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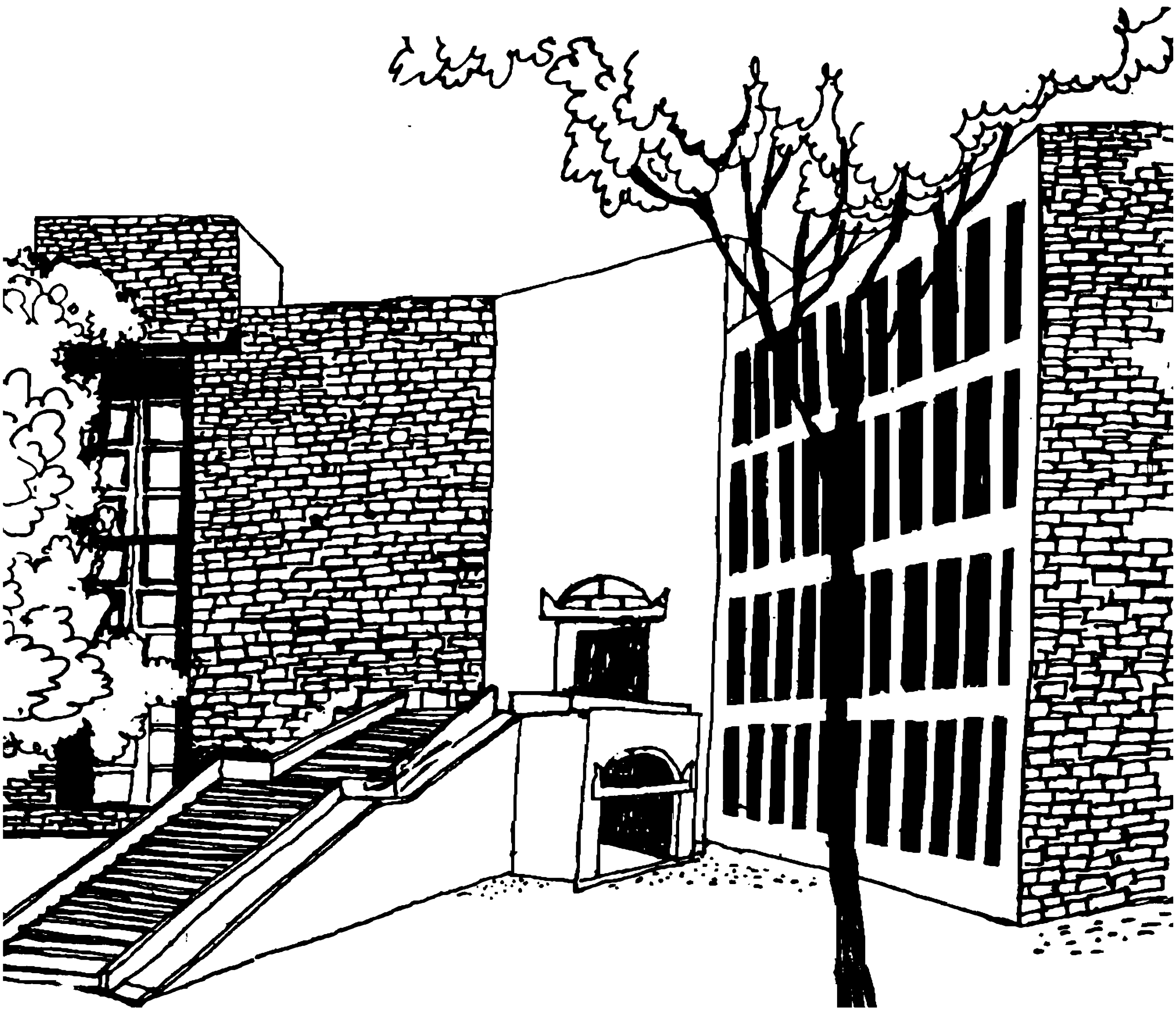

Linking Telecom Technologies: Complementarities, Capabilities and Policies

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Abstract

This paper is a preliminary exploration to develop a methodology for assessing the technological capabilities and needs of the telecommunications sector in India. It makes a case for strategic policy interventions to build adequate domestic capabilities in this crucial sector with significant externalities. We develop a model for mapping technological capabilities through the concept of a technology supply chain and establish the role of complementary assets (like manufacturing within and outside the sector) in developing and appropriating technologies. It is argued that policy initiatives need to be based on these considerations. A brief review of Asian experiences also supports this point of view.

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I. Introduction

The rapidly changing telecommunications technology has significantly changed the extent and quality of business and social life around the world including India. Telecom technology today comprises hi-tech electronics, semiconductors, new materials, computers, software and above all recent advances in physical sciences. As a result, traditional boundaries between industrial sectors or between firms are getting redefined. Policy makers all over the world are trying to grapple with this complexity and the speed of technological developments in order to choose the most appropriate trajectory of telecom development in their respective countries. Differences in technological endowments and stage of development complicates further the task of the State as countries have to continuously acquire and absorb technologies to provide enhanced access and varied services to its citizens. At the same time, there lies a promise of leapfrogging technological developments especially for those countries that have not sunk significant investments in older platforms of technology.

Till recently, telecom activity in India has largely been managed by the public sector - technology development by C-DOT (and erstwhile TRC); technology certification by TEC; equipment manufacturing by ITI, BEL, HCL; service provision by DOT etc. The new telecom policy has led to gradual privatization of many of these activities. These developments have brought to the fore several inter-related questions pertaining to technology which need policy attention:

(a) how do we plan to manage the changing technology needs as well as rapid introduction of new technology;

(b) how should we develop domestic technological capabilities to acquire, absorb, modify and build on new technology;

(c) if and how should we develop our design and manufacturing capabilities; should we focus on specific segments of telecom technology; and

(d) how should innovations in services be linked with changes in equipment technology ?

In this paper we highlight key issues that need to be considered while addressing the policy questions enumerated above. The above questions should be seen in the light of stated objectives of the National Telecom Policy of 1994. These include ensuring availability of telephones on demand as quickly as possible, making all villages accessible to telecommunication facilities, developing a modern digital network that is capable of providing state-of-the-art data, voice and video communications to business & industry, and developing India as a major manufacturer and exporter of telecom equipment. To put the subsequent discussion in perspective, we present some data on the current status and future requirements of telecom technology in the country. Table 1 provides the current status of telecom infrastructure and services in India. Some Planning Commission estimates of likely telecom developments in the country are reported in Table 2. And Table 3 summarises the production requirements of telecom equipments as projected in October 1996 by the Planning Commission for the 9th. Fifth Plan. It is evident that the penetration levels are low and our future requirements are likely to be extremely high if adequate telecom services are to be provided to large sections of the population. It needs to be emphasized that our equipment requirements are likely to be extremely high and local manufacturing may provide the only viable alternative due to the high foreign exchange requirements for importing such equipment. More on this later.

Some key technological developments in recent years have been integration of various media and telecom channels, digital compression, optical fibres and satellite communication. Since technology trajectory in this sector is a combination of 'science based[1]' and 'information intensive[2]' (Pavitt et al., 1989), innovation cuts across sectoral boundaries and requires significant R&D investments. Consequently, firms need to have access to complementary assets in order to appropriate full benefits of technology investments. It is partly because of this reason that one observes three simultaneous processes at work in this sector: (a) development of technology is requiring increased participation of a variety of other sectors, (b) software is starting to play an overwhelming role in telecom technology, and (c) technology developers are increasing their participation in the manufacturing of equipment as well as provision of services.

