Introduction

The Third Science and Technology Basic Plan, started in fiscal 2006, calls for science and technology to be "supported by the public and to benefit society" as its primary tenet.

Based on the Science and Technology Basic Law, Japan has been promoting science and technology under three successive Science and Technology Basic Plans since fiscal 1996 and endeavored to expand government-funded R&D investments despite its tight fiscal condition.

Every edition of the Annual Report on the Promotion of Science and Technology describes in its Part 1 science and technology-related movements based on a specific theme, and this year's edition seeks to comprehensively introduce the results of the past efforts to promote science and technology to people. This reflects the beliefs that in order to obtain public support for the promotion of science and technology, it is essential to have people understand the results of the promotional activities, and that it is the responsibility of the government to endeavor to provide sufficient explanations in this regard if it is to promote science and technology.

In modern society, benefits of science and technology have spread throughout the whole society, supporting our lives as well as society. Many of these benefits have been reaped as a result of long years of research activities, and the process of moving technology from basic research to commercialization involves, in many cases, the interlocking web of the persistent large efforts of researchers and the research environment that supports the work and public financial support.

Meanwhile, research activities spurred by the intellectual curiosity or unfettered ideas of researchers may go on to create values that could be prized as intellectual assets for the whole of mankind, such as the discovery of new principles. Such achievement may have an impact on our concept of nature and mankind and on our thoughts, or serve as a seed of invention that will create significant social and economic values in the future.

Another important result of the promotion of science and technology is fostering of next-generation human resources. By engaging in research activities under the instruction of the teaching staff, young people who should play an active role in the future will obtain knowledge and acquire the ability for and habit of identifying problems for themselves and seek to resolve them through the process of trial and error. Human resources thus developed, including not only researchers and engineers but also other types of skilled people, play an active role in various sectors of society and support the foundation of society.

The achievements of R&D, inherited by next generation human resources, may lead to the discovery of new truths or create new economic and social values when applied to real-life society. Thus, there arises a cycle of knowledge created by human beings, being inherited and utilized by other human beings, which in turn leads to yet another creation and utilization of new knowledge. All throughout this cycle, the capability of human beings involved is the critical factor.

The Third Science and Technology Basic Plan calls for a shift of emphasis from scientific infrastructures to human resources as its second tenet.

Part 1 of this report examines the results of the promotion of science and technology from three points of view - creation of knowledge, utilization of knowledge, and succession of knowledge - and provides explanations by citing specific cases. And then it provides an outlook of how science and technology should be promoted in the future in light of the specific cases of the people, research environment and public support involved.

1.1 Results of Promotion of Science and Technology

1.1.1 Significance of Promotion of Science and Technology

Summary

Science and technology make our lives safe, convenient and delightful by creating intellectual/cultural values and economic/social values. Achievements in science and technology are utilized in every aspect of modern society and affect our lives. Japan has been promoting science and technology under three successive Science and Technology Basic Plans and has continued to produce a variety of achievements in recent years.

1.1.1.1 Benefits Produced by Science and Technology

(1) Science and technology in modern society

Today, as achievements in science and technology have spread throughout the whole society, we are affected by science and technology in every aspect of our lives, whether we are conscious of it or not. Economic activity in modern times owes much to achievements in science and technology, which make our lives safe, comfortable, convenient and affluent.

Because science and technology thus greatly affect people and create essential values for society, modern states promote them by establishing a variety of programs and mechanisms and by spending a vast amount of public funds under the commission of people. There is strong awareness that as a basis for promoting science and technology, it is necessary to have S&T understood by people and supported by society.

(2) Creation of intellectual and cultural values

Since the prehistoric era, mankind has been puzzled by mysterious and unknown things surrounding him, such as a variety of natural phenomena, as well as by human existence and behavior, tackled questions and mysteries, resolved them and acquired knowledge in the process of doing so.

