Proceedings of the Sino-US Forum on Basic Science for the Next Fifteen Years

Beijing, People's Republic of China

February 16-17, 2004

Edited by William A. Blanpied

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Preface

Basic research is important for all nations and peoples, and its adequate support is of special importance to those nations with strong and growing economies like the United States and China. Questions such as "how much" support for basic research and "by what mechanisms" have not been fully answered, and engender debate even among the best-informed policy makers.

For more that a half-century the United States has been the world's leader in basic research. This can in part be traced to the 1945 report by Vannevar Bush entitled, *Science, the Endless Frontier*. That report, prepared for President Truman following the end of World War II, recognized basic science as an essential key to economic and social development. The report's fundamental point that basic research, adequately supported by government, would produce the new knowledge needed by the post-war economy and society has withstood endless and continuing debates over specific implementation strategies. As an added benefit, basic research was viewed as an essential component in the education and training of new generations of scientists and engineers, and as a central component of culture.

Modern China has developed its basic research structure more recently. For decades laboratories of the Chinese Academy of Sciences have been known for their excellence, and the reputations of top Chinese universities have grown substantially in recent years. Reforms resulted in the establishment of the National Natural Science Foundation of China (NSFC), a key to the development of a financial support infrastructure that emphasizes stability, excellence and effectiveness in the support of basic research. It is not surprising that when in the fall of 2003 the Chinese government announced the development of a Medium- and Long-Term Plan for Science and Technology Development the NSFC should be charged with coordinating the Working Group on Basic Sciences (one of 20 working groups constituting the planning process).

One difference between today and 1945 is that the relationship between basic research and economic growth has been credibly established. Based substantially on work by leading economists supported by the U.S. National Science Foundation, estimates of return on investments in basic research have been developed. These returns are very large, and make a persuasive argument for generous funding for basic research. The arguments as to how the actual performance of basic research (as distinguished from benefiting indirectly from new knowledge generated elsewhere) preferentially benefits the performer are more complex but are also persuasive. The questions then for governments supporting basic research are: how much, which fields, by what mechanisms, and how to assure adequate technology transfer.

Planning for research and innovation is very, very difficult. Scientific breakthroughs cannot be planned. But sound policies and adequate funding can greatly increase the probability of producing the new knowledge necessary for intellectual growth and economic expansion.

"Sound policies" encompass a broad policy framework. This framework means much more than money. It includes sound economic and educational policies, carefully crafted intellectual property protections and incentives, other supportive government laws and regulations, technology transfer mechanisms, international cooperation and competition, and committed industry support.

China is at a crossroads in its policy and financial policies toward basic research. But so is the United States. For better or worse, science and technology policies and programs require continual review and revision. The February 2004 Sino-U.S. Forum on Basic Science for the Next Fifteen Years was but the first step on both sides. Hopefully, over the near future, careful analysis and comparisons of science and technology policies in China and the U.S. will occur. This new knowledge in turn should enhance the abilities of both countries to improve their systems for the support of basic research, as well as to improve their ability to use the fruits of that research for the benefit of their citizens.

J. Thomas Ratchford
July 12, 2004

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A. Rationale and Overview

For a very long time, and especially since the 1945 report by Vannevar Bush entitled, *Science, the Endless Frontier*, the conduct of basic science has been widely recognized in the United States and most developed countries as an essential key to economic and social development. It is also viewed as an essential component in the education and training of new generations of scientists and engineers, and as a central component of culture. More recently but increasingly, the significance of these multiple aspects of basic science has come to be recognized in the world's more important developing countries. As a case in point, China's investments in basic research doubled between 1998 and 2001. Despite this impressive achievement, the percentage of the country's basic research expenditures are currently about 5.3 percent of its total R&D expenditures, compared with an average of approximately 20 percent for the OECD countries.

During the fall of 2003, the Government of the People's Republic of China announced the development of a **Medium- and Long-Term Plan for Science and Technology Development** under the guidance of **Prime Minister WEN JIABAO**, to be effective from 2006-2020. Twenty working groups composed of scientists, engineers, policy scholars, and relevant government officials were created with the charge to conduct strategic research on the main issues involved in drafting relevant portions of this plan. The **Working Group on Basic Sciences**, chaired by **CHEN JIA'ER**, who was then President of the **National Natural Science Foundation of China** (NSFC), is among these groups. Considerations on tentative plans for basic science in China for the next 15 years were developed, and served as a major component of this **Sino-US Forum on Basic Sciences for the Next Fifteen Years**. The forum took place in Beijing on February 16-17, 2004.

The forum was organized into four half-day sessions, in addition to an opening session, as follows:

1. Strategic Role of Basic Science
2. Major Scientific Issues in Basic Research
3. Disciplinary Development Layout of Basic Research

4. Mechanism, Talents and Policy of Advancing Basic Research Development

The Chinese side prepared formal presentations related to its emerging fifteen year plan. In particular, each session featured a presentation by a member of the **Working Group on Basic Sciences** intended as a means for stimulating discussion. At the conclusion of the forum, the US delegation tabled a set of 13 informal suggestions which it believes the Chinese side might want to consider in its further development of a plan for basic science in China (see Section C).

The **February 2004 Forum** provided explicit information to the US delegation about the approaches that the Chinese scientific community is taking to the complex set of technical and economic issues associated with the support and conduct of basic research during the medium and long-term future. The forum also provided information of a more implicit nature about the attitudes of the Government of the People's Republic of China, and of the Chinese scientific community, towards the support of basic research, and research and development (R&D) more broadly. One set of issues often mentioned but not explored in depth concerned the increasingly significant role of enterprises in China both in the performance and support of R&D. However, in view of its focus on basic sciences, the "world view" of the forum was necessarily limited primarily to that of government.

Hopefully the information gained as a result of the **Forum** will be useful to US and Chinese policy makers in government, universities and industry. Discussions are underway as how best to use the February 2004 Forum as a point of departure for a comparative study of **Science and Technology Policy in the United States and China**. The latter event would examine science and technology policies more broadly than the **Forum on Basic Science for the Next Fifteen Years**. Such an examination would permit experts to exchange views about the changing roles of, and interactions between, the public and private sectors in China and the United States in the support and performance of R&D. It would compare and contrast past and future policies in the two countries, note areas where additional, mutually beneficial interactions can occur, and deal frankly with areas of disagreement.

Co-chairs of the **Forum on Basic Science for the Next Fifteen Years** were **CHEN JIA'ER**, Honorary President of **NSFC**, and **JOSEPH BORDOGNA**, Deputy Director of **NSF**. Chinese participants included officials from the **National Natural Science Foundation of China**, the **Ministry of Science and Technology**, and key individuals from leading Chinese universities and research institutes of the **Chinese Academy of Sciences**, as well as several prominent science policy scholars. The US delegation consisted of individuals with long experience in the administration and management of basic research both in universities and at **NSF**. A full list of participants appears as Appendix 2.

The **Sino-US Forum on Basic Science for the Next Fifteen Years** was the sixth in a decade-long series of science policy dialogues which have been supported, since October 1999, by the **National Natural Science Foundation of China** and the US **National Science Foundation**. This program of cooperation in science policy, research and education is documented at http://techcenter.gmu.edu/ programs/science_trade_policy/us_china.html for information about other events in this series. US participation in these dialogues is supported by a grant from the **National Science Foundation** to the George Mason University Law School's **National Center for Technology and Law**, **J. Thomas Ratchford**, Principal Investigator.

B. Themes and Issues

Significance of Basic Science. Since the **Forum** was organized for the purpose of discussing the basic sciences component of China's **Medium- and Long-Term Plan for Science and Technology Development**, it was not surprising that considerable attention was paid to the significance of this activity. As **JOSEPH BORDOGNA** suggested during the opening session, "in a time of accelerated movement from research to market and of rapid advancement in knowledge, the quality of basic research is key to achieving our greater social, economic and security objectives"

During the past 25 years, studies conducted by several leading economists have demonstrated the economic value of basic research. These analyses have indicated that up to 50 percent of economic growth can be attributed to research and development (R&D), with basic research as the driving force. These analyzes also indicate that the social rate of return on investments in basic research is twice the private rate of return, suggesting that government is more likely to invest in basic research than private industry, and also that government investments leverage substantial research investments from other sources, primarily industry.

Basic research is also essential in teaching new generations of scientists and engineers about the detailed assumptions and processes of science, no matter what their ultimate career choices turn out to be. In particular, individuals who have received basic research experience at the PhD level constitute a key resource for translating scientific results into economic growth.

Finally, basic research is an integral component of culture. As **WU ZHONGLIANG** remarked during his presentation in Session III, "a culture without basic research can be neither a healthy nor a hopeful culture".

Status of Basic Science in China. By several measures, such as the ratio of basic research investments to Gross Domestic Product and the number of publications by Chinese scientists in journals listed in the Science Citation Index (SCI), China is indisputably first among developing countries in basic research. Yet the country lags behind developed countries in terms of the number of highly cited papers published in those journals. Although the country's investments in basic research increased by an average of 22.3 percent per year between 1991 and 2001, the ratio of basic research spending to total R&D spending actually decreased from 7.5 percent in the 1990s to its current level of 5.3 percent. Chinese participants asserted that a principle objective during the 2006-2020 period of the **Medium- and Long-Term Plan** should be to increase that ratio to something comparable to the approximately 20 percent levels of the OECD countries. In order for this to occur, China's policy makers as well as informed members of the general public need to understand better the indispensable role of basic research both in economic development and higher education.

The evident but often creative tensions between what **Zhang Shuangnan** in his presentation in Session II characterized as *pure science-driven* or *curiosity-driven* basic research and *strategic* or *demand-driven* basic research received considerable attention. Both types of research will continue to be important components of China's basic research planning during the **Medium- and Long-Term Plan** period, in part because the country's further economic development requires that the results of basic science be used to resolve several bottlenecks to such development. The **Ministry of Science and Technology** (MOST) and the **National Natural Science Foundation of China** (NSFC) are the primary supporters of basic science in China, while several institutes of the **Chinese Academy of Sciences** (CAS) and, increasingly, a number of premier universities are the principal performers. A substantial fraction of support available from **MOST** comes from major programs, such as its "973" program. In his presentation during Session III, **WU ZHONGLIANG** suggested that the bulk of **MOST**'s basic research support is, and should continue to be, in the *strategic* or what he called the *application-driven* category. On the other hand, several Chinese participants agreed that there is often excessive pressure to demonstrate short-term, strategic results from projects supported by the "973" program. Currently, **CAS** devotes approximately 40 percent of its budget to basic sciences; a good deal of that also appears to be in the strategic, application-driven category.

During the next 15 years, increasing demands will be placed on China's basic research capabilities. These demands are also likely to expand the space for basic science. **YAN CHUNHUA**, in his presentation during Session I emphasized that China, which has been a follower in basic science, is about to become a leader. In his presentation during Session II, **ZHANG SHUANGNAN** confidently predicted that China is about to enter its golden age of basic science.

