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MONITOR - SAST ACTIVITY
STRATEGIC ANALYSIS IN SCIENCE AND TECHNOLOGY

THE NEEDS AND POSSIBILITIES FOR COOPERATION BETWEEN SELECTED ADVANCED DEVELOPING COUNTRIES AND THE COMMUNITY IN THE FIELD OF SCIENCE AND TECHNOLOGY

(Sast Project N° 1)

COUNTRY REPORT ON INDIA

by
Kurt Hoffman, Sussex Research Associates Ltd
with the assistance of Dr. Vishnu Mohan

January 1991

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FOREWORD

This report has been prepared for the Strategic Analysis in Science and Technology Unit (SAST) of the Directorate-General for Science, Research and Development of the Commission of the European Communities. SAST activities are part of the MONITOR Programme which aims to identify new directions and priorities for Community research and technological development (RTD) policy and to help show more clearly the relationship between RTD policy and other Community policies.

For questions already identified as of interest for the development of Community policy, SAST projects provide an investigation of the perspectives opened up by science and technology. SAST projects thus serve as an input to the process of policy formulation. In the case of the SAST project to which this report contributes, "The needs and possibilities for cooperation between selected advanced developing countries and the Community in the field of science and technology", the context of policy questions includes the evolving economic relations between the Community and these countries, the interest to the Community of promoting international cooperation in science and technology with various types of countries, and the Community's role in European science and technology.

This report is one of a set of country studies carried out for the project. The set comprises the Republic of Korea, Thailand, other ASEAN countries, the People's Republic of China, India, Brazil and Mexico. An overall strategic review will also be available in 1992.

It should be borne in mind in reading the country studies that the fieldwork on which they are based was carried out almost entirely in the country concerned. The points of view of European industrialists/researchers/policy makers were not explicitly sought for this part of the project. (They will be sought as part of the work for the overall strategic review.)

SAST presents this report as a stimulus to reflection and debate within the European Community on the best strategies to adopt towards a group of increasingly important countries. It must be stressed, however, that the orientation and content of reports prepared for SAST cannot be taken as indicating the considered opinion of policy advisors within the Commission services.

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INTRODUCTION

The prospects for collaboration in science and technology (S&T) between the European Community and India will be directly influenced by India's development experience and by the debates that have historically shaped the direction and orientation of the country's industrial advance. However, since independence, India's economic progress has been characterized by such a paradoxical combination of backwardness, gradualism and success that it is difficult to render a balanced assessment of past achievements, present prospects and future possibilities.

Central to this conundrum is the fact that India's pursuit of development has always been beset by a fierce and deeply rooted conflict within and outside of the government over whether its priorities should focus on equity and the reduction of poverty or on the attainment of rapid industrialization. Even today these issues permeate policy discussions at the highest level of decision-making. However what has not been seriously questioned until recently by both sides in this debate is that central government should play a major role in controlling and directing the economy. This historical unanimity on the role of the state means that a wide variety of government-owned public sector organizations are deeply imbedded in the economy and now operate major industrial, infrastructural, cultural and service entities.

On the industry front, privately owned firms operate widely but are excluded from a (diminishing) number of areas considered centrally important such as space and defense. The government exercises firm control (now being slowly loosened) over the import of equipment and inputs and over the incidence and nature of collaborative activities between foreign and Indian enterprises. Agricultural production is in private hands but major support industries such as irrigation and fertilizer are largely state operated.

In many respects, an impressive share of the country's original social objectives have been met despite the constraints imposed by its size (800 million people), a per capita income of only $260, extraordinary cultural diversity and a degree of class and religious conflict that makes India one of the most inherently complex and difficult to manage societies in the world.

In the 43 years since independence, India has retained its status as the world's largest, functioning democracy (a notable achievement in its own right) and attained measurable progress in the areas of health, food and energy production. The overall level of advance in human terms is readily discernible in the improvement of life expectancy at birth from 46 years in 1971 to 57 years in 1988; a decline in the birth rate from 41 per 1000 in 1971 to 32.2 per 1000 in 1986 and a drop in the death rate from 15.7 per 1000 in 1976 to 12.5 per 1000 in 1986.

Likewise, there have been notable achievements in the industrial sector. A sustained and comprehensive planning effort has led to the development of broad array of heavy industries, a large degree of industrial self-sufficiency and ambitious high technology projects in the areas of nuclear energy, defense and space. A strong commitment to the creation of national scientific and engineering capabilities has lead the government to support a sizeable higher education system consisting of 157 universities and 5500 colleges and a massive network of 1000 research institutions.

However, alongside of these achievements, stand a number of glaring paradoxes. Without question the central difficulty is that the increases in income, wealth and well-being recorded over four decades of post-independence development are marred by the persistence of poverty afflicting almost half of the population concentrated in rural villages and burdened down by illiteracy, unemployment and extremely low incomes. In the eyes of many, this situation persists because of the overemphasis given to the pursuit of industrialization by government since independence. At the same time, blame for the poor record of GNP growth (less than 2 per cent yearly since 1950) that has allowed poverty to persist is laid at government's door because of its restrictive policies towards the productive sector.

These contrasting dimensions of state involvement in India's economic successes and failures and the pervasive and contentious debate over the direction of Indian development are the basic parameters that will inevitably define both the nature of future S&T collaboration between India and the EC and the strategies that must be pursued to take advantage of these opportunities. Five themes derived from this will run through the whole of our analysis.

First, the cumulative development of India's industrial infrastructure and the generation of a sizeable pool of well trained scientific and engineering resources constitute the central pillars around which EC-India S&T and industrial collaboration can be constructed. None of the other countries under study can offer the combination of advantages that India possesses - a large pool of low cost, skilled manpower resources, engineering expertise and world-class scientists - all embedded in one of the potentially largest domestic markets in the world.

Second, by virtue of the deep involvement of the government in S&T and advanced industry, any substantial projects must not only have government support but most probably extensive government participation as well. Given this, it was very encouraging that during the course of our interviews a sincere willingness emerged at the highest levels of government to explore the prospects for mutually beneficial collaboration between India and the EC.

Third, there were clear signs on the part of the recently removed Janata government that it would carry forward the process of liberalization begun by the Congress Party government of Rajiv Gandhi.[1] The new Chandra Shekar government shold not diverge too far from this commitment. This should provide a favourable context for large scale EC collaboration. However, the industrial "successes" achieved during the 1980s (for example, record industrial growth rates and a sharp upsurge in manufactured exports) as a result of liberalization have had a double-edged effect. On the one hand they have

1. This report was researched and prepared before the recent collapse of the Janata and Chandra Shekar governments, the assassination of Rajiv Gandhi and the election of the Congress Party government. However, most if not all of its main conclusions remain valid.

strengthened the hand of the reformers and created a dynamic new group of entrepreneurs and managers in both the private and the public sector who would be the natural partners of this collaboration.
At the same time, some of the perceived excesses of the 1980s (by a consumption-oriented, urban middle class) and the resentment caused by the efforts of foreign actors to influence Indian industrial trade and commercial policy has sparked off another round of fierce and contentious debate centring around the recurrent themes of equity versus growth and the permissible role of outside interference, foreign capital and foreign technology in the economy. This struggle may, at times, slow down and hamper visible forward progress in developing collaboration and must always be taken note of by those developing and implementing the EC strategy in this area.

Fourth, the large bulk of key decision makers within the government and the bureaucracy fiercely identify with the accomplishments of India since independence and attribute this to the policies of self-reliance and non-alignment that have been followed since independence. They do not see India's future success as being dependent upon the strengthening of economic or technological relations with any country or group of countries. Consequently, Indian policy makers, when publicly pressured to eliminate policies they feel have protected the economy from exploitation - as in the case of recent U.S. and EC pressure over the issue of IPR and access to national markets, resist strongly what they see as unwarranted outside interference in Indian affairs. This does not mean there are no ways around these issues but it does mean that if progress is to be achieved, it will best occur via interactions that take place at the sub-rosa level.

Finally, the scale and diversity of the Indian S&T and industrial apparatus and the complexity of Indian policy making, suggest that while there are great gains to be had from collaboration, a good deal more groundwork has to be done before it will be possible to specify precise areas and modes of collaboration. In that regard, the process of consultation and communication initiated by the SAST project, has created an important and timely opportunity for the EC to pursue its objectives in this area.

RESEARCH METHOD AND APPROACH

This report is based on desk research and a series of personal interviews carried out in India during May and June 1990 with senior policy makers in government, key actors representing the private sector, senior academic observers and directors and researchers in research institutes. Because of the size and complexity of the Indian S&T system, the Indian S&T enterprise and the decision-making process that guides Indian S&T and industrial endeavours, it was not feasible to undertake a comprehensive coverage of all the key actors and institutions involved nor to explore in detail the specifics of possible collaborations. Instead, our research strategy concentrated on investing a good deal of effort in gaining access to and discussion with a select group of influential government officials whose positive endorsement and involvement will be critical for any further discussions between the EC and India over the matter of mutually beneficial S&T collaboration.

ORGANIZATION AND STRUCTURE OF THE REPORT

This report is organized into two parts:

Part I presents a strategic review of the prospects for EC/India S&T collaboration and assesses the problems to be overcome, the factors to be taken account of in devising a strategy, and recommendations for proceeding forward.

Part II presents the "decision base" on the Indian economy an the Indian S&T situation. This consists of a background overview of the Indian economy and its recent performance; the thrust and focus of Indian industrial policy; the structure and functioning of the Indian S&T system and the S&T planning process; the structure of the S&T education and manpower situation; and an evaluation of Indian public and private sector R&D.

A set of 7 annexes, based on the case study approach, use information gleaned from desk research and interviews to discuss aspects of the Indian S&T scene and the industrial sector that are relevant to our concerns and illustrate the different forces at work within India.

EXECUTIVE SUMMARY

1. India and the European Community already have reasonably well developed scientific, industrial and trading links. This report argues that there is, however, ample scope to expand these links significantly via innovative forms of mutually beneficial S&T and industrial collaboration.

2. India possesses a broader range of scientific and industrial strengths than other advanced developing countries. Harnessed properly, these could enhance Community scientific competencies, open up a wide array of new commercial opportunities for European firms and contribute significantly to India's own industrialization efforts. The Community is uniquely well placed to play a key facilitating role in bringing about the collaboration necessary to allow this to happen.

3. Yet seizing these opportunities will require a concious strategy that takes account of the countervailing, contradictory and often confusing, political and economic forces that influence Indian policy towards collaboration with foreign firms and governments.

4. Politically, the new minority Indian government has still to consolidate its position and remains vulnerable. It also faces short term economic constraints in the guise of a balance of payment crisis, a growing fiscal deficit and a sharp slow-down in industrial growth - all of which have recently forced the government to impose austerity measures including new controls on imports of non-essential items including capital goods and some intermediates.

5. Such factors would inevitably create uncertainties for any efforts by the Community to pursue a deliberate strategy of achieving greater S&T and industrial collaboration. Moreover, the government's room for manoeuvre on this issue is further constrained by its cautious stance towards foreign investment and technology import borne of its opposition to the urban/consumption-oriented policies of the previous administration.

6. Yet underlying these uncertainties there are reasons for optimism both in general and in relation to the prospects for collaboration. On the political front, the Indian bureaucracy is a powerful stabilizing force. Provided Community initiatives have the backing of key officials in the bureaucracy, agreements reached will go forward even if the government falls and new elections are called.

7. Despite the short term economic constraints, Indian industry exhibits considerable strengths buoyed by a strong output and export performance over the last five years. This has been driven by the wide-ranging liberalization policies pursued by the previous government. These policies have fostered a new, more optimistic attitude on the part of Indian industrialists and foreign investors over future

prospects for the Indian economy. Surprisingly the new government seems committed to carrying forward the process of industrial liberalization.

8. Because of liberalization, a new breed of technocrat-entrepreneurs have emerged in both the public and private sector who represent a flowering of industrial and technological dynamism and realism that is new on the Indian scene. Not being constrained by the restrictive practices and attitudes of the past. these individuals and their enterprises could act as competent partners for Community sponsored projects that incorporate European firms and involve both R&D and production.

9. The Indian S&T system, though suffering many structural problems, also has considerable strengths. Some of its scientists are carrying out leading edge research in fields of interest to Europe. India also enjoys enviable depth in its pool of trained manpower in fields of applied technology such as engineering and software development. A third is the government's ability to relatively quickly marshal substantial resources and focus efforts on the pursuit of objectives in targeted areas.

10. A variety of innovative proposals for S&T and industrial collaboration that go beyond current EC-India projects were proposed in the course of our interviews with senior policy makers, scientists and industrialists. These include straightforward science projects and Indian participation in the Framework programme, the deployment of Indian software engineers on European-oriented system software development projects, European participation in technology-intensive infrastructure projects in India and major new initiatives aimed at strengthening Indian industrial standards capabilities and its producer services sector.

11. There were, of course, reservations expressed over the prospects for greater EC-Indian collaboration partly on the grounds of principal and fears of exploitation and partly because of concerns that systemic incompatibilities between the corporate and bureaucratic cultures of both sides would frustrate any truly innovative projects.

12. These reservations were far outweighed, however, by the strong expressions of interest from very senior policy makers in pursuing further discussions with the Community on the possibilities for enhanced and expanded S&T and industrial collaboration.

13. Care needs to be taken in how the next steps are organized, particularly with regard to discussions that define the principal of "mutual benefit" on which the collaborations must be based. However, the prospects are favourable that the Community could act as a catalyst for opening up a new era of scientific, technological and industrial collaboration between the European Community and India that would be of great benefit to all parties.

PART I : STRATEGIC REVIEW

I.1. FAVOURABLE CONDITIONS ENHANCING THE PROSPECTS FOR S&T COLLABORATION

India is a country that cannot be understood from a distance. The secret to success in India, whether at the level of the individual or the enterprise, has always been a willingness to commit the considerable time, effort and resources required to understand the country and the Indian way. Yet despite the difficulties, the benefits gained from cultivating this understanding and forging strong links with India almost always outweigh the effort and resources invested at the outset. Considered from this perspective, a compelling case can be made for the European Commission to pursue the development of mutually beneficial S&T collaboration with India .

For the Community and its member states, the potential gains arising from S&T and related industrial co-operation are tangible and significant. Certain aspects of India's S&T system and its industrial capabilities exhibit advantages that complement and extend those of the Community in directions not accessible via collaboration with virtually any other country.

Take skilled manpower availability for example, where Europe faces a critical shortfall capable of undermining its efforts to remain competitive internationally. India's stock of trained S&T manpower is close to three million people of which perhaps one-tenth are directly employed on S&T related activities within the country. Given this, it is not surprising that India has substantial reservoirs of trained, low cost and underexploited S&T manpower in fields such as fine mechanical engineering, software design and immunology that could be deployed on collaborative, large scale pre-competititive and near-market research projects.

Other advantages to the Community and its member states from Indian S&T collaboration are concretely documented below such as gaining access to new markets both in India and in third countries, strengthening Europe's knowledge base in a variety of fields where Indian science is well advanced, the low cost sourcing of low volume, technology intensive components and European consortium participation in major Indian high tech infrastructure projects in transportation, communication and energy. The benefits to Europe of substantial industrial and S&T collaboration with India constitute a strong and visible economic logic for the development of these relationships.

Of equal importance, there exists in India an overall favourable political and economic environment that will facilitate attaining agreement on collaborative S&T projects. On one side is the fact that S&T has always been accorded significance in the Indian context. For example, the government has supported the development of a large system of higher education (including universities, and technical colleges) capable of turning out 190,000 S&T trained graduates annually while also operating a massive network of R&D laboratories, a number of which now operate at the frontiers of science in well supported and highly targeted research efforts.

At quite another level, the Indian economy is not overwhelmed by economic crisis, as is the case with the other large market economies in the SAST project, Mexico and Brazil, whose governments will for some time be engaged in crisis management and be seriously constrained on the resource front. Of course, India has some very severe economic problems and faces considerable resource constraints but nowhere near the degree faced by these two countries.

Neither is there a contentious background of trade-related conflict with Europe in high technology areas as is the case with South Korea, Thailand and Brazil since the Indian government is not pursuing an export-oriented industrialization policy. High technology firms based in India (either local or foreign owned) do not now pose a serious competitive threat to European producers at home or in third markets. And while future competition is always a possibility, the focus of India's industrial efforts will for many years be primarily on the development of her domestic economy with her manufacturing firms inevitably being largely oriented towards meeting the needs of a home market consisting of nearly a billion people.

Finally, and significantly, a strong willingness was expressed by senior policy makers during our interviews to take seriously the EC's interest in collaboration and to further explore the possibilities of launching mutually beneficial S&T projects. This interest, and the fact that it was expressed openly and backed up by offers of immediate action (detailed below) represents a critical breakthrough in the Indian context.

For such initiatives to move forward in India, they will have to have political backing both at the highest political level (i.e. from the Cabinet and Prime Minister) but more importantly among the senior bureacrats that compose the S&T policy making elite. This is because major collaborative S&T projects are intensely political issues in India that will inevitably stir up much critical comment in the press and therefore must be strongly supported by the government or they will be abandoned. Moreover because of the Indian government's direct participation in the S&T system any sizeable collaborative project will not only require the strong endorsement of the government but conceivably its direct participation as well.

I.2. COUNTERVAILING PRESSURES WILL INFLUENCE THE DESIGN AND DEVELOPMENT OF S&T COLLABORATION PROJECTS WITH INDIA

Despite these generally favourable background conditions, the way forward towards the design and implementation of substantive collaborative efforts will not be an easy one. Inevitably there exists a wide range of factors derived from Indian political and economic circumstances that must be taken account of by the Community in assessing realistically the specific prospects for collaboration and in devising a strategy for exploiting these. These are best understood in the Indian context as three sets of interlinked countervailing conditions that will impinge directly and indirectly upon the decision making process and in turn have implications for the Community's strategy for establishing S&T collaboration with India.

I.2.1. POLITICAL UNCERTAINTIES OF A MINORITY GOVERNMENT UNDERPINNED BY A STABLE SYSTEM OF GOVERNANCE

The Janata Dal government unexpectedly elected in late 1989, after a quiet start, began to run into difficulties caused by its political makeup and the Hindu/Muslim religous divide that are eroding its authority and stability. These weaknesses arose mainly because the government was dependent for support upon both a fundamentalist right-wing religous party and parties of the left with both opposed to the previous government's liberal tendencies.

Given the tempestuous and combustible nature of Indian politics, the Janata government's future was difficult to predict. When this report was being researched and the first draft prepared, there was great uncertainty as to whether that government could survive through the autumn and thus serve out its full term. In the event, the government fell to be replaced by an even more fragile government headed by Chandra Shekar. This government soon fell as well only to be replaced by a weak Congress party government whose future cannot be assured but who seems committed to picking up again the road to liberalization begun by previous Congress government."

This uncertainty obviously poses some problems for the pursuit of Community S&T initiatives. However it is also the case that the Indian bureaucracy, as slow, cumbersome and obstructionist as it can be, is a powerful stabilizing force that has always ensured a certain degree of continuity in major programmes once they are agreed no matter what happens to the elected government. This is particularly true of the powerful S&T related ministries and departments since the development of India's S&T system has always enjoyed strong central government support at all levels. Consequently, even if the nnew government falls in the midst of negotiating with the Community, provided the process is secured by the backing of certain key senior S&T policy makers and advisers, such negotiations will go forward.

I.2.2. SHORT TERM ECONOMIC CONSTRAINTS IN THE CONTEXT OF IMPRESSIVE INDUSTRIAL ADVANCE

A number of problems are clouding the Indian economic picture in the short term. First, a fairly sizeable decline occured in industrial production in 1989 to 60 per cent of the previous year accompanied by significant overcapacity in some of the consumer durables sectors that had lead the earlier boom and by a 40 per cent fall in the rate of approval for foreign collaborations. Second a substantial fiscal deficit has developed approaching 4 per cent of GDP accompanied by an incipient balance of payments crisis which has seen reserves plummet to a level capable of sustaining less than two months worth of imports. This has lead recently to the imposition of austerity measures including a 15 per cent cut in imported components and raw materials and the reimposition of import controls on 32 categories of non-essential equipment imports.

Besides conceivably reinforcing the industrial slowdown reported above, these difficulties raise doubts about the prospects for any medium term projects with a high net import content as well as heightening criticisms of the pro-foreign investment and urban consumption-oriented policies followed by the previous Gandhi government that in turn places pressure on the present government not to go down the same path.

Counterbalancing these slightly worrying short term trends is the underlying strength of the Indian industrial sector as demonstrated over the last ten years. During the latter part of the 1980s, industrial output expanded at nearly 9 per cent annually - over twice the pace of the previous twenty years. Manufactured exports grew 26 per cent annually between 1987-1989 compared to just 1 per cent the previous decade, reaching a total of approximately $15 billion in 1988 of which the U.S. accounted for 19%, Japan 11%, and the EC 24.7 per cent. They have maintained and even increased that level of performance recently recording a 33 per cent increase in the first four months of 1990 over the same period last year.

Accompanying this improvement in output and exports, there was a 15 fold increase in the rate and scale of participation of foreign firms in local production through direct investment not only in traditional industries but in a number of high tech sectors such as electronics and fine chemicals. Within this there occured a significant deepening of the participation in India of firms from some European countries, such as the Federal Republic of Germany - though Europe's overall share in this category of activity declined compared to that of the U.S. and Japan.

While the above demonstrates that the confidence in India of foreign investors has grown significantly, there have been equally positive signs on the domestic front such as an order of magnitude increase over the last two years in the number of shareholders and in the amounts invested in domestic capital markets, substantive growth in aggregate private sector capital expenditure (by 34 per cent in 1989 over 1988), and a 55 per cent and 33 per cent increase respectively over the same period in loan agreements and disbursements by development finance institutions. Indian industry still has a long way to go with regard to attaining the level of dynamism and competitiveness pressent in some of the other ADCs - but considerable progress has been made over the last decade.

I.2.3. THE PARTICULARLY INDIAN PROCESS OF "HASTENING SLOWLY" TOWARDS INDUSTRIAL LIBERALIZATION

India's pursuit of development has always been beset by a fierce and deeply rooted conflict within and outside of the government over whether its priorities should focus on equity and the reduction of poverty or on the attainment of rapid industrialization via an open economy. Even today these issues permeate policy discussions at the highest level of decision-making due to the perceived excesses of the 1980s (by a consumption-oriented, urban middle class) and the resentment caused by the efforts of foreign actors (particularly the U.S. via Super 301 but also the EC) to influence Indian industrial trade and commercial policy. There is always the possibility that this antagonism could rebound against specific EC S&T initiatives.

At the same time however, the moves toward liberalization which began in the 1970s but really started to bite in the mid-1980s during the Gandhi government, are deeply rooted in the convictions held by India's governing classes - both senior technocrats and advisors and the powerful economic elite - that India must now begin to move with reasonable dispatch toward greater openness in the industrial sphere. Thus the policy changes already made giving firms more freedom of action to enter and exit markets, favouring investment and exports and enhancing internal competitivenss are unlikely to be set aside. Indeed, much to the surprise of many observers it is now clear that the earlier Janata government intended to carry forward the process of greater liberalization further than was ever expected.

This trend is demonstrated by the June 1990 announcement of a further easing of investment and technology imports restrictions removing an estimated 75 per cent of these deals from government control (moves that were heartily endorsed by the U.S. government and lead to the recent suspension of the 301 threat). Another example is that liberalization on the trade front (such as the proposed 30 per cent across the board reductions in tariffs) were being accompanied by moves towards greater openness within the domestic economy such as opening up further the steel and plastics sector to private investment and allowing state-owned firms to raise equity funds and assume 100 per cent autonomy. Despite the need to temporarily put the brakes on imports in order to save foreign exchange, it looks likely the process will go further (despite the change in administration) - as is indicted by our interview findings that the government was looking closely at such treasured policies as the 40 per cent limit on foreign equity and continued state ownership of some 248 production-oriented enterprises.

In India, where commitments to self-reliance and determination to avoid the excesses of capitalism and TNCs are so deeply felt, such policies are bound to generate storms of protest from within and outside of the government. Because of this the pace of change will be deliberate and measured. The new government's room for radical change is clearly constrained by the antagonisms towards liberalization of its minority supporters - the protectionist left and the rural based right wing parties. In addition, our interviews showed clearly that despite their liberal leanings, government planners are deeply fearful of the catastrophic and destabilizing effects on the poor of a radical and wrenching shift towards an open economy such as they claim to be now witnessing in the case of Mexico and Brazil.

I.3. THE EMERGENCE OF OPPORTUNITIES FOR A NEW WAVE OF EUROPEAN-INDIAN TECHNOLOGY-INTENSIVE INDUSTRIAL COLLABORATIONS

The largely positive assessment of trends in macro industrial performance and industrial policy given above suggests that a highly favourable climate may be emerging for the establishment of a greater European industrial involvement in India. Much of this can be traced to a change in the opinions and perceptions of national and foreign industrialists towards India as a "place to do business". The more open and competitive environment in local markets has lead to an increased awareness on the part of domestic industrialists of the need to upgrade quality and improve productivity (leading to an unexpected improvement in total factor productivity of 4.2 per cent during 1987-89 after two decades of literal stagnation) coupled with greater demand for state-of-the-art imported and domestic technology (as opposed to repeated imports of current vintages) and a significant increase in R&D investment by the private sector.

At the same time, even the relatively modest loosening of controls on foreign investment (with comparison to other advanced developing countries) lead to veritable avalanche of interest on the part of foreign investors in increasing their capital stake in India. True, the absolute levels of investment are much lower ($250 million in DFI) in India compared to $750 million to $1.5 billion in Thailand and China in 1988. Nevertheless, the rush of foreign firms to establish facilities or expand their capacity during 1985-1989 is a powerful indicator of the potential of the Indian economy to attract much greater levels of foreign investment in the future - provided, and this is very crucial in the Indian context, that the efforts of foreigners to establish an Indian presence are guided by a strategy based on a close reading not only of the operating conditions in India but of the politics and methods of doing business in India.

Our interviews highlighted some of these factors while also identifying a number of micro level developments that could conceivably define the focus for some of these activities and that indicate parallel activities by other international actors that need to be monitored carefully.

I.3.1. NEW AND OLD NODAL POINTS FOR TECHNOLOGY-INTENSIVE INDUSTRIAL COLLABORATION

Indian industry has historically been the focus for much criticism on the grounds of its (protection-induced) inefficiency, poor quality and small scale. Not surprisingly, there was no shortage of such criticisms in our interviews and large parts of the industrial sector were dismissed for having mercantilist attitudes and a "kit culture" mentality towards manufacturing while also being totally uninterested in technological development as indicated by the derisory amounts invested in R&D (around 0.7 per cent of sales on average) and the high percentages of reimports of same vintage technology.

While the political objectives have considerable merit, the costs of India's defensive industrial policies in terms of low productivity, inefficienct use of resources, limited international competitiveness, fragmented industrial structures and technolgoical dependence have been very significant. Of this there can be no doubt. However, there is also no escaping the evidence that in the wake of moves toward liberalization, the Indian industrial landscape is beginning to show evidence of the growth of significant flowerings of industrial and technological dynamism. Many of these exhibit the classic characteristics of the new type of small, flexible, technology-intensive industrial and service ventures that now flourish in the advanced countries. Well-managed Indian venture capital funds (which are a new feature of an already lively capital market) have already supported more than 100 small, high tech start-ups led by young scientist-entrepreneurs.

Most of these are performing well and promising above average returns while another 300-400 such projects are already in the pipeline; 4 science parks/cities are now well-established (with good support infrastructure and on-site training and testing facilities) and are proving to be a successful breeding ground for entrepreneurial firms (foreign and domestic) seeking to exploit India's low cost high skilled manpower base; the more open atmosphere created by the initial round of reforms in the mid-1980s stimulated the emergence of a large and visible number of service sector entrepreneurs who have built up large and highly successful activities by tapping into India's vastly unexploited service market; while the recent easing of industrial controls is widely expected to lead to another burst of small firm start-ups by entrepreneurs who under the old system were not able to wrangle a license.

These glimmerings of an industrial renaissance are not restricted to small, start-up firms but encompass a number of the old style industrial enterprises in the private and public sector whom many observers had written off as dinosaurs doomed for extinction. For example, India boasts a number of integrated technology intensive public sector enterprises (in sectors as diverse as computers and electronics to railways and bridge building) who have over the last decade been allowed to act increasingly as private sector enterprises, competing for contracts at home and abroad. In the process, they have developed an impressive range of management and technical competencies that suggest they may be suitable partners for EC S&T projects that incorporate European firms and involve both R&D and production.