This paper is organized as follows: the next section outlines the chain which characterizes technology linkages in the telecommunications sector. We also identify the industry groups involved in each segment of this chain. To the extent feasible, we also describe the basic features of industrial structure in these segments and compile preliminary information on the major sources of technology. In section III we discuss the role of complementary assets in developing technological capabilities and identify their strengths & weaknesses in the Indian environment. This is done with a focus on transmission technologies. Most major developments in the last decade, that are likely to have significant impact on how we telecommute in the future, have occurred in the area of transmission technology. As we shall discuss later, this has been an area of significant weakness in India. This preliminary evaluation of capabilities will be put in perspective in the context of recent developments in some Asian countries (section IV). The final section explores some policy imperatives that can facilitate better co-ordination between technology developments, appropriability and policy regimes.

II. Technology Chain

Telecommunications technology can be broadly classified into three segments: transmission, switching and terminal technologies. Transmission technologies transfer information between two or more communicating entities that are spatially separated from one another. Switching technologies establish and release connections between two communicating entities. In addition, they manage the routing, billing and other administrative functions that are becoming associated with newer intelligent networks. Terminal technologies initiate and receive various types of electronic communication. Key transmission technologies include cables of various types (coaxial, dry core, jelly filled and optical fibre), radios (microwave, cellular and paging), and satellite (geo stationary, low and medium earth

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[1] In 'science based' industries (e.g., biotechnology, electronics etc.) in-house R&D activities form the basis of exploiting scientific advances in physics, chemistry and biology thereby enabling horizontal diversification into new product markets. Access to complementary assets plays a crucial role in such diversification.

[2] In 'information intensive' industries (e.g., services) devlopments in software and innovations by specialized suppliers provides the basis for technology development. This assists in efficient information processing and allows fusion of new technologies to develop new products.

orbit). Cables could be laid on land on submerged. Various switching technologies consist of manual, electro-mechanical and electronic switches. Electronic switches come in analog or digital variety. Size in terms of number of lines and distance further classify these technologies. For example, small exchanges carry less than 2000 lines while mega exchanges will have more than 40,000 lines. Similarly, terminal technologies are embodied in telephone equipments, fax machines, answering machines, modems etc. In addition, there exist a few related technologies that are vital in implementing the above systems. These include multiplexers, transmitting and receiving equipments for optical fibres, signalling equipment and earth stations. Given the linkages across these segments, changes in technology in one segment may necessitate modifications in others either due to compatibility problems or in order to fully exploit the potential benefits of new technologies. Often these linkages also provide incentives for firms to co-ordinate technological developments across and within these segments.

There is yet another aspect to technology development which pertains to developments in industries that are allied to telecom. For instance, the cables segment of the telecom sector depends on developments and supplies from the following industries: synthetic fibres, petrochemicals, plastics, rubber, electronics, ceramics, semiconductor, copper smelting etc. Similarly, the chain of industries that contribute to the developments in radio based telephony are engineering fabrication, injection molding, electrical equipments, electronics & instrumentation, software etc. Those responsible for the advancement of satellite technology are aviation, engineering, electronics, semiconductor, software etc. Advancements in telecom sector have often followed breakthroughs in one or more of these allied industries. Capabilities in the telecom sector, therefore, are a combination of strengths and weaknesses in these allied industries. The Indian satellite program as well as developments in the optical fibre technology, for example, were adversely affected by inadequate capabilities in the semiconductor industry within the country. It is crucial to identify critical segments, both in terms of strategic needs of various sectors as well as technological requirements, in order to focus our capability building efforts. Moreover, policies across these related sectors have to be co-ordinated in order to achieve desired results. Even selective policy interventions need to take cognisance of this inter-dependence.

At this point one can question the very purpose of policy intervention for technology development in this sector. For new entrants in a market which is not very mature, the role of policy is clearly to give guidance on strategic thrusts for the future, widen the application base, and provide for measures that may help in increasing the skills needed for the development of the sector. Developments could still take place, in the absence of the above, albeit at a very slow pace. The current sector scenario in India has the following characteristics:

* possession of basic technological capabilities for switching equipment but do not have indigenous designs for advanced versions;
* wide-base manufacturing capabilities for the above including MNCs;
* significant capabilities in the satellite sector and potential for further development;
* weak in other transmission technologies chiefly in the newer developments like cellular, optical fibre, broadband ISDN etc.
* potential for innovation in software for telecom applications;
* low sunk investments in telecom technology - potential to leapfrog;
* diversification & growth of the economy would require continuous investments in technology upgradation;

* innovations in telecom would be necessary for the growth of key industries like software, engineering, space etc.;
* newer technologies are being imported;
* absence of significant value-added services like teleconferencing, voice mail etc.

What implications does the above scenario have in terms of developing a strong and competitive telecom sector. Governments all over the world have provided support to develop hi-tech industry. Such support has taken various forms like research funding (e.g., sector based research funding agencies like NSF and NIH in the US, NSERC in Canada, National Science Council of Taiwan etc.), incentives for co-operative R&D (e.g., Sematech in the US), procurement programmes, state ownership, protection, export subsidy, etc. State intervention is justified on the basis of high spillover/externalities potential of hi-tech industries. Besides, hi-tech industries are considered to be strategically important (where control of key upstream technologies is crucial) and have significant learning potential. A similar argument has been put forward by Nelson (1992) vis-à-vis hi-tech industries like semiconductors, computers, and new materials for developments in downstream industries like telecommunications etc. He has the following to say about hi-tech industries:

> "Advances in these fields provide the building blocks, the key opportunities, for technical innovation in a wide range of downstream industries, from high speed trains to cellular telephones to commercial banking. Many observers noting this have proposed that the nation that wants its firms to be strong over the coming years in the downstream industries had better not let foreign firms control the key upstream technologies. This argument is prevalent in some newly countries, like Brazil, Korea, and Taiwan, as well as today's high income ones." (Nelson, 1992:365)

The interlinkages referred to above enhance the need for state intervention further because of high co-ordination needs and research costs especially at a juncture when the sector is being opened up for collaboration and competition ('nascent liberalization' phase). However, the nature of this intervention would depend on existing domestic capabilities.

III. Complementary Assets

Successful implementation/commercialization of new technologies requires access to certain facilities that are broadly classified as 'complementary assets'. These include competitive manufacturing capabilities, marketing and after-sales support, complementary technologies and availability of specialized skills. Strengths in these areas allow better appropriation of investments by firms (Teece, 1986). In particular, an innovator who possesses strong complementary assests can delay imitation and thereby compete with firms that own complementary assets alone (Pisano and Wheelwright, 1995). It can be argued that a firm that does not have access to these resources cannot, in the first place, innovate on a continuous basis. It is the interaction of design capabilities in a "science & information based" firm and the status of complementary assets that define the ability of firms to catch-up or leapfrog technological developments. Further, for 'late comers' with decent technological capabilities, like India, it may be crucial (even strategically appropriate) to invest in strong complementary assets, especially manufacturing, in order to absorb and build on international technology flows in the future.

