S&T Policy Evolution: A comparison between the United States and China (1950-present)

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***Abstract*— In view of the evolution of Chinese and U.S. American research policy in the past 60 years, the two countries have undergone different stages of development. The S&T policy system in the United States was gradually built up since World War II, the benefit of research freedom adding to academic interest. The intervention and support for science and technology from the government has been gradually strengthened, promoting S&T development. Since the 1990s, the U.S. government has defined the five functions of science as serving national objectives, emphasizing S&T progress to promote sustainable economic and social development, and continued innovation to maintain the U.S. American leadership position. Although the country has experienced a number of economic or financial crises, the U.S. government's investment in basic research has followed a course of rapid growth, treating basic research as a source of innovation and power. The Chinese S&T system was established upon and developed on a very weak basis after the establishment of the new Chinese republic. In the 1950s, the recovery and establishment of the S&T system almost fully emulated the Soviet model. Up to the late 1950s, With the successful implementation of the 12-year S&T development plan, the key tasks and key engineering projects drove the development of the basic disciplines and initially established the basic research system in China. The Cultural Revolution decade made Chinese S&T undertakings grind to a standstill, further widening the gap in relation to advanced global levels. With the reform and opening up in 1979, the Chinese S&T system was restored again. Especially since the 1990s, the state increasingly invested in basic research more and more significantly, and S&T development in China entered a fast track of development while basic research as the source of innovation received more attention from government and community.**

***Index Terms*— Basic Research, Management System, S&T Policy, United and China**

I. The Background of Scientific Policy Evolution in the United States and China

A. *The scientific policy evolution of the United States*

THE enormous investment of the U.S. government in basic research did not start until World War II. Before then most of scientific research was subsidized by educational institutions and private foundations. The war strengthened the relationship between science and the government with the undisputable roles of both basic and applied research in national defense. Americans came to realize that government's participation would be helpful to the national development in many fields although some scientists were skeptical about the government's direct involvement in scientific research. From there, it was an inevitable trend that the federal government got involved in scientific research in a large scale.

The release of the report "Science: The Endless Frontier," assembled by Vannevar Bush, the former Director of the Office of Scientific Research and Development, to President Roosevelt is a had tremendous impact on post-war science policy This report, which aimed to find the best way to organize government support for science, laid the foundation for U.S. scientific policy after World War II. In this context, several federal research funding agencies were established, such as the Navy Research Office (1946), the Atomic Energy Commission (1946), the State Health Research Institute (1948), and the National Science Foundation (NSF) in 1950, to name just a few. They together constituted the modern science and technology funding and management system in the United States.

The successful launch of "Sputnik," the former Soviet Union's earth-orbiting artificial satellite, the Cold war, and the military technology competition between the United States and the Soviet Union further stimulated the government's investment in science and technology. Within the ten-year period from 1957 to 1967, the federal government's research and development investment quadrupled. A series of large-scale science research projects were implemented, while numerous American research universities established their global reputation. President Johnson's idea of *the Great Society* granted the NSF much wider responsibility. The NSF fund was increased from US$ 40 million in the fiscal year of 1957 to US$ 465 million in the 1967 fiscal year.

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Meanwhile, tremendous efforts to enhance the scientific research management by the federal government in this period were witnessed. In 1957, President Eisenhower reorganized the Science Inquiry Committee, an original subordinate to National Defense Mobilization Bureau, into the President's Scientific Advisory Committee. In 1962, President Kennedy established the Federal Science and Technology Committee to coordinate the federal government's management regarding science and technology plans. The Department of Defense (DOD), the Department of Health and Human Services (HHS), the National Aeronautics and Space Administration (NASA), as well as other federal agencies also set up ministerial scientific officials to lead the department's research work.

The economic crises in the late 1960s, however, forced the federal government to massively reduce national defense and space research funds. In the middle and late 1970s, American competitiveness was challenged by Japan and Europe, as evidenced by the reduced share of technical products on both the national and world market. Given the limited resources and budgets, more funds were shifted to solving social problems and promoting technology advancement. Consequently, in contrast to the general trend of the reduced federal government research and development, the research fund allocated to some priority fields, such as medicine, environment, and energy, demonstrated a slight increase.

In the early 1980s, Japan's ambition to surpass the United States and become the world economic power intensified the concerns among the U.S. representatives within global technological leadership. A set of science and technology policies and regulations were initiated, such as *The Stevenson-Wydler Technology Innovation Act*, *Patent and Trademark Act Amendments of 1980* (The Bayh-Dole Act) in 1980, the *Small Business Innovation Development Act* in 1982, the *National Cooperative Research Act* in 1984, the *Technology Transfer Act* in 1986, and so on. All of these, together with other stimulus plans, strengthened the U.S. American research and innovation capacity.

During Clinton's Administration, science and technology was put at the heart of the U.S. development strategy. In 1994, the report *Science in the National Interest*, which was the first presidential statement on science policy since 1979, set five main goals for U.S. science policy and corresponding policy measures. The functions of the White House Office for Science and Technology Policy (OSTP) were further strengthened to ensure the Federal investments in science and technology would make the greatest possible contributions to economic prosperity and national security.

In the Bush administration, the science and technology policies changed a lot after the terrorist attacks of 9/11 in 2001. The primary target was anti-terrorism and to defend the national security, the second was to maintain economical growth, while maintaining and to improving people's quality of life fell to the third goal. In July 2004, the White House Office for Science and Technology Policy (OSTP) issued a report named *Science for the 21st Century* and emphasized that science is a key factor in safeguarding the country's future security, prosperity and improving people's healthy standard and life quality, and will be always the key point of America. During his State of the Union address in 2006, President Bush announced the American Competitiveness Initiative (ACI) to encourage American innovation and strengthen our nation's ability to compete in the global economy. This ambitious strategy was expected to increase Federal investment in critical research, ensure that the United States continues to lead the world in opportunity and innovation, and provide American children with a strong foundation in math and science. The *American Competitiveness Initiative* commits $5.9 billion in the FY 2007, and more than $136 billion over 10 years, to increase the investments on research and development, to strengthen education, and to encourage entrepreneurship and innovation.

B. The Scientific Policies Evolution of China

When the People's Republic of China was founded in 1949, no more than 50,000 science and technology personnel and no more than 500 specialists were engaged in natural sciences research. The scientific research sector was extremely weak. Due to the special history, new China's science and technology enterprises at length followed the example of the Soviet Union in terms of organization, institution, management, strategy, plan, and education.

The Central Government established the Chinese Academy of Science in November 1949. In June 1955, the Academic Division of Chinese Academy of Science was established. This was a symbol that Chinese outstanding scientists could attend to the leading work of Chinese science and technology enterprise in a more organized way[1].

The Ministry of Education started to reorganize universities and colleges in 1951 so as to cooperate with the Soviet Union's aiding projects in terms of demand for professional experts. In 1957 the universities and colleges finished the reorganization with new management systems, disciplines, curriculum, teaching and textbook systems among other things. The educational scale was enormously expanded, and the urgent need for talent in economic development was solved. However, the reorganization also had negative effects such as narrow specializations, the separation between teaching and scientific research. With the help of the former Soviet Union in construction and equipment support, China made remarkable progress in industries like electric power, coal, petroleum, steel and iron, non-ferrous metal, automobile and aviation. Industries, provinces, autonomous regions, and municipalities directly under the Central Government established a series of scientific research institutions one after another.

China dispatched large numbers of students to study in the United States, Japan and England from 1946 to 1948, and 3,000 went back to serve the homeland until spring of 1957, which accounts for about 50% of the overseas students and scholars. From 1951 to

1960, 15,000 students were dispatched as interns to the Soviet Union and to Eastern Europe. The majority of them became outstanding personalities in and the backbone of Chinese scientific research and various professions.

Later, the Chinese science and technology enterprise began to take shape. Numbers of researchers grew beyond 9,000 and the numbers of research institutions increased from 40 in 1949 to more than 380. The variety of disciplines also increased. This progress laid a solid foundation for subsequent large-scale development in national defense, economic, and social development.