Similarly, some of the large industrial houses have been stirred out of their lethargy to enter new dynamic sectors such as IT and services as well as forming strategic development, production and marketing partnerships with foreign firms seeking to penetrate Indian and third country markets on the basis of the advantages conferred by scale economies. Moreover, many of the long established Indian industrial firms (domestic and foreign), particularly in the engineering sector, have begun to embrace the tenets of Japanese approaches to quality, management and production. Some of these efforts have registered surprisingly good results taken note of by other firms - a demonstration process that could soon lead Indian industry into the same frenzied adoption of these practices that is currently transforming industry and comeptition in Europe and the U.S.

Finally, a large variety of Indian firms again in the engineering sector (broadly defined) but also in more traditional sectors (from garments to perfumes) have begun to establish a wide array of export-oriented technology and production linkups with foreign firms. These involve the use of low cost but relatively high-skilled manufacturing labour (combined with a significant advacned engineering input) to produce products/components for export on a subcontracting basis and to third countries - such a development indicates that Indian producers are gaining the reputation for export quality and reliability that has always eluded them in the past. Recently some of these firms have begun to transform their dependent link with foreign firms into an independent relationship where the benefits of collaboration flow in both directions.

It is possible to dismiss these developments as "exotic" exceptions sustained by the hothouse conditions of the 1980s consumer lead boom that won't survive into the 1990s with the economy under the tutelage of a left-leaning agriculturally oriented, minority government. However, we believe these features can also be interpreted as signposts indicating both the future direction and character of a slowly transforming Indian industrial sector and flagging areas where European industry could use Community sponsored collaborative projects to cultivate a privileged presence in the more dynamic sectors of the Indian economy. Much more needs to be done on the Indian side to further enhance these developments through loosening of restrictive policies - the Community can play a valuable role here.

I.3.2. U.S. AND JAPANESE FIRMS BEGIN TO INCREASE THEIR LEVELS OF ACTIVITY WITH SUPPORT FROM THE PUBLIC SECTOR

Unlike the Asian NICs and second tier countries, India has never been a battleground in the global competitive war between Europe, Japan and the U.S. This is still the case. Recently, however there are signs that Japanese and the U.S. firms have begun to increase the tempo of their involvement while Europe, with the exception of West Germany has been flagging a bit. For example, the rate of both U.S. and Japanese DFI and collaborations increased markedly during the 1985-89 period while the European share declined - a pattern also reflected in the trading arena in technology intensive sectors such as non-electricial and electrical machinery.

In both cases, the public sector has supported these efforts, directly and indirectly through a variety of measures. For example, in the case of the U.S. despite a recent chilling of offical relations over differences in the treatment of IPR, the U.S. government through various agencies has funded an average of 200 or more co-operative S&T programmes with some industrial content every year since 1985 while also providing more than $50 million over that period to support high tech joint ventures between Indian and and U.S. firms. With a total trade of more than $5 billion including a substantial share of India's high technology imports and software exports, the U.S. effort, which has also recently begun to include well supported trade missions, is broad based and generally successful.

Japan on the other hand has been a relatively late starter in the cultivation of India, with Japanese industry being heavily deterred prior to the mid 1980s by India's poor reputation for industrial quality and discipline. However in the last few years, India has been particularly eager to attract Japanese investors while Japanese firms have begun to respond positively - albeit largely on an experimental basis and much more focussed (on motor vehicles and electronics) than in the case of Europe or the U.S.

The best known response has involved the twenty or so joint ventures and collaborative agreements that were launched at Indian government invitation in the motor vehicle and components sectors in the mid-1980s including the famed Suzuki-Maruti initiative. The excellent productivity and quality performance of these joint ventures and the willingness of Japanese partners to reduce import content and expand exports looks likely to open the doors to further Japanese involvement.

To that end, the government has established a "fast-track" approval process to expedite approvals of Indo-Japanese projects (a facility previously only open to West Germany). Indications are that approval willl soon be given to three major new initiatives - a Rs 1 billion expansion of the Suzuki-Maruti car project (it will involve making 30,000 units a year of a 1000 cc passenger car by 1991 in addition to the present 800 cc model); modernisation of the state owned IISCO steel plant which the Japanese will be allowed to carry out on a turnkey basis; and a series of joint venture/export oriented projects to make video cassette recorders in India. In addition there are expectations that a five year agreement signed in 1985 to bring Japanese electronics technology to India will be renewed in the near future as well.

Interestingly, there are also signs of Japan and India being drawn closer together on the financial front with perhaps two thirds of India's commercial borrowings (much of it for the funding of major infrastructural projects) coming from Japan on very favourable and innovative terms. In addition, Japan is also seen as the main target for a second India Fund launched by Unit Trust of India following the 1986 U.S. fund organised in collaboration with Merrill and Lynch.

While these steps can be seen from the Indian point of view as being part of a general strategy to tap Japanese savings surpluses, the experience of other Asian countries suggests that where Japanese concessionary financing goes first, Japanese DFI comes later in much greater amounts. The possibility that the growing financial links between India and Japan could be precursor to the same situation is reinforced by the vigourous lobbying efforts of the Japanese Prime Minister Kaifu during his recent trip to India when he argued that India should be prepared to accept greater flows of both technical assistance and Japanese DFI. This perhaps explains our finding that Japanesse development agencies have very eagerly responded to Indian requests for seminars and training projects concerned with introducing Indian managers and engineers to Japanese management practices.

The Japanese, like the Americans and Europeans before them, have become adept at linking government funded technical assistance with the promotion of private sector interests particularly in Asia. It may be that this same strategy is slowly being deployed in India. If so these developments need to be watched closely lest European firms wake up one day in the not too distant future to find themselves struggling to make inroads into rapidly growing Indian markets for products and technology already dominated by the Japanese.

I.4. THE FORMAL R&D SYSTEM IN INDIA: IDENTIFYING THE POCKETS OF EXCELLENCE AMIDST WIDESPREAD MEDIOCRITY

The Indian public sector S&T system is a massive and complex enterprise. On the educational side, there now exists a university and college based system of higher education that consists of 157 universities and 5500 colleges. These institutions annually turn out an additional 190,000 or so trained personnel (3500 with S&T Ph.Ds) to add to the country's existing stock of S&T manpower of nearly 3 million people. Out of this stock of trained people, an estimated 275,000 are engaged in productive employment utilizing their skills, and 90,000 work directly in R&D activities - the eighth largest number of R&D staff in the world.

When speaking about R&D in India, one must inevitably deal principally with government supported R&D. In 1988, the Indian government invested approximately $2 billions in state supported R&D activities. This accounts for nearly 90 per cent of all R&D expenditure in the economy and is equivalent to approximately 1.2 per cent of GNP and the level of expenditure has increased at 12 per cent annually since Independence. This level of support is second only to South Korea among developing countries and while falling far short of developed country R&D expenditure it is indicative of the measure of backing that the government has consistently been prepared to give to S&T activities.

The allocation of national resources to S&T activities has a formal and informal dimension. Formally, S&T and R&D expenditure is decided by the Planning Commission at the beginning of each plan period on the basis of submissions and negotiations by the major S&T agencies and the relevant socio-econmic ministries (health, agriculture, energy, industry, etc). Informally, there is a powerful group of elite civil servants, eminent scientists and industrialists and advisors to the government who combine together in different configurations depending on the circumstances and who are capable of pushing through agreement on and funding of ad hoc S&T programmes of some considerable significance.

The policy making and operational structure is very complex with the power and influence of different ministries, departments and commissions with S&T interests often ebbing and flowing depending on the issues, the political power of the minister or secretary, and the complexion of the government. Formally and still in practice, the Ministry of Science and Technology is the most important nodal point from the EC perspective and it encompasses two departments who play a particularly crucial role in directing the S&T system - the Department of Science and Technology, which is the premier S&T policy making body and the Department of Scientific and Industrial Research, which is the focal institution for government efforts to stimulate innovation in industry and is also responsible for the Council for Scientific and Industrial Research (CSIR) whose forty laboratories constitute the core group of industry-oriented R&D centres in India

There are numerous other agencies and departments whose activities have a strong S&T component and who play very important roles in policy making and R&D resource allocation within their particular sphere of interest. Among the most significant of these are the three defence related departments (the Defence Research and Development Organization and the Departments of Atomic Energy and Space) as well as the departments of biotechnology, electronics, environment, non-conventional energy and ocean development.

All of the above operate their own networks of R&D laboratories as do the socio-econmic ministries and the state governments. In total, the Indian central government, through all its ministries and departments probably supports 1000 R&D labs with the state governments supporting another 300 - though these are almost all oriented towards agriculture R&D.

The range of activities, strengths and weaknesses of an S&T system of this scale obviously cannot be easily summarized. However, our interview findings indicated that the following dimensions of the public sector S&T situation in India are particularly important from the perspective of this project.

I.4.1. A SUBSTANTIAL INDUSTRIAL R&D SYSTEM SUFFERING FROM STRUCTURAL WEAKNESSES

Despite the size and scope of the public sector R&D system, and the continual support of the Indian government to the development of Indian science, there is a widespread consensus outside of the S&T community that, with some very important exceptions discussed below, the R&D system has failed to play a major role in the country's drive for self-sufficient industrialization. The evidence is strong for this view. CSIR and many of its associated labs have had relatively limited success in developing and transferring useful and commercially viable technologies to Indian industry. The R&D and technology development efforts of the leading S&T agencies, particularly in defense areas, have failed to deliver on many of the objectives they set out to achieve.

And underlying all of this is a distorted S&T educational system where effort has been concentrated on building up truly impressive centers of excellence in teaching and R&D (such as the seven urban universities, the five Indian Institutes of Technology and the Indian Institute of Science) at the expense of adequate investment and support for the large rump of inferior universities and colleges scattered throughout the country where the education and research on offer are of dubious quality.

There have been numerous examinations of these problems and numerous attempts to increase the industrial relevance of the R&D carried out by the public sector - the latest of which involves requiring CSIR labs to generate a fixed percentage of their income from external, contractual, sources. There are signs of change and improvement in the direction of greater relevance within the R&D system. However, considerable pessimism was expressed in some of our interviews that the marginal tinkering usually proposed as a solution to its problems will never produce the sort of fundamental overhaul in attitudes and and behaviour (from within the R&D community and on the part of industry) needed to create a dynamic, R&D system that is integrated with and driven by the short and long term needs of industry.

Clearly, this situation remains one of considerable concern for Indian science policy and for the government. However, an assessment of the implications for SAST concerns of the parlous condition of the Indian industrial R&D system needs to be balanced by the additional evidence and insight generated by our interviews into the considerable but very specific strengths of the Indian R&D system.

I.4.2. POCKETS OF UNEXPLOITED EXCELLENCE OFFERING OPPORTUNITIES FOR COLLABORATIVE R&D IN BASIC SCIENCE AND APPLIED TECHNOLOGY DEVELOPMENT

While the gloomy assessment noted above largely originates from observers and analysts operating outside the formal S&T system, not surprisingly, those inside the system have a very different view and were able to provide equally convincing evidence of areas and fields where Indian basic and applied science was on par with any in the world. Apart from its impressive and well known capabilities in non-conventional energy, physics and space research, software and biotechnology (as noted below) India has, for example, world class credentials in natural resource assessment involving ground and air observation and extending to highly sophisticated satellite-based remote sensing, pattern recognition and imagery construction.

Another example of Indian R&D competencies can be found in the field of oceanography research where both its research vesssels and its oceanography research institutions are at the forefront of international research techniques and findings and these have lead to numerous international collaborations with West Germany, the U.S. and other countries. There are also fields where Indian labs have demonstrated that their work and skills are not only industrially relevant but internationally competitive. For example, the wind testing and model building capabilities at the National Aeronautical Laboratory as well as its instrument fabrication skills have allowed it to win a number of internationally tendered contract in these areas. The National Chemical Laboratory has recently made major breakthroughs in catalyst technology that have lead to joint ventures and lucrative licensing agreements with international firms.

To be truly complete, a cataloguing of India's strengths in applied R&D and technology development would have to include the many technologies successfully developed and adapted by the R&D system but not adequately or properly commercialized by labs themselves nor picked up on by Indian or international industry. There are, however, far too many to even list here. And beyond these accomplishments in applied R&D, we need hardly identify those areas of pure and theoretical science (such as astrophysics and particle physics; pure and applied mathematics; surface studies and fast kinetics; and even superconductivity) where India has a global reputation.

This broad spread of Indian science capabilities is further attested to by its standing in the international science publishing sweepstakes. Recent reviews in Scientometrics (volume 16, 1989) rank India in 8th place among all countries in terms of published papers; they also demonstrate that there is hardly any major field of science where Indian scientists do not publish in significant numbers and that Indian science capabilities are clustered in research fields where other developing country scientists are hardly represented such as biochemistry, physics, chemistry and chemical physics.

The above discussion provides ample confirmation (not really required by those scientists who know the Indian science scene) of the (selective) strengths of Indian science. There can be little doubt that these capabilities are wider and deeper than in any of the other SAST countries. With formal S&T international collaborative agreements with more than 40 countries and many hundreds more individual collaborative projects, it is clear that the competence of Indian science is recognized in Europe and elsewhere.

However, our interviews did generate indications that there were many more prospects for R&D collaboration than are currently being explored, that these could be of a form and focus likely to be of much greater substance and significance than those currently underway and that the EC could possibly help to unlock these possibilities - provided, that is, that the steps taken to do this do not run foul of the myriad array of bureaucratic obstacles and deeprooted sensitivities towards international collaboration that already exist within India. This is an issue we come back to below and in the rest of the paper.

I.4.3. THE INDIAN CAPABILITY OF CHANNELING R&D RESOURCES INTO TARGETED AREAS

One of the great strengths of the Indian S&T planning system and its combination of formal and informal decision-making and resource allocation mechanisms is that it is capable of fairly quickly channeling significant resources towards fields or problem areas deemed to be of national importance. This has most recently been done via the identification of what are called "thrust areas" for R&D, product development and skill creation in fields such as fusion research, new materials, parallel computing and digital switching. A good example of this approach at work can be seen in the efforts of the Indian government to create substantial national capabilities in the field of biotechnology.

On the basis of recommendations of an independent advisory board, a variety of actions have been taken since 1985 that have greatly accelerated India's movement towards the forefront of biotechnology R&D. The most important of these was the creation of a separate Department of Biotechnology with independent funding, policy making and co-ordination responsibilities and a mandate to focus on three main sets of activities:

(i) directing and supporting national R&D projects focussed on 9 separate basic research topics and a number of "mission mode" projects involving applied R&D;

(ii) manpower creation via the provision of financial and technical support for "model" systems of world class post-graduate and post-doctoral teaching in 20 selected universities and institutions; and

(iii) infrastructure creation that involved the provision of financial support to existing institutions to upgrade their research facilities to world class standards; while at the same time creating entirely new institutions with specific research and training mandates.

In addition to the activities of the DBT, both the DST and the CSIR, increased substantively their allocation of resources to biotechnology R&D projects and to strengthening institutions carrying out biotechnology related research. For example, the CSIR increased resources going to the Centre for Cellular and Molecular Biology and it is now recognized as one of the best equipped biotechnology laboratories in the world, staffed by 150 Ph.D. researchers distributed into eleven multidisciplinary groups.

Similarly, the ICMR established the the National Insitute of Immunology which in a few short years of work has generated commercially significant breakthroughs in a number of areas such as embryobiotechnology, the production of vaccines for controlling human and animal fertility, diagnostic kits for amoebic liver abcess, brucellosis, and typhoid, and a DNA probe for M. tuberculosis.

It is still relatively early days and there is much to be done particularly compared to the scale of India's needs and problems where biotechnology will have an impact. But as a result of the focussed efforts of the government, India has begun to generate skilled manpower resources on a substantial scale; is close to world standards in several specific fields; and is gradually laying down an impressive research infrastructure.

This example not only highlights biotechnology as a possible area of EC collaboration but also indicates the capacity of the Indian government to respond substantively to calls for targeted R&D and other activities provided it is convinced of the national value of taking such actions.

I.4.4. A DEEPROOTED COMMITTMENT TO THE DEVELOPMENT OF INDIGENOUS S&T CAPABILITIES IN INDIA THAT MUST BE RESPECTED

A critical dimension of the Indian science policy scene is the strong nationalist sentiments of the science establishment and of the elite group of advisors and policy makers who direct the Indian S&T enterprise. While accepting India's S&T weaknesses - particularly when compared to developed country performance, this group is fiercely proud of what India has accomplished in S&T and they remain genuinely committed to the ideal of Indian self-reliance. They do not blindly embrace autarchy but accept the costs associated with the long struggle to build an independent scientific and technological competence free of what they see as a debilitating and humiliating dependence on foreign sources of knowledge and technology.

What came across clearly in the interviews is that, rightly or wrongly, these perceptions directly influence policy decisions at the highest levels of government vis a whole range of S&T related issues - from the choice of sectors that should be opened to DFI and the participation of private capital to whether or not to respond positively to EC proposals for international S&T collaboration based on "mutual benefit".

These beliefs explain Indian sensitivities and intransigence over such issues as intellectual property rights where the pressure placed upon India to modify its position in bilateral and multilateral forums by the U.S. and the Community was, and still is, deeply resented; or even more specifically why the Indian government is sharply critical of the blatant efforts by TNCs from the U.S. and Europe to hire away India's most skilled S&T personnel so that they are lost to the country forever. They also underlie why India appears to be moving relatively slowly towards liberalization in the industrial sphere.

The Indian science policy elite wears its national pride boldly and, in our opinion, with considerable justification given the positive effect of Indian S&T accomplishments on the national character. Such attitudes go to the heart of the nation's strong sense of self-esteem and identity. For that reason alone they should be respected. However, and more than that, these perceptions must be taken careful account of in the development of any strategy to foster S&T collaboration between the EC and India.

I.5. SOME CAUTIONARY VIEWPOINTS ON THE VALUE AND FEASIBILITY OF MUTUALLY BENEFICIAL S&T COLLABORATION BETWEEN THE COMMUNITY AND INDIA

Two of the major objectives of the SAST project were to explore in practical terms the degree and nature of interest in India among leading policy makers, industrialists and scientists in pursuing mutually beneficial S&T collaboration with the EC; and to identify the areas or fields where such collaboration might take place and the modalities that might be followed. Unquestionably there was a favouable reaction overall among those interviewed to the prospects of greater collaboration and a number of useful ideas and proposals were put forward as to the areas where this might take place and the possible mechanisms for achieving such collaboration.

However before discussing these in the next section, we want to highlight briefly some of the more critical viewpoints and qualifications put forward regarding the issue of collaboration during the interviews and uncovered in the course of our research. We felt it might be useful to summarize these views both because coming as they do from senior figures in the S&T community, they need to be taken seriously and also because they actually provide to the Community insights as to how it might proceed in India that are as valuable (if not more so) than the more positive responses recorded in the next section.

The cautionary observations put forward with any consistency across the interviewees fall into both a general category regarding the problems of international S&T and industrial collaboration and a more specific subset of concerns relating to EC and European involvement in such collaborations. They can be encapsulated into the following five points.

I.5.1. INTERNATIONAL S&T COLLABORATIONS HAVE BEEN LESS THAN SUCCESSFUL BECAUSE OF A LACK OF COMMITTMENT TO THE PRINCIPLES OF MUTUAL BENEFIT

India currently participates in 40 or so international collaborative agreements which involve hundreds of different activities, most of which center on exchange of scientists, travel visits, seminars, etc. Quite a few of these agreements, and certainly those with the leading S&T countries emphasize mutual benefit as a criteria for project selection.

While this seems to represent a significant Indian committment, the net effect of this considerable experience with international S&T collaboration is that the Indian government, in sharp contrast to China, does not look to such collaborations as a main element in its domestic S&T programme. The existence of agreements is seen as a necessary part of normal political relations between states. And to certain parts of the science community, such agreements are very useful as additional sources of knowledge, contacts and resources for R&D and training in non-contentious areas.

They are, however, considered by senior policy makers to be of little strategic interest - in the developmental rather than the defense-related meaning of the word. They therefore do not attract either the resources or political attention of the more mainstream S&T initiatives discusssed above such as the technology missions or the implementation of the mission mode R&D programmes.

Perhaps underpining this view, considerable scepticism was voiced about the real gains likely to flow to India from its participation in "mutually beneficial" collaborative schemes. Past experience suggested that the initiative for establishing mutually beneficial S&T collaboration almost always came from the side of the developed country and that the meaning of mutual benefit was almost always defined according to the perceptions of the developed country - rather than emerging out of a joint consideration of what it meant in principle and more importantly in practice.

This problem is illustrated by the recent rejection by two European countries (with whom India has bilateral agreements) of Indian requests for joint R&D projects in fields that the countries felt "were not really open to co-operation despite previous committments that they were". While it was accepted that excluding certain areas from R&D co-operation was legitimate, the original principles of mutual benefit on which the agreements were signed were clearly not being adhered to.

Moreover it was felt that mutual benefit was retained as a guiding principle often only as long as it suited the wider political interests of the developed country partner. This is what happened recently when severe restrictions were placed on the scope of projects undertaken within the the U.S. STI framework after India and the U.S. clashed over issues of IPR and the U.S. threatened widespread retailiation under Super 301. The sensitivities of the Indian S&T community have been deeply aroused by this experience.

From the Indian perspective, both sorts of situation have inevitably lead to a one-way flow of the benefits away from India. The U.S. STI initiative is now very much viewed in this light. Expectations were voiced that recent EC proposals for India to collaborate on R&D in certain areas of tropical agriculture, health and weather forecasting would lead in the same direction. India has the expertise in these fields which it would be pleased to share - but the way the projects were proposed made it clear they were primarily designed to contribute to the strengthening of EC commercial capabilities while using India as a testing ground.

Thus in the perception of some, there were question marks over the committment of the Community to go beyond the statement of platitudes about developing projects of genuine mutual benefit doubts and its ability to actually deliver. A few doubted that the problems would be overcome. Others were prepared to give the Community the benefit of the doubt and were willing to examine the actual actions taken for evidence of its true intentions.

I.5.2. AVOID A DIRECT CONFRONTATION OVER MATTERS OF INTELLECTUAL PROPERTY RIGHTS AND PERCEIVED BIASES IN INDIAN INDUSTRIAL POLICY

The question of India's position on intellectual property rights is extremely sensitive at the present time. This is because the Indian government has just gone through a tense period waiting to see whether U.S. threats to impose unilateral trade sanctions because of this issue would be carried out. This has not happened for the moment, partly so the U.S. claims, because it was mollified by the recent changes announced in India's industrial policy and partly because it wants to see the outcome of current multilateral negotiations on the issue. The Indian government denies it was responding to any such pressures but nevertheless is under very considerable pressure from all sides not to be seen to succumb to what it considers is totally unwarranted and unjustifiable outside interference on either IPR or industrial and trade policy more generally.

As with India's defensive industrial policies, the economic costs of its restrictive approach to IPR now far outweigh any benefits gained. Technological dependence and its related effects is increased not decreased by overly restrictive IPR policies. However this is an issue of politics and not economics and the Indian perspective differs strongly on this from our own and that of the Community. Vis a vis EC concerns on this front, our interview findings suggest that any attempt to visibly link progress on IPR and other similar issues directly with agreement on any major proposals for S&T collaboration could be a major tactical error.

If there is pressure within the EC to engage India over this issue, then more might be accomplished at a "sub rosa" level via quiet diplomacy. It needs to be remembered that it is very rare for major policy shifts to be denoted in India by the passage of legislation. There have for example only been three major pieces of legislation regarding foreign investment and technology transfer since Independence. Yet since that time, real government policy, as opposed to its publicly stated position, has varied enormously depending on circumstances and the mix of pressures confronting the government of the moment. It is an understanding of this very "Indian" process of policy making and implementation that should guide EC strategy on this issue rather than the politics of confrontation favoured by the U.S.

I.5.3. EC PROJECTS SHOULD NOT SEEK TO OPEN UP INDIAN CONSUMER GOODS SECTOR TO EUROPEAN DFI NOR CREATE A CONDUIT FOR EXTRACTING INDIAN S&T MANPOWER

Though there were good prospects perceived by some for the promotion of industrial collaboration with a high S&T component, strong words of warning were directed against the "choice" of sectors where the EC might seek to facilitate the setting up of such collaborative projects. The basic message was that there was little chance that either straightforward DFI projects or EC sponsored S&T collaborative proposals would go forward if they were aimed at the urban consumer goods sectors on which so much foreign interest was presently concentrated. Foreign firms would not be allowed to cream off the higher value added segments of the market for luxury consumer items. The consumer-oriented excesses of the last administration when a deliberate policy of promoting urban consumption and DFI in this sector would not be repeated.

In a similar vein, it was made clear that though there were prospects for EC-India collaboration that took advantage of India's surplus manpower, these proposals should steer away from collaborative mechanisms set up primarily to permanently siphon off to Europe trained Indian S&T manpower in order to overcome European skill constraints. This had already been blatantly attempted by some countries and similar proposals from the EC would not be favourably received.

I.5.4. THE MISMATCH IN CORPORATE CULTURES AND WEAK INDIAN R&D CAPABILITIES WOULD DOOM MOST COLLABORATIVE EFFORTS

There was also a view expressed that the weakness of Indian industrial R&D capabilities and the general mismatch in corporate cultures would not be conducive at all to the successful establishment of major new R&D collaborations between private sector firms under the rubric of Community sponsored projects.

The rationale behind this position was that if S&T collaboration was going to lead to genuine mutual benefit then this had to come from the commercial application of the knowledge generated. For this to happen it was felt that there had to be much greater corporate synergy between Europe and India, particularly on the R&D front, then there is today. India's corporate R&D sector was very weak and offered no advantages to Europe; while European firms, primarily interested in penetrating India's domestic markets with unchanged products, had shown very little interest in starting local R&D activities.

Under current conditions, there did not appear to these observers to be any real prospects of closing this gap in perceptions and expectations. Considerable doubts were voiced by a few interviewees as to whether the Community was really in a position to foster or facilitate the development of closer corporate R&D synergies between Europe and India. It was felt in some quarters that the pursuit of this objective was best left entirely to private actors.

I.5.5. THE INVOLVEMENT OF THE EC AND INDIAN BUREAUCRACIES WOULD LOWER SUBSTANTIALLY THE PROSPECTS FOR ACHIEVING SUCCESSFUL COLLABORATION

Serious disquiet was voiced over the possibilitiy of any successful projects arising out of attempts by the EC and Indian bureacracies to establish new programmes of S&T collaboration. From inside the Indian government came expressions of unhappiness over the unwieldiness and relative ineffectiveness of the joint commission mechanism for generating truly useful S&T projects. In the case of the EC-India joint commission, insufficient political importance was attached to the S&T component and so inadequate funds were allocated and little effort was made by the Indian side to advance projects quickly.

In parallel there was a negative perception of the degree of interest on the part of the Community officials to promote genuine collaboration - though the aid aspect of the relationship worked reasonably well and the importance of trying to cope with commercial relations within the joint commission mechanism was given a high priority. Negotiations with multilateral agencies over technical assistance projects were viewed as being much more tortuous and time consuming than those with bilateral agencies - the experience with the EC to date had confirmed those perceptions.

From outside the government, the shortcomings of the Indian bureaucracy were widely acknowledged. And, we should stress, these criticisms are echoed with considerable legitmacy from within the European Commission as well. Moreover, doubt was expressed at the ability of either the Indian or the EC bureaucracy to provide the flexible adminsitrative framework necessary to facilitate the sort of innovative co-operative S&T projects envisioned by SAST. Considerable evidence was provided (not solely related to the EC but also to member state and Indian bureaucracies) of unnecessary delays caused to project implementation due to bureaucratic obstructions and procedural delays. This was viewed as inevitable if bureaucracies were involved and not specific to the Community.

I.6. DIVERGENT BUT WIDE-RANGING PROPOSALS FOR S&T AND INDUSTRIAL COLLABORATION BETWEEN THE COMMUNITY AND INDIA

Within the generally positive response among most interviewees towards the prospects of greater S&T collaboration with the Community, two strands of opinion emerged and need to be noted. The first, emanating mainly from the more senior policy makers was that while it was certainly possible to identify general areas where collaboration might occur and the modalities it might take, it was far too early to be thinking in such specifics.

Existing linkages with the EC were felt to be too limited to be built upon as yet since the Community is simply not a major player either in the field of industrial or S&T relations. Also they felt that there were a variety of questions and confusions that needed to be addressed first before proceeding to specifics. It was necessary to do this not primarily to resolve outstanding differences between the two sides, but rather because interchange over these issues would be a means of building up confidence between the two sides.

One set of general concerns that could be addressed in this way were anxieties over the implications of 1992 and the developments in Eastern Europe for Community policies and relations with India. Questions were raised about the impact of these developments on EC-India aid flows, about market access for Indian products to "Fortress Europe" and about the possible negative effects on the level of future investments by European companies in India caused by a diversion of their attention to Eastern Europe.