Indian technological capabilities in the telecommunications sector should be viewed in terms of its complementary assets that it owns or has access to. Until liberalization, the country depended mostly on the PSUs for the development of designs as well as manufacturing barring a few instances of technology transfer from MNCs. Successful indigenous efforts of this kind include the development of switching equipment by C-DOT (see Appendix 1). The manufacturing of these switches, however, was done by ITI and a number of other vendors that were developed by C-DOT. Design know-how as well as capabilities in complementary assets are almost non-existent in the case of transmission technologies. The shift towards digital transmission has further eroded the relevance of Indian manufacturers' capabilities in the production of transmission equipment. Manufacturing based on some primitive designs was initiated by ECIL, BEL and other state electronic corporations. However, none could match the international standards and developments. Since 1991, several of these and other Indian firms are exploring strategic alliances with international transmission firms. It should be appreciated that the technology chain within the transmission segment of telecom is more complex and diverse than in the other segments. Besides, a large number of industries feed into the developments of technology in this segment. Consequently, the scope of niche based innovations in transmission is also high. It is estimated that transmission media will require the maximum investments in the near future. Public investment of Rs 15,000 crores (out of Rs 40,000 crores to be spent for the telecom sector) was earmarked for the transmission segment in the eighth plan (1992-1997).

Developments in transmission systems like cables and digital multiplexers have not kept pace with the changes in the switching technology in the country. In cables, most production capacity is still concentrated in jelly filled variety (approximately 180 lakh ckm in 1994). About 17 firms manufacture such systems, many of which are in the private sector. One needs to ascertain if the prices and quality of these cables have changed with the entry of private players. Production of optical fibres, in contrast, is being done by about eight players with a total capacity of approximately 10,000 ckm (Ca ine Ole, 1996). Technical collaboration with foreign firms (e.g., HCL with NKT Denmark, O Furukawa, Japan, Finolex with AT&T USA, Birla with Ericsson Sweden) is the chosen rc technology acquisition. Sterlite Industries, however, has developed technology on their own. M these firms are manufacturing low count fibers (e.g., 6, 12, 24). While some raw material (including fibers) for manufacturing the optical fiber cables are being imported, most of optical fibre systems like laser/led based light sources, detectors, regenerators, testing & splicing equipments etc. are being imported. Estimated cost of optical fiber cables was around Rs. 1.19 lakh per km for 6 fiber (or Rs. 1.7 lahks/km for the 12 fiber) in 1993 [INFAC, 1993]. Another related transmission equipment is the fiber optic based digital mutiplexing system. India does not have designs or manufacturing facilities for this key equipment. The high cost of these systems is the main hurdle to the deployment of fiber optics in the Indian trunk & subscriber networks.

Domestic capabilities in the radio transmission systems are limited to 2/15 radio relay systems, microwave installation and other similar technologies from 1970s. Access to newer technologies like cellular wireless in the local loop, point to multipoint TDMA radio etc. is restricted as these are based on proprietary knowledge developed by MNCs. These technologies promise, in the short term, rapid diffusion of basic telecom services. Cellular services are provided by private JVs in each of the 18 regions of the country called 'circles'. DOT has auctioned licenses to two players per circle, the license fees being quite high. For example, Birla AT&T who have been given the licenses for Gujarat and

Maharashtra will spend about Rs. 5253.80 crores over the next 10 years. Of this, the license fees accounts for Rs. 3415.80 crores while the remaining will be capital cost. In all probability the bulk of the capital cost will constitute payments for embodied technology imports. India has adopted the GSM standards for cellular telephony. However, the issue of inter-connectivity with the trunk lines that use analog systems could stand in the way of full use of cellular systems. Cellular transmission equipment includes mobile switching centers, radio transmission equipments and interfacing equipments (e.g., billing). Currently all these equipments are being imported in SKD forms. It will be a while before any manufacturing of these equipments can start in India. Same observations will apply to subscriber hand sets. Other issues related to the growth of radio technology are: availability of frequency bandwidth, variety of services, effective after-sales service, expansion flexibility etc. Appendix 2 gives some details on CELFORCE, a cellular service provider in Gujarat. A short case study is presented on Tata-Telecom, a manufacturer of telecom equipment, in Appendix 3.

One year after the entry of paging in India, there are about 2.5 lakh pagers spread over 25 cities of the country. It is estimated that the number of pagers will reach 10 million by the year 2000. Some MNCs like Motorola have set-up manufacturing facilities for two way radio paging. In addition, Motorola has established a Pager Design Centre in Bangalore (one of the five such centres in the world) to design pagers f or India and the neighbouring countries (Capital Line, 1996).

In India, DOS is responsible for design, fabrication, launch and maintenance of satellites. Applications using the satellites are planned, developed, and managed by DOT and the Ministry of Information & Broadcasting. India ranked 14th amongst 20 satellite operators in terms of revenue earned during 1995. Of the total transponder capacity (3771 transponders), India owns about 2% (Foley, 1996). However, ISRO (an arm of DOS) has the distinction of being one of those few organizations that designs and fabricates its own satellites that are at par with the best around the world. ISRO has launched its INSAT-1& 2 series of communications satellites using launching stations abroad. However, it has developed capabilities to launch its IRS (Indian Remote Sensing) satellites using PSLV rockets that were developed within the country. ISRO also plans to launch its communications satellites in coming years using a GSLV rocket that is under development in India. The current INSAT system has 186 earth stations for telecommunication and over 175 telecom links between cities. The four communication satellites in operation provide more than 4200 two way speech circuits. About 700 public TV stations have been hooked through the INSAT system catering to 80% of the population. Also, several thousand VSATs have been set up all over India to handle data (Mama, 1996). Similarly, most of the earth stations have been designed and fabricated within the country. Appendix 4 provides some details of the capabilities developed at ISRO.

Both C-DOT and ISRO seem to be caught in what could be termed as a "features" trap - DOT specifies certain features in a product based on what is available in the state-of-the-art technology. The local developer is unable to meet all the requirements with its current technology (though it could develop the remaining few features in some time frame), it considers the remaining features as not very useful or critical for the Indian need. The order from DOT goes to an MNC while the local vendors stop developing on C-DOT's/ISRO's prototypes in the future. One big question before ISRO is how much "market driven" should it be ?

Software is a rapidly growing industry in India. According to some estimates the number of companies involved in this sector increased from about 700 in 1990 to more than 1200 in 1995 (Heeks, 1996). Unlike the Space program where developments have moved in tandem with the telecom needs, the software industry in India has not contributed significantly to the development of telecommunication technology. They have remained as users of telecom technology and often inadequacies in telecom infrastructure is seen as a major constraint to its growth. Similarly, India can boast of a large scientific and managerial pool of manpower. However, a very small proportion are trained specifically to meet the requirements of the telecom sector.