Two major plans, namely, Long-term Science and Technology Development Planning from 1956–1967 and Science and Technology Development Plan from 1963–1972, helped China step onto the development path of "planned science." The 12-year-plan from 1956–1967 proposed 57 important science and technology missions and decided on 616 key research topics. Among these, four urgent measures (computer, semiconductor, automation and electronics) and two confidential urgent measures (atomic bomb and missile) in 1956 functioned as the prelude to China's technological development. After the missile technology made breakthroughs, satellite research entered the national plan in January 1965. The 10-year-plan from 1963–1972 formulated the guidelines of self-dependence and catching up. At that time, the Sino-Soviet alliance was destroyed and developed into hostile relations. America started to enter Vietnam in 1961. China's international environment was extremely bad. The 10-year-plan proposed to concentrate on solving urgent and important science and technology problems in economic development. It set the principle of laying the solid foundation and grasping two ends. "Grasping two ends" referred to agriculture and science and technology related to food and clothing on one side, and science and technology of advanced national defense on the other. "Laying the solid foundation" referred to enhancing industrial science and technology rapidly, especially the basic industrial-technological level and the basic scientific research level.

Before the Great Cultural Revolution, the "Great scientific system" corresponded with China's planned economy obtained great success. The featured achievements were nuclear technology, astronautics technology, synthesized bovine insulin, and the discovery of the Daqing Oil Field. In addition, science and technology played a vital role in grain production, medical care, transportation construction, resources investigation and disaster defense.

The Great Cultural Revolution (1966–1976) seriously harmed Chinese science and technology. Scientific research management agencies were rendered nearly inoperable, and researchers' creativity suffered persecution. Basic research in China closed the door to the outside. Science and research stagnated. Although defense projects and key engineering constructions (e.g., the Gezhou Dam Hydro Power Plant and the Nanjing Changjiang Bridge) continued to obtain success. The science and technology gap between China and the Western countries grew.

In 1978, the Central Committee of CPC convened the profoundly significant national scientific congress. It dispelled chaos and restored order for the whole society. The right guidelines were set for scientific and technology. China's science and technology enterprises have entered a new development phase.

The Academic Division was restored at the Chinese Academy of Science in 1980. Many outstanding scientists returned to work in 1980. The doctoral and Master's degree systems were introduced in 1981. A natural sciences funding system commenced its trial phase in 1983. The national key laboratory construction plan began to be implemented in 1984; the post-doctorate research system started to pilot in 1985; the National Natural Science Foundation was established in 1986, and implemented science appraisal and applied a democratic policy-making funding mechanism to the basic research. In 1987, the National Science and Technology Commission (NSTC) has organized an investigation on the national basic research situation and development and formulated the National Medium- and Long-term Science and Technology Development Program. In 1989, the National basic research and applied basic research conference proposed explicitly that the basic research was one of three levels of China's science and technology developmental strategy, and China's basic research must persist stably. In 1990, the NSTC formulated the Eighth 5-year-plan of National Basic Research and Applied Basic Research.

The Central Committee of the CPC and the State Department issued the Central Committee of the CPC and State Department's Decision on Accelerating Science and Technology in 1995 and it explicitly proposed a strategy of reviving the country through science, technology and education. And to further strengthen basic science research, China started to formulate and implement the National Key Basic Research Development Plan ("973 Plan") in March 1997. Until then, the 973 Plan and the National Natural Science Foundation have constituted the Chinese government's two main channels of support for basic research.

In 1998, the Knowledge Innovation Program of the Chinese Academy of Science officially started. In 1999, the Program of Reviving Education for the 21st Century ("211 Program") started. These two great plans advanced basic research construction with Chinese characteristics.

After more than 20 years of reform and opening up, China's basic research has made remarkable progress and a framework and management of basic research with primarily indirect regulative mechanisms has been established. Chinese government and academia came to realize that indigenous innovation and quality-oriented are the keys for China's sustainable development of scientific research. Although China's basic research has made considerable achievements, there is still a big gap compared to the world's advanced level, especially the indigenous innovation achievements are quite few. Scientific papers of high quality are few, and the citation rate of scientific papers written by Chinese authors is still lower than the global average level. Scientific research infrastructure, especially the supporting conditions for basic research, is still obviously behind the international standard level.

The National Guidelines for Medium- and Long-term Plans for Science and Technology Development were issued in 2006, which has outlined scientific work for the next fifteen years. The Guidelines set a target to raise the share of China's R&D expenditures in GDP to 2.5% or above, with the contribution rate to science and technology progress reaching 60%, and the dependence on foreign technology being reduced by at least 30%. The authors of the document also expects that the increased number of Chinese invention patent grants and citations of Chinese scientific and technological (S&T) papers will make China reach fifth rank in the world. The guidelines established the principles of indigenous innovation, emphasis-based surpassing, development supporting and directing future. Basic research has a unique function in improving China's ability for independent innovation. Strengthening indigenous innovation is the main effort for independent innovation as well as the ultimate mission of basic research. In the future, Chinese scientific policies will be devoted to developing original innovation, providing impetus for significant breakthroughs, general technology and sustainable and coordinated development, and making contributions to cultivating emerging industries and leading the development of economy and society.

II. THE U.S. BASIC RESEARCH MANAGEMENT SYSTEM

As in all of its political systems, diversity is the main characteristic of the U.S. federal government's S&T management system. Legislation, judiciary, and administration intervened in policy-making and management regarding S&T from different angles. The U.S. federal government does not establish a department to manage overall S&T activities nationwide. Instead it adopts the pattern of disperse management and central coordination. Here, disperse management refers to each related department and organization of federal government that subsidizes and manages the S&T activities according to its special mission. Central coordination is mainly realized by the federal government's scientific development plan and budget decision-making process.

A. U.S. government S&T plan and budget decision-making system

The S&T development plan and budget of the federal government are decided by administrative departments under the direction of the President and Congress. The administrative departments are responsible for proposal, coordination, and demonstration of the scientific development plan and budget, and Congress is responsible for examining and approving the S&T budget.

1) Administrative departments for S&T planning and budgets' decision-making

Three administrative levels concern themselves with the S&T development plan and budget decision-making. The first is the National Science and Technology Council (NSTC), the second is the White House Office for Science and Technology Policy (OSTP), and the third are relevant federal government departments and organizations that subsidize and manage research and development activities. Each level has different responsibilities concerning the S&T plan and budget decision-making.

The NSTC was established in 1993 as an authoritative organization to aid the President in coordinating federal government science, space exploration, and S&T policy. The President is the chairman, and the members include the Vice President, the Director of OSTP, relevant cabinet ministers, the related principals undertaking important S&T responsibilities, as well as other White House officials. The NSTC has played a leadership role in S&T plan decision-making when President Clinton was in power. In S&T policy consultation, President Bush has laid even more emphasis on the President's Council of Advisors on Science and Technology (PCAST), the Office of Science and Technology Policy (OSTP), and the Office of Management and Budgets (OMB) undertaking the comprehensive coordinating functions in scientific policies.

Federal government departments proposed their S&T plans respectively and requested the R&D funds budget according to their missions. In fact, the majority of the federal government's S&T plans have been formed from the bottom up. It seems that the S&T plans and budget decision-making process are explicit and fixed, but the actual decision-making process is extremely complex.

2) Congress participation in S&T plans and budget decision-making

The Constitution gives Congress the right to legislative and budget approval involving the government budget of science and technology; consequently institutional settings and cancelling as well as making rules and regulations shall be subject to Congress for examination and approval before going into effect. The House and Senate set up different committees responsible for their related fields. Among them, the committees related to S&T plans and budget decision-making in Senate include the Appropriations Committee, the Budget Committee, the Commerce, Science & Transportation Committee, the Energy and Natural Resource Committee among others. The corresponding committees in the House include the Appropriations Committee, the Scientific, Spatial and Technological Committee, and the Environment National Resources Committee among others. In addition, three organizations of Congress support policy-making, namely the Congressional Budget Office, the Chief Audit Office, and the Congress Research Service Department.

