CHAPTER 2

NATIONAL-LEVEL INFRASTRUCTURES AND PROGRAM INITIATIVES FOR TELECOMMUNICATIONS

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INTRODUCTION

This chapter focuses on the panel's findings related to telecommunications research and development activities in China that are related to infrastructures and program initiatives at the national level. Specifically the highlights and the panel's impressions of the developments in large-scale technology development zones (science parks) and those of the research and education information networks in Taiwan and Hong Kong where the panel made visits to several sites and received briefings are presented. Data was also extracted from online or published literature on similar developments in mainland China, aimed at compiling a more complete picture of the entire region.

Two considerations made it necessary for inclusion of national infrastructures and program initiatives beyond a narrower scope of telecommunications. First is the premise that such national-level efforts for broad science and technology typically have a significant impact on telecommunications, not only locally but also across the region. Based on the panel's findings, such impact is clearly seen in Hong Kong, Taiwan, and mainland China individually, as well as on their cross-dealings among the three entities.

Another important consideration for studying these developments is the recognition of the rapid convergence of the three industries: computing, communications, and content. Together, over the last decade, these three component industries helped define what modern telecommunications has become and how the R&D capability of each of the component technologies has been integrated into that of telecommunications. Increasingly, in both academic and industrial research, there are more common issues to be shared and addressed across the traditional boundaries of computing, communications, and content areas: from signals, devices, optoelectronics, transportable software, horizontal integration, scalable infrastructures, and service evolution all the way to marketing and business models. In each of these issues, not only do the technical advances among the three disciplines overlap, but the resources needed to address them as well as the benefits from R&D are mutually sharable. Any assessment of telecommunications development would not be complete without looking at the three related technologies. Panel visits to the science parks in Taiwan and Hong Kong have reinforced our belief that their telecommunications R&D programs are highly integrated across the computing, communications, and content industries.

Furthermore, the developments of telecommunications are increasingly inseparable from those in information networks, such as the Internet. Indeed it is the Internet and World Wide Web that have dramatically changed the landscape of research and education and therefore technology innovation. Panel members specifically reviewed the national-level program initiatives on research and education networks in Hong Kong, Taiwan, and mainland China.

This chapter is organized as follows. Panel findings of the Hsinchu Science Park in Taiwan and the new Science Park under development in Hong Kong are first presented, with special attention to their implication in telecommunications. A review of China's high tech development zones is then discussed focusing on the Zhongguancun Science Park in Beijing. These science parks have similarities and differences, both among them and when viewed from other science parks in the United States. In the area of information networks, findings on China's Education and Research Networks (CERNET), Taiwan's Research Network (TANet2) and its new and broad National Telecommunications Program (NTP), and Hong Kong's academic and research network (HARNET) are presented. A comparative assessment of the science parks and research and education networks in the region relative to their counterparts in the United Stated is given, followed by a general conclusion section.

HSINCHU SCIENCE-BASED INDUSTRIAL PARK

Taiwan's economic growth in the last 20 years is attributable to many factors. One significant factor is the establishment of the Hsinchu Science-based Industrial Park and its related developments. Initially modeled after science parks in the west, the Hsinchu Science Park has since taken on it own set of characteristics and become an engine for change, growth and industrial vitality at the national level.

Begun in 1980, the Hsinchu Science Park was conceived to provide an environment in Taiwan that is conducive to high tech research and development, manufacturing, work, life, and entertainment all at the same time. In the ensuing 20 years, the Park has attracted a variety of high tech industries, large and small. Some of them have become the world's leading manufacturers and global companies. More importantly, the Park has also become one of the reasons that many of the overseas Chinese choose to return to Taiwan to start their own businesses as entrepreneurs, much like those attracted to the Silicon Valley in the United States.

Unlike the Silicon Valley, however, the Hsinchu Park is in a geographically "closed" setting. It occupies 605 hectares of land near Hsinchu, about 70 kilometers south of Taipei, Taiwan’s capital city. Within this compound, as of 2000, there are 289 companies, with approximately 102,000 employees. As part of a global strategy to gain a foothold in foreign countries, roughly one fifth of these companies have established branch offices overseas, many of them in the Silicon Valley. Also in sharp contrast to their U.S. counterparts, the Hsinchu Park is managed by the Taiwan government under the National Science Council. This is a government agency that also manages research grants for universities, a role similar to that of the National Science Foundation in the U.S. The Taiwan government provides a variety of tax and other incentives to attract industries and talented individuals to work in the Park.

Industrial Profile

An important benefit for the Park's tenants is "clustering" among the companies of the same types that can share resources and infrastructures. Initially dominated by electronics and semiconductor industries, the Park's 289 companies at present are roughly in six different clusters: Integrated Circuits, Computers/Peripherals, Telecommunications, Optoelectronics, Precision Machinery, and Biotechnology. Table 1 below illustrates the status of these groups relative to their employees, sales, and growth in the year of 2000.