Support, Organization and Management of Basic Science. In China, **MOST** and **NSFC**, and to a lesser extent the **Ministry of Education** (MOE) are major government supporters of basic research. **CAS** has its own government budget line item, 40 percent of which goes for the conduct of basic research in several of its institutes. Support by provincial governments and enterprises are virtually non-existent, and unlike the situation in the United States, private, charitable organizations that might support research are lacking. **RICHARD ATKINSON**, among others, spoke about the advantages of the US system in which many government agencies provide support for basic research in universities, with the **National Science Foundation** frequently playing the role of a balance wheel to assure that adequate support in all critical fields is forthcoming. In his opinion, China should seriously consider instituting a comparable system. China's central government, as well as the country's scientific community, might make greater efforts to obtain support for basic research from provincial governments and from enterprises, particularly since enterprises currently account for approximately 65 percent of R&D performance in China. With regard to enterprise support, **Atkinson** and **Bordogna** spoke about the importance of university-industry research cooperation, facilitated by several **NSF** programs, which leverage substantially greater investments by industry than the amount that the US government invests in those programs. Chinese funding agencies might consider creating an analogous set of programs.

Several Chinese participants agreed that improvements in both macro- and micro-management of the country's research enterprise are essential. At the macro-level, the **Leading Group on Science, Technology and Education** has not been particularly effective in developing a coherent research policy, in large measure because it consists of the heads of relevant but competing ministries and agencies. Perhaps a strong, non-government advisory council with representatives from industry, universities, and CAS institutes might be interposed between the **Leading Group** and the country's operating agencies.

At the micro-level, funding agencies as well as research organizations, particularly universities, need to be more flexible in order to encourage capabilities to respond rapidly to emerging opportunities and national needs. Chinese participants agreed the **Medium- and Long-Term**

Plan should also assign high priorities to improving the research capacity of universities and to providing incentives for young people to pursue careers in basic science.

Planning for Basic Science. Can a viable, single plan for basic science in China be formulated and implemented? Should there even be such a plan? There is no national plan in the United States, and most US participants agreed that that is probably positive. On the other hand, each government agency, including those that support R&D, is required by the **Government Performance and Results Act** (GPRA) which was enacted by the US Congress in 1993, to develop its own five-year strategic plans. In most agencies, including **NSF**, the organizational sub-units also have their own plans. Similarly, US universities and university departments develop and implement their own plans.

Unless the Chinese scientific community can agree on a plan for basic research (as well as for other aspects of the country's science and technology enterprise) to recommend to the government as a component of the **Medium- and Long-Term Plan**, then the government may well impose its own plan on the community. The question is not if a plan should be devised, but rather what its content should be and what is the best strategy for its development. In order to provide flexibility, government organizations as well as research organizations, including **CAS** institutes and universities, might also be encouraged to develop their own plans consistent with the overall plan.

In his presentation during Session IV, **WU JIARUI** suggested two alternative strategies for planning. He referred to the first as *project-based planning* in which the scientific community agreed on specific projects to be conducted during the period of the **Medium- and Long-Term Plan**. He referred to the second as an *environment-based strategy* in which agreement is reached on elements of the country's infrastructure that needed to be enhanced if its capacity for basic science is to become adequate to meet the demands likely to be encountered during the planning period. Essential elements of that infrastructure are *funding*, *workforce*, *facilities*, and *management*. A central issue is how to allocate financial resources among projects, workforce and facilities. Although **NSF** has not resolved this problem for all time, it has adopted a policy of allocating no more than 25 percent of its budget to facilities. Once levels of funding and allocations among projects, workforce and facilities are determined, then it is possible to allocate resources to specific projects, but always with a view to preserving flexibility in the event that new and unanticipated challenges and opportunities emerge.

Another important issue is how to allocate support to various scientific disciplines, particularly since the disciplines themselves are changing and the importance of interdisciplinary or trans-boundary research is increasing.

The Importance of Process. Bordogna recognized that devising a plan for basic science in China, given the current status of the country's economy and its science and technology enterprise, is no doubt more important than in it would be in the United States. **NSF** has wrestled with the problem of planning to meet the requirements of the **GPRA** legislation. However, in his opinion the process of planning is more important than the content of the plan itself. Planning tends to reveal all viable possibilities and options so that when an organization develops a viable plan and reviews it on a periodic basis, it can be ready to seize opportunities as they emerge.

Bordogna went on to note that **NSF**'s planning proceeds as a bottom-up process in which the scientific community is intimately involved. The grant proposals the agency receives are an essential source of information about the directions in which it should be proceeding. The scientific frontier continuously advances, often in unpredictable directions, so that any plan must have the flexibility to be able to support those working at whatever frontiers may emerge.

Scientific disciplines change, so it is probably more important to determine current priority areas for research support than to attempt to allocate resources among disciplines. Biology is often cited as the priority scientific area for the 21st century. But university biology departments in the United States are unrecognizable from what they were 30 years ago. The same is true for departments of physics and chemistry, for example. The availability of massive quantities of data in virtually all areas of science and technology is changing the structure of the academic disciplines and, therefore, of university departments, and this trend will no doubt continue. Interdisciplinary research will continue to be important, and new types of research across disciplines will no doubt emerge. These trends emphasize the importance of flexibility in any plan for basic science.

Integration of Research and Education. One significant contribution that basic research makes to a nation is to provide essential training to its scientists and engineers, both at the graduate student level and throughout their careers. **NSF**'s **Integrated Graduate Education and Research** (IGERT) program is one of several designed to encourage integration of research and education, as well as to introduce an interdisciplinary component into graduate education. University professors who apply to **NSF** for support to accept a group of graduate students into an **IGERT** project are required to offer those students at least one significant trans-boundary research experience. In this way, **IGERT** fosters interdisciplinary research and education in an integrated manner. The **IGERT** program also has an international dimension, enabling university professors to take a group of graduate students abroad for the summer months to continue their interdisciplinary work. One such group has been working at **Sichuan University** in Chengdu.

XUE LAN remarked that **NSFC** grants to university-based scientists have had the indirect effect of providing continuing education to faculty members. However, this has come about as an externality. He suggested that the **NSFC** might be given authority and responsibility to support advanced education directly, with an emphasis on the integration of research and education. Moreover, more emphasis should be placed on **NSFC** support for education of graduate students, rather than for working scientists as is now the case.

International Considerations. During his remarks at the opening session of the Forum, **CHEN YIYU** asserted that international cooperation would continue to be important in the development of basic science in China. Exchange of scientists at all levels has been significant in building bonds between the scientific communities of China and the United States. During the summer of 2004, approximately 30 US graduate students nominated by the **National Science Foundation** will conduct research in China for two months under the direction of Chinese host scientists. This experience at early stages in their careers will almost certainly condition these students to think internationally throughout their careers, and may also establish firm and lasting bonds between the American students and their Chinese mentors and peers.

China has emerged as a significant scientific country on the world scene. As such, it is contributing to several large scale international projects including the **Human Genome Project**, the **International Ocean Drilling Program** (IODP), and the **International Thermonuclear Experimental Reactor** (ITER). China is also being courted to participate in (and contribute to) additional large scale international projects. Of course the country needs to review its resource allocation strategies carefully to determine the feasibility of investing scarce resources in one or another of these big science projects. It was noted, however, that by contributing judiciously to worthwhile international projects, China could train many of its best young scientists in the intricacies of large scale basic science on an international scale. Additionally, China could showcase its rapidly rising capabilities in basic research, and demonstrate to the world community that it has become a solid contributor to the universal stock of knowledge.

Planning and Outreach. Several Chinese participants remarked that public attitudes towards basic science in the country are at best indifferent; the prevalent attitude among government officials and the informed public being that basic research makes few if any contributions to the country's economy or society. Thus, a concerted and coherent public outreach program ought to be an integral feature of any plan for basic science in China. For many years, there have been significant activities in the United States (some supported by **NSF**) to improve public understanding of science. Such programs have had some measure of success, even though success can never be taken for granted. China might consider placing even more emphasis on its public outreach programs such as those carried out by the **China Association of Science and Technology** (CAST).

In any country, there is more than one public whose understanding of the significance of basic science needs to be deepened and whose support for basic science needs to be enhanced. For example, the support of individuals who manage high-technology enterprises could be marshaled to convince the government about the importance of basic science. A different approach may be required to convince policy makers in government. As to members of the informed general public: scientists themselves might recall that beyond its economic value, basic science is an essential element of culture. Outreach programs to enable the informed general public to appreciate the significance of basic science are essential, regardless of whether these programs result in increased financial support for research.

C. Informal Suggestions

At the conclusion of Session IV, **JOSEPH BORDOGNA,** tabled, on behalf of the US delegation, a set of 13 informal suggestions which that delegation believe might be considered as principles for the development of basic research in China. These suggestions, together with an explanatory preamble, are as follows:

> During these two days of intense discussion in the Sino-US Forum on Basic Science for the Next Fifteen Years, we have been pleased to share our thoughts with you. We have been stimulated by the free flow of ideas and viewpoints between us and by your dedication to developing basic research in China.
>
> While we now have a better understanding of the challenges that you face in determining the proper approach to developing basic research in China, we cannot pretend that we fully understand the situation as well as you do.
>
> Nevertheless, as friends who wish to see you succeed in your desires regarding basic research in China, both for your sake and for the sake of U.S.-China scientific collaboration and partnership, and because you have graciously asked us here to share our experiences and thoughts with you, we would like to make a few suggestions regarding several principles that you may wish to consider as you develop basic research in China:

1. developing basic research capabilities in each ministry and agency to achieve success in its technological responsibilities;

2. bringing basic research funding to the level of leading economic countries in terms of percentage of R&D;

3. employing merit review as the underlying mechanism of determining the selection of basic research and education programs and projects;

4. promoting the capabilities of research universities as centers of basic research;

5. supporting basic research that fosters the development of intellectual capital, promotes the integration of research and education, and broadens participation in research through partnering with other relevant institutions and sectors of society;

6. supporting basic research across a broad spectrum of fields in order to ensure that China's researchers are enabled to meet challenges that will arise;

7. encouraging boundary-crossing research and education as a reflection of the holistic challenges facing science;

8. fostering international collaboration and contributing to the basic scientific knowledge of the world;

9. establishing the intellectual and physical infrastructure necessary for China to be ready always to address the constantly changing scientific frontier;

10. developing future talent concurrently with every research investment;
11. motivating the constantly changing character of established disciplines;

12. seeking best business practices to sustain organizational excellence and assure flexibility in decision making; and

13. thinking strategically with every investment made.

