

*International Technology Research Institute
Technology Transfer (TTEC) Division*

TTEC Panel Report on

Electronics Manufacturing in Hong Kong and China

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TTEC PANEL ON ELECTRONICS MANUFACTURING IN HONG AND CHINA

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ABSTRACT

As this report describes the current state of electronics technologies and manufacturing capabilities in China and Hong Kong. It is obvious from this study that China is rapidly closing the gap on critical component technologies needed to produce today's most advanced consumer electronics, including MP3 players, desktop sets, personal digital assistants, and cellular phones. China's IC design capabilities are competitive in the global marketplace. Companies are using leading edge manufacturing technologies for assembly that include chip-on-board, chip-on-glass, and chip-scale-packages. China's domestic need for semiconductor fabrication is not so much for the technology as for the supply of electronic components needed to meet the rapidly growing domestic demand. The integration of Taiwan and China could rapidly improve China's access to technology and capital, resolution of conflicts and reunification are continuing political priorities. A "One China" reality could rapidly change the real status of Chinese technology capabilities, especially in electronics.

We should not underestimate the attractiveness of a marketplace with 1.3 billion people. What is more, this market provides unlimited low-cost labor (\$100/month for urban factory workers), world-class industrial parks (53 high-tech industrial parks) that provide tax incentives for up to 8 years and maximum corporate taxes of 15%, and a rapidly opening marketplace (meeting WTO requirements). While there are significant short-term risks and uncertainties that relate to political corruption and a weak legal system, the government appears committed to utilizing foreign direct investment to help build its Western regions (adding significant investment opportunities and tax incentives). Such a commitment requires that the government build a business-friendly environment. If this does not happen, it is unlikely that the government can generate the new jobs needed to support continued restructuring of its economy, and the closure of many state-owned-enterprises that are not competitive in a free market economy.

In conclusion, the panel was impressed with the basic capabilities found in China. Many products and capabilities are considered equivalent to those found in the West or Japan. Where capabilities are lacking, it is primarily due to the lack of investment, such as in semiconductors, where additional capacity costs are extreme. Over the next five years, IC capacity should nearly double. Even then, this will only meet about 25% of internal demand.

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TABLE OF CONTENTS

Table of Contents	i
List of Figures	iii
List of Tables	iii
Executive Summary	v
 1. China's Economic Development Priorities <i>William R. Boulton</i>	
Introduction.....	1
Getting the Government Out of Business.....	2
Separating Military and Business Activities	3
"One China" Policy.....	3
Priority 1: Continue Economic Development.....	4
Priority 2: Create New Jobs	7
Priority 3: Increase Foreign Direct Investment	11
Priority 4: Increase Science and Technology	13
Golden Projects: Building the Information Infrastructure.....	18
The Torch Program: National High Tech Development Zones.....	21
 2. China's Semiconductor Industry <i>Michael Pecht, Weifeng Liu and David Hodges</i>	
Background.....	25
Domestic Semiconductor Manufacturers	32
Newer Fabs	36
Role of Foreign Companies.....	39
IC Industry Assessment.....	40
Acknowledgements	41
References.....	41
 3. Computers in China <i>Michael Pecht and Weifeng Liu</i>	
History of Computers in China	45
National Development Goals	46
China's Computer Market.....	47
Major Domestic Computer Manufacturers.....	51
Major Foreign Competitors	53
PC Distribution Channels in China	54
Acknowledgements	56
References.....	56
 4. Electronics Assembly Manufacturing in China <i>E. Jan Vardaman</i>	
Introduction.....	59
Low Cost Labor: How Long Will it Last?.....	59
Movement Into Advanced Electronics Products	60
Automation and the Expansion Into Advanced Contract Assembly.....	61
ISO Certifications and Quality Control.....	63

	China's Future as an Electronics Manufacturing Powerhouse	64
5.	Summary Findings of China's Electronics Industry	
	<i>William R. Boulton</i>	
	Technology and Labor are Competitive.....	67
	Increased Incentive for FDI.....	67
	One-China Policy.....	67
	Conclusions.....	68

APPENDICES

A.	Basic Policies Governing China's Foreign Trade and Economic Cooperation	69
B.	Biographies of Panel Members	79
C.	Site Reports	
	Hong Kong University of Science and Technology	82
	Compass Technology Company Limited	86
	Hong Kong Productivity Council.....	90
	Namtai Electronics, Inc.	92
	Whitways Enterprises Limited.....	98
	The Legend Group.....	102
	National Microanalysis Center, Fudan University	106
	Parlex (Shanghai) Circuit Co., Ltd.....	107
	Shanghai Huahong (Group) Co., Ltd.	114
	China Huajing Electronics Group Corporation	120
	China Integrated Circuit Design Center.....	123
	Ministry of Information Industry	138
	Tsinghua University.....	130
	Embassy of the United States of America.....	139
	IRICO Display Device Co., Ltd.....	141
	Xi'an Orient Software Co., Ltd. (Xi'an Orient)	142

LIST OF FIGURES

ES.1	Taiwan's PC component world market share.....	?
1.1	Taiwan's world market shares	4
1.2	China's slowing growth	4
1.3	China's deflation.....	7
1.4	China's income gap.....	8
1.5	China bandwidth	19
1.6	High tech industrial parks	22
2.1	Breakdown of Chinese IC Applications	29
3.1	PC Sales Volume and Growth of GDP in China, 1983-2000	49
3.2	Personal Computer Annual Sales of Legend Group Since 1994	54
3.3	Top 10 vendors and their PC market share in China	56
3.4	Top 10 vendors and their PC market share in the Asia-Pacific Region.....	57
4.1	Contract Manufacturing Sites (1994).....	61
4.2	Recent Figure Product Developments	63
4.3	Small Chip-on-Glass Mounting Equipment for the Chinese Market.....	65
4.4	Next Generation Cell Phones Production in China	67

LIST OF TABLES

1.1	Comparative Economic Statistics.....	5
1.2	Patterns of Foreign Direct Investment in China	13
1.3	Summary list of the Golden Projects.....	20
1.4	National High Technology Industry Development Zones	23
2.1	Total IC Demand and Production in China (million units).....	28
2.2	China's IC Import and Export Markets.....	28
2.3	China's IC Import and Export Product Type in 1999	28
2.4	IC Manufacturing Technology Status in China	32
2.5	IC Technology Development in China.....	32
2.6	Summary of Chinese IC Fabs.....	34
3.1	Personal Computer Market in China (US\$ million)	50
3.2	Personal Computer Sales in China by Brands (Unit sales: millions).....	51
4.1	Salary differences.....	62
4.2	Whitway's Equipment for Contract Manufacturing.....	64
4.3	Clean Room Requirements by Application	66
4.4	Global cellular phone market (million units)	67

EXECUTIVE SUMMARY

From April 9 to 19, 2000, a panel of experts revisited the People's Republic of China to assess the current status of electronics manufacturing technologies. This summary of the panels findings includes 1) a macro view of the economy and related policies, 2) a summary of the technologies that are central to the electronics sector, 3) a summary of the findings, and 4) reports of the site visits. The panel members' findings include discussion of the technological capabilities, political priorities, and implications of a "One China" policy.

CHINA'S RAPID DEVELOPMENT

Economic development continues to be China's leading priority. The new five-year plan targets development of Western China with 60% of its resources, including external borrowings in an effort to close the income disparities between eastern (over US\$1000/capita) and western (under US\$200/capita) regions of China.

The panel visited a China on the verge of joining the World Trade Organization, being rapidly driven towards deregulation and privatization of its state-owned-enterprises, and providing ever increasing incentives to attract foreign capital and technology. With a growing number of state-owned enterprises going out of business or downsizing, unemployment and welfare has become a major concern. It is estimated that over 18 million new jobs are needed annually to stay even. In addition, migrants are projected to reach 150 million per year. The prospect of civil unrest, even riots, requires more aggressive incentives and deregulation to entice foreign direct investment at a greater rate than ever before.

China's attempts to attract high technology firms have been successful. In 1999, China's 53 industrial parks generated aggregate revenues from technology, industry and trade of RMB 656 billion, with growth of 30% from 1998. The 17,900 enterprises located in national high tech development zones created profits of RMB 35.6 billion (US\$4.3 billion), tax paid RMB 27.5 billion (US\$3.3 billion) and foreign exchange earned through export USD 10.6 billion (a breakthrough of US\$10 billion for the first time in the sector). As a result, the enterprises whose output value have exceeded RMB 100 million (US\$12.5 million) reached 800 in number including some domestic renowned enterprises such as Legend, Haier, Hisense, Fangzheng.¹ The government plans to build 20 new high-tech industrial parks in western regions.

CRITICAL ELECTRONICS MANUFACTURING TECHNOLOGIES

The panel found most electronic assembly technologies widely available in China. For example, the world's leading electronics assembly firms already have established operations within China. Hong Kong firms are agents for equipment makers, including Japanese firms. Increasingly, producers of critical technologies and components are setting up operations, including flex tape and flex circuit manufacturers. LCD's and LCD modules for cellular phones are now produced in China. Namtai was producing advanced electronic components, such as LCD modules for hand-held electronic products, under license for export to Casio (Japan). Namtai was using chip-on-glass technology for its LCD modules. The availability of SMT and chip-on-board technology is widespread, including small contract assemblers like Whitways Enterprises Limited. Leading edge prototyping equipment and test and analysis equipment are also readily available. The primary problems in competitiveness come from state-owned enterprises that lack the capital to upgrade their production capabilities. One of the government's top priorities is to improve state-owned enterprise competitiveness through mergers and initial public offerings to raise needed capital for upgrading of technology.

¹ Development Targets of High Tech Development Zones Materialized Ahead of Schedule, *China Science and Technology Newsletter*, No. 28. March 20, 2000.

Semiconductor production in China is still limited to "prior generation" capabilities adequate to meet local customer needs. The real problem in semiconductors relates to the shortage of domestic supply, which requires imports of such components. China has about half the number of IC fabs as Taiwan or Singapore, which are much smaller countries and economies, of course. Most semiconductors sold in China are imported from fabs in Asia, including Japan, S. Korea, Taiwan and Singapore. Similar import problems occur with components used in electronics products produced in China, requiring imports until the local materials and component industries can be fully developed. This is a problem that plagues developing Asian countries. However, most components and materials are available from Japan and Taiwan, even though there are sometimes problems in obtaining the best quality in a timely fashion.

China Huajing Electronics Group Corporation has completed a joint venture with TSMC (Taiwan's leading semiconductor maker) to improve its MOS technology. Shanghai Hua Hong NEC Electronics is a joint venture with NEC (the world's largest semiconductor maker) that uses 0.35-micron design rules for fabrication of 8-inch wafers. Unfortunately, Hua Hong NEC's output is exported to NEC in Japan, not helping with local shortages. Given the shortage of semiconductors in China, any capacity not utilized internally is a weakness. China would like to double its number of semiconductor fabs during the next five-year plan.