Table 1 Hsinchu Science Park Industrial Profile

Industry	*Company*	*Employee*	*Sales (US$m)*	*Growth(%)*
Integrated Circuits	***116***	***61,288***	***18,496***	***67***
Computers/Peripherals	***49***	***16,064***	***6,815***	***8***
Telecommunications	50	7,334	1,628	28
Optoelectronics	44	16,167	2,595	61
Precision Machinery	***12***	***1,351***	***233***	***55***
Biotechnology	***18***	***636***	***36***	***75***
Total	***289***	***102.84***	***29,803***	***46***

Source: Hsinchu Science-based Industrial Park Publication

Two of these cluster groups are closely related to the telecommunications industry: Telecommunications, which makes switching equipment; optical transmission systems; xDSL equipment; high-speed modem and wireless communication equipment; and Optoelectronics with product lines in LED chips; LED display systems; thin-film transistor LCD; CD-ROMs; DVD-ROMs and digital cameras. While the Park's most dominant industry continues to be the IC sector (chip manufacture), the growth of computers and peripherals has slowed down. On the other hand, telecommunications and optoelectronics (as well as biotechnology) are on a path toward rapid growth. For this reason, and for technical reasons stated in the introduction, these two clusters (telecommunications + optoelectronics) will be combined in later discussions.

Research Environment

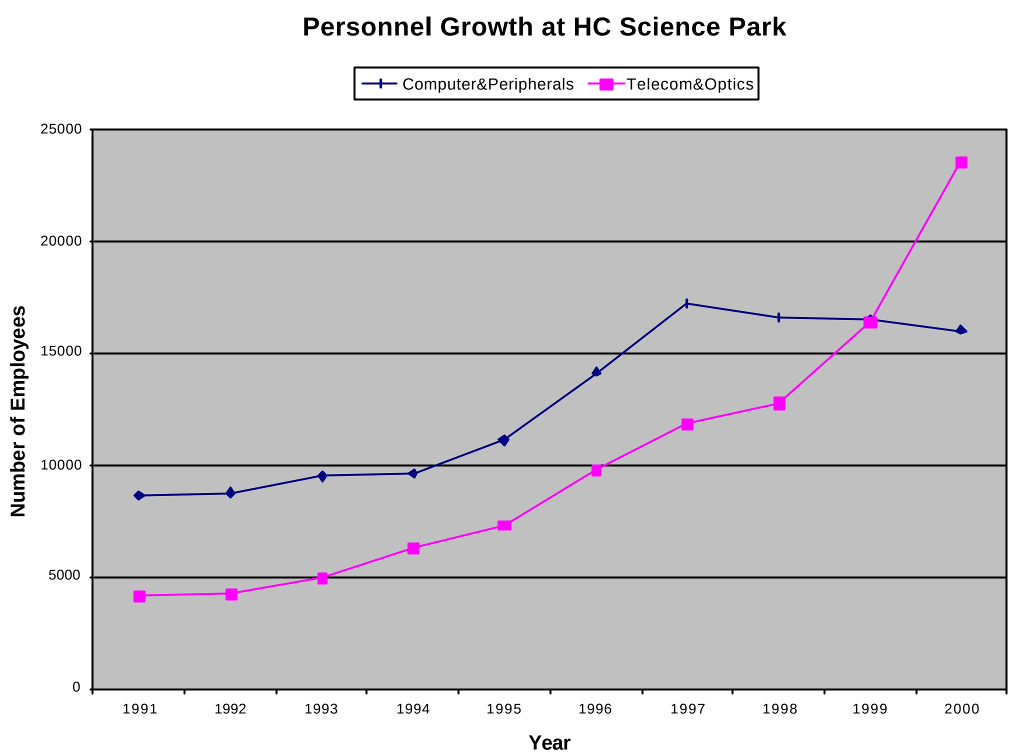
Like the Silicon Valley's connections to the nation's top research institutions, the Hsinchu Science Park is in close proximity to many of Taiwan’s leading universities and national laboratories. These include the National Tsing Hua University, the National Chiao Tung University, the National Central University, and the Industrial Technology Research Institute. All of them have major research programs in the telecommunications area and cooperate closely with the Park's industries in research and development. These cooperative research programs constitute a significant driving force of the park's vitality and growth when it comes to product related research and human resources training. The site reports in Appendix C contain additional information about the Park’s relationships to these neighboring universities and research institutes, which the panel also visited.

Fueled by a deliberate and active R&D investment strategy, the Park has seen steady growth in the past 20 years. In 2000, the combined sales revenue for the six industries reached US$30 billion, an increase of 46% over the previous year. Growth of paid-in capital was US$22 billion, up from US$18 billion a year before. Of the $22 billion, 92% is from domestic sources (4% government, 88% private) and 8% is investment from foreign sources.

Growth in Telecommunications

While the Park's dominant industry continues to be in semiconductors/integrated circuits, it is also clear that the telecommunications and optoelectronics sectors are making rapid inroads, especially if compared with the computers/peripherals industry. The following Figures 1 and 2 show the growth of these sectors, in terms of personnel and sales, respectively, in the last 10 years.

