Science and Technology in Brazil: A new policy for a global world

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This is the summary document of the science and technology policy study carried on by the São Paulo School of Business Administration, Getúlio Vargas Foundation, for the Brazilian Ministry of Science and Technology, within the Program for Scientific and Technological Development (the PADCT II agreement between Brazil and the World Bank). The ideas expressed in this text are the sole responsibility of its authors.

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SUMMARY

Introduction

Brazil developed, in the last quarter of a century, a very significant effort to build its scientific and technological capabilities, but in the last decade this sector has suffered intensely from lack of resources, institutional instability and lack of clarity about its role in the economy, society and education. Brazil's Science and Technology sector is in need of urgent action. Recent transformations in the world's economy have made a country's scientific, technological and educational competence more important than ever to increase production, raise the standards of living of its population, and deal with its social, urban and environmental problems. Policies for science and technology can only be fruitful in association with coherent policies and actions for economic adjustment, education and industrial development. Policies from the central government can only be effective if they involve the active participation of state and local governments and of business, workers, educators and the scientific and technological community. The proposals put forward in this document should not be seen in isolation, but as a contribution to a much broader effort.

This policy paper was prepared by the Getúlio Vargas Foundation at the request of Brazil's Ministry of Science and Technology and the World Bank, as established by the II Program for Scientific and Technological Development (the PADCT II agreement). The work was carried on with the cooperation of an independent group of scientists, economists and specialists of science policy in Brazil and abroad, which produced about 40 papers dealing with the international context, Brazil's scientific and technological capabilities, the links between science, technology and the economy, and Brazil's institutions for science and technology support. This final document is the responsibility of the projects' coordinating team, and does not express necessarily the opinions of the Brazilian government, the World Bank, the Fundação Getúlio Vargas, nor of the individuals who contributed with specific studies.

The main thrust of this policy paper is that there is a definite need to move from the previous mode of scientific and technological development into a new one, more adequate to the current and future realities. This policy paper presents a summary of what Brazil's science policy was in the recent past, the current situation, an overview of the recent transformations of science and technology in the international context, and puts forward some proposals for new directions. To implement these recommendations, the Brazilian government, with the support of the World Bank and other sources, should establish a high-level task force to evaluate this and other policy studies now being concluded, and propose specific policy measures to be carried on by the Ministry of Science and Technology and other agencies, and to be presented to Parliament to be enacted in law when necessary. The main recommendations are summarized below.

Recommendations

Science and Technology are more important than ever for Brazil, if the country is to raise the standards of living of its population, consolidate a modern economy, and participate as a significant partner in an increasingly integrated and global world. The economy must modernize, and adjust to an internationally competitive environment. Education should be expanded and improved at all levels. As the economy grows and new technologies are introduced, new challenges will emerge in the production and use of energy, environment control, public health, the management of large urban conglomerates, and changes in the composition of the labor force. Strong indigenous competence will be necessary to participate as an equal in international negotiations and in the setting of international standards that may have important economic and social consequences for Brazil.

The new policy should steer away from the extremes of laissez faire and centralized planning. A traditional, laissez-faire approach to scientific and technological development will not produce the necessary competence on the scale and quality needed for these tasks. Large-scale, sophisticated and highly concentrated technological projects are not likely to spin off into education and industrial development as a whole. Attempts to bring the whole field of science and technology under the aegis of centralized planning and coordination run the risk of stimulating large and inefficient bureaucracies, and to stifle initiative and creativity of research.

The new policy should implement tasks that are apparently in contradiction: to stimulate the freedom, initiative and creativity of the researcher, while establishing strong links between his work and the requirements of the economy, the educational system and of society as a whole; and to make Brazilian science and technology truly international, while strengthening the country's educational and S&T capabilities.

To fulfill these tasks, the following recommendations are made:

1. Technology and applied science:

a. To redirect the country's technology policies, in line with new economic realities. On the short run, policies should be geared to the reorganization and technological modernization of the industrial sector. Permanent policies should exist to induce the more dynamic sectors of the productive system to enter a continuous process of innovation and incorporation of new technologies, to follow the rhythm of technical progress in the world economy. Both approaches require, as the main priority, the incorporation of existing technology to the productive process.

b. Research groups in universities and government institutes should be strongly stimulated to link to the productive system and to engage in applied work, while maintaining a high level of academic and basic research activities. Resources for applied work should not come from the budget for basic activities, but from specific sources in governmental agencies, special programs, private firms, and independent foundations. Applied projects should be evaluated in terms of their academic quality, but also of their economic viability and social and economic significance.

c. The current situation, in which 80% or more of the current expenditures are public, should be changed. This should not be done by reducing further the government's expenditures in R&D, but by stimulating the private sector to invest more in this sector.

d. Government agencies dealing with matters requiring research work, such as health, education, environment, energy, communications and transportation, should have resources to contract research with universities and research institutions on matters of their interest. This practice should prevail upon the tendency of these agencies to create their own research outfits, and their projects should be subject to joint evaluations by peer review and policy oriented authorities. Research institutes and centers in public agencies and state companies should be placed under peer oversight, and required to compete for outside research support.

e. The current military projects should come under technical, academic and strategic evaluation with the participation of selected, high quality scientific advisers, and be either streamlined, discontinued, reduced, or converted to civilian projects.

f. Research programs in applied fields, like electronics, new materials, biochemistry and others, should only be established in association with identified partners in industry, which should be involved from the beginning in setting objectives and in sharing costs; they should be subject to independent evaluations of economic, managerial and scientific feasibility, and monitored on these terms.

2 - Basic science and education

. Support for basic science should be maintained and expanded, with special attention to its quality, according to accepted international standards. Basic or academic science, broadly understood as research work that does not respond to short-term practical demands, remains essential for Brazil. The information it generates is free, and is the main source for the acquisition and spreading of the basis of tacit knowledge that permeates the whole field of science, technology and education. For a leading country, heavy investments in basic science can be thought of as problematical, since their results can be appropriated by other countries and regions for very little cost. For the same reason, investments in basic science in small scientific communities can be extremely productive, since they allow tapping the international pool of knowledge, competence and information.

. The existing pool of scientific competence has to be protected. Many of the best R&D institutions and groups are being dismantled by absolute lack of resources, and emergency measures are needed to deter this process. The government should guarantee a stable and predictable flux of resources to its main S&T agencies for their daily routines and "over the counter," peer reviewed research supporting activities. The most qualified research institutions and groups should be preserved in their ability to keep their best researchers and their work and educate new scientsists. The main mechanism for this should be the implementation of the proposed system of "associated laboratories," which should provide stable resources to about 200 research groups and institutions, based on clear procedures of evaluation and peer review. The estimated cost for maintaining this program is approximately US$ 200 million a year; a similar amount will be needed to provide these laboratories with basic equipment and infrastructure.

. Research institutions, particularly in universities, should be required to play a very active role in the enhancement of undergraduate and technical education, not only through teaching, but also through direct involvement in the production of good quality textbooks, the development of curricula and new teaching methods and programs of continuous education. Adequate mechanisms should be devised to make these activities more rewarding and prestigious than they have been so far.

3 - International Cooperation

Globalization requires a profound rethinking of the old dilemma between scientific self-sufficiency and internationalization. They should not be perceived as contradictory, but as complementary. Brazil has much to gain as it increases its ability to participate fully as a competent and respected partner in the international scientific and technological community. To meet this objective, the following policies should be implemented:

a. Fellowship programs of CAPES and CNPq for studies abroad should be revised, maintained, and eventually expanded. Fellowships should be awarded only to first-rate students, going to first-rate institutions, with a clear perspective of returning to productive work in Brazil. Fellowships for doctoral degrees should be combined with "sandwich" fellowships for doctoral students in Brazilian institutions for reduced periods abroad, and with short-term support for training periods in laboratories and companies. The existence of good quality doctoral programs in a given field does not preclude the need to keep a permanent flux of students to the best foreign universities.

b. Provisions should exist for post-doctoral programs both abroad and in Brazil, and to bring top-quality scholars from other countries for extended periods, or even permanent appointments, in Brazilian university and research institutions.

c. The channels for international cooperation between Brazil, international agencies and institutions, and the international scientific community, should be kept open and expanded. The World Bank, the International Development Bank and the United Nations Development Program have played important roles in providing resources for capital investment, research support and institutional development for Brazilian institutions. This presence should be maintained not only because of the resources involved, but because of what they bring in terms of international perspectives and competence. In the future, such agencies could be very helpful in a process of institutional reform. As a rule, cooperation among scientists, research institutions and private foundations in different countries is established directly, and need the support, but not the interference, of governmental agencies.

d. The issues of protectionism vs. market competitiveness in scientific and technological development should be dealt in pragmatic, rather than in ideological terms. The country should not renounce to its instruments of technological and industrial policy, including tax incentives, tariff protection, patent legislation, government procurement and long-term investments in technological projects, in association with the private sector. Adequate legislation for patents and intellectual property should be established with the understanding that they are necessary for the normalization of Brazil's relations with the industrialized countries.

4 - Information and knowledge dissemination

New and systematic means to incorporate technology into the industrial process should be developed, with strong emphasis on the development and dissemination of norms and standards, information, and procedures for technological transfer and quality improvement. A well organized and properly funded knowledge infrastructure is necessary to assure the easy access of scientists to libraries and data collections in the country and abroad, making use of the latest technologies of electronic communication and networking. It is necessary to make these links effective and transparent to the individual researcher, and to establish mechanisms to bring texts and data to the scientist's working place. The role of CNPq's Brazilian Institute for Scientific and Technological Information (IBICT) should be reexamined in the light of the new technologies and competencies developed elsewhere.

5 - Institutional reform

. The Ministry of Science and Technology should restrict its role to matters of policy, financing, assessment and evaluation, without carrying R&D activities under its direct administration. Although a cabinet-level position for science and technology is clearly necessary, the very existence of a ministry of science and technology, with all its overhead costs and exposure to political patronage, should be reexamined.

. The existing system of federal institutions for scientific and technological support should be evaluated in terms of its ability to perform the functions needed by the sector: support for basic research, support for applied projects, large and small research grants, fellowship and training programs, scientific information, norms and standards, and others. Brazil needs a federal agency to provide long term, sizeable grants for institutions and cooperative projects. This was the role played in the past by the National Fund for Scientific and Technological Development (FNDCT), administered by FINEP. Whether these resources should be managed by FINEP, CNPq or by a new institution should be examined as part of a broad review of the roles, jurisdiction and competencies of the existing agencies.