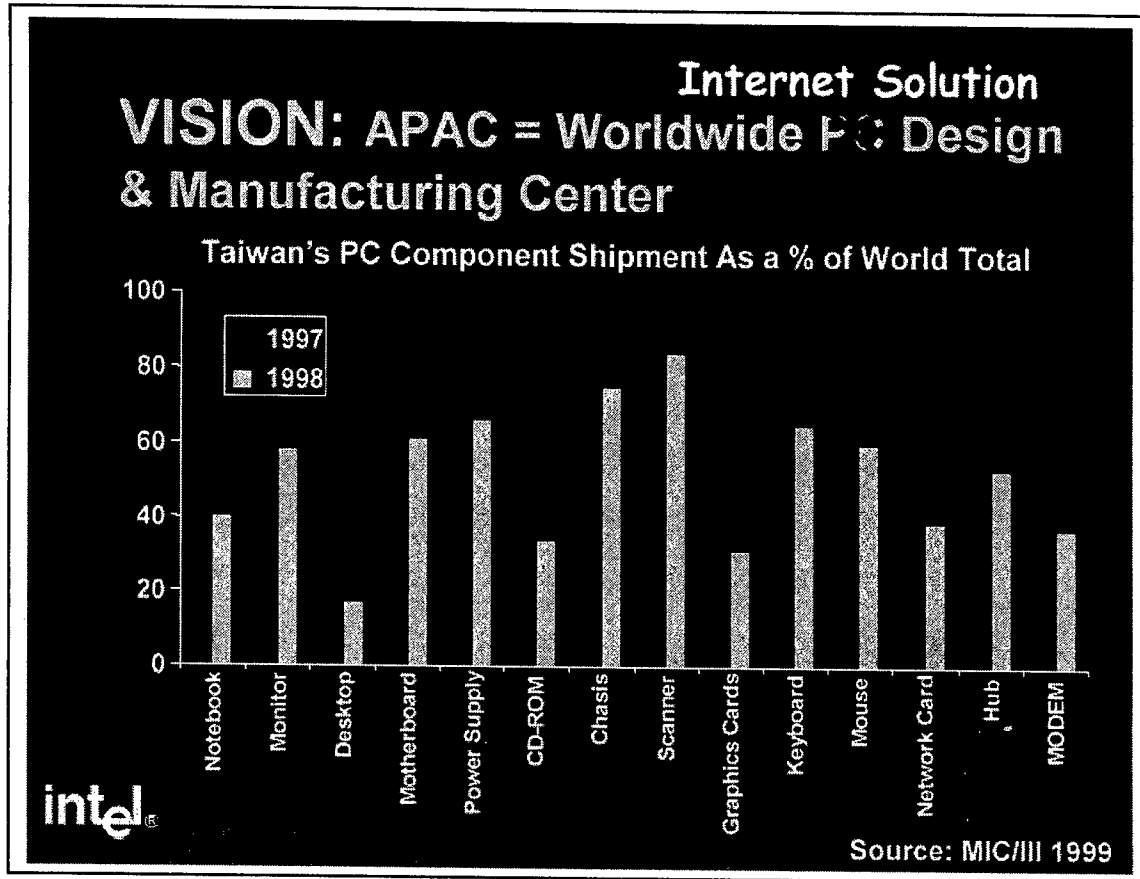
The panel found that design technologies available in China for electronics components and products are competitive with those found in the West. A Chinese state-owned enterprise, China Integrated Circuit Design Center (CIDC), is producing advanced electronics products such as set-top boxes and MP3 players. CIDC has developed its own electronic design automation tool, sold under the Panda brand, which is also used to develop ASICs for its own applications. Advanced ASICs can be purchased anywhere in the world, making it unessential for China to build the advanced fabs to manufacture them.

Chinese manufacturers were also gaining local market position. Legend Group, for example, controlled nearly 25% of the Chinese PC market. Legend produced about 1.3 million PCs in 1999 and was increasing capacity to 3 million in 2000 in anticipation of continued growth. Legend designs its own motherboards at its R&D facility in Shenzhen, and produces its boards in nearby Huiyang (Sun City). Legend has ISO 9001 and 9002 certifications.

ONE-CHINA POLICY

Now that Hong Kong and Macau have been returned to China, it seems inevitable that relations with Taiwan will be improved. The U.S. Administration continues to espouse the One-China policy. The question is one of timing, when discussion will resume. The proposed reunification of North and South Korea seems to support early action. With regards to technology, a One-China has interesting implications for improving China's overall technology base. Consider Taiwan's worldwide market share in PC and Internet hardware components. From Figure 1, these market shares would belong to China after reunification with Taiwan. This also means that related component technologies, such as Taiwan's 12.5% of the world market share for semiconductors, would also become part of China's calculations. At such time, China would not have a technology problem. Even more importantly, financial resources would also be available to support rapid transfer of such technologies to the mainland.

Figure ES-1: Taiwan's PC Component World Market Shares



CHAPTER 1

CHINA'S ECONOMIC DEVELOPMENT PRIORITIES

William R. Boulton

INTRODUCTION

In the 1990s, we completed a survey of electronics and information strategies across Asia. We sent teams to Japan, Taiwan, Hong Kong, Singapore, Malaysia, South Korea, and China to observe their competitive developments in today's most dynamic industries. The results of those studies were published in a number of documents, including *Electronic Manufacturing and Packaging in Japan* (1995), *Semiconductor and Electronic Manufacturing in the Pacific Rim* (1997), and *Information Technologies in the Development Strategies of Asia* (1999). With the advent of the Internet, the speed of globalization, technological change, and the rapid informization of society, it was time to initiate a follow-up study. We decided that China should be the first of these updates since much had changed with the reunification of China with Hong Kong and Macau.

This study, though intended to cover a broad range of electronics manufacturing technologies is also intended to provide a discussion in which the context of change is taking place in China today. The move toward entry into the World Trade Organization will further change the basic rules in which Chinese industry is conducted in the future. The separation of Chinese government and military organizations from industrial activities will further change the look of the Chinese industrial landscape. The move towards a more "democratic" political system, in which city mayors are elected locally, is expected to continue to become more widespread in the future.

China is moving towards a mixed economy with economic reforms and decentralization of political controls. The government still directs heavy industries and is attempting to revitalize its largest state-owned enterprises. Developing and sustaining competitiveness in the face of global competition is going to be China's major challenge. It will depend upon:

- The degree to which the foreign private sector is allowed to enter the market and raise the levels of performance to global standards.
- The degree to which state owned enterprises (SOEs) are forced to transform themselves from politically controlled bureaucracies to dynamic managements focused on competitive quality, cost, deliver and service to their customers.
- The degree to which labor markets effectively allocates talent and skills into the needed business sectors.
- The degree to which capital resources are made available to the needed industries and companies.

The message of this chapter is that China presents much the same dichotomy as a typical American city: one a rich, rapidly growing suburb (China's control region) and poor, decaying core city (inland China and the Northwest).

GETTING THE GOVERNMENT OUT OF BUSINESS

Today's economic environment is driven by globalization, exploding technologies, information-intensity, and entrepreneurial behaviors. It requires:

- Free access to global information and markets.
- Protection of physical and intellectual property.
- People able to communicate and associate freely.
- A government with sufficient legitimacy to comfortably join the global economy.
- An educated population.
- A rules-based polity.

These requirements do not conform to a highly authoritarian system. They are driving political change in China.

With increased prosperity, China's leaders have struggled to create and refine the institutional, legal and commercial structures required by a modern economy, and to integrate China more fully into the international trading system. Chinese policy-makers are attempting to address challenges including: misappropriation of intellectual property, imposition of ad hoc taxes and charges, corruption, smuggling, frequent sweeping changes in laws and regulations, and the blurring of lines of authority among various national, regional and local power centers.

At present, China's political center includes about 200 un-elected, often elderly, men. They have decentralized responsibility for economic growth to local level, while controlling the hiring and firing of local and provincial officials. Both Zhu Rongji and President Jiang Zemin were previous Shanghai mayors. Shanghai Mayor Xu Kuangdi, one of the closest aids to Chinese Premier Zhu Rongji, has been in office since February 1995. They have centralized the collection of tax revenues and, more recently, the rationing of credit to the state sector. This model will likely become the core of China's future political system. It is not unlike that of Singapore, and Singapore is often China's model.

Premier Xhu Rongji's address to the Ninth National People's Congress in Beijing on March 6, 2000 outlined the basis for separating the bureaucracy from business activities. Zhu called for intensifying industrial restructuring, product quality and economic performance to make industry more competitive in the global environment. Restructuring key state-owned enterprises is intended to reduce the number and increase the size of surviving firms.¹ His latest policies include:

1. Reducing production by obsolete state-owned enterprises (SOEs) with non-marketable products.
2. Effective measurement to speed up technological upgrading of SOEs, with implementation of improved methods for quality and manufacturing.
3. Vigorous efforts to develop high technology and emerging industries, particularly in the fields of information, bio-engineering, new energy sources, new materials and environmental protection; while China takes advantage of labor-intensive industries.
4. Industrial restructuring be continued to improve economies of scale and the optimization of distribution.

¹ Premier Zhu Rongji, "We still fall far short of people's expectation," *Hong Kong Business*, April 2000, p. 19.

The new five year plan also has set its goals to raise tertiary industries' proportion of GDP, including information, banking and financial services, tourism, community services and intermediary services.²

SEPARATING MILITARY AND BUSINESS ACTIVITIES

The military had cashed in on the relaxation of investment and trade guidelines. In the mid-1980s, the military was given relatively free rein to forge business links with foreign companies wanting to do business in China. The People's Liberation Army (PLA) oversees a defense budget of about \$40 billion, which includes a stockpile of nuclear warheads, chemical, and biological weapons, and ballistic and cruise missiles. By 1998, the PLA added an estimated 15,000 businesses, including airlines, hotels, and textile and pharmaceutical manufacturers. Officials estimated that PLA profits exceeded \$1 billion per year. PLA-backed companies were accused of counterfeiting compact discs and software, and selling weapons of mass destruction to rogue countries. In July 1998, President Jiang Zemin ordered the PLA to relinquish its massive network of commercial enterprises. The Chinese president was attempting to stem the smuggling by PLA-run businesses – whose trucks don't pay tolls and don't get stopped by police.³

The People's Liberation Army and the paramilitary People's Armed Police (PAP) have indeed either closed down or handed over to civilian control most of the purely commercial enterprises covered by the divestiture order. According to a March 1999 article in the monthly magazine *Shidai Chao*, published by the official People's Daily, the PLA and PAP had transferred 2,937 businesses to the state and closed a further 3,928 by an initial deadline of December 1998. Of those, 82% had belonged to a single department of the PLA, the General Logistics Department. Among the enterprises handed over were some of the crown jewels of the military's business empire, including China's largest pharmaceutical company, 999, and the Xinxing Group, whose core business is trade in military supplies such as uniforms, tents and port equipment.⁴

But the same Chinese official also said that an early 1999 audit found the military had failed to declare approximately 10% of the businesses covered by the divestiture order. The civilian leadership set a second deadline of August 1999 for the PLA and PAP to hand them all in. By early this year, the official says, the number of businesses handed in had risen to 3,530, employing some 230,000 people.

"ONE CHINA" POLICY

Politically, the continued implementation of a "One China" policy focuses attention on Taiwan. The domestic pressure on China's leaders to make progress toward unification is strong, in large part through their own making. Since Hong Kong's return to mainland rule in 1997, and especially since the return of Macau in December 1999, the party has raised popular expectations by repeatedly stating that it has moved the recovery of Taiwan into a top place on its agenda. Official speeches and editorials on Taiwan policy routinely promise, as a May 22 *People's Daily* commentary did, that "the Taiwan issue will be resolved. The country's complete unification will be realized. We absolutely will not allow this to be delayed indefinitely."