Industrial as well as R&D capabilities in areas of ceramics, semiconductors, precision instruments and aviation engineering are relatively weak in India. Inspite of setting up nodal manufacturing and research centres in each of these sectors, the focus of activities has remained indigenization presumably because of the inadequate foreign exchange resources. Moreover, these organizations have not emerged as independent entities (either by design or default) but have operated to meet specific public sector requirements. Consequently, many of their innovations have not followed international technology trajectories. Quite often, they have also missed important international waves of technological developments due to lack of urgent and appropriate policy initiative by the State. For example, technological developments in several sectors (including Space) have been constrained by inadequate manufacturing and design resources in semiconductors within the country. Many of these developments are of strategic importance and key technologies within them are not easily accessible to domestic institutions. Two instances which highlight this phenomenon come to mind: a ban on the supply of CRAY supercomputing technology on defence grounds by the US; and inability of ISRO to procure a specific electronic component being produced by an US MNC in India for its Space research program. It is clear that some strategic technologies could still be made unavailable to Indian organizations even when they are being produced on "Indian soil". The key policy question, therefore, is whether one needs specific State initiative to ensure availability of strategic technologies to Indian organizations. If 'yes' then what should be the nature of this initiative.

In summary, while developing complementary assets one may have to resolve the following set of issues: (a) optimizing the linkages among technology developers, manufacturers and service providers; (b) enhanced manufacturing capabilities to address gaps in transmission technologies, flexibility in manufacturing, and vendor development; (c) policy initiatives to encourage manufacturing as opposed to assembly (specially in the private sector) and minimize the ill effects of monopsony and "features" trap; and (d) facilitate the development of complementary technologie (e.g., software and electronic components) and technical skills required for the telecom sector.

IV. Lessons from other Asian Countries

Countries, especially in Asia, have followed a variety of routes to upgrade their telecom infrastructure. These range from complete privatization of services to state controls in the management of networks. Importantly, many hybrid systems, combining elements of these two extreme situations have been experimented with. It must be noted that the cost of improving this infrastructure is very high for two reasons: the quantum of equipments required to meet the telecom targets of the countries is very high and most of these countries do not have indigenous telecom technology. As a result, the cost of importing these technologies and the associated services turn out to be prohibitive. Most often, the choice of the upgradation route is dictated by the extent of domestic resources available for development of this network. Interestingly enough, countries in Europe & North America and Japan have developed advanced telecom technologies but their markets are not growing as rapidly. The markets exist in Asia but these countries do not have indigenous technology. In addition, some of the largest markets like India and China do not have adequate resources to buy these technologies off the shelf. Often these technologies have failed to perform as well in the local environment. Consequently, countries are using various models for improving their telecom infrastructure.

One of the interesting cases is China. Telecom planning and administration, in China, is done by the Ministry of Post & Telecommunications (MPT). It provides services through 31 semi-independent Provincial Posts and Telephone Administrations and municipal carriers. In addition, there exists an alternative telecom network called Lian Tong (now called China Com) which provides competition to the MPT network. Lian Tong is jointly owned by the Ministry of Electronics Industry, Ministry of Railways and the Ministry of Electrical Power. Lian Tong also provides (similar to MPT) data, local & long distance services, mobile, satellite & value added services. A sister company of Lian Tong, Ji Tong , manages network services like credit card networks, EDI network etc. Of late, the People's Liberation Army as well as some of the municipal telephone administrations have entered the market for providing services to the public through their independent networks (Chismar et al., 1996; Ingelbrecht, 1996). The urgency in developing this infrastructure and the inability of MPT to respond quickly is leading the Chinese to think of reorganizing MPTs into many regional subsidiaries. This goes well with the Chinese philosophy of letting different regions develop with differing velocities. One key consideration has been the need to let smaller groups make quicker decisions on technology choice and implementation. Table 4 gives some information on the status of Chinese telecom infrastructure.

China has emerged as the largest buyer of telecom technology. Its key strategy has been to develop a strong manufacturing base for telecom technologies through selective joint venture arrangements between Chinese & foreign manufacturers. For example, over 140 domestic switching manufacturers produce 70-75% of nation's switching requirements. These are mostly based on JV partners' design and their manufacturing quality is comparable with plants overseas. China is investing heavily in research on fiber optics so as to enable them to implement, by the year 2000, 22 new fiber routes on a national trunk grid across the country (covering 35200 km and at a cost of US$45 bn (Chismar et al., 1996)). Only a few JVs have been granted permission to enter the optical fibre market. Similarly, 100 brands of pagers (with an annual production capacity of 1 million sets) and a variety of cellular systems are now being manufactured in China. China has also become quite active in laying submarine cables. Once FLAG (fiberoptic link around the globe) becomes operational in September 1997, China will be connected with Japan on one side and UK on the other. Similarly, China has been investing heavily in developing indigenous satellite technology (both the payload as well as launch systems). It is emerging as a low cost satellite launching country and is starting to draw business chiefly from private US firms. For instance, China and Hughes Aircraft Company have signed a long term agreement to launch 10 satellites for the US company over the next 12 years (Hong, 1995). This is an interesting departure in China's self sustaining satellite program. It now has opportunities to learn from the American company. Its satellite network uses 18 earth stations in major cities and provides a total capacity of 7500 voice grade circuits (Chismar et al., 1996).

In addition to the task of slowly separating the roles of the regulator and the operator of telecom systems, the emphasis of telecom policy has been on choosing partners that would assist China in building technological capabilities (the prime stated reason for striking alliances with foreign firms). In that, there is a clear preference for US firms over the Japanese as the latter are more secretive about their technology. Foreign firms are allowed to set-up manufacturing plants in China but cannot participate in network development or management of services. Several foreign firms are either opening manufacturing facilities in China or relocating there from other parts of the world (e.g., Nokia has re-located from Hong Kong to China; Motorola, AT&T, Nortel etc. have set-up multiple manufacturing facilities). China appears to be installing a "basic" high-end telephone system and is consequently not leapfrogging technological developments. Lack of efficient management systems & capabilities form the key bottleneck to effective utilization of the hardware that is being employed (Warwick, 1996).

Singapore Telecom (ST) is an example of the successful deployment of telecom technology for revolutionizing services. Singapore's technology strategy has been to rapidly source state-of-technology from anywhere around the world for implementation in its hi-tech and service sectors. This kind of targeting and synchronized planning has led to immediate returns to the society on investments in telecom which have fuelled further investments in the next generation of telecom technologies. This led to further improvements in services quality and the cycle continued. This focused approach to telecom is evident from the restructuring of Singapore Telecom in 1989: three SBUs were created for business, mobile and residential - the three focus areas of Singapore Telecom with varying telecom needs. According to Staple (1994) the key reason for the restructuring and ultimately privatization of telecom (in 1992) was to give ST the financial and managerial flexibility to compete in the world markets (and not because of poor state of telephony or lack of investments or the need to raise funds to subsidize State's fiscal deficit etc.). He observes that that privatization of ST should be seen in light of the "20 years which led up to them-the period of monopoly developed under a strong, state-owned entrepreneurial board" during which financial, regulatory, and operational policies were managed effectively and honestly across the Ministry of Communication and Telecom Authority Singapore (unlike many nations where these overlapping interests could cause policy gridlock).

ST has been able to provide one of the world's cheapest and better quality services as well as one of the highest telephone penetration in the world by riding the waves of technological innovation of its suppliers. According to Singh (1995), this has led to lack of attention to manufacturing of telecom equipment and domestic R&D. Consequently, local development of complementary and supporting industries has been limited, constraining the development of leading edge technologies in the country. In general, by controlling operations of services, governments are able to reap the maximum financial benefits from value added activities. It also allows them to influence the diffusion of telecom in other sectors of business & industry. However, as services become more technology dependent (both hardware & software) in the long run, firms may need to innovate on technology in order to remain competitive.