. Financing agencies should be organized as independent, state owned corporations, and free of formalistic and bureaucratic constraints. They should be placed under strict limitations regarding the percentage of resources they can spend on administration, and should be supervised by high-level councils with the participation of scientists, educators, entrepreneurs and government officers. They should rely on external advise for their decisions, and their bureaucracy should be limited to the minimum.

. Research institutions and public universities should not be run as sections of the civil service. They need to be free to set priorities, seek resources from different public and private agencies, and establish their own personnel policies.

. No research institution receiving public support, and no government program providing grants, fellowships, institutional support or other resources to the S&T sector, should be exempt from clear and well-defined procedures of peer evaluation, combined, when necessary, with other types of economic and strategic assessments. Peer review procedures should be strengthened by the federal and state governments, made free from pressures of regional, professional and institutional interest groups, and acquire a strong international dimension. For instance, research proposals could be easily distributed to international referees through electronic mail.

6 - Goal-oriented projects

The broad changes suggested in this document do not preclude the adoption of well-identified projects linking science, technology and the productive sector, to deal with specific questions and problems and to strengthen the country's capabilities in selected areas. It is necessary to develop a list of main areas of established competence and social, economic and environmental relevance, which should be the focus of future investments; to identify areas that should be phased out, or reduced; and special weaknesses and competencies in need of strengthening and support.

Science and Technology policy in Brazil
A new policy for a global world

. Science and Technology in Brazil

Brazil developed in the last 25 years the largest system of S&T in Latin America, one of the most significant among semi-industrialized countries. There are about 15 thousand active scientists and researchers in the country, and about one thousand graduate programs in most fields of knowledge[1]. Fellowships keep several thousand students in the best universities in the United States and Europe at any time. The number of research papers in international publications is the highest in the region. Research takes place mainly in the major universities, such as the University of São Paulo, the Federal University of Rio de Janeiro, the University of Campinas and the São Paulo School of Medicine; in research institutes linked to the Ministry of Science and Technology, such as the National Institute for Space Research, the National Institute for Research on the Amazon and the National Institute of Technology; in research institutes belonging to the National Research Council (the Brazilian Center for Physics Research, the Center for Mineral Technology, the Institute of Applied and Pure Mathematics, the National Observatory, the National Laboratory for Computer Sciences, the National Laboratory of Astrophysics, the Emílio Goeldi Museum of Natural History, and the National Laboratory of Synchrotron Light); in the Brazilian Corporation for Agricultural Research (EMBRAPA), linked to the Ministry of Agriculture; in the Oswaldo Cruz Institute, linked to the Ministry of Health; in research centers kept by the largest state-owned corporations, such as Petrobrás (oil), Telebrás (telecommunications), Eletrobrás (Electricity) and Embraer (airplane construction); in research units linked to the armed forces, such as the Air Force Technological Center (CTA); in institutes belonging to state governments, specially in São Paulo, like the Butantan Institute (vaccines), the Biological Institute and the Institute for Technological Research (IPT); and in a few leading private corporations, such as Aracruz Cellose (paper), Itautec (computers), Aço Villares, Metal Leve (mechanical components), Elebra (computers), and others.

Most research activities in Brazil take place in universities. Brazil has about 1.5 million students enrolled in undergraduate programs, 30 thousand in masters and 10 thousand in doctoral programs. About one third of the undergraduate, and most of the graduate students are in public universities, which are free of charges. The remaining one

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1 This figure depends on what a "researcher" is. The Brazilian National Research Council (CNPq) listed 52,863 researchers in 1985, for about 3.5 million persons with higher education degrees. However, only 21.7% of those, or eleven thousand, had doctoral degrees. The number of university professors with doctoral degrees in 1991 was about 17 thousand, or 12% of the total. This figure is also consistent with the number of research proposals presented to FAPESP and CNPq each year (Brisolla, 1993; Martins and Queiroz, 1987; Schwartzman and Balbachevsky, 1992). As for the graduate programs, the figure depends on whether one counts degrees offered or course programs proper.

million attends private institutions, which, with very few exceptions, do not have graduate education and research. The Federal government spent about 3.4 billion dollars on higher education in 1990[2], and the state of São Paulo an additional 871 million for its three universities (Goldemberg, 1993b; Durham, 1993; Campanário and Serra, 1993). The gross per-capita costs for students in public universities are between five to eight thousand dollars a year, with most of the money going for salaries and the maintenance of hospitals[3]. For research, university professors have to apply to Federal or State agencies, national and international private foundations, or to engage in research contracts with governments, public corporations and, to a lesser degree, private institutions.

Table 1. Brazil, expenditures in science and technology and Gross Domestic Product, 1980/1990, in US$ millions of 1991(*).

year	I-federal budget(2)	II-state budgets(2)	III-Government expenditures(I+II)	IV-Expenditures of the Productive sector	V - National Expenditures (III+IV)	VI - National expenditures as % of GDP	VI - Gross Domestic Product (GDP)(3)
1980	824.5	496.8	1321.3	330.3	1651.6	0.43	386863
1981	1519.6	672.4	2192.0	548.0	2740.0	0.74	370279
1982	1863.3	654.6	2517.9	629.5	3147.4	0.85	372122
1983	1475.4	462.6	1938.0	484.5	2422.5	0.67	359727
1984	1426.9	500.7	1927.6	481.9	2409.5	0.64	378422
1985	1953.9	501.9	2455.8	613.9	3069.7	0.75	408151
1986	2288.6	651.3	2939.9	735.0	3674.9	0.84	439451
1987	2556.1	466.9	3023.0	755.7	3778.7	0.83	455424
1988	2506.4	396.7	2903.1	725.8	3628.9	0.80	454918
1989	2147.1	512.5	2659.6	664.9	3324.5	0.71	469663
1990	1679.0	672.2	2351.2	587.8	2938.9	0.72	406906

Source: Brisolla, 1993. Data from MCT-.CNPq/DAD/SUP/COOE.
Notes: (*) Deflated according to general price index of the Fundação Getúlio Vargas (IGP-DI/FGV) and converted to US dollars according to the average rate for 1991; (2) - actual expenditures; (3) - Corrected for inflation and converted to US dollars according to the average rate for 1991.

The development of these activities was accompanied by the creation of a complex system of institutions, which are presently led by the Ministry of Science and Technology (MCT). MCT is formally responsible for coordinating S&T policy in all areas, directly or through agencies such as the National Council for Scientific and Technological Development (CNPq) and the Financing Agency for Studies and Projects (FINEP). Besides, both MCT and CNPq have research institutions under their jurisdiction. The

2 These figures are only rough estimates, because of high inflation and unstable exchange rates.

3 For different perspectives on student costs, see Paul and Wolynec, 1990, and Gaetani and Schwartzman, 1991. The estimation is that hospitals absorb about 10% of university's budgets (they have also other sources of income).

Brazilian Science in Context

Brazil is a scientifically small country, performing much less than 1% of the scientific research in the world, and this attracts much less that 1% of the citations in subsequent literature. No Brazilian scientist was among the nearly three thousands mentioned as principal contributors or significant influentials in a survey of scientists elsewhere. Brazilian research amounted to a little less than half of the research performed in the rest of Latin America and about a third of that performed in Israel where scientific performance was high as indicated by the rather frequent mentioning of Israelis as great contributors and influentials. In economy and population, Brazil is roughly half the size of the rest of Latin America, as in science. But Brazil is a whole order of magnitude larger than Israel in terms of the economy and even more in terms of population and yet far less research is performed in Brazil than in Israel. This shows that scientific performance in a country is not a reflection of the size of the country in terms of population or economy (there is only a very weak correlation with population and a weak correlation with the economy). These differences in scientific performance seem shaped by differences in institutionalization of science.

Thomas Schott, 1993.

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1989, Brazil spent between about two and three billion dollars a year in science and technology activities, amounting to about 0.6 to 0.8% of the GDP. Of this, only about 6% came from the private sector, and another 10% from state-owned corporations (Brisolla, 1993; Coutinho and Suzigan, forthcoming; Wolff, 1991). These resources have been subject to high levels of instability in the last several years, in a context of near hyper inflation and economic stagnation.

Impressive as some of these achievements may be, they still leave Brazil as a minor player in the world's scientific community (box 1). Articles by Brazilian authors published in the international literature are less than 1% of the world total. In 1992 Brazil ranked twentieth among nations in scientific production in absolute terms, trailing China, Belgium, Israel and Denmark, and ahead of Poland, Finland, Austria, Norway, Taiwan and Korea (Castro, 1986; Schott, 1993). Links between scientific research and the productive sector are weak, and its impact on the quality of undergraduate and technical education is limited, a few significant exceptions notwithstanding.

. Background

. The beginning: S&T development in a period of economic expansion

Some of Brazil's scientific institutions date from the late 19th century, and the National Research Council from the early 1950's. The larger part of the current S&T

4 The estimate, made by SBPC, is that in 1991 the states were supposed to provide 317 million dollars for research activities, but granted only 84 million. Figures for 1992 were 182 and 82 million. Of the total spent, about 70% came from FAPESP. Brisolla, 1993.

capability, however, was built during the 1968-1980 years, in a period of military rule (Schwartzman, 1991). Three factors contributed to this rapid expansion. The concern of some military and civilian authorities with the need to build up the country's S&T competence, as part of a broader project of national growth and self-sufficiency; the support this policy received from the scientific community, in spite of earlier (and often continuing) conflicts between scientists and academics and the government; and the economic expansion of the period, in which Brazil's economy grew at an annual rate of 7 to 10 percent. Another important element was the improvement of the government's ability to carry out policies in those years, through the establishment of small, independent agencies outside the federal bureaucracy, and an expanding fiscal basis.

The policies of the last 25 years should be seen in terms of the changes in Brazilian society and economy in the previous decades. Between 1950 and 1980 Brazil turned from an agrarian into a highly urbanized society, but with high levels of social and economic inequality between regions and social groups. Employment in the primary sector went from 59.9% of the active population to 29.9% in those 30 years, while industrial employment went from 14.2% to 24.4%; the service sector, meanwhile, went from 25.9% to 45.7% (Faria, 1986). The industrial sector developed under the protection of tariff and non tariff barriers that shielded national, multinational and state-owned companies in the Brazilian territory from international competition. By 1970, the Brazilian industry supplied most of the demand for manufactured goods in the internal market, depending only on the import of sophisticated machine tools, chemicals, oil and electronics. A Strategic Program for Development, set by the Military government in 1968, sought to overcome these limitations. The country should build its own basic industry, develop its own sources of energy, and absorb the latest advances in science and technology. Starting with the Second National Development Plan, public corporations were created or expanded, subsidies were provided for the private sector, and barriers were raised against foreign competition, to protect the country's infant industries. Science and technology were perceived as a central ingredient in this strategy, and received unprecedented support.