After the President submits the S&T proposal to Congress, the related Congress committees will hold a series of public hearings and invite government officials and the public to attend and express their opinions. The committee may authorize, revise, or even veto the proposal. After the committee has discussed the proposal, it will be delivered to the Senate and House for public debate. After it has passed in the Senate and House, namely is passed by Congress, it is signed by the President, who will establish the President's Federal S&T Budget.

3) Factors influencing the S&T plan and budget decision-making process

U.S. American public policy-making is a complicated process. The decision-making bodies mainly include the White House, Congress, various government departments and organizations, members of Congress, and various lobbies (or interest groups). Because they have different statuses in the process, interests, and viewpoints, their power for influence are also different.

For the administrative departments, they always fight by any possible means for more allowance in the budget for their own plans. Among them, the Department of Defense and the Department of Health and Human Services are the most powerful departments concerning national security and people's well-being. They have accordingly obtained larger research and development budgets. The President is the advocate for national benefit who makes decisions in terms of national overall benefits, such as global environmental change, national objectives, national security, economical competitiveness, and citizens' quality of life. Congress makes decisions more in accord with constituency interests. Meanwhile, lobbies, major enterprises, specialized organizations and environmental protection organizations will make decisions for their own benefits and attempt to influence the S&T development plan and decision-making process. Public science organizations (for example National Academy of Science) and other nonprofit scientific research organizations will influence legislative decisions on development and needs of S&T and enhance the organization's academic prestige by providing authorized analysis reports for government or Congress. So the final result of policy-making will be an accepted scheme through different organizations' compromise and bargain. Generally speaking, the administrative opinion will dominate; that is to say, the U.S. American S&T plan is a political decision considering national benefit and a feasible common basis of compromise for different organizations. The structure of the U.S. government's S&T plan and budget decision is shown in figure 1.

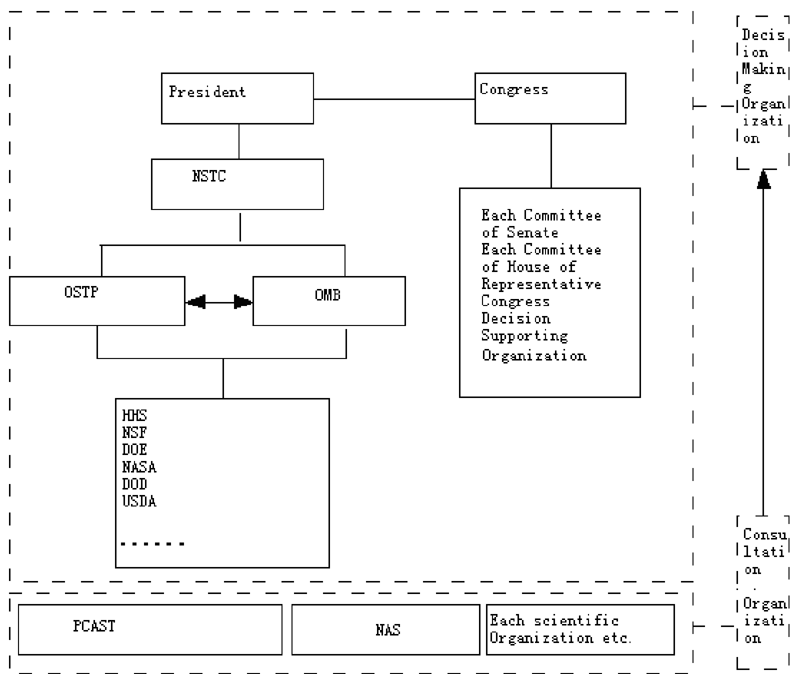

Fig 1. Structure of the U.S. government S&T plan and budget decision-making.

B. Main government departments responsible for funding and managing basic research

Six main departments (organizations) fund and manage basic research: the Health and Human Service department (HHS), the National Science Foundation (NSF), the Department of Energy (DOE), the National Astronautics and Space Administration (NASA), the Department of Defense (DOD), and the Department of Agriculture (USDA). The proportion of the total federal government's basic research budget going to these six departments (organizations) amounts to more than 95% (Table 1).

TABLE 1.
BASIC RESEARCH FUND AND R&D FUND OF SIX U.S. FEDERAL GOVERNMENT ORGANIZATIONS (FY2003) US$ BILLION

Department (organization)	Basic research fund	R&D fund

HHS	14.1	27.6
NSF	3.4	3.9
DOE	2.6	8.2
NASA	2.4	11.0
DOD	1.4	58.6
USDA	0.9	2.2

The Health and Human Service department mainly supports American's biomedicine research, whose research and development budget is only inferior to DOD, and ranks second among federal government departments. Half of HHS's R&D total fund has been used to support basic research in the universities and hospitals.

The Department of Energy (DOE) supports R&D activities regarding energy and related fields, and further encourages and participates in international R&D cooperation concerning energy and environmental issues. Some universities also manage laboratories that do applied research, such as Brookhaven (BNL), Los Alamos (LANL), Livermore (LLNL) and Argonne (ANL) National Laboratories.

One of the scientific research department with the biggest expenditures in the federal government is the DOD, whose total amount of scientific research funds has continuously accounted for 50% of the federal research budget for many years. DOD allocates funds directly to development facilities and signs research contracts with research organizations, industrial enterprises, and universities entrusted to support research and development for DOD. The overwhelming majority of scientific research funds of DOD (about 95%) is used to support applied research and experiment development. Very little of it (3–4%) is used to support universities' basic research.

The USDA is one system with vast research departments, which includes the Belz Vyell National Agriculture Research Center, four regional federal agriculture research labs, 68 award-winning agriculture colleges and universities, and 50 state-established agricultural experimental stations. Its system encompasses a total of 488 agricultural, educational, experimental research and technical promotion organizations, which have formed an agricultural research management system that unifies education, research and promoted application. Most of USDA's scientific research fund has been applied to the development facilities among which the basic research fund accounts for 40% of total scientific research funds.

The NSF is an independent agency of the U.S. federal government, which is primarily responsible for funding the basic research, education, and infrastructure development for all whole U.S. American universities and other academic organizations to guarantee the comprehensive and coordinated development of U.S. American science, engineering, and various other disciplines. The NSF's continuing mission is spelled out in the preamble to the *National Science Foundation Act of 1950* (Public Law 810507): NSF's mission is to promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense; and for other purposes.

III. The Management and Planning System of Chinese Basic Research

A. *The Chinese basic research management system*

After 20 years of reform and opening up, China's basic research management system reform has achieved significant progress, as evidenced by indirect control mechanisms for the basic research management system, which has strengthened the macro decision-making, the coordination of basic research, and established the science foundation and contract systems for allocating research funds. Generally speaking, China's basic research management system is highly centralized. The Chinese government has centralized the power of policy, planning, management, and assignment of funds into specific management and funding departments, while other departments are responsible for policy-making and the implementation of short-term projects. Composition of the national basic research management structure is divided into three levels: the highest decision-making level is the National Science and Education Leading Group; the coordination level is the Cross-ministry Coordination Leading Group of National Basic Research Programming; the executive level mainly includes the Ministry of Science and Technology (MOST), the Ministry of Education (MOE), the Chinese Academy of Science (CAS), the National Natural Science Foundation of China (NSFC), the National Development and Reform Commission (NDRC), the Ministry of Agriculture, the Ministry of Health, the Ministry of Land and Resources, the Ministry of Information Industry and others. Among them, MOST, MOE, CAS, and NSFC are dominant in the overall planning and budgeting of national basic research. They are respectively responsible for the formulation and implementation of important national basic research plans. Other departments also participate in the related basic research management according to their respective missions (Figure 2).