Premier Zhu Rongji made it clear to the world in March 2000 that the Chinese people were "ready to shed blood and sacrifice their lives to defend the sovereignty and territorial integrity of the motherland." They have also allowed the popular state-controlled press and government-backed scholars to engage in emotional discussions of preparations for war—naval blockades have been a favorite topic. That has "created an expectation at the lower levels that the senior leadership will do something"—possibly militarily—"because it hasn't been shutting off the venting of spleen."

² Ibid.

³ Tim Ito, Overview: Military, *The Washington Post* ([washingtonpost.com](http://www.washingtonpost.com)), July 1998.

⁴ Susan V. Lawrence, A model people's army, *Far Eastern Economic Review* (www.feer.com), July 13, 2000.

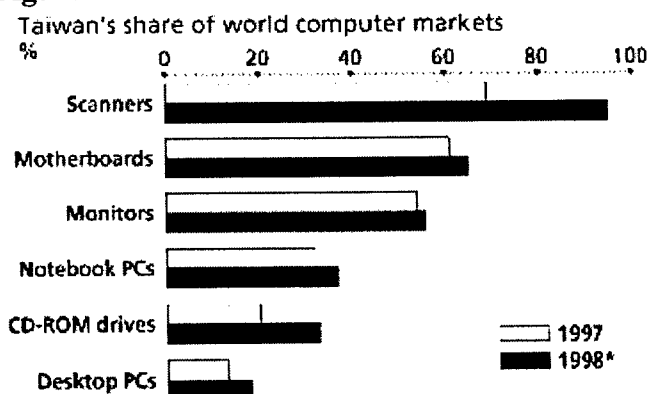
Many Chinese maintain that the Taiwan issue is tied up not only with the legitimacy of the party and the state, but also with China's fragile self-confidence as a nation. "When you try to modernize, especially as a developing country, you want to feel confident about yourself," Jia explains. "If you cannot even protect your own territory, how can you be sure you can modernize? How can you prove your leadership is viable?"⁵

Beijing's policies only favor high tech companies, with integrated circuit (IC) and software firms receiving the latest extension of tax incentives. However, the reunification of China and Taiwan raises more interesting implication for the world's electronics industry. Taiwan is a world leader in most of the critical components used in computers and Internet devices. For example, Taiwanese firms hold over 60% of the world motherboard market, 95% of the scanner market, 55% of the monitor market, and 40% of the notebook computer market. Taiwan holds a 12% market share in semiconductors, with TSMC being one of the world's leading semiconductor firms.

While Chinese firms will continue to dominate not parallel low-tech and medium level industries needed to supply its enormous domestic market, it is still short of capacity to supply the key components needed for more advanced products. China has a significant pool of engineering talent, and the ability to keep manufacturing wages low by tapping workers from the hinterland, as operations move into the impoverished West.

Failure to reform and privatize state-owned enterprises limits competitiveness in heavy industries and high technology industries. The closure of state-owned enterprises is putting pressure on government to improve the welfare system. The opportunities for corruption that will arise from state assets being stripped by officials and managers of state enterprises are also a cause for pessimism. Access to capital is a problem for all firms, but especially for entrepreneurial firms. The sale of state-owned enterprises is expected to provide the needed funds to establish a state-based welfare system.

Figure 1.1: Taiwan's World Market Shares



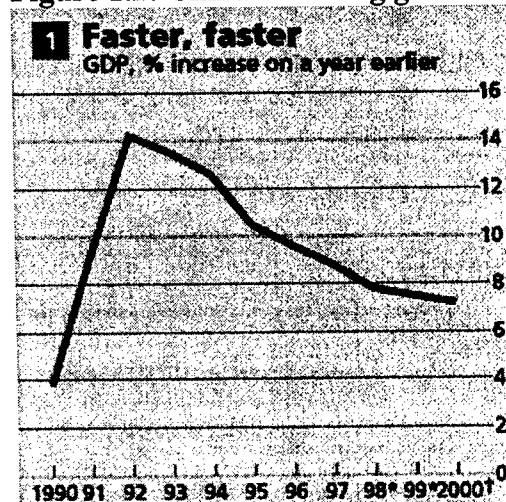
Sources: Market Intelligence Centre, IDC; The Economist estimates *Forecast

PRIORITY 1: CONTINUE ECONOMIC DEVELOPMENT

China has become the world's second largest economy, surpassing Japan in the 1990s (Global Change Exhibit 1-1). The Government disbanded agricultural communes and allowed capital and (particularly) labor to move into low-end manufacturing. The Government moved out of the way to allow for growth. Double-digit growth rates created new jobs for workers made redundant by inefficient state-owned enterprises, migrants from the countryside to urban areas, and the hoards of young people looking for their first job from the growth of that huge population.

With a declining rate of growth (Figure 1-2), China is creating fewer new jobs. The first two decades of reform generated gains from allowing capital and labor to enter

Figure 1.2: China's slowing growth



⁵ Susan V. Lawrence, Cross-Straits Relations: Breathing Space, *Far Eastern Economic Review*, June 1, 2000.

the low-end manufacturing and processing industries directed at export. The Government's role was to get out of the way.⁶ Between 1992 and 1995, Chinese consumers spent 78 cents out of every dollar earned, saving 22 cents. As the Government continues to deregulate the economy, forcing state-owned enterprises to stand on their own, job security has become even more uncertain. Price deflation has resulted from savings rates rising as spending declines (Figure 1-2). Consumer spending fell to only 60 cents out of every dollar, leaving savings of 40 cents.

Table 1.1: Comparative Economic Statistics*

	China	Hong Kong S.A.R.	Taiwan	Singapore	South Korea
Country Size	4th largest country	N/A	N/A	N/A	N/A
Population	1236914658	6706965	21908135	3490356	46416796
Budget Expenditures	N/A	\$ 14100000000	\$ 55000000000	\$ 13600000000	\$ 101000000000
Budget Revenues	N/A	\$ 19000000000	\$ 40000000000	\$ 16300000000	\$ 101000000000
Economic Aid	\$ 1.98 billion	N/A	N/A	N/A	N/A
Electricity Production	1135 billion kWh	28 billion kWh	125 billion kWh	21 billion kWh	174 billion kWh
Exports	\$ 182.7 billion	\$ 180.7 billion	\$ 122 billion	\$ 125.6 billion	\$ 129.8 billion
External Debt	\$ 131 billion	N/A	\$.08 billion	N/A	\$ 154 billion
GDP	\$ 4250 billion	\$ 175.2 billion	\$ 308 billion	\$ 84.6 billion	\$ 631.2 billion
GDP Agriculture	20 %	1 %	3 %	N/A	8 %
GDP Industry	49 %	16 %	36 %	28 %	45 %
GDP Per Capita	\$ 3460.00	\$ 26800.00	\$ 14200.00	\$ 24600.00	\$ 13700.00
GDP Real Growth Rate	8.8 %	5.5 %	6.8 %	6 %	6 %
GDP Service	31 %	84 %	61 %	72 %	47 %
GNP	\$ 1055.4 billion	N/A	N/A	N/A	N/A
Imports	\$ 142.4 billion	\$ 198.6 billion	\$ 114 billion	\$ 133.9 billion	\$ 150.2 billion
Industrial Growth Rate	13 %	3.2 %	7 %	7 %	8.2 %
Inflation Rate	2.8 %	5.1 %	.9 %	1.8 %	5 %
Total Debt	\$ 16.3 billion	N/A	N/A	N/A	N/A
Telephones	89000000	4370000	10010614	1400000	16600000
Televisions	75000000	1750000	10800000	1050000	93000000
Highways	118000000 total km	1760.00 total km	19701.00 total km	3010.00 total km	83400.00 total km
Military Expenditure	\$ 91 billion	N/A	\$ 4.03 billion	\$ 17.4 billion	\$ 11.5 billion
Military Percentage	N/A	N/A	4.3 %	3.3 %	3.6 %

*Sources: This data is collected from the CIA World Fact Book, the World Bank and the International Monetary Fund for 1998

After inflation hit 28% in 1994, government slowed the economy with the introduced a 17% value added tax for domestic transactions. Much of the government's economic policy since has been designed to avoid a recurrence of the inflation nightmare. China has memories of runaway prices in the late 1940s. Half a century on, it can be argued that Zhu Rongji and his economic team tamed inflation rather too brutally. Along with

⁶ *Survey China: Now comes the hard part, Economist*, April 8, 2000

the Asian financial crisis came more stable prices by the late 1990s. The drought and locust outbreak in 2000 has threatened to devastate agricultural output, which may lead to higher prices and food shortages. In addition, global petroleum shortages and related price increases could put further price pressure on the growing economy. This could lead to economic instability within China.

For China's leaders, a prolonged industrial slump and a restive population, demands serious structural change and market reforms. China's national economy is projected to continue to grow at rates over 7%. Shanghai, the business center that sets the economic trends for the nation, continues to grow at rates above 10%. Hence there continues to be a commitment to a private sector that breaks free from the state, to reforming the state sector, and to membership in the World Trade Organization (WTO). China's central government has committed itself to creating a market economy at home that is tied to the world at large. China's leaders understand that the Communist Party is history unless it can deliver growth. And for each of the past seven years now, economic growth has been slowing, risking dissatisfaction amongst the people. Even so, Zhu Rongji, the prime minister, has proposed that China become a freely elected parliamentary political system by 2030.

Zhu Rongji insists that new sources of growth must come from shrinking the state. The 15th Communist Party Congress in 1997 marked the start of this new phase with the suggestion that tens of thousands of small and medium-sized state enterprises would be cast loose upon private waters, to float or sink. In 1999, private sector guarantees were actually written into the state constitution. Membership in the WTO will prove as momentous a step as Deng Xiaoping's opening to the world in late 1978. China's closer integration with the world economic order will increase the pressure on it to become much more open, liberal and receptive. China's Minister of Foreign Trade and Economic Cooperation has published a list of policies that are intended to guide China's trade and investment activities under WTO (see www.moftec.gov.cn). All these economic changes will force profound changes in China's political system and its society generally.

Financial Reforms

An overhaul of the tax system in 1994 gave the central government the ability to collect revenues from the provinces. Annual revenues are now equivalent to 13% of GDP (compared with 31% for America).⁷ China's central bank, the People's Bank of China, used to operate like other state enterprises with branches in every local area to support the pet projects of local party bosses. The central bank has now been reorganized into nine regional branches. The central bank monitors branches of the four state banks, which provide credits to local state enterprises.

In January 2000, the governor of the People's Bank, Dai Xianglong, an ally of Premier Zhu Rongji, told the state banks that "they had had their last dinner." The state bank's non-performing loans are 1.2 trillion yuan, or equivalent to 15% of GDP. The government's outstanding debt equals 20% of GDP. There are some estimates that it could be double that amount. The loans are being put into asset-management companies to restructure, repack and sell over a period of ten years. The government hopes it can recover almost one-third of the bad loans, a questionable goal.

China's annual tax revenue (of which nearly one-fifth goes on paying interest on government debt) is its main asset. In all, the government's liabilities are approximately 100% of GDP. Government debt is expected to peak at 60-70% of GDP, a high but still manageable level. But should bad loans increase or tax revenues stagnate, the debt ratio could spiral out of control. The sale of state enterprises is considered one possible source of additional revenues, but in a socialist country there are still intense ideological objections to selling control of telecom, energy and transport companies. China's under-invested railroads and urban-transport networks will be difficult to sell. China Telecom raised \$3 billion in Hong Kong over two years ago, and its shares have since soared. It is a company in a growing, forward-looking business, without a pension legacy, and with a near-monopoly position. China Unicom, China's second largest telecom provider, raised \$5

⁷ *Survey China: Whatever it is, we cant afford it, Economist, April 8, 2000.*

billion on the New York Stock Exchange in June of 2000.⁸ In total, by June 2000, China held \$158 billion in foreign exchange reserves.