D. Session Highlights

D-1. Opening Session, February 16, 2004

CHEN JIA'ER, Co-Chair of the Forum and former President of the National Natural Science Foundation of China, opened the session and invited **CHEN YIYU** to make an opening speech. **CHEN YIYU**, in his capacity as President of the **National Natural Science Foundation of China** (NSFC), began his remarks by referring to the long-standing cooperation that both **NSFC** and the **Chinese Academy of Sciences** (CAS) have enjoyed with the US **National Science Foundation** (NSF), noting that frank and open exchange has provided a sound basis for that cooperation. He referred particularly to the decade-long series of **science policy dialogues** jointly organized by **NSFC** and **NSF** since 1999, of which the current **Sino-US Forum on Basic Science** is the sixth.

Chen then explained, largely for the benefit of the US participants, that 20 Working Groups of scientists and government officials have been actively engaged for the past four months to study the main issues in developing relevant sections of a draft **Medium- and Long-Term Plan for Science and Technology Development** to be effective from 2006 through 2020. **CHEN JIA'ER** has been chairing the **Working Group on Basic Sciences**. During the Forum, the Chinese side would present some results of those deliberations as a basis for discussion with the US side on how best to proceed to finalize the basic sciences component of the plan. He noted that a high priority must be to change the mind set of prominent officials, as well as the general public, so that they will come to recognize that a considerable period of time is often required before the tangible benefits of basic research are realized. Additionally, it must be emphasized that basic science is an integral part of culture.

Chen concluded by asserting that international collaboration will continue to be important to the development of basic sciences in China. Scientific cooperation between China and the United States can also continue to provide a firm foundation for the stability in bilateral relations that both countries so earnestly desire.

JOSEPH BORDOGNA, speaking in his capacity as Co-chair of the Forum, expressed the US delegation's appreciation for the invitation to come to Beijing to exchange views on the critical roles that basic science and engineering play in the overall development of science and technology.

The specific context of the Forum is the fifteen-year **Medium- and Long-Term Plan for Science and Technology Development** that is being developed under the leadership of the **Prime Minister Wen Jiabao** with overall coordination provided by the **Ministry of Science and**

Technology. The **Working Group on Basic Sciences** is one of 20 groups consisting of scientists, technologists, other scholars, and government officials that are involved in developing the overall plan. Aspects of the plan being considered by all these groups are important parts of the whole. But in a time of accelerated movement from research to market and of rapid advancement in knowledge, the quality of basic research is key to achieving our greater social, economic, and security objectives.

Planning is a critical role for a nation's science and engineering enterprise. **NSF** is constantly looking to the future and assessing its plans and, more important, its planning process.

Bordogna suggested that the particular subjects selected for the four sessions of the Forum are all extremely important and well chosen. These are: (1) understanding the strategic role of basic science; (2) major scientific issues in basic science; (3) disciplinary development layout of basic science; and (4) necessary policies for advancing basic science development. At the same time, in order to explore these topics fully, it is necessary to consider them in their overall national and international contexts. He stated that members of the US delegation will be pleased to share their experiences from the American context, while recognizing that differences in national experiences may result in unique approaches.

Bordogna concluded by reemphasizing that although plans are important, the process of continually rethinking a plan may be more important than the plan itself.

D-2. Session I: Strategic Role of Basic Science, February 16, 2004

The session was chaired by **JOSEPH BORDOGNA**, Deputy Director of the **National Science Foundation**; the prepared presentation entitled Strategic Role of Basic Science was delivered by **YAN CHUNHUA**, of the State Key Laboratory of Rare Earth Materials, Peking University.[1]

In his opening remarks, **Bordogna** noted that the strategic role of basic science and engineering in fostering national prosperity has become a truism for government policymakers around the globe. Phrases such as "curiosity-driven science," "science for its own sake," "blue-sky science," have become familiar, as has recognition that such research provides important national benefits. However, as the costs for doing research increase, as more and more is expected of the research community by the public and by the public's representatives in government, and as other national priorities compete for finite budgetary resources, the challenge of making the case for increased basic scientific research funding grows.

As a result of the **Government Performance and Review Act** (GPRA) enacted by the US Congress in 1993, all US government agencies–including science agencies—are required to develop five year plans based on strategic goals, as well as annual implementation plans based on those five year plans. Agencies are required to report annually on their progress in meeting their goals, as measured against criteria contained in their implementation plans.

The GPRA mandate presents a considerable challenge to **NSF** and other basic science-oriented agencies. It demands that the agency must strike a balance between the fundamental nature of basic research and its timeframe of years/even decades for new discoveries to manifest their usefulness on the one hand, and the requirement to identify and produce tangible results on the other. Through time and effort, **NSF** has devised and continues to improve measures of basic research that are both quantitative and qualitative. The agency is constantly revisiting its methods so as to insure that it is performing its strategic role of *"enabling the nation's future through discovery, learning and innovation."* This strategic goal stresses the importance of **NSF** assigns to supporting science at the frontiers. Ten years ago, only discovery would have been mentioned. Now learning and innovation are regarded as equally important.

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1. Tabular and graphical material embedded in the texts of Sessions D-2 through D-5 have been copied from the PowerPoint files used by the presenters in those sessions and are reproduced with their permission.

NSF's strategic goals are to support and develop *people*, *ideas* and *tools*. The tools part has become a great challenge. A fourth goal adopted more recently is *excellence in management*. The organization must run well or all is lost.

In every investment decision NSF asks three questions:

- Does this foster the development of intellectual capital?
- Does this integrate research and education?
- Does this promote partnership including international, high schools and university, local government, industry, partnerships?

Consistent with **NSF**'s strategic plan and these strategic goals, in 1997 the agency revised its peer review, or what it now calls merit review criteria from four elements down to two. The reasons for doing so were as follows:

- to avoid some of the ambiguity in the former criteria,
- to emphasize the importance of integrating research and education, and
- to increase diversity in all of the Foundation's programs, projects, and activities.

Criterion 1 specifically asks "What is the intellectual merit of the proposed activity?" Expert reviewers consider the importance of the proposed activity to advancing knowledge and understanding within its own field or across different fields. How well qualified is the proposer (individual or team) to conduct the project? (If appropriate, the reviewer will comment on the quality of prior work.) To what extent does the proposed activity suggest and explore creative and original concepts? How well conceived and organized is the proposed activity? Is there sufficient access to resources?

Criterion 2 is "What are the broader impacts of the proposed activity?" How well does the activity advance discovery and understanding while promoting teaching, training, and learning? How well does the proposed activity broaden the participation of underrepresented groups (e.g., in terms of gender, ethnicity, disability, geographic, etc.)? To what extent will it enhance the infrastructure for research and education, such as facilities, instrumentation, networks, and partnerships? Will the results be disseminated broadly to enhance scientific and technological understanding? What may be the benefits of the proposed activity to society?

Bordogna emphasized that these two merit review criteria are not listed in order of importance; they are equally important.

These two criteria have enabled **NSF** to maximize the nation's investment by producing the best science with the greatest potential for benefiting the nation, by integrating research and education and by fostering diversity in the U.S. science and engineering workforce.

Bordogna proceeded to consider a number of parameters and objectives pertinent to Session I, including:

- the role of basic research in terms of enhancing national competence;
- the social function of basic research; and
- how to convince the public and society to attach more importance to basic research.

He then invited **YAN CHUNHUA** to deliver his prepared presentation.

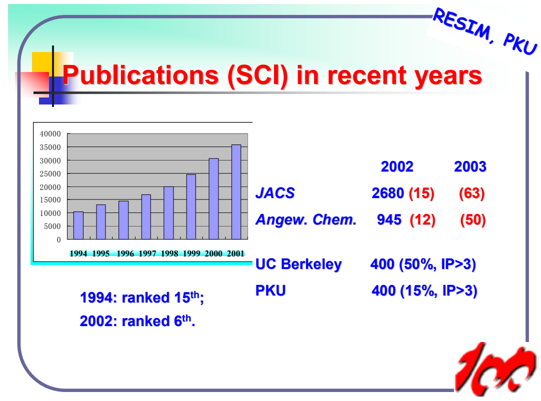
Yan began by referring to basic science as the summation of human cognition concerning the intrinsic rules of nature. The principal driving forces for the development of basic science are the desire to know and the demands of development. Basic science is important as a resource for the development of high technology. It is also significant as an incubator for experts in various fields, including scientists and engineers, of course, but also individuals who select careers in other fields. Basic science is a prerequisite for sustainable development, for protection and maintenance of the environment, and for human health. Finally, it has long been a cornerstone of advanced culture.

For the past 50 years, government support has played the dominant role in the development of basic science. Its scope continues to deepen and widen, disciplines have become more differentiated, while integration has proceeded a pace. Cooperation has increased, but so has competition.

Status of Basic Research in China

China, according to **Yan**, ranks first among developing countries in the support and performance of basic research. The country is at a turning point from being a follower to being an innovator; from accumulating knowledge largely developed elsewhere, to being able to make its own breakthroughs. Yet the overall innovative ability and research level of Chinese scientists are still far behind those of the developed countries. Nor can basic research, as it currently stands in China, meet the demands of social and economic development.

China's ranking in terms of papers published in Science Citation Index (SCI) journals in chemistry rose from 15th in 1994 to 6th in 2002. However, the international citation rate to these papers remains disappointing. Of 400 chemistry papers authored by scientists at the University of California, Berkeley, in 2002 over 50 percent were among those with the greatest international impact. By comparison, of the same number of papers published during that year by scientists from Peking University, only 15 percent had a comparable international impact. A similar situation regarding growth in the number of papers published accompanied by disappointing international citation rates prevails in other disciplines as well.



China's investments in basic research increased by a factor of almost 6.5 between 1991 and 2001, an average of 22.3 percent per year, and were approximately 5.6 billion RMB in the latter year. But both total investment in basic research and investment per researcher are lower than in developed countries. Indeed, the ratio of basic research spending to total research and development (R&D) expenditures actually decreased from 7.5 percent in the 1990s to its current level of 5.3 percent.

There are currently 957,000 people engaged in R&D in China, 79,000 of them in basic research, so that the ratio of basic research scientists to the R&D total is 8.3 percent. The overall quality of the basic research workforce has clearly improved, as is evident from the increase in China's ranking of papers published in SCI journals. Still, according to **Yan,** the country lacks world-class scientists.

Yan cited historical data from several countries, including Japan and Korea, suggesting the importance of investments in basic research on the order of 20 to 25 percent of total R&D as being essential at the take-off stage of social and economic development. These data suggest that there is an approximately 15 year time lag between the onset of substantial investments in basic research by a country and what he referred to as a sustainable basic research system. A principal reason for this 15 year lag may be that PhD students who receive a first rate education in basic research achieve positions of influence in about that time period. In any event in Yan's opinion, China should make a concerted effort to support basic research today if it expected to have a world class basic research system by 2010.

Age of Chinese Researchers

Yan then turned to the age distribution of applicants for grant support by the **National Natural Science Foundation of China**. In 1990, the peak of the distribution of applicants was between 51 and 55. By 2002 the peak ages were between 36 and 40. While it is no doubt encouraging that younger scientists are applying for research grants and are succeeding, there could be long-term negative consequences. In particular, the age distribution curve may increase and decrease too abruptly, and the peak itself—with a half-width of five years—may be too narrow.

