INTERACTION BETWEEN BASIC AND APPLIED RESEARCH

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BRIDGES

DIALOGUES TOWARDS A CULTURE OF PEACE

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The recently published study by the Institute of Higher Education of the Shanghai Jiao Tong University on "The American Ranking of World Universities 2003" has had a great deal of impact in the entire world. The ranked list of the first fifty Universities is dominated by the United States, with 34 in the first 50. The United Kingdom follows with 5; Canada, Japan and Switzerland with 2; Australia, Germany, The Netherlands and Sweden with 1. France and Italy did not appear at all in the first fifty.

In particular, these findings caused quite a bit of dismay in Europe. On March 2000, at a meeting in Lisbon, the heads of European States had affirmed their intent that the European Union should become by the year 2010 "the most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion". The Shanghai report made clear how long and difficult it would be to achieve the goal the EU had set for itself.

Germany was particularly stung by these findings given the long tradition of excellence by German academic and research institutes in the past. President Schroeder proposed a plan to quickly make up for this situation. He noted that the greatest preoccupation in European countries had been to lift the educational level of the greatest possible number of citizens. Inadequate attention had been given to the fact that the most innovative research is most often the result of well funded research programs at elite institutions. He proposed the creation of twenty new centers of excellence in Germany to meet the challenge. This initiative came to naught due to the opposition of the provinces into which Germany is divided.

In France the budget for research was decreasing, rather than increasing in August 2003, as pointed out by Pierre Papou, ex-Director General of CNRS in an editorial in Science magazine. He notes how difficult it will be for Europe to make up for the inadequate funding of the past. While the EU is spending only 1.9% of the GDP in research, the United States spent 2.8% of GDP and Japan 3% of GDP. He considers increased Research and Development as crucial to the future economic and social well being in Europe.

Why this increased attention to the knowledge base of the economy? It has become clear to thoughtful people all over the world that education plays a central role in the well being of nations. Certainly, educating a broad segment, or better, all of the population in a country in primary skills such as reading, writing and arithmetic, is accepted as a goal by most governments. After this level is achieved, further education can provide new opportunities for the general welfare by preparing a skilled manpower for a variety of jobs. Manufacturing of high technology systems and sub-systems has been at the basis of the rapid advances of Asian nations in the last few decades. Knowledge resources have played a significant role in this process from production of cars to that of computer chips and consumer electronics.

The perception in Asia, Europe and the United States is that the next area that requires attention is the creation of new knowledge which will be the engine for future innovations. Advances achieved by research in medicine, physics, chemistry, biology and computer sciences will have a major impact on the health and wealth of people. It is necessary for all countries to adopt a forward looking approach, rather than the widespread and debilitating preoccupation with "global inequality". As pointed out in an editorial in the "Economist", the tendency by the UN and many other agencies to be more interested in economic justice and wealth redistribution, rather than in the creation of wealth, have generally resulted in actions which have failed to improve the lot of poor people and countries.

This mindset is based on the assumption, tacit or explicit, that there is only so much wealth to go around and that the rich countries achieve their wealth at the expense of the poor ones. The fact is that the wealthy countries are wealthy because they produce their wealth. A clear example of how enriching a poor country does not have to occur at the expense or against the rich is given by the tremendous economic strides of China and India in the recent past. Once they decided to enter the world markets and sufficiently modify the internal structures to be successful in the global economy, their progress has been amazing. The conclusion is that it is more profitable to focus our attention in increasing each nation's wealth through reforms and increased productivity, and to aim for further improvements in the quality of life that can be brought about by further research and development.

Our goal should be to increase the available wealth in the world and to widen the number of countries that benefit from it. Most scientists see as the great challenge in their own countries not only the level of funding, but also the reform of the research system and the creation of new institutions to achieve success in Research and Development activities.

I will quote only some remarks by a few eminent people that summarize their conclusions:

Yixun Yau, Vice President of the Chinese Academy of Sciences states:
"It is well known that knowledge resources play a significant role in the process of creating wealth and a decisive factor is played by human resources which create knowledge".

Peter Gross, President of the Max Planck Society remarks about the German situation:
"It is now a matter of making up lost ground for the international race for the best education, the best minds, the best research ideas and ultimately the best products".

Of great concern to each of the authors is the issue of the relationship between basic and applied research. Many people still hold the view that basic and applied research are quite different. This includes industrialists, politicians and at times the scientists themselves. This group fails to understand the revolution which is now occurring. Again, quoting Yixum Yan "in the era of the new economy and, in particular, in the fastest developing fields like information technology, biosciences and technology, it takes less and less time to transfer the knowledge gained from basic research to applications. It even becomes very difficult to classify the types of research work using conventional criteria. For example, it becomes more and more ambiguous to distinguish the interface between basic research and applied research and its applications.

I will use my own work in X-ray astronomy as an example of the close link between the scientific drive for the discovery of new natural phenomena and the rapid technological developments. These in turn provide the basis for processes and products of interest to the broad public.

Basic Research

In 1959, after teaching at the University of Milano and spending a Fulbright Fellowship at the Universities of Indiana and Princeton, I joined American Science and Engineering, a private 30 person corporation in Cambridge, Massachusetts. There I started a group to develop space science initiatives, particularly in x-ray astronomy (which can only be carried out from space). We developed new detectors and techniques that permitted us to discover the first x-ray star during a rocket flight in 1962, carried out under the sponsorship of the US Air Force. The detection of this star required an improvement of the techniques used up to then, by a factor of 100.

