established for the sole purpose of serving the distribution needs of large cities. In order to make this system function efficiently, in the case of Tokyo, a tunnel with a total length of from 300 to 400 km and 150 underground distribution centers will be required. Transporting the containers on trucks is one of the shipping methods under consideration. The system will be connected to highway interchanges, ports, and harbors.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, the present juncture in the R&D stage would be assigned a numeric value of 60, which means that it would be around the year 2010 when the practical utilization of the underground distribution network would be realized.

Comparison of advanced industrial nations' R&D efforts at this point indicates that if Japan were to be given a score of 100 points for its achievements in the field, then the United States would merit a score of 80 points and Europe, also, 80 points. Japan, therefore, is slightly ahead of the rest of the world.

Key technologies requiring breakthroughs will include (1) an unmanned freight carrier technology (linear-motor driven), (2) an automatic unloading and sorting technology, (3) a centralized technology for total navigational management, (4) a high-speed and massive volume distribution information management and communication technology, (5) an underground disaster prevention and maintenance management technology, and (6) structural technology designed for great depth and large-scale underground space.

Obstacles to practical implementation from the standpoint of social constraints would be the problem of deep underground land ownership, a consensus view of the present state of the transport industry, and restrictions imposed on construction sites for distribution centers by the presence of existing buildings' basement floors.

As for economic constraints, because of high costs of total construction and the length of time required for construction, initial investment, of necessity, will be large.

In order to solve these problems, it will be essential to make the underground distribution network as the basic social facility, a clear-cut statement of its place in the framework of future city planning, and to pursue this aim as a specific plan under the strong leadership of the national government providing investment figures and detailed examination of direct and indirect effects.

Technological problems will be solved by intensive research investments. It will be necessary to clarify the problem of underground land ownership rights as soon as possible as this fact will greatly affect the extent of investments.

3. Impacts on Industrial Economy

It is expected that The scale of the underground distribution network market will reach the 5 trillion-yen level (approximately 500 billion yen for the year) for the entire business (land costs not included). Accompanying this will be an increase in the number of related company research laboratories to 80.

Positive impacts created by the underground distributions network on the industrial economy will include the revitalization of (1) the construction industry which constructs underground facilities, (2) the wheel manufacturing industry which manufactures linear motor cars, (3) the parts industry which manufactures tracking coils, and (4) the electric and electronic industry.

The automobile (truck) manufacturing industry will be negatively impacted.

From the technological assessment viewpoint, easing of traffic congestion, reduction in nitrogen oxide exhaust gas fumes, resolution of labor shortage problems in the shipping and distribution industry, and ease with the maintenance of the 24-hour distribution setup need to be considered.

Deep Underground Railway and Road Facility

1. Outline of Technology and Products

The underground railways and roads will be constructed in the great depth of the underground lying beneath the metropolitan area. Because of the construction zone's great depth, existing facilities above ground will not be affected. The deep underground railways will be planned as a newly-built lines and a four-track line of the existing lines, and the function of "business building" most likely will be added to large-scale terminal underground stations with a multi-layered underground mall. The underground road probably will be planned as a route to supplement existing metropolitan highways.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then the present juncture in R&D would be assigned a numeric value of 80, which means that practical utilization of the deep underground railway and road facility would be realized in the year 2005.

Comparison of advanced industrial nations' R&D effort at this point indicates that if Japan's accomplishments were to be given the score of 100 points, then the scores of both the United States and Europe would be 70 points, giving us the impression that Japan is slightly ahead of those two.

Key technologies requiring breakthroughs will be those for construction of a tunnel with great depth and distance, an intensive exhaust gas processing technology, an intensive waste heat utilization technology, a linear motor rail technology, and an integrated disaster prevention technology for the underground.

As obstacles to practical utilization from the standpoint of social constraints will be the huge sum of money required (1) to provide the deep underground railways and roads with an identity as a social foundation to be maintained in urban areas, (2) to strengthen government's support to systems set up to further efforts in this field, (3) to resolve property rights to deep underground space, and (4) to maintain the main lines. As for economic constraints, since we feel that there will be a sufficient number of potential users, the same rates as those established for existing lines should be charged.