This ambitious project of scientific, technological and industrial self-sufficiency, however, did not receive more than scattered support in the productive sector, and remained for the most part restricted to special segments of the state bureaucracy and the academic community. For most firms, including the large, state-owned corporations, the origin of technologies used in their activities was less important than their cost and reliability. Restrictions to the entrance of foreign technology and capital - as it happened with the computer sector in the eighties _ were perceived as a hindrance and a burden. This difficulty was accentuated because there was no understanding of the effective mechanisms and policies leading to technological innovation in the productive sector. The need to strengthen the country's basic technological infrastructure _ metrology, normalization, quality control and certification _ received only secondary attention, at least until the late seventies.

. Main initiatives

The main initiatives of this period were the following:

- The university reform of 1968, with the partial adoption of the American system of graduate education and the reorganization of the universities in terms of institutes, departments and the credit system;

_ The placement of science and technology under the responsibility of the economic policy authorities, which allowed for a much higher influx of resources to S&T than ever before;

_ The creation of a new Federal agency for S&T under the Ministry of Planning, the Financing Agency for Studies and Projects, FINEP, unencumbered by civil service routines and restrictions, and responsible for the administration of several hundred million dollars a year for science and technology support (Guimarães, R., 1993);

_ The establishment of a few large-scale centers for R&D, like the Coordination for Graduate Programs in Engineering of the Federal University in Rio de Janeiro (COPPE) and the University of Campinas, geared toward technological research and graduate education in engineering and sciences;

_ The beginning of several programs of military research, such as the space program and the "parallel" nuclear program;

_ The agreement with Germany for cooperation in nuclear energy, which was to create an autonomous capability in the construction of nuclear reactors based on locally reprocessed fuel;

_ The establishment of a policy of protected market for the computer industry, telecommunications and microelectronics, linked to an emerging national private sector;

_ The formulation, by the Federal Government, of successive National Plans for Scientific and Technological Development;

_ The establishment of centers for technological research under the main state-owned corporations, which sought to keep up with the technological frontier, develop standards and transfer technology to their main suppliers;

_ The strengthening and expansion of EMBRAPA, the Brazilian Corporation of Agricultural Research;

_ The consolidation of peer review procedures in some of the main public agencies for science, technology and graduate education: CNPq, CAPES and the São Paulo Foundation for Research Support (FAPESP). The main federal agency for science and technology development in the seventies and eighties, however, FINEP, never introduced systematic peer review procedures although it works routinely with external consultants. Larger decisions of resource allocation in CNPq also remained usually outside peer review.

. *Crisis in the eighties and nineties*

It is possible to point to several weaknesses in an otherwise successful policy of scientific growth. Links between S&T and the productive sector remained weak, lacking demands for advanced technology, in an economic environment characterized by protectionism and reliance on cheap labor and natural resources. The only significant exceptions occurred in the modern, export oriented sector of agriculture, which benefitted from research on the introduction of new varieties, the control of plagues, and the biological fixation of nitrogen, with very significant gains in productivity (Malavolta, 1986); in sectors associated with the large state corporations, such as telecommunications, energy, and the chemical industry; in the production of military equipment; and in the computer industry, with the attempt to link research with a protected industry of small computers for the internal market (Lucena, 1993; Tigre, 1993). In the universities, the new research and graduate programs remained often isolated from undergraduate education and teacher training. The quality of the scientific institutions created and expanded in the seventies was often not very high, and peer review procedures for quality control not always prevailed.

After 1980, the science and technology sector entered a period of great instability and uncertainty, characterized by institutional turmoil, bureaucratization, and budgetary uncertainty. The evolution of national expenditures for Science and Technology in the eighties, as illustrated on table 1, followed two parabolas. It grew in the first years of the decade, fell in 1983 and 1984, increased again with the short-lived economic expansion of the Cruzado Plan in 1985 and 1986, and fell rapidly when inflation picked up again in 1988, reaching its lowest levels in 1991 and 1992 (Brisolla, 1993). In 1985, the National Fund for Scientific and Technological Development administrated by FINEP was just one fourth of its 1979 value. This instability and uncertainty were related to economic stagnation, but also to an expanding arena of conflicting interests striving for public funds, and to an increase in political patronage (Botelho, 1990 and 1992) (box 2). The S&T sector became one among many interest groups pressing for more resources, sometimes with partial success, but losing ground on the long run. The same pattern took place in most public universities, particularly in the federal system. The growing unionization of academic and administrative personnel allowed for significant gains in salaries, employment benefits, and participation in the universities' management, but stifled the institutions' ability to improve quality and make better use of their resources.

The World Bank supported Program for Scientific and Technological Development (PADCT I, 1985, followed by PADCT II in 1990) was conceived in the early eighties, when the full dimension of the crisis was still to unfold. The program was supposed to improve the decision making capabilities of government and to strengthen R&D in biotechnology, chemistry and chemical engineering, earth sciences and mineral technology, instrumentation, physical environment and science education. In practice, instead of building upon a basis of existing resources, PADCT became often the only source of public support for the fields included in its priorities. Instead of improving the country's management and decision-making capabilities, it may have had the opposite effect, by creating an additional bureaucratic layer upon the existing institutions (Stemmer, 1993). Contrary to some claims, PADCT did not introduce peer review in Brazil, which had existed since the fifties. However, it may have strengthened it, since its projects were significantly more substantial and were submitted to more detailed analysis and discussion than those of CNPq.

In the early nineties, there was a trend to make science and technology more directly relevant to industrial competitiveness, in a new international context characterized by increased market competition and the growing relevance of science based industries (Guimarães, E., 1992). A few features of this trend can be listed:

What Global Figures do not show

Between 1985 and 1988 the federal government budget item related to general administrative expenditures jumped from 4.7 to 10.4% of the total expenditures for science and technology. This change reflects an increase in political patronage that takes hold of Brazilian bureaucracy at the time of the 1986 elections. At the same time, the National Commission for Nuclear Energy alone absorbs 25% of this item, which was a way to provide money for discretionary expenditures for the Brazilian nuclear program. We can add to this figure the capital investments in state companies in 1988, which included the bailing out of Nuclebras and other items marginal to science and technology as such, like airport infrastructure, debt payments, and others. The total comes close to one third of the federal budget for science and technology. This bureaucratization of science appears also in the fact that, in that year, about 25% of the resources from the Ministry of Science and Technology were used for administrative activities, most of it in its central administration (excluding supervised institutions such as the Institute for Space Research). The remaining expenditures were given to applied research (33%), basic research (7.7%), graduate education (8.6%) and fellowships (6.5%). Military expenditures took a significant bite from the applied research item: 12% for the old National Security Council, 8% for the Armed Forces General Staff (EMFA), and 5% for the Navy. Science and Technology expenditures in the Ministry of

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_ The increasing concern with university managerial autonomy and accountability, and transparent rules for public financing to the sector.

Cooperation and partnership between university and industry

The Department of Mechanical Engineering of the Federal University of Santa Catarina works in three important areas - fine mechanics, new materials and industrial automation and quality control. It has a support program for small and mid-size industries financed by Germany's Geselschaft für Technische Zusammarbeit, in an agreement with the Program of Human Resources in Strategic Areas of the Ministry of Science and Technology, and cooperates with the state's Secretary of Agriculture in the development of agricultural equipment prototypes, and in the development of environmentally safe agricultural technologies, which has also the support of the World Bank.

The Department has long-term contracts for research and development with many industrial firms, including Embraco, Portobello, Pirelli, Weg, Mannesman-Demaq, Braun-Boweri, Volvo, Bosch, Eletrosul, Copesp, CNEM and CTA. Such contracts account for about

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efficiency (Schwartzman, J., 1993). On the positive side, the state universities in São Paulo were granted a fixed percentage of the state's tax basis for their financing, and increased autonomy to manage their resources. In some places, like at the School of Engineering at the Federal University of Santa Catarina (box 3), the situation led to new experiences of cooperation and partnership among university departments, local and foreign governments, private firms and donors, for research and development and for the creation of new high technology firms ("incubators") (Castro, M. H., forthcoming).

. The achievements of the 1970s and the realities of the 1990s.

The scientific and technological competence acquired by Brazil in the last decades is an important asset for its continuous drive for social and economic modernization. There are, however, important questions and concerns about the adequacy of this system of S&T, as it was organized in the 1970s, to achieve what is expected from it. Part of the difficulty lies in the persistence of the assumptions that presided the S&T policies in the sixties and seventies, when faced with the realities of the nineties; and part on the structures and vested interests created along these years.

. The "endless frontier."

The basic assumptions that presided the development of S&T in Brazil during the sixties and seventies were not very different from those in the United States and other developed countries at the time. In both cases there was the notion of science as an "endless frontier," worth expanding for cultural reasons, for its beneficial effects in the quality of education, and for its promises in terms of practical applications. All fields of knowledge were equally deserving, and all good projects and initiatives should get public support. There were other resemblances: the importance given to military R&D; the notion that scientists should be funded by the state, free to control their institutions and distribute research resources according to their own criteria; and the assumption that social and economic benefits to society as a whole would necessarily derive from basic S&T in the universities and military research in government institutions (Branscomb, 1993).

. Planning

There were also important differences. Brazilians believed more in comprehensive planning, and in planning for science and technology, than Americans did. There was, as there is still, a dire need for reliable information, and stable decision procedures for resource allocation and the establishment of long-term projects. The tradition was to try to fulfill these needs with comprehensive planning exercises, which could be turned into law and administered by the bureaucracy, thus making further decisions unnecessary. Three National Plans for Scientific and Technological Development were issued since the early seventies. Complex coordinating bodies (such as the Council of Science and

Technology, CCT) were devised to try to link the research activities of different ministries. The Ministry of Science and Technology was created in 1985 as a response to demands from leading personalities in the scientific community, which expected it to fulfill this planning and coordinating role, emaking it more relevant to the country's economic and social needs. The notion that these links were to be achieved through centralized planning contributed to the development of large bureaucracies for S&T administration. CNPq and FINEP increased their staff several times between the sixties and the eighties, and the bureaucratic apparatus of the new Ministry also grew.

. *Import substitution in science.*

Another difference was that the development of S&T in Brazil was understood as part of a broader pattern of import substitution that was dominant in the economy, and led to barriers against foreign competition and the protection of infant industries. Although Brazil never attempted to develop a "national science," and valued its access to the scientific international community[5], the level and intensity of international interchanges was never as intense as that of other small scientific communities (Schott, 1993), and its research institutions and programs were seldom exposed directly to international standards of quality and evaluation. Considerations about regional inequalities and short-term needs, and political pressures for the creation of academic and research institutions throughout the country, led often to the weakening in the criteria for resource allocation by the government agencies.

