CHAPTER 1

OVERVIEW AND SUMMARY OF FINDINGS

Magdy F. Iskander

INTRODUCTION

This study on Asian Telecommunications was organized as a follow-up to an earlier study on "Wireless Information Technology and Networks," conducted during the period of 1998-2000. Similar to the wireless study, sponsors of the Asian Telecommunications Update requested the evaluation of the state-of-the-art of the telecommunications industry in the Far East-specifically in Hong Kong, Taiwan and mainland China and an assessment of the Chinese competitiveness in this global market. Members of the panel were expected to travel and meet with educators and research colleagues within China and exchange ideas on ongoing research activities and modern educational procedures, and possibly identify avenues for potential international collaboration in the telecommunications industry. Findings from this Asian Telecommunications Update are expected to complement the earlier assessments and recommendations made by the wireless panel. The integrated findings can be used by federal agencies in making decisions regarding promising technologies, areas of research, and future research funding allocations. The findings can also be useful in establishing ties with international research groups with common interests and complementary research and technology expertise.

In this report, we describe the overall objective of the study, summarize the activities, and provide an overall evaluation of the findings. In addition to the highlights included in this section, the report includes additional chapters prepared by members of the panel on the various technical areas and business aspects of the telecommunications technology. Copies of the site reports have also been included in Appendix A.

OBJECTIVE

As indicated earlier, the objective of the Asian Telecommunications Update is to review research and development activities in telecommunications technology in Hong Kong, Taiwan and mainland China and assess China's competitiveness in comparison to the United States in this global industry. Technical and business findings from this study will complement earlier findings reported in the "Wireless Information Technology and Networks" study, where the focus was placed on research and development activities in Europe and Japan. In the present study, as was the case in earlier ones, every effort is made to identify opportunities for international collaboration, including collaborative projects, joint ventures, and exchange of scholars and scholarly activities.

STUDY PROCEDURE

To achieve this objective, a panel of six individuals with internationally recognized expertise in the area of telecommunications technology was formed to review the various technical and business aspects of this

technology within China. Table 1 lists the names and affiliations of the members of the Asian Telecommunications panel, while Table 2 indicates the various areas of technology assigned to each member. In a meeting with the sponsors of this study, a list of specific tasks was vigorously discussed and approved, and a list of industrial sites as well as research and educational institutions to be visited by the panel was approved. Lists of sites visited in both Taiwan and Hong Kong are given in Table 3. Every effort was made to cover most of the technology areas of the telecommunications industry, and workshops were planned in Hong Kong to exchange ideas and help share the panel's findings with hosts and participating institutions. It was, however, difficult to visit all sites of interest within the one-week travel schedule. Therefore, it was decided to divide the panel into two groups as follows:

Group A	**Group B**
Magdy F. Iskander	William R. Boulton
Wayne E. Stark	Y. T. Chien
Keith Warble	Jack Winters

Table 4 shows the detailed itinerary.

Table 1. Panel members, affiliation, and areas of expertise.

NAME	AFFILIATION	AREAS OF EXPERTISE
William R. Boulton	Auburn University	Strategic management
Y. T. Chien	ITRI, Inc.	Computer and information systems
Magdy F. Iskander	University of Utah	Computational techniques, antennas, and propagation modeling
Wayne E. Stark	University of Michigan	Communications and signal processing
Keith Warble	Motorola Inc. (retired)	System engineering, roadmaps, satellite technology
Jack Winters	AT&T Research Labs	Smart antennas, signal processing

OBSERVATIONS AND SUMMARY OF FINDINGS

To help emphasize differences in technological advances as well as the philosophical and strategic approaches adopted in each distinctive area within China, we will present separate observations for Hong Kong, Taiwan and mainland China and then include a comparison at the end of these summaries.

Observations and Summary of Findings from Taiwan Visits

Throughout the panel's visits to various universities, research labs, companies, and industrial parks in Taiwan, it was clear that there is an overarching national vision that drives educational activities, research and development in Taiwan. In this brief summary report, we will describe the perceived national technology vision and strategy in Taiwan, provide some examples illustrating the adopted implementation procedure, and also describe some highlights of the research and educational activities in Taiwan. This section will be concluded by a brief statement of the challenges facing the telecommunications industry in Taiwan and a reflection on why some of these challenges are of some concern to the U.S.

Table 2. Task distribution.

Task / Panel Member	Industry	Communications and Signal Processing	RF Front-end Devices and Propagation Models	Information Systems	Systems	
					Software	Engineering
Boulton	☆					☆
Chien				☆	☆	
Iskander			☆			☆
Stark		☆				☆
Warble	☆				☆	☆
Winters		☆				☆

Table 3. Lists of site visits in Taiwan and Hong Kong.