Mankind has learned about the history and structure of the universe by exploring and studying outer space as well as oceans in an attempt to resolve questions about nature and "matter," and gone on to study the world of fundamental particles that constitute matter, and on to study the origin of the universe. Moreover, mankind has studied how life has come about in the first place and how the human species has evolved, in an attempt to resolve existential questions such as "Who are we?" and "From where did we come?"

This activity of intellectual exploration initially arose from personal questioning and inquiring for the purpose of resolving mysteries, not for the purpose of taking advantage of the knowledge acquired to develop practical technologies.

However, many of the people involved in such intellectual exploration have contributed to spreading new knowledge beyond their own geographical and time limits to civilized society at large by resolving mysteries and discovering new laws and principles of nature. Such people have also had great impact on people's concept of nature and mankind and thus transformed the behavior of individual people as well as the activity of society. There are many discoveries and new ideas that have revolutionized existing thinking, such as Charles Darwin's theory of evolution and Albert Einstein's theory of relativity.

New knowledge, after being sorted out, systematized and passed on to new generations, constitutes part of mankind's common intellectual assets. Based on the knowledge acquired through their own research activities and inherited from them, we deepen our understanding of the universe and nature, extend the limits of and improve the efficiency of our activities, including intellectual exploration, and acquire further new knowledge.

Intellectual assets thus inherited have a cultural aspect. Intellectual assets acquired as a result of people's questioning and inquiring spirits in a variety of fields satisfy the intellectual curiosity of the subsequent generations of people and provide guidance on how to understand themselves and mankind in general as well as nature and society. Therefore, the richness of the culture of a society depends on to what degree the society has accumulated such intellectual assets.

Modern society is often called a knowledge-based society. While all sorts of social activities, including manufacturing and economic activities, can be conducted only with the use of advanced technologies and only under advanced social systems, newly acquired knowledge leads to further development. It can be said that further development of Japanese society will depend on the strength of its intellectual base, namely the level of accumulation of intellectual assets. Scientific research, which seeks to tackle unknowns, resolve mysteries and

acquire new knowledge, is expected to grow further in importance.

Science and technology are becoming more and more advanced and complex. However, achievements in science and technology are filtering through our daily life so much that we may enjoy the convenience of various products without being conscious of the difficult theories and mechanisms that underlie them. Ironically, as a consequence of the easy convenience and familiarity thus realized, it has been said, science and technology have become a "black box" whose inner workings are invisible to ordinary people. Monopolization of science and technology by a small group of people with special knowledge and expertise and alienation of ordinary people from them could pose a threat to the very foundation of our society, for which a broad and diverse base of knowledge is essential.

In order to foster a social environment in which intellectual values are highly regarded and inquiring spirit is respected, it is important to vigorously implement measures for broadening and deepening people's understanding of science and technology, just as we seek to spread the benefits of achievements in science and technology widely and instill them into daily life.

(3) Creation of economic and social values

The progress of science and technology has brought a variety of benefits to society in the form of new products and technologies and also promoted economic development at the same time by creating new industries and expanding markets.

The 20th century was an era when industrialization enabled by science and technology proceeded rapidly, new industries developed and economic activity expanded substantially. Japan, in particular, achieved remarkable economic growth after its post-war economic reconstruction, supported by the technological progress due to people's unflinching efforts, companies' active capital expenditures and vigorous research and development activities. This achievement owed much to Japan's tradition of craftsmanship.

Since then, there have been many cases in which the results of unique research by Japanese researchers eventually led to the development of new products, created new markets and expanded existing ones.

For Japan, which has limited natural resources, its technological prowess backed by science achievements acts as the engine of economic development and serves as the source of its national power amid intensifying competition with other countries.

In addition, science and technology help to significantly advance people's health and welfare and resolve social problems.

Overcoming diseases and realizing good sanitary conditions have always been the wish of people. Improvements in medical treatments and food supply conditions due to the progress in science and technology have remarkably extended life expectancy and helped to overcome many diseases. Moreover, forecasts of natural disasters and disaster prevention and mitigation technologies have made our lives safer, and advanced traffic systems have made it much more convenient. In addition, the progress in information and communications technologies in recent years has made great contributions to the creation of new means of entertainment. Thus, achievements in science and technology are utilized in every aspect of our lives.