Challenges for the Next Fifteen Years

The next 15 years provide opportunities for the development of basic research in China. Targets for the country's development are placing substantial demands on its basic research capabilities. However, these demands also create a larger space for the development of basic research itself. During the next few years, research activities on the borders of biology, chemistry, physics, mathematics, and information science are expected to develop significantly. Partially solved problems in cosmology also suggest that physics may be on the verge of new breakthroughs.

Important strategic objectives for basic research in China are to:

- obtain several important achievements at the frontiers of the principal scientific fields;
- realize a substantial elevation in the ability of basic research to solve significant problems, especially those that constitute bottle-neck problems to the country's development;
- provide a high-quality personnel reserve for the construction of an affluent society and for stable social and economical development; and
- develop a reasonable number of world-class scientists.

To achieve these objectives, the current 8.3 percent ratio of the basic research workforce to the total R&D workforce should remain approximately constant, but the overall quality of the workforce must increase. The ratio of financial resources per person engaged in basic research to resources available to per individual in the overall R&D workforce should increase by a factor of two. Importantly, the state management system for basic research should be improved and a more congenial cultural context for the conduct of basic research should be developed.

Support for basic research will continue to be based both on the desire for knowledge on the part of individual scientists and the demands of the country for relevant research. Support must be kept stable, originality and creativity must be encouraged, and an appropriate balance must be struck between basic and applied sciences, as well as between science and technology.

Discussant's Comments

After a brief review of the general topic of the session, **J. THOMAS RATCHFORD**, who served as discussant, suggested that it might be easier than one thinks to address the issue of balancing various needs and demands. Consider the following points:

- Government supports basic research because it is useful.
- In the United States, industry recognizes the importance of basic research as evidenced by the many supportive comments from the **Industrial Research Institute** often mentioning both the **National Science Foundation** and the **National Institutes of Health**..
- Studies by leading economists prove that the return on investment in basic research is large.
- The social function of basic research is important but not sufficient in the overall rationale for supporting basic research. Knowledge can be used for good or evil. Ethical issues are important
- Research and education should be regarded as equally important. Research universities are perhaps the most important link between knowledge generation and human capital growth.
- It is easy to speak about the importance of basic research, but you need people outside the basic research community to tell the story. If 60 percent of China's R&D is now performed by enterprises, they should speak up.

General Discussion

Economic Significance of Basic Research

RICHARD ATKINSON opened the general discussion by stating that the economic significance of basic research merits strong emphasis. In the 1970s much of the story about the important economic impacts of basic research was anecdotal. Then **NSF** decided to support studies of the economic impacts of investments in basic research. This program seeded a substantial body of literature. Many of these studies were summaries in a report by the **President's Council of Economic Advisers** during the 1990s which concluded that on the order of 50 percent of economic growth came from investments in R&D, and that basic research had been the driver of these investments. Industrial leaders in the United States continually make statements to the effect that investments in basic research and education in universities is the vital key to sustained economic development.

Bordogna noted that the importance of these economic studies was a leading factor that convinced **NSF** to create a Directorate for Social and Behavioral Sciences. Two current high priority areas for the agency in these fields are:

- Science of Learning Centers to create a knowledge base about how people think and learn, and
- Human and Social Dynamics which focuses on cross-boundary issues in the social, behavioral and economic sciences.

PEI GANG noted that on the basis of his observations as a student in the United States, he had come to recognize the fundamental importance of basic research to society. But China is not in a position to provide adequate support for basic research. Although the **National Natural Science Foundation of China** has received substantial annual budget increases during the past few years, it may be approaching the maximum level of support. A critical problem is that basic research in China cannot obtain support from other sectors, such as a non-profit sector which does not exist in the country. At least at present, the central government must be relied on as virtually the only supporter. But basic research is accorded a very low priority by the finance ministry.

Ratchford noted that the federal government is the principal supporter of basic research in the United States as well. He reiterated a point made early by **Atkinson** that studies by economists indicated the importance of basic research to the economy. In the 1980s, Edwin Mansfield estimated a 50 percent return on investments in basic research and also found that the social rate of return from such investments is double the private rate of return. Government investments in basic research have a multiplier effect leading industry to invest more heavily in applied research, for example. Why should China invest in basic research rather than relying on the basic research of other nations? One important reason is that China needs people trained to transfer basic research into economic growth.

Pei interjected that the Chinese government understands the importance of funding R&D, but not basic research. Japan relied on basic research conducted elsewhere while investing primarily in applied research as an engine of its economic growth. Why shouldn't China adopt the same strategy?

Bordogna remarked that conducting basic research is complex and difficult. We are not really sure how much basic research is being conducted in the United States. NSF emphasizes supporting research at the frontier. But the frontier moves on, and it is essential be on guard so that the constituency of researchers that builds up in what was formerly a frontier area does not inhibit the development of new research frontiers.

University-Industry Research Cooperation

Atkinson referred to the importance of university-industry research cooperation in the United States. Such cooperation often accelerates the movement from basic to applied research and can be beneficial to graduate students since they obtain first hand experience in industrial research. But such cooperation requires that issues such as patenting and intellectual property protection need to be resolved.

Bordogna built on Atkinson's remarks by explaining that NSF programs to support the academic side of industry-university basic research cooperation invariably leverage additional funding from the private sector. **NSF's Industry-University Cooperative Research Centers** (IUCRCs) program, which has just celebrated its 30th anniversary, requires matching funds from industry. In practice, industry does better than that. At present, for every dollar invested in such centers by NSF, industry contributes as much as an additional $8 to $11.

Because of the success of the IUCRCs, during the 1980s the more ambitious Engineer Research Center (ERC) and Science and Technology Center (STC) programs were established. These awards provide support at levels of $5 to $10 million per year for up to 10 years. NSF does not specify the fields in which proposals for such centers will be considered. Rather, it selects the best proposals based on rigorous and extensive peer review.

NSF tries to broker many types of partnerships, including partnerships between universities and industry and international partnerships. Its Partnerships for Innovation Program was established to leverage support for basic research from the state governments by convincing them that such investments can pay handsome dividends in terms of their economic development.

Bordogna remarked at this juncture that in starting any new program, it is essential to have a strategy or at least an understanding about how to stop it when it has run its course. There is a peculiar disease in the United State known as *democrasclerosis*. That is, in a democracy it is very hard to stop things.

Public Involvement as a Guide to Planning

ZHU ZUOYAN reiterated a comment made earlier by **Pei Gang**: namely, that although the importance of basic research is well understood in the United States, this is not the case in China. What steps can be taken to increase that awareness in the country?

TOM COOLEY emphasized that various external events had brought home the importance of basic research to the informed US public and the US Congress. For example, after the Soviet Union launched its first two Sputniks in 1957, government funding for basic research and education increased dramatically. In particular, **NSF's** budget increased by 250 percent in two years. Also, **NSF** has made concerted efforts since the early 1970s to support programs to emphasize the importance of basic research to the US public.

ZHANG SHUANGNAN did not question the effectiveness of such outreach programs in the United States. However, China has no elected Congress whose votes might be determined by public attitudes towards science. Nor is there currently a problem with university enrollments in science and engineering as there has been in the United States since the 1970s. So what would be the benefits of public outreach programs in the country? They would be unlikely to increase funding for basic research.

Bordogna remarked that China will change. An important principle is that unless you reach out, they may not come. Lao Tzu had put it well: *If you do not change direction, you may end up where you are heading.* That is, if you do not change, the world will change around you.

He continued that proposals tell **NSF** where it is going and where it should be going. The US Congress has made it clear that the agency cannot have enough money to support everything that it considers worthwhile. So it has had to decide on its broad, overall priorities. It has determined that both the size of its grants and their duration needed to be increased. Too many good researchers have been spending too much time writing grant proposals and doing administrative tasks for the research enterprise to work effectively. Also, graduate students have been spending too many years working on their doctorates. It is essential to get them out into the productive research world. So **NSF** has told Congress that it needs adequate funds to support average grant awards at a level of $300,000 for five years rather than $100,000 for three years as is currently the case.

In response to a question from **XUE LAN** about how NSF argues about changes in direction with the US Congress, **Bordogna** responded by emphasizing that NSF does not simply ask for more money for physics or chemistry. Rather, it goes to Congress with holistic stories related to issues that Congress is interested in such as risk assessment and response to crises, for example.

Bordogna went on to provide a further example of how external trends often assist NSF in planning for the future. The **Semiconductor Association Institute** (SAI) has developed the fourth of its periodic roadmaps, which is available on the www. SAI believes that there are no more than 15 years remaining for silicon. It has argued in favor of a significant budget for NSF and also wants **NSF** to help fund the development of their roadmaps. Congress is pressing the agency to provide such assistance, but **NSF** is resisting what it regards as a narrow, focused approach. Rather, NSF has taken the lead in developing a new paradigm for government support for manufacturing in partnership with industry in which NSF will support only the relevant basic research.

WILLIAM BLANPIED noted with regard to public understanding of science that there is more than one public. There is the general informed public, the politicians, and managers of enterprises, for example. Each group needs to be approached in a different way. Also, since the value of basic research cannot be gauged in purely economic terms, it is essential for each group to understand the full importance of basic research to society and culture.

Sources and Levels of Support

Atkinson emphasized that in the United States, several other agencies besides NSF support basic research. These agencies are referred to as mission agencies because they support research in pursuit of specific missions defined by Congress, whereas NSF has been mandated to support research because of its own intrinsic value. There are many examples of important developments that resulted from basic research funded by more than one agency. For example, research underlying development of the Internet has been based on research supported jointly by **NSF** and the **Defense Advanced Research Projects Agency** (DARPA).

During the 1970s the **National Science Board** (**NSB**, the policy making body for **NSF**) determined that the agency should serve as a balance wheel among government agencies for the support of basic research. For example, although the **Department of Agriculture** supports considerable research in land grant colleges in the United States, most of this research is in the form of formula grants rather than competitive, peer reviewed awards, and little of it is at the frontiers of biosciences. So **NSF** stepped in and developed what has turned out to be a very effective program in basic research in plant science, with an emphasis on plant genetics.

ZHANG XIAN'EN remarked that everyone in the Chinese research community recognized that the country's current investments in basic research at 5.3 percent of total R&D investments are too small compared with the OECD average of approximately 20 percent. But how can the country increase its expenditures substantially? Currently, the Chinese government provides one-third of the total R&D support in the country. If it increased its basic research expenditures to the OECD level, then over 70 percent of those expenditures would be for basic research.

WANG DANHONG, a science news journalist, remarked that in the United States, non-profit philanthropic organizations support basic research both in universities and their own laboratories? Are their government incentives to encourage such support?