LIST OF SITE VISITS IN TAIWAN	**LIST OF SITE VISITS IN HONG KONG**
• Chunghwa Telecommunications Labs • Hsinchu Science-based Industrial Park • Institute for Information Industry • ITRI Computer and Communications Research Labs • National Central University • National Chiao Tung University • National Taiwan University • National Telecommunications Program • National Tsing Hua University	• Chinese University of Hong Kong • HK University of Science & Technology • Information Technology and Broad-casting Bureau • Innovation and Technology Commission • Office of the Telecommunications Authority • Pacific Century Cyber Works HKT • University of Hong Kong

National Vision and Strategy

1. Move Taiwan's capability up the supply chain from chips to handsets to communication infrastructure.

2. Develop new high value-added in high technology industries such as information technology, optoelectronics, and biotechnology.

Asia Telecommunications Update Study
Itinerary
<< As of May 19 >>

		Fri/Saturday May 25/26	Sunday, May 27	Monday, May 28	Tuesday, May 29	Wednesday, May 30	Thursday, May 31	Friday, June 1	Saturday, June 2	Sunday, June 3
Subpanel A: Iskander Stark Warble	**AM**	Panelists arrive in Taiwan (Airport pick-up provided)	Kickoff meeting **9:00-12:30** Conference Room (Business Center) 1F Howard Plaza Hotel	National Taiwan University Prof. Zsehong Tsai College of Electrical Engr. **Confirmed: 9:00-11:00**	Industry Technology Research Institute (ITRI) Computer & Communications Research Laboratories Dr. Teddy Huang, Deputy General Director **Confirmed: 9:10-11:20**	Travel to Hong Kong Boulton - 9:30 am Iskander - 10:00 am Chien - 10:20 am Kordella - 10:20 am Stark - 10:20 am Warble - 10:20 am Winters - 10:20 am (Airport pick-up porvided)	Pacific Century Cyber Works HKT Paul Cheung, Sr. Vice President of Technology **Confirmed: 8:30-14:00** (with lunch invitation)	Workshop co-hosted by University of Hong Kong **Invited Participants:** Prof. J. Wang, HKU (organizer) Prof. Victor Li, (HKU) Prof. T.S. Ng (HKU) Prof. Peter Yum, Chinese U. of HK Prof. Letaief, HK U. of S&T Mr. Au, OFTA Mr. Adam Wong, HK Telecom Dr. Z. Li, China Unicom	Workshop with China Researchers **Confirmed participants:** Prof. Wen Xun ZHANG, Southeast University, Nanjing Prof. Ping ZHANG, Beijing Univ. of Post and Telecommunications Prof. Hai-Ge Xiang, Peking Univ. Confirmed: 9:00-13:00 (with lunch)	Panelists return to United States
	PM			Joint Meeting with National Chiao Tung University and National Telecommunications Program Office Prof. Jason (Yi-Bing) Lin Dept. of Computer Science & Information Engineering **Confirmed: 14:30-17:00** (with dinner invitation)	National Central University College of Electrical Engr. & Computer Science Prof. C.D. Chung, Chair, Institute of Telecommuncations **Confirmed: 14:30-17:00** (with dinner invitation)	Innovation and Technology Commission Francis Ho, Commissioner **Confirmed: 14:30-17:00**	HK University of Science & Technology Prof. Khaled Ben Letaief Electrical and Electronic Engineering Dept. **Confirmed: 14:30-17:30**	**9:30 am -**	Wrap-up meeting Conference Room Hyatt Regency Hotel **13:00 - 16:00**	
	Evening			Dinner with NCTU/NTPO	Dinner with NCT			Dinner with China/HK representatives		
	Hotel	Howard Plaza Taipei	Howard Plaza Taipei	Hotel Royal Hsinchu	Hotel Royal Hsinchu	Hyatt Regency	Hyatt Regency	Hyatt Regency	Hyatt Regency	
	Member	All members	All members	Iskander, Stark, Warble	Iskander, Stark, Warble	Iskander, Stark, Warble	Iskander, Stark, Warble	All members	All members	