In order to solve these problems, it will be necessary to limit private property rights (parcelled land rights) insofar as deep underground space marked as a public facility is concerned so that costs involved in use of underground sites can be kept low. Moreover, it is important for the country to establish a clearcut policy concerning public investment in enterprises which augment social capital funds.

3. Impacts on Industrial Economy

It is expected that the scale of the market for the deep underground railway and roads facility will reach the 230-billion-yen level a year. Accompanying this will be an increase in the number of related company research laboratories to 100.

Positive impacts of the deep underground railway and road facility will be directly felt by (1) the construction industry which builds underground facilities, (2) the electric and machinery industry which manufactures the related equipment and machinery, and (3) the material industry (metals, cement and other materials). The construction of railways and roads will induce new regional development and urban redevelopment.

Negative impacts will be felt by existing shopping malls.

From the technological assessment standpoint, disaster prevention and safety factors, ventilation systems for exhaust gas, changes in the underground water systems, and removal of massive surplus soil are the areas which require attention.

Underground Heat Reserve System

1. Outline of Technology and Products

The total amount of exhaust heat generated in an entire city, involving use of energy saving technology which effectively employs hot exhaust heat generated within a city, factory exhaust heat, subway exhaust heat, and building exhaust heat, is huge; however, its thermal density is low. An underground heat reserve system is designed to store heat bit by bit and to supply it when demand arises. This heat reserve system utilizes the deep underground space.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, the present juncture of R&D in the underground heat reserve system would be assigned a numeric value of 5, which means that it would be around the year 2020 when practical utilization will be realized.

Comparison of advanced industrial nations' R&D efforts at this point indicates that at present neither the United States nor Europe is pursuing R&D in this field.

Key technologies requiring breakthroughs will include a heat recovery technology for low density heat exhaust; a heat-pump thermal exchange technology for deep underground soil foundations; an explanation of the compound action of the soil foundation's underground water osmosis, temperature, and pressure; and a deep underground-soil composition survey technology.

Obstacles to practical implementation requiring attention from the standpoint of social constraints would be the part which will be played by the preservation of a city environment in building a city's "heat island" and obtaining consensus of city residents on the need for energy saving.

As for economic constraints, it will be necessary to establish competitive utility rates, after comparing the heat-reserve system with other systems of energy use, not only from the viewpoint of what beneficiaries must pay in order to cover the cost but also from the viewpoints of preservation of the environment and of energy saving, as well.

To solve these problems, the country must have a strong determination to implement effective use of unused energy (from the viewpoints of city environmental preservation and energy saving) by means of a soil foundation-based heat reserve system. required.

3. Impacts on Industrial Economy

It is expected that the market scale of the underground heat reserve system will reach the 150 billion-yen level. Accompanying this will be an increase in the number of related-company research laboratories to the level of approximately 30.

Positive impacts created by the underground heat reserve system on the industrial economy will include the revitalization of the heavy machinery industry; the construction industry; and the metallic materials industry, used in heat supply pipes and other related products.

Negative impacts will be felt by the suppliers of conventional types of heat.

From the standpoint of technological assessment, any effects on underground water flow and any chafes which may occur in it should be taken into account.

CO_2 Catalytic Fixation Technology

1. Outline of Technology and Products

Of the catalytic techniques which convert CO_2 into fuels and useful chemicals, the following methods show the most promise: (1) the catalytic hydrogenation method which creates methane, ethanol, and formic acid, mainly by using the VIII group metal-bearing solid catalysts; (2) the electrochemical method, which obtains reduction of CO_2 using electric heat of metals (mercury, lead, etc.); (3) the photochemical fixation reaction method, which uses ruthenium, lead, and other metal colloidal catalysts; and (4) the artificial photosynthetic method designed to imitate natural photosynthesis by using porphyrin.