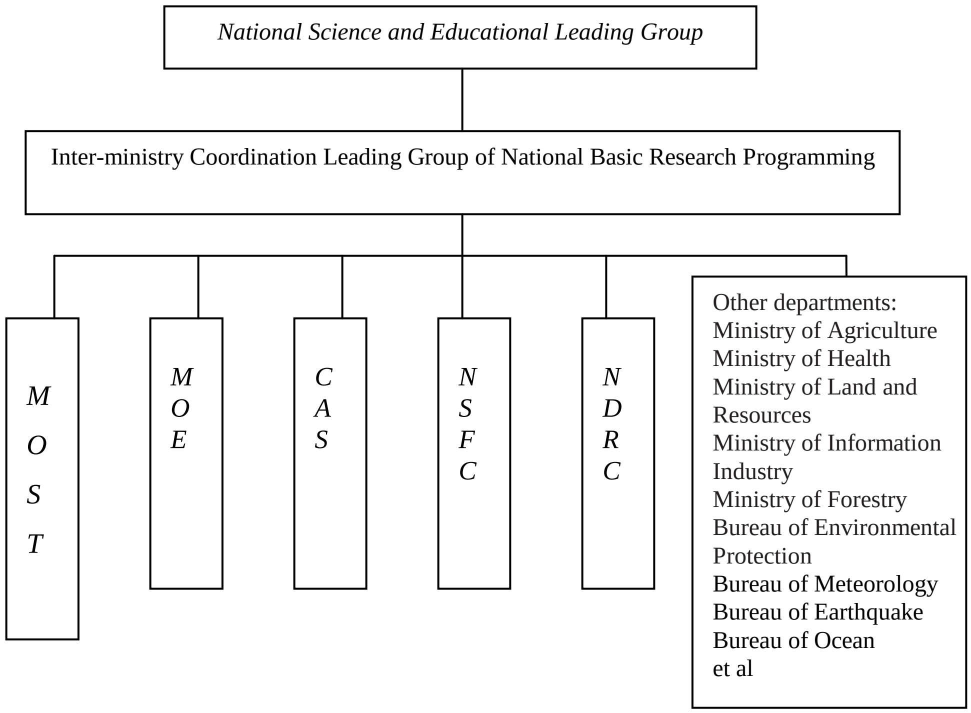

Fig. 2. Chinese basic research management systems

B. The Programming and planning system of Chinese basic research

The characteristics of the programming and planning system of Chinese basic research are *overall planning and implementation of sub-sectors*. The *National Guidelines for Medium and Long-term Plan for Science and Technology Development (2006–2020)* contains the top layout outlining Chinese science and technology work for the next 15 years and has the commanding function over national science and technology work. The *2006–2010 National Basic Research Plan* is the second-level plan, which implements the goals and tasks of the *National Guidelines*, comprehensively outlines national basic research work for the first 5 years, and instructs regarding formulating and implementing the national basic research plan as well as various departments' basic research work. China’s basic research programming and planning system are illustrated in figure 3.

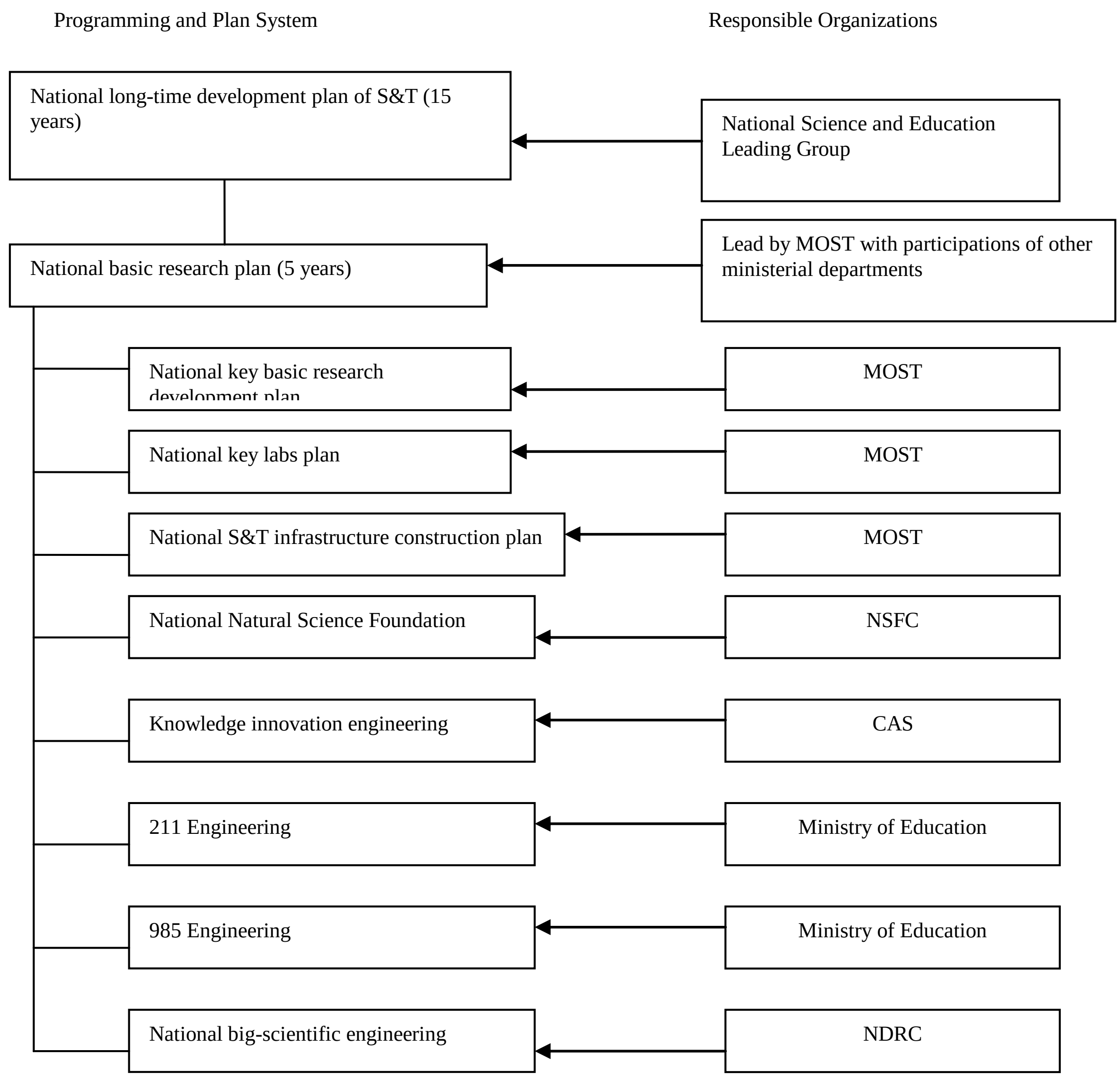

Fig. 3. Chinese basic research programming and planning system

1) *National Key Basic Research Development Plan*

The 973 Program was created by the National Steering Group for S&T and Education to build on existing research activities managed by the National Nature Science Foundation and organize basic research to meet China's major strategic needs. It was approved at the third meeting of the National Steering Group for S&T and Education on June 4, 1997 and is operated by the Ministry of Science and Technology. The National Basic Research Program (973 Program) is an on-going keystone research program in China. The strategic objectives of the 973 Program are to stimulate original innovations and to address scientific issues important for national economic and social development. The Key priorities of the 973 Program are threefold: (1) to improve research capabilities and advancing knowledge in fields that are critical to the development of the national economy and society; (2) to nurture research personnel with advanced proficiency in science; and (3) to create clusters of high-level, interdisciplinary research centers [2].

To date, the 973 Program has deployed 143 key projects with vital importance and guidance to the national economy and technical development: 17 of these projects are related to agriculture, 15 to energy, 18 to information, 18 to resources and the environmental, 29 to population and health, 18 to materials, and 27 interdisciplinary subjects. In total 206 research projects have been undertaken from 2001 to 2005, and the nation has altogether invested 4,000 million Chinese Yuan [2].