		Fri/Saturday May 25/26	Sunday, May 27	Monday, May 28	Tuesday, May 29	Wednesday, May 30	Thursday, May 31	Friday, June 1	Saturday, June 2	Sunday, June 3
Subpanel B: Boulton Chien Kordella Winters	**AM**	Panelists arrive in Taiwan (Airport pick-up provided)	Kickoff meeting **9:00-12:30** Conference Room Howard Plaza Hotel	Institute for Information Industry Dr. M. Feng Deputy Director Planning & Evaluation Office **Confirmed: 10:00-13:00** (with lunch invitation)	National Tsing Hua University College of Electrical Engr. & Computer Science Prof. Wen-Tsuen Chen, Dean **Confirmed: 10:00-13:00** (with lunch invitation)	Travel to Hong Kong Boulton - 9:30 am Iskander - 10:00 am Chien - 10:20 am Kordella - 10:20 am Stark - 10:20 am Warble - 10:20 am Winters - 10:20 am (Airport pick-up porvided)	Information Technology and Broadcasting Bureau Eva Cheng, Deputy Secretary **Confirmed: 9:30-11:30**	Workshop co-hosted by University of Hong Kong **Invited Participants:** Prof. J. Wang, HKU (organizer) Prof. Victor Li, (HKU) Prof. T.S. Ng (HKU) Prof. Peter Yum, Chinese U. of HK Prof. Letaief, HK U. of S&T Mr. Au, OFTA Mr. Adam Wong, HK Telecom Dr. Z. Li, China Unicom	Workshop with China Researchers **Confirmed participants:** Prof. Wen Xun ZHANG, Southeast University, Nanjing Prof. Ping ZHANG, Beijing Univ. of Post and Telecommunications Prof. Hai-Ge Xiang, Peking Univ.	Panelists return to United States
	PM			Chunghwa Telecom Labs Dr. Lir Fang Sun, Managing Director **Confirmed:14:30-16:30**	Hsinchu Science-based Industrial Park **Confirmed: 14:00-17:00**	Offict of the Telecommun-cations Authority (OFTA) Anthony Wong, Director General **Confirmed: 14:30-17:00**	Chinese University of Hong Kong Prof. Wing Wong, Chair, Information Engineering Dept. **Confirmed: 14:30-17:00**	**9:30 am -**	Wrap-up meeting Conference Room Hyatt Regency Hotel **13:00 - 16:00**	
	Evening							Dinner with China/HK representatives		
	Hotel	Howard Plaza Taipei	Howard Plaza Taipei	Hotel Royal Hsinchu	Hotel Royal Hsinchu	Hyatt Regency	Hyatt Regency	Hyatt Regency	Hyatt Regency	
	Member	All members	All members	Boulton, Chien, Kordella, Winters	Boulton, Chien, Kordella, Winters	Boulton, Chien, Kordella, Winters	Boulton, Chien, Kordella, Winters	All members	All members	

Implementation Procedure

Through a collaborative effort among various government agencies, industries, and universities, the implementation procedure includes:

1. Creation of government- and industry-supported research organizations and industrial parks. Examples of this include:
    a. Institute for Information Industry (III)
    b. Industrial Technology Research Institute (ITRI)
    c. Hsinchu Science-based Industrial Park
2. Support university research and educational activities
    a. State-of-the-art laboratories: IC fabrication labs, microwave and millimeter-wave measurement labs, optoelectronic labs, etc.
    b. Strengthen ties between university research and industrial needs, including relaxed intellectual property agreements, low overhead charges on research grants (6-20%), and graduate degrees provide credit for military service
3. Sponsor unique and innovative educational programs at universities
    a. Virtual City (EduCities) at National Central University
    b. Wireless Center and multimedia distance learning and training at Chiao Tung University
4. Encourage participation of academic professionals in government agencies
    a. Prof. Den, head of National Science and Technology in Telecommunications Program (NTP)

Chapter 2 prepared by Dr. Chien addresses in detail the national-level infrastructures including the technology development zones and science parks. In the following section, we will provide a brief description of national coalitions and centers.

Highlights of National Coalitions and Centers

This section includes a brief discussion of some of the nationally funded research programs, institutes, and laboratories. These examples illustrate the implementation of the national technology vision in Taiwanese universities and educational institutions.

1. National Science and Technology Program for Telecommunications (NTP)

Objective

Coordinate the research effort among ministries and councils, and address the training needs of the telecommunications industry. Participating government agencies include the Ministry of Transportation and Communication, the Ministry of Economic Affairs, the National Science Council, and the Ministry of Education (see Fig. 1).