The cost of state workers' pensions is projected to reach 50% of GDP. This has affected strategies for raising capital. For example, PetroChina, seeking to float a minority stake on the New York Stock Exchange, lost the support of fund managers when it disclosed that funds would be used to pay pensioners.

PRIORITY 2: CREATE NEW JOBS

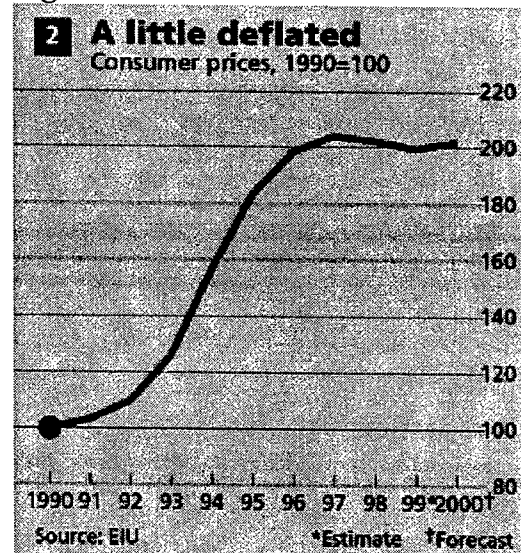
The country's 1.3 billion people make up one-fifth of the world's population, but they live on only one-fifteenth of the world's land. In fact, because a large part of China is inaccessible and inhospitable, the density in the main population centers is much higher than those figures suggest. Two-thirds of Mainland Chinese live in the fertile eastern fifth of the country. China has 31 provinces, including the four municipalities with province-level status and the five autonomous regions (like Xinjiang and Tibet). In addition, Hong Kong and Macao are special administrative regions with closely policed territorial borders with the motherland.

By land area, the biggest province is Xinjiang; three times the size of Spain. China's largest city, Shanghai, has a 15 million population; five times the population of Singapore. China's most populous province, southern Sichuan, has over 110 million people, nearly 85% as many as Japan. Guangdong, Hubei, Anhui, Hunan, Hebei, Jiangsu, Shandong and Henan each have between 59 million and 93 million people, comparable to countries like France and Mexico. The Guangxi Autonomous Region, with 46 million people, is more populous than Poland.

The scope of China's development problems is difficult to fathom. The productivity of the land and the two-thirds of China's 1.3 billion people that still live in the countryside has almost reached its natural limits, given China's severe shortage of water. The central government has proposed a \$12 billion pipeline to carry water from the Yangtze River to the northern areas. Higher productivity in agriculture will come at the price of 8 to 10 million people a year leaving the land for urban areas—and those jobs will need to be created. Another 6 million jobs are needed to allow for the modest natural increase in the urban population each year. In addition, 4 to 7 million a year are being thrown out of work by shrinking state-owned enterprises. The total is a minimum of 18 million urban jobs that the economy must create every year for the next few years.

In a socialist country, the problem of unemployment is down played. That is why China's official unemployment rate is only 3.1%. The feudal state-enterprise has traditionally paid the employee's salary, provided their flat, sent their children to a company-run school, put them in a company hospital when ill, paid their pension and even provided burial services. Since 1995, the system has been breaking down. State-owned enterprises, the 1997 Party Congress decreed, had to sharpen themselves up for the market, and that meant optimizing their workforce (i.e., sacking large chunks of it). The state banks reinforced the message by starting to cut credit. The phrase *xia gang* refers to people who are sent home on nominal pay, though not yet officially sacked. Similar euphemisms are used for people whose jobs have evaporated or are waiting for work; early retirees; and those absent from their posts.

Figure 1.3: China's deflation



⁸ Lester J. Gesteland, *China Unicom IPO exceeds expectations: closes at US\$22*. *ChinaOnline News*, June 21, 2000.

The Prosperity Gap

Although China's communist leaders have had two decades of growing prosperity, mainland Chinese want to be like the more prosperous Chinese in Hong Kong or even like the Japanese. The national average per capita income (excluding Hong Kong and Macau) was \$735 at 1998 prices, which makes China somewhat poorer than Indonesia. That average, though, conceals great regional inequalities (Figure 1-4). In 1999, GDP per capita in the West fell to 4,300 renminbi (\$520), or just 40% of the level in the East - down from 56% in 1983.⁹ The poorest province, Guizhou, has a GDP per head of \$280, on a par with Bangladesh or Yemen. Sichuan, with a figure of \$525, is level with Pakistan. Meanwhile, Shanghai's residents, at \$3,400, are up there with Turkey or South Africa. However consider Hong Kong, which at \$22,990 has a higher per-head income than Britain, its former master. The typical commuter on the Hong Kong Star Ferry is likely to be 90 times wealthier than the vegetable-seller in Guizhou.

Under national legislation, overtime should be paid at a rate of 50% above that for normal hours, and be limited to 36 hours a week. But the migrant girls in Guangdong factories are generally worked for 12 hours a day, six days a week. With that, young working women from the countryside make between 500 RMB (\$62 at Whitways) and 1000 RMB (\$125 at Namtai) per month, depending on the location and company.

Figure 1.4: China's Income Gap



Source: Economist Intelligent Unit

Regional inequalities are a serious matter for Beijing's leadership. Equally serious is the wealth gap between city and countryside. In cities, 90% of households have washing machines and color televisions. On farms, the most widely owned consumer durable is the sewing machine, found in 70% of all households.

⁹ Bruce Gilley, *Saving the West*, *Far Eastern Economic Review*, May 4, 2000, p. 22.

In spite socio-political concerns, China's industry continues to grow. Suzhou in Jiangsu Province, and Xian in Shaanxi Province are targeted to become super cities comparable to Shanghai and Beijing. Some \$20 billion was budgeted for the Suzhou Industrial Park, with plans for 600,000 people to move in. The Singapore government supervised installation of water treatment and power plants. Some 220 Chinese officials were trained in Singapore to administer the industrial park.¹⁰ To date, the project has been less than successful, but continues its development. Xian will not receive the next major infusion of government investment as the basis of moving economic development further west.

Growing Unrest

Much of the new unemployment is in the northeastern provinces of former Manchuria, where most of the old heavy industry is concentrated. The almost feudal dependence of the urban proletariat on its state-enterprise employer is hard for westerners to comprehend. According to a study of unemployment in northeastern China by Antoine Kernén and Jean-Louis Rocca (published in *China Perspectives*), Liaoning had an urban working population of about 12 million in 1995. The authors calculate that in the West about 329,000 of these would be classified as unemployed, including young people looking for their first jobs. By the end of 1996 that unemployment total had risen to 800,000; by the end of 1997 to 1.8 million; and by the end of 1998 to 2.2 million, or 18% of the labour force. It is no doubt very much higher today, if only because 400,000 people were officially scheduled to be laid off in 1999 and 2000.

In the northeast, strikes, sit-ins, petitions and even factory occupations have multiplied. Yet the unmanageable social unrest predicted has not yet materialized. That may be because, despite the lack of jobs, this urban proletariat is better off than it appears at first sight. For a start, almost all of these new poor keep their state housing. And where state enterprises are walking away from their welfare role, municipal governments are stepping in to organize retraining and to find jobs for the locals.

But unemployed state workers are tied to one place by their housing, their welfare arrangements and their hope of a new job. In the Northeast, strikes, sit-ins, petitions and even factory occupations have multiplied. Impoverished and demoralized state-industry workers are attacking their Communist Party managers, looting their own factories and taking to the streets in protest. In a startlingly frank series of recent articles in the journal of the Ministry of Public Security, senior police officers say they expect the unrest to worsen as lay-offs and factory sell-offs and closures continue.

In Fujian, police chief Chen Youcheng reported that state-enterprise workers in his province staged 31 mass protests in the first half of 1999, up from just four in the first half of 1998. Anhui province in central China logged 5,156 cases of theft from state-owned enterprises in the first nine months of 1999. Dai Shaoqin, a senior police official from Anhui, reported that it's now common to see "workers collectively besieging enterprise leaders, hurling abuse at them, and even detaining them under duress." Angry workers at the struggling Huainan Mining Corp. have physically attacked low-level managers no fewer than 60 times in the last three years, he says. In February, some 20,000 people revolted in the remote northeastern town of Yangjiazhanzi following the closure of a state-owned mine. Dai states that young workers in failing state factories steal raw materials and machines and sell them to illegal metal merchants and the privately run steel-rolling mills that now operate outside many state-owned factories and mines in the province.¹¹ The short-term solution of industrial unrest in China, observers note, is to disburse more cash to sidelined and laid-off workers. In the long term, the answer is to speed up development of the private sector.¹²

The Search for Jobs

Villagers in the countryside are looking for work in the local township and village enterprises, quasi-collectives that thrived in an unregulated environment; or they have made their way to the coast to work in

¹⁰ Ibid.

¹¹ Susan V. Lawrence, *Mercury Rising: Police officials acknowledge a growing problem of unrest among state workers*, Far Eastern Economic Review, April 27, 2000.

¹² *Survey China: Country cousins*, Economist April 8, 2000.

the processing plants of foreign joint ventures, or in factories like those at Guizhen. The migrants to the cities, such as the Henan rubbish collectors in Beijing, live a life on the fringe of urban society. They do the menial jobs as janitors, street-sweepers, etc. that the laid-off workers from state enterprises refuse to take. In Beijing the construction workers are from Shandong province. The nannies are from Anhui or Hunan. The rubbish collectors are from Henan. And the prostitutes are from everywhere.

Nobody knows exactly how many economic migrants there are, but the number is huge: estimates range from 80 million to 130 million, and still growing. Their presence in cities is a measure of how controls over people's movements have loosened. But migrants still lack many privileges conferred on urban residents by their *hukou*, or household registration. Without a *hukou*, for instance, they cannot get access to schooling, health care or housing. That is why migrants rarely bring their families with them when they seek work in the cities. The Government uses harsh measures to control this migration. Before the celebration of China's 50th anniversary of the People's Republic, 300,000 migrants including beggars, prostitutes, drivers of three-wheeled carts, children and the mentally ill were expelled from Beijing.

Inland Development

Developing China's inland regions is one of the most pressing tasks for the central government. The state statistical bureau reported per capita income in Hohhot, a city in Inner Mongolia, at \$362 in 1995 compared to \$1411 in Shenzhen, the special economic zone in Guangdong Province. In central China, like Gansu Province, the average household income is only \$60 per month. This disparity results from heavy foreign investment along the coast near Hong Kong. Improvement of the economics of western and central regions in China has become a top priority since 1996. Of the \$38 billion in foreign direct investment (FDI) in 1995, over 80% was invested in coastal cities, with only 10% going to rural areas. The central government hoped to raise the percentage of FDI in western and central regions from 12.7% (\$4.29 billion) in 1994 to 20% (\$8.5 billion) in 1996. The government plans to channel investment inland from various coastal sources to defuse the discontent of regional governments in poorer regions. A plan has been developed for government municipal enterprises in coastal regions to invest in the interior. The next five-year plan budgets nearly 60% of government investments for the inland regions. This, of course, causes concern for the coastal cities that represent nearly two-thirds of the population.