Serious effort in developing these technologies has not yet begun. Only the future can tell us which technology will become a major force.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, the present juncture in R&D would be assigned a numeric value of 10, which means that it would be around the year 2010 when practical utilization would be realized.

Comparison of advanced industrial nations' R&D efforts at this point indicates that the levels of achievements of Japan, the United States, and Europe in this field are about equal.

Key technologies requiring breakthroughs will be those used in improving catalytic reaction efficiency and achieving high performance, i.e., a longer life-span, and an explication of artificial photosythetic-reaction mechanisms.

An obstacle to practical implementation considered important from the standpoint of social constraints will be the necessity to develop usage for materials produced by the CO_2 catalytic fixation technology. As for economic constraints, since a huge quantity of catalysts will be required by this technology, it is important that every means of achieving low costs should be tried.

To solve these problems, a government-sponsored development project will be necessary. Since the themes which must be dealt with cover an extensive area, planning for an efficient means of research will be important.

3. Impacts on Industrial Economy

It is expected that the scale of the CO_2 catalytic fixation technology market will reach the 300 billion-yen level by the year 2010 when practical utilization is predicted.

Positive impacts on the industrial economy will be the formation of a new industry which manufactures CO_2 fixation equipment and a fixed CO_2 treatment industry, as well as the revitalization of the industry which manufactures equipment designed to deal with environmental pollution, of the catalyst manufacturing industry, and of the waste treatment industry.

No industry will be negatively impacted by this new technology.

From the standpoint of technological assessment, the environmental impact of the fixed CO_2 treatment site will offer an important research theme.

CO_2 Plant Fixation Technology

1. Outline of Technology and Products

This technique immobilizes CO_2 through the use of the photosynthetic capacity of sea or land plants. In the case of sea plants, use of algae (brown algae, such as giant kelps and sargassos, and microorganic algae, such as the cyanobacteria) in the fixation technique are receiving attention. Development of massive cultivation technology using the optic-fiber photoconductive system and food and feed technology using algae are currently in progress.

On land, the fixation method, basically, is employed in afforestation; especially noteworthy is the high-water-absorption polymer method used in turning deserts into green land and in mangrove afforestation.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then a numeric value of 5 would assigned to the present juncture in R&D, which means that practical utilization will be realized at sometime between the years 2020 and 2050. The reason why such a wide margin is allowed for the prediction is that the technology must go through the following stages: (1) the collection of plants which offer a high success rate of photosynthesis; and then if this is successful, (2) biotechnological R&D which entails conversion of the photosynthesis success rate into genetic recombinant technology. Moreover, at the present stage, the research itself has just begun, and we feel that there are still too many uncertain elements to be dealt with.

Comparison of advanced industrial nations' R&D efforts at this point indicates that in this field Japan, the United States, and Europe are approximately at the same level.

Key technologies requiring breakthrough will be the high-density algae cultivation technology and a technology designed to promote the growth of forests.

Obstacles to practical utilization in terms of social constraints will be in the area of international cooperation requiring the understanding of developing nations. Economic constraints will be in the area of government support, which is crucial to utilization.

In order to solve these problems, a government-led project will be essential, and the fact that international cooperation, including that of developing countries, especially is important in promoting this kind of project.

3. Impacts on Industrial Economy

Since it is difficult to predict how the CO_2 plant fixation technology market will develop, we are not able to write a market creation scenario; hence the difficulty of predicting the market scale.

Positive impacts of the CO_2 plant fixation technology would be the formation of a new food and feed industry and revitalization of the green industry, the food industry, and the feed industry.

It will not be likely that any industry will be negatively impacted.

From the standpoint of technological assessment, it is important to bear in mind the effects of the uncontrolled growth of seaweed will have on the marine product environment.