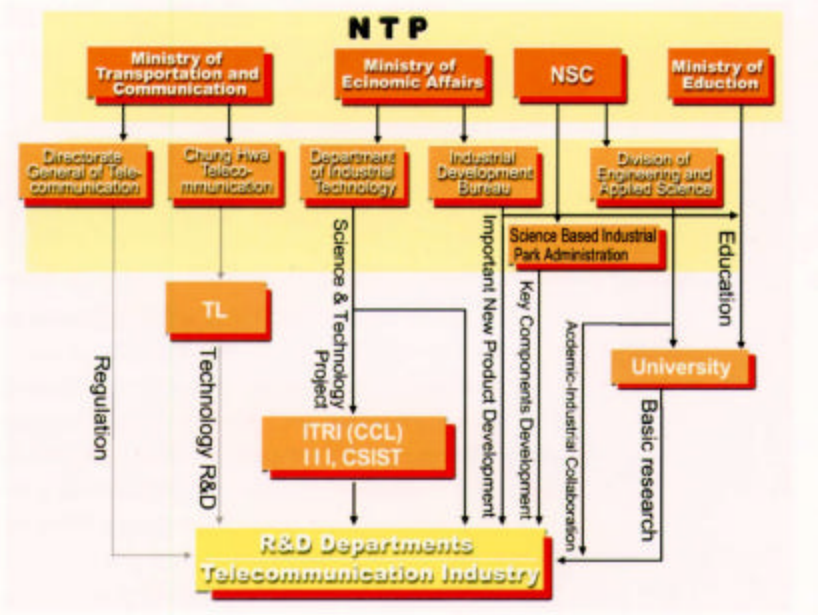


Fig. 1. Relation among industry/government/academia.

Scope

Major R&D topics include broadband Internet, wireless communication, and building a National Broadband Experimental network to serve as a test bed for various advanced networking protocols and broadband multimedia applications.

It is very impressive to see four different ministries in Taiwan trying to coordinate their activities in telecommunications technology through a single organization headed by a university professor. This focused effort is expected to enhance the quality of research and its impact on developing key technologies for wireless communication and broadband Internet, address the training needs of this technology, and ultimately enhance Taiwan's competitiveness in the telecommunications industry. Among the new initiatives in NTP is participation in 3G advanced research topics and the establishment of the Mobile Internet Consortium.

2. National Nano Device Laboratories

The National Nano Device Laboratories (NDL) that was visited by the panel near the Science-based Industrial Park in Hsinchu is one of six national laboratories operated by the National Science Council (NSC) in Taiwan This lab was established in 1988 and is presently providing facilities for a wide variety of technologies ranging from Si-based semiconductor devices and materials with a special focus on deep submicron MOS technologies to testing and modeling capabilities for radio-frequency integrated circuits (RFIC). The lab currently has over 600 square meters of class 10 and class 1,000 clean room space and over 1,500 square meters of class 10,000 clean room area. The center also provides a wide variety of courses for VLSI technology and equipment training.

3. National Infrastructures, Technology Development Zones, and Science Parks

These national technology infrastructures represent a long-standing commitment by the government to upgrade traditional industries, develop high value-added in new technologies, and provide a conducive environment to high-tech R&D and manufacturing. Examples of these institutes include the Institute of Information Industry (III) and the Hsinchu Science-based Industrial Park. To give an idea of the activities involved, it may be worth mentioning that III has trained over 200,000 IT professionals and has been maintaining the Taiwan air traffic management system.

On the other hand, Table 5 lists the six major industries in the Hsinchu Science-based Park, while Table 6 shows the breakdown of the R&D expenditures by company in the Park. Examination of the presented data shows that the Park has been a major engine of economic development in Taiwan for the last 20 years-first for semiconductor fabrication, then PC and computer peripherals, and more recently in telecommunications, optoelectronics, and biotechnology. It has been recognized as a highly successful "Silicon Valley of the East." A more detailed discussion of the activities of Taiwan's research and technology infrastructures is presented in Chapter 2.

Table 5. Industries and technologies in the Hsinchu Science-based Industrial Park.

Industry	***Companies***	***Employees***	***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***	***102,840***	***29,803***	***46***

Source: Hsinchu Science-based Industrial Park Publication

Table 6. R&D expenditures in the Hsinchu Science-based Industrial Park.

Industry	***R&D (US$m)***	***% of Sales***	***R&D Personnel***	***% of Total Personnel***
Integrated Circuits	861	7.63	5,578	11.6
Computers/Peripherals	197	3.14	2,335	14.3
Telecommunications	56	5.55	1,032	20.1
Optoelectronics	79	5.91	1,052	10.3
Precision Machinery	11	2.62	131	7.8
Biotechnology	6	26.92	101	23.2
Total	***1,210***	***5.94***	***10,228***	***12.5***

Highlights of Research Areas and Educational Activities

In this section we will summarize some of the research and educational highlights observed during the visit to Taiwan.

Highlights of Research Areas

Throughout the panel visits to universities and national laboratories, the team was exposed to a wide variety of research activities that encompass all aspects of the telecommunications industry-state-of-the-art research in smart antennas, microwave device technologies, radio channel modeling, fast DSP algorithms and data compression, broadband networking technologies, and optical fiber communication systems. In many sites, research facilities and laboratories were outstanding and the scholastic productivity in the form of journal articles and participation in technical conferences was excellent. The following is a highlight of some of the research activities.

Research in semiconductor device processing, VLSI design, and fabrication

This research area is a common one in all institutions visited by the panel. In some cases, the fabrication facilities were highly advanced (NCTU), while in others funding has just been secured and lab construction is underway. In some of the superb lab facilities such as those in the National Nano Device Laboratories in NCTU, researchers demonstrated the capability of fabricating 0.1 micron devices and have ongoing research in modern areas such as SiGe, MEMS, and biochips. Achievements were illustrated by comparing the number of journal publications of the top ten institutions with strong activities in this area. Tables 7 and 8 show the results of this comparative study. It is clear that researchers at NCTU are active and highly productive scholars.