The star system we had observed was of extraordinary astronomical interest. It represented a new class of celestial objects previously unknown, a thousand times more luminous than the sun and emitting 99.9% of its energy in x-rays by some unknown process.

This finding stimulated the development of more sophisticated satellite-born instrumentation, under NASA sponsorship, which culminated in 1970 with the launch of a satellite “UHURU”, a 1000 times more sensitive than the rocket experiment (Fig. 1.). With this satellite more than 300 x-ray sources were discovered (Fig. 2).

To summarize the findings;

- We found the first x-ray binaries, normal stars with a neutron star or a black hole companion (Fig. 3);
- We found a hot (millions of degrees) gas pervading the spaces between galaxies in clusters, containing more mass than the galaxies themselves. We realize now that this gas may provide most of the normal matter in the universe;
- We found the first x-ray emitting galaxies and quasars containing super massive black holes.

These findings changed our view of the Universe and underlined the importance of high-energy observations to all of astronomy. This in turn, stimulated further technical development. The concept of an x-ray telescope initiated at ASE in 1959 and developed by the corporation for more than twenty years came to fruition as a NASA facility costing more than 1 billion dollars. The satellite CHANDRA was launched in 1999 (Fig. 4) and can see sources in the Universe a billion times fainter than the star first discovered in 1962 with an angular resolution comparable to that of the best optical telescopes (Fig. 5)

Application of the Technology

During the early period of these developments, that is in the 60's and 70's, the staff at American Science and Engineering also developed new x-ray technology relevant to health, security and defense. The same scientists that were studying the x-ray universe invented the x-ray scanning techniques which permitted the x-ray imaging of objects with radiation doses a million times lower than in the conventional x-ray film approach. This technology was first embodied in the airport scanning machines which ASE pioneered and with which we are all familiar (Fig. 6). Security threats and border controls have now expanded this technology, in which ASE is still involved, to examination of cargo or illegal border crossings (Fig. 7 & 8).

The very same techniques have also permitted the development of medical instrumentation such as computer axial tomography scanners (the CAT) which has had a revolutionary impact in medicine (Fig. 9). The imaging technology in x-rays has found application in diagnostics for fusion research. The commercial value of these activities is in the billions per year.

Lessons Learned

How was all of this possible? I am convinced a primary role was played by the close working relations between industry and university typical in the United States research scene and the easy exchange of scientists between universities, research institutions and commercial enterprises. I myself, moved from Princeton University to a private corporation (ASE) in 1959 and then in 1973, I left the company of which I was executive Vice President for a full professorship at Harvard University. It is hard for me to say where I had the best opportunity for basic research.

The high degree of competitiveness in obtaining government grants for research and the need for new ideas to sustain the commercial side of the corporation stimulated a tremendous degree of creativity by the staff at ASE and provided strong stimulus to achieve excellence in science and in technology. The very existence of ASE and of the many similar corporations which are continuously formed, grow and survive (or perish) in the market is made possible by the availability of start up capital and abundant credit. The existence of research opportunities in private, as well as public institutions outside the universities provide training and career paths which are much more diverse and flexible then available in universities alone. Fundamental to obtaining a synergistic interaction is the decrease of the barriers for exchange of people and ideas between the ivory towers of academia and the world of application and realization of the diverse science and technology discoveries for societal benefit.

General Conclusions

I would like now to conclude with a few comments on what I believe is essential to create a climate favorable to research and development in a country.

1) Basic and Applied research should both be adequately funded.
2) Stable, possibly slightly increasing funding as a percentage of the GDP is required. The basic level of 2.5 to 3% of GDP appears adequate. A rate of increase of greater than 3% per year appears healthy and sustainable. Private industry financing of a substantial fraction of R&D is desirable.
3) The distribution of this research funds must be very carefully considered. They can not be simply distributed in an equalitarian way. A substantial fraction of them must be concentrated through open competition based on merit, in particular areas of research, in centers of excellence, in the most talented individuals and the best programs.
4) The encouragement of free and open discussion on scientific issues is a must. In a recent article in the "Harvard Business Review", Lawrence H. Summers, the current President of Harvard University and a former Secretary of the U.S. Treasury, emphasizes that "…..ideas are the currency of the twenty-first century economy. But what is most special about the American research university is that it is a place where the authority of ideas, rather than the idea of authority reigns supreme". He goes on to state "If you look at the organizations in the economy where the greatest value is being added, they are increasingly the organizations that share the value and character of (research) universities. Organizations that foster an environment where creativity is rewarded, that prepare themselves to respond to challenges and execute their strategy in a nimble way, and that discourage rigid adherence to hierarchy will be best able to meet the challenges of this new century".
5) It is widely recognized that one of the main difficulties in the realization of the benefits of science to society is due to the cultural gap between the science and technology community and the management and investment community. Several government initiatives (such as the Advanced Technology Program) were started in the late 80's to provide support for the transition from research to development. The ATP program was considered successful, but may come to an end in 2004 due to concerns about political patronage and possible market distortions caused by subsidized R& D.
6) In response to the perceived need to provide technology transfer, Private and State Universities in the U.S. have in recent years taken a lively interest in providing on-campus infrastructure and legal support to entrepreneurs in their faculties. This had led to a much closer interaction between basic research and R&D activities than had prevailed in the past. In a sense the Universities themselves are becoming interested in supporting technological innovation. Successful commercial exploitation provides not only societal benefits but also much needed endowment funds.