Figure 1. Personnel Growth at Hsinchu Science Park



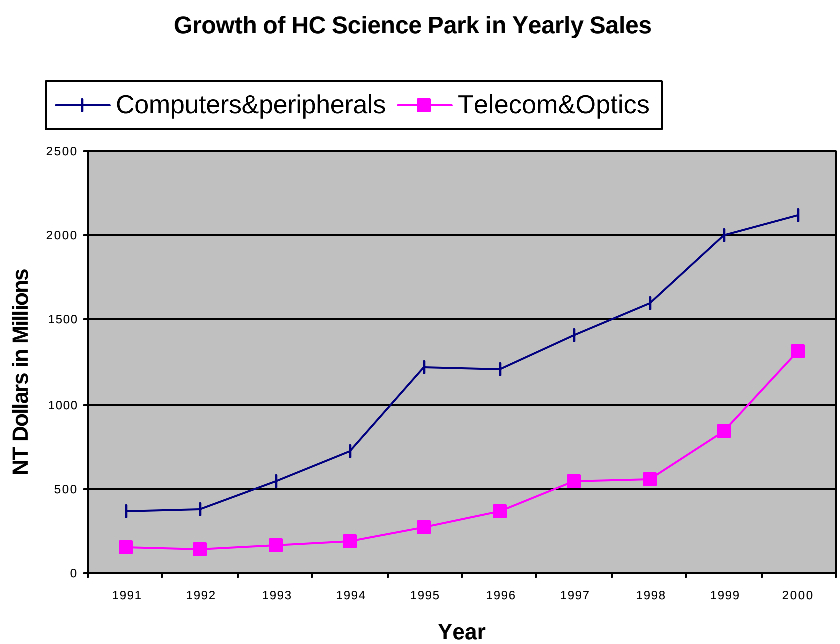
Source: Hsinchu Science Park Publication

This trend of growth in telecommunications and related optoelectronics sector at the Park appears to be closely tied to the way that the Park's administration makes its research and development investment. As shown in Figure 3, over the last 10 years, the Park has consistently made higher R&D investment in the combined telecommunications and optoelectronics sector, from a high of close to 20% to a low of roughly 7% of sales. This compares to an anemic less than 4%, and declining investment, for the computers and peripherals sector.

Expansion and Outlook

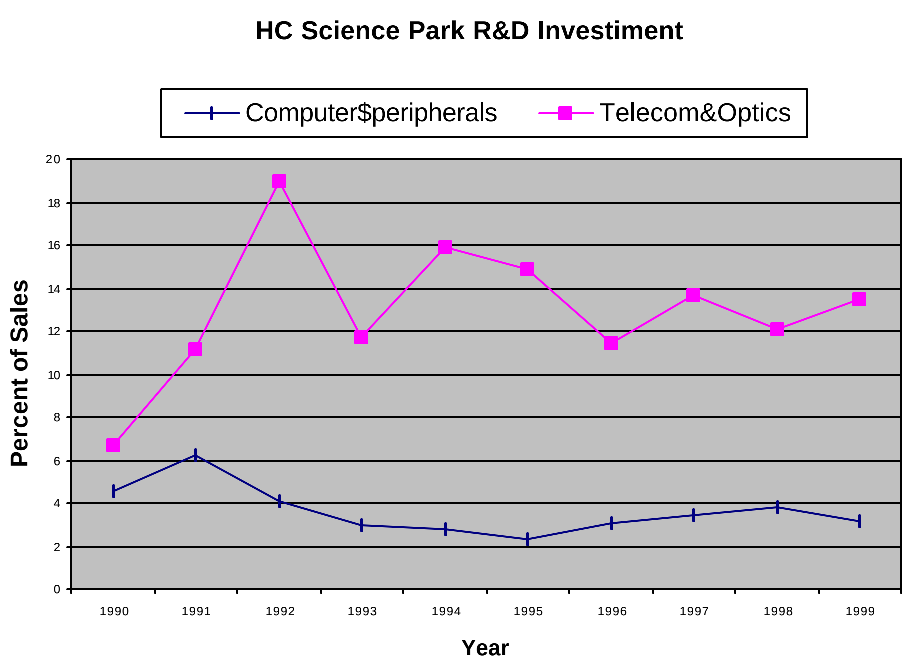
Over the years, Hsinchu Science Park has outgrown itself due to its limited access to open land for expansion. As a result, there has been a two-prone strategy for future growth. One is to develop satellite parks near the Hsinchu site. Since 1999, two such sites have been in development. The 118-hectare Chunan satellite park broke ground in 1999 and when completed, will be primarily for industries in the biotechnology and telecommunications areas. A second satellite park is in Tungluo, expected to be in operation in 2003, will be devoted to optoelectronics, telecommunications, and micro-electro-mechanics industries. Another major expansion in the works is a second science park located in southern Taiwan - the Tainan Science-based Industrial Park. Clearly, Taiwan hopes to duplicate its success at Hsinchu in the south. This is one of the key national programs that Taiwan is undertaking at a critical juncture of its future growth, amidst both economic and political uncertainties ahead.

Figure 2. Revenue Growth in Hsinchu Science Park



Source: Hsinchu Science Park Publication

Figure 3 Trend of R&D Investment in Hsinchu Science Park



HONG KONG SCIENCE PARK

Since 1997, Hong Kong's Special Administrative Region Government has aggressively pursued a number of broad innovation and technology initiatives for research and development towards economic growth. These initiatives include the Cyberport, Digital 21 program, and the creation of a special Innovation and Technology Commission as a government agency to foster research in information technology. Among the specific programs that will have long term impact on Hong Kong's future economic competitiveness is the establishment of a high tech industrial zone - the Hong Kong Science Park.