Broadband networking technologies

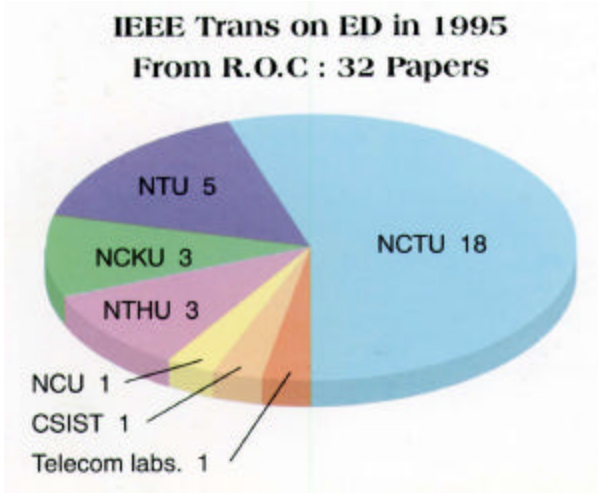
This is another research area that was addressed in several of the sites visited by the panel. Example projects include:

1. Next-generation information network and system technologies such as switching backbone based on multi-protocol label switching and dense wavelength division multiplexing (NCTU).

2. Development of high-confidence information systems including key defense and domestic security technologies (NCTU).

3. Broadband Internet.

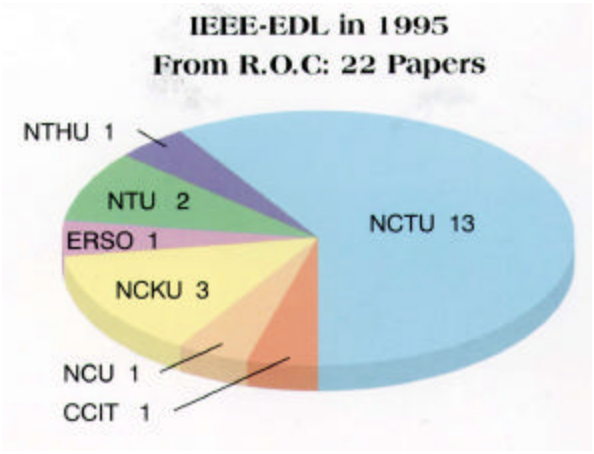
Table 7.



Top10 Institutes in Number of Papers Contributed to IEEE Trans. on Electron Devices in 1995

NCTU	R.O.C	18
Hitachi	Japan	12
MIT	U.S.A	11
NEC	Japan	10
IBM	U.S.A	10
Texas Instrument	U.S.A	10
Toshiba	Japan	9
NTT	Japan	9
Motorola	U.S.A	8
University of Florida	U.S.A	8

Table 8.



Top 10 Institutes in Number of Papers Contributed to IEEE Electron Device Letters in 1995

NCTU	R.O.C	13
Motorola	U.S.A	11
California (Berkeley)	U.S.A	7
Seoul National Univ.	Korea	7
IBM	U.S.A	6
NTT	Japan	6
Texas(Austin) Univ.	U.S.A	6
AT & T	U.S.A	6
MIT	U.S.A	5
Stanford Univ.	U.S.A	5

Microwave and mm-wave technologies

This is another strong research area in Taiwan that was strongly highlighted at NTU, NCTU, and NCU.

1. The electromagnetics research group at NTU conducts research in microwave circuit design, fabrication and measurements, computational electromagnetics, and antenna design and scattering calculations and measurements. State-of-the-art microwave laboratory facilities including an anechoic chamber and network and spectrum analyzers are also available at this university.

2. AT NCTU, microwave and mm-wave research activities include MMIC design, antenna and antenna arrays, radio-frequency integrated circuit design and fabrication, and radio channel modeling and measurements. The channel sounding and modeling effort is particularly attractive.

3. AT NCU, there are strong ongoing research activities in the area of propagation studies. These activities are aimed at supporting research at the Center for Space and Remote Sensing and also to address emerging research in the area of wireless communications. Studies are focused on K- and Ka-bands and include tree and rain effects on LMDS communication systems.

Highlights of Educational Activities

In all cases and throughout the visits, our hosts emphasized the strong connection between ongoing research and the educational and training activities. Preparation of the future engineering workforce and training professionals in the area of Information Technology are important and were well-emphasized in almost all the research and educational institutions in Taiwan. Most of the activities are related to modernization of courses, laboratory training, and graduate programs for Master and Ph.D. students. The Virtual City project at NCTU is unique and innovative and therefore will be further described in this section.