Communes transferred control of municipal enterprises to cities, towns and villages as China moved from a planned to a market economy. Municipal enterprises have benefited from special tax incentives and other favorable treatment. They suffer less government interference in their operations than state-run companies. According to the Ministry of Agriculture, about 250,000 township enterprises exist nationwide with total output almost worth half the production of state-run enterprises. More than 1,000 township enterprises have even taken their investments overseas. Nanjing City officials announced that by the end of September 2000, restructuring will be completed at more than 90 percent of the state-owned small- and medium-size companies in the city's industrial sector. Nanjing plans to sell 80 percent of these companies' state-held shares.¹³

The National People's Congress in Beijing made Chongqing one of China's four nationally controlled cities, instead of a provincial city under Sichuan province. This is the same status as Beijing, Tianjin and Shanghai. Chongqing has a population of 15 million, of which 11 million come from the surrounding countryside. Only \$700 million of the \$100 billion invested in China has reached the city. Cheap labor costs about 2 yuan (25 cents) to carry 20 kilos (44 lb) for 20 minutes. Chongqing has responsibility for resettling one million people being displaced by the Three Gorges Dam project 410 miles down the Yangtze River. The city was also given administrative authority over two neighboring cities, adding another 15 million people. A new highway puts the city only four hours away from Sichuan's more prosperous capital, Chengdu. Chengdu is also one of western China's electronics centers.

Xian, Chongqing and Chengdu have relatively well educated workforces, since China's restrictive policies on employment mobility have prevented many qualified workers from moving east. Three sectors in which FDI is expected to grow include electronics, automotive components and machinery processing. Investors are

¹³ The *Zhongguo Xinwen She* (Chinese Overseas News Agency) reported on June 19, 2000.

expected to be able to tap the strengths of the old military enterprises and benefit from the proximity of raw materials in the West.

PRIORITY 3: INCREASE FOREIGN DIRECT INVESTMENT

Zhang Xiaoqiang, director of foreign investment utilization under the State Development Planning Commission, announced at the APEC 2000 China forum that China had a new package of policy incentives for implementation of the strategy of developing the western region. To attract more overseas funds into the country's central and western regions, more areas will be opened to foreign investment and restrictions will be eased. Foreigners investing in "encouraged fields" will enjoy preferential treatment when importing equipment and technology. China now encourages foreign investors to enter sectors including transportation, power, petroleum and natural gas, urban infrastructure construction, the development of mines, and the restructuring of the machinery industry. Foreign investment in the retail sector will be extended to the capital cities of western provinces and regions in the near future, and insurance, telecommunications, and yuan banking business will also be gradually opened to foreign investors. Zhang also pledged that more sectors would be opened to foreign investors in western China.¹⁴

The central government will also add more funds to hasten economic development in areas in central and western China. In the future, 60 percent of the country's budgeted basic construction capital and 60 percent of the loans from policy banks will be used for infrastructure construction, environmental protection, and science and education projects in these regions. The central government will direct more preferential loans from international organizations, such as the World Bank and the Asian Development Bank, to the central and western regions, increasing the amount for these areas from 60 percent to 70 percent. In addition to traditional joint venture, cooperative firms, and solely foreign-funded firms, China will introduce other channels for foreign funds in the western region, including Build-Operate-Transfer (BOT) projects, project financing, stock issuing, and the setting up of industrial funds and venture capital.

Since 1993, China has for six years been the second largest recipient country of foreign direct investments (FDI) after the USA. By the end of 1998, China had approved 324,000 foreign invested projects. These projects have a combined contractual FDI of US\$572.5 billion, of which US 267.4 billion has already been used. The Chinese foreign investment laws (CFILs) have encouraged the development of FDI in China. The legal developments of FDI admissions have affirmed China's open attitude, which provide better investment environments for foreign investors, and meet China's needs for further reform and wider opening to the outside world.¹⁵ Some previously restricted industries, for example, have been opened.

- The government now permits the foreign insurance companies to set up businesses in Shanghai and Guangzhou. By April 1998, 11 foreign-funded businesses had been approved with 180 liaison or representative offices also being opened.
- Five Sino-foreign trading equity joint venture companies were approved by the central government by October 1998. Such ventures are still restricted and require that the majority ownership be Chinese.
- FDI is now restricted to majority Chinese ownership in construction and operation of trunk railways.
- With majority Chinese partners, FDI is encouraged in construction and operation of branch and local railway lines, and the associated bridges, tunnels and ferrying facilities, the production and operation urban underground trains and light rails, the construction and operation of roads, independent bridges and tunnels, and construction and operation of ports public utilities, and the construction and operation of civilian airports.¹⁶

¹⁴ *MOFTEC News*, May 31, 2000.

¹⁵ Xeng Huaqun, "Legal developments of FDI admission into China, *China Mail*, vol 13, no.1, January-March 2000, p. 48.

¹⁶ *Op. cit.* p. 35-37.

China has provided new policy incentives and market access to attract more FDI. The policies aim to encourage FDI in technological innovation, provide stronger financial support to foreign invested enterprises, and encourage FDI to expand into central and west China.¹⁷

- All existing FDIs in target areas will receive wider tax exemptions when they import equipment, technology, and components to upgrade their production facilities.
- FDI enterprises are exempted from paying income tax when they acquire locally made equipment to upgrade production facilities or high tech products. They will also receive VAT rebates on locally made equipment, sales tax exemptions on technology transfer or resultant profits (with tax bureau approval). Exports for plants established before the end of 1993 are tax exempt.
- FDI in the west will enjoy full exemptions on import duties, including new industries. Firms that expand into the central and west regions will receive tax incentives for operations with 25% shares.
- FDI in targeted areas can be approved by provincial governments, thus saving the time and hassle of dealing with the central bureaucracy.
- Restrictions on sole foreign ownership and equipment appraisals of imported equipment will be selectively removed.
- FDI firms operating on leased land will be exempt from paying land use fees.
- MNCs will have more opportunity to sell products through their local ventures, and allow them to handle logistics within China.

China now encourages multinationals to set up R&D centers in China. Research centers set up by foreign investors in China can be exempt from import duty and import tax on equipment, auxiliary technologies, accessories, and components for their own use that cannot be sufficiently supplied in China. Transferred technologies are exempt from business tax, in accordance with the policy on domestic scientific research institutes. Foreign-invested enterprises, whose input in technological development is 10% higher than in the previous year, are allowed to use 50% of the actual amount of technological development to off set their tax that year.

Restructuring FDI Priorities

The rules for foreign direct investment have been revised to open up investment in more sectors. Currently, nearly 60 percent of China's foreign industrial investment goes to its consumer-goods industry, with the remainder going to the country's heavy industry. The State Development Planning Commission (SDPC) has decided that China's allocation of foreign capital should be roughly 20 percent for its primary industry, 50 percent or less for its secondary industry, and 30 percent or more for its tertiary industry. These figures apply for 2001-05, or even for 2001-10. While sole foreign investment reached 38.7% in 1999, this shift in policy is expected to increase the percentage of sole direct foreign ownership in China (Table 1-2).

Tax reforms and local fees and charges have caused some confusion and made it difficult for foreign firms to predict their actual tax liabilities. For example, foreign firms are now required to pay 25% in retirement fees on expatriates' worldwide salaries, though maximum retirement payments are only 250 yuan per month (approximately US\$30).

The National People's Congress, in 1991, adopted the "Income Tax Law for Enterprises with Foreign Investment and Foreign Enterprises", and then the State Council enacted the "Detailed Rules for the Implementation of the Income Tax Law for Enterprises with Foreign Investment and Foreign Enterprises", which stipulates that the income tax for enterprises with foreign investment is levied at a rate of 30%, local income tax at 3%, totally 33%. The income tax on enterprises with foreign investment established in Special

¹⁷ "China attracts FDI with new incentives and market access", Ibid. p. 37.

Economic Zones and enterprises with foreign investment established in Special Economic Zones and enterprises with foreign investment of a production nature in the Economic and Technological Development Zones is levied at a reduced rate of 15%. Enterprises with foreign investment of a production nature established in coastal Economic and Technological Development Zones shall be levied at a reduced rate of 24%. Enterprises with foreign investment established in coastal economic open areas, in the old urban districts of cities where Economic and Technological Development Zones are located or in other regions designated by the State Council, within the scope of energy, communication, ports and harbors, wharfs or other projects encouraged by shall be levied at the reduced rate of 15%.

Table 1.2: Patterns of Foreign Direct Investment in China	1998		1999	
	Amount (US\$100 millions)	%	Amount (US\$100 millions)	%
Direct foreign investment	US\$454.63	100	US\$402.98	100
Of which, Joint-Invested Operation	183.48	40.36	158.44	39.2
Cooperative Operation	97.19	21.38	82.15	20.3
Sole Foreign-Invested Operation	164.70	36.23	156.27	38.7
Foreign-Invested Shareholding Company	7.07	1.55	2.92	0.7
Cooperative development	1.79	0.39	3.84	0.1
Other	0.40	0.09	0.37	0.09

Source: *ChinaOnline* News, June 1, 2000

Any enterprise with foreign investment of a production nature, scheduled to operate for a period of no less than 10 years shall be exempted from income tax for the first and second year and allowed a 50% reduction in the third to the fifth years.

Export-oriented enterprises with foreign investment may, upon the expiration of the tax exemption and reduction period as provided for in the tax law, further enjoy the 50% reduction the corporate income tax based on the rate stipulated by the tax law, if the value of their export products of the year exceeds 70% of the total value of products of the year.

Enterprises with foreign investment shall be exempt from customs duties and value-added tax levied in the import links, to import equipment and materials needed for the establishment of factories, or offshore petroleum development projects.

PRIORITY 4: INCREASE SCIENCE AND TECHNOLOGY

*A nation without good scientific and cultural quality
will be unable to get a foothold in world competition.*

President Jiang Zemin

Under the Ninth Five-Year Plan, the Chinese State has established a goal of national economic construction and social development. As part of the State's role, training of high-caliber industrial workers in scientific knowledge will be strengthened. Scientific and technological advances and improving the quality of workers are considered to be the only solution for developing social productive forces, raising overall national

strength, and improving the people's living standard. Spreading scientific knowledge is considered a social systems engineering project of far-reaching significance. Science and technology are considered the primary productive forces in making the country prosperous.

To support technological modernization, expenditures have increased from \$10.8 billion in 1990 to nearly \$24 billion in 1995. Investment in science and technology (S&T) amounted to \$10 billion in 1995, or 0.5% of GDP. By 2000, the Chinese Government plans to triple the amount of R&D to 1.5% of GDP. Key objectives include the development of rural industries, the improvement of basic industries and infrastructures, the strengthening of export competitiveness, the development of advanced technologies, support of new industries and products developments, and the development of a supporting service sector. The top three priorities are to transfer technology into agricultural industries, to develop a national information infrastructure, and to improve factory automation processes.

China has a national commitment to develop advanced technologies, to encourage entrepreneurs, and to create linkages between technology and the economy. The 1996 five-year plan was based on interlocking strategies for technology, industry, and trade. It shifted the government's focus from supply-oriented research to market-oriented technology development and dissemination. Its objectives were to expedite technology into basic industries, to improve product quality and competitiveness through technological advances, to improve manufacturing processes, and to improve social welfare through disaster planning, and to protect public health and the environment. The law on promoting transformation of science and technology achievements was promulgated on May 16, 1996 to facilitate technology activities. The law created a system for the government to manage domestic technology commercialization, to protect foreign and domestic intellectual property rights, to provide royalties to researchers for inventions, to protect trade secrets, and to support to technology-based transactions.