Conceptually, the Hong Kong Science Park, currently under construction, is very similar to that in Taiwan and to those in mainland China. Its stated mission is to stimulate the growth of local science- and technology-based industries, to attract new investments and create synergies for new ventures, and to unlock commercial values of Hong Kong's research investment in science and technology. With Hong Kong's limited land resources, the Park will only occupy a land area of 22 hectares to be developed in three phases over a period of nine years. Like the science parks elsewhere in Asia, it will focus on such industrial clusters as electronics, precision engineering, biotechnology, information technology and telecommunications. Historically a free port with strengths in commerce and service industries, Hong Kong's new science park will represent a bold, and perhaps necessary first step, towards its digital high technology future.

As part of its research and development strategy, the Hong Kong Science Park will fashion a variety of alliance programs, particularly keyed to the academic resources in Hong Kong's six major universities (the park is actually situated next to the campus of the Chinese University of Hong Kong). Such programs are expected to foster collaboration between industries and academic institutions in research projects, technology transfer, R&D funding, personnel training, professional services and facility resources. One of the key tenants in the Park will be the new Applied Science and Technology Research Institute (ASTRI).

ASTRI appears to be modeled after the Industrial Technology Research Institute (ITRI) near the Hsinchu Science Park in Taiwan. It is set up by the Hong Kong government as a key research institute to improve Hong Kong's capability for technology development. Its stated mission puts emphasis on transforming Hong Kong from a service-oriented economy to one that is technology competitive: performs research for transfer to industry; enhances Hong Kong's human resources in science and technology; assists in attracting international talents to Hong Kong; acts as a spawning ground for entrepreneurs; and promotes university-industry links. At present, ASTRI is functioning as a government-funded operation but will become an independent organization governed by a board of directors with representatives from industry and government.

Much of the research funding and infrastructure support for Hong Kong's Science Park and for the ASTRI is provided by the new Innovation and Technology Commission. This new Commission is a potent arm of Hong Kong's government to implement its policy of encouraging university-based research for industrial development (see site report in Appendix C for details of this Commission). How well this policy is carried out may well determine the future of the Hong Kong Science Park in particular and Hong Kong's high technology future in general.

CHINA'S SCIENCE AND TECHNOLOGY INDUSTRIAL PARKS

Under a series umbrella programs, including the China Torch Program and the “863” programs, announced in March of 1986, China has successfully implemented an ambitious project on high-tech industry development zones. While the initiative came from the national government agencies, including the Ministry of Science and Technology and the Ministry of Information Industry, most of these development zones or science parks are now administered locally at the provincial or city levels. Began in the late 1980's with the establishment of its first high tech zone, there are now 53 science parks across 29 provinces in China. Figure 4 below illustrates the distribution of these high tech zones.

Figure 4. The Distribution of High-tech Development Zones in China

Two important points should be made here about China's science parks in general. First, the above figure clearly shows that these development zones are largely concentrated in east and central China, leaving a vast area of the west and inner China virtually untouched. For whatever reasons, geographical, economical, or political, the underdeveloped region represents both a challenge and new opportunity for China's future growth. Second, the large number of science parks speaks to the enormous scale of high-tech development efforts in China, relative to places such as Taiwan or other Asian countries. These numerous science parks are of course at different stages of development and not many of them have reached the success level of Taiwan's Hsinchu Science Park or Silicon Valley in the U.S., a model many desire to emulate. Nevertheless, their contribution to China's scientific capability, high tech development, and economic growth in the past decade is undeniable. For example, in 2000, according to the published statistics by the Chinese government [5,10], the total annual income reached 500 billion yuan (~8 yuan to 1US dollar) and is expected to reach 1750 billion in 2005. Another evidential statistic that illustrates the potential for these development zones is their attraction of external direct investment in diverse industries as well as for collaborative research and development [11,12].

To give a more concrete picture of how these high-tech development zones have progressed and where they are headed particularly in the context of telecommunications-related capabilities, the highlights of the Zhongguancun Science Park (ZSP) in the Beijing High-tech development zone are described. ZSP is one of the most developed science parks in China, unique in its character and yet embracing many of the features of other successful science parks. It is also a case study in the literature on science parks (e.g., Xiaomin [4]), which, together with the information gathered from other sources, formed the basis of our analysis here.

Zhong-guan-cun at-a-glance

Zhong-guan-cun is the name of a place in the Haidian District, northwest of Beijing. In May 1988, the State Council gave approval to establish a Haidian experimental zone for the development of high tech industries in Beijing, now known as the Zhongguancun Science Park (ZSP). ZSP actually is a science park of five science parks in one city: Haidian Park, Changping Park, Fengtai Park, the Electronic Zone, and Yizhuang Park, spread throughout the greater metropolis of Beijing.

As a leading and exemplary development zone in China, ZSP has many of the salient features of a successful science park: It is in close proximity to some 70 universities and research institutions, including Beijing University, Qinghua University, Beijing University of Post and Telecommunications, the Chinese Academy of Science and many national research institutes and laboratories. At present, over 6000 companies claim residence in the science park, with a variety of ownerships: joint-stock company 43%, state-owned 23%, collective joint-venture 14%, and the remaining 20% foreign joint-ventures. Like those in a typical science park, dominating these enterprises are clusters in several industries: Computers and Telecommunications (68%), Optoelectronics (10%) , Materials and Energy (12%), and Biotechnology and Medicine (10%). The collective growth of these industries is substantial as reflected by annual revenue output in the recent past. Overall 1999 total revenue of technology, industry and trade amounted to about US$8 billion, a 40% increase over the previous year.