The project, entitled "EduCities," represents "the first Virtual City in the world to educate its citizens about the Internet." The project was launched in January 2000 and is expected to reach students in Taiwan's more

than 4,000 schools. It is a collaborative effort among NCTU, National Hsinghua University, National Yang Ming University, and the National Hualien Teachers College. EduCities created a web site, http://www.EduCities.edu.tw, which provides students with many kinds of educational and interesting information. It also offers parents and teachers different channels to communicate with children and students. The quality of the contents is controlled by a mayor and on-line police officers who are elected and will be on the look out for users who post indecent articles. EduCities provides the community with the various services a web site should possess including email, web pages, and data search functions. It also allows participants to interact, share, and study.

Challenges to the Telecommunications Industry in Taiwan

A lack of available engineering talent represents one of the main challenges to the telecommunications industry in Taiwan. For continued growth and to enable Taiwan to be in a competitive position in this technology, a larger engineering and computer science workforce is needed. Attractive environments for their continued growth and productivity need to be created.

Another challenge that is facing the telecommunications industry in Taiwan is the new landscape created by the rapidly developing science parks in many parts of mainland China. China is offering attractive business and technical environments including free land, cheap labor, high-quality universities and research institutions, and access to a huge market for many high-tech industries. As a result, a large number of Taiwan companies are moving their capital and/or base operations to China.

This trend also presents a concern for the U.S. as will be described in the next section.

"Taiwan's Tech Migration to China Worries the U.S."

This title is actually taken from Taiwan's newspaper, *Taipei Times*, published on May 30, 2001. The newspaper article simply points out that as Taiwan's chip subcontractors continue to migrate to China, the U.S. is likely to end up in an odd position: its main supplier of PCs and information technology gear will be its main strategic adversary. The article seconds the panel findings regarding the industry challenges in Taiwan and, in addition to the high cost of land and the lack of engineering manpower, it points out a lack of and the high cost of power in Taiwan. It also provides numbers that support the claim that U.S. companies such as Dell, Compaq, and Gateway are highly dependent on subcontracts from Taiwan to build their computers and maintain their business. These numbers are listed here for reference (see Table 9). The panel's observation that this trend of Taiwan's technology migration to China has been amply emphasized and its consequences are described in this newspaper article.

Table 9. Taiwan's technology migration to China.

ASSEMBLED IN TAIWAN …		**… BUT MADE IN CHINA**
Percentage of world output bought from Taiwan, 2000		Percentage of that output produced in China
SCANNERS 93%	→	80%
MONITORS 54%	→	45%
DISK DRIVES 39%	→	50%

Source: Institute for Information Industries, Taiwan

Observations and Summary of Findings from Hong KongVisits

Hong Kong has been one of the largest business ports in the world. Government-set strategies have always been based on a hands-off approach, an open market, and providing a regulatory environment that is fair, facilitates a level playing field, and encourages competition. More recently, there have been new initiatives intended to build Hong Kong's high-tech industry and facilitate, through Hong Kong's open business environment, its leadership participation in some of the fast-growing technologies such as optoelectronics, biotechnology, and telecommunications. Avenues to achieve this goal include the establishment of the "Innovation and Technology Commission" and providing funding to build state-of-the-art and even "futuristic industrial parks" and infrastructures. These include the Cyberport, HK Science Park, and the Digital 21 Program. In addition, there was a renewed commitment to education and strong support to research innovations at universities and educational institutions. Among the stated objectives of the Innovation and Technology Commission, besides fostering research innovations and strengthening R&D collaborations between universities and industry, is to establish industrial research chairs at universities to help attract talented and distinguished researchers to Hong Kong. The Cyberport, HK Science Park, and Digital 21 programs, on the other hand, are still in the development stages and collectively will ensure Hong Kong's active participation in the development as well as use of next-generation technologies including wireless telecommunications, Internet, electronics (smart card and digital television), and biotechnology. In each case, emphases are placed on funding collaborative research efforts among universities, strengthening ties between universities and industry, encouraging technology transfer and development of innovative products, and providing modern education and personnel training for the future work force in Hong Kong.

Regarding research activities at the universities observed during our visit, it is fair to say that they are state of the art, addressing challenging issues in the telecommunications technology. As cited by one of our panelists in the digital signal processing and communication areas, the observed research activities and the quality of research are comparable with research in the top 25-50 universities in the U.S. More specifically, the DSP, Mobile Radio Communication, and Electromagnetic Laboratories at the University of Hong Kong were equipped with state-of-the-art laboratory facilities. Research work at the Hong Kong University of Science and Technology "Center for Wireless Information Technology" (CenWIT) is characterized by collaborations among faculty with different expertise and is highly productive particularly in the area of publication of journal articles. Major research areas at CenWIT include wireless multimedia communication, broadband wireless access [particularly using Orthogonal Frequency Division Multiple access (OFDM)], and wireless networking including mobile-IP and ATM. A more detailed description of the research efforts in these areas is included in the chapter on communication (Chapter 3) and the chapter on DSP (smart antennas) technologies (Chapter 4).