Science and technology should continue to play a significant role in the future by leading research results to the development of new products and technologies, thus producing a major impact on people's lives as well as on the society and economy and enhancing welfare, and it should also contribute to resolving global problems.

(4) Positive and negative aspects of science and technology

Although science and technology have generated a lot of benefits for us, it cannot be denied that it also has a negative aspect given the problems they have brought about.

Throughout the 20th century, the range of human activity expanded quickly due to the rapid progress in science and technology, leading to mass consumption of resources, mass production and mass disposal on a global scale. This has caused environmental problems such as depletion of resources, global warming and the destruction of the ozone layer, and also widened the economic gap between developed and developing countries.

Moreover, the rapid progress in life sciences has raised ethical problems related to the fundamentals of life, by enabling genetic engineering, for example.

In order to tackle such problems, it is important to avoid entrusting science and technology entirely to the care of experts and treat them, including both their positive and negative aspects, as an issue for society at large and look for the right solution based on repeated debates by people in a wide range of fields. If we are to enjoy the benefits of the progress in science and

technology, we should naturally deal with the problems brought about by it as well. In this context, it will become more important to make efforts to forge a consensus, based on open debate, as to whether or not a certain technology should be promoted, how it should be utilized and how its impact should be controlled.

It cannot be denied that global environmental problems and many other worldwide problems have arisen due in part to the rapid progress in science and technology. However, it is also true that appropriate utilization of science and technology is essential for resolving those problems. We pin high hopes on the future role that science and technology will play in efforts to resolve problems common to people around the world.

1.1.1.2 Science and Technology Basic Plans and Government R&D Investment

Since the Meiji Era, science and technology have made immeasurable contributions to the modernization of Japan. Moreover, science and technology served as the engine of development for Japan during the periods of its postwar economic reconstruction and the ensuing high economic growth. In recent years, Japan has been promoting science and technology through public-private joint efforts, with a view to becoming an advanced science and technology-oriented nation.

Since the Science and Technology Basic Law was established in 1995, three successive Science and Technology Basic Plans (the first for 1996-2000, the second for 2001-2005 and the third for 2006-2010) have been adopted by the Cabinet, under which the Government as a whole has implemented measures for promoting science and technology.

In line with the plans, governmental R&D investments for the promotion of science and technology have been expanded, with investments under the First and Second Science and Technology Basic Plans totaling 38.7 trillion yen (Figure 1-1-1).

Under the Third Science and Technology Basic Plan, it is necessary to keep the amount of governmental R&D investments as a proportion of GDP at a level similar to the ones in the United States and European countries in order to continue the science and technology promotion efforts made under the first and second plans. To do so, investments totaling 25 trillion yen are expected during the period covered by the third plan (This figure is based on the assumption that governmental R&D investments during the period of the third plan in GDP will be 1% of GDP and that annual GDP growth will average 3.1% during the period in nominal terms).

The Third Science and Technology Basic Plan calls for "science and technology to be supported by the public and to benefit society" as its primary basic tenet in implementing the plan. Thus, the plan stipulates that it is