. *Elitism in technology and education.*

A final feature of the Brazilian S&T development effort has been the elitism of its technology and educational policy orientations, despite the political and socially progressive outlook of many of its promoters. Military technology was expected to be the harbinger of economic and technological modernization, leading to a disproportionate concern in government, diplomatic and academic circles, with the international constraints on the transfer of sensitive technologies. The two PADCT programs placed strong emphasis on the higher-end, frontier technologies, with a much smaller place given to science education, management and diffusion. Except in the field of health, there were no organized efforts to bring the benefits of scientific knowledge to the population as a whole, or to the basis of the productive system. In spite of the initial influence of the American Land Grant colleges, Brazilian agricultural education and research remained restricted to a few institutions, and geared to the capital intensive, export sector of the economy (Azevedo, 1993). The recent effort to develop indigenous capability in computer science concentrated in the protection of the national hardware industry, rather

5 There were several proposals to create a typically "Brazilian" social science, based on the country's peculiar historical and cultural nature, from Gilberto Freyre to Alberto Guerreiro Ramos. nothing similar, however, ever existed in the natural sciences, except in applied fields such as agriculture, natural resources and earth sciences, as should be expected.

than in the generalization of the use of the new technologies and competencies throughout society (Lucena, 1993; Tigre, 1993).

In education, Brazil tried to generalize the university research model before any serious attempt to deal with the problems of basic, secondary, technical and mass higher education. In consequence, the country has, simultaneously, some of the best universities and graduate programs, and one of the worst and unequal systems of basic education in the region. In practice, the university research model remained restricted to a few public universities in the São Paulo and in the federal system. Most other public institutions incorporated the institutional features and costs of modern universities (including full-time teaching, departmental organization, integrated campi, besides free tuition), without adequate mechanisms for quality assurance and the efficient use of public resources. About 65% of the students in higher education do not have access to public institutions, and attend the less prestigious, paying private institutions (Goldemberg, 1993b; Schwartzman, Durham and Goldemberg, 1993).

Table 1: Brazil, Education figures: population of 5 years of age and above.

	Brazil	Women	Rural	Northeast
Literacy (1990): Can read and write. self reported).				
5 years and more	76%	77%	58%	57%
10 to 14 years	86%	89%	70%	67%
60 years and more	56%	53%	32%	44%
Educational attainment (years completed)				
Total	100%	100%	100%	100%
one or more	82%	82%	65%	65%
two or more	77%	77%	57%	57%
three or more	68%	70%	46%	48%
four or more	59%	60%	34%	39%
five or more	41%	42%	17%	28%
six or more	33%	34%	11%	22%
seven or more	29%	30%	09%	19%
eight or more	25%	26%	07%	16%
nine or more	18%	19%	04%	12%
twelve or more	06%	06%	01%	03%
total (thousands)	113,629	58,373	28,011	31,614

Source: Fundação IBGE, *Anuário Estatístico*, 1992.

Brazil had always been a highly stratified and unequal society. Even when the intention was there, governments had faced enormous difficulties in reaching the broader population with services like education, health and extension work. This situation should be reversed, but this does not mean that efforts to create good universities and competent research groups should be postponed until the problems of basic, technical and secondary education are solved, since these skills and competencies are essential for carrying on the needed transformations. It would be a mistake, however, to suppose that scientific, technological and educational investments could not have had a broader impact on professional education and the dissemination of general and technical competence than they did. They can, but specific policies are needed for that.

. New realities

. Changes in the role of science and technology in the international scene.

The international scene for science and technology has changed dramatically since Brazil begun its drive for S&T development in the sixties. The main features of the new context can be described as follows:

_ Science and technology are much closer to industry and markets than before (box 4). Industries depend, for the development of new management skills, processes and products, on specialized knowledge that cannot be generated anymore, as a matter of course, in their daily activities. The consequences have been an increase in R&D investments, the setting up of specialized laboratories and research departments, and the search for new links with universities. There is a renewed concern with the problems of intellectual property, which occurs in association with an expanded knowledge industry, carried on through licensing, technical assistance projects and international consulting.

_ The pace of technical innovation and competition in industry has accelerated, requiring from firms a permanent capability to change its organization, absorb new

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Fundamental and Economically Relevant Research: The New Links.

In all industrial countries, governments have tended to shift, in recent years, to indirect actions intended to promote the development of a trade-oriented research environment: legislative and regulatory measures considered to be obstacles to the diffusion and application of knowledge have been lifted (for example, various anti-trust regulations were removed in the United States to facilitate pre-competitive research co-operation between firms); new rules were adopted to encourage scientists to take a more active interest in the exploitation of their work (for example by allowing academic research-workers and institutions to apply for patents, even when the invention had been the result of federally sponsored programs, or by relaxing academic rules so that professors could participate in commercial ventures); incentives multiplied in order to promote science-based industrial activities (i.e. fiscal incentives, schemes to develop employment of scientists by firms of all types, research funding instruments for industry-university collaborative ventures, etc.).

This focus has been accompanied by gradual re-direction of the public research support towards new types of programs, in order to channel efforts onto areas of greater economic relevance. This has affected all types of research activities. For example, institutions that have traditionally been bastions of fundamental research (from the CNRS in France to the National Science Foundation in the United States) devote more and more attention to applied research and strategic research justified by its economic implications. Pre-competitive research

entrance requirements in terms of the standardization of scientific instruments, language and patterns of communication, leading to new inequalities and concentration of resources and skills.

_ As the economic and military importance of scientific and technological knowledge increases, there is a growing tendency to limit its diffusion through legislation on intellectual property and governmental barriers to the diffusion of "sensitive" technologies. This tendency, however, is offset by the intense international competition of firms and governments to sell their technologies, and by the lack of well-defined boundaries between academic (and therefore free) and proprietary knowledge. The net result is that the bulk of modern technology is available for countries with the necessary pool of competence in engineering and basic sciences, except for a few military items that can still be controlled by the main powers.

Major Changes in American S&T Policies

Americans now understand that the world has radically changed. But the paradigms on which the post-war S&T policy consensus rests are still firmly planted in many people's heads, especially in Washington, and the institutions of government that will be needed to implement a new consensus have changed hardly at all. But three major changes in the U.S. will require not only a rethinking of technology policy, but changes in institutions and new international linkages as well:

(a) Recognition that defense priorities will no longer dominate the U.S. federal government's technology policy. Instead defense must face a drastically shrunken production and weapons acquisition base, will have to increase the fraction of the defense budget devoted to exploratory development and prototyping, even as the defense R&D budget decreases. Because the technologies critical to the new force structure will increasingly fall into areas in which commercial industry is ahead of defense industry, especially the information and communications technologies, defense agencies will have to gain access to commercial technologies. This will require radical change in defense acquisition policies and practices.

(b) Recognition that progress in modern, science-based engineering depends increasingly on a publicly-provided infrastructure of basic technical knowledge, tools, materials, and facilities. Between the realms of basic science and proprietary technology there lies a large domain of public good technology, whose value in application is clear but in which

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engineering (David, 1992). The current view is much more complex. Scientific discoveries often take place in the context of application; there is no clear-cut distinction between basic and applied work; tacit knowledge and incremental improvements are more important than isolated scientific breakthroughs. One consequence of this changing perspective is that support for basic research has lost ground, when not linked to identifiable products and results.

_ The development of new patterns of international scientific cooperation, with the establishment of large-scale international ventures such as the Human Genome Project and global research activities in the fields of meteorology, global warming, astrophysics, and regional cooperative projects. While traditional "big science" programs, such as the European Consortium for Nuclear Research (CERN), were characterized by large scientific installations, the recent ones tend to be organized in terms of extended and closely linked networks of scientists and research groups. For small scientific communities, the alternatives are either to participate in some aspects of these ventures, or to lag further behind (box 6).

European Cooperative Projects

Eureka Projects:

- 646 projects in 9 areas: medical and biotechnology, communications, energy, environment, information technology, lasers, materials, robotics and production automation, transport;
- EU 95: High Definition Television 1986-93, Budget: $750 million
- EU 127: Joint European Submicron Silicon Programme, 1989-1996. Budget: $4.6 billion.

European Community Projects:

- Framework III Programme, 1990-1994, 12 member countries, Precompetitive Research. Total budget, $7.99 billion.
- DGXII: Science, Research and Development. Brite/EURAM: Industrial and materials technologies, plus other research programs
- DGXIII: Information Technology and Communications. RACE, communication technologies; TELEMATICS, information exchange.
-DGIII: Industry. ESPRIT (moved from DGXIII).

Science, 1993

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conventional organization of teaching and education along disciplinary lines, bringing a further source of tension between teaching and research. Government agencies for science support are being revised and transformed. The links between universities, government and industry are deeply changed by new patterns of technical education, cooperative research and financing, generating new opportunities and tensions. Traditional scientific careers are perceived as less rewarding, prestigious and secure than in the past, while new professional patterns emerge.

. Changes in the nature and capabilities of the Brazilian state.

Brazil, which presented one of the world's highest rates of economic growth until the 1970's, did not adapt to the changing international environment of the eighties, and entered a prolonged period of economic stagnation *cum* inflation from which it is still to recover. Different explanations are given to this fact, going from the exhaustion of the import substitution model that characterized the country's economy since the 1930s, to the political and institutional inability of governments, since the eighties, to carry on long-term policies, in a context of international hardship and intense political competition for public subsidies. There is a clear notion, today, that the State has to reduce its size and its presence in the economy, while gaining competence to set and carry on long-term policies of economic growth, social welfare and environment protection. It is not clear, however, how this change should affect the S&T sector.

This situation of instability and lack of vision affected the S&T sector in two important ways. The most obvious was the reduction of resources for most existing programs, and the lack of perspectives for new projects and initiatives, even when international commitments, such as the loan contracts with the World Bank and the

Interamerican Development Bank, required well defined matching funds according to prescribed time tables. Probably more important were the problems of institutional and financial instability. The Ministry of Science and Technology changed name and status several times, budgets allocated to R&D institutions oscillated, and the actual delivery of these funds depended on constant, painful and daily negotiations with often unsympathetic economic authorities at the lower ranks in the bureaucracy. Not only resources were limited, but there was no consensus in government, public opinion, or international agencies, about the importance and role of scientific research, or about matters like basic vs. applied, civilian vs. military, academic vs. industrial research. This instability has been a matter of great concern, given the long time it takes for scientific institutions to mature, compared with the speed in which they decay in conditions of budgetary and institutional insecurity. In the early nineties, the state of Brazilian science and technology can be summarized by the following points:

_ The federal agencies for science and technology support (FINEP and CNPq) are very limited in their ability to grant resources for research projects. Most of CNPq's resources are used for fellowships, while FINEP is specializing on loans to technology projects in the private sector. On the other hand, São Paulo's Foundation for Research Support (FAPESP), was preserved as an efficient and prestigious institution, and even increased its share of the state's main tax revenue (from 0.5 to 1.0%), supposedly for applied work and industrial development. Several other state-level research support institutions were created in the late eighties, but few are active and efficient.