At a level relating specifically to the issue of S&T collaborations there was a degree of caution with regards to the Community's underlying objectives in pursuing this initiative. This is where concerns were raised about the Community's interpretation of "mutual benefit" and the range of areas and activities where it was prepared to collaborate. Finally there were also fears that accesss to European big science projects and EC labs would be made even more difficult because of the pressure to allow in scientists from Eastern Europe.

These concerns did not diminish this group's interest in collaboration. But it was felt that at this stage, it was far more important to concentrate on the process of building confidence and understanding between the Community and India rather than specifying individual projects. This process had begun with the round of consultations undertaken in the course of the SAST project but had to go much further. The implications for action raised by this group are reflected in more detail in the strategy discussion in Part I.7.

The industrialists and senior scientists consulted exhibited a much greater willingness to engage in concrete discussion about the specific areas for collaboration and the forms it might take. There was some caution in this group that it might be best to begin with collaborative efforts in non-controversial fields such as "pure" science, health and the environment. However, most saw ample opportunites for beneficial R&D collaboration in a wide range of fields - often linked into commercial production activities.

Our fieldwork in India also generated recommendations and insights of a more general nature concerned with the identification of projects and possible collaborating actors and agencies within India. Below we present a selection of both general and specific proposals for collaboration that could be both expanded and more fully developed if necessary.

I.6.1. CAREFUL TARGETING OF PROJECT DESIGN IS REQUIRED

Maintaining political support for such projects is critical in India and must be done carefully. Thus the projects developed need to be targeted in one of two directions. The first is to appeal to the progressive nationalist aspirations of the Indian middle class. Because of the dualistic and class nature of Indian society, such projects could either incorporate high tech elements (such as aerospace, professional electronics, advanced machine tools or new materials) or they could address the development needs of the bulk of the rural based population via a technology-centered approach.

The second direction that could be taken would be to design projects that would find favour with the mainstream bureaucracy situated primarily in the sectoral (transports, communications, energy, steel, petrochemicals) and the socio-economic ministries (health, industry, agriculture etc.) These bureaucracies represent a stable constituency that, if brought onside, would be able to sustain support for collaboration through periods of political turmoil. There were many possibilities here but further preliminary contact with key figures in these ministries would be necessary to identify the most appropriate focus.

I.6.2. LOOK FOR SPECIFIC COLLABORATORS AMONG THE NEW BREED OF TECHNOCRAT-ENTREPRENEURS

If industrially-oriented R&D projects linked to production are an objective, look either to small scale, high tech entrepreneurs currently flocking towards venture capital funds for support or to joint sector (public-private) companies operating in engineering, information technology and bio-technology sectors. These are perceived as the only sectors with substantial R&D capabilities at the enterprise level outside of the CSIR R&D network where the firms are also managed aggressively by young competent technocrat-entrepreneurs. Such projects could be developed through the Investment Partners Scheme - which in India still needs to be activated, primarily because of delays on the Indian side.

I.6.3. AVOID CONSUMER GOODS AND SEEK SYSTEMIC PROJECTS THAT HAVE AN AGRICULTURE AND/OR RURAL DIMENSION

We have already noted the strong feelings of the government against further projects focussed on the urban consumer. However, it is also clear that powerful government support would be forthcoming if the collaboration proposals put forward were for projects or processes that meet rural needs and/or contributed to rural industrialization. There was a feeling that contrary to the opinion of foreigners that such projects could find a ready market either via government programmes or because the steady rise in rural incomes was in fact beginning to be felt in the market place.

These projects could be based on imported high or low tech solutions but would need to involve both adaptive R&D and production in India. They would also need to take a systemic approach - be designed to take account of all aspects from raw materials procurement to distribution and distribution. Such projects could be tied to technology missions or mission mode projects in areas such as the provision of drinking water, rural communications or the development of the dairy industry. Alternatively they could be linked into food processing activities (for domestic consumption or export) or environmental conservation activities linked to small scale industry. There were already examples of such projects involving foreign collaboration and more would be welcome. This was an area where aid funds could be used and where the Indian government would be also prepared to make a substantial contribution.

I.6.4. BE PREPARED TO BE PATIENT AND TO MAKE A COMMITTMENT TO INDIA

There is no quick and easy route to success in India. With all the best will in the world, things take time, the bureaucrats are frustrating and there are massive inefficiencies to be overcome. Unless foreigners are prepared to accept these operating conditions, and unless they are prepared to put their "heart" into the project and make a long term committment of time and resources, the prospects of success are limited. Those foreign companies who have made such a committment have been very sucessful (such as Siemens and Larson-Turbo) - those who have not, such as ICL or Phillips have found it far more difficult. Committment counts in India. That is why many Indians expect that once the Japanese, with their long term view of market and industry development, begin to take a serious commercial interest in India, as they are now doing, they will be highly successful.

I.6.5. EUROPE-CENTERED HIGH TECH JOINT DEVELOPMENT PROJECTS

Joint participation was proposed by Indian public sector "gateway" enterprises in large scale, Europe-oriented high tech development projects where low cost, highly skilled Indian manpower could be coupled with European technology and project management skills. Large system software development projects were the most obvious possibility. However, a similar approach could be used to other manpower-intensive high tech development projects in areas such as parallel processing, the development of "micro motor" technology, the development of engineering plastics, molecular modelling or protein engineering - all areas where India has already built up a significant manpower and knowledge base.

An additional attractive element and boon to such projects would be if they could be used to entice back NRIs from the U.S. who themselves would be major sources of absorbed technology - though to do this such projects would have to be operating absolutely at the frontiers of knowledge.

I.6.6. SCIENCE-BASED DEVELOPMENT AND PRODUCTION PROJECTS

There are a range of science-intensive activities and projects underway in India where collaboration would be possible. For example, a major new radio astronomy project is being planned that will involve the design, fabrication and erection of the world's largest telescope. European scientists and instrument engineers could be involved in the joint development with India of this telescope and Europrean specialist producers could then undertake the supply of the many specialized parts not available in India nor likely to ever be produced there.

I.6.7. DOMESTIC IT DEVELOPMENT PROJECTS WITH EXPORT POTENTIAL

There are many possibilities here. For example, a variety of remote communications projects are underway where India has developed specialist expertise in some areas but needs production technology and where jointly developed products could be exported to third countries. Areas of focus might include the development of low cost remote sensing and software image processing equipment, the development of low noise amplifiers; satellite system payload fabrication, and the development of advanced gyroscope technology and solar arrays. Software is another area. Canada is sponsoring a $15 million joint software development project focussing on the development of applications for railways, banks and other services to be marketed in India and Canada and exported to third countries.

I.6.8. EUROPEAN PARTICIPATION IN TECHNOLOGY INTENSIVE INFRASTRUCTURE PROJECTS IN INDIA

The Indian government has a large number of major infrastructure projects planned. These incorporate extensive high technology hardware, software systems and design elements where European participation might be possible in both applied R&D, design and supervision and component fabrication. These include the planned modernization of Bombay and Delhi airports, development of the inland waterways and port systems, and water and power provision where, for example, an integrated, computer-controlled hydro system is being planned involving 30-40 dams. Though overall supervison will be done by Indian companies, major opportunities exist for a European consortium to undertake joint control system development, engineering R&D and component production as well as backstopping Indian engineering firms on critical segments of overall project - though in making this offer the question was raised by the Indian side if Indian firms would then be allowed to tender for similar activities in Europe?

I.6.9. NEW TECHNOLOGY-BASED PRODUCT DEVELOPMENT WITH DOMESTIC AND EXPORT POTENTIAL

A number of possibilities were identified for the joint development of a wide variety of products suitable for and demanded by the enormous Indian domestic market that would also have export possibilities. Among the products and processes identified were solar power technology, vaccines for communicable diseases, herbal medicines, biotechnology based fertilizers, and pollution control and monitoring equipment for traditional and small scale process industries.

I.6.10. STRAIGHTFORWARD COLLABORATION IN SCIENCE

There are a number of fields where India has world class scientists. In many of these areas, government is placing increasing pressure on Indian scientists to carry out relevant research and useful results. European collaboration on these projects would be valuable but they are not currently encompassed by EC and bilateral co-operative agreements.[2] Such fields include nuclear physics, deep sea oceanography, heavy ion physics, plasma physics, surface studies, mathematical modelling and fast kinetics.

I.6.11. CLOSER LINKS WITH CSIR LABS TO PROMOTE COMMERCIALIZATION OF ON- THE-SHELF TECHNOLOGIES AND STRENGTHEN THEIR CONTRACT RESEARCH CAPABILITIES

Many CSIR labs have generated and are now generating many potentially commercially viable applications of technology in which Indian industry has taken little interest or is no prepared to support the necessary development work. There are opportunities here for collaboration between CSIR and the EC which would focus on the marketing and then development of these tecnologies on a worldwide basis. At the same time such a project could help advance the ability of CSIR labs to generate revenues in the future by strengthening their international competitiveness as contract R,D&D labs.

I.6.12. COLLABORATION IN THE DEVELOPMENT OF INDUSTRIAL SCIENTIFIC SUPPORT SERVICES

Though India has a well developed Bureau of Standards that is competent in conventional areas, it has weaknesses in other areas partly caused by lack of funds and by lack of government recognition of its importance. This means it is unable to carry out "R&D" on many high technology areas and it is struggling to stay in touch with global developments. There are, however, signs that government is now beginning to appreciate the importance of standards as the economy becomes more open and Indian firms are being placed under pressure to export.

Standards is one of the areas covered by current EC-India industrial collaboration agreements and it was felt in India that this was a good and useful project. However, there was also concern that the project underway is too limited and has as yet failed to fully exploit opportunities for EC to play a major role in development of Indian standards. If it were to do so, this could have significant commercial implications for the future. There is thus great scope for a larger, more imaginative standards project bringing in private and public sector participation and having both an aid and technical assistance component and a commercially oriented component. Provided it was presented properly as a joint project not designed to "pressure" India in a particular standards direction, the prospects are good such a project would be strongly supported by the government.

[2] The Commission already supports a sizeable fellowship programme under which Indian scientists (40 for the 1990-91 period) spend time working at EC laboratories; as well as 6 multipartner joint research projects in the fields of bio-technology, health and advanced materials.

I.7. IMPLICATIONS FOR A COMUNITY STRATEGY TO DEVELOP INDUSTRIAL AND S&T COLLABORATION WITH INDIA

Interviews carried out for the SAST project with senior policy makers, scientists and industrialists indicated a significant degree of general and specific interest in the possibility of establishing innovative industrial and S&T collaborative arrangements with the European Community. An interesting range of proposals was made as to the type of projects that might be feasible and the sectors, products and topics that could be the focus of these collaborative efforts. We now need to address ourselves to the issue of what steps the Community might next take in order to respond to this interest in collaboration on the Indian side.[3]

A key starting point to discuss these issues is to understand the motivations that lay behind India's interest in developing greater collaborative links with the Community. Importantly, it is not because attaining their industrial goals for the 1990s depends critically on gaining access to European markets for their manufactured exports. Obviously India does want to maintain access on as favourable terms as possible since nearly one-third of its total trade is with Europe and the promotion of exports is a key objective of current government policy. But India is not pursuing an export-oriented industrialization strategy that depends critically on achieving expanded market share in Europe as is the case with South Korea and Thailand. This is undoubtedly why policy makers are still prepared to support a relatively more restrictive industrial policy and inefficient industrial structure than in those countries.

Likewise, India is not seeking to counterbalance the pervasive presence of the Japanese within their economy as producers and as sources of finance and technology. Though recently Japan has begun to pay a bit more attention to "cultivating" India along similiar lines to what they have done in Thailand and the other ASEAN states, their presence is still very limited and narrowly confined to a few areas. Nor is India so saddled with a crippling foreign debt that it is unable to respond to any overtures which have financial expenditure implications as in the case of Brazil and Mexico.

In that sense, India will be dealing with the EC's proposals for collaboration from a position of strength rather than weakness. India's interest in collaboration instead arises because the country has now reached the point in its pursuit of self-reliant industrialization where it needs to substantially strengthen its S&T base - particularly in relation to the industrial and infrastructural sector and particularly in the areas of high technology where its capabilities are weakest except for certain pockets of expertise. And much more so than in the past, Indian policy makers in key positions outside of the S&T ministries (such as in the ministries of industry and commerce) are prepared to explore different methods of interacting with foreign sources of science and technology particularly if this interaction helps rather hinders the government's cautious movements towards greater openness and liberalization.

Nevertheless, it needs to be borne in mind that Indian policy makers are increasingly determined to reduce the repetitive and debilitating dependence of much of Indian industry

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[3] These proposals are by no means proposed as an alternative to the wide range of programmes and projects that the Commission currently supports within the context of its formal relationship with India. Indeed some of the proposals made parallel closedly programmes already underway. Our aim is to offer suggestions that will complement, strengthen and extend existing relationships.

on imports of outdated technology. They are slowly moving to the recognition that the best way to do this is via less not more restrictions. Likewise, though more open than previously to greater foreign participation in the economy, they are determined not to allow foreign firms to set up shop if their only aim is to produce non-essential consumer goods for the urban elite. Finally they are perhaps more aware than ever that in certain sectors and fields India has a set of S&T assets that gives it a competitive edge abroad as well proving attractive to foreign scientists and companies.

India is clearly willing and anxious to explore the possibilities of greater S&T collaboration with the Community. But for reasons of past and recent history, culture and personality, and its record of S&T achievements and failures, India will only go forward towards greater collaboration on terms that it deems equitable to its own long term interests.

Given this background, we want to conclude this report by putting forward the following six proposals for consideration by the Community in determining its strategy towards achieving greater S&T collaboration with India.

I.7.1. CONTINUE INFORMAL DISCUSSION WITH KEY S&T POLICY MAKERS ON THE POSSIBILITIES AND PROSPECTS FOR S&T COLLABORATION

The SAST interviews with senior policy makers concentrated on a small number of key individuals and discussing the general issues involved. There are however many more individuals who have to be brought into the picture on an informal basis before moving forward to the next stage. This is necessary to weave an invisible web of support for the general thrust of this initiative within the Indian S&T policy community based on understanding and trust.

This will not be an easy task if solely pursued on a formal basis. The informal nature of the SAST enquiries and past good relations between SRA and certain key individuals meant they were willing to listen and engage in an honest and critical discussion. The groundwork has now been laid for more direct contacts between the Community and senior people but the openings created have to be pursued carefully and diplomatically since once the Community is directly involved, a different set of rules of "engagement" will apply.

I.7.2. CONTINUE GENERATING GREATER UNDERSTANDING WITHIN THE COMMUNITY OF THE INDIAN S&T/INDUSTRY SCENE AND THE FORMAL AND INFORMAL DECISION-MAKING PROCESS RELATING TO INNOVATIVE INTERNATIONAL COLLABORATION IN S&T

The main report identifies a number of the key institutions and decision-making nodal points within central government such as the Department of Science and Technology, the STAC committees in the main socio-economic ministries, the Departments of Electronics and Biotechnology, the Planning Commission, and the Committee on Technical Collaboration within the Ministry of Industry.

There is more to learn however since in recent years, a good deal of power and presence on the S&T scene has devolved to sectoral ministries and departments such as the Ministries of Steel, Power, and Transportation as well as to public sector "gateway" corporations such as Engineers India and the Computer Maintenance Corporation and increasingly even to state governments and state joint sector companies. Better understanding is needed of how these relatively new players fit into the overall picture. Along the same lines, because of the advent of a new and as yet unstable, minority government, the individuals and groupings vested with power in the S&T area are still emerging. They need first to be identified and then monitored closely to understand their relationship to the established technocrats who have long dominated S&T policy and practice.

I.7.3. CLARIFY AND DEFINE THE MEANING OF MUTUAL BENEFIT THROUGH S&T COLLABORATION AND ESTABLISH THE ROOM FOR MANOEUVRE ENJOYED BY THE COMMUNITY IN RELATED AREAS

As indicated above, some of the policymakers and senior scientists interviewed were, on occasion, quite sceptical about the real degree of mutual benefit that would arise from collaboration with the Community. This is an issue that will come up very early on in any substantive discussions with India - and with every other SAST country. While it cannot be finally settled in the case of specific countries except via mutual discussion with that country, it seems necessary that the Community debate and discuss this issue internally because its position on this issue will essentially determine the whole tenor of any subsequent collaborative arrangements that are agreed. Our sense at the present moment is that there are still significant differences between what the Community means by mutual benefit and what the SAST countries interpret this phrase to mean.

Associated with this need to "clear the air" on certain points, there a series of other issues that may also need to be discussed internally in order to free up the channels of communication with India and other SAST countries. Among these questions are issues such as the scale of resources the Community itself would be prepared to commit to launching these initiatives; what would be the role of the member states; and how can ongoing EC-India S&T projects be accomodated in the new era of collaboration.

In addition to the above the broader set of concerns raised about the wider implications of 1992 and developments in Eastern Europe for EC relations with India will also need to be discussed. The SAST project is clearly not in a position to address these issues but they will also need to be considered by the Community in sorting out its own position and strategy vis-à-vis collaboration with India. A means will then have to be found to collectively address these issues within the Indian context - ideally as part of the informal process of consultation and confidence building called for above.

I.7.4. ESTABLISHING THE FRAMEWORK FOR COLLABORATION VIA HIGH-LEVEL MEETINGS AND DETERMINING THE SPECIFICS THROUGH LOW KEY CONSULTATIONS

In our discussions, while there was agreement on the value of proceeding further, there was a divergence of opinion on how best to proceed.

One group argued that forward progress would only be achieved if there was first a minsterial level agreement on a statement of intent. It was felt that this would give the appropriate signals to the bureaucracy. Discussions were held with relevant officials to discuss the purpose of such a meeting, when it might take place and what the agenda would be. Our understanding is that the Government is therefore ready to respond now to an invitation from the Commission to hold such a meeting sometime in the near future.

Another, equally influential group of senior policy makers interviewed felt that this was precisely the wrong manner in which to proceed and was the surest way to ensure that nothing of any substance would happen. Instructions from the Prime Minister's office to negotiate collaborative S&T agreements have been handed down many times before. Such agreements are usually concluded - but actual implementation is often resisted by a resentful bureaucracy and non-co-operative science community.

An alternative strategy was put forward of setting up one or a few working groups composed of Indians and Europeans choosen for their expertise in particular sectors or fields to meet together over the next six months to a year to hammer out the details of specific projects that would capture the full and enthusiastic response of the bureaucracy and the scientific and industrial community. It was felt that these meetings would have to take place before the requisite ministerial meeting (giving official approval) and would serve to build the consensus and support necessary to carry the collaboration proposals through to success.

Some mixture of the two approaches seems to make the most sense. This could be structured perhaps so that a working group can get together to discuss the initial terms of the broad framework agreement prior to a ministerial meeting. These preparatory meetings would be genuine joint working groups involving substantive interchange and debate over the tough questions of principle - such as the practical meaning of "mutual benefit"; how IPR questions would be dealt with; and the nature of government committment expected to let the projects go forward. The more detailed discussions on identifying specific project areas and modes of collaboration could then take place after the ministerial level meeting.

However this issue is resolved, the critical point is that all agreements - preliminary and detailed - are reached via mutual discussion rather than by bureaucratic, adversarial negotiations over a fixed set of proposals as is usually the case.

I.7.5. CONSIDER THE NEED TO PROVIDE EVIDENCE OF GOOD INTENTIONS

Indian scientists, much as those in countries such as China, South Korea and Brazil would very much like to be given greater access to European laboratories and be allowed to participate in European and Community sponsored multilateral projects such as EUREKA and those covered by the Framework Programme. This is clearly a matter for internal discussion and decision making by the Community. However, it should be noted that opening up such opportunities for collaboration to the Indians would certainly go a long way towards demonstrating the Community's committment to the principles of mutual benefit. This would help clear the way for the wider ranging forms of collaboration envisioned by the SAST project.

I.7.6. EXPLORE THE POSSIBILITY OF SETTING UP FLEXIBLE INSTITUTIONAL MECHANISMS FOR FUNDING AND MANAGING EC-INDIAN S&T COLLABORATION

Flexibility and responsiveness will necessarily be a key characteristic of any mechanism used to promote, finance and oversee the sort of innovative collaborative arrangements that the SAST project set out to explore. Strong arguments can be made for setting up a new institutional mechanism that would actually function outside of the existing bureaucratic structures in the Community and India.

The Indian government and some of its senior bureaucrats have already seen the wisdom of such arrangements and have recently created flexible mechanisms (based on the concept of a scientific society or association) to oversee international collaborative S&T projects with France aand Canada. The Indo-French Center (total budget of $10 million from France and India) funds and oversees joint R&D projects but is completely independent of the DST. In the case of Canada, the software development project mentioned earlier is based on Canadian and Indian government funds, involves private firms in joint R&D on products ofor domestic and export markets, and is managed by an independent scientific association, the Centre for Technology Development in Karnataka.

While these two mechanisms represent an administrative solution to the problems that arise from excessive bureaucratic control of bilateral technical assistance programmes, we do not know if it is feasible or even permissible within the context of the EC. It does appear, however, to be an option worth pursuing both from the perspective of future arrangements with India and with the other SAST countries. Within this context, the new initiative to establish a "Business Forum" - run by the private sector via European and Indian chambers of commerce - could be an ideal mechanism for facilitating EC-Indian commercial links along the lines suggested above.

PART II : DECISION BASE

II.1. - PRE-1985 ECONOMIC PERFORMANCE AND INDUSTRIAL POLICY: THE BACKGROUND TO LIBERALIZATION

II.2. - INDUSTRIAL ADVANCE IN THE CONTEXT OF LIBERALIZATION: A NEW BEGINNING OR A FALSE DAWN

II.3. - EVOLUTION OF INDIAN SCIENCE AND TECHNOLOGY POLICY AND INSTITUTIONS

II.4. - SCIENCE AND TECHNOLOGY IN INDIA: INSTITUTIONAL STRUCTURE AND PLANNING MECHANISMS

II.5. - INDIAN R&D EXPENDITURE AND ALLOCATION: STRUCTURE AND RECENT TRENDS

II.1. PRE-1985 ECONOMIC PERFORMANCE AND INDUSTRIAL POLICY: THE BACKGROUND TO LIBERALIZATION

Perceptions of the overall performance of the Indian economy since independence differ widely, particularly regarding the pace of growth, variations over time and the contribution of different sectors to the growth in national product. In terms of movements in real national income (net national product at factor cost measured at constant prices), the performance has been neither spectacular nor dismal. In the post independence period as a whole, the compound annual rate of growth of real net national product works out at 3.6 per cent, a persistently middling rate of increase which has been termed "the Hindu rate of growth". [4]

Given rapid population growth, this suggests that the average annual rate of growth of GNP per capita over the period 1965-85 was at 1.7 per cent. This GNP growth rate is far less than what Indian economic planners had hoped for and is clearly substantially lower than most other comparable developing countries. Indeed, as the gap in economic performance and in the underlying GNP growth rates between India and other advanced developing countries grew ever wider during the 1970s, critics from both spectrums of economic opinion argued that this was evidence of the long term mismanagement of the economy and pressed increasingly loudly for fundamental change in policy. As we shall see this fundamental policy change did in fact begin to emerge in a coherent fashion in the mid-1980s, having a major impact on industrial performance and marking the beginning of a significant departure from previous policies.

This change and the resultant impact on the economy has once again sparked off a fierce debate over the direction of development and the role of foreign firms whose outcome will directly affect prospects for EC-India collaboration in the future. For this reason, it is worthwhile looking in a little more detail first, at the initial objectives of industrial policy and the mechanisms used and then at the historical performance of industry and agriculture in order to provide an informed context for discussing the current period.

II.1.2. OBJECTIVES OF INDUSTRIAL POLICY: THE ATTAINMENT OF SELF-RELIANCE

The Indian economy at independence was characterized by features typical of a backward ex-colonial country. It was predominantly agrarian, with industry contributing about 15 per cent of national income and less than 10 per cent of employment. Nearly 78 per cent of organized sector production consisted of traditional activities like textiles, food processing while capital goods and intermediates had still to be imported. Consequently manufactured goods accounted for 85 per cent of India's imports. The principal aim of state policy was to achieve rapid acceleration of industrial growth while also overcoming barriers to productivity increases characteristic of predominantly agrarian economies.

[4] However between 1978/79-1986/86, the rate of growth of NNP works out to 4.4 per cent. This figure also points to an additional increase in real per capita incomes of around 1 per cent a year. But the dynamism of the aggregate figures conceals the distortions reflected by trends in sectoral growth rates. Between 1970 and 1985, while the contribution of the primary sector (agriculture and allied activities) to GDP at constant prices grew at 2.6 per cent per year, that of the secondary sector (dominated by manufacturing) grew by 3.92 per cent annually.

Four initiatives were considered crucial. First, extensive protection was offered to manufacturing through an across the board increase in tariffs and the institution of quantitative restrictions on imports. Second, a massive increase in public investment to create infrastructure but also resulting, directly through purchases of commodities and indirectly through the creation of incomes, in a rapid growth of a protected home market. Third, a sharp increase in the rate of savings, accompanied by measures that would channel these funds to the state sector (taxation) as well as through mediation of the state financial institutions to the private sector. And finally, the introduction of a wide range of controls on capacity creation, production, industry entry and exit and prices which would ensure that these funds would be directed towards what were priority areas in the perception of the government. [6]

II.1.3. THE CHARACTERISTICS OF SELF-RELIANT INDUSTRIALIZATION

The industrial strategy based on these initiatives produced an unprecedented spurt in industrialisation. A compound growth rate of 7.2 per cent in the index of industrial production between 1948 and 1966 was accompanied by a substantial diversification of the industrial sector away from traditional consumer goods in favour of the heavy industrial sector, in particular chemicals, machinery and engineering goods. The secular boom, however, came to an end in the mid 1960s, after which the economy entered a period of stagnation. Between 1966 and 1975 the rate of growth of the industrial index registered a decline of 4 per cent with only a slight recovery to an average of 4.8 per cent during the ten-year period until 1985.

Though there is much debate, two major sets of factors have allegedly been responsible for the sharp slow-down in the growth rate of the industrial economy during the 1970s and early 1980s. The first in fact relates to the performance of the agriculture sector which in India, unlike the other SAST countries (with the exception of China), plays a major if not dominant role in the economy accounting in 1985 for 39 per cent of the net domestic product and involving 77 per cent of all Indians. Despite this importance, the overall performance of the sector between 1970 and 1985 was unimpressive with growth in output virtually stagnant and recording an absolute increase of only 4 percent in constant prices.

In India's case, poor performance in the agricultural sector has major implications for the industry and by extension for the shape and thrust of economic and industrial policy. By serving as a source of livelihood for nearly two-thirds of the working population, agriculture constitutes a major source of demand for the products of the industry. Moreover, most of India's traditional industries like cotton and jute textiles, sugar, vegetable oils are agro-based, rendering their output directly dependent on agricultural performance and the consequent availability of agricultural inputs. Consequently, an indifferent performance in the agricultural sector acts as a severe drag on industrial growth.

The second set of factors responsible for India's poor industrial performance relate to the nature of the post-independence industrialization process and more specifically to the

[6] The theoretical underpinning's of the strategy that emphasised protection and public investment was provided by the Mahalanobis model. This argued that since the current world situation did not permit a rapid increase in exports, the only route to industrialisation was via the creation of an indigenous industrial sector (including capital goods) catering to the domestic market.

policies followed by a government firmly committed to state control of the economy. The weakness of the import substitution model followed by India is that by the mid-1970s the stimulus for growth that had arisen from the protective regime followed by the government had exhausted itself. Import substitution resulted in a once-for-all increase in output and once domestic markets were captured by indigenous producers, further growth depended on expansion of domestic demand which because of agricultural stagnation, was growing very slowly.

The mainstream critique of India's industrialization strategy. A much more substantive and in the end, telling set of criticisms was levelled by critics both inside and outside the country at the industrial policies and the system of control followed by the government over that period. [6] While there were few who disagreed with the view that the strategy followed resulted in the creation of a rather large and diversified industrial sector, many argued that in return it had extracted too great a price in terms of high costs, technological obsolescence and inefficiency.

Leaving aside the issues raised regarding direct state involvement in production, five elements of these criticisms should be mentioned here that directly related to the performance of privately owned industry:

- Rigid investment licensing and controls on output and technology acquisition led to a state of permanent product shortages that inhibited competitive behaviour;

- The high import barriers created by widespread quantitative restrictions and high tariffs effectively isolated many Indian industries from technological developments and competitive pressures in the rest of the world; [7]

- Rigidities created by the regulatory system constrained firms' abilities to enter new markets and expand output thus further inhibiting competition, [8] as well as limiting their ability to restructure or close down;

- In many sectors, continued production by financially weak firms, held afloat by subsidies, undermined the viability of the more efficient enterprises that remained;

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[6] For example the World Bank was of the most persistent critics of Indian industrial strategy through the 1970s and most of the 1980s.