South Korea is another country in Asia that has invested heavily in newer telecom technologies. The Korean Telecom Authority has encouraged foreign participation and competition in telecom related manufacturing while holding monopoly status for service provision. They have been able to attract almost all telecom majors to set-up manufacturing JVs in Korea. Korean R&D was earlier conducted through Electronics and Telecommunications Research Institute (ETRI) as part of the Korean Advanced Institute. Interestingly, a section of ETRI that does research on computer networks, software R&D and systems engineering is being transferred to KTAs (Crawford, 1987; Cho et al., 1996). Unlike the above mentioned Asian nations, the State owned NTT in Japan has played an important role in the development of advanced telematics. NTT has undertaken collaborative R&D with its suppliers thereby ensuring strong linkages between manufacturing and technology development (Fransman, 1996).

Table 5 summarizes the key features of Asian experience in Telecom. Most of these fast developing Asian economies have focused on the development of a domestic manufacturing base, and to the extent possible, R&D capabilities in the course of telecom expansion in their economies. Singapore is the only notable exception which may now be experiencing certain constraints to further growth.

V. Policy Imperatives: Privatization, Competition, and Innovation

The discussion so far has highlighted a few inter-related features of telecom technology. The concept of technology supply chain is extremely useful in understanding the evolution of telecom technology and identifying the gaps in domestic capabilities. Therefore, the supply chain can also facilitate the process of ascertaining the locus and scope of policy intervention in order to enhance these capabilities. For example, our rudimentary analysis suggests that India is weak in certain capabilities relating to transmission technology and these technologies may be crucial (as well as strategically important) for future growth of telecom services in India. However, policy initiatives to correct these gaps may need to take cognizance of the capabilities in other segments of the technology chain.

Moreover, policy initiatives also need to take into account the availability of the relevant complementary assets in the implementation of new telecom technologies. The inadequacy of complementary assets may reduce the appropriability of benefits which flow from the diffusion of new technologies. It has been shown that learning potential and spillover benefits of foreign technologies are a positive function of the availability of complementary assets (especially manufacturing) in the host countries (Kokko, 1992).

In this broad context, what are the policy imperatives for a country like India? Conventionally, regulatory regimes are assessed (and often designed) on the basis of cost containment and price reductions. Recently, in the developed country context, "network modernisation" has emerged as a new focus for regulatory reform (Berg and Foreman, 1996). Apparently, a narrow focus on price/cost reductions in the short run created a potential for "technological involution" or "technology lock-in", which is antithetical to the modernisation principle. This shift in focus has resulted in better appreciation of the role of telecom technology as a parameter for regulatory initiatives.

It can be argued that the focus on "modernization" has implicitly recognized the relevance of technology supply chain. The sunk costs involved in the adoption of new telecom technologies are very high. Issues relating to compatibility of various technologies and the linkages among technology segments contribute significantly to these high costs. High sunk costs increase the probability of "technology lock-in" and therefore policy initiatives focusing on "modernisation" need to explicitly take account of the likely technological trajectories in each segments of the supply chain.

Some recent developments bring the role of supply chain and complementary assets into sharper focus. At the same time, these changes redefine the boundaries of telecom technology segments and telecom markets. Increasingly, some of the services provided by the telecom network (e.g., electronic communication, information services), are being generated by service providers outside the traditional telecom sector. As firms discover new economies of scope and as policies permit new firms access to the network value added services, voice, data, information and video are coming together to form the emerging telecom markets.

Emergence of the new service providers was facilitated by a few key technology developments. The growth of electronic services as a distinct component of the information infrastructure has provided avenues for designing new services to fulfil specific customer needs. Integration of computing and telecom has resulted in the introduction of the digital standards of computing into the telecom system. This gets reflected in the design of modern telecom equipment and the software that is developed to operate the network. Digitalization has facilitated another type of technological convergence. As the content being transmitted over the network (e.g. films, television programming, print, data bases etc.), gets converted into digital form, it can be transmitted on the digital telecom network, enhancing, the opportunities for interactive multi-media services. (See Melody, 1996, for more details on these changes).

These and other technological changes have challenged the notion of natural monopoly in the telecom sector.

> "Technology is not only making the local exchange more susceptible to competition, it is further blurring the distinction between inter exchange and intra exchange services. Regulatory distinctions between categories of services themselves affect technical choice and network design, and therefore may themselves be an important factor in determining the direction of innovation and the nature of competition". (Rosston and Teece, 1995:791)

For example, since fiber optics are so much more efficient than micro-wave technology, the cost of transmission of calls is much less sensitive to distance than it was earlier. As a consequence of these negligible cost differences, "it is hard to determine why a ten mile call should be `local' and a hundred mile call long distance". An interesting by-product of such decline in transmission costs may be a substitution of fibre for switching; a circuitous routing of calls over fibre networks, if it minimizes switching costs, may become more cost effective if the cost of transmission decreases faster than the costs of switching (Rosston and Teece, 1995: 794).

As a consequence of these developments, artificial barriers across market segments are likely to fall as technological changes bring telecom markets together. We have seen that the delivery technologies are diverse and evolving: traditional copper wireline, co-axial cable, fiber optics and so on, while formats can be digital or analog. No single firm or country is likely to be the least cost supplier for all these services using all these technologies. Under these circumstances, the fundamental issues facing the regulatory authority are two fold:

I) How to make the transition from what were once viewed as natural monopolies to clusters of inter-connected delivery systems which are becoming competitive with one another? Given the economies of scope, facilitated by technological convergence erecting regulatory barriers between markets may dampen incentives to innovate and discover new ways of satisfying consumer demands (Berg and Foreman, 1996). More on this later.

ii) How to facilitate building up of basic technological capabilities and complementary assets to absorb evolving telecom technologies and continuously `modernize'? Also, how to build state of the art capabilities in some key strategic components of the emerging technologies?

The Indian Predicament

The Indian policy makers are faced with an interesting situation. The country has the potential to leapfrog into the latest technologies because we do not seem to have any large sunk investments in technologies which are locked-in. However, the state does not have access to a large enough resource pool (especially of foreign exchange) to make significant investments to bring in the latest technologies through the public sector initiatives. Besides, technological capabilities and the complementary assets necessary to absorb and build on new technologies are inadequate. Given the asymmetric distribution of capabilities/assets across segments of technology chain and the affiliated industries, it makes logical sense to launch a strategic initiative in the form of selective intervention. The strategic relevance of telecom technology, its high learning and spillover potential justify state initiatives in this sector. What should be the nature of such strategic intervention? In what follows, we highlight some elements of this package.

One strategy may be that of a fast follower. In order to become fast followers rapid diffusion of process innovations needs to take place. According to Antonelli (1991: 20), this would be possible only with :

(a) high levels of investment and growth;
(b) strong cognitive and network externalities generated by lead users and critical mass;
(c) fast decline in the purchase prices of innovated capital goods;
(d) proximity to lead producers such as MNCs; and
(e) systemic technologies with high levels of sunk costs.