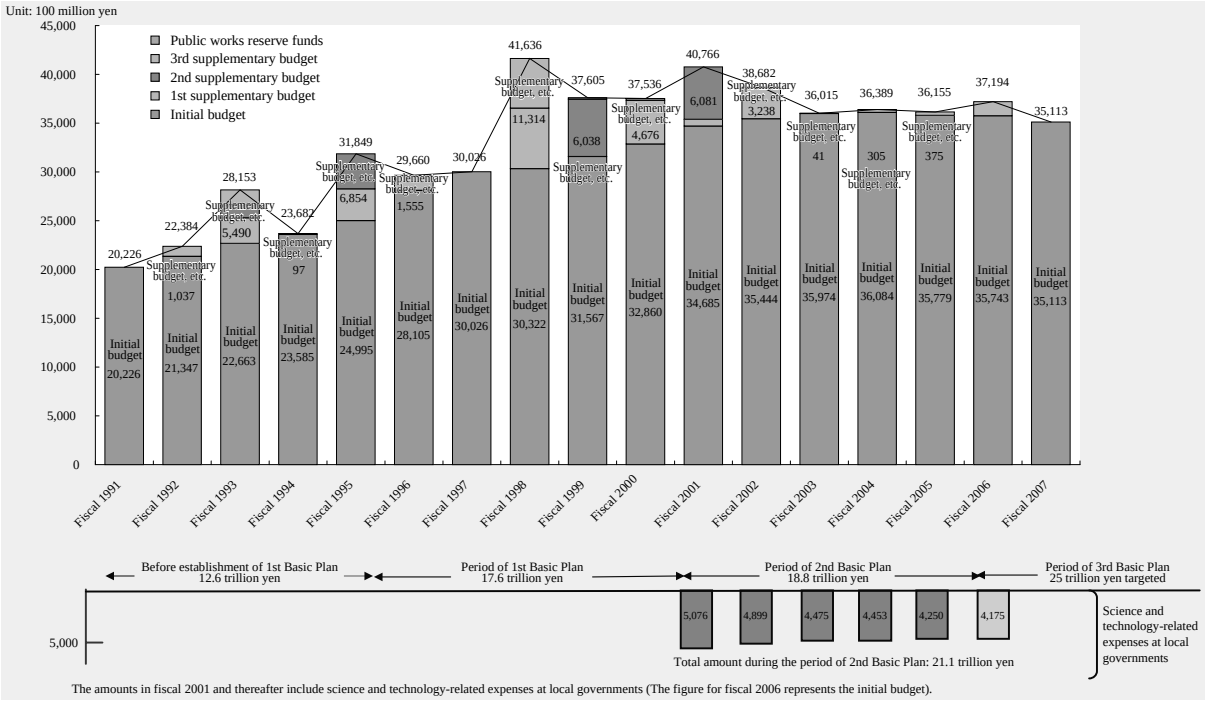

Figure 1-1-1 Trends in science and technology-related expenses

necessary to obtain public understanding of and support for science and technology through measures such as: making R&D investments in a more effective manner; creating intellectual and cultural values; increasing efforts to feed back the results of R&D to society and people; enhancing efforts to perform accountability to the public by providing comprehensive explanations concerning science and technology policies and their results.

1.1.1.3 Results of Promotion of Science and Technology

Over the past 10 years or so, Japan has endeavored to promote science and technology in a systematic manner under the Science and Technology Basic Plans. In many cases, the fruits of science and technology can be reaped only after many years of dedicated efforts, and it is not unusual that the origin of technologies now available and products now widely used dates back to 20 or 30 years ago (Table 1-1-2).

Below, we provide, from three points of view, an outline of the achievements of science and technology in recent years that had a significant impact on people's lives and the economy while referring to the history of how those achievements were arrived at.

(1) Creation of intellectual assets of mankind - Creation of knowledge -

Dr. Hideki Yukawa, the first Japanese Nobel Prize laureate, and other Japanese scientists have made world-leading achievements in the field of particle physics, which explores the fundamentals of matter. In recent years in particular, Japanese scientists have created a new academic field called neutrino physics and made world-leading research achievements in this field. In the field of outer space observation, meanwhile, Japanese scientists have found clues to what the Earth was like around the time of its formation based on data collected through detailed scientific observation of asteroids.

In the field of life sciences, Japan has also made world-class achievements, as shown by its participation in the successful attempt to decode the human genome under an international project and by the fact that Japan is the largest source of papers frequently cited around the world with regard to innate immunity.