[7] Protection for the capital goods sector had meant that by the mid 1970s the share of indigenously produced machinery in the total supply of capital goods stood at 85 per cent. But this rather diversified growth of the industry was accompanied by symptoms characteristic of inefficiency. For example an UNCTAD study relating to the period up to 1980 found that 53 per cent of the designs introduced into the Indian market were more than 9 years old abroad and only 12 percent were less than 5 years old. See UNCTAD, Capital Goods and Developing Countries, Geneva, 1985. Another point is that in an area characterized by substantial economies of scale Indian producers operated with extremely small batch sizes. Finally, protection also resulted in high prices. For example, in the case of hydraulic excavators, prices in India were three times as high as those in the industrialised countries, where as prices in South Korea were only 1.5 times higher than international prices. See S. Jacobsson, "Government Policy and Performance of the Indian Engineering Industry", Mimeo, Dept of Industrial Management, Chalmers University of Technology, Sweden, 1988.

[8] For example by restricting licences to MRTP companies government policies set up barriers to entry that ensure dilution of competition in markets that are often characterized by large investment, high levels of concentration and excess profits.

- Finally, the heavy indirect taxes on all stages of production had a cascading effect that raised domestic prices and limited firms' abilities to achieve scale economies.

Substantive evidence can be marshalled to demonstrate how this regime of industrial control negatively affected the performance and competitiveness of Indian firms. The net conclusion of numerous studies is that in many industrial subsectors in the 1970s and early 1980s, Indian firms were functioning with technology far removed from international best practice; their (permitted) volumes of output were well below levels where scale economies could be achieved; and not surprisingly performance in the area of productivity, efficiency and quality was significantly lower than international standards. [9]

It is also clear that policies pursued through the mid-1980s contributed extensively to India's poor export performance during that period. Where one would have expected a country with the combination of entrepreneurial flair, skill, low wages and technology absorptive capacity of India to be a keen exporter (despite the lure of the domestic market), in fact just the opposite was the case. The lack of export incentives and the commitment to maintaining the rupee at an artificially high exchange rate created conditions where manufactured exports (which in the early 1980s accounted for about 70 per cent of India's total exports) grew on average less than 3 per cent annually in real terms between 1980 and 1986, and represented a small and, significantly, a declining share of industrial output, dropping from 7.2 per cent at the beginning of the decade to less than 5 per cent in 1985.

We would add one important and positive qualification to this critique that must be borne in mind. Despite the negative effect of the policy environment on firm performance, Indian firms, even as far back as the 1970s, had a depth of engineering competence unmatched by any other developing country. Though this competence was for the most part badly underutilized, there is ample evidence documenting considerable engineering achievements across a wide range of sectors. These capacities remain intact today and form a sound foundation upon which European enterprises could build major collaborative ventures in engineering-intensive production activities.

[9] See for example A.V.Desai, "How they see us : Technology Suppliers' view of Indian Industry", Economic and Political Weekly, Vol 20, Nos 45-47.

II.2. INDUSTRIAL ADVANCE IN THE CONTEXT OF LIBERALIZATION: A NEW BEGINNING OR A FALSE DAWN

Partly in response to this sustained barrage of critical analyses, (and partly in response to a crisis in government revenues)[10] , the government of Rajiv Gandhi launched, in 1985, a major overhaul of industry and financial policy aimed at stimulating domestic demand, encouraging a greater role for the private sector in the economy, enhancing domestic competition and strengthening the competitiveness and efficiency of Indian industry. Enshrined in the Seventh Plan (1985-1989), annual budgets, a new Long Term Fiscal Policy and a whole series of official policy statements, this "New Economic Policy" had essentially five elements.

1) Regulatory policy has been substantially liberalized across the board through the dismantling of many controls over prices, investment, production, capacity creation and foreign collaboration and by opening up areas and sectors previously reserved for the public sector and small scale industries.

2) Taxation policy was reformed via the simplification of and changes to income and corporate taxes, direct and indirect taxes (intended to stimulate consumer demand), value added tax and taxes on small scale industry.

3) Changes in import policies were introduced that watered down quantitative restrictions and reduced tariffs providing domestic producers with wider access to cheaper capital equipment, intermediates and technology, as well as pressurising indigenous producers to reduce costs in the face of import competition.

4) Exit barriers and controls on the closure of firms were eased, so that the process of restructuring industry is not hindered by the inability of private capital to abandon outdated plant and obsolete technologies.

5) Finally export policy and administration was fundamentally reformed via the adoption of a flexible and realistic exchange rate policy (resulting in a 30 per cent devaluation by 1989) and the streamlining of duty exemption and duty paying schemes.

While there is considerable debate over whether these policy changes were fundamental or merely the first step on a long hard road, there is little doubt that in the post-1985 period, there were significant developments in the performance of Indian industry and its relation to the outside world that should be reviewed here. On the one hand, they effectively define the broad direction of that performance for the future; and on the other, conflicts arising from these developments will influence at least in the short term the direction of industrial policy and indirectly the nature of any Indian response to major EC S&T initiatives.

Below we consider three sets of developments with particular relevance to our concerns - the pattern of industrial and economic growth during the 1980s and the underlying contribution of industry; the chief characteristics of recent trends in Indian imports and exports of manufactures; and the main features of Indian technology collaborations and DFI.

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[10] Which continues to the present time and has recently caused the new government to impose sharp cutbacks on government expenditure and imports.

II.2.1. POSITIVE AND NEGATIVE ASPECTS OF INDUSTRIAL PERFORMANCE DURING THE 1980S

The macro statistics show clearly that Indian industry developed quite strongly during the 1980s, with the 1985-1989 period being particularly favourable. During the 1980s, the economy grew at average annual rate of 5 per cent, nearly twice as high as the historical average while it appears that the industrial sector was the driving force behind this performance. During the 1980 - 1988 period, industrial production grew at a compound rate of 7.6 per cent compared to 4.2 per cent between 1971 and 1979. The improvement over the last four years is even more marked as shown by Table 1 which shows that industrial growth rates over the 1985-1989 period averaged nearly 9 per cent compared to 5 per cent for the 1981-84 period. The positive picture of strong domestic growth was reflected also in the rate of growth of manufactured exports which during the three year period between 1987 and 1989 averaged an annual increase of 26 per cent compared to just 1 per cent p.a. during 1980-1984.

TABLE 1 : Annual percentage rates of growth of GDP and industrial output, 1981-1989

	GDP	Industrial output
1981/2	6.0	7.5
1982/3	2.4	2.5
1983/4	8.0	6.8
1984/5	3.6	8.5
1985/6	5.1	8.3
1986/7	3.2	9.2
1987/8	3.0	7.4
1988/9	9.0	9.7

Source : Adapted from UNIDO (1989), New Sources of Industrial Growth, Vienna

As we will document later, this encouraging industrial performance has been accompanied by significant changes in the perceptions and attitudes of foreign and domestic industrialists and many outside analysts regarding the future prospects for the Indian economy and some such as the World Bank are cautiously optimistic about the prospects for Indian industrial development for the first time in nearly 25 years. At the same time, numerous observers have noted the emergence of a dynamic class of Indian entrepreneurs and technocrats who seem determined to play a major role in transforming Indian industry and making it capable of playing a full part on the world stage in the 21st century.

Our interviews identified a number of examples of progressive developments little noticed by the outside world such as the recent launching of high tech development projects funded by venture capital and the emergence of progressive public sector enterprises operating in engineering and technology intensive sectors capable of tackling large scale projects at a level of competence equal to many European firms.

However, as is so often the case where Indian economic performance is concerned, closer examination of the underlying trends and determinants of India's industrial renaissance and its overall effects on the economy reveals a number of problems with the interpretation that the 1985-1989 period marked the movement of the Indian economy onto a new growth path.

There is, for example, considerable evidence that the industrial growth recorded during the last half of the 1980s was largely driven by a rising demand for consumer durables. This is shown in Table 2 which documents the strong spurt in growth in this segment between 1981 and 1987; and Table 3 which compares the growth rates of different segments of the manufacturing sector and shows little growth in the mass consumption segments of food and textiles, a decline in capital goods and transport equipment and an enormous rise in electrical machinery and appliances - the segment that encompasses consumer durables. To a large extent, it now appears that this consumer-led boom was driven by increased government expenditure in its current account[11] and paid for by an increase in the balance of payments deficit as is shown clearly by Table 4.

Serious questions have been raised by a number of analysts (and in our interviews) about the medium term implications of a continuation of this government-financed, demand-led industrial regeneration for the balance of payments, for the future role of foreign capital, for the capacity of the economy to sustain its most recent rate of expansion and in particular with reference to the deleterious effect it could have on growth in agricultural incomes and on the overall direction of India's development.[12]

These issues, the public debate they have sparked and the government's recent response form an important backdrop to our discussion in Part One of the strategic options open to the Community (and indeed to European industry in general) in seeking to develop S&T and industrial collaboration with India.

TABLE 2 : Annual rates of growth of output in consumer durables, 1981-1987

1981/2	10.9
1982/3	9.1
1983/4	16.1
1984/5	21.6
1985/6	18.7
1986/7	19.5

Source : Compiled from The Economic Survey, 1986-87, Government of India

[11] The six-fold increase in current account deficit financing between 1983-84 to 1986-87 was allied to growing expenditure on public administration and defense. This helped increase middle and upper middle incomes which in turn sustained the demand for consumer durables and luxuries. This is unlike earlier years when the diversion of public revenues to investment purposes resulted in direct demand for plant and equipment. Another allied effect of the increase in public expenditure was a substantial growth of 5.82 per cent in the contribution of the service sector to the growth in GDP.

[12] See for example C.T.Kurien, "Indian Economy in the 1980s and on to the 1990s", Economic and Political Weekly, April 15, 1989.Vol 20, Nos 45-47.(1989) and P.Balakrishnan, "Economic Consequences of Rajiv Gandhi", Economic and Political Weekly, February 10, 1990.

TABLE 3 : Annual growth of manufacturing output by industry grouping 1980-1985 to 1984-1989

	1980-1 to 1984-5 (%)	1984-5 to 1988-9 (%)
Food products	4.7	5.5
Cotton textiles	0.6	1.3
Chemicals	9.3	13.1
Basic metal products	1.8	9.7
Machinery and machine tools	6.3	5.8
Electrical machinery apparatus and appliances	10.4	23.9
Transport equipment and parts	7.1	6.8
Total manufacturing	5.7	8.9

Source : P. Balakrishnan, "The Economic Consequences of Rajiv Gandhi", Economic and Political Weekly, 2/10/90, Table 1.

TABLE 4 : Balance of payments and external debt, 1980-1988

	BTG	CA	CA/Y
	Crores Rs		%
1980/1	-7808.3	-1656.6	1.35
1982/3	-9813.1	-2296.4	1.45
1985/6	-11521.9	-5927.3	2.55
1986/7	-11272.2	-5830.0	2.25
1987/8		-6292.6	2.16

Source : Adapted from Balakrishnan (1990), Table 5, op.cit.
BTG = balance of trade on government account;
CA = current account balance
CA/Y = balance on current account as share of GNP

II.2.2. RECENT TRENDS IN TECHNOLOGICAL COLLABORATION AND DIRECT FOREIGN INVESTMENT

Historically, despite the government's long term commitment to support of the formal S&T system, Indian industry has always relied on imported technology as its main source of technological change. The extent of this dependence is shown by the fact that in 1988 more than 75 per cent of electronic items, 70 per cent of agricultural machinery, 65 per cent of transport machinery and 35 per cent of all drugs and pharmaceuticals made in the country were products of foreign collaboration.[13]

[13] Even more significantly, about 80 per cent of the foreign collaborations have been renewed between two and five times, and 20 per cent six times or more. These repetitive foreign collaborations indicate the generally low level of absorption and high dependence on foreign technology often noted in India.

Through 1964 there was a consistent inflow of DFI and technical collaborations, with DFI slowing markedly after 1964 due to a downturn in the economy. Up until 1974, equity participation by foreign firms was allowed partly because of the inflow of foreign exchange it brought and partly because of pressures exerted by foreign governments.[14] This position was abruptly altered by the Foreign Exchange Regulation Act of 1973 that required foreign subsidiaries to reduce their equity holdings to below 40 per cent, though there were exceptions for export oriented firms and in some specified items. This law and the self-sufficiency anti-TNC rhetoric that characterized Indian policy through the whole decade had a variety of negative effects on the attitude of foreign firms towards DFI in India.

The number of new investment projects involving foreign equity remained low through the decade. Some foreign firms already in India, including a number of U.S. firms, left outright while others maintained their presence but reduced the level of their "commitment" to the country and their affiliates. Nevertheless, firms from a number of European countries, most notably the Federal Republic of Germany, continued to invest in new projects while also building up their existing investments. This behaviour has had the important beneficial effect of deeply imbedding these companies in the Indian economy and legitimizing their continued and conceivably expanded presence in the 1990s.[15]

However, in line with the general trends towards greater openness, the government has significantly liberalized policy pertaining to foreign financial participation and technology collaboration since the early 1980s. For example, 100 per cent foreign equity holding was allowed in the case of units producing exclusively for export while a number of sectors such as motor vehicles, motorcycles and components were selectively opened up to DFI. Between 1985-1989 further steps were taken to water down controls on foreign investment:

- an increase in the threshold of assets for the purpose of defining a 'large' undertaking requiring registration under the Monopolies and Restrictive Trade Practices (MRTP) Act.

- an expansion of the list of industries in which investment can be made or expansion undertaken without clearance under the MRTP Act while special emphasis has been placed on the need to establish capacities at economic scales of production;

- the concept of 'broadbanding' was introduced in several industries so as to provide flexibility to adjust product mix within the overall licensed capacity.

- foreign equity participation in existing Indian companies in high technology areas is now permitted as well as in new ventures in preference to the outright purchase of technology;

- in addition there has been an increase in the permitted limit on royalty payments for high technology beyond the original ceiling of 5-8 per cent.

Positive upsurge in technology collaborations and foreign investments. The effect of this loosening of the bonds on foreign collaboration and investment were dramatic as is shown

[14] A part of the massive food aid given by the USA under PL 480 was, for example, earmarked specifically for the use of American firms and resulted in a 220 per cent increase in the number of foreign collaborations approved by the government over the relevant period.

[15] It was consistently noted in our interviews that the form and substance of Indian-German collaboration in both the industrial and scientific fields was highly successful and constituted a good model for the EC to follow.

by Table 5. Between 1979 and 1980 alone, the number of arms length collaborations and projects involving foreign investment doubled from 267 overall to 526. From that point on through 1988 the rate of growth new projects continued to increase both in terms of total number and, perhaps more significantly, in terms of the share of these involving foreign equity participation. By 1985, 900-1000 projects involving collaboration were being approved annually (compared to an average of 280 during 1977-1979) while an average of 22 per cent of those approved involved foreign equity participation compared to 12 per cent over 1976-1979.

TABLE 5 : Foreign collaborations and investments approved

Year	Number of FC approved	FC with foreign equity	% of FC with foreign equity	Total DFI	Average FDI per case Rs'000
1970	183	32	17.5	24.52	766.3
1971	245	46	18.8	58.38	1269.1
1972	257	36	14.0	62.27	1683.0
1973	205	34	16.6	28.17	828.5
1974	352	55	15.6	67.13	1220.5
1975	277	40	14.4	32.05	801.2
1976	282	39	13.8	72.69	1863.8
1977	267	27	10.1	40.03	1482.6
1978	307	44	14.3	94.06	2137.7
1979	267	32	12.0	56.87	1777.2
1980	526	73	13.9	89.24	1222.5
1981	389	57	14.7	108.71	1907.2
1982	590	113	19.2	628.06	5558.1
1983	673	129	19.2	618.73	4796.4
1984	752	151	20.1	1130.02	7483.6
1985	1024	238	23.2	1260.66	5296.9
1986	957	240	25.1	1069.52	4456.3
1987	852	242	28.4	1077.05	4450.6
1988	930	134	14.4	2395.12	9086.7
TOTAL	12707	2530	19.9	8913.16	4387.9

Source : India Investment Centre List of foreign collaboration approvals.; Government of India, Ministry of Industry, Secretariat of Industrial approvals

Note : * These figures include the period January-June.

The total and the per capita amounts invested by foreign firms also increased dramatically during the 1980s. Total annual investments more than doubled between 1978 and 1981 and increased by more than tenfold by 1984, remaining at that level through the rest of the 1980s and reaching a record (for India) of $250 million in 1989. The average investment cost per project grew four times in real terms between the 1976-1981 period and the 1982-1988 period. Along with this rise in the inward flow of foreign capital, there was a sharp increase in the outward flow of technology payments by Indian firms. This is shown clearly in Tables 6 and 7 where there was nearly a fivefold rise in total payments between 1979 and 1986.

TABLE 6 : Technology payments, 1970-1986 (million rupees)

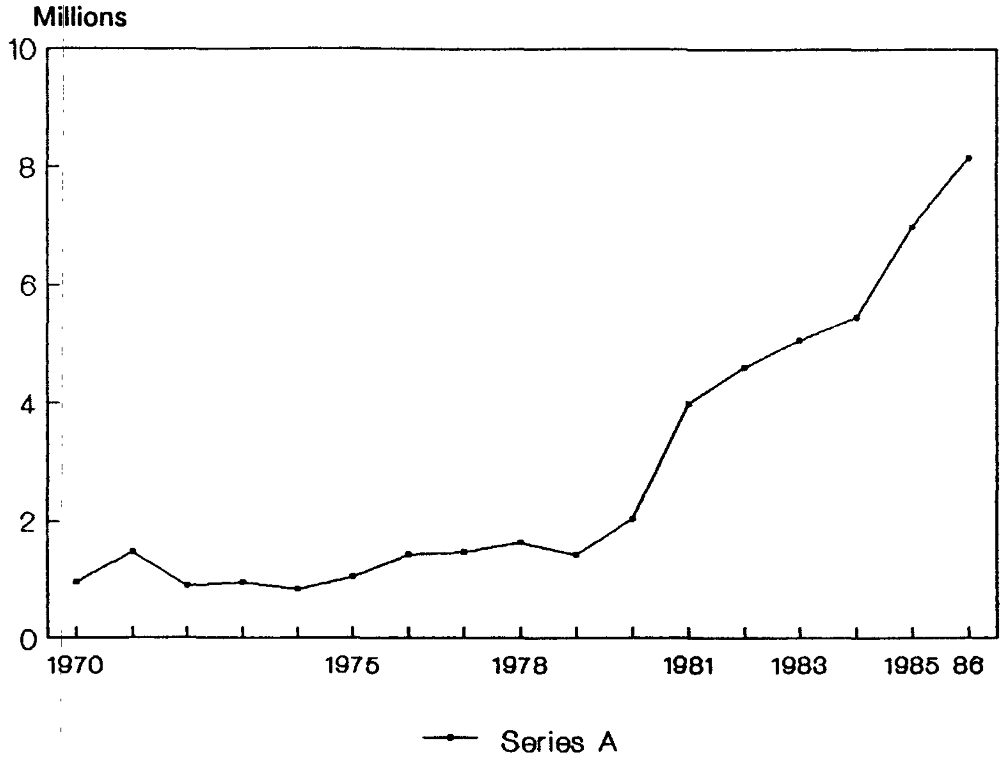

TABLE 7 : Technology payments (Rs million)

Year	Profits	Dividends	Royalties	Know-how	Interest	Total
1970	131.2	434.3	52.3	206.3	128.0	952.1
1971	99.4	388.7	58.6	121.3	807.0	1475.0
1972	155.4	390.8	73.3	113.3	156.0	888.8
1973	219.1	375.1	62.1	140.8	162.7	959.8
1974	71.9	184.6	84.6	125.6	367.0	833.7
1975	203.6	248.4	104.9	236.6	256.6	1050.1
1976	193.9	454.7	158.8	378.0	251.1	1436.5
1977	101.3	680.1	195.0	281.4	227.0	1484.8
1978	102.4	543.5	126.5	555.2	314.4	1642.0
1979	143.7	509.2	93.3	439.7	252.2	1438.1
1980	121.0	559.2	88.8	1049.3	232.2	2050.5
1981	121.6	589.2	159.9	2707.0	410.8	3988.5
1982	191.2	703.1	397.2	2505.8	802.3	4599.6
1983	200.0	621.1	276.0	3148.9	815.1	5061.1
1984	166.8	745.8	284.9	3006.0	1239.1	5442.6
1985	118.0	752.0	235.0	3679.0	2187.0	6971.0
1986	106.0	855.0	401.0	3584.0	3189.0	8135.0

Source : Government of India, Ministry of Industry, Secretariat of Industrial Approvals

Sectorwise and countrywise distribution. Tables 8 through 10 lay out the sectorwise and countrywise distribution of foreign collaboration and DFI both during the 1980s (till 1987) and across one year, 1987. Five general points should be noted. First in terms of country concentration, Europe's share of foreign collaborations in the 1980s is clearly declining, explained for the most part by a decline in U.K. collaborations and a marked rise in collaborations with Japan, while the U.S. share stayed roughly constant.

Second, during the 1980s, there is marked shift in the country ranking between foreign collaborations and DFI with Japan and the U.S. together accounting for 43.4 per cent of DFI projects compared to only 31 per cent of foreign collaborations compared to Europe's 27.1 per cent of DFI and 47.2 per cent share of foreign collaborations with the differences again accounted partly for by a jump in the level of Japanese involvement and by German and U.K. preferences for foreign collaborations.

Third, both the 1981-1987 aggregate and the 1987 sectoral figures highlight the emphasis placed by foreign investors and Indian collaborators on strengthening domestic capabilities in technology intensive sectors such as electronics, chemicals and capital goods. Electronics in particular stands out because of the marked rise in its share of overall collaboration from 19 per cent during 1974-1980 and nearly 25 per cent over the 1981-1987 period.

Fourth, the 1987 figures demonstrate the relative overall strength of the U.S. and Europe as foreign investors and collaborators compared to the sector specific strengths of Japan and individual European countries. Of particular importance here is the pre-eminent position that has been attained by Germany as a source of technology and technical assistance to Indian enterprises. It is recognized by leading actors in both the public and the private sector as being far and away the most important European country to which India looks for technological and industrial collaboration.

TABLE 8 : Foreign collaborations 1981-1987

Country	1981	1982	1983	1984	1985	1986	1987	Total	%
USA	85	109	135	143	229	203	217	1121	21.2
Germany	74	110	129	132	187	188	154	974	18.4
UK	80	105	119	123	149	134	130	840	15.9
Japan	27	51	58	78	111	111	82	518	9.8
Italy	18	37	30	37	59	58	54	293	5.5
France	23	28	40	38	63	40	43	275	5.2
Switzer-land	26	41	47	30	43	32	32	251	4.7
Sweden	11	15	15	14	32	30	20	137	2.6
Nether-lands	9	13	13	14	18	24	30	114	2.2
Others	36	79	87	131	150	140	148	771	14.5
Total	389	588	673	740	1041	960	903	5294	100.0

Source : Government of India, Ministry of Industry, Secretariat of industrial approvals

Finally, the value of DFI, though growing, is still very low compared both the size of the economy to the levels of direct foreign investment in countries such as Thailand, South Korea, Brazil, and China. These low absolute levels of DFI in India have undoubtedly been due to its historically restrictive policies towards foreign investment. Neither these restrictive policies nor the reluctance of the foreign investment community is likely to change dramatically in the short term. Nevertheless the rapid upsurge in investment in the 1985-89 period is a clear sign that given the right signals, DFI could grow substantially with major positive implications for India's future - particularly if some way can be found to harness foreign investment and technology to the beneficial development of the rural market and technology intensive sectors simultaneously.

TABLE 9 : Total foreign collaborations by sector - 1987 (number of agreements)

Sector	USA	FRG	UK	Japan	Others	Total
Electrical & Electronics	65	22	38	28	74	227
Industrial machinery	35	47	21	10	52	165
Chemical	37	23	15	11	52	138
Mechanical engineering	18	17	12	9	27	83
Others *	62	45	44	24	115	290
Total	217	154	130	82	320**	903

Source : Government of India, Ministry of Industry, Secretariat of Industrial Approvals
* Other sectors include transport (37), metallurgy (35), machine tools (24), and miscellaneous (168)
** Other countries include Italy (54), France (43), Switzerland (32), Netherlands (23) and Sweden (20)

TABLE 10 : Countrywise distribution of foreign collaborations, 1981-1987 (% of total collaborations)

USA	21.2
FRG	18.4
UK	15.9
Japan	9.8
France	5.2
Italy	5.5
Switzerland	4.7
Sweden	2.6
Netherlands	2.5
Others	14.5

Source : Government of India, Ministry of Industry, Secretariat of Industrial Approvals

II.3. EVOLUTION OF INDIAN SCIENCE AND TECHNOLOGY POLICY AND INSTITUTIONS

The performance of India's science and technology structures is as paradoxical as that of the country's development experience in general. While there have been remarkable achievements in the fields of agricultural research, oceanography and biotechnology, nuclear and space technology, the performance is extremely uneven in other areas such as health and most importantly in relation to industry where, with notable exceptions, the formal S&T system has failed to live up to the early expectations that it would act as the main source of industrial technology for Indian industry.

Nevertheless, from our perspective the Indian S&T system boasts a variety of uniquely positive attributes that distinguishes it from the other SAST countries and opens up a a range of possibilities for collaboration. These stem not just from the size of its network of educational and research institutes and the substantial reservoir of highly qualified manpower. They arise also from the existence of pockets of world class scientific research, a well-developed standards institution, and a variety of R&D and consulting institutions that are very effective technological gatekeepers due to their expertise in absorbing imported technology, developing their own and effectively transferring both to industry. Most importantly, there has been a perceptible shift in industry's willingness to finance its own R&D and in the re-orientation of the formal S&T system towards pursuing demand-led R&D that bodes well for the future given the enormous size and potential of India's human and institutional S&T resources.

Creation of the S&T infrastructure. The first two decades following independence saw the establishment of a broadbased S&T infrastructure in education, research and supporting facilities. Most of the major government institutions including the Council on Scientific and Industrial Research (CSIR) came into existence during this period. No demands were placed on the S&T establishment to contribute directly to economic progress as all effort was directed at creating institutional and human assets. Industrial development took place through import of technology and scientific research went forward under the spirit of free enquiry and was undisturbed by economic successes and failures. Scientific leaders were given responsibility for formulating priorities and efforts to develop effective S&T policy instruments and mechanisms were very weak.[16]

Reappraisal of the unfettered expansion of the formal S&T system. For a variety of reasons, from the beginning of the 1970s, the emphasis began to shift towards an expectation that linkages between the research infrastructure and economic progress had to be strengthened and so science policy and plans were re-assessed and re-oriented.[17] The National Committee on Science and Technology, set up in 1973, prepared for the first

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[16] While formal science policy advisory structures existed, such as Scientific Advisory Committee to the Cabinet, with a mandate to advise the cabinet on scientific priorities and funding, the policies were based on the close relationship between the scientific elite and Nehru. Large organizations such as Department of Atomic Energy and several CSIR institutions came into existence without consideration of the SACC. W Morehouse, "Professional Estates as Political Actors : The Case of the Indian Scientific Community", Philosophy and Social Action, vol 11, no 4, 1976, pp 61-95.

[17] The economic and political context of the early 1970s was characterized by severe balance of payments crisis following two wars with China and Pakistan and the effects of a severe three year drought that left the country vulnerable to international pressures.

time a plan for science and technology, and from that point on S&T plans became an integral part of the five year planning exercise.

On the industrial front several policy changes were made with regard to the import of technology, the exclusion of foreign investment from certain sectors and the use of patents that influenced the utilization of domestic R&D capabilities. Thus research institutions focussed on "import substitution" and directed their efforts into areas where foreign technology would not be introduced.[18] Private industry began to set up R&D labs while the accumulating strengths of Indian engineering consultancy organizations began to be manifest in greater bargaining power on the Indian side in negotiations over technology transfer.

The period also saw indigenous research being transformed into production in electronics, drugs, pesticides, chemicals and power generating equipment. New capabilities and institutional structures (in the shape of specialized R&D labs and government departments) were created in non-conventional energy, ocean resources, new materials, space applications, fast-breeder reactor technology, the environment and bio-technology.

Science Policy in the era of Liberalization. The thrust of S&T policy during the 1980s in part reflected the industrial/urban priorities of the Gandhi government that had lead to economic liberalization and in part reflected considerable optimism in the S&T capabilities of India, three and half decades after independence, to achieve major breakthroughs in the solution of its most difficult development problems.