2) *National Key Laboratory Plan*

The National key laboratory plan started in 1984. After more than 20 years of development and construction, this plan has already become an important part of the national S&T innovation system, the base for organizing high-level basic research and applied basic research, outstanding trained scientists, high-level academic exchange. The national key laboratory plan has firstly implemented the operational mechanism of opening, flowing, united and competition, and emphasized a innovative cultural environment. It has formed the evaluation and management system that encourages innovation and competition. The central financial sector has invested 1,080 million Chinese Yuan in the national key laboratory plan before the end of 2003. At the end of 2003, 161 national key labs had been established with a fixed personnel of 5000 and more than 30 hundred million Chinese Yuan worth of instrumentation equipments. This enterprise has covered most fields of China's basic research and applied basic research (see figure 4).

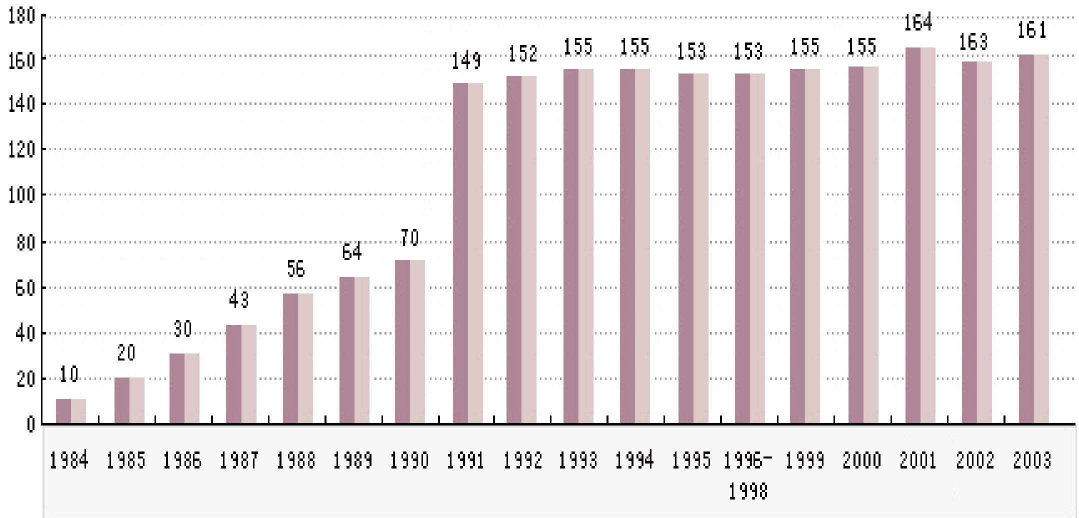

Fig. 4. Distribution of national key laboratories by year (1984–2003)

3) National Natural Science Foundation of China (NSFC)

Established in 1986, the NSFC is one of the important Chinese government agencies in support of basic research. The mission of the NSFC is to promote and finance both basic research and applied research in China. The NSFC manages the National Natural Science Fund and seeks to encourage innovation and support excellent and creative researchers who are funded on a competitive basis. The NSFC is administrated by the NSFC Council, which consists of a president, several vice presidents and council members. Members of the council are all experts in science, technology, or management; they are appointed for a term of four years. The NSFC has two offices, five bureaus, and seven scientific departments. The two offices are the General Office and the Office of Discipline Inspection, Auditing, and Supervision. The former coordinates the administrative work of the NSFC, and the latter supervises its funding activities. The five bureaus are the Bureau of Planning, which develops fund allocation plans; the Bureau of Policy, which researches policy aimed to develop the natural sciences and the management of natural science funds; the Bureau of Finance, which is responsible for financial management of NSFC funds; the Bureau of International Cooperation, which organizes natural science funds related to international cooperative activities; and the Bureau of Personnel, which is in charge of human resources. The seven scientific departments include the Department of Mathematical and Physical Sciences, the Department of Chemical Sciences, the Department of Life Sciences, the Department of Earth Sciences, the Department of Engineering and Materials Sciences, the Department of Information Sciences, and the Department of Management Sciences. These scientific departments are responsible for the management of funds and for developing research policy in their respective areas of expertise.

The NSFC fund has grown consistently over the years. The total amount grew from 80 million Yuan in 1986 to 3,400 million Chinese Yuan in 2006. The NSFC has utilized approximately 18,000 million Chinese Yuan invested by the country to support 100,000 outstanding scientific research projects. The NSFC insists on supporting basic research, has cultivated a large number of creative results, played a founding role in S&T activities. The Council further insists on remaining people-oriented, has trained a group of young outstanding talents and creative teams, and has played a nurturing role in scientific personnel training. Moreover, the NSFC insists on promoting balanced and harmonious development of disciplines and has promoted interdisciplinary research and of new disciplines' development, insists on promoting the combination of knowledge creation and technological innovation and has promoted the construction of the National Innovation System, insists on expanding the channel of international cooperation and has created a good environment of international cooperation and exchange (Figure 5).

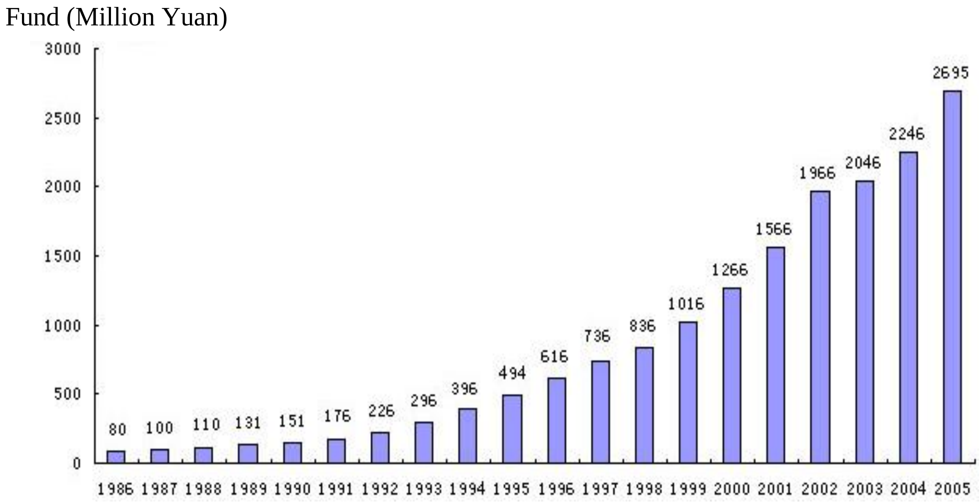

Figure 5. Increasing trend of NSFC’s fund from 1986 to 2005

4) Knowledge Innovation Program (KIP)

The Knowledge Innovation Program (KIP) was inaugurated by the Chinese Academy of Sciences (CAS) in 1998 and is expected to be completed in 2010. It is divided into three phases: the Initial Phase (1998–2000), the Phase of All-round Implementation (2001–2005), and the Phase of Optimization (2006–2010). The program provides funds to research institutes affiliated with CAS based on their achievement in order to allocate additional resources to the most promising institutes and research fields. By doing this, KIP aims to improve the scientific performance of CAS and build it into China's pre-eminent S&T centre for innovation capability. The Knowledge Innovation Program (KIP) is implemented in the form of three types of projects: Projects of Disciplinary Frontiers, which support frontier research in basic science and high technology; Projects of Major Research Orientations, which target fundamental and exploratory research that is important to economical and social development; and Key Projects, which support advanced research with industrial applications. Each sub-program has a different set of rules concerning its mode of operation. Selection criteria vary among sub-programs. Generally, proposals are evaluated based on the scientific merit of the project, the feasibility of the project within the time frame and research budget, capability and composition of the research team (favoring young researchers), and the potential impact on industrial application and social development [2].

5) 211 Project and 985 Engineering of the Ministry of Education

In 1997, as the State Department approved the 21st Century Action Plan for Invigorating Education, the Ministry of Education began implementing the "211" project, which emphasizes the construction of about 100 key universities and a number of key disciplines in the 21st century,

The *211 Project* has provided the necessary and advanced equipments for scientific frontier research for some key disciplines, which has strengthened the schools’ overall scientific equipment and enhanced the abilities to carry out frontier research and undertake nationally significant scientific research.