_The administrations of some federal agencies for S&T suffer the effects of swelling bureaucracies, low salaries and political militancy of their employees. Others, on the contrary, are understaffed, and unable to hire adequate persons to fulfill their functions. CNPq has been particularly affected by a permanent tension between its employees and the council's academic advisory bodies. Most federal research institutions, including the research institutes under CNPq, are paralyzed by lack of resources and incentives.

_ There is no consensus about what to do with the large-scale projects of the past, which are in large part paralyzed by lack of resources. The military doctrine of technological development from the 1970s seems intact within the Armed Forces, in spite of the current constraints. None of the large projects was discontinued - the atomic submarine, the space project (including the development of rockets and satellites) and the construction of military airplanes. The space project is moving from military to civilian control, and the government has sent a bill to Congress to create a Brazilian Space Agency, which would consolidate this transition (Cavagnari, 1993).

_ Benevolent legislation allows for early retirement (at the age of about 50), with full benefits, of many professors in public universities and the civil service. About 30% of current expenditures in the federal universities are used for retirement benefits, and this figure is growing. Lacking information, it is difficult to know how this is affecting the pool of active researchers, whether they are continuing their activities in other (and sometimes the same) institutions, and how they are being replaced. The general perception is that the private benefits of early retirement, combined with the instability and low prestige of many teaching and research institutions, are depleting Brazil's active scientific community. While this situation does not change, it is important to stimulate the retiring, well-qualified professors to remain productive in other roles, starting for instance new careers as entrepreneurs. Retirements should be used also as an opportunity to open the vacancies to a new generation of young academics and researchers.

_ Within these extremely adverse conditions, the Ministry of Science and Technology is trying to put forward some ideas and policies for the sector (box 7). One of its main tasks has been to assure a regular flow of budgetary and non budgetary resources to the sector. The proposal for the federal budget is to obtain between one and one and a half billion dollars for the activities under the Ministry of Science and Technology for 1994. The government has decided that a substantial part of the resources obtained through the privatization of public companies should go to the science and technology sector; and recent legislation granted tax benefits to firms engaged in technological development. The official expectation is that these two sources alone could double the resources for science and technology for 1994. The Ministry is also engaged in continuous negotiations with economic authorities for the stabilization of the flux of resources to the agencies, and with international institutions for continuing or renewed support for the S&T sector. The second goal of the Ministry is to continue and conclude some of the large projects that have already started, and are stalled for the lack of resources. The two most preeminent are the space and satellite program and the laboratory of synchrotron light. The ministry has also proposed a bill establishing a unified career structure for researchers and employees in federal institutions. In the Ministry of Education, CAPES, the agency for high-level manpower education and training, maintains a stable line of fellowships and support for graduate programs. Some projects created during the Collor period (1990-1992) to stimulate quality and competitiveness in the industrial sector are still in place, although with very little resources to go on.

Activities of the Ministry of Science and Technology, 1993.

a) permanent activities carried on by MCT or with its support:
- large projects involving investments in basic infrastructure;
- research projects in the basic, natural and social sciences;
- technology development projects in the fields of biotechnology, with emphasis on genetic engineering and its applications; in new materials, including microelectronics; in chemistry, including the synthesis of natural products, all with strong impact in the modernization of the productive system.

egional programs, like the weather and climate forecast projects for the Northeast and the Center-South regions

c) the definition of new legal and financial instruments for the S&T sector:
- incentives for industrial investment in R&D;
- rules for the implementation of the Informatics and the Amazon Free Zone legislations;
- utilization of resources derived from the privatization program for strategic projects such as the Satellite Launching Vehicle, the supercomputer of the National Laboratory of Computer Sciences, the National Laboratory of Synchrotron Light, the National Laboratory of Nuclear Physics, the research program in the Antarctic region and the survey of natural resources in Brazil's continental shelf.
- creation of the National Commission for Industrial Technological Qualification;

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The main thrust of this policy paper is that there is a definite need to move from the previous mode of scientific and technological development into a new one, more adequate to the current and future realities. Science and Technology are more important than ever for Brazil, if the country is to raise the standards of living of its population, consolidate a modern economy, and participate as a significant partner in an increasingly integrated and global world[6]. The economy must modernize, and adjust to an

The Internationalization of Trade, Business and Technology

The internationalization of trade, business and technology is here to stay. This means that national borders means much less than they used to regarding the flow of technology, at least among the nations that have made the now needed social investments in education and research facilities. National governments have been slow to recognize these new facts of life. Indeed, the last decade has seen a sharp increase in what has been called "techno-nationalism", policies launched by governments with the objective of giving their national firms a particular edge in an area of technology. Our argument is that these policies to not work very well anymore. It is increasingly difficult to create new technology that will stay contained within national borders for very long in a world where technological sophistication is widespread and firms of many nationalities are ready to make the investment needed to exploit new generic technologies. A closely related observation is that a well-educated labor force, with a strong cadre of university trained engineers and scientists at the top, is now a requirement for membership in the "convergence club".

Nelson and Wright, 1992.

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The new policy should implement tasks that are apparently in contradiction: to stimulate the freedom, initiative and creativity of the researcher, while establishing strong links between their work and the requirements of the economy, the educational system and of society as a whole; and to make Brazilian science and technology truly international, while strengthening the country's educational and S&t capabilities. To achieve this, the individual researcher, and their research unit or laboratory, should be freed from bureaucratic and administrative constraints, and stimulated to look for the best opportunities and alternatives, in the country and abroad, for the use and improvement of his competence. This requires, in turn, a competitive environment based on public incentives and private opportunities that rewards achievement, increases the costs of complacency and underachievement, and gears a substantial part of the R&D resources

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6 The term "global" conveys the notion of an interdependent world civilization, with permeable boundaries and no clear hegemonic centers. There is a growing literature on the global nature of modern societies. See for instance Albrow and King, 1990; Robertson, 1992; Featherstone, 1992; Wallerstein, 1990.

toward a few important and strategic selected goals. More specifically, the new policy should include the following tasks:

_ To increase the links between academic science and the productive sector, and to increase the share of the latter in the national effort for scientific and technological development, approaching the patterns of the modern, industrialized economies, where most of the R&D effort takes place in the productive sector. This requires a significant increase in private investments in R&D, not a reduction of the already limited public funds.

_ to create two different "markets," one for academic science, another for applied technology. The academic market needs a system of rewards and incentives for scientists, appropriate career structures, and means to increase public support for science. The market for applied technology should combine the requirements of competence and quality with those of economic feasibility and social need.

_ to increase the links between science, technology and education, from the graduate programs down to technical and basic education;

_ To invest heavily in the development of innovative capabilities of the productive system as a whole, through incentives, extension programs and the strengthening of the country's infrastructure for basic technology;

_ To support a few integrated projects of clearly identified social and economic relevance and in need of S&T research and education, in areas such as energy, environment preservation and control, transportation, public health, food production, and in social fields such as basic education, poverty, employment and the management of urban conglomerates (Goldemberg, 1993; Soke and Tucker, 1993; Castro, N., 1993).

_ To create the conditions for Brazil's participation in international programs dealing with global issues;

_ To make the government agencies for science and technology more flexible and bound to peer review procedures, and to stimulate research groups and institutions to search for partnership and support from a variety of sources and through different procedures, beyond what governments can provide and do.

. Policy recommendations

To achieve these goals, the following recommendations are made:

. To redirect the country's technology policies, in line with the new economic realities.

Technology policies are needed to make it possible for the country to enter a new pattern of industrial growth, centered on increasing levels of competitiveness. On the short run, the policies should be geared to the reorganization and technological modernization of the industrial sector. Then, permanent policies should exist to induce the more dynamic sectors of the productive system to enter a continuous process of innovation and incorporation of new technologies, to follow the rhythm of technical progress in the world economy (box 9). Both approaches require, as the main priority, the incorporation of existing technology to the productive process. Sectorial policies are needed for the reorganization and technological modernization of less efficient parts of the economy, and for the consolidation and expansion of the more dynamic industrial sectors. Support for research and development activities should be selective, and clearly associated with broader processes of innovation based on the transfer, diffusion and absorption of technological competence.

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Technology transfer: the new economic policy orientations

Regarding the transfer of technology from abroad, it is necessary to preserve and consolidate the economic policy orientations introduced in the nineties, aimed to remove existing obstacles and restrictions affecting the main transfer channels - the import of capital goods, technology contracts and foreign investment. It is necessary to go further regarding the use and diffusion of foreign technologies incorporated in capital goods, with the liberalization of import mechanisms for equipment, and the reformulation of the informatics policy. It is also necessary to proceed with the revision of the traditional administrative procedures for the registration of technology transfer contracts. These practices amounted to strong government intervention and restrictions in the transference process. In the same vein, policy changes in the informatics sector, eliminating restrictions to the presence of foreign companies and the establishment of joint-ventures, helped to remove a significant block to technological transfer, which was specially important because it affected precisely the industrial sectors where technical progress is more intense.

Eduardo A. Guimarães, 1993.

Recommendations about the Patent Law

-Some changes, such as the concession of patents to pharmaceutical products and process, are unavoidable to normalize Brazil's international economic relations.

-the new legislation should be based on the text being negotiated with within GATT, as it is the case of the proposal put forward by the Interministerial Group. American pressures to include the patenting of life forms and the "pipeline" do not correspond to internationally accepted rules as yet. In addition, no short-term agreement of free trade with the U.S. is being considered, to justify such concessions. A rapid approval of a new legislation without transition adjustment periods for specific industrial sectors would attend, in general terms, American demands.

Financial Stability and the PADCT

Financial stability is essential for reaching results, specially for experimental laboratories. There is no point in granting resources to buy expensive equipment if there are no additional resources for installation, operation and maintenance, and more specifically for hiring and training technicians to operate it. Large time lags occurred frequently within PADCT between the arrival of equipment and the availability of operational resources. Difficulties to import equipment created absurd situations in which projects were to be carried on in one or two years, but the equipment arrived two or three years later, when there was no money left for installation, salaries, training and operation.