The policy therefore moved in three directions: increased investment in advanced technology in order to secure national capabilities for India in these areas; the direct harnessing of the country's S&T capabilities to the solution of major socio-economic problems affecting the fundamental economic progress of the society; and the provision of a substantial boost to the role of the private sector in industrial development by strengthening and encouraging the development of its R&D and S&T capabilities.

In line with the first thrust, major research programmes linked into development and production were launched in areas such as biotechnology, new materials, parallel computing and digital switching. Case studies of the biotechnology research programme and the telecommunications technology development initiative are presented as annexes.

Towards the second objective a number of "technology missions" were launched and pursued amidst a great deal of fanfare in the middle of the decade. These "Missions" were in essence time-targeted technology development and deployment programmes involving activities which spanned R&D to the actual delivery of products and services to industry, government and ordinary consumers. The "technology missions" related to drinking water, oil seeds, immunization, communications, literacy and dairy products. Unfortunately, despite their innovative approach and promising start, little has been heard of the Technology Missions since they were launched. We can only hope this innovative attempt to break away from the burden of past ineffective approaches to harnessing S&T to Indian development has not been made a victim of the fickle Indian political process.

[18] Simultaneously several fiscal measures were introduced (but withdrawn in 1984) to promote in-house R&D in the industry. Tax write-offs of 100 percent on capital investment for R&D from taxable income and 133 per cent for expenditure on sponsored research were made available to the industry. These were withdrawn in 1984.

A related set of major S&T initiatives, launched during the last half of the 1980s and also in the mission "mode" but still surviving, focussed on a wide variety of problem areas from health to the establishment of networks of major technology intensive infrastructural facilities and supporting institutions. These include the creation of the Technology Information and Assessment and Forecasting Council and the Technology Development Fund; the setting up a national center for weather forecasting to aid farmers; the creation of a Natural Resources Data Management System and the development of a national system of data-base management support for decentralized socio-economic planning.

A number of steps were also taken to further strengthen formal and informal links between the R&D system and industry. CSIR, whose industry related activities had been long and loudly criticised for their lack of relevance, was subjected to a major and highly critical review which recommended, along with a variety of other measures to build links with industry, that by 1992-93 one third of its revenue should be generated from sources other than budgetary support.[19] Though there is great scepticism within the industrial community and among outside observers as to whether CSIR institutes, given their structure and mentality, can ever hope to be a major source of technology for industry,[20] it is nevertheless the case that a number of CSIR's R&D institutions have already made major strides towards this objective. In addition to these CSIR focussed efforts, Science and Technology Advisory Committees (STACs) were set up for all economic ministries to identify S&T needs at the sectoral level and to explore cross sectoral S&T linkages via an Intersectoral Science and Technology Advisory Committee.

Finally in relation to the objective of strengthening industry's R&D and S&T capabilities the government introduced a number of policy changes and new initiatives. It brought in legislation and made policy changes intended to facilitate greater state financing of private sector technology development, including the provision of venture capital. It also launched five new programmes directly aimed at encouraging in-house R&D. As we shall see below these initiatives have had a significant impact on the scale and orientation of private sector R&D efforts.

[19] Further measures adopted to build links between industry and CSIR include increased representation of industry on the governing board of the CSIR; encouraging more effective technology transfer through building engineering design capability and links with engineering design organizations; encouraging the institutions do carry out their own technology marketing and encouraging researchers to consult with industry by permitting to augment their incomes substantially.

[20] See for example v. Govindarajulu, "India's S&T Capability", Economic and Political Weekly, February 17, 1990.

II.4. SCIENCE AND TECHNOLOGY IN INDIA: INSTITUTIONAL STRUCTURE AND PLANNING MECHANISMS

There is hardly any other developing country, and only a few developed countries, that can rival India in the scale and spread of it scientific and educational institutional set-up. Since independence, the institutional structure for education and scientific research expanded enormously to more than 1000 research institutions (RIs), 157 universities and 5500 colleges. The number of in-house R&D units, both in the public and private sector is about 1000, and that of consultancy firms about 150. Out of a stock of nearly 3 million trained people, about 275,000 S&T personnel are economically active in S&T and by now some 90,000+ are directly engaged in R&D activities in various public and private sector R&D institutions. See Table 11. Though slightly dated, Table 12 shows this compares favourably in quantitative terms with advanced developing countries such as Korea, as well as some of the industrialized countries such as France and Germany.

TABLE 11 : Full time equivalent of manpower employed in R&D establishments (as of January 1986)

	Number of R&D personnel
A. Institutional sector	
Department of Atomic Energy	6062
CSIR	6546
DRDO *	7950
Indian Council of Agricultural Research	5403
Department of Space **	6827
Indian Council of Medical Research	605
Other ministries and agencies	6993
State governments	18253
B. Industrial Sector	
Public sector including joint sector	9511
Private sector	17159
TOTAL	85309

Source : Government of India, Department of Science and Technology R&D Statistics, 1986-1987

* 1982-1983; ** 1984-1985 data

TABLE 12 : Total R&D personnel in selected countries

India	(1986)	85,309
Korea	(1985)	41,473
US	(1985)	790,000
France	(1983)	92,682
FRG	(1981)	115,443
Japan	(1985)	381,282

Source : Government of India, Department of Science and Technology, 1988

The real volume of resources devoted to R&D multiplied fifty-fold between 1950 and 1986 rising at an annual growth rate of some 12 per cent. As shown in Table 13, they amounted to a mere 0.02 per cent of GNP in 1950. The share was raised to 1.1 per cent in 1988, exceeded among developing countries only by South Korea. Tables 14 and 15 give some idea of the growth in S&T expenditure between 1951 and 1988 and of the growth in infrastructural facilities between 1977 and 1986.

Obviously given a national enterprise of this scale, it is difficult if not impossible to comprehensively describe, summarize or analyze either verbally or statistically India's S&T system, institutional structures and resources. We have however, done our best in the discussion that follows concentrating first on the education system and manpower situation, then describing the organization and structure of the S&T system and concluding with a brief note on the S&T planning mechanism.

TABLE 13 : Trends in national expenditure on S&T activities (million rupees)

Year ending March	S&T expenditure	Percentage of GNP
1951	46.8	0.02
1956	121.4	0.12
1959	288.1	0.23
1966	850.6	0.39
1971	1733.7	0.47
1976	3979.9	0.60
1981	10034.5	0.66
1986	22239.1	0.96
1988	33035.1	1.10

Source : Government of India, Department of Science and Technology, R&D statistics 1986-1987

TABLE 14 : Trends in the growth of S&T expenditure (million rupees)

Five year plan period	Total S&T expenditure	Average per annum
First (1955-60)	200	40
Second (1960-65)	670	134
Third (1965-70)	1440	288
Fourth (1970-75)	3750	750
Fifth (1975-80)	13810	2762
Sixth (1980-85)	37160	7432
Seventh (1985-90)	75350	15070
Eighth * (1990-95)	100000	40000

* Projected

Source : Department of Science and Technology, R&D statistics 1986-87, R&D statistics 1986-87, New Delhi, 1988, p 38. See also The Hindu, September 4, 1989.

TABLE 15 : Trends in the growth of S&T infrastructure in India

	1977	1986
Universities and Institutions of higher learning	1145	160
Colleges offering science and general education	4317	5723
Intake of students	2432000	3571000
Colleges offering engineering courses	155	236
Professional and Technical colleges	272	320
R&D institutions under central and state governments	660	1150
In-house industrial R&D centres	na	876
Stock of trained S&T manpower	188000	2275000
Economically active S&T manpower	132000	823000
S&T manpower engaged in R&D	15000	84000

Source : Derived from Government of India, Department of Science and Technology, R&D statistics, various years

II.4.1. HIGHER EDUCATION FOR S&T AND THE STOCK AND DISTRIBUTION OF INDIAN S&T PERSONNEL

India began, at independence with 20 universities in major cities and with a major commitment on the part of the leadership to rapidly expand the pool of trained manpower available for tackling the enormous developmental challenges faced by the country. This number grew to 160 in 1989 linked to about 5500 colleges. A policy of promoting centres of excellence has led to the creation of hierarchically placed academic institutions that vary widely in quality. The 7 major city universities and their associated colleges as well as the five Indian Institutes of Technology (with a restricted curriculum focussed on science and engineering) and the Indian Institute of Science are of extremely high quality and involved in world class research and graduate training of scientists and engineers. On the other hand, many of the rural universities and particularly the isolated colleges far removed from urban centres are barely capable of giving adequate science and engineering training.

In 1985, 5 million students were enrolled in higher education, surpassed only by the USA and USSR, taught by 200,000 faculty members. Of these 169,000 belong to engineering discipline, 133,000 in medicine, 48,000 in agriculture, 11,000 in veterinary sciences and astonishingly, 725,000 in sciences; in 1983-4, 3040 doctoral degrees (44 per cent of the total awarded) were granted in science and engineering. Table 16 shows the outturn of scientific and technical personnel from universities from 1947 to 1984. This figure in 1988 stood at 194,500.

TABLE 16 : Stock of scientific and technical personnel 1950-1980 (000's)

Category	1950	1955	1960	1965	1970	1980
Engineering & Technology						
(i) Degree	21.6	37.5	62.2	106.7	185.4	221.4
(ii) Diploma	31.5	46.8	75.0	138.9	244.4	329.4
Science						
(i) Post Graduates	16.0	28.0	47.7	85.7	139.2	217.5
(ii) Graduates	60.0	102.9	165.6	261.5	420	750.3
Agriculture						
(i) Post Graduates	1.0	2.0	3.7	7.7	13.5	96.5*
(ii) Graduates	6.9	11.5	20.2	39.4	47.2	0.0
Medicine						
(i) Degree	18.0	29.0	41.6	60.6	97.8	165.4
(ii) Licentiate	33.0	35.0	34.0	31.0	27.0	2.2**

Note : During the year 1980, the number of B.Scs who were also B.Eds were estimated to be 166,000. Similar figures for the earlier years are not available.

* Including Graduates;

** Represents B.Sc (Nursing). Particulars regarding number of Licentiates not available.

Source : Department of Science and Technology, Research & Development Statistics 1986-87, New Delhi, 1988.

Almost all the institutions are under the financial jurisdiction of the Indian states, though a number of those in large cities have been deemed "nationally important", including the IITs and IIS, and therefore receive central funds. In addition to the support provided by the state governments, the University Grants Commission and the Department of Science and Technology are major central government supporters of science and engineering education annually giving between $100 and $120 million for this purpose with the majority going to the universities and teaching cum research institutions deemed to be of national importance. India's universities also carry out research (and account for approximately 9 per cent of national R&D expenditure) and the capabilities in place in some university departments are highly rated internationally if not given the same recognition nationally.[21]

Not surprisingly, numerous analysts have identified a large number of problems with India's S&T educational system that need to be put right and can only be done so by the government and the system itself. One of the most important of these for our concerns is the very uneven nature of the educational facilities and opportunities offered leading to problems of uneven quality in the available human resources. This derives in large part due to the marginalisation of University education that has occurred over the last decade or so as resources have been devoted to building up research institutions on the one hand and on the other by a policy of creating new teaching institutions outside the universities.

Another problem derives from the nature of expansion of engineering education. The number of engineering colleges has increased from 155 in 1981 to 236 in 1985. However, we were told during interviews that a matter of grave concern is the mushrooming number of engineering colleges that are financed purely on the basis of capitation fees. Admission to these colleges is not governed by merit but the capacity of the student to pay the fee. Teaching and curicula are also not regulated in these colleges. The consequences for the quality of the stock of technical manpower of this pattern of engineering education could be very serious.

The Indian manpower scenario presents a complex picture: on the one hand educational institutions turn out a large number of students at various levels and on the other hand there are serious shortages of competent manpower to meet the growing requirements in certain specialized areas. For example, the education system produced a large number of graduate engineers but not enough technicians who take up shopfloor jobs. (The ratio is almost 1 to 1 in India, where as in developed countries it is 1 to 8). Moreover many of the engineering graduates are either weak technically or find it difficult to adapt to shopfloor conditions because of the overly theoretical nature of their training.

General science undergraduates who do not go on to graduate education often suffer from a similar mismatch in their training and what is expected of them in the workplace. Those who do go on to graduate training receive a generally high standard of training but still there are serious gaps. For example many areas of software engineering and biotechnology are relatively well stocked but the skill base in new materials is very limited. As we shall see below such problems are exacerbated by the outward emigration of much talented manpower.

<u>The stock and distribution of Indian S&T manpower</u>. It is hardly surprising that given the size of the educational system (relative to the size of "modern" segment of India's economy) and the scale of the resources devoted annually to this purpose, India, more so than virtually any other country, has an unabsorbable surplus of trained S&T personnel. The stock of science and technology personnel, even when narrowly defined crossed 2.7 million in 1985 and is now certainly close to 3 million. Of these, some 275,000 are officially estimated to be economically active, with at least 90,000 directly engaged in R&D activities and placing India ninth among all countries in this respect. Table 17 gives the best estimates of the distribution of S&T personnel across activities.

[21] See the excellent discussion in F.A.Long, "Science, Technology and Industrial Development," <u>Technology in Society</u>, Vol 10. 1988. of many of these points.

TABLE 17 : Estimated stock, number of economically active S&T personnel in 1985 and 1990

Category	1985 (000)		1990 (000)	
	Stock of manpower	Economically active population	Stock of manpower	Economically active population
Engineering degree	372.6	324.2	454.4	395.3
Engineering diploma	564.2	490.9	734.8	639.3
Medical graduates	258.7	225.1	302.4	263.1
Dental surgeons	9.5	8.3	12.0	10.4
Nurses (B.Sc.)	3.7	307.0	5.5	5.4
Agricultural graduates	133.3	1.4	162.8	127.0
Veterinary graduates	28.3	24.6	33.4	29.1
Science graduates	1138.3	887.9	1339.4	1044.7
Science post grads	350.3	273.2	419.7	327.4
* B.Ed. (B.Sc.)	280.7	218.9	344.8	269.0
TOTAL	3139.6	2560.8	3809.2	3110.7

* Estimated on the assumption that 25 per cent of Education Graduates would be with Science background.

Source: Planning Commission, Seventh Five Year Plan. 1985-90 Vol 2.

About 74 per cent of the R&D personnel work in S&T agencies funded by government where as the private sector constitutes 26 per cent. Of the personnel engaged in R&D, 44.4 per cent were from engineering and technology background, 37.7 per cent from the natural sciences, 12.5 per cent from agricultural sciences, 2.9 per cent from social sciences and 2.5 percent from the medical sciences. In regard to educational level about 16 per cent were Ph.D.'s., 29 per cent with post-graduate qualifications, 30 per cent with graduate and 25 per cent with diplomas.

As we noted above in addition to the 3 million strong reservoir of trained personnel, every year India's higher education system turns out an additional 190,000 new entrants to the labour market who have had some form of S&T-related training (including, in 1986, 3500 doctorates in S&T related fields). This vast and growing pool of human resources competes for a much smaller number of appropriate jobs - probably at an upper limit of 400,000 existing places - within the economy that genuinely require some form of technical and scientific training. This oversupply creates a considerable number of problems for India not least of which is the seemingly unstoppable outward flow of trained Indians who choose to emigrate abroad.

Astonishingly, many tens of thousands of these individuals, primarily the best and most highly trained , have left India and now reside and work in other countries, particularly the U.S. Many of the departing graduates are from elite institutions such as the IITs and the well equipped laboratories of India's seven leading universities (one interviewee claimed that over the last two years about 80 per cent of the Ph.D.'s. from the School of Life Sciences of the Jawaharlal Nehru University migrated to the US).

The numbers already lost and the size of the annual flow, combined with the fact that these non-resident Indians (NRIs) are highly concentrated in some countries and sectors such as biotechnology and electronics in the U.S. (where they account for a significant share of all senior level technical positions in the private sector), explains why the whole topic of "brain-drain" has again become an emotive and divisive issue in India to an extent not found in any other country. The scale of the problem and the reactions engendered among senior policy makers and scientists comes out particularly graphically in our discussion of software exports from India in Part One.

This unique manpower surplus situation creates both opportunities and problems for EC hopes of S&T collaboration with India. On the one hand, this pool of trained manpower is clearly an enormous, and enormously underutilized, resource that India could bring to collaborative S&T projects that are skilled manpower intensive in areas such as software where Europe has acknowledged skills shortfalls. At the same time, the negative publicity given to recent attempts by U.S. and European software firms to take advantage of the Indian skills surplus has sensitized policy makers towards the political pitfalls of such arrangements.

II.4.2. ORGANIZATION AND STRUCTURE OF THE INDIAN S&T SYSTEM

Table 18 shows the organizational structure of the central government's S&T system that plans, supports, carries out and integrates S&T with production. The government is the main source of funds for R&D and related S&T, contributing 85 per cent of national S&T expenditure. The prime minister has always been the official head of science and technology and the Janata government had installed two leading scientists, Profs. MGK Menon and R Ramanna, who held senior positions in the previous government, as Ministers of State for Science and Technology and Defence respectively.[22]

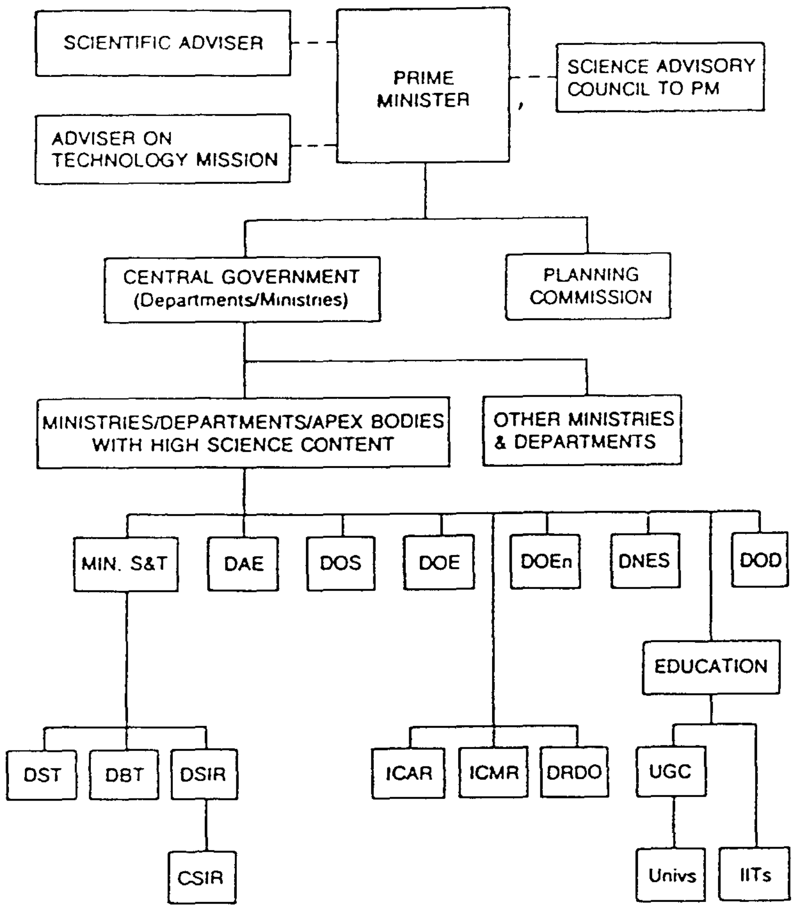
A Ministry of Science and Technology was created in 1985 encompassing three major S&T departments with direct responsibility for S&T - the Department of Science and Technology, Department of Scientific and Industrial Research and the Department of Biotechnology. The Department of Science and Technology, the premier administrative body for the S&T system has responsibility for formulating policy guide-lines in S&T, the promotion of new areas of S&T, S&T entrepreneurship development and international scientific and technical affairs, including international S&T collaboration - though in the case of agricultural research this responsibility is vested with the Ministry of Agriculture. The Department of Scientific and Industrial Research was created in 1985 to act as a focal point for the government's efforts to promote greater innovative and R&D activity in industry. DSIR administers a wide variety of support and incentive schemes to this end, most of them instituted within the last few years.[23]

DSIR is also responsible for the CSIR whose network of forty laboratories constituted the core group of industry-oriented R&D centres in India. As noted elsewhere, there is much criticism of the CSIR and the relevance of a good deal of the work carried out in its

[22] Rajiv Gandhi as prime minister had three advisory mechanisms : the scientific adviser, the adviser for technology missions, and an independent Science Advisory Council which replaced the earlier Scientific Advisory Committee to the Cabinet. The Janata Dal government which came to power in 1989 did not restore these three formal advisory mechanisms and the structure and mechanisms for scientific advice remained ill defined. The position of the new government on this issue is not known.

[23] For example, five specific programmes to assist industrial R&D operated by the DSIR - the recognition of in-house R&D facilities; provision of import facilities for R&D activities; customs duty exemption; preferential treatment in licensing and fiscal incentives for scientific research. In addition it operates other schemes such as the Technology Absorption and Adaptation Scheme, the Transfer and Trading in Technology Scheme and the Program on Promotion and Support to Consultancy Services.

TABLE 18 : Science and technology framework for central government



DAE : Dept. of Atomic Energy
DOS : Dept. of Space
DOE : Dept. of Electronics
DOEn : Dept. of Environment
DNES : Dept. of Non-conventional Energy Sources
DOD : Dept. of Ocean Development
DBT : Dept. of Biotechnology
DST : Dept. of Science & Technology
DSIR : Dept. of Scientific and Industrial Research
ICMR : Indian Council of Medical Research
ICAR : Indian Council of Agricultural Research
DRDO : Defence Research & Development Organ.
CSIR : Council of Scientific and Industrial Research
UGC : University Grants Commission
IIT : Indian Institutes of Technology
Univs : Universities

laboratories - though in recent years some CSIR labs have made major strides in improving their links with industry. However, there is also no question that numbered among the CSIR resources are some outstanding human and institutional scientific capabilities that have not only contributed to Indian development but have also provided the basis for a wide ranging set of international collaborations with more than 40 countries. Moreover, there is conceivably a wealth of commercially valuable but still unexploited knowledge available in CSIR labs that, given their mandate to generate income, they may be willing to develop and commercialize in co-operation with European labs and firms.

Councils similar to CSIR run research institutions under the control of other departments. The Indian Council of Agricultural Research which has a chain of 40 labs in agricultural and animal husbandry research and the Indian Council of Medical Research which is the apex body for formulating, coordinating and promoting biomedical research and has 18 R&D institutions under its control.

Other departments with a strong S&T component to their activities who also support R&D laboratories are atomic energy, electronics, space, environment, non-conventional energy sources, ocean development and education. The Department of Atomic Energy is responsible for R&D in the area of atomic energy and has under its control 12 R&D units of which five are focussed on basic research - Saha Insitute of Nuclear Physics, the Tata Institute of Fundamental Research, the Bhabha Atomic Research Centre, Indira Gandhi Centre for Atomic Research and the Centre for Advanced Technology.

The Department of Space is responsible for satellite communication and remote sensing programmes. The Department of Electronics is the executive wing of the electronics commission which deals with formulation of policies and programmes for the development of electronics and also directs the implementation of such programmes. The Department of Environment is the focal point for planning, promotion and coordination of environment programmes. The Department of Ocean Development is entrusted with the responsibility of promotion of R&D, mapping the resources of EEZ, deep sea-bed mining, and Antarctic research. The Department of Non-conventional Energy Sources promotes utilization of solar energy and bio-gas plants.

In addition there are several socio-economic departments such as health, agriculture, defence, industry and communication which have major research establishments (numbering over 100 and covering a diverse array of fields) as well as other components of S&T in their activities. For example, the Defence Research and Development Organization has a network of over forty laboratories covering a wide range of disciplines such as aeronautics, gas turbines, instrumentation, material science, food, and armament. The Research Design and Standards Organization (RDSO) is connected to the Ministry of Railways, the Telecommunication Research Centre to the Ministry of Communication, and the Indian Statistical Institute to the Ministry of Planning.

Finally, state governments have also set up institutions primarily designed to meet the R&D needs of traditional sectors such as agriculture, animal husbandry, health, forestry, etc. In all the Indian central government, through its various ministries and departments, provides support to 1000 laboratories while the state governments support another 300 laboratories. In 1986, 55 per cent of total S&T related expenditure went to the scientific departments while the S&T component of the socio-economic ministries accounted for 45 per cent of the outlay.

II.4.3. THE S&T PLANNING MECHANISM

Because India adopted early on a planning approach to development of its S&T system there is an elaborate formal planning mechanism at the national and state level. S&T plans are prepared as part of the main five year plans with responsibility for preparation entrusted to the Planning Commission member in charge of S&T. Extensive consultations are undertaken with agencies, individual experts and NGOs over priorities and allocations and ultimately this process results in a chapter on S&T in the plan document. Frequently as part of this process, specialized task forces are set up to consider actions necessary to tackle particular problems - for the Eighth Plan, fourteen task forces were established.

After the main document is prepared, individual S&T agencies then elaborate upon the parameters provided to prepare their own five year plans. These are submitted to the Planning Commission at the beginning of the plan period and then discussed annually. Simultaneously, state level S&T agencies also get involved with the planning process via the preparation of their own state-level S&T plans which are in turn discussed with the Planning Commission. The financial allocation for the S&T sector is finalized at Planning Commission level through a joint consultative process involving other members of the Commission representing other sectors and the Ministry of Finance.

The national S&T plan and the S&T agency plans in effect provide the framework for programme and project planning at the level of individual institutions. These institutions at the start of the planning process make draft plans that are integrated by their parent agency as inputs to the process of preparing the national plan. The different working groups and task forces that actually prepare the plan are constructed so that all the relevant agencies and institutions have an opportunity to provide an input.

Above we have only given the barest of outlines of the S&T planning process and have not entered at all into the myriad debates that have taken place over the years with reference to the effectiveness of the S&T planning process. One issue that always comes up is the existence of a parallel but informal decision making process regarding S&T plans and resource allocation. The existence of such a process has long been accepted as a necessary fact of life within the Indian context arising from the complex social and political pressures that influence the decision making process in science and technology.

Thus, even though the formal mechanisms of science policy were institutionalised as early as the 1950s, the effectiveness of these bodies throughout the last 40 years has always been constrained due to the problems of clarity of their position in the governmental hierarchy and the composition of their membership. Decisions are often taken not on the basis of the advice tendered to the political leadership by the official advisory bodies, but as a result of informal and tacit interactions between concerned individuals in the scientific community, the executive and the polity and independent of the formal national science policy apparatus.[24]

This issue is particularly important from our specific perspective Simply put, senior government officials and S&T policymakers within the Indian government have always found mechanisms to create a mandate and allocate resources to the pursuit of S&T related objectives that have emerged outside of the planning process as important (for whatever reasons) for the national interest. This is precisely what happened initially in relation to the technology missions and the major biotechnology and supercomputer R&D programmes that were launched on an ad-hoc basis.

This is also what we expect could happen with any major S&T collaborative programmes that the EC might propose. Provided the political will is there, a way would be found to respond to the initiative on an ad-hoc basis and any steps taken in terms of resource or manpower allocation would ultimately be officially incorporated within the system. Thus the rather informal and sub-rosa process of fostering the political will necessary to support any initiatives is far more important in India than pursuing these via official procedures - a point that we take into consideration in our strategy discussion in Part I.

[24] For example see A. Parthasarathy, "Appearance and Reality in Two Decades of Science Policy", in A. Rahman and K.D.Sharma (eds) Science Policy Studies, 1974.

II.5. INDIAN R&D EXPENDITURE AND ALLOCATION: STRUCTURE AND RECENT TRENDS

Over 85 per cent of India's R&D expenditure in 1986-87 was made by the government sector, while industry, public and private accounts for between 21 per cent and 25 per cent - a figure that could be closer to 30 per cent if contract research is accounted for. As Table 19 shows while public and private R&D investments have grown rapidly in real terms during the 1980s, government spending has grown much faster with a consequent reduction in the share of industrial R&D in the overall total.

TABLE 19 : Public and private R&D expenditures (million rupees)

	1980	1981	1982	1983	1984	1985	1986-87
National total	7605	9407	12060	13811	17816	20688	26675
Central Govt.	5805	7219	9120	10533	14223	16541	21576
State govts.	593	718	971	1199	1261	1628	1929
Private sector	1207	147	1979	2078	2332	2519	3181
Central Agencies of which							
CSIR	406	461	877	900	967	900	1104
DOE	54	75	48	38	41	48	56
Public sector	864	1078	1224	1617	1712	1986	237167
Research Assons.	83	94	114	130	143	163	260
Industrial R&D	2129	2416	3015	3600	3964	4432	5542
Shares % Private sector/Total R&D	16	16	16	15	13	12	12
Ind./Total R&D *	28	26	25	25	22	21	21

* Includes private and public enterprises and research associations.