(2) Returning the results of science and technology to the society - Utilization of knowledge -

There are a number of instances of Japan's achievements in science and technology in recent years contributing to the resolution of social problems and helping to enrich people's life. With regard to global warming, which is one of the greatest problems mankind

Table 1-1-2 Time of invention/discovery to commercialization regarding technology seeds

Technology	Time to commercialization	1960 1970 1980 1990 2000 2010 2020 2030	Outline of invention/discovery
Helical CT tech. useful for early detection of lung cancer	Approx. 10 years		1982: Acquisition of helcal CT patent by a private company (Japan) 1991: Commercialization of helcal CT (Japan)
Perpendicular magnetic recording tech. (for HDD)	Approx. 30 years		1976: Invention of perpendicular magnetic recording tech. by a university (Japan) 2005: Commercialization of HDDs using perpendicular magnetic recording tech. (Japan)
Tech. to increase density and extend operating life of lithium batteries	Approx. 10 years		1979: Development of lithium cobalt oxide as positive electrode material (UK) 1991: Commercialization of lithium batteries using lithium cobalt oxide in positive electrodes (Japan)
Photocatalyst materials	Approx. 30 years		1967: Discovery of photo disintegration of water (Japan) 1994: Commercialization of tiles/building materials using photo catalyst (Japan)
Residential photovoltaic power generation system	Approx. 40 years		1954: Fabrication of solar cells by Bell Laboratory (US) 1994: Start of subsidy program for Residential photovoltaic power generation systems (Japan)
Laser-based processing tech.	Approx. 20 years		1960: Dr. Maiman's successful attempt to produce laser beams using ruby laser (US) 1980s: Wide applications of laser for processing (Japan)

: Period between innovation/discovery and commercialization regarding technology seeds

Source: "Study for Evaluating the Achievements of the S&T Basic Plans in Japan" by the National Institute of Science and Technology Policy (NISTEP Report No.89, March 2005)

faces, Japan's achievements in science and technology have made worldwide contributions to the compilation of scientific data concerning climate change forecasts. In addition, Japan is also playing a prominent role in solar power generation, which helps to reduce carbon dioxide emissions, as the country has become the largest producer of solar cells.

Moreover, research results achieved in Japan have produced breakthroughs in technologies and products closely related to people's lives and generated great economic impact. Research conducted in Japan has also yielded significant results with regard to tasks for which social needs are high, such as the development of new disease treatment techniques, early diagnosis methods and drugs.

Meanwhile, joint research programs of universities and companies have increased rapidly as a result of the promotion of coordination between industry, academia and government, and in some cases, such programs have led to the development of new products based on research results obtained by universities, thus producing economic effects, or have helped to deal with environmental problems, thus making significant social achievements.

(3) Development of next-generation human resources - Succession of knowledge -

It is not too much to say that the development of science and technology depends on the capability and efforts of people involved in science and technology research activities. Therefore, the development of excellent human resources and the cultivation of an environment in which talents can be fully utilized form the basis of the promotion of science and technology.

Research activities at universities are conducted as one with education, an arrangement that enables graduate students and other young researchers to inherit knowledge obtained as a result of their predecessors' research activities and engage in research activities themselves in pursuit of new knowledge, thus acquiring the ability and habit of identifying problems and finding solutions.

Such education and research activities have the function of not only fostering and training academic researchers but also developing human resources capable of playing an active role in various sectors of society. Intellectual assets thus created are returned to society and contribute to social development through human resource development by universities and other institutions of higher education. Human resource development is an important element of the promotion of science and technology, while the benefits of knowledge succession spread beyond the circles of people involved directly in science and technology.

As the globalization of the economy proceeds and international competition intensifies, countries around the world are vying fiercely to secure science and technology-related human resources. For its part, Japan is also implementing measures for supporting young researchers, bringing diversity to university campuses and improving research facilities, with a view to attracting talented researchers, revitalizing the research environment and creating a favorable condition for researchers to fully exercise their capabilities.

As the Third Science and Technology Basic Plan attaches importance to the development of human resources and the creation of a competitive environment as a basic tenet, the importance of human resource development for the promotion of science and technology is expected to grow further.

In Section 2 and later, we will show specific examples of achievements in science and technology from the three points of view mentioned above.