Telecom products increasingly have short product life cycles and rapidly declining prices. The strategy enunciated in the new telecom policy tries to ensure the involvement of telecom MNCs in various segments of the industry, although much needs to be done in this respect. Through the decision tc make digital fiber optics and GSM as the national transmission standards for the coming years, th State has *de facto* chosen a platform of technologies for future investments. The economic reform expected to unleash forces which will result in high investments and growth. The state initiative no needs to focus on developing network inter-linkages among various telecom technology segmen related industries and service providers.

Some key elements of the strategic initiatives to develop technological capabilities include :

(1) identification of foci for domestic technological development;

(2) identification of the nature and scope of alliances amongst domestic and foreign entities for developing world class, export oriented manufacturing capabilities;
(3) "corporatisation" of technology development ;
(4) technology blending and building on existing technologies; and
(5) development of telecom specific skills.

We discuss each of these issues in some detail in the following paragraphs.

Foci for Technological Development

It is apparent from our discussion in the earlier sections that transmission media should be the focus of our attention for the purposes of developing technology, both from the perspective of its importance in the emerging telecom technology chain as well as the weak status of domestic capabilities. Of late, the State has opened up the radio transmission segment and many domestic players with foreign participation have entered the fray and intensified the levels of competition. Sophisticated digital multiplexing equipment (e.g., based on SONET technology) has come into the country through foreign licenses. However, the benefits of developing such equipment domestically will require large amounts of resources and may not provide significant externalities for the other segments of the chain. On the other hand, given the large requirements and the potentially high spillovers, it is imperative for the country to develop design and manufacturing capabilities in the fiber optics segment. The same logic will apply to the space segment which has been singularly responsible for the development of scientific capabilities and various complex technologies in the country. The case for development of domestic capabilities in this segment is further strengthened by the fact that it is of strategic importance to the nation and we have significant capabilities in this area.

Further, our strengths in the software industry provide us with a key 'complementary asset' to exploit the technological potential of emerging telecom technologies. A focus on this sector should include software development for operating and managing transmission equipments as well those which will improve the application potential of telecom technology for other industries. The latter development will facilitate rapid diffusion of telecom technologies and enhance productivity. While we have reasonable capabilities in the software industry, our dependence on imports for our electronic requirements is almost complete. Given the pervasiveness of micro-electronics in telecom and other sectors and the strategic nature of this sector, we need to build a manufacturing base on our soil. One such product domain can be chips that have telecom software embedded in them.

Manufacturing and Alliances

As mentioned earlier, development of complementary assets like competitive manufacturing is necessary for rapid diffusion of new technologies and for technological learning. Such capabilities are also a pre-requisite for the growth of allied industries. The government's decision to allow multinationals to come in with 51% equity (with opportunities to raise equity to 100%) has improved competitiveness in equipment manufacturing. However, telecom policy has not provided adequate impetus for setting up manufacturing facilities on our soil, especially for transmission equipment. While the scales of production which can be maintained at the current level of domestic requirements are small, the potential market in the country is very large. The attractiveness of this potentially large market may be used by the State to seek export oriented manufacturing from foreign equipment firms entering telecom sector. A differential license fee structure can be followed for firms desirous of exporting equipment manufactured by them in India. Similar incentives may be provided for firms who enter into alliances with some commitment to create R&D facilities. The relatively large weightage of license fee (72%) vis-à-vis indigenous procurement in awarding licenses for basic services may not provide strong incentives for the service providers to create domestic local manufacturing facilities. One can argue for an upward revision of the of 3% weightage announced for indigenous procurement to induce domestic manufacturing or for earmarking a share of license fee for developing local technological and manufacturing capabilities.

Corporatisation of Technology Development

The Committee on the Commercialisation of Infrastructure has recommended corporatisation of DOT as a holding company with circles as regional subsidiaries and other functional subsidiaries such as a separate long distance company. The idea of DOT as holding company (i.e., India Telecom) can be expanded to include a unit focusing on the twin functions of developing and manufacturing telecom technology. Most companies around the world which undertake these functions are large entities and are independent in managerial and financial terms. Domestic companies of this kind can make large investments in technological development and ably negotiate alliances to bring newer telecom technologies from abroad. In recent years ITI and C-DOT have entered into technical collaborations with foreign firms to acquire, manufacture or develop new technologies. Merger and corporatisation of C-DOT and ITI with significant restructuring has the potential of providing us with such an entity. Equity participation of employees should be part of such a restructuring. Besides, institutional participation of the Department of Electronics in this endeavour would be essential. The intensity of participation envisaged here is much more than the "part time" involvement recommended by the D.K. Gupta Committee. A part of the license fee being collected for various services should be earmarked for the development of such an organisation. In the course of time such an entity should be completely privatised. The basic idea is to create a domestic entity which will be able to compete globally.

From Existing Technologies to New Skills

For many years to come, the switching technologies developed by C-DOT (especially ISDN compatible mega-switches) will be adequate for the requirements of basic services in most parts of India. These technologies are also the cheapest and most robust, especially for rural and semi-urban environments. Installation on a mass scale of these technologies is probably the best solution to satisfy the demands of basic telephony in these areas. The technological challenge before us is to adapt and develop new transmission technologies which will be compatible with these installations. It should be recognised that such efforts will require significantly different hardware and software skills which do not seem to be available in the country.

VI. Conclusions

In this paper we have raised several technology related issues that will affect the development of telecom infrastructure in the country and the ability of the nation to take advantage of such technologies in becoming globally competitive. The need for "strategic" policy intervention is underscored. Such policy interventions need to explicitly take account of inter-linkages among various segments of telecom technology, domestic capabilities and the availability of complementary assets. Development of complementary assets would require a consideration of the likely technological trajectories in this sector. This would help us in not making the same mistake that we did in the case of semiconductors.

Despite recent developments in telecom technology that have changes the scenario vis-à-vis economies of scope and scale existence of large domestic players may be extremely essential to make significant R&D efforts (which is to the tune of 10-13% of turnover for leading international firms in this sector) and to efficiently absorb technologies that are being developed elsewhere. Inspite of such large investments in R&D, most of the major telecom equipment suppliers have entered into various kinds of alliances with each other to augment their capabilities. Restructuring of DOT and its corporatization needs to be explored to fulfil these objectives. The investments in telecommunications infrastructure will reap benefits with the development of applications industries like software and the consequent diffusion of telecom technologies. What is going to be most important in the future is not only what hardware one has but how one uses it to manage the telecom networks and develop value-added applications. In this context, interaction among technology developers, regulators and the users would become increasingly critical.

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APPENDIX I

C-DOT

The Centre for the Development of Telematics (C-DOT) was set up in 1984 as an autonomous body under the DOT. The aim was to develop indigenous capability in telecom technology. Initially, its R&D was confined to switching , now it has diversified into transmission technologies as well. However, very little is being done in this area.

C-DOT has received acclaim for its technologies from small Rural Automatic Exchanges (128-port) to the state-of-the-art 40,000 line exchange with a BHCA (busy hour call attempts) of 800,000 with features such as CCS No 7 signalling , which is a new feather in its cap.