Atkinson responded that the primary incentive for philanthropic foundations to invest their money is their tax free status.

Ratchford noted that detailed international comparisons of research expenditures are notoriously difficult to make. The *Frascati Manual* provides specific definitions and criteria that OECD countries use, in principle, to report R&D expenditures in various categories. However, different agencies within OECD countries often depart from these definitions. So it is more important to look at internal consistency and progress on an annual basis then to rely on international comparisons.

In this regard, a big problem for China is that the size of its economy measured in terms of the International Monetary Fund (IMF) Exchange Rate is very different from its size measured in terms of Purchasing Power Parity (PPP). According to the former, China's GDP is approximately $1 trillion; according to the latter, approximately $5 trillion.

Zhang Xian'en responded that using standard purchasing power parity (PPP) rates as a means for comparing research investments internationally can be very tricky. For example, it is true that manpower costs in China are one-tenth or less of what they are in the United States. On the other hand, China must import most of its scientific instruments and reagents, so that the costs for such items are more expensive than in the United States.

Summary

WANG YUAN, Director of the Centre of S&T Development of the **Ministry of Science and Technology**, summarized three points that he found particularly important from the discussion during Session I.

1. The importance of basic research to the whole society: government, industry, and the general public. Its importance not just to create new knowledge but to train people and the whole society in scientific attitudes, and to transfer knowledge into technology.

2. In China, investments in basic research as a fraction of total R&D (about five percent) are low. We need to push the government and society to invest more in basic research.

3. Integration of research with education at all levels is very important. The **National Natural Science Foundation of China** should be encouraged to follow the lead of **NSF** in this respect.

D-3. Session II, February 16, 2004: Major Scientific Issues in Basic Research

The session was chaired by **PEI GANG**, President of the Shanghai Institutes for Biological Sciences; the prepared presentation entitled, Highest Priority Direction and Fields of Basic Research, was given by **ZHANG SHUANGNAN** of the Physics Department, of Tsinghua University and the Institute of High Energy Physics, the Chinese Academy of Sciences

Zhang began by reminding the audience that in barely three decades, China has made a transition from a primarily agricultural economy to a traditional industry dominated economy. At the same time, basic scientific research in China has experienced the most rapid development in the country's history. However in most fields of basic research, China is still far behind the major developed countries.

Goals for Basic Research in China

Future stable and rapid economic growth and social development of China, combined with the size of China's economy could provide unprecedented resources and motivations for significantly enhanced basic science research activities in China. In **Zhang's** opinion, the golden era of China's science is coming.

*He suggested that m*ajor goals for basic research in China should be to:

- Play leading roles in some research frontiers
- Educate and train the next generation of high quality work force.

The highest priority tasks must be to:

- identify the most important and urgent problems of basic science facing the world scientific community. Breakthroughs on understandings of these problems would have broad and significant impacts in many fields of basic science.
- identify the bottle-neck scientific problems demanded by China's future knowledge-based and natural resource-efficient economy. Understanding these problems would bring massive breakthroughs for future technology

Principal, enduring questions include:

- what is the universe made of? We have a small part of the answer.

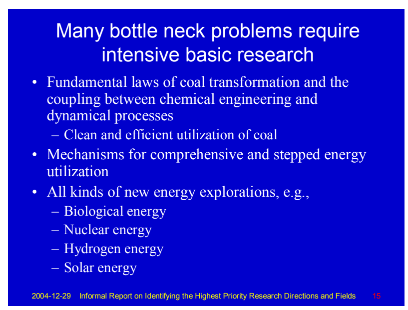
- how was the universe created? The 'big bang" mechanism is now generally accepted. But many details are still lacking.
- what is and what determines the fate of the universe? We have no idea as yet.

Even approaching answers to such questions involves confrontations between physics and astronomy. Fruitful confrontations may lead to an ultimate law of nature unifying the very large and the very small.

These are a sample of fundamental challenges to world science. An important goal for basic research in China is to contribute significantly to the understanding of such problems.

Strategic Demands

Zhang then turned to strategic demands on basic research in China in terms of bottle-neck problems for the country's sustainable development. Energy-related issues and strategies include the following:



- Although there is sufficient coal in China, many environmental problems must be solved.
- China's energy security is a serious problem.
- There is great potential for the development of natural gas.
- A high priority has been assigned to the development of hydrology power.
- While nuclear energy policy remains uncertain, its development is encouraged.
- The development of reusable energies should be speeded up.
- Strong emphasis should be placed on developing new types of energy sources.

The solution of associated bottleneck problems will require intensive basic research in many disciplinary and cross-disciplinary areas.

Zhang, a member of the **Working Group on Basic Sciences** for the **Medium- and Long-Term Plan for Science and Technology Development**, then described, briefly, the process through which the group has identified elements of its draft plan. First, there was a nationwide call for suggestions from individual scientists, research institutions, most scientific societies and related organizations. Various discussion groups and workshops have been organized based on the results of these suggestions. The Working Group then summarized these suggestions and discussions, analyzed the science policies and plans of other countries, wrote research reports on priority directions and fields that emerged from this process, and carried out iterative communications with the broader scientific community.

Criteria and Priorities for Pure- and Strategic Demand-Driven Problems

The **Working Group on Basic Sciences** has agreed on criteria for identifying the highest priority research directions and fields of basic science research. Different criteria have been used for "pure-science" driven and "strategic-demands" driven research. Two major special plans for basic science research are also recommended for major emphasis. Support for these plans will require participation of several ministries and agencies.

Identification criteria for "pure science" driven problems are:

- To have significant impacts to the understanding of nature and the development of basic science.
- Those with a good potential for future development in China because of the existence of scientists with a solid background, or those reflecting the special resource advantages and geographic characteristics of China, in order to promote rapidly the international position of China's basic research.
- Key basic science problems which may become the bottlenecks of China's future technology development.
- Problems which constitute interdisciplinary and potential growth points of new research fields.

Identification criteria for "strategic-demands" driven problems are:

- To have long-term and broad impacts on the strategic demands of China's economic and social development, national security and environmental protection.
- To have significant impacts on China's contemporary development.
- Those of fundamental importance to China's economic and social developments, even though not currently advantageous.
- Those which may strengthen the interactions between basic science and applied science, thus fostering emerging industries/sectors with strong international competitiveness

Examples of priority directions and fields for pure-science driven problems include:

- Quantitative research and systematic integration of life processes.
- Quantum manipulation and the foundations of future information science.

- Basic structures of matter, physical laws of large scales, the origin and evolution of the universe.
- Core mathematics and the interactions between mathematics and science and technology.
- The processes of the earth system, resources, environments and catastrophe.

Examples of priority directions for strategic-demand driven problems include:

- Functional genome and molecular genetic modifications of important agricultural organisms.
- Fundamental problems of human population and health.
- Efficient and clean utilization of fossil energies and new energy explorations.
- Non-linear interactions, formation, prediction and control of catastrophes of complex systems.

The Need for Flexibility

Historically, many important developments and breakthroughs in basic science were not among the high priority directions and fields recognized at the time by the scientific community. Therefore a significant portion of resources must be put aside to support creative basic research programs aimed at revealing the basic laws of nature but not yet covered by identified highest priority directions and fields.

Additionally, it must be recognized that there are difficulties in establishing and keeping high priority directions and fields unchanged in the long-term, since:

- Scientific frontiers change rapidly and unpredictably.
- National strategic demands evolve constantly.

Therefore a mechanism must be established for dynamic and macroscopic adjustment of the highest priority directions and fields. This entails periodic reviews of the progress of current high priority research programs, as well as constant monitoring and analysis of scientific frontiers and national strategic demands.

Special Candidate Research Programs

Zhang explained that in order to advance the development of a broad range of basic science fields and to meet national long-term strategic demands, the **Working Group on Basic Sciences** has been studying the details of two special candidate long-term major research programs which some scientists recommended to it. Each would require support from several agencies. Program I is called **Research on Life Reproductions**. Program II is called **Quantum Manipulations**. **Zhang** called on **CHANG ZENGYI** of the Institute of Life Sciences at **Peking University** to provide details about Program I, including its significance, principal objectives and resource requirement, after which he provided a comparable description of Program II.

Zhang concluded his presentation with what he called "struggles in my mind":

- Should a bottom-up or top-down approach be adopted in identifying the highest priorities?
- How to decide resource distributions among different fields, and between "planned" research and "unrestricted explorations (individual's curiosity)"?
- How to resolve different opinions and controversies on high priority directions and fields among experts?

General Discussion

Efficacy of Plans and Planning

JOSEPH BORDOGNA commended **Zhang** for an interesting presentation but suggested that it ended with too many "x vs. y's"—e.g., a top-down vs. a bottom-up approach. **NSF** never does anything that is truly top-down. It may organize a workshop or have a small pilot solicitation to determine the extent of the existing capability to conduct excellent research in a new area. But any new area becomes interesting only because working scientists ask the agency to consider it. Several years ago **NSF** had a special Opportunity Fund which its hopes to revive in 2005. The intent of this fund is to experiment with new directions so that regular programs do not become too locked in.

RICHARD ATKINSON was worried about the emphasis thus far on a single plan and a single process. He also agreed with a remark made by **Bordogna** in Session I that the planning process itself is far more important than any plan. In the United States, there are many different science and technology plans: government agencies, universities, and private companies all have their plans. Indeed, it would be interesting to look at the history of the plans of US government agency to determine how many were actually carried out and/or how they were modified as events obliged agencies to change direction.

Bordogna emphasized that the most important function of planning is to reveal all important options and then to be ready. He described how the current $700 million/year US government interagency **National Nanotechnology Initiative** emerged. Eight years ago an **NSF** program officer became interested in the area. He convinced **NSF** to conduct several workshops, which led the agency to recommend to the **Office of Science and Technology Policy** (OSTP) that it should establish an interagency committee on nanotechnology. **OSTP** declined to do so, until one day, the **White House Domestic Policy Council** recognized that perhaps there was a nanotechnology market. Two weeks later, the committee that **NSF** had recommended was created.

PEI GANG commented that whereas a good deal of the discussion about the paramount importance of the planning process as opposed to the plan itself was certainly applicable to China, in his opinion both a plan and a process were essential for the country. There is considerable concern that if the Chinese scientific community does not come up with a reasonable plan, then a bad plan will be imposed by government. The primary issue is not whether there will be a plan, but whether scientists are to have any choices in the matter. The scientific community wants to do the right thing, and also do things right. So a large challenge is to establish correct, widely accepted procedures not only for planning, but for review and implementation.

The United States is sufficiently wealthy to support research in all fields. But China has only a fraction of the budget for basic research and must plan carefully. **Pei** emphasized that the two special programs that **Zhang** had mentioned in his talk was intended to supported far more broadly than by the **National Natural Science Foundation of China**. They are meant to be truly national plans.