Of special interest is the significant focus on telecommunications-related technologies. According to the data published by the ZSP administration [5], of the top 100 companies in annual sales, 52 are in telecommunications, computers and optoelectronics, with a combined sales of 98.4 billion yuan (about 80%) and 48 are in other technologies - materials, energy, and biotech, with a combined sales of 25.8 billion yuan (about 20%). This clearly reflects the dominance of telecommunications industries, and information technology in general, in ZSP's development strategy towards future growth and technology capabilities.

Located in Beijing, China's political and cultural center, ZSP has attracted a considerable amount of foreign presence. This is not just in trade and business activity, but also more significantly in investment of joint research and development, especially in telecommunications-related fields. As of 2000, 15 multi-national companies have R&D centers in Beijing, all but 4 are in telecommunications and computers. These include:

- 9 U.S., including IBM, Sun Microsystems, Microsoft, Lucent, Motorola, Intel
- 3 Japan, including Matsushita, Fujitsu
- 1 Canada Northern Telecommunications
- 2 Denmark (in biotechnology)

The ZSP has announced an ambitious goal of reaching 50 Centers, with a $500 million R&D Budget, by the year 2005. With China's anticipated entry into the World Trade Organization soon, which will likely further fuel the interest of foreign investment, this is a goal perhaps of reasonable expectation, but hardly one that can be easily duplicated for other high-tech zones.

COMPARISON OF SCIENCE PARKS

To assess the capabilities and potentials of national level infrastructures and programs in the region, the panel has attempted a qualitative comparison of the science parks in Taiwan and mainland China relative to those that preceded them elsewhere.

The set of elements used as yardsticks for comparison are taken primarily from those used in the literature of science parks [4]. These include the research environment - access to academic institutions and talents; the dynamics, infrastructures and clustering effects; capital formation and availability (foreign, domestic, and venture); labor mobility; market conditions; levels of innovation and entrepreneurship; role of government; and finally their impact on telecommunications R&D. The assessment is purely subjective and the number of X's in each of the elements are used as an indicator for weakness or strength.

To complete the table of comparison (table below), the panel has chosen the famed Silicon Valley and a science park in Japan - primarily the Tsukuba Science City plus the new Bit Valley in central Tokyo. Silicon Valley is a natural and almost a must choice, as many science parks in Asia and around the world attempt to emulate its success if not its characteristics or methodology. The addition of Japan's science park is for its similarities and unique combination of high tech in Tsukuba and the newer dot.com industries in the Bit Valley of central Tokyo, a combination that challenges the vision of Japan and also the rest of Asia.

Table 2. Comparison of Science Parks

Key Elements		Hsinchu Science Park	Zhongguancun Science Park	Silicon Valley	Tsukuba+ Bit Valley
University and research institution		xxx	xxx	xxx	xxx
Industry	Dynamics	x	xx	xxx	xx
	Infrastructure	xxx	xx	xxx	xx
	Clustering	xxx	xxx	xx	xxx
Capital	Foreign	xx	xxx	xx	x
	Domestic	xx	xx	xxx	xx
	Venture	x	x	xxx	xx
Labor Mobility		x	x	xxx	xx
Market	Overseas	xxx	xxx	xx	xx
	Domestic	xx	xx	xxx	xxx
Innovation & Entrepreneurship		xx	xx	xxx	xxx
Role of Government		xxx	xxx	xx	xx
Impact on Telecommunications Research		xxx	xxx	xx	xxx

X – Weak/Average XX – Strong XXX – Very Strong

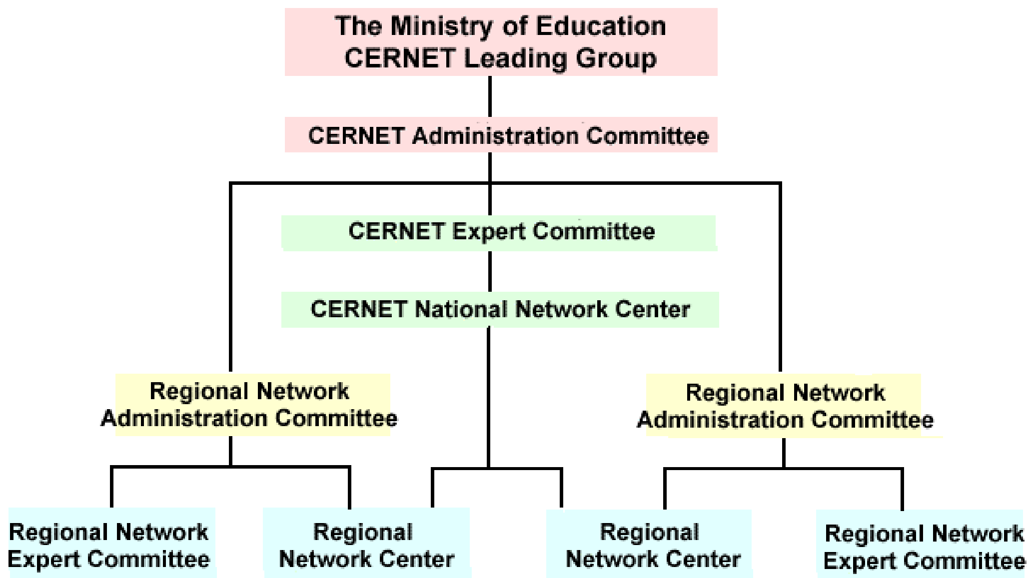
INFORMATION NETWORKS

Because of its geography and huge population, the region's commercial Internet markets are some of the most vibrant and fastest growing in the world. This has major implications in telecommunications as the Internet and the traditional telecommunications infrastructures began to converge both in technologies and in services. At the same time, like the U.S. and other developed countries, information networks in mainland China, Hong Kong, and Taiwan that are dedicated purely to academic research and education are separately managed, independent of the commercial Internet. The impact of these experimental networks on the future of telecommunications is even more significant and direct, from the viewpoint of assessing the potentials for innovation and technology leadership. In this and the following sections, the status of these networks are described.