C-DOT technologies have been transferred to 77 companies. The products manufactured include both switching and transmission products. The switching products under manufacture are 128p RAX, 256p RAX, SBM RAX and MAX-L The transmission products are SC-VHF, DMX-8, DMX-34, 6RU-10, OLTE and VSAT. The transmission products that are manufactured by maximum number of companies are OLTE and 6 RU-10 while the VSAT is manufactured by only one company. C-DOT's new MAX-XL has a capacity of 40,000 lines. It is validated by the Telecom Engineering Centre and the technology has been given to the Indian Telephone Industries for manufacturing. After one year , the technology will also be given to four or five private companies. MAX-XL will have the ISDN features in a few months time.

C-DOT is currently working on the development of Wireless in the Local Loop (WLL) technology based on the European standard called DECT. It is being jointly developed by C-DOT and the National Semiconductor Ltd, a US based company. They have also entered into other alliances with MNCs (e.g., Motorola) for joint development of technology.

C-DOT has suffered due to weak complementary assets (like absence of any world-class facility both in pcb as well as in equipment manufacturing), poor access to components (especially new designs) and delays due to State intervention in making decisions that affect its operations as well as high employee turnover. There appears to be an absence of modern perspective on vendor development for long term association especially since DOT seeks fresh tenders for the manufacturing of each new equipment designed by C-DOT. Interestingly, C-DOT and its vendors depend on DOT for business and now have to compete with foreign vendors for DOT's equipment needs.

APPENDIX II

CELFORCE

Celforce cellular service , is one of the two companies responsible for the entire infrastructure - Mobile Switching Centre, Cell sites and SIM cards, of cellular services in Gujarat.

The network is designed and supported by Nokia OY of Finland. Celforce cellular service, is provided by a joint venture between the Hindujas, HFCL, Kotak Mahindra, Shinawatra and Bezeq. The foreign investors, Shinawatra and Bezeq own 49% of the equity; their respective shares being 33% and 16%. The Indian investments are shared by Hindujas-30%,HFCL-10% and Kotak Mahindra-11%. The total project cost is Rs. 750 cr and they have to pay a royalty of Rs. 163 cr per annum on a quarterly basis of Rs. 43.3 cr per quater.

Nokia , the network and equipment provider, are the world leaders in GSM technology. The technology and the providers were selected, for Celforce by a consulting firm (Stanley-Morris) on a royalty basis. They also train people for service and maintenance. Equipment was delivered to Celforce in SKD form.

Celforce have launched their operations in Ahmedabad and Gandhinagar from the 24th of January, 1997 in their first phase and during the second phase spread it to Baroda, Nadiad, Surat and other important centres in Gujarat. The initial response has been very positive and the trend in cell phones which was estimated to be only a fraction of the pagers, has shown better results in the metros where they are falling short by only numbers. The early market trends and penetration in India was projected based on the performance of Cellular transmission in the South-East Asian countries . According to this, the performance is comparable to Thailand's and Indonesia's and much better than China's.

The entire market in India is divided into four metros and 19 circles. There are two operators allowed in every circle. The company feels that although opening up of the market is a very healthy proposition, the investments required (both project cost and licence fees) are extremely high which will dampen the market growth. The cellular industry is trying to attain 1% penetration of the Indian population .

APPENDIX III

TATA TELECOM

Tata Telecom started with the manufacturing of India's first Digital EPBAX. Now it produces a variety of telecom equipments that range from office communications systems to network access systems to transmission systems. They have tied-up with OKI of Japan for advanced office communications systems. Digital UHF Transmission systems is provided in technical collaboration with Japan Radio Company. The third joint venture - Trans -India Network Systems is with AT&T- provides solutions for Network Access.

In each of these joint ventures, for a particular product range, the transfer of technology has taken place. Each of the joint ventures have separate sets of terms and conditions depending on the product and the collaborator. These are mainly pertaining to the product range and the domain (geographical location). It involves a technology transfer fee, which varies form product to product based on the technology involved. For example, Rs 1.15 cr. was paid for technology transfer to OKI for mini PABXs (10-15 lines) and Rs. 2.25 cr. for medium range. There are also other payments required for technical training, setting up of lines etc. The collaborators provide specifications for the product, which includes the technical documentation and customer documentation. The technical specifications specify the electronics, PCB, mechanical and other details.

Once the technology is transferred, manufacturing is carried out in phases. In the first phase an entire system is imported from the collaborator and tried in the market. The second phase is the SKD phase, wherein units are bought from the partner and put together here and the next phase is the CKD phase, in which maximum possible indigenization is done. The extent to which indigenisation is achieved on various specifications of the collaborator is shown below:

Component	Value (%)	Indigenized (%
Electronics	60	40-50
PCB	20	100
Mechanical	10-15	100
Others	3-5	90

The systems / system designs provided by the collaborators are not always absorbed as it is. There is constant R&D on the specifications in order to indigenize as well as tailor make it for customer needs. Some times there are terms from the partners which requires the use of their component as it is: no modification is permitted due to proprietary reasons.

Tata Telecom selects its product portfolio on the basis of an extensive survey of DOT's five year plans. It caters to the technological changes envisioned by them. An example is the optimux or the radio systems. Keeping the new telecom policy in mind, they have already joined hands with Lucent Technologies of USA to plan the telecom needs of the high end customers once this market is opened.

The various products of Tata telecom are capable of providing solutions to a wide range of customers. On the one hand, products like mini EPABXs (3-12 lines) or digital EPABXs (40 to 7500 lines) and optimuxs provide solutions to business centres. On the other , there are the 10 channel digital UHF radio or 30/120 digital UHF radio and MAR-30 for rural communication (also for inaccessible areas). A customer of the former range of products is TISCO, Jamshedpur. The latter are mainly bought by DoT. Other customers include ONGC, defence etc.

APPENDIX IV

ISRO

The Indian Space Research Organisation, a PSU, has been guided by a twin objectives of development oriented applications of space technology and self reliance. ISRO works closely with the Indian industry in five different areas. These are Technology Transfer, Technology Consultancy Services, Technology Utilisation, Indigenisation and Vendor Development, and Procurement of goods and services. It has indigenously designed, fabricated and launched a variety of communication and remote sensing satellites.

The Indian satellite communications scene has a single player namely ISRO. ISRO's role includes designing, fabricating and soon also launching the communications satellites. Their applications are left to various branches of the Department of Telecommunications and the Ministry of Information and Broadcasting.

Existing Insat transponders are used in a large number of captive satellite networks for State owned enterprises like ITI, NTPC, ONGC, Coal India, Gas Authority of India Ltd, Nuclear Power Corporation, National Fertilisers and the National Stock Exchange. The telephonic links with the interiors of the country are poor. Under a new scheme, inland areas of large states like Bihar, Uttar Pradesh, and Madhya Pradesh, are being linked to state head quarters through 300 [satellite] terminals. In another scheme, the National Informatics Centre Network (NICNET) will connect every single district headquarters to its state capital, and to Delhi through a data network. The NICNET VSAT-based network is expanding very rapidly, and now has more than 700 VSATs.

The Bay of Bengal, faces some of world's worst cyclones every year. An adequate warning time would make a great difference. Now, India's entire coast has a total of 400 simple, rugged and unattended battery operated receivers which are placed to give a warning of an approaching storm. Selective [satellite] receivers are activated with a one-minute warning siren. ISRO has made remarkable strides in the area of remote sensing both in terms of designing specific payloads as well as developing a variety of applications. ISRO has formed a corporation called Antrix to commercialize in-house developments in technology. It has also entered in a collaboration with Ecosat Corp. in USA where the latter will market ISRO's hardware and software in this area.