Pei resonated with **Bordogna**'s point about the need to be ready for opportunities. As an example, when the SARS crisis emerged, there were no facilities in China capable of conducting research on the corona virus. By the time that those facilities were ready, the crisis had passed. That is, SARS showed the need for work on the corona virus. Every one jumped on board. Now interest in this line of research has receded.

Bordogna sympathized with **Pei**'s remarks, but reiterated that in his opinion, the principal function of a plan is to get people to think. He reminded the group that historically, the best generals were those who made good plans, but also knew how and when to depart from them.

He also emphasized that NSF does not have a formula for being ready. However, it makes over 30,000 grants per year and has a large reserve pool of people it has funded in the past. As opportunities and crises develop, NSF can search its extensive grantee reserve data base, bring people together and get their recommendations on where to go.

People and Tools

J. THOMAS RATCHFORD noted that NSF had had a number of programs with specific objectives in the past such as the **Materials Centers** and **Global Change Research**. Have there been explicit efforts to evaluate the research that resulted from such programs?

Bordogna responded that the **Materials Centers** were started because the United States lacked sufficient experts in materials research. Originally 12 were funded by the **Defense Advanced Research Projects Agency** (DARPA), and later moved to **NSF**. The original centers have now transformed themselves into a total of 25 centers and large research groups which are evaluated every three years. Their directions change continuously. As a case in point, several are now deeply involved in nano research.

Ratchford wondered if the results would have been better or worse if the funds given to the **Materials Centers** had been made available for competitive, peer-reviewed grants.

Bordogna responded that there was no way of knowing. An important function of the centers was to produce PhDs and conduct research across disciplinary boundaries. It is frequently necessary or at least desirable to fund large centers because scientific tools are becoming more expensive, more sophisticated, more exotic. An important current issue is whether **NSF** should accept responsibility for the tools infrastructure for all basic research in the country.

New approaches to the issue of expensive tools are being sought. For example, nine years ago there was considerable pressure on **NSF** to build a shake table for earthquake studies at the University of California, Berkeley. One argument give was that Japan was spending $400 million for the world's largest shake table. **NSF** decided to adopt a different approach by developing a distributed earthquake engineering system. Several large earthquake studies centers with state of the art tools are being supported. They are being connected by means of broadband communication technology. The system is being devised so that it is greater than the sum of its parts. Access to this distributed system will be available to all qualified university researchers and can be used for undergraduate teaching.

Support for Basic Research

Ratchford noted that many comments made by the US participants are conditioned by the special circumstances of the US system, which in many ways is probably very different than the Chinese system. **NSF** is certainly important in the United States. However, its basic research budget is only about 25 percent of the US government total for basic research. What is the situation regarding the distribution of support for basic research in China?

CHEN JIA'ER responded that the **National Natural Science Foundation of China**, the **Chinese Academy of Sciences**, the **Ministry of Science and Technology**, and the **Ministry of Education** all share responsibility for basic research. **NSFC**'s budget amounts to approximately 20 percent of the total for basic research, and basic research accounts for approximately 5.3 percent of total R&D spending.

WILLIAM BLANPIED noted that **Zhang**, in his presentation, had referred to the need for latitude to support exploratory research. It is possible to have a plan and to build provisions for exploratory research into the plan. How is that being done?

Chen Jia'er responded that the **NSFC** has two types of plans: one for exploratory research, the other for strategic research.

ZHANG XIAN'EN provided additional data and information about support of basic research by the Chinese government. The **National Natural Science Foundation of China** is the principal organization for funding university research. The **Ministry of Science and Technology** develops and implements policies for science and technology and provides research support driven by national demand at levels four to five times that of **NSFC**. A good deal of **MOST** support for basic research comes via its **"**973**"** program. About five percent of university researchers receive support both from **NSFC** and through 973 projects. About 40 percent of the research budget of the **Chinese Academy of Sciences** is also devoted to basic research.

YAN CHUNHUA remarked that in the case of funding through the 973 program, researchers are asked to produce results of more or less immediate use by industry, so striking a balance between basic and applied research can be very difficult. This is particularly true for universities and **CAS** institutes.

Atkinson reiterated a point he made earlier: that in the United States many government agencies support basic research. He asserted that all or at least many agencies in China might also set aside funds for basic research support.

Ratchford asked, rhetorically, whether the situation regarding health-related research in China would be better off if the **Ministry of Public Health** had a unit devoted to support of basic research?

According to **Zhang Xian'en**, a major difference between China and the United States is that in China, many researchers in other agencies have to apply to **NSFC** for support, whereas in the United States support is available as a part of the regular duties of researchers. Indeed, **NSFC** funded most SARS-related research.

ZHANG SHUANGNAN noted that at one time many ministries supported research. However, they did not provide research funds broadly to universities and comparable research institutions. Instead, many had their own research facilities and even their own universities so that most of their research support went to those institutions. After **NSFC** was created in 1986 and as a result of other reforms, most of these "babies" were either abolished or merged with other institutions and thereby broadened. There is some concern within the scientific community that if other ministries were encouraged to support research, including basic research, that some of these former negative practices might be revived.

The situation in the United States is quite different. For example, 20 percent of the research budget of the **National Institutes of Health** (NIH) research budget goes to support its own in-house laboratories, while the remainder is allocated to research in medical schools on the basis of peer reviewed proposals.

Chen Jia'er noted that there is a separate fund for supporting social science research in China. The **NSFC** has a management science program, and there is some support for bringing social sciences into that program.

NSF's Response to GPRA

Referring to the discussion during Session I of the **Government Performance and Results Act** (GPRA), **CAO JINGHUA** asked for more details about **NSF**'s response. **Bordogna** responded that **NSF**'s first reaction was that it was impossible; when you are at the frontier, you don't know where to go so how can one evaluate probable future directions in quantitative terms? The agency supports the creation of new knowledge. Some of the projects it supports fail. But even a good attempt that fails tells us something important about where to go and where not to go. How can that be quantified?

Then **NSF** read the GPRA law carefully and discovered that if an agency found that a purely quantitative assessment would be difficult, it could negotiate with the **Office of Management and Budget** (OMB) for an alternative approach.

NSF measures accomplishments by integrating discovery over all 42 of its divisions, and it does so retrospectively. Each year all these divisions submit "nuggets" on what they regard as the most significant activities they have supported, so **NSF** maintains a catalog of nuggets. External advisory committees evaluate those nuggets, and these evaluations form the basis for the annual performance reviews which are sent to **OMB** and the **US Congress**.

NSF also has performance goals related to management. For example, a goal set several years ago is to reach a decision on whether to support or reject all proposals within six months of their receipt. It has largely achieved this goal. **NSF** is very proud that last year it was selected as the best managed federal agency.

The GPRA law requires **NSF** to have a strategic plan. Also, each directorate has its own plan. **NSF** is a participant in implementing several interagency initiatives, such as the **National Nanotechnology Initiative**. However, the United States does not have a national R&D plan. Not having such a national plan is a good thing!

TOM COOLEY went on to explain that the original GPRA concept was for each agency to carry out its own self-assessment. Although that has since been modified somewhat, **NSF** has appointed an external advisory committee to assess its performance in terms of its strategic plan. In establishing its procedure for responding to the GPRA requirements, **NSF** had the advantage that for many years each division has had an external Committee of Visitors (COVs) that come in to assess their respective performance every three years. So NSF already had in place a process to tell it what it is doing correctly and what might be improved. The way in which the agency goes about fulfilling the GPRA requirements consists of a merger of performance and accountability. As one important example, **NSF** publishes a brochure annually that reads something like the annual report of a company to its stockholders to explain to the public what it is getting from its investment.

Roles of the Non-Government Scientific Communities in the United States

Atkinson referred to the important role that the **National Research Council** (NRC) plays with respect to science policy in the United States. The **NRC**, which is a private organization, conducts in-depth studies on a wide range of scientific issues that are widely considered to be authoritative. Some of these studies are commissioned by government agencies or the US Congress. But many are conducted in response to important issues raised by the scientific community itself. The independence of the NRC is a very important aspect of its work and the important role it plays in the US scientific enterprise.

Picking up on **Atkinson**'s point, **Blanpied** noted that an essential aspect of the US scientific system that is often overlooked or not well understood is the essential role played by a large number of independent, non-government organizations, including the **NRC**. These include professional scientific societies such as the **American Physical Society**, as well as private organizations devoted to special interest areas such as the environment.

Bordogna noted that in fact there are many voices telling **NSF** what it should do. The situation is chaotic, but that is the state of the frontier. Without having many diverse voices expressing their own opinions, **NSF** could not make reasoned judgments about what to do.

D-4. Session III: Planning the Deployment of Academic Disciplines in Basic Science

The session was chaired by **RICHARD ATKINSON**, President Emeritus of the University of California. The prepared presentation was given by **WU ZHONGLIANG** of the Graduate School of the **Chinese Academy of Sciences**.

Atikinson opened the session by referring to several key recommendations made by **Vannevar Bush** in his classic 1945 report to **President Harry S. Truman** entitled, *Science—the Endless Frontier*. This report is regarded as one of the principal cornerstones of post-World War II science policy in the United States. **Atkinson** believes that there is much in it that would provide useful ideas to China as it develops its strategy for the support of basic research during the next 15 years.

The **Bush** report recommended that the support and conduct of applied research should be left to industry, which has the knowledge and experience to establish priorities and directions in accord with possibilities for commercialization. But applied research has to be based upon adequate basic research results. During the pre-World War II era, universities were largely responsible for the conduct of basic research in the United States. Yet they received no federal support for that activity. In what was considered to be a bold proposition in 1945, **Bush** asserted that the federal government had both the Constitutional authority and the obligation to support basic research in colleges and universities and other non-profit organizations in order to assure that an adequate pool of basic research results would always be available to industry. He argued that the federal government should also support the education of future scientists and engineers to assure the existence of an adequate science and engineering workforce. **Bush** insisted that decisions to support basic research projects by the government should not be made primarily by Washington bureaucrats, but rather should be based on the merits of the proposed research as determined by scientists themselves.

Incorporation of **Bush**'s principal recommendations into the policies of the government led, within a few years, to the flowering of academic science in the United States and to the unique system that couples research with graduate education. The level of funds available to academic scientists from the government became so large that until the 1970s, most universities ignored possibilities of support from industry, which had been an important source of funds prior to World War II. However, during that latter years of that decade key individuals in the university, industry and government research sectors recognized the desirability of encouraging cooperation between academic and industrial researchers, in part to assure that the basic research conducted by universities would be of interest to industry, and in part to provide graduate students with industrial research experience. As one result the US government, with **NSF** in the lead, created the first programs to facilitate such cooperation. In must such research projects government normally provides support for the university side of the collaboration, while industry pays its own share. Frequently the industrial portion of support has been two or three times or more than the government's level of support. In this way, government funds have been used to leverage industrial support. University-industry research cooperation has flourished during the past 25 years, to the benefit of the US economy.