Source : Government of India, Department of Science and Technology, R&D statistics, various years

Of the government expenditure on R&D, 92 per cent came from the central government, amounting to Rs 21580 million ($1.726 billion) in 1986-87 and the rest from the state governments. As shown by Table 20, 12 major agencies of the central government account for bulk of the central government R&D expenditure. The Defence Research and Development Organization alone accounts for 37.4 per cent of the expenditure by the major agencies. The three major defence agencies, DRDO, Department of Atomic Energy and the Department of Space account for 64.4 percent of the total for these agencies. Funding for medical research and research on the environment is surprisingly modest - as is the amount of money channelled through the Department of Electronics. However, here one has to keep in mind the predominant activities of the three leading agencies mentioned above since their R&D activities represent a key locus for high technology capabilities within the Indian scene.

TABLE 20 : R&D expenditures by major scientific agencies, 1986-87 ($m)

Defense Research & Development Organization	DRDO	518.6
Department of Atomic Energy	DAE	130.6
Department of Space	DoS	243.7
Council of Scientific & Industrial Research	CSIR	134.2
Indian Council of Agricultural Research	ICAR	128.1
Department of Science & Technology	DST	86.9
Department of Ocean Development	DOD	9.5
Department of Environment	DoE	68.7
Indian Council of Medical Research	ICMR	33.8
Dept of Non Conventional Energy Sources	DNES	18.9
Department of Electronics	DoE	4.4
Department of Biotechnology	DBT	8.3
Total		1385.7

Source : Government of India, Department of Science and Technology. R&D Statistics 1986-87, New Delhi

The allocation of R&D resources for the three leading S&T agencies was half of the total in 1958 and rose sharply to account for almost two-thirds in 1987. During the same period the share of expenditure on the Council of Scientific and Industrial Research recorded a decline. Table 21 captures the changing pattern of R&D expenditure by major S&T agency. This data suggests a significant decline in the share of R&D expenditure accounted for by civilian research agencies possibly due to the rise in the number of S&T agencies putting in resource claims from the same source; or by a general shift in the government's national priorities from civilian research to military applications.

TABLE 21 : **Changing pattern of distribution of R&D expenditure by major S&T agency - 1958-1987**

S&T Agency	Per Cent Distribution		Change
	1958-59	1986-87	
Department of Atomic Energy (DAE)	41	9	-4.55
Council of Scientific & Industrial Research (CSIR)	27	10	-2.7
Indian Council for Agricultural Research (ICAR)	20	9	-2.22
Indian Council for Medical Research (ICMR)	3	2	-1.5
Defense Research and Development organization (DRDO)	8	37	+4.63
Department of Science and Technology (DST)	1	6	+6.0
	(1980-81)		
Department of Space (DOS)	13	18	+1.39
Department of Electronics (DOE)	1	1	
Department of environment (DOEn)	1	5	+5.0
Department of Ocean Development (DOD)	-	1	+1.0
Department of Non-conventional Energy (DNES)	1	1	
Department of Biotechnology	-	1	+1.0

Source : V. Govindarajulu, (1990) "India's S&T Capability", Economic and Political Weekly, February 17, 1990. Table 5.

However, Tables 22 and 23 cast another light on this question of the distribution of R&D effort that suggest that India's S&T effort is moving in a positive overall direction. Table 22 shows the distribution of R&D expenditure by field of science and demonstrates the growing concentration of resources on engineering and the natural sciences while Table 23, based on three year moving averages show a slight but significant shift towards applied and experimental research - both areas where India needs to strengthen its capabilities.

Table 24 gives further information on the central government research effort by grouping expenditure for 1985 according to R&D programme area field of study of the major R&D programmes supported by central government for 1985 and the numbers of R&D establishment associated with these programmes. These programmes spend 77 per cent of all government R&D funds through a variety of institutions and programmes with large bulk of the institutes involved in development work, particularly in the case of the CSIR labs. Some however, such as the leading R&D institutions operated by the Dept of Atomic Energy are principally involved in basic research.

TABLE 22 : Changing pattern of distribution of R&D expenditure by field of science

S&T Field	Percent distribution		% change
	1984-85	1986-87	
Natural sciences	35	31	-1.13
Engineering	44	49	+1.12
Medical sciences	5	5	+1.00
Agricultural sciences	16	15	-1.07

Source : Govindarajulu, (1990) op cit. and Government of India, R&D statistics, 1984.

TABLE 23 : Changing pattern of distribution of S&T expenditure in terms of research activity 1980-1987

Research activity	Percent distribution	
	1980-81	1986-87
Basic research	20	14
Applied research	26	30
Experimental development	28	32
Other activities	26	24

Source : Govindarajulu, (1990) op cit. and Government of India, R&D statistics, 1984.

TABLE 24 : Leading government R&D programmes by field of research, 1985

Research field	R&D units	Expenditure ($m)	
Defense			
- DRDO	42	204.9	
- Defense production	10	52.5	
Total			257.4
Agriculture			
- ICAR	41	119.2	
- State programmes	100	128.5	
Total			247.7
DAE	12	194.2	
DOS	8	158.8	
CSIR	42	132.4	
DST	19	114.2	
Total			599.6
TOTAL			1104.7

Source : Adapted from F.Long, "Science, Technology and Industrial Development in India", Technology in Society, Vol.10, 1988,Table 4.

Again the predominance of the military and defense R&D interests of the state is well demonstrated in this table. What is important to note however is that all three are preoccupied with high technology development that is manifest in both the military research and the civilian research programmes (such as the well-known atomic energy and space programmes) that are sponsored by these agencies. It is here in the activities of these three sets of agencies and their R&D labs, whose activities are well hidden from public view, where India's true high tech capabilities particularly in electronics and communications are to be found.

Apart from the major scientific agencies, the ministries of central government support research on a more or less sectoral basis. As shown in Table 25, the Ministries of Petroleum, Defence Production and Industry account for almost 50 per cent of the R&D expenditure of the central ministries and the top 10 spend 85 per cent of the total. The strength of these ministries within the Indian S&T scene has increased substantially in recent years to the point where they could occupy key nodal positions as far as the EC and future S&T collaborative initiatives are concerned.

TABLE 25 : R&D expenditure by Central Ministries/Departments, 1985

Ministry/Department	Expenditure ($m)
Petroleum	59.4
Defense production	52.5
Industry (heavy industry)	41.0
Communication	30.0
Irrigation	20.9
Steel	13.3
Industry (Industrial development)	10.3
Railways	10.2
Commerce	9.2
Chemicals and fertilizers	9.1
Others *	46.6
TOTAL	302.5

Source : Adapted from Long, 1988, op.cit Table 3.

II.5.1. R&D ACTIVITIES IN THE INDUSTRIAL SECTOR

In 1986-87, the Indian industrial sector (including both public and private sector enterprises) altogether spent 5551.7 million rupees on R&D ($440m).[25] This is an increase of 21 per cent on the figures for 1984-85 as shown in Table 26 and has probably

[25] It is difficult to arrive at accurate sectoral figures for industrial R&D expenditure in India, given the Department of Science and Technology practice of segregating data on institutional basis. DST provides figures of R&D expenditure by public and private sector industrial units but does not include the expenditure of government agencies such as the CSIR, Department of Space or the Department of Atomic Energy. Thus the DST figure for industrial R&D expenditure as 19.4 per cent of total national S&T expenditure is certainly an underestimation.

risen to close to $700m by 1989. In 1986, enterprises operating in 11 sectors accounted for 85.4 per cent of the total expenditure and within these, the expenditure is highly concentrated with about 36 per cent of the R&D units accounting for 47 per cent of the total expenditure.

In terms of industrial sectors there is a clear segmentation of R&D interests. The public sector dominates electrical & electronics, defence, fuels, telecommunications and fertilizers accounting for 53 per cent. of the total. The private sector activity is concentrated in chemicals, drugs, transport and textiles accounting for 47%. The most striking difference between the two is in the number of R&D units where the work is carried out with the private sector numbering 960 and the public sector only 95.

TABLE 26 : R&D expenditures of by industry groups in public and private sector 1986-87

Industry group	Public sector R&D	No of Units	R&D as % of STO*	Private sector R&D	No of Units	R&D as % of STO	Total R&D
Elect.& Electronics	53.92	18	1.82	33.27	136	1.11	87.18
Defense Industry	42.98	5	8.59	-	-	-	42.98
Fuels	11.19	6	0.10	0.11	6	0.50	12.26
Chemicals**	9.21	8	1.08	52.69	152	1.45	62.16
Metallurgical	24.38	17	0.24	8.29	35	0.31	32.67
Drugs&Pharma	3.28	4	2.53	37.61	74	2.23	40.90
Industrial mamchinery	1.87	6	0.70	18.97	71	0.95	20.84
Telecom-munication	18.39	6	4.84	0.16	22	1.42	20.25
Transportation	0.11	3	0.23	12.91	6	0.52	14.01
Fertilizers	0.78	6	0.47	0.09	2	0.29	8.65
Textiles	0.01	3	0.08	11.03	30	0.37	11.19
Other groups	19.38	13	-	56.65	222	-	60.15
Total	185.50	95	0.61	227.80	781	0.81	413.3

* Sales turnover; ** Chemicals other than fertilizers

Source : Compiled from Government of India, Department of Science and Technology, R&D statistics, 1986-87, New Delhi, pp 21, 52-53.

Though these figures suggest that there has been a recent improvement in the level of R&D activity and in the apparent commitment of some Indian enterprises to technology development, it has to be recognized that the overall level of R&D performance and commitment by the Indian (private and public) industrial sector leaves much to be desired. Although in-house research is concentrated in technology intensive sectors (electronics, chemicals, pharmaceuticals and engineering goods were the focus of 775 of the 960 recognized units), the levels of research expenditure are comparatively low - though the figures vary according to the source. Table 27 which provides some contrast with Japan and Korea shows that with the exception of pharmaceuticals, though there was an increase in technological "intensity" in some sectors, the average expenditure is still less than 1 per cent of sales. The DST survey of R&D expenditures shows that in 1986-87, found that public sector firms spent only 0.6 per cent of their total sales turnover on R&D as against a corresponding figure of 0.8 per cent of the private sector.

TABLE 27 : Research intensities of major industrial subsectors * of India, Korea and Japan

Sector	India		Korea	Japan
	1980	1987	1985	1985
Drugs and pharmaceuticals	1.72	2.2	n.a.	n.a.
Industrial machinery	1.03	0.99	3.06	2.74
Transportation	0.87	0.64	2.20	2.90
Chemicals	0.87	1.45	0.96	3.79
Electricals and electronics	0.72	1.11	4.12	5.10
Cement and gypsum	0.61	0.45	n.a.	n.a.
Agricultural machinery	0.48	0.41	n.a.	n.a.
Rubber goods	0.44	0.32	n.a.	n.a.
Metallurgical industries	0.44	0.67	1.14	1.59

* Defined as ratio of R&D expenditure to total sales
Source : Government of India, Department of Science and Technology

This macro evidence of a less than wholehearted approach to R&D is confirmed by numerous micro level studies showing that much of the R&D activity in the private sector in India is geared towards minor adaptations of the imported technology and quality control and not to become a source of technology for the firm.[26] If patents are taken as an indicator of the performance of the private sector R&D, a study of 500 Indian companies registered with DST showed that their share in the total number of Indian applications has declined over the period 1969-81. Amongst these firms, as many as two-thirds did not apply for a single patent. It was also found that while a reasonable number of multinational corporations were very active in carrying out adaptive R&D, five firms in fact accounted for almost half of the total foreign applications. This poor performance of Indian enterprises in the patenting sweepstakes is confirmed by Table 28.

TABLE 28 : Number of applications for patents from persons in India and abroad from 1976 to 1986

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
India	1129	1342	1097	1124	1055	1159	1093	1135	1055	1001	999
Foreign residents in India	34	23	37	13	37	19	19	25	2	-	
Foreign residents abroad	1833	1739	1736	1795	1888	1776	1877	1950	2065	2316	2527
Total	2996	3104	2870	2932	2980	2954	2989	3085	3145	3319	3526

Source : Annual Report of Controller General of Patents, Designs and Trade Marks, 1984-85 and 1985-86

The above discussion of the macro figures shows that conduct of market driven R&D designed to secure a technology-based competitive advantage in the marketplace remains

[26] For example see A.V. Desai, "The origin and direction of industrial R&D in India", Research Policy, No.9, 1980.

one of India's major S&T weaknesses - despite the vast sea of technical skills and resources that surrounds its productive enterprises. This has been a long standing problem. Prior to the early 1970s, R&D by industry was minimal since virtually all technology needs were imported. At that point, the government instituted fiscal and financial incentives for firms to engage in R&D. Under these arrangements (withdrawn in 1984), firms with recognized R&D facilities were permitted to deduct 100 per cent of capital expenditures from taxable income. There was some response by firms to these incentives but by and large industrialists and managers continued to show little interest in genuine indigenous technology generation.

The unfettered monopolistic advantages accorded them by protection combined with an isolated and unresponsive S&T system reinforced this disinterest in technology generation and maintained it across many sectors and firms throughout the 1970s. However during the 1980s, these conditions have changed and, as noted above the level of R&D activity has begun to measurably increase.

These developments can be attributed to two broad sets of factors. First beginning in 1985 with the establishment of the DSIR, the government launched a variety of new initiatives to promotion industrial innovation and to encourage firms to increase their own R&D efforts as well to be better users of the output of the formal S&T system. Though there are still many sceptics who claim that while Indian industry remains protected and regulated that these moves will have only marginal effects on firm attitudes to R&D, there is little question they have had some effect. This is evidenced by the fact that reported industrial R&D expenditures grew surprisingly rapidly at over 21 per cent p.a. in nominal terms between 1977 and 1987 while over the same period the number of private sector firms with recognized in-house R&D units grew from 125 to 960.

Secondly, it should be noted that many firms have registered R&D units primarily to take advantage of government tax incentives. And there are still many critics of the mercantilist attitude of the many Indian entrepreneurs who are still reluctant to invest in innovative effort.[27] However, there is also clear evidence that the rise in recorded R&D activities is genuinely indicative of the emergence of a new awareness among entrepreneurs and managers of the importance of innovation and technology as a determinant of competitive advantage.

This is manifest both in the emergence of start-up high technology companies supported by venture capital groups, the widespread attention being given by the private sector to the pursuit of quality improvement and productivity gains through technical change and the successful commercialisation of a number of innovations generated via legitimate R&D in the private and public sector. We highlight a number of these examples in the case studies presented as annexes below.

[27] For example see "Technological Self-Reliance and Systemic Constraints", Economic and Political Weekly, June 11, 1988.

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ANNEXES

ANNEX 1 - TRANSFORMATION AND TURMOIL IN THE TELECOMMUNICATIONS EQUIPMENT SUPPLY SECTOR

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ANNEX 6 - SOME ANECDOTAL EVIDENCE ON NEW FORMS OF INDUSTRIAL DYNAMISM IN THE INDIAN CONTEXT

ANNEX 7 - INDIAN'S FORMAL R&D SYSTEM: SELECTIVE EXCELLENCE AND THE PURSUIT OF SELF-RELIANCE

SPECIFIC ASPECTS OF THE INDIAN S&T SYSTEM AND INDUSTRIAL SECTOR OF PARTICULAR RELEVANCE TO PROSPECTS FOR EC S&T COLLABORATION WITH INDIA

In the annexes that follow, we present a very selective and more in-depth analysis of specific features and characteristics of the recent evolution of the Indian S&T system and the development of industry and agriculture that are directly relevant to our concerns. In the case of a country such as India, there are in fact far too many "critical" dimensions of the S&T and industrial systems and the contextual environment influencing the policy making process to be covered adequately in a report such as this. Consequently we have confined ourselves to dealing with issues on a case study basis where the research work carried out for the project has provided particular insights that might be useful in the formulation of the EC's strategy towards developing further S&T co-operation with India.

ANNEX 1 : TRANSFORMATION AND TURMOIL IN THE TELECOMMUNICATIONS EQUIPMENT SUPPLY SECTOR

Telecommunications in India is a political, industrial and technological battlefield that is a reflection of the same pressures for change that is driving the global transformation of the sector. By 1980, decades of underinvestment and public monopoly had resulted in a telecommunications system of appalling quality and very limited availability. Since then, internal and external pressures for liberalization, expansion and improvement have forced the government to introduce a variety of fiercely contested changes in market structure, institutional responsibility and regulatory policy.

Among many developments these include attempts to streamline policy making (so far unsuccessful); the opening up of markets for EPABAX, telephones, teleprinters and cables to private producers using indigenous and imported technology; the slow dismantling of the previous monopoly on service provision exercised by the Ministry of Telecommunication via the spinning off of the Bombay and Delhi networks and the international network; and the permitted proliferation of a variety of dedicated networks in the public and the private sector such as Vikram, a public switched data network for medium and large business users in urban areas, the satellite based Remote Area Business Network doing the same for rural businesses, and Indonet providing computing facilities and data bases to remote users on leased lines.

While all of these developments should be of interest to Europe, the changes most directly relevant to our concerns are taking place in the area of equipment supply. Here, an as yet unresolved struggle, has been taking place for the last decade between those advocating self-reliance and indigenous supply by the public sector (primarily the Department of Electronics and C-DOT) and those (primarily the Ministry of Telecommunications) whose main concern is to greatly expand supply whatever way possible even if this means allowing private production, using imported technology and inviting the direct participation of foreign capital. This is where we focus our attention in this note.

International companies such as Alcatel of France, Siemens of West Germany, AT&T and Bell Labs of the U.S., Ericsson of Sweden and NEC and Fujitsu of Japan have long considered access to India's estimated $50 billion domestic telecommunications market as one of the most glittering prizes still to be won in the global telecommunications sweepstakes. They have concentrated on winning contracts to set up digital exchange production facilities as these offer the best way in but this segment has been virtually closed off to foreign collaboration for the last five years. However recent, heavily politicized, developments concerning the future of initiatives launched during the previous administration have created real possibilities that major new deals could be struck involving extensive foreign collaboration. To understand the implication of these developments for our concerns a little background is required.

Initial reliance on outdated and overpriced imported technology. Indian Telephone Industries (ITI), the main public sector equipment producer commenced indigenous production of Strowger switching equipment in 1951 even though it was clear that this would soon give way to a new generation of switches. ITI finally got around to the production of crossbar switches in 1964 via a collaboration with Bell Telephone Manufacturing, Belgium only to discover the system was totally unsuited to Indian telephone usage pattern. Adaptive R&D was carried out but production of an indigenously designed crossbar system did not begin until 1981 - during which time the world had made the transition from electro-mechanical to electronic switching.[28]

In 1979 the Sarin Committee recommended that future expansion of the network be on the basis of digital exchanges. In 1980, international tenders were invited for the supply of digital switching technology. What followed was a period of prolonged dithering by policy makers, fierce lobbying by the telecommunications multinationals from Europe, Japan and the U.S. and bureaucratic infighting. Finally the contract was awarded to CIT-Alcatel of France in a manner that effectively short-circuited the whole tendering process. The deal, which also included a sizeable technology transfer element, was part of a larger set of high technology transactions between France and India (brought about via prime ministerial agreement) that also involved Indian procurement of French enriched uranium, the purchase of Mirage fighters and, critically, a soft loan from the French government to finance the whole package.

Despite the favourable loan terms, the way in which the deal was concluded caused great consternation among the more self-reliant minded members of the Indian S&T bureaucracy. This was greatly exacerbated when it emerged later that India had paid dearly both in terms of cost and technology for their French connection. Apparently the Indians paid over three times more for the Alcatel telecoms technology than did the Brazilians who, around the same time, had acquired similar exchange technology from Ericsson of Sweden. Further, the French E10-B system was considered (even by the French) to be less technologically advanced than the corresponding AXE system sold to the Brazilians.[29] Alcatel still enjoys considerable support in India but bureaucracies have long memories and it may be that the negative aftereffects of the Alcatel deal have worked against the closing of other French high technology transactions in India ever since. Production of the first generation (1977) 512 line E-10B Alcatel switching system is still being carried out under license by ITI at a 500,000 lines p.a. plant in Uttar Pradesh.[30]

<u>C-DOT and self-reliance</u>. Alcatel's opening into the Indian switching market was abruptly closed off in Sept. 1984, when a charismatic U.S. trained Indian electronics engineer, Sam Pitroda, convinced then Prime Minister Rajiv Gandhi, he could develop an all Indian switching system within three years using Indian technology and components. This argument appealed to the perennial governmental objectives to achieve self-reliance and so Pitroda was given (relatively limited) funding by the government and told to go away and

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[28] At the end of the adaptive R&D project BTM was called again to set up the Indian Cross Bar project at Rae Bareili. Production never stabilized at Rame Bareili and it is planned to phase out electro-mechanical exchanges by 1992. See Sunil Mani, "Technology Acquisition and Development : The Case of Telecom Switching Equipment", <u>Economic and Political Weekly</u>, November 25, 1989.

[29] See C. Brundenius and B. Goransson, <u>The Quest for Technological Self-Reliance : The Case of Telecommunications in India</u>, Research Policy Institute, University of Lund, October, 1985.

[30] The Alcatel project has faced a wide variety of difficult start-up problems ranging from political obstruction by the bureaucracy to the need to overcome an almost total lack of infrastructure facilities. These difficulties have lasted throughout the life of the project so far and have prevented the plant from operating at full capacity. See J-P Vercruysse, "The Development of Telecommunications in India : Issues and Prospects", Mimeo, Center for the Study of New Media and Information Technology, Free University, Brussels, September 1989.

develop a wholly Indian exchange.[31] The government from that point forward effectively stopped all imports of switching components and all negotiations on further foreign involvement in component production and technology transfer.

The Centre for Development of Telematics (C-DOT) to carry out the promised technology development. Staffed by 400 engineers, the mandate for C-DOT was to develop, within 36 months with a budget of $36 million, a family of digital switching systems suited to Indian conditions and having commonality in hardware, software, packaging, documentation, installation and maintenance.[32] The ultimate objective was to produce a digital Main Automatic Exchange (MAX) with a capacity of 16,000 lines and capable of handling integrated voice and data communications comparable to ISDN.

C-DOT decided to follow a modular approach based on a basic EPABX module that would be the standard form from which the full family of exchanges would be developed. So far among the main C-DOT products released for testing and manufacture have been the 128 PBX, a state of the art SPC switching system with 128 terminations (already in manufacture via 34 licensed contractors); a 128 RAX (rural automatic exchange) licensed to 27 manufacturers with 300,000 lines capacity; the C-DOT 512 MAX which is the base for the 16,000 line MAX and contains about 90 per cent of the hardware and software of the larger system; and still on test but expected to be released for production in 1991 (some 2-3 years behind schedule) is the flagship of the first phase of the C-DOT mission, the C-DOT 16000 Port Exchange.

Despite this lag on its most visible and important product, C-DOT has undoubtedly achieved a great deal both in terms of technology[33] and its influence on industrial policy where for example it has demonstrated the validity of an entirely new approach to the organization of high tech R&D in India.[34] However, controversies plagued this initiative from the start. These arose partly because of Pitroda's visible role as India's self-appointed technology messiah;[35] partly because of the controversial ban on foreign collaboration and component imports; and partly because of C-DOT's delay in meeting its original timetable for the MAX exchange.

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[31] From the Indian perspective (which is also a widely shared view elsewhere in developing countries) the rationale for self-reliance in telecommunication does not stem from the necessity to internalize production linkages within the economy since these are not really very significant. Rather they would argue that if a nation wants to establish and maintain a reliable telecommunication network, it has to internalize all the requisite know-how and expertise by designing and building one itself. This is partly because system maintenance is know-how intensive and, more importantly, its because network design has to be tailored to local requirements. For a clear statement of this position see Business World, "C-DOT : A Report to the Nation", 1 october, 1987.

[32] The system had to accept fluctuations in power supply, be tropicalised and be capable of functioning with very little maintenance. In addition, it would have to cope with a very high traffic rate : 20 BHCA per line in the cities and be non-blocking.

[33] For example by 1985, the C-DOT designed EPABX was being manufactured from 85 % indigenously made components while the cost per line will be between Rs2000-2500 compared to Rs4000 to 5000 for EPABX's manufactured under foreign license. See K.Varma and S.Wadekar, "EPABX: Consumers call the tune, " Telematics India, December 1988.

[34] See the discussion in B.Bowonder (1990) "Development of Digital Switching Systems Technology : Case Study of C-DOT in India" Mimeo. Administrative Staff College of India, Hyderabad.

[35] Pitroda was also given responsibility for the Technology Missions (described earlier) as well as being appointed head of the newly formed Telecommunications Commission. He has now been effectively removed from those positions of responsibility.

As a result, in January 1990, an official enquiry into C-DOT and its performance was launched.[36] The report was highly critical of C-DOT on technical and administrative grounds. It claimed that the main exchange designed by C-DOT cannot stand up to Indian conditions[37], that it should be redesigned (which would take another three years) and that in the meantime ITI should establish two more 500,000 line factories based on an updated version of the Alcatel technology.

Implications for foreign collaboration and Community initiatives. Interpreting the impact of this report and the current controversy on the future of C-DOT, Indian telecommunications equipment supply policy and ultimately on the prospects for EC support for European involvement in the Indian telecommunications supply industry is extremely difficult - even with the benefit of our interviews - because the events are so recent and because of the change in government. The technical critique of C-DOT has its supporters and opponents - with C-DOT supporters currently having the upper hand because of the demonstrated superiority of the C-DOT switch to the Alcatel switch.[38]

Similarly there are those who support and oppose the commission's recommendations for reopening negotiations with Alcatel (over which France has applied very considerable pressure) or with other foreign suppliers. Those opposed argue that to do so might appear to be going against the cherished rationale of self-reliance on which C-DOT was established. Further confusing the matter is the recent decision (January 1990) to grant a small ($15 million) but significant contract to Ericsson of Sweden to supply four digital gateway AXE exchanges to handle all India's (still very poorly served) international telephone traffic. This could be interpreted to mean that Ericcson and not Alcatel or other European suppliers not has the inside track to larger switching deals in the near future.

Quite the opposite may be true however since it is clear that ITI and other new domestic entrants have, in the last few years, been permitted to undertake foreign collaborations in switching and in other equipment segments where European suppliers are involved. For example:

- As part of liberalizing the EPABAX market, technologies from three foreign companies (GTE-ATEA, OKI and Jeaumont-Schneider) are now under licensed production in direct competition to the C-DOT techoology;

- ITI has a collaboration with FACE (an Alcatel subsidiary) for manufacturing pushbutton telephone sets, while Ericsson and Siemens designs are also under licensed production;

- The previous teleprinter monopoly of Hindustan Teleprinters has been broken and Siemens, among others, expects to be allowed to produce electronic machines in the near future;

- ITI and Bharat Electrical are collaborating with NEC of Japan in the manufacture of microwave transmission systems (production beginning this year) as part of an Rs 8

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[36] See Vercruysse (1989) op.cit.

[37] For example, to suit the Indian traffic requirements, the standard the C-DOT had to respond to was 10,000 BHCA. An inter-departmental committee reported that system cannot handle more than 6000 BHCA. Interestingly, the TNC telecommunications firms interested in the Indian market all support this criticism - while C-DOT denies it.

[38] For example see Vercruysse (1989) op.cit. and Bowonder (1990) op.cit.

billion investment in transmission, while NEC also has a contract with DOT to import fibre optic equipment to link Delhi and Bombay and a 32,000 line equivalent of small exchanges;

- NKT from Denmark is setting up a Rs 490 million fibre optic factory and R&D lab with ITI and Hindustan Cables Ltd; Fujitsu of Japan is also in negotiation with ITI to establish collaborative fibre optic production;

- AT&T-Phillips is collaborating with ITI in the production of digital coaxial transmission systems;

- Equatorial (USA) is collaborating with ITI in the manufacture of low cost earth satellite stations. This latter deal, though small, is expected to set an example for a wide range of subsequent transmission collaborations because Equatorial has taken out a 40 per cent equity share and given a commitment to effect full technology transfer;

- The DOE has recently organized the importation of 1.5 micron technology from VLSI Technology Inc of the U.S. to allow ITI to manufacture ASICs for telecommunications and defense purposes.

While the above listing indicates the gradual emergence of substantial opportunities for foreign collaboration in transmission and peripherals, information from our interviews also suggested that once things settle down vis the C-DOT controversy, there may be substantial opportunities for further European involvement in local production and transfer of digital exchange technology.