Long-term programs are needed, specially for centers of excellence. Projects could be approved for several years, with a firm commitment for the first year and additional payments term grants based on past performance ("laboratórios associados"), which requires prompt implementation. Estimates of size and cost of such a network vary, but the scale of the operation is not too difficult to determine. Of the estimated 15 thousand active researchers in the country, about a third, or five thousand, could be included in 200 such "laboratories" of 25 persons each, supported with one million dollars a year in average, or 40 thousand dollars per person, two hundred million dollars in total. This would be the cost of keeping the pool of competence in place, providing a basis from which other policies can be devised. A similar amount will be needed to provide these laboratories with basic equipment and infrastructure. Most of this money is already being spent as salaries by universities and other government agencies, so that the cost of this program would be even less (although the resources for research and infrastructure should be provided *in addition* to what is needed for regular graduate education). Ideally, the program should compensate for oscillations in salaries, guarantee resources for current expenditures, and provide means for the acquisition and modernization of scientific equipment, regardless of the group's institutional location. Resources should be allocated competitively, under strict peer review evaluation, and for limited periods (typically three to five years). The criteria for allocation should be the laboratories' track records, the quality of their researchers, their ability to get funds from other sources, and their long-term perspectives and projects.

This network of research laboratories should be strengthened by a specific line of support for individual scientists, allowing them to move around to find the best places to use their competence; laboratories could be rewarded for the quality of people they can attract.

A competent and prestigious peer review procedure is essential for the project of "laboratrios associados" to work. On the long run, difficult problems of choice between equally competent groups and proposals may appear, requiring decision procedures that go beyond traditional peer review. However, given the current small size of Brazil's scientific community, most competent groups are likely to be supported, without increasing the historical levels of expenditure.

> . *To develop a three-pronged policy for S&T development, with clearly distinguished support mechanisms for basic science, applied work and extension and education.*

The fact that basic science, applied R&D and high level technical education are very often indistinguishable, and take place simultaneously in the same institutions, does not mean that they should not be treated separately in terms of their supporting mechanisms, working from different perspectives and with different approaches.

_ *Basic science research and education.*

Basic or academic science, broadly understood as research work that does not respond to short-term practical demands, remains necessary not only for its eventual role as the source of privileged discoveries for applied work, but because of its nature as an

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Basic research: the Laboratory of Synchrotron Light

The source of synchrotron light that is being built at the National Laboratory of Synchrotron Light (LNLS) in Campinas is a large undertaking with a strong interdisciplinary content. The equipment consists of an electron accelerator and a storage ring. Electrons circulate at high speed producing electromagnetic radiation of high intensity, covering an extensive energy band. This radiation can be used for different purposes, from basic research in solids, atoms, molecules and biological materials to different applications such as photolithography for the fabrication of highly integrated electronic circuitry. The light source is being built by a well-coordinated team of physicists, engineers and technicians, using many components developed in association with national companies. About US$ 11m have been invested so far in the project. It is the first Brazilian experience of building and, later, operating a large physical laboratory to be used by researchers from the whole country. Its success or failure will have important consequences regarding future decisions to go ahead with other large projects. The total estimated cost of the light source is US$ 35 million.

Sérgio Resende, 1993.

Besides its eventual impact on the productive sector, basic science can play a fundamental role in enhancing the quality of higher education for engineers and for society as a whole. This role, however, does not take place as a matter of course. Universities have to develop explicit links between their graduate and undergraduate programs; intellectual and financial investments have to be made for the development of materials for science teaching, from handbooks to educational software and experimental kits. When these links and investments exist, basic science becomes more legitimate, and more likely to be supported by society.

Changes are also necessary in scientific and graduate education. Master degree programs should be shortened, and turned either into well-organized courses of professional specialization, or short entrance and leveling programs leading to doctoral degrees. Non-degree, specialization courses should be stimulated, with very little bureaucratic formalism, and as self-supporting as possible.

Globalization requires a profound rethinking of the old dilemma between scientific self-sufficiency and internationalization. The experience of small, high-level scientific communities in countries like Canada, Israel, the Netherlands and Scandinavia, shows that this may be a spurious question. They build their competence through a purposeful effort to be present in the international scientific scene, by the extensive use of the English language, participation in joint research projects, evaluation of their research

7 Only about 15% of the resources for "public good" research in the US comes from the productive sector (Aron Kupperman, private communication).

activities by scientists from other countries, and a constant international flux of students, researchers and information; they are not less developed, and their science less relevant for their societies, for that reason.

The current fellowship programs of CAPES and CNPq for studies abroad need to be revised. Fellowships should be awarded only to first-rate students going to first-rate institutions, and with a clear perspective of returning to productive work in Brazil. Fellowships for doctoral degrees should be combined with "sandwitch" fellowships for doctoral students in Brazilian institutions, and short-term support for training periods in laboratories and companies abroad. Procedures should be devised to constrain the beneficiaries to pay back the money received if they fail to get their degrees or to return to their institutions; fellowships for countries and institutions with poor records of academic achievement for fellows should be avoided. Under these conditions, the current number of fellowships awarded should be maintained and even expanded. The existence of good quality doctoral programs in a given field does not preclude the need to keep a permanent flux of students to the best foreign universities. Provisions should exist for post-doctoral programs both abroad and in Brazil, and to bring top-quality scholars from other countries for extended periods, or even permanent appointments, in Brazilian university and research institutions (De Meis and Longo, 1990).

_ *Applied science*

The central feature of applied science is that it has a user, and the knowledge generated in the R&D process tends to be proprietary. The main clients for applied science in Brazil have been the military, the large state-owned corporations and a small section of the private sector, including the export-driven agricultural firms.

Applied R&D should be evaluated in terms of its short-term scientific quality and

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Multi-client program in Forestry Research

The Research Institute of Forestry Research (IPEF) of the School of Agriculture Luiz de Queiroz, São Paulo University, was created 25 years ago in Piracicaba, bringing together five private companies, Champion, Duratex, Rigesa, Industrial de Papel Léon Feffer and Madeirit, to deal with questions of common interest. Today, there are 23 associated companies, and the results have been surprisingly good. The average productivity of wood, which was around 15 m^3/ha/year, is now about 30 m^3/ha/year for the companies associated to IPEF. The institute has contributed to this increase in productivty through basic research and education and training of personnel for the companies. Its germ research center, recognized by UN's Food and Agriculture Organization, is the largest in the southern hemisphere in genetic materials, and commercializes about three tons of seeds each year, exporting to countries like Indonesia, Venezuela and Thailand. As an example, 300 kg of seeds from *Eucalyptus urophilla* where sold recently to Indonesia, which is the country from where this species originates. The associated companies are located in the states of Bahia, Minas Gerais, Espírito Santo, São Paulo, Pará, Paraná, Rio de Janeiro, Santa Catarina and Rio Grande do Sul. This model of association was followed by other institutions. Today, besides IPEF, there is the Fund for Forestry Research in Curitiba, Paraná (FUPEF) and the Society for Forestry Investments in Viçosa, Minas Gerais (SIF). Research takes place also in state research institutes such as the São Paulo Forestry Institute, which sells about 23 tons of seeds yearly joint R&D projects that would not otherwise find support through commercial banks. General policies and support mechanisms for applied R&D are difficult to devise, since they refer to an extremely variegated range of activities, and require different combinations of economic, scientific and strategic considerations. A few suggestions, however, can be made:

_ Research groups in universities and government institutes should be strongly stimulated to link to the productive system and to engage in applied work, while maintaining a high level of academic and basic research activities. It is as unwarranted to expect that all basic science should be linked to production as to assume that they should be kept isolated from each other. There is no reason to believe that applied work would necessarily distract researchers from their basic and academic oriented activities. However, tensions and conflicts of interest may arise, and need to be administered case by case. Links between academic research and the productive system can take place at multiple levels, depending on the capabilities and needs of each side. They can go from help in the solution of short-term problems and difficulties faced by industries, to the transfer and scaling up of innovations produced by research centers for industrial production; and, at the higher end, to the development of large scale, cooperative projects of R&D (Frischtak and Guimarães, 1993). Links can be established either with single institutions or with associations and consortia of users, as in the example of the Institute of Forestry Research of the Universidade de São Paulo (Azevedo, 1993) (box 13). Resources for applied work should not come from the budget for basic activities, but from specific sources in governmental agencies, special programs, private firms, and independent foundations.

_ Government agencies dealing with matters requiring research work, like in health, education, environment, energy, communications and transportation, should have resources to contract research in universities and research institutions on matters of their interest. This practice should prevail over the tendency of these agencies to create their own research outfits, and their projects should be subject to joint evaluations by peer review and policy oriented authorities. Research institutes and centers in public agencies and state companies should be placed under peer oversight, and required to compete for research support outside their agencies.

_ The current military projects should come under technical, academic and strategic evaluation with the participation of selected, high quality scientific advisers, and be either streamlined, discontinued, reduced, or converted to civilian projects (Cavagnari, 1993) (box 14).

Military Research and competitiveness

The goal of making Brazil a world power can only be achieved if the country can survive and develop in a competitive international environment, which depends on the non-military components of its strategic capabilities - mainly its scientific and technological capability. In consequence, the country's efforts should be directed to this goal, without giving priority, necessarily, to military R&D. There is no doubt that the main current military projects should be continued until their completion, but the perspectives of military R&D regarding the more advanced technologies is limited, given the tendency of civilian R&D to administer such technological projects as efficiently as the military.

The difficulties found in the development of military programs could be reduced if the development of higher end technologies is not militarized. This, however, does not mean that the Armed Forces should be excluded from research and development activities. On the

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the establishment of appropriate objectives; they should be subject to independent evaluations of economic, managerial and scientific feasibility, and monitored on these terms.

_ New actors should be brought in projects of local and regional development, including local and state governments, business associations, financial institutions, universities and technical schools.

- Education

The main challenge for Brazilian science and technology in the coming years is to spread competence for innovation horizontally, to the productive system as a whole, and to increase the educational level of the population. While this is not done, the S&T establishment is bound to relate only to a small part of the country and its economy, with limited resources and relevance.

Policies for science and technology should not wait for educational reform, but they cannot be expected to succeed without profound transformations in the educational system as a whole, through increased access to educational opportunities, quality improvement of basic and secondary education, strengthening of technical education and diversification and better use of public resources in higher education. Questions of educational policy lie beyond the scope of this document. However, a few items should be stressed regarding the interfaces between the educational and the S&T sectors:

Technical Education. Brazil has maintained a wide gulf between education for the academic professions, including engineering, and middle-level professional training, the first provided by universities, the second by federal and state technical schools (and also by industry and commerce through their own institutions, SENAI and SENAC). The knowledge-intensive basis of modern industry and services requires the development of general skills for the technician, and proximity with industry for the institutions trying to provide technical education through formal course programs (Castro and Oliveira, 1993)

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Human resources development in South Korea.