CO_2 Treatment Technology

1. Outline of Technology and Products

The CO_2 treatment technology can be further divided into recovery, liquefaction, and CO_2 storage technologies. The recovery technology consists of an alkanoramine group liquid-based chemical absorption method, a zeolite-based chemical absorption method, a zeolite-based adsorption method, and a film-separation method employing a separation membrane. Existing liquefaction technology, although usable, has a problem of a tendency to decrease in liquefaction power energy, a problem which must be resolved. At present, use of cold LNG is being considered.

As for the storage technology, a deep sea storage method currently under investigation utilizes the characteristics of CO_2 (viz., it turns into a sherbet-like substance when atmospheric pressure is above 300 and temperatures range between 0 and 10°C).

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, then the present juncture in the R&D stage would be assigned a numeric value of 30. As for the year when practical utilization will be achieved, of the CO_2 treatment technology, the recovery technology already has adsorption and film separation methods in place; it is estimated, therefore, that its practical use will be achieved around 2010. As for the liquefaction technology, all that must be done is to improve the existing technology. Because of the massive volume of CO_2 involved, the storage technology has a long way to go before we can make some kind of estimate as to its utilization stage. One of the methods of storing CO_2 is to use the ocean bottom, and it is predicted that partial utilization will be realized by the year 2010.

Comparison of international R&D efforts at this point indicates that the United States is slightly ahead of Japan and Europe, which find themselves at about the same level in this field.

Key technologies requiring breakthroughs will include development of materials used in separation films, adsorption, and absorption liquid; also required will be a deep sea structure construction technology and an energy saving-type liquefaction technology.

Obstacles to practical implementation, from the social standpoint, will be societal concern for how the ocean floor storage of CO_2 may affect the ocean depths. Economic constraints will be in the area posed by the question of how CO_2 can be put to use, as it will be produced in huge quantities.

3. Impacts on Industrial Economy

It is estimated that the market scale of the CO_2 treatment technology will reach the 100 billion-yen level around the year 2010, when practical utilization will commence.

Positive impacts of this technology on the industrial economy will include the formation of the new CO_2 equipment manufacturing and CO_2 waste treatment industries, and revitalization of the environmental pollution equipment and the chemical material industries. It will not be likely that any industry will be negatively impacted.

From the standpoint of technological assessment, because of the huge quantities of CO_2 being produced, it will be important to watch closely the environmental effects of treatment sites and the dissolution of CO_2 into sea water at the ocean bottom.

Freon Substitution Gases

1. Outline of Technology and Products

At present there are five types of freon which are specified as toxic and must be replaced by some other substances. Of these, substitution gases for the most widely used CFC11, CFC12, and CFC113 are currently under development. However, this does not mean that these substitutes are completely free of environmental pollutant; they are temporary substitute freon gases. Research and development of a completely harmless third generation of gases will be undertaken at sometime in the near future.

2. Long-Range Prediction for Practical utilization

If the practical utilization of freon substitute gases were to be assigned a numeric value of 100, the current juncture of R&D for temporary freon substitutes would be assigned a value of 80, which means that the practical utilization would be achieved around 1995.

Comparison of international R&D efforts at this point indicates that the United States is ahead in this field, followed by Japan; Europe is lagging considerably behind.

Key technologies requiring breakthroughs will be those used in improving properties of substitute freon and in achieving low cost.

As for obstacles to practical utilization, social constraints will be in the area of international regulations which must be strengthened and in the general public's concern for the global environment.

In order to solve these problems, it is important that the government grapple with them from the standpoint of research and development as well as from their legal aspects.

3. Impacts on Industrial Economy

It is estimated that the scale of the freon substitution gas market will reach the 50 billion-yen level in the year 1995, the year when practical utilization would be realized; for temporary freon gases, the 80 billion-yen level would be reached in the year 2000, and that thereafter, growth would cease, remaining at the 80 billion-yen level.

Positive impacts on the industrial economy will be mostly of the secondary effect type; these will touch the electronic and refrigerator industries. Other than these, we see nothing which could be called "new impacts."