In May 1998, the Ministry of Education decided to support several universities in establishing world first-class universities and high-level universities, i.e., *985 Engineering*). The State Department has forwarded the *2003–2007 Education Promotion Planning* submitted by the Ministry of Education in March 2004. One of the two key strategies is to advance high level university and key discipline construction and continue to implement the programs *985 Engineering* and *211 Engineering*.

6) National Big-Science Engineering

National Big-Science Engineering is the key method for impelling Chinese scientific enterprise development and developing basic research, which is the important symbol of the national S&T development level, and it also manifests the country’s comprehensive power. In the s*eventh five-year plan* period, China has constructed 10 big-science engineering projects such as the Beijing positive and negative electron reactor and scored a number of international first-class research achievements such as *τ-lepton quality precision measurement.* In the ninth five-year plan period, China successively implemented 5 big-science projects, that is the national synchronization radiation laboratory second phased project, the China diastrophism observation network, the Datian Region area multi-objective optical fiber spectrum telescope, the HT-7U ultra request Carmack fusion test installation and the Lanzhou heavy ion accelerator cooled storage link. These projects have not only provided powerful support for obtaining significant unprecedented research progress, but have further improved China’s international scientific research status and prestige as well. At present, 19 big-science projects have been completed or are under construction, like the Beijing positive and negative electron reactor, the Lanzhou heavy ion accelerator and others. The implementation of national big-science projects plans has greatly improved China’s basic research condition and played an essential role in improving China’s knowledge and innovation ability, developing high and new technology, advancing discipline development, training outstanding talents, maintaining national security, and cooperating and competing internationally. During the e*leventh five-year plan* period, China will invest 6,000 million Chinese Yuan in the construction of 12 big-science projects.

IV. A COMPARISON OF THE UNITED STATES AND CHINA ON BASIC RESEARCH INPUT AND OUTPUT RATIOS

A. Analysis of U.S. American basic research funding

Basic research funds in the United States, R&D funds, the proportion of basic research funds to R&D funds and the GDP from 1953 to 2004 are shown in table 2.

TABLE 2.
PROPORTION OF U.S. AMERICAN BASIC RESEARCH FUND IN TOTAL R&D FUND AND GDP: 1953–2004

Year	Basic research	R&D funds	GDP	Basic research /R&D	Basic research /GDP	R&D/GDP
1953	2,387	26,805	1,973.9	8.91%	0.121%	1.36%
1958	4,360	50,659	2,162.8	8.61%	0.202%	2.34%
1963	9,196	76,276	2,690.4	12.1%	0.342%	2.84%
1968	12,840	93,881	3,466.1	13.7%	0.370%	2.71%
1973	12,220	92,271	4,123.4	13.2%	0.296%	2.24%
1978	14,434	101,057	4,760.6	14.3%	0.303%	2.12%
1983	17,514	130,676	5,132.3	13.4%	0.341%	2.57%
1988	24,687	166,935	6,368.4	14.8%	0.388%	2.62%
1993	30,560	176,270	7,062.6	17.3%	0.433%	2.50%
1998	34,158	219,288	8,508.9	15.6%	0.401%	2.58%
2002	44,810	249,678	9,439.8	17.9%	0.475%	2.64%
2004	50,644	270,826	10,180.8	18.7%	0.498%	2.66%
yearly average increase rate						
	6.173%	4.639%	3.269%			

As can be seen in table 2, the U.S. American GDP's yearly average increase rate has been 3.3% for 51 years and the yearly average increase rate of basic research funds and R&D funds respectively are 6.2% and 4.6%. Namely the yearly average increase rate of the basic research fund is 1.33 times that of R&D funds and amounts to 1.89 times the GDP's yearly average increase rate. In these 51 years, the American GDP has increased from US$ 1,974 billion (with a GDP per capita of more than US$ 10,000) to US$ 10,181 billion (with a GDP per capita of more than US$ 30,000), which is an increase by 4.16 times. The basic research funds have increased from US$ 2,387 million to US$ 50,644 million, which is an increase by 20.22 times. Funds for R&D have increased from US$ 26,805 million to US$ 270,826 million, which represents a growth by 9.10 times. In these 51 years the increase of basic research funds has amounted to 200% of the R&D fund and 500% the GDP.

Over the above examination period, the proportion of U.S. basic research funds to R&D funds has doubled, increasing from 8.91% to 18.7%. The proportion of U.S. American basic research funds to the GDP has nearly quadrupled from 0.1% to 0.5%, which means that the increase of U.S. American basic research funds is not synchronized with the national economy. It is obvious that basic research is of great importance to the national development.

A close relationship exists between the proportion of basic research funds to R&D funds and the funding structure of R&D funds. The more highly the central government funds R&D, the higher the proportion of basic research funds in comparison to R&D funds is. The proportion of the basic research funds of U.S. American funding departments in comparison to the national basic research funds of 1953–2004, and the proportion of basic research funds of American funding departments in comparison to R&D funds have been shown in table 3 and table 4 respectively.

TABLE 3.
PROPORTION OF U.S. BASIC RESEARCH FUNDS FROM DIFFERENT SECTORS IN THE TOTAL BASIC RESEARCH FUND (1953–2004)

year	federal government	industry	university	non-profit organization	non-federal organization
1953	57.7%	33.5%	1.3%	6.1%	1.4%
1958	57.0%	30.9%	2.5%	6.3%	3.3%
1963	68.3%	20.1%	2.7%	5.3%	3.5%
1968	71.1%	15.9%	4.6%	4.6%	3.9%
1973	69.5%	14.8%	5.4%	5.5%	4.8%
1978	71.1%	13.9%	5.7%	5.5%	3.7%
1983	66.6%	17.8%	6.8%	5.5%	3.3%
1988	61.2%	21.6%	7.7%	6.0%	3.6%
1993	57.1%	24.8%	7.9%	6.9%	3.3%
1998	58.9%	18.9%	9.9%	8.5%	3.8%
2002	58.9%	18.5%	10.3%	8.9%	3.4%
2004	61.8%	16.4%	9.6%	8.8%	3.4%

TABLE 4.
PROPORTION OF THE U.S. BASIC RESEARCH FUNDS BY SOURCE OF FUNDING: 1953–2004

year	federal government	industry	university	non-profit organization	non-federal organization
1953	9.5%	6.9%	16.3%	50.7%	16.9%
1958	7.7%	7.9%	43.4%	55.5%	43.2%
1963	12.4%	7.8%	60.0%	57.1%	60.0%
1968	16.0%	6.0%	70.1%	53.2%	70.8%
1973	17.2%	4.6%	65.0%	53.7%	65.1%
1978	20.3%	4.3%	58.7%	52.3%	58.7%
1983	19.4%	4.7%	60.2%	54.7%	60.2%
1988	20.1%	6.3%	60.5%	56.7%	60.5%
1993	27.1%	7.4%	61.1%	53.6%	61.1%
1998	31.3%	4.5%	67.6%	60.2%	67.5%
2002	37.4%	5.1%	68.2%	60.2%	68.2%
2004	38.6%	4.8%	68.3%	60.1%	68.4%

As can be seen in table 3, the U.S. federal government is the main funder of basic research, accounting for between 57–71.1%. The industry sector is the second largest source of funding of U.S. basic research, which accounts for between 13.9-33.5%. It is noted that universities support for basic research has continually grown over the past five decades, with an initial share of 1.3% to 10.3%. Non-profit organizations are the rank fourth among supporters; their proportion of contributions rises and falls, its lowest proportion was 4.6% in 1968 and the highest was 8.9% in 2002. Non-federal organization are in fifth place as supporters; their lowest proportion was 1.4% and the highest was 4.8%. Although the latter three departments' proportion is relatively small, together their contributions have already surpassed the second supporter, industry. In 2004, the proportion of the latter amounted to 21.8%, but industry's proportion is just at16.4%.