CHINA EDUCATION AND RESEARCH NETWORK (CERNET)

China's Education and Research Network (CERNET) is, perhaps appropriately, under the jurisdiction of the Ministry of Education and technically managed by Tsinghua University in Beijing, along with other leading universities. Architecturally, CERNET has a four-layer hierarchy: the nationwide backbone is run by Tsinghua University, followed by 10 regional networks, 38 provincial networks (excluding Taiwan), and more than 800 campus networks throughout China. Figure 5 below shows the administrative aspects of the hierarchy.

Figure 5. CERNET's four level hierarchy



In 2000, CERNET's backbone operates at 2.5Gbp and regional networks at 155Mbps. It has international connections at over 100Mbps to the U.S. Internet2, Canada, the U.K., Germany, Japan, and Hong Kong. China is also a member of the Asia-Pacific Advanced Network (APAN), - a consortium of networks from Asian countries including Japan, Singapore, Korea, not including Taiwan, for collaborative research and development in advanced networks and applications.

CERNET's research activities are both centrally coordinated and locally distributed. Among the former, CERNET is being used as a key platform for China's remote learning initiative to improve education and research capabilities in rural and less populated regions. This effort has great potential in stimulating and improving the infrastructure and content delivery in future telecommunications technology and services across the vast geographic landscape of China.

China is also a member of the international 6bone working group of some 50 countries and regions to conduct experimental research on the Internet's transition to IPv6. Among the research projects are:

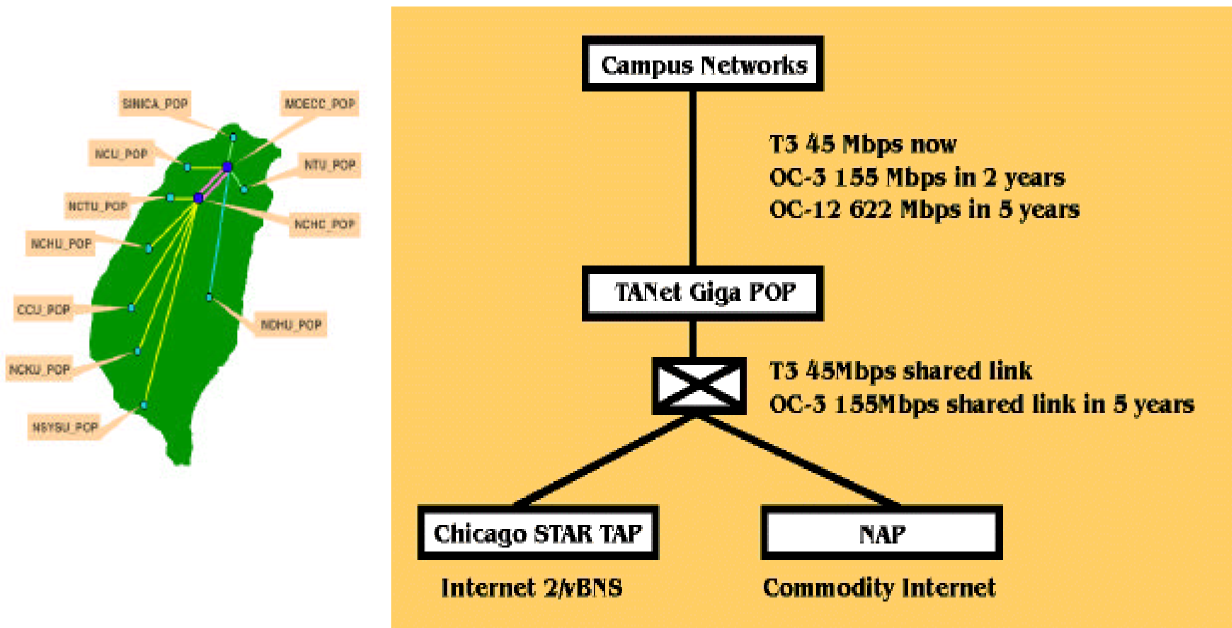
- Building a nationwide IPv6 tested based on CERNET
- Exploring next generation Internet technologies, including network security, QoS, mobile access over legacy Internet, and Internet-based media technologies

The Ministry of Education and other agencies as well as various local governments provide funding to support a wide range of research and educational activities in universities and other institutions on next generation network technologies and applications.

TAIWAN RESEARCH NETWORK (TANET2)

Taiwan's research and education network, known in the current version as TANet2, was established in 1990. It has since become one of the largest information networks in the Asia-Pacific region designed for research and education. Figure 6 illustrates the general architectural configuration and its functional capabilities and milestones for the immediate future.