Telecommunications in China

> "The number of cellular phones in use in China at the end of July reached 120.6 million, surpassing the number in the United States (120.1 million) to take first place globally. The number of cell-phone users is expected to continue to grow 20% annually through 2005." (*China Economic Times*, September 25, 2001)

After contacting several of our research colleagues in mainland China and making plans to visit their institutions and some of the major telecommunications research centers, an unfavorable political environment developed on the international scene, and all the panel visits to the mainland were cancelled. To help the panel continue with its work, however, two workshops were scheduled in Hong Kong to which colleagues from research centers on the mainland were invited to participate and make presentations. In addition, when the panel presented its findings in a workshop in Washington, DC, colleagues from the mainland were invited, and this helped the panel revise and consolidate some of its findings. The fact that many of these findings are based on presentations by others rather than on observations by the panel and the fact that some of the observations were based on translation of information available on the Internet as well as on earlier visits by some members of the panel make these findings subjective and incomplete. Another visit to this

region may be required to develop the much-needed comprehensive view and to complete the limited set of findings currently available.

There is no question that the Chinese telecommunications market is the largest in the world, and it has an annual growth rate that may exceed 100%. The number of subscribers reached a total of 73 million in 2000, and efforts by the Chinese government are underway to position the People's Republic of China as a technology leader in this phenomenally growing market. In addition to providing the Chinese people with the latest fiber and wireless technologies, China has recently developed its own wireless standard (TD-SCDMA) to help address its growing needs and, equally important, to reduce reliance on existing standards and their foreign implementation in China. PRC continues to encourage joint ventures and foreign participation in building the telecommunications infrastructure in its country just to meet the growing communication and education needs of its people. In addition, and with the support of the government, China has recently been able to develop new versions of available technologies (e.g., ATM switch router technology, OCDMA switch technology, and smart antennas) to help boost innovation, provide legitimate participation in the technology, and avoid paying royalties. Furthermore, the Chinese government has been establishing a strong presence in the telecommunications industry through its support of the Datang Telecommunications Technology and Industry Group. This government-controlled group consists of eleven research institutes and centers, eight excluded or joint venture companies, and one company that is now participating in the Chinese stock market. Establishing these joint ventures involves some real and virtual business dealings with companies both in China and abroad. A more detailed discussion of this aspect of the telecommunications industry is included in the business-related chapter prepared by Prof. Boulton (Chapter 9). Also, more detailed descriptions of some of the science and technology parks in China as well as some of the more prominent research institutes are included in the chapter on the telecommunications infrastructure and science parks prepared by Dr. Y. T. Chien (Chapter 2).

In the remaining part of this section, we summarize some of the research activities at some of the major research universities including Tsinghua University and Beijing University of Posts and Telecommunications. The Tsinghua University (which is the most prestigious technology university in PRC) houses the Research Institute of Telecommunications and Microwave. A wide variety of telecommunications research is being conducted in this institute including microwave circuits and systems, antennas, ASIC design, modulation techniques, software radio, and software for full simulation of communication systems and wireless networks for IP and ATM systems. In addition to the large volume of research, the Institute has a very impressive group of industrial sponsors including Hewlett-Packard, Texas Instruments, Agilent Technologies, and Lucent Technologies from the U.S.

Among the several colleges in the Beijing University of Posts and Telecommunications is the College of Telecommunications Engineering and its Wireless Technology Innovation Lab. Once again, a wide variety of research projects were reported in this lab including optimization of spreading codes, smart antennas, OFDM, wireless networks including ad hoc networks, and software radio. No details are available regarding the magnitudes and the specific accomplishments in these projects; nevertheless, it is felt that ongoing telecommunications activities in China are far beyond implementing available technologies to meet the expanding demand. Instead, a good portion of the ongoing efforts are aimed at positioning the PRC to be a legitimate and effective player in the continued and future development of next-generation telecommunications and information technologies.

ASSESSMENT OF FINDINGS AND CONCLUDING REMARKS

It is fair to say that given the difficult circumstances under which this study was conducted and even with the cancellation of all site visits to the mainland, the study was very successful. Discussions with researchers and colleagues in Hong Kong, Taiwan, and mainland China participants in the workshops were conducted in a cooperative and scholarly environment. Participation by colleagues from PRC in both the workshops in Hong Kong and the one in Washington, DC was quite valuable, and their presentations significantly benefited the study and enhanced its findings.