As seen in table 4, the three greatest funding sources are universities, non-profit organizations, and non-federal organizations over the above time period. The share of federal government's basic research funds in relation to R&D funds has continually increased, from 9.5% in 1953 to 38.6% in 2004. The proportion of basic research funds in relation to R&D funds, however, is relatively small.

Tables 5 and 6 show the proportion of the support rendered by the U.S. American performing sector in the total off national basic research funds and its proportion of the basic research fund in their respective total R&D fund from 1953 to 2004.

TABLE 5.
BASIC RESEARCH FUNDS OF THE U.S. AMERICAN PERFORMING SECTOR IN THE TOTAL NATIONAL BASIC RESEARCH FUNDS FROM 1953 TO 2004

year	federal government	industry	university	non-profit organization
1953	22.1%	32.8%	34.6%	10.4%
1958	15.8%	31.3%	42.1%	10.9%
1963	13.5%	24.7%	51.2%	10.6%
1968	14.3%	19.0%	57.9%	8.8%
1973	15.9%	15.5%	60.0%	9.0%
1978	15.0%	15.0%	61.5%	8.6%
1983	14.4%	18.5%	58.5%	8.7%
1988	10.7%	22.8%	58.7%	7.8%
1993	9.1%	24.1%	57.7%	9.1%
1998	8.5%	18.2%	62.3%	11.0%
2002	9.3%	16.9%	60.0%	14.0%
2004	8.4%	17.5%	61.1%	13.4%

TABLE 6.
THE PROPORTION OF THE BASIC RESEARCH FUND OF THE U.S. AMERICAN PERFORMING SECTOR IN THEIR RESPECTIVE R&D FUND TOTAL FROM 1953 TO 2004

year	federal government	industry	university	non-profit organization
1953	10.0%	4.2%	39.4%	43%
1958	9.9%	3.7%	49.2%	48.2%
1963	11.1%	4.1%	61.6%	55.6%
1968	13.3%	3.7%	67.2%	35.6%
1973	13.5%	3.0%	64.5%	34.6%
1978	15.0%	3.1%	63.3%	35.5%
1983	16.0%	3.4%	63.6%	37.7%
1988	14.8%	4.7%	61.8%	41.8%
1993	15.9%	5.9%	64.4%	43.3%
1998	17.3%	3.8%	69.3%	47.9%
2002	19.4%	4.3%	70.4%	50.9%
2004	19.8%	4.6%	71.4%	50.3%

As illustrated in table 5, universities are the main executor of U.S. basic research. The proportion of universities' basic research funds in relation to the total of U.S. American basic research funds is more than 50% in about 40 years and has remained at about 60% for a long time. The proportion of basic research funds from the federal government's executing facilities in relation to the total of U.S. American basic research funds has continually dropped, from 22.1% in 1953 to 8.4% in 2004. The proportion of the basic research funds from industrial sectors in relation to the total of U.S. American basic research funds is reverse; namely it has dropped from 32.8% in 1953 to 15% in 1978, then increased to 24.1% in 1993, and finally dropped again to 17.5% in 2004. The proportion basic research funds from non-profit organizations in relation to the total of U.S. American basic research funds have fallen from above 10% to below 8% and subsequently risen to 13.4%.

As illustrated in table 6, American universities take the lion's share of basic research funding.. The share of universities executing basic research in relation to their R&D funds is above 60% in the last 40 years, reaching 71.4% in 2004. Non-profit organizations have also treated basic research as one of the important parts in their research work; basic research occupies about 35–55% of their total research expenses. Federal government facilities have paid more and more attention to basic research, and its proportion in relation to R&D funds has risen from 10% to nearly 20%. The proportion of industry executing basic research in relation to total R&D funds is quite small at about 3–6%.

B. Analysis of Chinese Basic Research Funding

Chinese basic research funds have increased fast in the recent 20 years from 450 million Yuan in 1987 to 11,70 million Yuan in 2004; this growth tendency has particularly intensified since 1995 (figure 6).

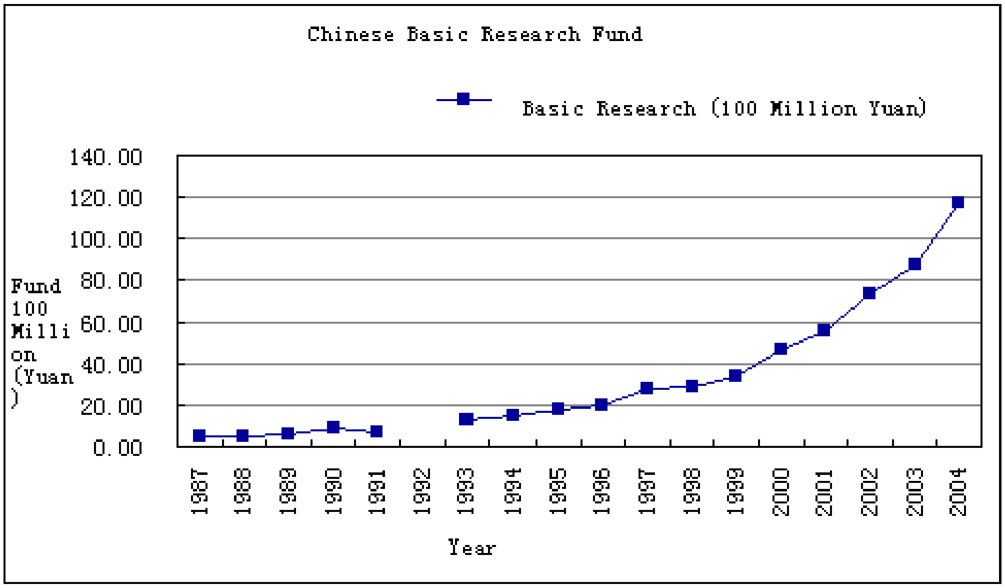

Fig. 6. Chinese basic research funds investment (1987–2004)

C. Comparative Analysis of Sino-US Basic Research Funding

In table 7, the proportion of Sino-America basic research funds in relation to R&D funds and the GDP has unceasingly increased since 1990. But in 2004, the proportion of Chinese basic research funds in relation to R&D was 1/3 smaller than that of the United States, and the proportion of Chinese basic research funds to GDP is 1/7 smaller than that of America.

TABLE 7.
PROPORTION OF BASIC RESEARCH FUNDS TO R&D FUNDS AND GDP IN UNITED STATES AND CHINA (1990–2004) (%)

	proportion of R&D				proportion of GDP			
	1990	1995	2000	2004	1990	1995	2000	2004
America	15.1	15.9	18.1	18.7	0.40	0.40	0.49	0.50
China	4.1	5.0	5.1	6.0	0.03	0.03	0.05	0.07

Source: National Bureal of Statistics, Ministry of Science and Technology. China Statistical Yearbook on Science and Technology. 1991-2005.