Whether the Community can or should play a role in exploiting these possibilities is an open question. What is certain is that some form of public sector support will strengthen the hand of European suppliers (either individually or collectively) and that in order to be effective this support must be wielded with tact and with an understanding of the recent events surrounding Indian telecommunications equipment supply policy as depicted above.

ANNEX 2 : THE ELECTRONICS SECTOR IN INDIA: CONTRASTING PROBLEMS AND POSSIBILITIES FOR COLLABORATION IN HARDWARE AND SOFTWARE

The Indian electronics industry moved rapidly onto a high growth path during the 1980s due to major government policy initiatives, the rapid entry of the private sector into production in a major way and fortuitous conditions in international, particularly software, markets. Between 1980-85, output and exports grew respectively at 25 per cent and 27 per cent annually while between 1985 and 1989 the respective rates of growth increased to 35 per cent and 37 per cent annually. Table 29 shows the sector and productwise breakdown of the growth of the industry and exports during 1985-1990. As can be seen, part of the high growth rate is due to the low starting point while the 1990 output and export totals of some $5.6 billion and $105 million respectively are still very modest compared to India's size and the performance of other economies. Nevertheless these growth rates have given both the public and the private sector good reason to have great optimism for the future.

TABLE 29 : Sector and product breakdown of electronics production, 1985-1990

	1985	1988	1990*
(A) Consumer electronics	901.6	1589.0	1976.1
- Radio receivers	102.5	120.1	107.8
- TV receivers			
Black & white	319.6	511.6	613.8
Colour	348.3	604.6	718.6
- Tape recorders	73.8	155.0	191.6
- Others	57.4	197.7	344.3
(B) Industrial electronics	323.8	523.3	832.2
- Instruments	65.6	104.7	125.7
- Process control eqpt	98.4	124.0	167.7
- Power electronics	94.3	135.7	323.3
- Medical electronics	20.5	27.1	35.9
- Other inc office eqpt	45.0	131.8	179.6
(C) Professional equipment	525.6	849.8	1167.6
(i) Communication & broadcasting			
- Broadcast	29.6	62.0	77.8
- Telecommunication	299.1	515.5	760.5
- Two-way comm.	16.4	23.2	29.9
(ii) Strategic electronics	180.5	249.1	299.4
(D) Computer systems (including microprocessor systems)	147.5	328.7	449.1
(E) Components	360.7	600.8	958.1
Sub-total	2259.2	3891.6	5383.1
(F) Free-trade zones (hardware)	65.6	85.9	110.8
(G) Software for export	28.7	62.0	104.8
Total	2353.3	4039.5	5598.7

Source : Adapted from data provided by the The Electronics and Computer Software Export Promotion Council

* 1990 data is estimated based on returns from January-April.

The industry, of course, faces many problems which particularly private sector producers and external agencies such as the World Bank have been assiduously highlighting in recent years, not least of which is the lack of an IC production base and large segments of uncompetitive producers in the public and private sectors, particularly in the area of computers, and limited R&D expenditure.[39] Not surprisingly, excessive government regulation is one of those criticisms that came up frequently in our interviews.

Two other serious problems caused by past protectionist policies and constraints on technology import are demonstrated in Tables 30 and 31 which document the problems of small scale compared to world best practice and excessive import dependence - which totalled Rs 16 billion in 1988 and accounted for 40 per cent of total production in 1988. What is interesting about these two problems is that they also highlight opportunities for European firms to establish linkages with Indian producers as the government is keen to use foreign collaboration to overcome these obstacles to growth - provided genuine technology transfer occurs and the net foreign exchange costs are limited.

Apart from bearing in mind the criticisms of the Indian electronics industry as mentioned above, three aspects of the structure and evolution of the Indian electronics industry and its future prospects for collaboration emerged during our interviews as being of specific interest to our concerns. First, the Department of Electronics, which is the main body responsible for planning, policy and administrative of public sector R&D and production, will necessarily be a key player in any major initiative that the EC seeks to launch in relation to Information Technology in India - the private sector alone will not be a suitable partner.[40]

Second, the emergence of Silicon Valley-like agglomerations of electronics firms in certain urban areas such as Bangalore that feature extensive foreign participation and point the way towards possible growth areas for European collaboration; the third aspect relates to the possibilities (and problems) for collaboration being generated by the development path currently being followed by India's software industry. These last two aspects are discussed below.

The emergence of India's Silicon Valley and new models for foreign collaboration. One of the more intriguing electronics sector-related developments of recent years has been the evolution of Banglaore as a center for the Indian electronics industry with most of the leading hardware and software houses (foreign and domestic) now already in place or soon to arrive. However, unlike similar developments in other developing countries where government has attempted to create a Silicon-Valley clone, the electronics agglomeration in Bangalore is, uniquely, built upon a firm foundation of pre-existing capabilities and infrastructure in the public sector and is being driven by the competitive drive of the private sector rather than government incentive. In the opinion of many, this pedigree gives Bangalore a significant comparative advantage as the locus for the continued rapid growth of the Indian electronics industry in the future.

Quite apart from the relatively recent arrival of the electronics industry, Bangalore boasts a strong industrial base consisting of more than 130 medium and heavy scale technology-intensive private sector industrial enterprises, plus some 45-50,000 small scale

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[39] See for example S. Mahalingam, "Computer Industry in India : Strategies for Late-comer Entry", Economic and Political Weekly, October 21, 1989. See also E.J. Girdner "Economic Liberalization in India : The New Electronics Policy" Asian Survey, November, 1987.

[40] This will be particularly the case if the projects involve a major R&D component. Though there are other agencies involved in electronics R&D, particularly in the defence sectors, the DOE is the main source of R&D funds and manages the public sector production enterprises. Among the major R&D centers under the DOE are the Center for the Development of Advanced Computing currently concentrating on the development of an indigenous supercomputer; the Council for the Development of Materials for Electronics; the Society for Applied Microwave Electronics Engineering and Research and the Advanced Technology Programme in Computer Networking.

units engaged in subcontracting. Its R&D credentials are impressive as well with many of the countries best high tech R&D labs located in Bangalore such as those of the Indian Space Research Organization, the Central Power Research Institute, the Defense Research Development Organization, the National Aeronautics Laboratories, the Indian Institute of Astrophysics, the Raman Institute and the Indian Institute of Science.

On the electronics side, Bangalore began building up a production base in 1948 when Indian Telephone Industries started its manufacturing activities, followed in 1955 by Bharat Electronics Ltd and the subsequent establishment of specialized defense electronics contractors and research institutions such as the Electronics and Systems Division of BHEL. With these establishments providing the infrastructure and pool of human resources, it is not surprising that the civilian electronics industry was strongly attracted to the Bangalore area and is likely to stay for the longer term.

The most recent evidence of this is the establishment of an "Electronics City" outside of Banglaore (one of four in India) consisting of an integrated complex of large, medium and small scale electronics industries constructed around an impressive technical infrastructure including training institutes (one financed by the Swiss government) and service facilities. Beginning with its establishment in 1985, more 125 letters of intent were issued to firms planning to set up manufacturing facilities there. Among the leading Indian electronics firms established in the complex are United Telecom, Tatas, Blue Star, Hindustan Computers Ltd and Khautonics

Among the international electronics firms who have recently established production and in some cases design and research facilities in Bangalore, there are European (such as Sinclair, Siemens and Asea) and Japanese firms but U.S. producers predominate including Intel, Texas Instruments, Motorala, DEC, Sun Microsystems, Kodak, Hewlett Packard, Control Data Corporation, Digital Equipment Corporation and Unisys. While much attention has been given to the Bangalore-based Texas Instruments software tie-up (discussed below) Bull of France has embarked on a new joint venture in computer production that is indicative of the new perspective that foreign electronics firms now have towards collaboration in India and of the difficulties that need to be overcome to make such ventures a success.

Bull, after trying to get into India for some time via a link up with the state-run producer, ECIL, has now taken a 40 per cent stake in PSI Ltd, one of India's best known computer firms. It has gone into India with three objectives - production of its DPS 7000 mainframe to gain a 30 percent share in India's mainframe market (now growing at 30-35% a year); becoming a market leader in developing hardware and software packages for use in banking and finance, industrial production control and telecommunications; and subcontracting a considerable share of component and software production for export back to France for which there are significant buyback arrangement in place already - $30 million in the case of software.

PSI was initially chosen as a partner by Bull because of the high calibre of its technical staff of 430 (of whom one-third are research engineers) and its system and component production capabilities. However extensive technology transfer activities are now underway with engineers flowing in both directions and PSI constructing a new facility to make the DPS 7000. Bull has had to sustain PSI over a few difficult years while also putting the company through a painful rationalization process. However, Bull is committed to India over the long term and its commitment is already beginning to show a return with production, market share, exports and new product development all moving in the right direction.

Selected possibilities for software collaboration. One of the expressed interests of the Community in S&T collaboration with advanced developing countries is the possibility of forming alliances on projects that are skill and manpower intensive in sectors where Europe suffers from manpower shortages. Software development is clearly one of those areas and India alone among the NICs being studied in the SAST project appears to have the requisite manpower and institutional resources to support such initiatives.

Though estimates vary there is a stock of approximately 200,000 engineers and software programmers at work in India scattered across some 600 software firms, numerous hardware manufacturers and in the 25 or so public sector institutions extensively involved in software related development and research projects.[41] This stock of manpower is being added to at fairly rapid rate via government training initiatives such as the Generation of Manpower for Computers programme under which 250 institutions have launched government sponsored advanced software and systems design courses, the output of approximately 100 new university level programming degree courses that have been added each year since 1988, and the large number of lower level trained personnel being turned out by thousands of technical institutions and private sector training courses.

Though the pool of software manpower suffers from some weaknesses and shortages, by and large Indian programmers and software developers are rated very highly internationally. They are usually trained on UNIX which is a great advantage and are conversant with all major computer systems - IBM, CDC, DEC, UNISYS, ICL, Wang, HP and others. Indian engineers are acknowledged to be capable of carrying out the whole variety of technical activities from routine and conversion programming through highly specialized jobs such as developing UNIX kernel networking applications and X-Windows-related job assignments where skills are extremely scarce in the West.

Coupled with this combination of skilled manpower with experience in the most advanced computer systems as well as proficiency in English, the Indian software sector can also offer tremendous cost and considerable productivity advantages. Indian software professionals cost about 1/8 to 1/10 less than British or US professionals with comparable experience levels and at least four times less than Southeast Asian professionals.

This wage differential makes Indian software engineers attractive to overseas companies in their own right (as we shall see below) and also means Indian companies can be extremely competitive in the marketplace - one interviewee claimed his company was able to consistently provide tailored software solutions to British clients that are 40-50 per cent cheaper than anything else on offer, while also achieving productivity levels as high as 150 per cent better than their counterparts in the UK.

On top of these advantages, the software sector is one of the sectors where the Indian government has gone furthest in its attempt to stimulate the expansion of private supply and encourage foreign investment. In addition to its training initiatives, Indian government policies are oriented to the establishment of infrastructure, streamlining investment procedures and promoting exports. An important part of recent infrastructure investments have been the establishment of four software technology parks in Bangalore, Pune, Bhubaneshwar and Chandigarh. These parks provide facilities such as satellite links and dedicated data lines while import license requirements are waived and do not attract any duties.

[41] For example the National Informatics Centre alone has over 1600 post graduate trained programmers at work on 50 different projects.

Some qualifications. All of this suggests there are great possibilities for the development of major collaborative initiatives in the software area between the Community, European firms and India. However our interviews brought out four important points that need to be borne in mind in assessing these possibilities.

First, there is already considerable competition for access to India's software manpower resources. U.S. firms in particular have reacted quickly to the possibilities and a large number have already established software development facilities and collaborative arrangements in India. As a result, sales to the U.S. accounted for nearly 70 per cent of India's estimated $100 million worth of software exports in 1989.[42] Nevertheless, despite the competition from the U.S., European and particularly U.K. firms are beginning to establish links with India but more on a subcontracting basis rather than via direct investment.[43] In most cases, most of the work being done by the Indian side tends to involve the preparation of low level routine or conversion software.

Second, our information suggests that while there are many Indian software firms willing to engage in this sort of low level software subcontracting work, it is beginning to attract some strongly negative comment within the government. This is because the bulk of Indian export income, possibly as much as 80-95 per cent, comes from forms of subcontracting that have come to be known as "bodyshopping" that either involves the operation of software "sweat-shops" in India or the actual export of Indian software personnel to carry out the contract work overseas.

From the Indian perspective this practice is of questionable value because it does little to upgrade the technical skills of its professionals who are often assigned tasks requiring relatively limited skill input. Nevertheless, the number of Indian professionals working on overseas assignments is high. One estimate we were given is that about 3000 programmers in India are working in the export sector and perhaps another 1500 are currently working abroad developing software for clients. While no one expects the government to intervene directly in this situation, it is certain that they will not respond favourably to any proposals coming from the EC for collaboration on similar projects.

Thirdly and related, there is, as mentioned in Part I, considerable unhappiness over the permanent loss of high level Indian software manpower to foreign countries, again particularly to the U.S. This is not surprising since the thousands of expatriate Indian software engineers currently working in the U.S. account for perhaps the top 10 per cent of India's most highly skilled IT manpower resources. Also not surprisingly, actions such as those by Microsoft, who advertised in India for programmers to join its headquarters in Washington and hired 50 top-flight engineers away from Indian companies, or those of

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[42] Among the firms already well established are Ashton-Tate, Bellsouth, Citibank and, of course, Texas Instruments. The TI link is via a subsidiary in Bangalore staffed with 50 software specialists who are in turn connected to TI's Dallas headquarters via an earth station satellite link on the top of the building. Costs were recovered in less than two years and the company is planning a 200 per cent expansion in its software activities in India. Citibank is using engineers to write financial software programmes in the Bombay free trade zone; while in an operation to be launched by 1992, the government of the State of Massachucetts is co-operating with the DOE to set up two software technology parks linked by satellite to allow small-medium sized specialized software firms can collaborate on programme development.

[43] Among the projects identified during our research is one involving Tata Consultancy Services of Bombay, IIS of Delhi and Britannia Building Society in the joint development of a $1.5 million specialized loan programme whereby the Indian programmers work on Britannia's computers via a satellite link; another involves the Computer Maintenance Corporation of Delhi carrying out a $400,000 project to develop an enhanced Computer-aided Railway Time-tabling system.

specialized U.S. based recruitment firms who headhunt in India, have attracted very considerable resentment.

Some of this official "anger" is directed specifically at the U.S. government who seems to be encouraging such practices. For evidence of this, those interviewed pointed to the fact that U.S. immigration regulations have recently been amended so that professionals with 'distinguished merit or ability' qualify for permission to work in the US in a fraction of the time it normally takes thus allowing U.S. firms to take only the cream of Indian expertise. These concerns lead to suggestions, discussed further in Part I, that any collaborative proposals which could be structured so as to entice NRI (non-resident) Indian software personnel back to India would be very favourably considered.

Finally, it needs to be noted again that the private sector segment of the Indian software industry is plagued by a number of weaknesses. Principal among these is small size and lack of financial resources. For example, while there are over 360 firms specializing solely in software only the top three had annual revenues in 1989 of over $10 million while approximately 75 per cent had revenues of less than $100,000. Such low turnovers and the still limited availability of venture capital seriously constrains their ability to expand and develop internationally competitive skills, tools and products.

This aspect has two implications for our concerns. First, it means that collaboration with the private sector on major projects, unless these are carried out with the handful of large firms already present, will require the injection of considerable resources to create an institutional base capable of supporting the available manpower; and second, it may be therefore that in the shortrun the public sector institutions are likely to be the best place to look for large scale EC-India collaboration possibilities because they have the manpower and the resources to support such projects.

TABLE 30 : Scale of component production in India compared to world scale

Electronic component	World scale	Typical capacity in India
B/W picture tube	2-5 M	0.5-1 M
Colour picture tube	1.5-2 M	0.5 M
Discrete semiconductor devices	-	50 M
IC's (bipolar) SSSI/MSI		
- WO/wafer fab	50 M	10 M
- W/ wafer fab	600 M	-
Medium power devices	50-100 M	10 M
PCB's double sided	20,000 sq.mts	10,000 sq.mts
Film resistors	1000 M	100-200 M
Film capacitors	500 M	50 M
Tantalum capacitors	50 M	1 M
Ceramic capacitors (disk)	5000 M	50 M
Multi-layer ceramic	1000 M	-
VCR W/tape deck and head	1 M	-
DC micromotors	10 M	1 M
Tape deck mechanism	5 M	0.5 M
Soft ferrite	5000 M	500 M
Hard ferrite	10000 M	1000 M
Loudspeaker	50 M	1 M
Connectors	10-20 M	1 M
Video tapes	500-10000 MRM	500 MRM

Source : Adapted from data provided by the The Electronics and Computer Software Export Promotion Council

TABLE 31 : Material content in electronic components (as percentage of ex-factory value of components)

Component type	Raw materials *		Duty
	Imported	Indigenous	
B/W & Colour picture tubes	40	10	25
Hybrid circuits	30	8	19
Power semiconductors	40	8	22
Potentiometers	20	30	8
Plastic Film capacitors	25	2	13
Electrolytic capacitors	40	10	25
B/W TV	20	45	10
Colour TV	30	10	33
Crystals	10	3	6
Magnetic tapes	45	5	20
Floppy diskettes	15	3	10
Tape deck mechanisms	25	20	20
Connectors	20	10	15
Relays	15	10	7
Hard Ferrites	-	12	-
Transformers & Coils	15	40	10
Metalised films	40	4	30

Source : Adapted from data provided by the The Electronics and Computer Software Export Promotion Council

ANNEX 3 : INDIAN'S GROWING STRENGTHS IN BIOTECHNOLOGY: AN EXAMPLE OF SUCCESSFUL NATIONAL PLANNING

While many criticisms can be made of Indian S&T planning with regard to industrial innovation, it is also the case that one of the great strengths of the S&T planning mechanism has been its ability to channel financial and manpower resources into tackling priority problem areas. This has most recently been done via the technology missions and the identification of what are called "thrust areas" for R&D and skill creation. A good example of this approach at work in an area offering important opportunities for EC collaboration is the efforts of the Indian government over the last decade to create substantial national capabilities in the field of biotechnology.

The first moves in this direction were taken in the early 1980s via the work of the National Biotechnology Board which in 1983 issued a long term plan for biotechnology (one of the first by any developing country). Strong emphasis was placed on the need for major programmes of manpower development, the launching of basic research programmes in a variety of areas of direct relevance to India's needs and the creation of a research infrastructure and incentive system to promote the development of industrial applications.[45]

These recommendations were accepted by the government and via DST a variety of programmes and actions have been taken since 1985 that have greatly accelerated India's forward movement into biotechnology. Chief among these was the establishment of a separate Department of Biotechnology, with independent funding to oversee and co-ordinate the planning and implementation of numerous programmes and projects being pursued by the DBT and other agencies.

Apart from these activities, which includes being the nodal point for bilateral and multilateral collaboration, DBT has three main sets of activities - directing and support of national R&D projects focussed on specific problems; manpower creation and infrastructure development. On the research side the DBT operates in two modes - via the recommendations of scientific committees to identify and fund basic research in 9 topics at institutions throughout India; and through "mission mode" projects which involve applied R&D.[46]

The strategy adopted by DBT (in co-operation with the UGC, ICAR, ICMR and the Department of Ocean Development) for developing trained manpower in biotechnology centers around the creation of "model" systems of world class post-graduate and post-doctoral teaching in selected universities and institutions. The best students at these institutions are offered DBT studentships while the Department also makes major contribution for specialized research facilities and buildings, for expanding and upgrading

[45] These areas of research interest were genetic engineering, photosynthesis, tissue culture, enzyme engineering, alcohol fermentation and immunology and all have received considerable attention through the 1980s.

[46] The mission mode projects for which DBT has responsibility are in the areas of prawn and fish production, poultry production, production of immunodiagnostics and immunological approaches to fertility control.

faculty positions, for visiting professors and overseas travel, etc. Over twenty higher educational institutions are now either affiliated with this programme or have started their own specialized courses generating already perhaps 2000-3000 highly trained young researchers. In addition to this core exercise, the DBT has launched an impressively wide variety of other training initiatives.[47]

In addition, DBT has embarked on a major programme of infrastructure creation to support biotechnology R&D. Selected institutions such as IIS, the National Institute of Nutrition, the Centre for Biochemicals, and JNU have been provided with the financial support necessary to upgrade their research facilities to world class standards while at the same time some entirely new institutions with specific research and training mandates have been created as well. Among these are the Institute of Microbial Technology[48], three Genetic Engineering Units; the National Facility for Oligonucleotide Synthesis; the National Facility for Blue Green Algae Collection, the National Facility for Plant Tissue Culture; the National Animal Facility; and the Biotechnology Information System. Other infrastructural facilities are also being established such as facilities for the import and distribution of fine biochemicals; for the production of enzymes and biochemicals; and for biochemicals engineering research and process development.

In addition to the activities of the DBT, both the DST and the CSIR, as a result of government decision to target biotechnology, increased substantively their allocation of resources to biotechnology R&D projects and to strengthening institutions carrying out biotechnology related research. DBT is also actively involved in providing financial support and co-ordination to these units.

For example, the DST became the lead agency for negotiating the citing of the U.N. funded International Center for Genetic Engineering and Biotechnolgy, a major new international training and R&D institution focussing on developing country problems whose location in India will enormously enhance India's own biotechnology capabilities. The CSIR greatly increased resources going to the Centre for Cellular and Molecular Biology, established in 1977, and now recognized as one of the best equipped biotechnology laboratories in the world. With 150 Ph.D. researchers distributed into eleven multidisciplinary groups, the Centre is capable of carrying out leading edge research projects in diverse areas such as primary culture and cell biology, the synthesis and structural analysis of biomolecules, and

[47] Among these mechanisms is a placement unit for post-graduate students, Biotechnology National and Overseas Associateships, Visiting Scientists from Abroad Programme, technician training programmes and training courses for industrial R&D personnel.

[48] Though its main facilities are still under construction, the Institute has already developed a simplified process for purification of urukinase from human urine; an improved yeast strain for ethanol production that gives 14.5 per cent (v/v); a rapid method for identifying rifamicin B producing colonies of Nocardia medirranei; and techniques for the selective delivery of antileishmanial drugs to macrophages. In addition IMTECH has a variety of major projects planned or underway in which it is looking for international collaboration. These projects include the construction of expression vectors in S. cerevisae; the development of antifibrin monoclonal antibody; the isolation and purification of streptokinase; the development of DNA probes for detecting microflora; the diagnosis of oil-bearing formations and the mass production of monoclonal antibodies. The institute also plays host to three national facilities - Microbial Type Culture Collection; the Biochemical Engineering Research Centre and the Distributed Centre for Enzyme Engineering.

the investigation of biomolecular structures using techniques such as optical rotatory dispersion, circular dichroism and NMR.[49]

Similarly, the ICMR established the National Insitute of Immunology which in a few short years of work has generated significant breakthroughs, some of which are commercially applicable. One area that the NII concentrates on is immunocontraception where its work is oriented towards the production of vaccines for controlling human and animal fertility. It has recently developed a product for animal birth control under the trade name TALSUR. The vaccine is being successfully used for castration of stray dogs and of cattle. Another important product that has already undergone the first phase of clinical trials is a vaccine against pregnancy hormone, the human chorionic gonadotropin (HCG). In addition, NII has already produced diagnostic kits for pregnancy, amoebic liver abscess, brucellosis, typhoid, and a DNA probe for M. tuberculosis as well as a genetically engineered vaccine against rabies.

Another major research area is embryobiotechnology. Here, its main research themes are embryo transfer in buffaloes; the maturation of buffalo oocytes invitro; the microinjection of human growth hormone; gene constructs in fish embryos; and the purification of genetically engineered human growth hormone.

NII also has several collaborative programmes with institutions abroad. It collaborates for example with the Institute of Protein Research in the USSR in peptide chemistry, gene expression using invitro translation system; protein crystallization in space; and structural studies on macromolecular complexes and has a collaborative programme with the Pasteur Institute under which a monkey model for hepatitis non-A and non-B has been developed.

It is still relatively early days and there is much to be done particularly compared to the scale of India's needs and problems where biotechnology will have an impact. But there can be little doubt that as a result of the focussed efforts of the government, India has begun to generate skilled manpower resources on a substantial scale; it is building up an in-depth knowledge base that makes it a world leader in several specific fields; and it is gradually laying down an impressive research infrastructure. All of these accomplishments are on top of the formidable manpower and research resources that have already been created in areas such as agriculture and health via 40 years of generous state support.

Taken together, these scientific resources already provide the base for India to participate in a wide array of more than 20 international collaborative R&D programmes in biotechnology, including some major research and commercialisation activities with the U.S., France and Germany. Nevertheless there is still great scope for further collaboration in research and genuine interest was expressed during the interviews in expanding collaborative activities with the EC.

However, while there is great confidence in Indian capabilities on the research and science side, there are, from India's perspective, many more questions over the country's industrial capabilities in biotechnology. Our expectation, and that of some of the Indian experts interviewed, is that the expansion of industrial capacity will for quite some time yet take

[49] Major projects are concerned with the mechanisms of cell division and malignant transformation; the molecular basis of sex determination; the structure and confirmation of proteins and nucleic acids and their interactions; the secretion and transport of protein ribonucleases; protein degradation; micelles and membrane active proteins; molecular evolution and proteins sequence data analysis; mathematical modelling of genetic and metabolic processes; the genetics of osmoregulation in E Coli; the initiation of transcription in yeast; the use of Lanthanium in scanning electron microscopy; and the flow sorting of mammalian chromosomes.

place on the basis of imported technology - though a few of the biotechnology start ups funded with venture capital look promising.[50] This situation also offers possibilities for EC collaboration but ones that would differ significantly from the more straightforward areas of research collaboration between labs. Here the attractions of developing and producing biotechnology-based products destined for India's enormous agricultural market are significant. The present government could be expected to look with favour on proposals for industrial collaboration in biotechnology that had agriculture and rural problems as a focus.[51] The problem of course is that for obvious reasons, foreign biotechnology firms have not signalled their interest in moving into this area. It would be a major and long term challenge for the Community to launch a biotechnology initiative combining research and production activities and aimed at the Indian agricultural sector but the returns to Europe and to India could be enormous.

[50] For example, Biocon is a highly successful start-up financed by venture capital and involved in the production of enzymes for the brewing, distiing, dairy baking and animal feeds industry as well as for the pharmaceutical sector. The company exports 50 percent of its turnover and has recently developed a new, 110 percent export-oriented product (for the food industry) that is already attracting considerable advance orders from Asia and Latin America.

[51] Interestingly, one of the key factors that prevented the Janata government from cancelling the Rajiv Gandhi-agreed Pensacola project was the fact that Pepsi had committed itself to investing in export-oriented agricultural projects.

ANNEX 4 : VENTURE CAPITAL INITIATIVES IN INDIA: CREATING THE RIGHT CONDITIONS FOR ENTREPRENEURIAL EXPANSION IN HIGH TECH

During the late 1980s, as part of the liberalization process, the Indian government permitted the first steps to be taken in the creation of new sources of finance to support the emergence of innovative, start-up firms and risk-taking, technology development projects within established firms. While still small, these initiatives are an important indicator of the changed business environment in India and thus merit close monitoring. They also indicate possibilities of combining European financial assistance with collaborative technology development projects.

Domestic resource mobilization in India has been a notable success with national savings rates during the 1980s being in the 22-24 per cent and household savings in the 15-17 per cent range. This occurs via a wide range of savings mechanisms linked to the formal financial sector and the spread of banking offices (from 8300 in 1970 to 65,000 currently) under the control of mainly state-owned commercial banks. Until recently (see Part II), this has allowed India to finance its declining public sector savings rate and the growing central deficit with low inflation and little effect on private investment.

The development finance sector consists of national and state level banks and investment institutions. The premier national development banks - the Industrial Development Bank of India (IDBI), the Industrial Credit and Investment Corporation of India (ICICI) and the Industrial Finance Corporation of India (IFCI) - among other functions, concentrate on channelling long-term finance to large private and joint (public/private) sector companies. The State Finance Corporations (SFCs) and the State Industrial Development Corporations (SIDCs) are promotional agencies of state governments who extend loans and take equity shares to fund the start up and expansion projects of medium sized companies.

This system of financing has evolved primarily to support industrial projects carried out by existing firms in the large and medium scale category. Some of the national and state level banks have begun to offer a wider array of services in response to the delicensing policy of the Government. Yet despite these more liberal lending policies, the development finance system found that during the 1980s it was not able to respond adequately to the capital needs of the small, technology intensive, start-up firms that began to emerge in that period.