South Korea developed a massive effort in the fields of education, Science and Technology since the 1960s, as part of their strategy of industrial conversion. Besides the sheer size of the effort, there are some strategies worth stressing, regarding the bridges they sought to create between the worlds of education and research and the world of industrial production.

- Long-term programs of institutional development. Universities, individual professors and research centers received support for 5 to 6 years long projects, time deemed necessary for the creation of groups of graduate students.

- well-known scientists were dissuaded to lend their names just to fatten the curriculum of projects. Those who gave their names had to be involved. With this, it became easier for young scientists to take the leadership of important projects.

- scientists and engineers were sent systematically to short courses abroad, in selected fields. Typically, their courses lasted two months, but they received four months fellowships. During their courses, their had to negotiate with their professors for training internships in European firms, to absorb technology.

- An excellent researcher had difficulties linking to the productive sector. He received a grant to organize monthly lunches with business leaders, to discuss questions related to the interaction between basic science and applied technology.

documents (handbooks, standards, technical manuals for craft and skilled workers) needed for general use in industry and education. These activities already take place in some universities, but are usually considered of low prestige, and inimical to academic excellence. It does not have to be so. High quality research centers can attract more resources, increase their relevance and involve more people through extension activities. Institutions with little to offer in terms of research can gather strength and recognition, and provide their students with significant opportunities for practical training. Since most of these activities can be paid for by users, they do not require much in additional resources, but there should be means to provide rewards, incentives and recognition for this type of work.

Teaching of science and technology. Academic departmemts in universities should take more responsibility for undergraduate education. The current departmental structure tends to leave undergraduate career programs without intellectual leadership, and undergraduate teaching is often seen as a burden by professors engaged in graduate education and research. Incentives should be created to stimulate researchers to get involved with undergraduate education, by writing textbooks, bringing undergraduates to their research projects, and participating in the upgrading of their course programs. Fellowships for undergraduates ("bolsas de iniciação científica") should be expanded, and successful involvement in undergraduate education should be added as a criterion for CAPES in its evaluation of graduate programs.

General education. Most undergraduate education in Brazil, as elsewhere, is in fields like administration, languages, social sciences and the humanities. They can be considered "general education" course programs, since they have little knowledge specificity, and are supposed to provide the students a broad spectrum of cultural, social and historical disciplines. There is a tendency to see these "soft" fields as a waste of time and resources, under the assumption that they are not directly relevant to the production of goods. However, general skills, social and cultural abilities are central components of modern economies and societies, characterized by intense flows of information and communication, the continuous expansion of services and a shifting social and economic environment. The situation of neglect should be reversed, with the graduate and research sector taking responsibility for improving the quality of secondary and undergraduate general education, through direct involvement in the production of good quality textbooks, the development of curricula and new teaching methods. Here again, adequate procedures should be devised to make these activities more rewarding and prestigious than they have been so far.

Distance learning. Modern technologies for distance learning have not been adopted in Brazil except in some isolated experiences in basic education. A systematic effort should be made to incorporate the international experience, and a few universities should be stimulated to begin pilot projects using the newly available instruments, from computers to electronic mail.

. Infrastructure for information and knowledge dissemination.

New and systematic procedures to incorporate technology into the industrial process should be developed, with strong emphasis on the development and dissemination of norms and standards, information, and procedures for technological transfer and quality improvement. Brazil has several institutions created for these tasks, such as the National Institute of Metrology, the National Institute of Intellectual Property and the Brazilian Institute for Scientific and Technological Information (IBICT). These institutions, however, have lived in a no-man's land between the researcher in academic institutions and the productive sector, both of which were either protected from external competition, or linked directly to their own sources of information and technology outside the country. Without closer interaction with the users of their services, these institutions tended to become rigid and bureaucratic, weakening still further their links with the scientific and productive sectors.

To reduce this problem, users should play a much stronger role in the definition of the goals and practices of these institutions. A well organized and properly funded knowledge infrastructure is necessary to assure the easy access of scientists to libraries and data collections in the country and abroad. Significant advances have ocurred in the last few years, through the gradual generalization of access to Internet and similar networks for Brazilian universities and research groups, and the development of computerized library catalogs in some of the main universities. Now it is necessary to make these links more widely used, more effective and more transparent to the individual researcher, and to establish means to bring the documents and data to the scientist's working place. A coherent policy for creating, maintaining and expanding these information resources is needed, and should rely on the competence developed by FAPESP, the National Laboratory of Computer Science Research (LNCC), the Institute of Applied and Pure Mathematics (IMPA), and other groups that have built and developed the current facilities.

. Institutional reform.

For these policies to be carried on, governmental agencies for S&T policy should become smaller, more flexible and more efficient. The Brazilian agencies for science and technology are considered more efficient, and less plagued with problems of political patronage and bureaucratic formalism, than most of Brazil's civil service. However, with a few exceptions, the general evaluation of the main government agencies is not very positive. CNPq has grown to be a large bureaucracy, going from 1,502 employees in 1988 to 2.527 in 1992, about half of them without a university degree (Barbieri, 1993, table 2). Its administrative expenditures have varied enormously throughout the years, and most of its resources are now given to fellowships. Researchers and fellows applying for its resources complain constantly about the difficulties in getting information and receiving their fellowships and grant money on time. The agency could never establish a competent information system about its own activities, and there is little or no follow-up of the results of its investments in research and graduate education. FINEP also increased its bureaucracy to about 700 employees, while its resources shrank (Frischtak, coord, 1993). There are no established dates for submission of projects and proposals nor public announcement of awards. Without systematic peer review, there is no information on how decisions are made. In both cases, the problems were compounded by budgetary uncertainties. The agencies do not know how much money they will have at any given time, and their decisions are often based on expectations that are not fulfilled. Finally, these agencies have not established adequate procedures to receive proposals in constant values and protect their grants from inflation. The consequence is that, when a project is finally approved, its value is significantly lower than when it was presented, and still lower when the money is received and spent.

Table 3: CNPq, Budget according to main lines of activity, 1980-1992. Millions of US$ of 1992 (a)

Year	Fellowships	Grants (b)	Institutes	Administration	Other (c)	Total
1980	42,252.3	23,166.3	26,233.9	40,598.9	4,243.2	136,494.6
1981	46,567.7	21,815.5	29,557.7	41,837.5	2,420.1	142,198.5
1982	72,396.3	37,793.5	34,489.4	35,032.4	2,265.8	181,977.4
1983	68,137.6	28,106.6	26,949.6	28,769.8	3,194.6	155,158.2
1984	61,400.8	21,521.1	23,092.8	37,682.4	5,034.5	148,731.6
1985	88,153.1	41,517.0	33,141.5	33,631.7	5,212.8	201,656.1
1986	94,630.1	50,996.2	35,497.9	27,931.3	7,552.3	216,607.8
1987	184,069.4	48,886.4	57,739.4	63,729.7	4,416.3	358,841.2
1988	238,004.4	46,552.1	49,322.2	47,281.9	4,415.3	385,575.9
1989	236,143.1	33,570.1	85,569.2	48,693.0	22,732.4	426,707.8
1990	178,339.5	41,672.8	50,529.1	36,513.3	14,684.5	321,739.2
1991	232,440.4	19,884.0	30,838.3	26,361.2	14,907.9	324,431.8
1992	193,820.4	7,635.8	30,655.5	17,362.2	10,603.2	260,077.1

(a) compensated for inflation according to the General Price Index of Fundação Getúlio Vargas, and converted to dollar according to the mean exchange rates of 1992.
(b) includes special projects
(c) includes debt service payments, fringe benefits to emplolyees (for food, nursery, and transportation), persons working for other government agencies.

Source: CNPq, *Informe Estatístico,* Brasília, 4(2), Abril, 1993, p.13.

In contrast, FAPESP, in the state of São Paulo, and CAPES, at the Ministry of Education, are perceived as success cases. FAPESP works almost exclusively through peer review, its administration is very small, communication with applicants is very efficient, its grants are fully corrected for inflation, and has well-designed follow-up procedures for its grants and fellowships (box 16). CAPES suffers some of the difficulties of being within the Ministry of Education, but has an established tradition of peer review assessments. Its leadership has been always recruited among persons of good academic standing, and its bureaucracy remains small.

The FAPESP model

The "FAPESP" model is characterized by three main aspects. First is the source of its resources. Initially, FAPESP was granted 0.5% of São Paulo's state revenues. The 1969 state Constitution increased this legal percentage to 1%, less 25% of the trade tax ("imposto de circulação de mercadorias") which is transferred by the state to the municipalities; and it determined that the resources to be calculated each month, and transferred in the following month. To this basic source one should add the revenues of FAPESP's capital investments, which allows the agency to spend more that what it gets from the government in a given period.

The second aspect is related to its relative independence from political fluctuations. FAPESP is governed by a council of 12 members with fixed six year mandates, which is responsible for its administrative, scientific and patrimonial policies. Six members are designated by the state governor, and the other six are also chosen by the governor from lists submitted by the state's public universities and research institutes. The president and vice-president of the council are also appointed by the governor. In practice, all names are suggested to the governor by the scientific community.

The third aspect is that most of the resources go to individual researchers working in the state of São Paulo, and only rarely to institutions. Proposals are submitted to FAPESP and evaluated by peers. Their identities are not known to the applicant, and their recommendations

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Scientific and Technological Development (FNDCT), administered by FINEP. Whether these resources should be managed by FINEP, CNPq or by a new institution should be examined as part of a broad review of the roles, jurisdiction and competencies of the existing agencies.

- Financing agencies should be organized as independent, state owned corporations, and free of formalistic and bureaucratic constraints. They should be placed under strict limitations regarding the percentage of their resources they can spend on administration, and should be supervised by high-level councils with the participation of scientists, educators, entrepreneurs and government officers. They should rely on external advise for their decisions, and their bureaucracy should be limited to the minimum.

_ Research institutions and public universities should not be run as sections of the civil service. They need to have the flexibility to set priorities, seek resources from different public and private agencies, and establish their own personnel policies. While this is not changed, there is always the alternative of developing hybrid institutions with flexible mechanisms coexisting with more rigid procedures (the Brazilian academic community has some experience in this). Universities should develop appropriate settings for interdisciplinary work in new fields such as biotechnology and artificial intelligence (Carvalho, 1993; Silva, 1993).