China borrowed program elements from around the globe for national models that employ technology to achieve economic development goals. Seven programs were established to more effectively transfer research into industrial production.

1. The State Science and Technology Commission's national key technology selection group established key technology R&D programs. They included the areas of information, manufacturing automation, advanced materials and biotechnology. The list included 24 key technologies and 124 specific technology items to address economic concerns.
2. The national basic research priorities program promotes international cooperation, technology exchange, education, and laboratories and equipment to support math, physics, chemistry, mechanics, astronomy, geology, and biology.
3. The 863 program for high technology research was to determine the feasibility of further investments in biotechnology, energy conservation, aerospace, mechatronics, advanced materials, information, and micro-electronic developments.
4. The Torch program addressed the commercialization of 863 developments by providing funds for production of key technologies, for renovating basic industries, and to promote international cooperation.
5. The Spark program was established to diffuse agricultural technologies through loans, information, and management training.
6. Technology diffusion programs were primarily directed at agriculture and related economic developments.
7. Trial production of new products and the appraisal of advanced technologies are concentrated in high-technology development zones (HTDZ).

The Hi-Tech R&D Program or 863 programs, initiated in March 1986, addressed seven priority development areas: biotechnology, space technology, information technology, laser technology, automation technology, energy technology, and new materials. The program operates under expert committees covering seven areas. The

experts are responsible for directions and making decisions in plan formulation, project arrangement, fund use, etc. Research projects guidance for each subject is issued nationwide every two years.

The Torch program, initiated in 1988, provides guidelines for developing new high technology industries and established 27 new high-tech industrial development zones (Beijing, Wuhan, Nanjing, Shenyang, Tianjin, Xian, Chengdu, Weihai, Zhongshan, Changchun, Harbin, Changsha, Fuzhou, Guangzhou, Hefei, Chongqing, Hangzhou, Guilin, Zhengzhou, Lanshou, Shijiazhuang, Jinan, Shanghai, Dalian, Shenzhen, Xiamen, and Haikou). The Torch program set policies for reforming and opening up industries to the outside world, and promoting commercialization, industrialization, and internationalization. The Spark program was implemented in 1986 to facilitate rural industrialization, including raising the technical skills and management level of village and township enterprises, helping rural industries to develop by relying on advances in science and technology and raising the education level of the workers.

The National S&T Achievements Spreading Program was instituted in 1990 to put advanced, appropriate and mature S&T achievements into the nation's economy. The Trial Production and Appraisal Program attempts to further link science and technology with the economy through new product development and production. New products are classified as state level or regional level. New products developed and produced nation wide for the first time are state-level new products. New products developed and produced for the first time in a province, autonomous regions or municipalities are regional-level products. The National Tax Bureau formulates and publicizes the list of new state-level products whose taxes are reduced or remitted.

Implementing 863 Research Results

The first industrialization base for research results of National 863 Program was officially put into operation on Feb. 26, 2000 in Shenzhen. This is a new initiative after 14-year implementation of National 863 Program. Li Xueyong, Vice Minister of Science and Technology, said the Central Government has made a new plan for accelerating the industrialization process of high level research results while steadily promoting the implementation of Phase II 863 projects. The Ministry of Science and Technology has formally approved the first 16 enterprise bases for the application of scientific research achievements from the "863 Program" high-tech R&D projects.¹⁸ The bases are as follows:

1. Shenzhen Kexing Biology Product Company Limited;
2. Beijing Zhong Zi Hanwang Science and Technology Company;
3. Dongfang Software Company Limited;
4. China Great Dragon Information Technology Company Limited;
5. Langchao Information Industry Company Limited;
6. Fenghuo Communications Science and Technology Company Limited;
7. Datang Telecom Science & Technology Company Limited;
8. Wuhan Huazhong Numerical Control System Company Limited;
9. Shenyang Xinsong Machine Automation Company Limited;
10. Zhong Liao San Pu Battery (Shenyang) Company Limited;
11. Guangdong Fenghua High and New Science and Technology Group;
12. Tianjin Heping Haiwan Real Estate Development Company;
13. Shenzhen Leidi Science and Technology Enterprise Company Limited;
14. Beijing San Huan New Materials High-tech Inc. (of CAS);
15. Shandong Tian Da Medicine Company Limited;
16. Shandong Rong Cheng Xun Shan Aquaculture Group Corporation.

¹⁸ Reported in *Keji Ribao* (Science & Technology Daily). January 27, 2000.

Located in Shenzhen's "Biological Valley", Kexing is the largest high tech company producing biological products in the country. Jointly operated by Weiming Biological Group of Peking University and U.S. Handing Asia and Pacific Venture Investment Fund, its new product Sairuojin interferon is the first industrialized biological product in China's 863 Program and also the first genetic engineering drug approved by Ministry of Health for its mass production. The company is proud of its first class scientists' team headed by Dr. Chen Zhangliang and experienced senior management team. At present, the company has an annual capacity for 20 million interferon capsules, 60% of the domestic market.

It is reported that after being named as an industrialization base for 863 research results, Kexing is planning to expand by constructing the so-called Shenzhen Peking University Biological Valley. With its major products centered around hot genetic engineered products such as interferon, insulin, sinalbin-I and sinalbin-II and human growth hormone, the new biological valley expects an investment of RMB 300 million for its Phase One project among its total investment of RMB 700 million.¹⁹

Ministry of Science and Technology Oversight

The Ministry of Science and Technology (MOST) oversees the Department of Industrial Technology, the Department of International Cooperation, and the Department of Science and Technology Restructuring. The Department of Industrial Technology oversees 1) the 863 program for advanced technology development, 2) the Torch program for technology deployment and commercial feasibility of 863 programs, and 3) the productivity promotion centers responsible for rural industrial development.

In January 2000, MOST announced the new 863 programs that included the following 50 projects:

1. R&D of reagent packages for detecting the antigens of the Hepatitis C Virus (HCV) and the AIDS virus (HIV);
2. R&D of the growth factors for restructuring human alkaline fibroblast;
3. R&D of the activators for restructuring human urinary fibrillolytic zymogen;
4. R&D of the immunity-building drugs against liver cancer;
5. Use of genetic engineering for saccharomycetes and vegetative acid enzymes in the manufacture of feed;
6. R&D of new disease-resistant wheat strains (Yangmai Nos. 9 and 10, and Shengkang No. 1);
7. Implementation of the breeding project for Xiangyun crucian carp;
8. R&D of storage-resistant tomatoes with transferred genes;
9. Industrialization of the production of insect-resistant cotton;
10. Industrialization of the manufacture of genetic engineering drugs for restructuring human insulin and growth hormones;
11. Demonstration projects for the internationalization of the software industry;
12. R&D of key photo-electronic components and target products;
13. R&D of 16' 10 Gb/aSDH wavelength division multiple access (WDMA) systems;
14. Application demonstration of intelligent agricultural information technologies;
15. Development of a high-performance computing environment;
16. Development of the third generation of mobile communications;
17. Development of digital equipment and products;

¹⁹ *Development Targets of High Tech Development Zones Materialized Ahead of Schedule*, CHINA SCIENCE AND TECHNOLOGY NEWSLETTER (The Ministry of Science and Technology People's Republic of China) N. 218, March 30, 2000.

18. Construction of industrial bases for the transformation of the scientific research achievements in photo electronics;
19. Demonstration and presentation systems for the key geo-survey technologies and applications;
20. Development of domestic high-speed information demonstration networks;
21. Development of integrated platforms and framework systems supporting the rapid implementation of CIMS;
22. Engineering and industrialization of open structure intelligent numerical control systems
23. Development of rapid punching machines (RPM);
24. Development of database management systems;
25. Development of enterprise resource planning management systems (ERP);
26. Server profiling automatic spraying and painting systems with high-speed rotary cups;
27. Development of robotic automatic spraying and painting systems for TV casing;
28. Industrialization and application engineering of arc-welding robots;
29. Development of automatic packing robots and piling production lines;
30. Development of NiH batteries;
31. Development of board electronic components;
32. Industrialization of the manufacture of high-grade ferro-neodymium borate (Nd-Fe-B) rare-earth permanent magnetic materials;
33. Industrialization of the manufacture of organic optical cylinders;
34. Development of new technological processes for the colloidal forming of high-performance ceramics;
35. Development of lithium ion batteries;
36. Rolling of aluminum-stainless steel composite strips in semi-solid states;
37. Development of aluminum oxide ceramic plates;
38. Development of ferro-neodymium borate ((Nd-Fe-B)) magnetos;
39. Industrialization of the manufacture of hydrogen-containing alloys;
40. Continuous production of foamed nickel;
41. Polyploid seedling growing, breeding and aquaculture of saltwater animals;
42. Development of technologies for the manufacture of highly efficient pelletized feed series for the breeding of aquaculture;
43. Network wide area differential GPS;
44. Development of multi-functional, acoustic ocean-current section-meter for vessels;
45. Industrialization and application of the scientific research achievements for the new anti-tumor drug K-001;
46. Industrialization of the manufacture of the new ecological farm chemical "Nong Le No. 1" and development of the product series;
47. Popularization and application of the technologies for producing healthy prawns;
48. Development of eight-armed dip meters;
49. Technologies and demonstration experiments for the three-dimensional automatic monitoring systems for the marine environment;
50. Industrialization of the comprehensive utilization of oysters.

The Department of Science and Technology Restructuring has responsibility for renovating the state owned enterprises in cooperation with the State Economic and Trade Commission. State owned enterprises had lacked market-driven initiatives and duplicated research efforts. Specific companies were targeted to implement new technologies and management methods to improve their operations and competitiveness.

The Chinese Academy of Science was responsible for state key laboratories and engineering and research centers (ERC) that included 55 state key laboratories and 14 engineering and research centers.

The Ministry of Information Industry was formed to integrate the Ministry of Electronics Industry and the Ministry of Posts and Telegraph. The primary concern was to ensure that electronics manufacturing and Internet capabilities were meeting the needs of China's industrial development plans. Without equivalents to Samsung Electronics and Goldstar Semiconductor companies that transformed South Korea's electronics investments into a world-class semiconductor industry, foreign dependence is hard to avoid.

GOLDEN PROJECTS: BUILDING THE INFORMATION INFRASTRUCTURE.²⁰

To modernize the information technology infrastructure, the Government is developing an economic information and data communications network spanning 500 cities and 12,000 large enterprises. China's telecom market is already booming, and the Internet is catching on fast. Duncan Clark, who runs Beijing-based consultancy BDA China, says China now has more than 100 million fixed-line subscribers, 80 million pager users (the world's biggest market), and 40 million mobile-phone subscribers. China also has one of the world's biggest cable networks, with 80 million subscribers packed into easy-to-service high-rise apartments. This year the number of Internet subscribers tripled, to 6.7 million. Clark predicts that by 2003 that number will rise to 34 million.

China's first move to build a national information infrastructure was the initiation of what were known as the Golden Projects. The Chinese Government established three Golden Projects in the early 1990s that were scheduled for completion by 2003. In December 1993, the creation of a high-level leading committee under the State Council, known as the Joint Committee of National Economic "Informatization," officially launched the projects with three overarching goals:

- To build a national information highway as a path to modernization and economic development.
- To drive development of information technology in China.
- To unify the country by tying the center to the provinces and by allowing the Government to act across ministerial and industrial demarcation lines.