Atkinson concluded his introductory remarks with a brief description of a State of California initiative which provides seed money to university scientists to help them attract higher levels of research support from California industry. This program has also been a considerable success and has shown that support of basic research can lead to substantial economic benefits at the state level.

Atkinson then called upon **Wu Zhongliang** to deliver his presentation.

Wu began by suggesting that one gauge of the growth of science might be the increase in the number of recognized basic research disciplines. Nature, of course, recognizes no disciplines. Rather, the ways in which scientific research progresses tend to define and redefine academic disciplines through a process of self-organization. Organization of research by discipline is useful as a means for providing a vision that will permit effective planning.

Aspects of Planning

There are five aspects involved in planning a coherent program for basic research, as follows:

- Provision of a stable framework for the accumulation of scientific knowledge;
- Education and scientific capacity building;
- Rational financial allocations;
- Public understanding of science; and
- Development of culture

Science as a culture

- The value of science lies not only on the result of knowledge (and potentials of applications), but also on the research process itself which is an important component of culture
- A nation's culture without basic science is not a healthy and hopeful culture

With reference to the final aspect, he suggested that the value of science lies not only in research results and their potential for applications, but also on the research process itself which is an important component of culture. "A culture without basic research," **Wu** asserted, can be neither a healthy nor a hopeful culture."

Unpredictable and Predictable Aspects of Basic Research

The philosophy underlying the development of a plan for basic research must recognize that there are aspects of basic research that are unpredictable, as well as other aspects that are predictable.

Basic research is inherently unpredictable for the following reasons:

- Results of a basic research project are unknown prior to the conduct of the research itself;
- The significance of those results in terms of their impacts on the development of one or more scientific disciplines are frequently unpredictable, at least in the short-term; and
- Their potential applications are also normally unpredictable in the short-term.

On the other hand, a good deal about the overall directions of basic research can be predicted. As an important example, the conduct of basic research depends strongly on available tools which depend in turn on the state of development of several key technologies. Additionally, selection of national research priorities often depends on social needs. **Wu** cited as a case in point the development of global seismology to understand and predict earthquakes on an international level.

Basic research priorities also depend on the readiness of one or more disciplines for critical advances. At the turn of the 19th century and the early years of the 20th century, the development and application of mathematics and physics predominated. In the first decade of the 20th century the foundations of modern physics—namely, relativity and quantum mechanics—were at the forefront. With the identification of the structure of DNA in 1953 and establishment of the mechanism of plate tectonics in the 1960s, the stage was set for critical advances in the biosciences and geosciences. Since the 1960s, interdisciplinary studies have become increasingly predominate. Will the 21st century be the century of the biosciences?

Issues Underlying Planning for Basic Research

Based on his discussion of un-predictability and predictability, **Wu** highlighted several issues that any long-term basic research plan should address. First, China has many special problems related to its geographical extent and population, as well as the current and medium-term future course of its economic and social development. The country has to solve these problems by itself. However basic research results obtained elsewhere and mutually beneficial cooperative international projects can be of considerable assistance.

China's large population provides the potential to increase the absolute number of individuals active in research, including basic research. However, the percentages themselves are currently rather small. At present, about 79,000 people are active in basic science, which is less than 1/10,000 of the total population. In contrast, the fraction of the total population working in basic science in the United States is 4/10,000.

The unpredictability of the future course of basic sciences suggests that adequate support should be available for research across the entire spectrum of disciplines. However in **Wu**'s opinion, neither Chinese policy makers nor the general, informed public have regarded basic science disciplines as useful. Therefore adequate support has not been forthcoming.

Because developments in science and to some extent social needs for science are frequently unpredictable and dramatic, the capacity for rapid response in the deployment of resources is essential. Development of sufficient numbers of adequately trained researchers in all important disciplines for deployment in important emerging areas is therefore essential.

Additionally, active international exchange and cooperation can be significant in assuring the rapid detection of, and responses to, emerging frontiers in science. Flexibility in deploying financial and human resources at the level of research organizations is essential. However, in China academic institutions do not have a great deal of liberty in how to deploy resources by discipline. This sort of stability may be good for quality control. However, it entails a loss of flexibility.

Several groups have produced studies on priority setting in basic research, including:

- Panels of the **Chinese Academy of Sciences** and the **Chinese Academy of Engineering**;
- Joint research groups of the **National Natural Science Foundation of China** and the **Ministry of Science and Technology**;
- The **Institute of Science and Technology Information of China** ,
- The **China Association of Science and Technology**; and
- The **Ministry of Education**.

Categories of Scientific Disciplines

Based in part on these studies, the **Working Group on Basic Sciences** proposes that a framework for that plan should consist of three categories of scientific disciplines, namely:

- pure basic sciences;
- application-oriented sciences; and

- interdisciplinary fields encompassing the natural and social sciences.

The objective of the pure basic sciences set of disciplines is to gain fundamental knowledge and understanding of natural phenomena without specific applications toward processes or products in mind. There is general agreement that six disciplines ought to be encompassed by this category:

- mathematics,
- physics,
- chemistry,
- astronomy,
- earth sciences, and
- biological sciences.

The objective of the second, application-oriented set of disciplines should be to gain the knowledge or understanding necessary to determine the means by which a recognized specific need may be met, with an emphasis on the fundamental and long-term character of such needs. Nine specific disciplinary areas are encompassed by this category:

- information,
- energy,
- materials,
- space,
- natural resource (including natural disasters) and environment;
- agriculture,
- health,
- ocean, and
- engineering.

High priority fields of study encompassed by the third, interdisciplinary category are:

- psychology and cognition, and
- management and economy.

In summary, a framework for long-term planning for basic science in China can usefully be thought of in terms of six pure basic research disciplines, nine application-oriented fields, and two fields involving interdisciplinary research between the natural and social sciences. This can be called the six-plus-nine-plus-two configuration. Deployment of necessary resources for the pure basic research and interdisciplinary basic research categories should be the province of the **National Natural Science Foundation of China** and, to a lesser extent, the **Ministry of**

Education. Deployment of resources in the application-oriented basic sciences fields should be the responsibility of the **Chinese Academy of Sciences**, the **Ministry of Science and Technology**, **National Key Laboratories**, and **State Ministries and Bureaus**. [*Editor's note*: most of the basic research support provided by the **Ministry of Science and Technology** appears to be in the application-oriented or strategic areas. Although 40 percent of the budget of the **Chinese Academy of Sciences** is currently allocated for basic research, a good deal of this research is also in application-oriented areas.]

Useful Ideas from Day 1

Wu made note of what he regarded as useful ideas which had emerged in discussions during the first day of the **Forum**: namely, that:

- all government ministries and agencies should have some responsibility for supporting basic research;
- the **National Natural Science Foundation of China** should act as a balance wheel to assure adequate deployment of resources across disciplines;
- organizations that conduct basic research should deploy resources in such a way as to be ready to meet new challenges and opportunities;
- a specific education component should be included among the responsibilities of the **National Natural Science Foundation of China**;
- periodic performance reviews (particularly external reviews) of scientific organizations are essential.

Discussions during **Day 1** also suggested several policy measures that he believes should be adopted:

- to be more active in international exchange and collaboration;
- to provide scientific institutions with more flexibility in determining the deployment of resources among disciplines, subject to adequate evaluation and effective management; and
- to encourage interdisciplinary studies.

Science as a depository

- The value of science lies not only on the direct short-term potentials of applications, but also on the long-term capacity deposit to meet the unexpected challenges in the future

Discussions at the **Forum** had also reemphasized that the value of basic science lies not only in direct short-term potential for application, but also in the long-term capacity to meet unanticipated future challenges.

Wu concluded his presentation by asserting that the scientific community in China should do a better job of convincing policy makers and the general public that all sciences are important, and that academic institutions should have more liberty and flexibility to deploy resources among various disciplines.

General Discussion

Disciplinary Structure of Science and Engineering

Wu's summary about how best to identify and organize scientific disciplines for developing a framework for basic research in China stimulated considerable discussion. **RICHARD ATKINSON** observed that during the 1960s and 1970s whenever new possibilities within an existing discipline emerged or when a new interdisciplinary area became established, universities were frequently tempted to create new departments. However, more recently this practice has diminished considerably in favor of an approach that provides existing disciplinary departments with sufficient flexibility to accommodate such developments as they emerge. Thus, in **Atkinson**'s opinion, no great effort needs to be made to assure that in developing a framework for supporting basic research in China all important disciplines are represented on the one hand, while avoiding an unnecessarily long list on the other.

ALEX DEANGELIS noted with respect to the changing character of scientific disciplines that departments of biological sciences are not what they were 30 years ago. Instead, they rely heavily on tools from physics and chemistry to conduct cutting edge research in biology. **JOSEPH BORDOGNA** picked up on this remark by noting that physics and chemistry departments have also changed substantially. Indeed, one might say that large areas of physics have literally been reinvented because of biology. A wide range of scientific disciplines now make use of massive quantities of data. The requirements for, and challenges of, "big data" are likely to be an important factor in changing the character of these and other disciplines.

Research, Education and the Role of Universities

Bordogna described a **National Science Foundation** program called **Integrated Graduate Education and Research Training** (IGERT) which is designed to provide graduate students with at least one substantial cross-disciplinary experience. **IGERT** grants are made for three years at levels between $50,000 and $100,000 and are awarded to university faculty who accept student applications from all over the United States. This program has become very popular. Many proposals stress interdisciplinary from the outset.

DeAngelis added that **IGERT** projects often incorporate an international component. For example, a professor at the University of Washington in Seattle has recently received such an award which will permit her students to conduct research in ecology at **Sichuan University** in Chengdu.

Some time was devoted to discussing requirements for admission to Chinese universities. **PEI GANG** explained for the benefit of the American participants that entrance to undergraduate programs is determined by nationwide entrance examinations. There has been some discussion about whether individual universities should have flexibility to tailor entrance requirements to their own vision of their education and research directions. However, the imperative for social justice is one of the principal reasons for continued sole reliance on nationwide entrance examinations, since there is a strong consensus that nationwide examinations assure that entrance to undergraduate programs will be determined on the basis of merit alone.

Bordogna agreed with the need for social justice in university admissions. But he noted that equality of opportunity is a prerequisite for social justice, in this case to assure that all students desiring to enter universities receive adequate preparation for nationwide examinations.

While the Chinese participants supported the continuation of nationwide education in some form as a means for social justice, many also believed that universities must have more autonomy from the central government in reorganizing themselves and deploying their resources internally.

Summary

WANG YUAN, Director of the Centre of S&T Development of the **Ministry of Science and Technology**, suggested that four large issues which emerged from this session need to be addressed in China's planning for basic sciences:

1. How can the capacities of Chinese universities for research and graduate education be enhanced?
2. How many fields of basic research should China support, and how much should be taken from other countries?

3. How can government support for basic research be effectively organized, and how can adequate incentives be provided for careers in basic research?
4. How can high quality interdisciplinary research be encouraged and fostered?