To a certain extent, India's capital markets were able to act as an alternative financing mechanism for these firms. Based on 14 regional stock exchanges, the capital market system is one of the largest in the developing world, has over 4000 companies listed (more than any other country except the U.S.) with a market capitalization similar to Spain or Denmark and more than double that of Korea and Mexico. The latter part of the 1980s saw a boom in these markets and more scope was provided for financing start ups via new issues. However there are still many problems associated both with the as yet underdeveloped nature of India's capital markets and with the classic problems that high technology start-up firms have always faced when looking solely to the capital markets as a source of growth financing.

In response to this gap, a number of national and state institutions began in the late 1980s to create funds for technology development and venture financing using their own resources, those of institutional investors, and from bilateral and multilateral sources provided by agencies such as the World Bank, U.S. AID, the Asian Development Bank, IFC and the Commonwealth Development Corporation. Among the main institutions now actively involved in venture capital and technology development financing are ICICI, IDBI, IFCI, the State Bank of India, Canara Commercial Bank (3rd largest in India), Andhra Pradesh Development Corporation and Gujarat Industrial Investment Corporation.

The efforts of ICICI to enter into this area of financing are worthy of note since ICICI has earned a reputation as one of the most professionally managed and effective development finance institutions in the developing world. It offers a wide range of services, recently diversifying into areas such as merchant banking, leasing, hire purchase and credit rating while, in addition to its operational activities, it also advises the government on industrial issues and generates new ideas for improving the financial markets.

In 1988, after a very successful involvement with an innovative U.S. funded project designed to foster U.S.-Indian high technology joint ventures[52], ICICI decided to develop a major capability to promote and finance advanced technology development in Indian industry. It is now doing this through two mechanisms. The first involves direct support to technology development within existing firms via the activities of a specialized Technology Group and a high-powered Technology Board presided over by ICICI's chairman. This Group advises firms where to look for technology and joint venture partners in India and abroad, structures finance for R&D projects and acts as a conduit for directing commercially promising ventures and ideas to ICICI's venture capital arm.

The Technology Development and Information Company of India (TDICI), based in Bangalore is ICICI's venture capital arm and was created in 1988 to provide venture financing to commercial, market oriented technology ventures. It does this by managing a series of venture capital funds subscribed to by domestic and international financial institutions as well as corporate and private investors. Presently it has three such funds in operation and planned with a subscribed value of Rs 105 crores ($65 million) and has already supported more than 60 projects with another 50 in the pipeline. As Table 32 shows, the projects cover a wide range of innovative products and services with niche market potential (both domestic and export) ranging from alloys and fine chemicals to advanced engineering products, biotechnology, software and services, with an average value (in 1989) of $500,000, projected sales of between $750,000 to $4 million and royalties of between 1 per cent and 7 per cent of sales.

Collectively, Indian venture capital initiatives have probably supported already more than 100 new start-up, technology-intensive firms, with another 300-400 projects in the pipeline or expected to emerge over the next few years. While these may be small numbers compared to the venture activities in the industrially advanced countries, they are nonetheless significant in the Indian context. Indian and foreign financial sources are increasingly willing to support innovative technology development projects and there seems to be no shortage of entrepreneurially minded young Indian scientists willing to try commercializing their ideas into marketable products. These developments, along with the moves toward liberalization and the proliferation of other initiatives to promote innovation, underline the much more upbeat nature of the changing business climate in India and the

[52] This programme, called PACT, is sponsored by AID and finances joint ventures between Indian and U.S. firms for the development of technology-intensive products and process with major commercial possibilities.

considerable potential for greater European private sector involvement individually or collectively via some form of EC sponsored project.

TABLE 32 : Selected start-up high tech ventures assisted by TDICI

Technology area and project description	Level of support ($m)
Computer hardware	
- Dev and mfr of intelligent notepads	2.76
- Commercialization of data system for dairy applications	1.47
Computer integrated manufacture	
- Dev of CAD/CAM system for mfr of garments	2.36
Computer software	
- Dev and commercialization of expert system for structural engineering	2.12
- Dev of integrated software package for UNIX	2.94
Telecommunications	
- Dev and mfr of miniature sensitive relays	1.02
- Dev and mfr of terminals for fibre optic communication systems	3.53
Environmental engineering	
- Dev of distillery effluent treatment system	2.64
Chemicals and polymers	
- Dev of immobilized enzyme used in mfr of 6 APA	2.06
- Dev of engineering polymers coatings	1.88
Special Materials	
- Dev of filament wound FRP tubes	0.65
- Dev of heat resistant synthetic rubber lining compounds	0.10
Biotechnology	
- Dev of restriction enzymes and allied molecular biologicals	1.53
- Dev of ornamental flower, vegatable and fruit micro-plants	5.18
- Dev of fungal enzymes such as pectinase	0.47
- Dev of bioprocess vaccines and immunodiagnostics for poultry	2.47
- Dev of blood platelet aggregation measurement kits	0.94

Source : Adapted from information provided by TDICI

ANNEX 5 : INDIA-USA S&T RELATIONS: LONG-TERM NEGATIVE SIDE EFFECTS FROM THE CONFLICT OVER INTELLECTUAL PROPERTY RIGHTS

A brief analysis of the evolution and current state of U.S.-Indian S&T relations provides a valuable insight into the somewhat jaundiced attitude of segments of the Indian S&T elite that we encountered towards the value to India of "mutually beneficial" international S&T collaboration. It also offers a mechanism for exploring aspects of contentious issues such as intellectual property rights where India and the EC have yet to resolve their differences.

U.S.- Indian political relations have always been subject to tensions that have sometimes spilled over into the commercial technology arena but have not until very recently affected scientific collaboration.[53] A recent example is that in the early 1980's, Indian-US private sector co-operation and technology transfer arrangements came under the shadow of US Export Administration Regulations. During that period, the US (driven by Reagan's anti-Soviet rhetoric) imposed restrictions on the transfer to India (and 14 other countries) of an ever widening range of "dual purpose" technologies that they feared would find their way to the USSR. India's 12 year attempt to acquire a $12 million Cray XMP 14 supercomputer for meteorological, health, agriculture and physics research purposes got tangled up in this impasse[54] while a good deal of suspicious and unwanted attention was paid by the U.S. to India's nuclear and space programmes for the same reason.

Yet throughout these years, India and the U.S. carried on, via the joint commission mechanism, an active programme of scientific exchange and collaboration in the context of a very sizeable foreign aid programme. This is a positive aspect of relations between the two countries - though some of the policy makers interviewed now wonder how beneficial this past S&T co-operation was to India. They argue that whatever short-term benefit these programmes may have generated, they are believed to have helped create the "demand" conditions that lead to the large, and now much criticised, outflow of Indian scientists and engineers to the U.S. during the 1980s.

In 1982, politics played a major role in leading the U.S. (under Reagan) and India (under Indira Gandhi) to launch the Science and Technology Initiative (STI) and agree its renewal in 1985. This programme provided an umbrella for a wide ranging set of "mutually beneficial" S&T collaborations (of a traditional nature) in fields such as agriculture, health, energy and the weather. It also set the stage for a distinct warming of technology relations during Rajiv Gandhi's reign when India made certain concessions to the U.S. in order to acquire dual purpose technology as part of its measured (arguably cynical) response to an

[53] This pattern can be traced back at least until the early 1960s when the U.S. pulled out of an aid commitment to supply India with steel making technology because it was going to a public sector (e.g. "socialist") enterprise - at which point the Indians promptly turned to the Russians to supply the technology. Similar problems crept in as a result of the U.S. pro-Pakistan tilt in the 1970s and early 1980s; over U.S. irritation towards Indian's non-aligned posturing during the same period; and towards US TNCs as a result of the Bhopal disaster.

[54] For example, although the sale of the Cray to India was finally agreed certain restrictive conditions were attached such as the Pentagon's insistence that U.S. personnel be assigned to it to prevent leakage of the technology !

American strategy that sought to wean the country away from the Soviet Union through a diet of military technology.

However since 1988, the Indian-U.S. STI and wider scientific collaborations have been negatively affected by U.S. policy on IPR. In April 1987, the President issued an executive order to the effect that the U.S. government must take into account whether countries adequately protect IPRs, while negotiating science and technology agreements. After much hesitation on the Indian side, the STI was renewed in October, 1988 but the atmosphere within which the different projects went forward became increasingly acrimonious. The U.S. first tried to use co-operation via STI to get India to change its patent policies by offering various inducements such as inclusion of high technology areas in the STI.[55]

When this was resisted and India carried its opposition into the multilateral Uruguay-round trade talks, the U.S. significantly widened the scope of its demands to include reforms of India's treatment of foreign investment and domestic competition in manufacturing and services. This culminated in the placing of India on the Super 301 "priority watch" list in 1989 (along with 8 other nations who were all subsequently removed) and the public insistence that India accede to a set of what most Indians felt were grossly unfair demands.[56] After months of impassioned negative reaction in India, the threat of sanctions against India was not actually removed until June 15, 1990 - when the action by the U.S. was suspended pending the outcome of the Uruguay round talks.[57]

The net impact of this sustained period of controversy on STI collaboration was very negative as several of the projects became extremely controversial. Fierce criticisms were

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[55] The U.S. (and for that matter EC) opposition is focussed on the Indian Patents Act of 1970 and is criticised because : (a) it has broadened considerably the grounds for compulsory licensing; (b) allowed unrestricted use of patented inventions by the government for its own purposes; (c) allowed the use of patented inventions for purposes of experiment; research and teaching; and (d) resulted in greatly revenue flows to the original inventors.

In fact, the India Patent Act has not transformed Indian industry into a tiger which poaches on world intellectual property rights. Nr has it resulted in any marked decline in foreign patenting activity in India or in the willingness of foreign firms to transfer technology. Data on patent applications between 1980-1985 show that in aggregate terms the total number of Indian patents has experienced a decline, while those by foreign countries has shown a steady increase. This is particularly so in the case of the US. its applications increased from 570 in 1980-81 to 968 in 1985-86 and constitute more than two-thirds of total applications by foreign countries. Other countries active in patenting in India are Germany, UK, France, Japan and Switzerland.

From the Indian side strong patent regimes are regarded as fostering the abuse of monopoly rights by those with patents, especially by MNCs, who tend to abuse these monopoly rights which result in a decrease of social utility. India has catalogued some of these abuses. See Government of India, "Standards and Principles Concerning the Availability, Scope and Use of Trade Related Intellectual Property Rights", Mainstream (New Delhi), August 5, 1989, pp.25-31.

[56] India was among the 8 and has been required to : (i) assure improved and adequate patent protection for all classes of inventions, (ii) eliminate discrimination against the use of foreign trade marks, (iii) register service marks, (iv) improve access and distribution for US motion pictures, (v) improve enforcement against piracy, (vi) include an intellectual property annexe to the bilateral science and technology agreements, and (vii) participate constructively in multilateral intellectual property negotiations.

[57] Not surprisingly it is a matter of some debate within India as to whether U.S. pressure on IPR and other issues had any impact on the Government's recent continued movement towards greater liberalization on the industrial policy front. This is hotly denied by the government. However the reality is that India was in a very weak bargaining position on these issues at the national level. The US is India's leading trade partner with the two-way trade exceeding $ 5.5 billion in 1988. It accounts for 19 per cent of India's exports and 11 per cent of its imports, many of the imports being of technically advanced items, such as Cray computers; while India accounts for under 1 per cent of US trade and is in surplus to the tune of around $ 800 million.

(and still are) voiced in India that the agreement was biased in favour of the U.S. so that, for example, data generated during the health and meteorological research projects would only benefit U.S. commercial interests. Thus STI has come to be seen by large parts of the Indian S&T policymaking and scientific establishment as a typical example of one-sided, exploitative S&T collaborations that the west usually imposes on developing countries .

From the U.S. side, interest in STI definitely waned during the 1988-June 1990 period as only projects without any IPR implications were undertaken. It is also argued that recent reductions in U.S. aid commitments to India (down to $400 million) are linked to the IPR/STI conflict. Indian scientists now feel that the programme was never genuinely mutually beneficial and only lasted as long as a semblance of symmetry and reciprocity could be maintained - a charade that was dropped as soon as wider political pressures were brought to bear by the U.S. side.

Given that the 301 decision was just taken, it is difficult to gauge the future effect on STI and wider scientific collaboration with the U.S. (such as the formal collaborative arrangements now in place with DBT and the Department of Space) but there is certain to be a cooling of relations and little real collaboration until after the completion of the Uruguay round.

There seem to be fewer problems on the technology and investment front. Interviews indicated that except for narrow segments of U.S. (and European) industry, most firms were not put off making investments due to Indian IPR restrictions. During the period from 1987 to 1989 when the IPR conflict was at its height, the U.S. remained a major source of investment funds and technology with new equity investments recording a dramatic increase between 1987-1988 alone from Rs 290.5 million to Rs 970 million. And interestingly, U.S. AID has maintained its commitment (begun initially through the PACT programme described above) to support the venture capital initiatives of ICICI and IDBI to the tune of $30-35 million per year over the next three years.

As far as the EC initiative is concerned, the relevance of this situation was brought home during a number of interviews where it was made very clear that India's sensitivities towards outside pressures of the sort applied by the U.S. have been greatly exacerbated. The Community needs to note this fact in the formulation of its strategy to pursue greater S&T collaboration with India. This issue is discussed in detail in Part I.

ANNEX 6 : SOME ANECDOTAL EVIDENCE ON NEW FORMS OF INDUSTRIAL DYNAMISM IN THE INDIAN CONTEXT

The thrusting, dynamic entrepreneur and dedicated production manager willing to work all night in order to meet a deadline are common characters in the Asian NICs and lay behind much of their economic success. However such actors have historically been in very short supply within the Indian industrial scene. However there can be little doubt that during the 1980s, the landscape of the Indian manufacturing and service sectors began to sprout, in ever greater numbers, new growths of entrepreneurial and managerial dynamism that fit the Asian NIC model.

As we indicated in Part I, there are many who dismiss the significance of these new industrialists, attributing their meteoric rise to the consumer-and debt led boom of the Gandhi administration. In the eyes of these perennial critics, Indian industrialists (and the bureaucrats who still manage and control large parts of the economy) continue to operate within the same mercantilist/protection-oriented mentality that has stifled innovation and competitiveness among Indian industry for the last four decades.

Undoubtedly there is more than a little truth in these charges. However, our research and interviews also generated clear, if still anecdotal evidence, that the changed business environment created by liberalization has begun to foster an industrial class with a progressive outlook towards technology, quality and competition that bodes well for industrial development in India - and implies a much more fertile ground for European collaboration than has previously existed.

A number of features of this new environment and the different actors involved are worthy of note. First, the conditions are pervasive and there are cases of this new dynamism to be found in many areas - not just the high-tech start up firms supported by the venture capital initiatives outlined in Annex 4.

For example, there have been some highly successful start-ups in the service sector such as the "Skypak" group who, linked in with DHL, generated a number of innovative services tied to the rapid delivery concept in a number of market niches such as banking (where overnight inter-city clearances were offered) and is now turning over $20 million annually as largest courier service in India. Another is the Apollo Group operating 3 specialty hospitals (with 14 more planned) managed on a corporate basis, funded by private venture capital and profitable enough to keep 30 per cent of hospital capacity available for free treatment of the poor - a strategy that has lead to generous government treatment in relation to customs and import duties.

Second, similar dynamism has been shown by the colossal industrial houses that grew sprawling and cumbersome under conditions of protection, and by tradtional industries such as garments which had never performed anything like their counterparts in the NICs. The Tata Group is one such industrial house with widespread interests in engineering goods, chemicals, commodities and hotels who at the beginning of the decade was largely assumed to be a moribund colossus unable to overcome a long period of stagnation and destined for dismemberment.

Yet in the space of five years, the Tatas have become major players in the competitive, fast moving worlds of computers (Tata-Unisys) and software (Tata-Consultancy); are in the midst of a massive multi-billion dollar programme of investment and technological refurbishment in their core engineering and refining activities; and are poised to enter telecommunications, financial services and aerospace. These plans are underpinned by a strong emphasis on exports and by signs that the Group for the first time is willing to forge links with foreign firms in order to achieve an international presence. They, and the other large industrial houses, retain significant influence within government and could be expected to be powerful partners in any collaborative project they thought would meet their interests.

In the garments industry, Indian clothing firms have suddenly discovered just how lucrative and fast growing exports markets can be - and not just in low wage products but in design intensive, higher value-added garments. The industry increased its exports by many orders of magnitude during the 1980s to reach $1.4 bn in 1989 with this expected to rise to $5.1 bn by 1994. One firm visited specialized in high fashion clothes designed under contract for it by French, German, Italian and American designers and exported 75 percent of its $15 million turnover to high fashion shops elsewhere in Asia and the Middle East. A technology and design tie-up with a European or Japanese firm leading to even greater production and exports is on the cards.

This may not be the sort of commercial success the EC wants to hear about. Nevertheless, there are many more such Indian firms, operating in the traditional and low technology segments of the market, who are just beginning to mature under the new conditions, who are looking for innovative partnerships with foreigners and who are determined not to be held back by domestic or international protectionist barriers.

Third, while the Indian public sector boasts more than its fair share of inefficient, technologically stagnant and uncompetitive enterprises, it is also the case that a number of Indian public sector enterprises began, during the 1980s, to behave very much like private sector firms in seeking to be nationally and internationally competitive in their engineering, production and management activities. They have now developed both R&D and product/process engineering capabilities and, by seeking and winning a large number of international contracts, have not only proved their international competitiveness but have built up valuable overseas project management experiences.

Among those who fit this bill are the Computer Maintenance Corporation (CMC) Ltd, Rail India Technology and Engineering Services (RITES), Engineers India in the petrochemicals sector, Walcend Industries of Bombay in advanced civil engineering, UPTRON, the Uttar Pradesh State electronics corporation and Hindustan Aeronautics. There was a strong sense given during the interviews that these companies could play a key role as "gateway" companies for any major technology intensive EC collaborations involving integrated R&D, engineering and production activities (in India or abroad) that would also require sizeable state investment from the Indian side.

Another category of dynamic public sector agencies that could play a role in Community projects are those that act as development promotion or development finance institutions such as the SDICs mentioned earlier. There are 26 in total and many of them are unprofitable and poorly run. However, some of these agencies such Andhara Pradesh Industrial Development Corporation, the Gujarat Industrial Investment Corporation, and those from Maharastra, Uttar Pradesh and Haryana state have performed very well in recent years in their main task of extending risk and development finance to small and medium sized firms and to joint sector enterprises for specific, increasingly technology-intensive projects.

These agencies have developed cadres of competent and professional managers who operate within an internal culture that is highly business and entrepreneurially oriented. With their links to both the more dynamic actors in the productive sector and with state R&D institutes, some of which are of high quality, they could prove to be very useful partners for the Community.

Fourth, particularly during the latter part of the 1980s, a number of medium-to-large Indian enterprises (though not as large or as sleepy as the big houses) who had developed within the comfortable context of a highly protected industry, began to court and be courted by large, mass production oriented foreign enterprises seeking an Indian base that would provide access to the domestic market, allow significant cost savings on any re-exports back to the home market and provide a launching pad for exports to the East. This is an entirely new form of foreign linkage for Indian firms because it gives access to technology, marketing and distribution on an international level that these previously inward looking firms had not been previously interested in acquiring.

It is a pattern that seems to be carrying on into the 1990s. For example there have been recent indications by large European food and cycle manufacturers of plans to form equity tie-ups with large Indian producers in the same sectors. In both cases, a good deal of marriage brokerage was required to cement the attraction and this was provided by specialized agencies of the European countries involved - suggesting an obvious angle for EC involvement in the future.

Finally, we found considerable evidence that a wide range of Indian enterprises have begun to grapple with challenges posed by the new emphasis on quality as a determinant of international competitiveness and the current worldwide fascination with the new management and production practices emanating from Japan. To those familiar with the traditional, rather cavalier attitudes to quality of many Indian firms, this may come as a surprise but there is little doubt that concepts such as JIT, TQM, kaizen and TPM have begun to be understood and embraced by Indian industry. These ideas are entering into the industrial sector via different routes.

Japanese motor vehicle, cycle and component firms who were permitted to establish subsidiaries or joint ventures in the mid 1980s are all now well into the programmed transfer of their indigenous management practices to their local production affiliates and component suppliers. The effects on productivity of using these techniques in Indian conditions are impressive. One firm we visited that was producing Yamaha motorcycles under license was using their production approach to manufacture 6000 bikes monthly using 640 employees while in the same group, production of an indigenous bike using old methods required over ten times as many workers (8000) to turn out less than twice as many bikes (10,000)!.

Similarly, western TNCs who have adopted these practices in their domestic plants have begun to introduce the new techniques in their Japanese subsidiaries as well. One such U.K. firm has found that its Indian subsidiary has achieved the best productivity gains of all its plants world-wide using a kanban system of component delivery via ox-drawn carts!

The demonstration effects of these examples of successful organizational change have been very important in terms of alerting more progressive Indian firms to the competitive advantages inherent in adopting the new practices. This fact, and their appreciation of the growing importance of quality certification at the international level (e.g.ISO 9000) have lead to escalating demands for technical assistance in these areas. As a result, many industrial associations, including the national bodies such as the Confederation of Engineering Industries, FICCI and Assocham have either regular conferences and workshops where managers and entrepreneurs are introduced and trained in these practices, or as in the case of CEI have actually set up a TQM division working full time on spreading the gospel. While some of this demand is being met from local experts, there is a a considerable shortfall in availability, opening up possibilities for foreign consultancy services.

So far this demand is still limited and is being met in only an ad-hoc and partial fashion by foreign consultancy firms. Not surprisingly, Japan seems to be the only country willing to provide any sizeable measure of technical assistance in the management training and quality improvement areas via JUSE sponsored seminars and OECF funded training programmes. One such seminar was held in April 1990 and was attended by more than 100 senior executives from leading Indian engineering firms.

It is still early days yet in the JIT/TQM movement in India. Nevertheless, three points can be noted. First if it does take off at anything like the scale that it has done in the U.S. and parts of Europe, the market for these "producer services" will be enormous. Second the nature of the Japanese involvement in the provision of technical assistance in this area so far suggests it may be part of an attempt by the Japanese government to establish a bridgehead in India for Japanese DFI in the future. This is standard practice as far as Japan is concerned, and has certainly happened throughout the ASEAN countries with the net results that are well documented in the Thailand case study. Thirdly, the possibility of the EC developing a programme of technical assistance in the area of quality, standards and new management practices through the participation of European consultants and European firms was raised in our interviews and is worthy of further exploration.

ANNEX 7 : INDIA'S FORMAL R&D SYSTEM: SELECTIVE EXCELLENCE AND THE PURSUIT OF SELF-RELIANCE

It is inherently difficult to formulate any kind of informed assessment of the strengths and weaknesses of the Indian R&D system because of its scale and complexity and because of the limits of the SAST research format. Nevertheless, our research has generated some general and specific insights and information that are worthy of note.

As noted earlier there is a widespread consensus among S&T policy analysts inside and outside of India, among Indian industrialists and confirmed to a certain extent by our interview findings, that the country's sizeable R&D system has not yet made a significant contribution to the country's industrialization effort. The evidence supporting this contention is substantial and relates to the poor quality of the basic research and scientific education being carried out in its universities and labs, the very limited success of CSIR labs in developing and transferring technologies of use to Indian industry, and the inability of the massively well funded defense and space related research systems to meet many of the technological development targets set for them.[58] Needless to say, these problems pose enormously difficult challenges for Indian science policy.

However, from the perspective of the EC, any interpretation of this damaging assessment of Indian R&D capabilities needs to be tempered by an appreciation of two other facets of the state of science in India that were also brought out by our interviews. First, there is equally widespread agreement and evidence that the Indian science and R&D systems also exhibits a number of pockets of excellence where the country, if not a world leader, is certainly capable of state of the art, internationally competitive research in basic and applied science.

We have already noted the country's growing capabilities in software and biotechnology, its long established expertise in space technology and the premier positions that many Indian scientists and engineers hold abroad. In addition to these, the following is a small sampling of the other evidence that emerged during our interviews and research attesting to India's impressive, if selective, S&T credentials.

The country, in the context of institutes such as the National Physical Laboratory, the National Remote Sensing Agency, the National Geophysical Research Institute and Anna University possesses outstanding capabilities in natural resource assessment involving ground and air observation, pattern recognition and extending to highly sophisticated satellite-based remote sensing and imagery reconstruction.

[58] For example, CSIR recently reviewed standards in Indian basic research and scientific education and concluded that only 2 percent of basic research was relevant and in 80 percent of India's universities, Ph.D supervisors met with their students less than once a year; a recent study of CSIR institute, the Central Mechanical Engineering Research Institute, showed that in the last decade only 5 products or processes were released annually to industry and most were not used-this parallels the performance of other CSIR labs where research has shown that between 1955 and 1980, eight labs had put forward only 295 processes for commercial exploitation, only 50 were actually released and production started in less than 15 percent of the cases. See "Indian Science : Rotten to the Core", Nature, Vol 345, June 1990, p.651; Govindarajulu, 1990, Economic and Political Weekly, June 4, 1988. For a critique of the accomplishments of India's defense and space research programmes see "Technological Self-Reliance : Systemic Constraints", Economic and Political Weekly, June 11, 1988.

Indian oceanography capabilities, particularly as manifest in its research vessels such as the Sagar Kanya and its National Institute of Oceanography are recognized as world class and have resulted in many invitations for research collaborations with Germany and other countries. The wind testing and model building capabilities at the National Aeronautical Laboratory as well as its instrument fabrication skills have allowed it to win a number of internationally tendered contracts in these areas.[59] The National Chemical Laboratory has recently made major breakthroughs in catalyst technology that have lead to joint ventures and lucrative licensing agreements with international firms.[60]

The Central Leather Research Institute, in collaboration with the TNO of the Netherlands have won global contracts for the risk analysis of chemical plants based on the work carried out on the Bhopal disaster by CLRI researchers. And finally, ample evidence was provided, via the existence of international collaborations, of India's outstanding reputation in pure and theoretical science in such fields as astrophysics and particle physics; pure and applied mathematics; surface studies and fast kinetics; and even superconductivity where researchers at a number of Indian institutes and universities (such as the IITs at Madras and Bombay, the Bhabha Atomic Research Centre, NPL and the Tata Insitute of Fundamental Research) were able to quickly duplicate and then advance the superconductivity breakthroughs that were actually announced by C.M.Verma (an NRI) of ATT labs in the U.S. at the International Conference of Valence Fluctuations held in Bangalore in January 1987.

From our perspective, such examples, and the considerable body of additional evidence that could be marshalled, do unquestionably attest to the strengths of Indian science in certain areas and indicate that whatever the overall weaknesses of the Indian S&T and R&D systems, there is certainly ample room for mutually beneficial collaboration with this system at the level of basic and applied R&D - probably more so than with any other SAST country. During our interviews, a number of proposals were put forward for co-operative projects related to these strengths.

Third, and directly related to the above, the science establishment, and the elite group of advisers and policy makers who direct the Indian science enterprise, despite acknowledging the country's R&D weaknesses, are fiercely proud of what they have accomplished so far and are passionately committed to the ideal of Indian self-reliance. This commitment does not extend blindly to autarchy, of course, but does mean that they are ready to accept the higher costs and lower benefits attached to the long struggle to build an independent scientific and technological competence in certain critical areas in order to avoid dependence on other countries. Such attitudes go to the heart of the nation's sense of self-esteem and identity for that reason must be respected.

These perceptions are deeply ingrained and without a doubt directly influence policy decisions vis resource allocation and international co-operation. For example, one of our interviewees pointed out that fairly recently India had rejected the opportunity of

[59] One example involved NAL winning a European contract to design and fabricate Light Combat Aircraft models for wind tunnel testing because its costs were four times less than those quoted for by European labs and its accuracy and quality were an order of magnitude better; in another NAL was awarded an international contract for the design and fabrication of multiplexing and demultiplexing satellite filters which they provided in half the time required and at a fraction of the cost.

[60] These have involved NCL developed catalysts for - the conversion of pyrolysis gasoline to aromatics; the manufacture of zeolite catalysts for hydrocracking; and catalyst technology for the manufacture of chlorphthalic anhydride, a plastics intermediate.

participating in a major co-operative R&D and production effort in aerospace precisely because they could not see how participation would contribute to Indian self-reliance. This is not an isolated example the same thing happened when Rolls Royce wanted to collaborate with NPL in the development of titantium powder.

The Indian science policy elite wears its national pride boldly and, in our opinion, with considerable justification, given the pockets of excellence identified above and the positive effect of Indian S&T accomplishments on the national character. Any attempt to involve India in a major S&T collaborative effort particularly in fields or sectors considered critical to their development effort will need to take careful account of the strength of Indian feeling about such issues.

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