These three goals overlap, but are significantly different in nature. The first is concrete — an information infrastructure over which data can flow. The second is emotional — a cry for the country to become a modern nation. The third is a combination of goals one and two: it is clearly the most important, and the driver of the other two. Realizing it will allow the Central Government to reacquire administrative control by being able to act as an information gatekeeper for the country.

Initially, the Golden Projects consisted of three elements: Golden Bridge, Golden Card and Golden Gate.

- **Golden Bridge** is the infrastructure for "informatizing" the national economy. At its core is a project to build the infrastructure backbone over which other information services will run. First proposed in March 1993 by then vice-premier Zhu Rongji, it has been built as a hybrid network combining satellite and landline networks. Tying together its 30 provincial and regional nodes is a network center in Beijing. So far the Golden Bridge Network has been constructed as a medium-speed "information highway", but its goal is to implement a wide bandwidth multimedia network over which other Golden projects can transmit and receive data.

²⁰ Peter Lovelock, *E-China: Putting Business on the Internet*, Maverick Research Inc., October 29, 1999. (www.virtualchina.com)

- **Golden Card**, an electronic money project, is linked with President Jiang Zemin's June 1993 call for accelerating the development of banking and credit card systems in major cities within China. The project aims at setting up a credit card verification scheme and an interbank, inter-region clearing system. One of its key goals was to have 200 million credit cards in use across 400 cities within China by 2000 — a lot sooner than many observers anticipate.
- **Golden Gate** was first proposed in June 1993 by then vice premier Li Lanqing. It is a foreign trade information network aimed at improving import-export trade management by linking the Ministry of Foreign Trade and Economic Cooperation and the Customs Bureau. Before 1978, only the foreign trade ministry and its 12 trade corporations were permitted to engage in international trading activities. By the early 1990s, the Open Door policy had resulted in more than 9,000 organizations providing international trade services. The Golden Gate Project is designed to develop an information network to re-centralize administration and control of China's foreign trade activities.

Since the initial three golden projects were proposed, a series of other programs have emerged and been implemented. While the agenda of the initial projects was the implementation of information networks, these later projects have generally involved user-driven applications designed to use the information infrastructure to promote economic reform. With most of these Golden applications, government agencies are attempting to both increase economic efficiency and centralized control of information (Table 1-3). Two are particularly worthy of note. The Golden Sea Project, despite receiving little publicity, exemplifies the leadership's interest in information networks. It interconnects China's top government leaders and provides them with immediate access to reference data from other institutions, organizations and offices under the direct jurisdiction of the Communist Party Central Committee. Launched in 1994, it was the first Golden Project to be finalized (it was up and running by 1995). Among the organizations it brings together are the State Statistical Bureau, People's Bank of China, and the State Information Center.

The other is the Golden Intelligence Project, better known as CERNET: the China Education and Research Network. CERNET was the vehicle for the Internet's entrance into China. Initially funded with Rmb80 million (US\$9.6 million) of seed money from the Central Government, it will ultimately interconnect all campus networks with each other and into the international Internet. There is a certain irony in the Government allowing the very group of people which fomented the pro-democracy movement of April to June 1989 — the academic community in general, and students in particular — to be the first to gain access to the Internet.

In addition to CERNET, three other data networks in China offer direct Internet access: China Science and Technology Network (CSTNet), Golden Bridge Network (GBNet) and China Telecom's ChinaNet (Figure 1-5). CSTNet is similar to CERNET, but smaller in scale: it connects subsidiaries of the Chinese Academy of Sciences. GBNet is the "other" network, run by JiTong, a state-owned company formerly linked with the now abolished Ministry of Electronics Industry.

ChinaNet is by far the most important of these four, since the operator of China's national public telephone network runs it. Often referred to as the 163 network after the number users dial to gain access to it, it is the only part of the Internet in China with a legal Internet protocol address and a formal Internet domain name. This means it controls who can set up Web sites and which Web sites can be blocked. Although technical means exist for users with the know-how to find their way to blocked sites, fundamentally this means that China Telecom remains in overall charge of who accesses the Internet via the public telephone system.

Only ChinaNet and GBNet can sell Internet on commercial terms to other Internet service providers (ISPs), the companies that in most other parts of the world act as the link between a user and the Internet. Because China Telecom has the vast majority of the infrastructure in place, this in effect means that it is the monopoly supplier. All the 150 or so of China's ISPs are small and local, and China Telecom has shown no compunction to date in squeezing as much money from these businesses as possible. The result is that, while in the United States, line rental only accounts for 5% of an ISP's costs, in China the average is nearly 80%.

Figure 1.5: China bandwidth

Total Bandwidth (million bits per second)	
ChinaNet	195
GBNet	18
UNINET	12
CERNET	8
CSTNet	8

Source: CNNIC

Table 1.3: Summary list of the Golden Projects

Name	Full Title	Major Ministries, Departments
Golden Bridge (JinQiao)	National Public Economic Information Communication Network	Ministry of Electronics, State Information Centre, Ji Tong Co.
Golden Card (JinKa)	Electronic Money Project	PBoC, Ministry of Electronics, Ministry of Internal Trade, Great Wall Computer Co.
Golden Customs (JinGuan)	National Foreign Economic Trade Information Network Project	Ministry of Foreign Trade, Customs Department, Ji Tong Co.
Golden Sea (JinHai)		State Statistical Bureau, PBoC, State Information Centre
Golden Macro (JinHong)	National Economic Macro-Policy Technology System	China ExIm Bank, Ministry of Finance, State Information Centre
Golden Tax (JinShui)	Computerized Tax Return and Invoice System Project	Ministry of Finance, Ministry of Electronics, National Taxation Bureau, Great Wall Computer Co.
Golden Intelligence (JinZhi)	China Education and Research Network (CERNET)	State Education Commission
Golden Enterprise (JinQi)	Industrial Production and Information Distribution System	State Economic and Trade Commission
Golden Agriculture (JinNong)	Overall Agricultural Admin. and Information Service System	Ministry of Agriculture
Golden Health (JinWei)	National Health Information Network	Ministry of Health
Golden Info. (JinXin)	State Statistical Information Project	State Statistical Bureau
Golden Cellular (JinFeng)	Mobile Communications Production and Marketing Project	Ministry of Electronics Industry
Golden Switch (JinKai)	Digital 2000 Switch Systems Production Project	Ministry of Electronics Industry, Ministry of Posts and Telecoms

Even more restrictive is a China Telecom practice of linking line rental to the amount of revenue per line. Consequently, instead of rental declining with volume, it rises; making an ISP less profitable the more it increases its user base or usage. Given a playing field tilted so steeply against them, most independent ISPs have not only found it impossible to compete with ChinaNet, they have found it impossible to stay in business without receiving some degree of assistance or lenience from China Telecom. As a result, although China saw a small blossoming of ISPs in 1997 and 1998 (many being small bulletin board service operations that decided to go commercial), many companies granted ISP licenses have stopped offering ISP services, or have been incorporated into the ChinaNet framework.

As a consequence, the majority of subscribers, whether companies, organizations or individuals, are connected with ChinaNet, either directly or indirectly. Educational users will of course access the Internet via CERNET, and those in the Chinese Academy of Sciences via CSTNet. The Golden Bridge Network, although offering Internet access to individuals, is still essentially a network in development and is being developed principally to service corporate accounts.

So, much as many people might like to think the Internet is part of a bottom-up explosion of individualism in China, it is not. It is instead a highly centralized network, largely running through a single carrier, China

Telecom, and a monolithic infrastructure, China Telecom's public network, to carry data services to all other Chinese and foreign ISPs, companies and individual users.

The development of China's information superhighway requires coordination among more than 20 government ministries and hundreds of thousands of other organizations. The production and marketing information system was expected to link 360,000 state-owned enterprises and 8.6 million other firms with government offices to improve utilization of personnel, capital, and natural resources.

The Torch Program: National High Tech Development Zones

To promote the industrialization of China's high technologies and optimize industrial structures to spur economic development in the country, China has established 53 national high tech development zones in economically and technologically developed areas such as Beijing, Shanghai, Shenzhen, Xi'an and Suzhou. These zones were modeled on foreign techno parks. This process has been greatly encouraged through favorable policy and treatment offers. Executive deputy mayors usually chair the management committees of the development zones or even mayors, to demonstrate the importance attached to them by the local government.

Madame Zhu Lilan, Chinese Minister of Science and Technology, reported on March 16, 2000 that 53 national high tech development zones in the country had sustained a high growth trend last year by meeting their national targets one year ahead of schedule.

Madame Zhu added that 1999 revenues from technology, industry and trade and aggregate output values of these high tech development zones reached RMB 656 billion and 566 billion respectively, which were increases of 35% and 30% compared to the previous year. 17,900 enterprises located in national high tech development zones have created profits of RMB 35.6 billion, paid tax of RMB 27.5 billion, and earned foreign exchange through export of USD 10.6 billion. (This is a breakthrough of USD 10 billion for the first time in the high tech sector). As a result, the enterprises whose output value have exceeded RMB 100 million reached 800 in number including some well-known enterprises such as Legend, Haier, Hisense, Fangzheng.

Madame Zhu said the high tech development zones have become major industrial development bases for electronic information, new materials, biotechnology, integrated optical-mechanical-electronic system, new energy and environmental protection.

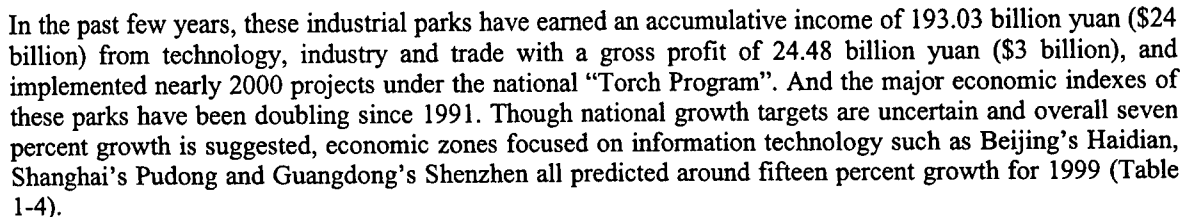
Successful Development Zone Strategies

The purpose of economic development zones are to formulate preferential policies; improve the investment environment; raise funds; establish comprehensive support service systems, welcome research institutes, universities, enterprises and technical personnel to set up new establishments in the zone, create new high-tech enterprises, and develop new high-tech products and industries, providing funds by oneself, autonomous operation, responsibility for one's own profits and losses, self-restraint and responsibility for one's own growth. All these purposes have to be encouraged through intensification of reform.

Special industrial zones (SEZ) began in several provinces and have expanded along China's coast. A number of these are also free trade zones (FTZ) that allow for duty-free imports of materials and components used to produce goods for export. The Beijing Experimental Zone for the Development of New Technology Industries, the first science and technology industrial park in China, was approved by the State Council in 1988. Also in 1988, the "Torch Program" aiming at promoting the commercialization, industrialization and internationalization of China's high-tech achievements began. Since then, as the major part of the "Torch Program", science and technology industrial parks have been vigorously promoted.²¹ By 1995, the Central Government had approved 52 high-technology development zones (HTDZ), which integrate research institutions like universities, start-up incubator facilities, and firms that are committed to utilize the technologies Figure 1-6). Six high-tech development zones have been established in cities of Shanghai, Nanning, Wuxi, Changzhou, Suzhou, and Hanzhou.