_ No research institution receiving public support, and no government program providing grants, fellowships, institutional support or other resources to the S&T sector, should be exempt from clear and well-defined procedures of peer evaluation, combined, when necessary, with other types of economic and strategic assessments. Peer review procedures should be strengthened by the federal government, made free from pressures of regional, professional and institutional interest groups, and acquire a strong international dimension. For instance, research proposals could be easily distributed to international referees through electronic mail.

_ It should be the task of the Ministry of Science and Technology to stimulate such reforms in other branches of the federal government. The Ministry of Education should have a particularly important role in maintaining the quality and the autonomy of the research groups in the federal universities.

_ It should be also the task of the Ministry of Science and Technology, in cooperation with the Ministries of Finance and Foreign Affairs, to keep the channels open for international cooperation between Brazil, international agencies and institutions, and the international scientific community. The World Bank, the International Development Bank and the United Nations Development Program have played important roles in providing resources for capital investment, research support and institutional development of Brazilian institutions. This presence should be maintained not only because of the resources involved, but because of what they bring in terms of international perspectives and competence. In the future, such agencies could be very helpful in a process of institutional reform. As a rule, cooperation among scientists, research institutions and private foundations in different countries is established directly, and need the support, but not the interference, of governmental agencies.

. *Goal-oriented projects*

The broad changes suggested in this document do not preclude the adoption of well-identified projects linking science, technology and the productive sector, aimed at the strengthening of specific fields and orientations in the natural and social sciences, the establishment of instruments for S&T diffusion and education, and others. Proposals of this kind are present in the background studies commissioned for this study, and will emerge as a matter of course whenever decisions have to be made about the allocation of scarce resources, the beginning of new lines of work, and the phasing out of others. It is necessary to develop a list of main areas of established competence and social relevance to be the focus of future investments; to identify areas that should be phased out, or reduced; and special weaknesses and competencies in need of strengthening and support. Two very broad principles should preside this policy-making process:

_ It would be inappropriate to assume that science and technology would develop and increase its usefulness in a peripheral region if left alone to respond to market mechanisms of economic and scientific competition. The distribution of science and technology, as it is well known, is very lopsided in any given field and region, and the current expansion of communications and trade is leading to further concentration of knowledge, competence and technical resources. Policies are needed for general and technical education, for bringing flexibility and introducing accountability in public-supported institutions of higher education, research and development, and for introducing standards of quality. The trend toward concentration cannot be stopped by policies of isolation and self-sufficiency, or subsidies to second-class institutions and research groups. But it is not a zero-sum situation. As the world gets more integrated, information circulates, and the knowledge basis increases, there are new opportunities to be grasped. For this, they have to be properly perceived and understood, and adequate investments in education should exist.

_ Brazil has had some experience of integrated programs covering specific areas of interest, such as tropical diseases, natural resources, energy and computer sciences. PADCT has followed a similar pattern, by choosing a few, selected areas for support, and assigning a given fraction of its resources to them. An integrated program would have, ideally, resources for combined activities of basic and applied research, graduate education and training. For the fields chosen for such programs, the benefits seem obvious, since their resources are guaranteed, and the links between basic and applied research and education can be made more coherent (box 17). There are, however, three pitfalls for such programs, which should be avoided. First, they run the risk of isolation. As with any applied project, integrated programs need to have clearly identified and active partners outside the research and education sector - be they the health ministry, the electronics industry or public utility companies. In fields that are economically relevant, they should be linked to specific industrial policies, and the participation of relevant business leaders. When this pattern is not present, the results of the integrated project are not used, and the effort can be wasted. Second, there is always the temptation to distribute the R&D resources arbitrarily among programs, creating unwarranted imbalances. Third, self-contained programs are prone to shun peer review evaluations and give excessive protection to a few institutions and research groups, disregarding excelence in favor of selected subjects or problems. If these difficulties are considered _ if there are clearly identifiable partners in government and industry, if there are no arbitrary block assignations of resources, and if peer review procedures are kept in place _ integrated programs can be important and forceful instruments for improving the country's S&T capabilities.

A goal-oriented project: Strategic Development of Computer Science

The strategic development of computer science project (DESI) is supported by the National Research Council, through its division of special projects, and the United Nations Development Program. It combines research projects proposed by members of the scientific community with a broad project aimed to develop a national software industry for export and a national infrastructure for communication and computer applications.

The project is divided in three programs, the National Research Network (RNP), the Multi-institutional thematic program (PROTEM) and the software program (PROTEX). RNP is a computational infrastructure aimed to create a network linking all scientific and research institutions in Brazil with each other and with the rest of the world. PROTEM was initiated by the National Research Council's advisory committee in computer science to create, for their

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plurality of activities, from basic to applied science, from graduate education to extension work and teacher training. They should be also stimulated to diversify their sources of money, from government to private companies, nonprofit foundations and paying clients and students. Specialization will take place, is necessary, and should grow through a combination of external incentives and internal drive. Scientific research and development, to remain alive, should take place in a highly nternationalized and competitive environment for resources, prestige and recognition; and the leading scientists should be also entrepreneurs of this knowledge enterprise.

Papers commissioned for this study:

a) General papers:

Branscomb, L., 1993 _ *U.S. Science and Technology Policy: Issues for the 1990s.* - Lewis M. Branscomb, Director, Science Technology and Public Policy, Center for Science and International Affairs, Harvard University.

Brisolla, S., 1993 _ *Indicadores Quantitativos de Ciência e Tecnologia no Brasil* - Sandra Brisolla, Núcleo de Política Científica e Tecnológica, Universidade Estadual de Campinas, São Paulo.

Castro, C. M. and Oliveira, J. B., 1992 _ *Os Recursos Humanos para a Ciência e Tecnologia* - Cláudio de Moura Castro e João Batista Araujo e Oliveira, International Labor Organization (presently at the World Bank)

Ferné, G., 1993 _ *Science & Technology in the New World Order* - Georges Ferné, Organization of Economic Cooperation and Development, Paris.

Guimarães, E. A., 1993 - *A Política Científica e Tecnológica e as Necessidades do Setor Produtivo*. Eduardo Augusto Guimarães, Instituto de Economia Industrial, Universida de Federal do Rio de Janeiro.

Schott, T., 1993 _ *Performance, Specialization and International Integration of Science in Brazil: Changes and Comparisons with Other Latin American Countries and Israel* - Thomas Schott, Department of Sociology, University of Pittsburgh.

Skolnikoff, E., 1993 _ *U.S. Science and Technology Policy: the Effects of a Changing International Environment* - Eugene B. Skolnikoff, Massachusetts Institute of Technology, Boston.

b) basic and applied sciences:

Azevedo, J., 1993 _ *A Pesquisa Agropecuária no Brasil* - João Lúcio Azevedo, Escola de Agricultura Luiz de Queiroz, Universidade de São Paulo.

Carneiro Júnior, S. 1993 _ *O Estado atual e potencialidades do Ensino de ps-graduação e da Pesquisa em Engenharia no Brasil* - Sandoval Carneiro Júnior, Coordenação dos Programas de Ps-Graduação em Engenharia (COPPE), Universidade Federal do Rio de Janeiro.

Carvalho, A., 1993 _ *Biotecnologia*, Antnio Paes de Carvalho, Instituto de Biofísica da Universidade Federal do Rio de Janeiro and Fundação Bio-Rio.

Cavagnari, G., 1993 _ *P & D Militar: Situação, Avaliação e Perspectivas,* Geraldo L. Cavagnari, Núcleo de Estudos Estratégicos, Universidade Estadual de Campinas.

Cordani, U., 1993 _ *Geociências*. Umberto Cordani, Instituto de Geociências, Universidade de São Paulo.

Dietrich, S., 1993 _ *Botânica, Genética e Zoologia*. - Snia M C. Dietrich, Instituto de Botânica, Secretaria do Meio Ambiente do Estado de São Paulo.

Lucena, C., 1993 - *A situação atual e o potencial da área de computação no Brasil*, Carlos J. P. de Lucena, Departamento de Informática, Pontifícia Universidade Catlica do Rio de Janeiro

Paiva, A. 1993 - *Physiological Sciences*. Antnio C. M. Paiva, Instituto de Biofísica, Escola Paulista de Medicina.

Ramos, O. L., 1993 - *rea da Saúde* - Oswaldo Luiz Ramos, Escola Paulista de medicina

Reis, F., 1993 _ *A Avaliação das Ciências Sociais.* Fábio Wanderley Reis, Universidade Federal de Minas Gerais

Rezende, S., 1993 _ *Avaliação da rea e Proposições Para a Física no Brasil* - Sérgio Rezende, Departamento de Física, Universidade Federal de Pernambuco

Riveros, J., 1993 _ *Uma Visão Atual da Química no Brasil,* José M. Riveros, Universidade de São Paulo

Silva, W. S., 1993 _ *A Pesquisa em Inteligência Artificial, seus Antecedentes Intelectuais e suas Características Locais*, Walzi Sampaio da Silva, Universidade Federal Fluminense.

c) technology and industry

Castro, N, A., 1993 _ *Impactos Sociais das Mudanças Tecnológicas: Organização Industrial e Mercado de Trabalho.* Nadya Araujo Castro, Universidade Federal da Bahia e CEBRAP.

Goldemberg, J., 1993 _ *Tecnologia, Política Energética e Meio Ambiente.* José Goldemberg, Universidade de São Paulo.

Kupfer, D., 1993 _ *Política de Qualidade no Início da Década de 90* - David Kupfer, Instituto de Economia Industrial, Universidade Federal do Rio de Janeiro.

Pereira, L., 1993 _ *Sistema de Propriedade Industrial no Contexto Internacional*, Lia Valls Pereira, Universidade do Estado do Rio de Janeiro

Tigre, P., 1993 _ *Liberalização e Capacitação Tecnológica: o caso da informática ps-reserva de mercado no Brasil* - Paulo Bastos Tigre, Instituto de Economia Industrial, Universidade Federal do Rio de Janeiro.

Verulm, R. 1993 _ *O Setor de Bens de Capital no Brasil.* Roberto Verulm, Faculdade de Economia e Administração, Universidade de São Paulo.

d) institutional aspects:

Barbieri, J., 1993 _ *Conselho Nacional de Desenvolvimento Científico e Tecnológico* - José Carlos Barbieri, Fundação Getúlio Vargas.

Campanário, J. and Serra, N., 1993 _ *Sistema Estadual de Ciência e Tecnologia (São Paulo)*, Milton A. Campanário and Neusa Serra.

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