As for a comparison between the panel findings in Hong Kong, Taiwan, and mainland China, we certainly observed varying approaches by their governments for facilitating strong participation in telecommunications technology. While an overarching national vision for strengthening R&D, encouraging innovation, giving strong government support for education and university research, and providing value-added (not only cheap) to products from industry was observed in Taiwan, focus in Hong Kong was on business stimulation, manpower training, and on providing a level playing field and a fair and competitive business environment. In mainland China, on the other hand, there is a national vision that calls for continued international collaboration to build the telecommunications infrastructure and to meet the fast-growing needs in education, communication, and possibly entertainment. At the same time, there is a large and widespread government-funded effort to build Chinese-owned technologies, develop their own telecommunications standards (e.g., TD-SCDMA for wireless), and start competing (in spite of the late start) in this rapidly expanding and potentially lucrative market. The observation regarding Taiwan's potential high-tech migration to the mainland is also of interest. In addition to its overarching government-imposed vision, China is providing attractive business deals, free land, and privileged access to their huge market. Much of the manpower working in these companies consists of qualified individuals from mainland China, and in spite of its desire to control the flow of technology to PRC, the Taiwanese government seems helpless and this trend worries the U.S. Statistics given earlier in this chapter regarding the heavy reliance of the U.S. computer industry on chips that were being manufactured in Taiwan and are now being manufactured in mainland China are of concern, and alternatives need to be found to address this issue and better secure the interest of the U.S.

Regarding the observed technological advances and how they compare with the R&D trends reported in the earlier wireless study in Europe and Japan, the panel with the help of colleagues from PRC prepared Table 10 for reference. From this comparison, it may be observed that the magnitude of the R&D activities in Europe and Japan is much larger and that perhaps, because of its small scale, the R&D activities in China are also strongly focused on niches and software-related fields and research areas. Activities in the development of system-wide approaches for next-generation telecommunications technologies in China are almost nonexistent. Strong trends, however, exist towards the development of high-tech development zones, science parks, and large conglomerates of research institutes and training centers. The chapter on this topic prepared by Dr. Chien provides a more detailed description of these efforts and a comparative evaluation of their growth rates, focus technologies, role of government, nature of capital investments, and overall innovation and entrepreneurship. Table 11 provides a comparison of some of the main science parks, while Table 12 shows a comparison between research and education Internet networks.

Table 10. Telecommunications technology.

Technology	Europe Status	Japan Status	U.S. Status	Taiwan Status	Hong Kong Status	China Status
Hardware						
mm-wave circuits and systems	****	*****	**	*	–	**
Packaging/interconnect	***	****	*****	*	–	*
CAD	***	**	*****	**	–	**
SiGE/Si	****	***	****	*	–	*
III-V	***	*****	*****	**	–	**
GaN	***	****	****	–	–	–
Antennas	***	****	***	*	*	***
Passive components	****	*****	****	**	*	**
Amplifier technique	****	****	*****	–	–	***
MEMS	**	***	****	–	–	*
Channel Characterization and Propagation						
Statistical/empirical	***	***	***	**	–	**
EM-based deterministic	**	*	***	*	–	*
Integrative models	**		*	**	–	**
Microwave and millimeter wave	*	**	**	**	–	**
Coding, Modulation, and Multiple Access						
Multi-user detection	**	***	*****	*	**	*
Coding	*****	***	*****	**	**	***
Multiple access	****	****	****	*	**	**
Software Radios						
Software radio technologies	***	***	***	–	*	**
Energy-efficient communications	***	*	***	–	*	*
Integrated approaches	*	***	*	–	–	–
Optical technology	*	***	***	*	–	–

Table 11. Comparison of science parks.

Key Elements		Hsinchu Science Park	Zhongguancun Science Park	Silicon Valley	Tsukuba+ Bit Valley
University and research institution		***	***	***	***
Industry	Dynamics	*	**	***	**
	Infrastructure	***	**	***	**
	Clustering	***	***	**	***
Capital	Foreign	**	***	**	*
	Domestic	**	**	***	**
	Venture	*	*	***	**
Labor mobility		*	*	***	**
Market	Overseas	***	***	**	**
	Domestic	**	**	***	***
Innovation and entrepreneurship		**	**	***	***
Role of government		***	***	**	**
Impact on telecommunications research		***	***	**	***

* – Weak/Average ** – Strong *** – Very Strong

Table 12. Comparison of research and education networks.

Research and Education Networks	China's CERNET	Taiwan's TANet2	U.S. NGI/Internet2
Infrastructure	**	**	***
Basic research	*	*	**
Applications research	**	***	***
Innovation and initiativeness	**	**	***
Outreach and education	***	***	**
Collaboration across borders	*	**	***
Government/industry/academia links	**	**	***
Impact on telecommunications R&D	**	**	**

* – Weak/Average ** – Strong *** – Very Strong