Neither do we see any industry which may be negatively impacted; from the technological assessment standpoint, however, since temporary freon substitution gases will not be completely free from toxicity, the development of non-hazardous freon substitute gases should be pursued on a long-term basis.

Freon Recovery and Treatment Technology

1. Outline of Technology and Products

The recovery technology of refrigerants already has been established, technically, simply by using a recovery container and pressure differential. Recovery in the purification field already has been perfected. Widespread use of these technologies in the consumer field, however, is faced with bottlenecks. Technically, adequate recycling treatment also can be achieved easily.

2. Long-Range Prediction for Practical Utilization

If the practical utilization stage were to be assigned a numeric value of 100, the current juncture in the R&D stages would be assigned a numeric value of 90, which means that practical utilization of the technology in question would be realized in approximately 1995. In the electronic industrial field, the freon recovery and treatment technology already has been put to practical use and is being sold as equipment. The industry will be targeting the consumer field. Equipment to recover and treat freon from refrigerators and automobile/home appliance coolers is currently under development.

International comparison of R&D efforts at this point indicates that Japan is ahead of the United States, and the United States ahead of Europe in this field.

There are no key technologies which require breakthroughs.

As obstacles to practical implementation, in terms of social constraints, establishment of a recovery and treatment setup for waste in the consumer field will be important. Economic constraints include those which hamper industry's efforts to deal with non-marketing principles and to achieve low costs.

In order to solve these problems, establishment of the freon recovery and treatment setup in the consumer field and an aggressive national policy aimed at excluding the technology from any application of the high-pressure gas control law.

3. Impacts on Industrial Economy

It is estimated that the scale of the market for the complete freon recovery and treatment technology will be somewhere from the 80 billion-yen level to the 100 billion-yen level.

Positive impacts of the technology on the industrial economy will include revitalization of the environmental control equipment industry which manufactures freon recovery equipment, freon recycling and treatment equipment, etc.

The freon substitution gas industry will be negatively impacted as the new technology will be competing with that industry.

From the standpoint of technological assessment, it will be necessary to turn recovered freon gas into a non-hazardous substance and to discard it.

Nature-Degradable Plastics

1. Outline of Technology and Products

Of natural decay plastics, R&D of photodegradable plastic and biodegradable plastic are currently in progress. Because its characteristics limit the area of applications and because decomposition does not take place if no light is available, photodegradation plastic is not suitable for general use as wrapping material. Biodegradable plastic, on the other hand, is a plastic material decomposed by microorganisms in Nature. The latter technology is currently under development, and can truly be called the technology of the future.

2. Long-Range Prediction for Practical Application

If the practical utilization of the nature-degradable plastic were to be assigned a numeric value of 100, then the present juncture in the totality of R&D stages would be assigned a numeric value of 30, which means that its practical utilization will be realized in approximately the year 2020.

Comparison of advanced industrial nations' R&D efforts at this point indicates that the United States is ahead in this field, followed by Europe and Japan, in that order. The reason why Japan is trailing in this field is that regulations governing the use of plastics already have been established.

Key technologies requiring breakthroughs will include biotechnology and high polymer technology.

Obstacles to practical utilization in terms of societal constraints will be the need for government support in terms of funding and organizational setups and regulations governing use of currently available plastics. We perceive see economic constraints in the areas of creating a market and lowering costs without, at the same time, violating laws and regulations.

Solutions of these problems will depend on the country's willingness to do something about them.

3. Impacts on Industrial Economy

It is estimated that the market scale of the nature-degradable plastic market will reach 100 billion-yen level in the year 2020 when practical utilization will be realized. By the year 2010, it is estimated that it will reach the 500 billion-yen level.

A positive impact on the industrial economy will be the revitalization of the packaging-machine material industry.

Industries which will be negatively impacted are the refuse incinerator industry and plastic packaging material (for inventory goods) industry.

From the standpoint of technological assessment, it will be necessary to bear in mind that areas of garbage disposal sites will vary greatly, depending upon the amount of time required by the biodegradation process.

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