ISRO's indigenisation programme identifies specific components, materials or subsystems of high reliability, currently imported ; and indigenisation is taken up. Through efforts in SAC, several items such as 100 Mhz Temp Compensated Crystal Oscillator, C-band Hybrids, Power Dividers, Couplers, Drop-in Isolators, Metallised Alumina substrates etc. have been successfully indigenized. Significant efforts are underway in the area of digital compression.

Some of the new thrust areas include provision of long term buyback commitments, establishment of special divisions/manufacturing lines in industries, operation of special in-house facilities by industry on contract basis, promotion of industrial consortia and organised vendor development for special products. Efforts are in progress for developing industries in several product categories of relevance to ISRO's future programmes based on the technologies generated in ISRO. Maximum number of technologies that have been transferred from ISRO to industry are in the area of telecom, broadcasting and navigation related applications (close to 30%).

In harnessing the applications of space technology, ISRO's role is to plan, manufacture, launch and maintain satellite and earth stations. All ground activity including transmission centres, design of application programs etc. is done by DOT. DOT is the only user of ISRO's technology. The latter is affected by DOT's technology related decisions as well as its project management to utilize space technology. Like C-DOT, ISRO also suffers due the non-availability of critical components, lack of co-ordination in key polices affecting the space industry, clarity in the objectives of the space program in the new environment, and high turnover of technical manpower. Like C-DOT, ISRO is also dependent on the State (by design) for its development. Though it licenses its technology to vendors, the vendors have to seek business from the government.

TABLE 1: Status of Telephone Infrastucture & Services

PANEL A: Telephone Infrastructure (1994-1995)

Departmental exchange (nos.)	Equipped switching capacity '000s	Direct exchange lines '000s	Telephone waiting list '000s	Telephone registered demand '000s
20000	12024	9795	2100	11895

PANEL B: Telephone Services (1993-1994)

Telephone metered calls (min.)	Calls per DEL (nos.)	Number of faults per 100 phones	No. of effective trunk calls (min.)	Trunk calls per DEL (nos.)
46724	5822	18.3	162	20.2

Source : DoT

TABLE 2 : Telecom Developments : Some Projections

	1997-98	1998-99	1999-2000	2000-1	2001-2
SWITCHING CAPACITY (in '000 lines)					
STATUS	18783	21683	24883	28483	32483
URBAN PCOs (in '000s)					
STATUS	609	717	836	969	1117
VILLAGE PUBLIC PHONES (in '000s)					
STATUS	614	626	639	654	670
OPTICAL FIBRE CABLES (in Route Kms.)					
STATUS	56374	66374	76374	86374	96374
DIRECT EXCHANGE LINES (in '000)					
STATUS	15510	17910	20560	23510	26810
MICROWAVE SYSTEMS (in Route Kms.)					
STATUS	85569	113489	141529	169689	197969
TAX (in '000s)					
STATUS	1034	1194	1374	1574	1784
UHF SYSTEMS (in Route Kms.)					
STATUS	131006	150006	170006	191006	213006

Source: DoT

TABLE 3: Equipment Requirements for 9th Five Year Plan

EQUIPMENT	TOTAL
SWITCHING EQUIPMENT (In million lines)	
For Small Exchanges	8.431
For Large Exchanges	21.296
TAX Equipment	1.93
TRANSMISSION EQUIPMENT	
2 Ghz/8 Mbps	10000
6 Ghz/140 Mbps M/W Equipment (TX/RX)	2500
7GHz/34 Mbps M/W Equipment (TX/RX)	2500
11GHz/140 Mbps M/W Equipment (TX/RX)	1500
13ghz/34 Mbps	1000
16/18/23/38 Ghz M/W Equipment (TX/RX)	20000
4/36 Analogue MARR in UHF band	10000
565/140/34/8 Mbps Optical Equipment	25000
SDH Optical Equipment (Terminals)	5000
VSAT for rural areas (Terminals)	10000
Optical Fibre Cable (long distance communication)	100000
Optical Fibre Composite Cable	6000
EXTERNAL PLANT & TERMINAL EQUIPMENT	
Telephone Instruments	246.2
Telephone Poles	73.9
Under-ground Cable	1822
WILL Systems	1349300
HDSL Systems	44975
PVC Pipes	36000
FAX Machines	9.07
DATA COMMUNICATION EQUIPMENT	
Modems - Leased (Numbers)	29310
Modems - Dial up (Numbers)	248101
Data Multiplexers	2800
Data Switches and Concentrators (Public): 1000 ports switch	35
Data Switches and Concentrators (Public): Concentrators (50 ports)	210
Data Switches and Concentrators (Public): 50 port Switches	191
Data Switches (Private) : 50 port (Numbers)	375
Data Switches (Private): 10 port (Numbers)	250
Frame Reley Switches	18
ATM Switches (Numbers)	15
Routers (Numbers)	15900
VSATs (Terminals)	8500
Digital Cross-connects	275

Source : DoT : Communications Today, Nov - Dec 1996

TABLE 4 : Development of P&T Services in China

	Unit	1990	1994	1995	Growth rate of 1995 over 1994 period (%)	Average annual growth rate in 8th FYP period
Real capacity of urban and rural telephone exchanges	Thousand lines	20 259	62 607	85 100	38.1	33.2
Total capacity of office exchanges	Thousand lines	12 007	49 262	70 960	44	42.7
Capacity of mobile telephones	Thousand	–	3 716	6130	72.7	–
Capacity of digital mobile telephone exchanges	Thousand	–	105	890	10.2(times)	–
Total length of toll optical cable	Thousand kilometres	3.3	73	100	37	97.8
Total number of telephones	Thousand	12 753	40 673 (mobile included)	56 620 (mobile included)	39.2 (mobile included)	34.7
Mobile telephones	Thousand	18	1 568	3 630	131.6	189
P&T establishments	–	53 629	60 447	62.88	4	3.2
Total P&T turnover	Billion RMB Yaun	15.55	68.82	98.6	42.2	44.7
Total Telecom turnover	Billion RMB Yaun	10.95	59.23	87.33	47.4	51.5
Number of local telephones	Million	6.85	27.295	40.69	49.4	42.8
Residential telephones	Million	1.527	17.643	29	67.4	80.2
Public payphones	Million	0.046	0.387	0.834	115.5	78.5
Mobile telephone subscribers	Million	0.018	1.568	3.63	131.6	189

Source : Asia Communications , October 1996

TABLE 5: Lessons from Asia

- CHINA
  - Strong Manufacturing Focus
  - Opening up on the basis of Learning Potential
  - Competition among State Agencies
  - No Foreign Participation in Network Design & Services
  - MNCs in Joint Venture with Chinese Manufacturers

- SINGAPORE
  - State of the Art Technology
  - Service Sector Applications - Resources Ploughed Back
  - Capabilities in Manufacturing and R&D Weak

- SOUTH KOREA
  - Opening-up in Phases - Similar to India
  - MNCs in Joint Venture with Korean Manufacturers
  - No Foreign Participation in Services
  - Internal Competition in Services
  - R&D Focus on Applications

- JAPAN
  - R&D Collaboration between NTT and Vendors
  - Focus on Technology Development
  - Most Manufacturing by Vendors