Figure 6. Connections, capabilities, milestones of TANet2



TANet2 connects all of the major research institutions in Taiwan and is one of the first major research partners with connections to Internet2 in the United States. As in Internet2, TANet2 is an experimental network whose primary goal is to explore new ideas and technologies in network design and applications. These research activities are mainly funded by government agencies, including the National Science Council and distributed over participating academic institutions and national laboratories on a competitive basis. There is also collaborative research with other Internet2 institutions, primarily in the United States, on such projects as network traffic analysis, digital libraries and Collaboratories to support high-performance computational science. However, the scope and funding level of these projects are relatively insignificant compared to domestic research on either side.

NATIONAL TELECOMMUNICATIONS PROGRAM (NTP)

Taiwan's vision on telecommunications and information technology made a significant step forward with the recent establishment of the National Science and Technology Program for Telecommunications (NTP). The NTP, announced in 1998, is still in its early stages of operation but is becoming an influential force in steering the R&D activities for the future of Taiwan's telecommunications arena. A program office under the jurisdiction of the National Science Council administers the NTP. NTP's main goal is to:

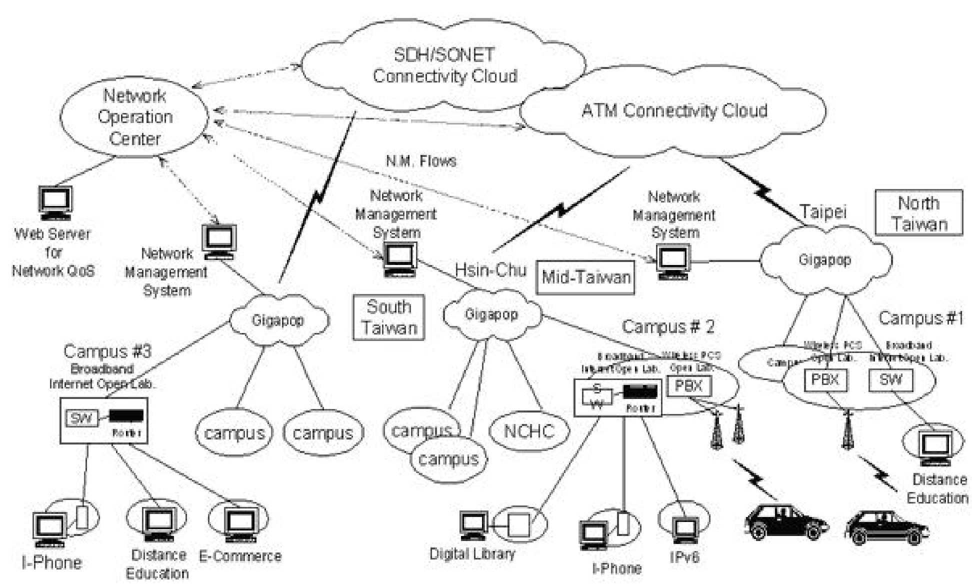
- Coordinate telecommunications research efforts among several ministries and councils in government
- Developing key technologies for next generation telecommunications needs
- Training needed talents in the telecommunications industry
- Enhancing national competitiveness for telecommunications services and manufacture
- Supporting collaborative research with international communities

The NTP itself does not directly control research budgets but exerts its budgetary and policy influence with its role as a neutral coordinator among various government agencies that develop their individual goals and operating budgets to collectively meet the NTP's mission. In many ways, the NTP functions very much like the Next Generation Internet initiative for information technology research in the United States. The similarities are not only in their goals but also in the management structures, with a central program office serving as the coordinator for participating agencies.

For the immediate future, the NTP has set two areas for its research focus: Broadband Internet and Wireless Communication. Besides supporting research projects in various components of each area, the NTP's centerpiece is the National Broadband Experimental Network (NBEN). NBEN's main mission is to deploy an experimental network with QoS to serve as a platform for testing multimedia broadband applications and various network protocols (e.g., Mbone, IPv6, I-Phone, etc.). Like the Internet2 initiative in the United States, NBEN promotes partnership of industry, government and academia in research and infrastructure development. Unlike Internet2, which is run by a university-initiated consortium, NBEN relies on government funding, management, and oversight. Not directly comparable to Internet2 in scale and mission, NBEN is basically a blueprint for Taiwan's government and the public sectors to launch other new initiatives tailored more specifically to such new manufacturing technologies as wireless/mobile 3G platforms, multimedia content development, network management, and new business models, among others.

Figure 7 shows a logistical map showing the deployment of various components of the NBEN at different levels of deployment.

Figure 7. Taiwan's National Broadband Experimental Network



A Deployment Plan of National Broadband Experimental Network

HONG KONG ACADEMIC AND RESEARCH NETWORK (HARNET)

Hong Kong has a very extensive commercial infrastructure for Internet products and services that are intimately related to the telecommunications industry. Its Internet development is also closely linked to Hong Kong's vision for its digital future through its ambitious programs such as Digital 21: Connecting the World. However, for pure experimental research free of commercial traffic and interference, Hong Kong's Academic and Research Network (HARNET) has rather focused objectives and limited resources.