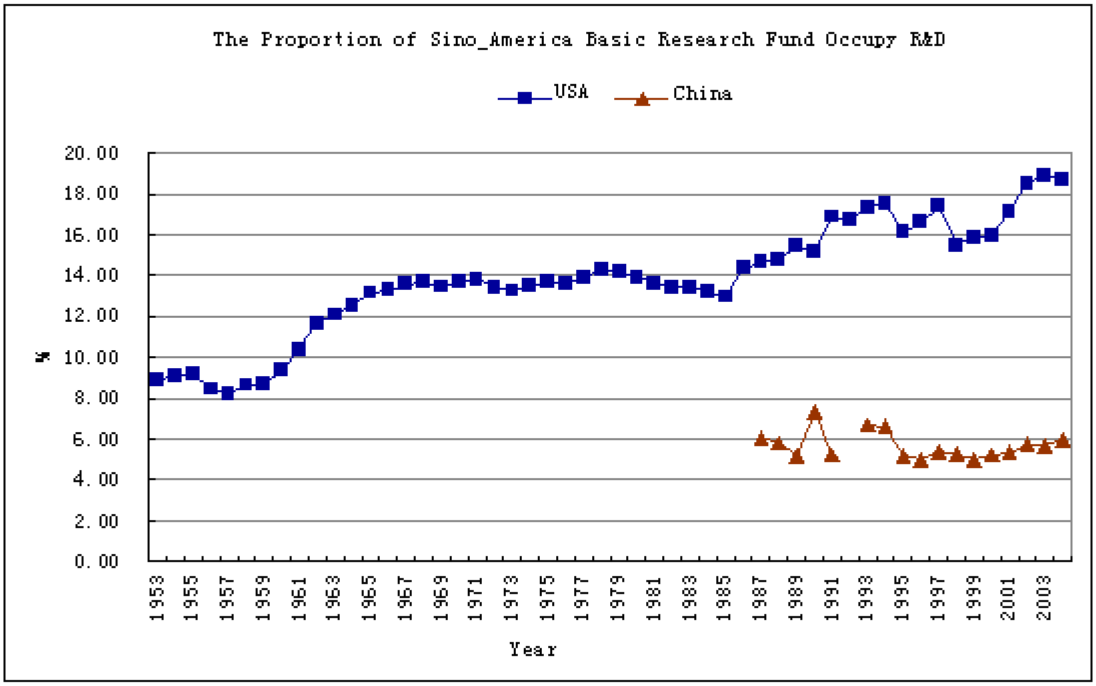

Fig.7. Proportion of Chinese and U.S. American basic research funds to R&D funds

No unified data exists about basic research funds differentiated by funding source. It is estimated that more than 80% of basic research is funded by the central government, about 5% comes from regional governments, while the remaining investment finds come from universities, scientific research institutions, and industry.[1]

From the proportion expenditures by executing departments of basic research in relation to R&D expenditure, the share of Chinese universities has increased from 16.6% in 1998 to 23.9% in 2004. The share of Chinese scientific research institutions has increased from 7.7% in 1998 to 12% in 2004. The remarkable difference lies in the comparison with the share of U.S. American universities, which was above 60% in 1963 and had reached 71.4% in 2004. Moreover, the share of America non-profit organizations had reached 50.3% in 2004.

D. Comparative Analysis of Research Output in United States and China based on SCI-indexed Papers

TABLE 8.
AMOUNT OF CHINESE VERSUS U.S. AMERICAN SCI PAPERS AND THEIR PROPORTION

year	1997	1998	1999	2000	2001	2002	2003	2004
Amount of Chinese Paper(piece)	16883	19838	24476	30499	35685	40758	49788	57377
The proportion of world paper amount （%）	1.84	2.13	2.51	3.15	3.57	4.18	4.48	5.43
rank	12	12	10	8	8	6	6	5
American paper amount (piece）	302521	299932	314120	305616	327199	313613	359610	342261
The proportion of world paper amount （%）	33.01	32.23	32.27	31.58	32.73	32.17	32.36	32.38
rank	1	1	1	1	1	1	1	1

The quality of scientific papers from China has rapidly improved, and their international influence has also been enhanced. Table 8 shows that Chinese SCI papers have increased in number yearly by an average 19.1%, and their proportion to world publications

[1] This is based on the author's own calculation of national major projects.

has increased from 1.84% to 5.43%; Chinese papers have risen in rank from twelfth to fifth. Meanwhile the number of U.S. American SCI papers has increased by a yearly average of 1.8% since 1997; and the United States have consistently ranked in first place.

From the number of papers as indicated by the data from American ISI, Chinese papers have been cited 842,000 times from January, 1994, to 31August, 2004, which represents an increase of 27.9% compared with 658,000 citations from 1993 to 2003. The Chinese national ranking rise from nineteenth to eighteenth position. The number of each paper's average citation has reached 3.01 times, which represents an increase from 2.78 times in the time period from 1993 to 2003. The Chinese ranking has risen from 127 to 124, which indicates that the influence of Chinese scientific papers has improved.

China's research level in the top field can be seen by analyzing papers issued in international high-quality periodicals, according to JCR data from American ISI. There are 85 periodicals with an international influence factor Imp≥10 (this refers to papers that are cited more than 10 times within these periodicals), and 22 of these periodicals evidence papers by Chinese authors, which amounts to a share of 26%. Among 17,799 papers in these 85 periodicals, 55 papers were published by Chinese authors, accounting for 0.3%. It is obvious that Chinese international scientific papers have little influence in the world.

V. CONCLUSION

In view of the evolution of Chinese and U.S. American research policy in the past 60 years, the two countries have undergone different stages of development. The S&T policy system in the United States was gradually built up since World War II, the benefit of research freedom adding to academic interest. The intervention and support for science and technology from the government has been gradually strengthened, promoting S&T development. Various national benefits and goals drove the efforts in different periods, such as the Cold War arms race, economic crises and social problems during the 1970s, and the pressure of improving the competitiveness of industries during the 1980s. These factors have profoundly affected S&T development in the United States. Since the 1990s, the U.S. government has defined the five functions of science as serving national objectives, emphasizing S&T progress to promote sustainable economic and social development, and continued innovation to maintain the U.S. American leadership position. Although the country has experienced a number of economic or financial crises, the U.S. government's investment in basic research has followed a course of rapid growth, treating basic research as a source of innovation and power.

The Chinese S&T system was established upon and developed on a very weak basis after the establishment of the new Chinese republic. In the 1950s, the recovery and establishment of a S&T system almost fully emulated the Soviet model. Up to the late 1950s, China built the "big science system". With the successful implementation of the 12-year S&T development plan, the key tasks and key engineering projects drove the development of the basic disciplines and initially established the basic research system in China. The Cultural Revolution decade made Chinese S&T undertakings grind to a standstill, further widening the gap in relation to advanced global levels. With the reform and opening up in 1979, the Chinese S&T system was restored again. Especially since the 1990s, the state increasingly invested in basic research more and more significantly, and S&T development in China entered a fast track of development while basic research as the source of innovation received more attention from government and community.

In view of management systems for basic research, although the U.S. government employs the dispersion management model, there is no uniform development plan or program. However, the science policy has maintained a high degree of coordination and stability, and Congress and government carry out their duties in the program and budget management system. This promotes the coordinated development of basic research. In addition, the consistent long-term and high-strength investment in basic research by the government provides good conditions for retaining a globally leading status. The Chinese basic research management system employs a highly centralized management model, unified planning and programming. The government's basic research fund is allocated according to several major scientific programs; MOST and NSFC play the dominant roles in program management. Since the reform of the S&T system in the mid-1980s, competition was introduced in the allocation of basic research funds through the Science Foundation System. Bidding for the allocation of funds for major projects has become an important method while gradually increasing special funding for the national key laboratories, universities, and research institutions. The main problems are as follows: coordinating management is difficult due to the excessive proportion of competitive funding, leading researchers struggle to cope with short-term projects; few companies invest in basic research, which circumstance leads to the industry's lowered capability for innovation.

In terms of basic research, the scale and intensity of U.S. basic research funding consistently maintains a higher level than China. The government's investment has occupied a dominant position, while the business investment in basic research also holds a high proportion. Despite the fact that funding for basic research in China has increased rapidly since the 1990s, business investment in basic research is relatively weak. In view of both publications and citations of papers, the U.S. basic research retains global leadership. The number of scientific papers from China has grown rapidly in the past 10 years and brought China into global top ranks, but overall China is still short of high-quality papers, and its international academic influence is still far below from the influence of the United States. This means that continued efforts are needed for the future.

In sum, China, as a large rising and developing country, has formed a relatively complete policy development and management system for basic research with remarkable achievements, but still cannot quite build itself to an innovative country that can compete with global levels. In this situation, China needs to learn and draw lessons from the experiences of the United States, enhance their cooperation with the United States and other developed countries, and promote the internationalization of basic research. These efforts would not only contribute to the development of China but also promote the advancement of human civilization.

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