D-5. Session IV: Mechanisms, Talents and Policy for Advancing Basic Research Development

The session was chaired by **CHENG JINPEI**, Vice Minister of the Ministry of Science and Technology; the prepared presentation, entitled Funding, Workforce, Tools and Management, was given by **WU JIARUI** of the Shanghai Institutes for Biological Sciences, Chinese Academy of Sciences.

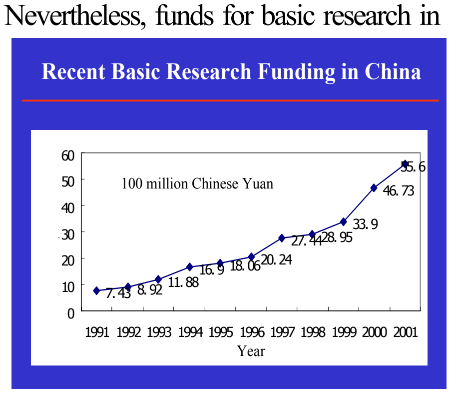
Wu began by suggesting that there are at least two possible strategies for developing a basic sciences plan. The first, which he called project-oriented planning, proceeds by first identifying various projects that might conceivably be conducted or at least initiated during the period of the plan, establishing priorities for those projects, and then seeking the necessary resources to carry them out. The second approach proceeds by considering the environment required to conduct basic research at an adequate level, then proceeds to details about possible projects that could be carried assuming the existence of such a research environment. The **Working Group on Basic Sciences** has adopted the later strategy.

Four elements need to be considered in this type of planning:

1. Funding
2. Workforce
3. Facilities
4. Management

Funding

Funding for basic research in China doubled between 1998 and 2001 and continues to increase. In the latter year, it was approximately 5.6 billion Yuan. Nevertheless, funds for basic research in 2001 were only 5.3 of total expenditures for research and development (R&D), as opposed to 17.8 percent for applied research and 76.9 percent for development. In order to increase funds available for basic research, both the size of the entire R&D pie and the size of the basic research slice need to be increased. Currently, China's R&D investments are in excess of 1.1 percent of its Gross Domestic



Product (GDP), with the goal of reaching 1.5 percent by 2005. A reasonable goal, in **Wu**'s opinion, would be to increase the R&D/GDP ratio to 2.0 percent during the 2005-2010 period and to 2.5 percent during the 2011-2020 period. At the same time the fraction of R&D allocated to basic research might increase to 10 percent during the 2005-2010 period and to 15 percent during the 2011-2020 period.

Currently virtually all funds for basic research come from the central government. **Wu** emphasized that efforts should be made to obtain support from provincial and city governments, as well as from enterprises and philanthropic organizations.

In terms of the character of the basic research supported in the medium and long-term future: an appropriate balance must be struck between funds allocated on a *competitive* and *non-competitive* basis. *Competitive* research support should be balanced between idea-oriented and purpose-oriented research. *Non-competitive* support should focus on development of the scientific workforce, research platforms, and facilities.

Workforce

In 2001, there were 878,000 full time equivalent scientists and engineers engaged in R&D in China, of which 79,000 or 8.3 percent were engaged in basic research. Of the latter number, 51,000 conducted research in universities, and 24,000 in institutes of the **Chinese Academy of Sciences**. A reasonable goal would be to increase the size of the total R&D workforce, while maintaining the approximately 8 percent ratio working in basic research and taking steps to improve the quality of those scientists and engineers.

Facilities

Currently there are four categories of research facilities in China:

1. the 162 **National Key Laboratories**;
2. big science facilities, most notably the **Beijing Electron Positron Collider**;
3. collections of natural resources, including living things and minerals; and
4. libraries, the Internet, and the information highway.

All four of these categories need more adequate support, and a balance must be struck regarding allocation of support among the four. Additionally, the **National Key Laboratories** should be upgraded to the status of **National Laboratories**, and other big-science projects such as a **National Synchrotron Light Source** should be supported.

A balance also needs to be struck regarding support for **workforce**, **projects**, and **facilities**. An allocation of 37.5 percent, 37.5 percent, and 25.0 percent, respectively, appears to be reasonable.

Science Management

Currently, macro-management of basic research in China is carried out under the overall guidance of the **National Leading Group for Science, Technology and Education**. The administrative organizations of the government responsible for supporting basic research are the **Ministry of Science and Technology**, the **National Natural Science Foundation of China**, the **Chinese Academy of Sciences**, and the **Ministry of Education**. These organizations also develop their own policies for the support and conduct of basic research. In order to improve macro-management of basic research in China, it would be useful to have a **National Advisory Committee on Science and Technology** located organizationally between the **Leading Group** and the existing administrative organizations. This body would be responsible, among other matters, for advising the **Leading Group** on the allocation of resources for basic research, and assuring the coherence of China's basic research activities.

The tools for managing basic research at the micro-level include periodic administrative reviews of organizations conducting basic research, the Science Citation Index (SCI) for evaluating organizations and institutions, and peer review. Evaluation of basic research should rely more heavily on peer review than at present. Additionally, better ways to evaluate interdisciplinary research need to be devised.

International Collaboration

Strategies for increasing international collaboration need to be considered as integral aspects of China's basic research planning. These should include:

- strengthening the design and coordination of internationally-collaborative big science projects by the central government;

- opening more channels for Chinese scientists to collaborate with foreign scientists at institutions and facilities located outside the country; and
- opening more channels for foreign scientists and students to conduct research in China.

Discussant's Comments

TOM COOLEY, serving in his capacity as discussant for the session, commended **Wu** on a well organized presentation that dealt with what he believes are the four major areas that need to be considered in any plan: namely, **funding**, **workforce**, **tools** and **management**. It is particularly important to consider management issues carefully, otherwise other aspects of a plan are likely not to be implemented effectively.

Cooley noted with interest the allocation proposed in **Wu**'s presentation among funds for **workforce** (37.5 percent), **projects** (37.5 percent) and **facilities** (25.0 percent). For several years, the **National Science Foundation** has assigned an upper limit of 25 percent of its annual budget to support construction of major new facilities or upgrading of existing facilities. Division of the remaining 75 percent has sometimes been contentious, although there is general recognition in the US scientific community that in the absence of adequate, sustained support for the education of future generations of scientists and engineers, no viable research projects can be implemented effectively. As an example, the Astronomy Division's advisory committee has made it a policy that project support, including capital support, should never exceed workforce support. Of course like all divisions, the Astronomy Division is subject to NSF's overall rule that no more than 25 percent of its budget can be devoted to major new facilities.

On the matter of research support, **Cooley** noted that whereas in the United States the federal government is the principal supporter of basic research, some support is also provided by industry, non-profit organizations, state and local governments and universities and colleges themselves. Stability is an important value in having the federal government as the principal supporter of basic research. Funding from other sources is likely to diminish during economic downturns, as has been the case during the recent recession in the United States. But federal support is likely to remain at least constant and thus damp the problems faced by researchers when other sources of funding for basic research decrease.

General Discussion

Macro-plans and Mini-plans

Turning to the general issue of planning, **RICHARD ATKINSON** asked, rhetorically, whether it is better to have one macro-plan for basic research across the whole government, or a series of mini-plans for each funding organization and each organization that conducts basic research. In the United States individual universities, as well as university departments, have their own plans. Such a system, for example, provides universities and university departments with the flexibility to allocate available financial and human resources effectively in the light of changing scientific opportunities.

Cooley agreed with **Atkinson's** comments regarding mini-plans. According to the **Government Performance and Results Act** (GPRA) discussed in earlier sessions, all federal agencies, including the **National Science Foundation**, are required to develop five-year strategic plans. However, at **NSF**, there are plans within this large-scale plan developed by the agency's seven Directorates. **NSF** requires that all such mini-plans meet two criteria: *first*, that they be flexible and agile; *second*, that they emphasize partnership opportunities, including partnerships with industry, state and local governments, and foreign research organizations.

Basic Research and the Cultivation of People

XUE LAN emphasized that in making the case for increased support for basic research, more emphasis must be placed on the essential role of basic research in cultivating people. The **National Natural Science Foundation of China** has done a good job in cultivating people through its research grants to university researchers. However, this result is an externality having come about as an indirect result of research funding. Additionally, the people currently being cultivated through NSFC grants are primarily university faculty. Considerably more emphasis should be given in the forthcoming **Medium and Long-Range Plan for Science and Technology Development** to cultivating future generations of scientists and engineers by providing opportunities for adequate support and meaningful working experiences for graduate students.

J. THOMAS RATCHFORD picked up this point. There are, as he noted, numerous Chinese graduate students who are completing their PhD work in foreign universities in several countries, including the United States. In developing the basic research component of the **Medium and Long-Range Plan**, perhaps some serious attention might be paid on how to cultivate these students as many prepare to return to China. One way to do so would be to involve them in cooperative international research projects.

Atkinson suggested that the youthfulness of researchers in China means that the country lacks a healthy continuum. One problem this presents could be difficulties in developing an adequate peer review system. In the years prior to World War II, the United States gained a great deal by arranging to absorb the influx of European scientists. How will China be influenced by the burst of scientists in the younger age group?

International Aspects of Basic Science

ALEX DEANGELIS remarked on the importance of international cooperation to China in fostering basic research in the country. **WILLIAM BLANPIED** picked up on this remark by suggesting that by contributing financial and human resources to international cooperative projects, particularly in big science, China would be seen as contributing to the development of the world's pool of scientific knowledge. Additionally, such cooperation is an excellent way to train future generations in the conduct of basic research. Possibilities for international collaboration provided an additional justification besides purely economic justifications for strong support of basic research in China.

Cooley emphasized the importance of considering funding for contributions to large-scale internationally planned, constructed and operated facilities. **Ratchford** agreed, while emphasizing that major contributions to large-scale international facilities should come from "new" money. Any attempt to provide support for large-scale projects from existing budgets is likely to reduce substantially funds available for smaller scale research projects, whether internationally cooperative projects or purely domestic projects.

CHENG JINPEI noted that China has already contributed to large-scale international facilities, such as the **Human Genome Project**, the **International Ocean Drilling Program** (IODP), and the **International Thermonuclear Experimental Reactor** (ITER), and is likely to continue to be asked to make such contributions in the future. While China appreciates such invitations as evidence of increasing international recognition of its scientific capability, it must also think carefully about how to balance support for such international activities with support for domestic basic research projects.

Informal Suggestions

Bordogna asked for and received permission from the chair to table a set of 13 informal suggestions which the US delegation believed might be considered as principles for the development of basic research in China. These suggestions, together with an explanatory preamble, appear in Section C.

Chen Jia'er thanked Bordogna and the US delegation for their useful suggestions, as well as their contributions to two days of stimulating discussion.

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Sino-US Forum on Basic Science for the Next Fifteen Years

February 16-17, 2004, Beijing, China

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