HARNET is managed by the Joint Universities Computer Center for eight government-funded universities in Hong Kong. It provides connections and other services for member universities and the rest of the academic community to China's research and education network (CERNET) and connects to Internet2 via CERNET (direct link is in progress). As an experimental facility, HARNET itself supports limited R&D for member universities, with scattered research projects in information and network systems funded by government/industry.

COMPARISON OF RESEARCH AND EDUCATION NETWORKS

Assessment of the current and potential capabilities of the region in telecommunications is, at least in part, an assessment of the present and future status of the research capabilities in information networks, independent of the commercial Internet activities. The crucial factors in determining where the competitive forces are in the region are very much reflected in where Taiwan and mainland China (to a lesser degree Hong Kong) stand in their uses of resources, strategic planning, and management styles in making information networks a new path towards technology innovation. To this end, China's CERNET and Taiwan's TANet2 (with its NTP program), and their counterparts in the United States, specifically the Next Generation Internet (NGI) and the Internet2 initiative are examined in combination. While CERNET and TANet2 have their own visions, goals, and implementation agenda, the NGI/Internet2 initiative of the U.S. precedes them both and has been a source of inspiration for many other countries [3]. A 3-way comparison here therefore is useful.

A number of subjective criteria are used to make the comparison. These range from the status of infrastructure; capabilities in basic research and applied research; trends and eagerness for innovation; programs that connect to society such as efforts in outreach and education; desire and ability to collaborate with others, both domestic and international; and effectiveness of linkages among government, industry, and academia. How these networks have impacted telecommunications in particular are also important. The comparison here shown Table 3, like the one for science parks, is made by indicating areas of perceived weaknesses (X) or strengths (XX or XXX).

CONCLUSIONS

In this chapter, the panel has focused on national-level infrastructures and program initiatives with special attention to science parks and information networks. The premise is that the developments in these infrastructures in the past 15 to 20 years have had a significant impact on telecommunications related R&D in Taiwan, Hong Kong, and mainland China, though the degree of that impact varies in the region. The panel’s visits to the region and the data collected for this study support that premise. Furthermore, they have helped the panel to draw a few conclusions, some of which were not totally anticipated at the beginning of the study.

First, the scale, intensity and growth of the telecommunications-related R&D vary in the region, as expected from their differences in geography, size of economy, and political systems. In the developments of science parks and research Internet, Taiwan's experiences precede Hong Kong and mainland China and have shown more results of success. China's rapid growth, however, clearly leads Hong Kong and Taiwan and, in some measures (e.g., number, size, human resources), the rest of the world.

Table 3. Comparison of Information Networks

Research and Education Networks	China's CERNET	Taiwan's TANet2	U.S NGI/Internet2
Infrastructure	**XX**	**XX**	**XXX**
Basic Research	**X**	**X**	**XX**
Applications Research	**XX**	**XXX**	**XXX**
Innovation and Initiativeness	**XX**	**XX**	**XXX**
Outreach & Education	**XXX**	**XXX**	**XX**
Collabration across borders	**X**	**XX**	**XXX**
Government/Industry/Academia links	**XX**	**XX**	**XXX**
Impact on Telecom R&D	**XX**	**XX**	**XX**

X – Weak XX – Strong XXX – Very Strong

Second, the entire region is clearly aware of the changing environment of high tech industries. The success of IC and computer industries in Taiwan, much of it attributable to the Hsinchu Science Park, has shown signs of waning as worldwide economy slows down. Partly in response, at various levels of policy making, the push is on in Taiwan, and to a similar degree in mainland China, to institute programs that can facilitate the transfer of the IC and computer manufacturing capabilities to the new and growing telecommunications industry. Evidence to support this conclusion includes the kinds of R&D investments in telecommunications related fields, with emphasis on 3G and broadband for example, in the entire region. At a minimum this is a strategy for survival. In the best of scenarios, on the other hand, the region may emerge once again as the world' most potent telecommunications suppliers, much like the IC/computers of the past decade.

Third, in the area of research and innovation, the region receives mixed reviews. Many of the institutions, including those visited by the panel, have done first class research measured from the quality of their work, equipment, personnel, and available resources. On the other hand, with exceptions, the scope, goals, and overall vision of most of the projects examined tend to follow those of the western countries, particularly the United States. Collaborative research across borders, when pursued, also tend to gravitate towards the more familiar territories and settle for less risky approaches even in forming partnerships.

One unexpected finding from the panel’s visits and discussions with the hosts in Taiwan, Hong Kong, and mainland China is that there have been very active and deliberate interactions across the Taiwan Strait in business investment, economic development as well as in research. All of these activities are kept officially in the private sector, though until recently government sanction was also at work. According to published data [11,12], Taiwan's accumulative investment in mainland China has reached some US$50 billion, a level similar to that of the United States. Adding to these financial investments are the movement of technology and people from Taiwan to mainland China, posing a challenge to not only Taiwan but also to other Asian neighbors.

Finally, the region holds great promise for its contribution and challenge of intellectual properties in the telecommunications field. With the R&D capabilities in science parks and other national level infrastructures and a huge domestic market, mainland China (and to a lesser degree Taiwan) has the potential of developing and using its own standards in telecommunications. The introduction of TD-SCDMA, developed jointly by China and Siemans and recently approved by the International Telecommunications Union as a third wireless standard, is a case in point. Will China go its own way or be part of the world's telecommunications community? Either way, opportunities and pitfalls await the Asian region and its global competitors.

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