²¹ Mr. Xu Guanhua, Vice Chairman, State Science and Technology Commission (September 1995)

國家高技術產業開發區分佈圖 (52區)
National High and New Technology Industry Development Zones (52 Zones)



The Chang Jiang Delta is one of China's economic powerhouses. One of the high-tech development zones in the area is Shanghai's Caohejing Hi-Tech Development Zone. It occupied 6 sq-km and has 500 companies of which 150 are funded from overseas. Major multinationals, such as AT&T, GE, 3M, ICI, Philips, Toshiba, and Dupont, have subsidiaries in the zone. High-tech firms in the zone are in microelectronics, bioengineering, new materials, automation meters, aviation, and space technology. Firms in the zone were shifting to increased value-added products through science and technology.

Table 1.4: National High Technology Industry Development Zones

<u>Beijing</u>	<u>Nanchang</u>	<u>Guiling</u>	<u>Guizhou</u>
<u>Beijing</u>	<u>Heilongjiang</u>	<u>Nanning</u>	<u>Guiyang</u>
<u>Fengtai</u>	<u>Daqing</u>	<u>Shandong</u>	<u>Guangdong</u>
<u>Changping</u>	<u>Harbin</u>	<u>Weihai</u>	<u>Feshan</u>
<u>Tianjin</u>	<u>Shanghai</u>	<u>Zibo</u>	<u>Tianhe</u>
<u>Tianjin</u>	<u>China Textiles</u>	<u>Weifang</u>	<u>Zhongshan</u>
<u>Hebei</u>	<u>Zhangjiang</u>	<u>Qingdao</u>	<u>Huizhou zhongkai</u>
<u>Shijiazhuang</u>	<u>Caohejing</u>	<u>Jinan</u>	<u>Shenzhen</u>
<u>Baoding</u>	<u>Jiangsu</u>	<u>Henan</u>	<u>Zhuhai</u>
<u>Shanxi</u>	<u>Suzhou</u>	<u>Luoyang</u>	<u>Hainan</u>
<u>Taiyuan</u>	<u>Wuxi</u>	<u>Zhengzhou</u>	<u>Hainan Intertional</u>
<u>Inner Mongolia</u>	<u>Nanjing</u>	<u>Hubei</u>	<u>Yunnan</u>
<u>Baotou Rare Earth</u>	<u>Changzhou</u>	<u>Wuhan Donghu</u>	<u>Kunming</u>
<u>Liaoning</u>	<u>Zhejiang</u>	<u>Xiangfan</u>	<u>Yunnan</u>
<u>Dalian</u>	<u>Hangzhou</u>	<u>Hunan</u>	<u>Shanxi</u>
<u>Shenyang Nanhu</u>	<u>Anhui</u>	<u>Zhuzhou</u>	<u>Xian</u>
<u>Anshan</u>	<u>Hefei</u>	<u>Changsha</u>	<u>Baoji</u>
<u>Jilin</u>	<u>Fujian</u>	<u>Sichuan</u>	<u>Gansu</u>
<u>Jilin</u>	<u>Fuzhou</u>	<u>Chongqing</u>	<u>Lanzhou</u>
<u>Changchun</u>	<u>Xiamen</u>	<u>Chengdu</u>	<u>Xinjiang</u>
<u>Jiangxi</u>	<u>Guangxi</u>	<u>Mianyang</u>	<u>Urumuqi</u>

Source: torchina@chinatorch.com

The Sharighai Jinqiao Export Processing Zone is 19 square kilometers located in the middle of Pudong New Area. The Pudong New Area also includes the Lujiazui Financial and Trade Zone, The Waigaoqiao Bonded Zone, and the Zhangjiang High-tech Park. It has undergone changes over the last five years as part of China's "opening-up" policies to the outside world.

CHAPTER 2

CHINA'S SEMICONDUCTOR INDUSTRY

Michael Pecht, Weifeng Liu and David Hodges

BACKGROUND

Domestic demand for semiconductors, especially integrated circuits (ICs), is growing rapidly in China, stimulated by the development of information technology and advanced telecommunication infrastructures throughout the country, and by growing demand for common consumer products. Although it is difficult to gauge the exact number of ICs being imported, various estimates of China's semiconductor market (e.g., by Dataquest, the Japan Electronics Industries Association, and SEMI) indicate that the market size was about \$5 to 7 billion in 1996 and \$8 billion in 1997 [Lammers 1997, Koo 1997]. In 1999, chip sales in China totaled \$8.6 billion, or about 5.9 percent of worldwide semiconductor revenues. Market researchers from Cahners In-Stat Group estimate that China's chip purchases will increase at a 33 percent annual rate from 1999 to 2003, pushing the country's semiconductor market to nearly \$27 billion in the next three years, or 8.6 percent of the world market. It is expected that, by 2010, China will become the world's second largest market for semiconductors, next to the U.S. [Semiconductor Business News, 24 February 2000].

In contrast to the highly sophisticated production facilities of Korea and Taiwan, China's semiconductor industry still consists of relatively small-scale manufacturers with low productivity and low-level process technology. In fact, the semiconductor manufacturing sector is the weakest link of China's electronics industry; 95 percent of the electronic products produced in China are in some way or another dependent on semiconductor components imported from the U.S. and Japan.

China's wafer fabs generally only have the capability to commercially produce 5- and 6-inch wafers with 0.5 to 1.6 μm line widths. They currently produce less than one percent of global chip production, meeting only 20 percent of domestic demand, far short of what is needed [Johnson 1999a]. Clearly, predictions that China will account for 15 percent of the total Asian demand for semiconductors, with projected annual sales of over \$2 billion [Simon 1996] will not be realized.

The poor infrastructure, poor economic system and long supply chains for raw materials and manufacturing equipment contribute to inefficiency in the industry. Ongoing inability to transform technology into commercial success impedes shifting from R&D to production and marketing. Technology export control from developed countries blocks China's efforts to import advanced manufacturing equipment and to upgrade wafer-processing technology.

Despite limitations, China's semiconductor industry is expanding rapidly. From 1994 to 1997, the average growth rate of China's IC production was more than 60 percent. In 1998, China produced 1.5 billion ICs, an

increase of more than 25 percent over 1997 [China's Electronics Industry Yearbook, 1999]. In 1999, China's IC production amounted to 2.3 billion, over 50 percent more than that of 1998 [Xinhua News, 3 May 2000].

INTEGRATED CIRCUITS

China's IC industry was virtually nonexistent before 1980. In 1996, China produced less than one percent of the world's ICs. But the strength of the country's growing electronics sector —already a major exporter —assures a ready market for any suitable IC that Chinese wafer fabrication plants can produce. Help for this budding semiconductor industry is coming from global companies such as Motorola, NEC, Mitsubishi, STMicroelectronics, Philips, Siemens, and Toshiba. These companies are transferring technology, investing capital, building wafer fabs, and forming joint ventures with Chinese partners.

Government Goals for China's IC Industry

During China's Eighth Five-Year Plan (FYP) period (1991-1995), the electronics industry experienced rapid increases in production and technology capability, output, and international trade volume. By the end of the Eighth FYP, the total output of China's electronics industry reached \$30 billion [Schumann 1997]. However, the output of integrated circuits was far from meeting the ever-increasing demand of the electronics industry. In its Ninth FYP (1996-2000), the Chinese government was anxious to further increase the production capability of its domestic IC industry. China's government expressed its goals for IC production in broad terms [Schumann 1997]:

- reach large-scale production levels for 6 inch and 0.8 μm process technology;
- enter industrial production for 0.5 μm and 8 inch wafer technology;
- increase IC design capability to meet market demands;
- pursue R&D in 0.3 to 0.4 μm and advanced packaging technology;
- develop 8 inch, single-crystal wafer technology and begin domestic production.

In pursuing these goals, China had to rely on foreign technological know-how, while at the same time taking steps to protect its large market from foreign domination. Therefore, many restrictions were imposed on China-foreign joint ventures, as well as on wholly-owned foreign enterprises, to guarantee a certain level of technology transfer to China and to dedicate a significant portion of output for export.

Project 909

As a major part of China's Ninth FYP, to encourage domestic IC production capability and to reduce reliance on semiconductor imports, in 1995 China launched its largest ever IC development project in the Pudong New Area of Shanghai. With an investment of more than \$1.2 billion, this project is the largest project ever undertaken in China's electronics industry. The Pudong Microelectronics Center enterprise is just one piece of a larger project known as Project 909, sponsored by China's Ministry of Electronics Industries (MEI), which merged in 1998 with the Ministry of Posts and Communications to become the new Ministry of Information Industries). The project calls for the establishment of five major IC production companies and as many as 20 design and development centers by 2000 [Johnson 1999b]. Its primary targets in semiconductors are to develop advanced 0.3 μm chip technology in labs; produce 0.5 μm chips on a trial basis, and mass-produce less sophisticated 0.8 μm chips, with a production goal of 1.2 billion units in the year 2000 and gross sales reaching 10 billion yuan (\$1.2 billion). Shanghai was chosen as the site for the project because it had become the center for microelectronics production in China. In 1995, Shanghai plants accounted for 21 percent of total Chinese production of semiconductors [Simon 1996]. Project 909 started with the development of an 8-inch 0.35 μm wafer manufacturing facility in a joint venture between Huahong Group and NEC of Japan. Production began in March 1999 and one year later reached 10,000 wafers per month. Output, primarily DRAM memory chips, is exported back by NEC to Japan markets. Plans for several other

manufacturing facilities with similar technological capability have not yet come to fruition. The limitation has been unavailability of large capital investments under terms that would maintain a large degree of Chinese control. The ultimate goal of Project 909 is to bring 0.35 μ m very large-scale integrated circuit (VLSI) technology to bear on telecommunication and computer-use ICs for both Chinese and export markets. [Lammers 1997].

IC Production and Market Size

China's total output in IC products reached close to 760 million units in 1996, which accounted for less than 0.5 percent of total world production [Weng 1996]. In terms of technological sophistication, China first applied 5 μ m process technology, which was the technological level in the U.S. and Japan during the early 1970s, to manufacture IC products in 1986. In 1994, China was able to improve its IC mass production process capability to 3 μ m, which was applied to two MOS LSI production facilities in Hua Jing Electronics Group [Weng 1996].

In 1995, the Chinese Government approved a total of 150 million yuan (\$257 million) to build several VLSI plants. Of this, 1.4 billion yuan (\$168 million) was spent for Hua Jing to construct a single 0.8 ~ 1.0 μ m VLSI product line. The monthly output capacity was expected to be ten thousand pieces of 6-inch wafer and more than fifty varieties of IC products [Weng 1996]. In 1997, of some three thousand different kinds of IC products, most were small-scale ICs using 0.8 μ m processing technology, which satisfied about 10 percent of total domestic demands. The technology in 1997 was 0.8 μ m on 4, 5, and 6-inch wafers. The Chinese Government is seeking business partners from industrialized nations for transferring 0.5 μ m (and smaller) and 8-inch (and bigger) semiconductor manufacturing technology.

Despite rapid increases in production capacity and technological sophistication, China's IC production is unable to meet domestic demand. Imports accounted for two-thirds to four-fifths of China's needed ICs. LSI and VLSI products are almost entirely dependent on imports. The Chinese Government continues to make great efforts to increase the local production of ICs and reduce the dependence on importing IC products.

Tables 2-1, 2-2 and 2-3 display China's growth in domestic IC demand and production, as well as the status of IC import and export. Figure 2.1 breaks down China's semiconductor market by type of application. Color TV was the largest user of IC products; however, the percentage has dropped from 33 percent in 1992 to 27 percent in 1995. In 2000, it is expected that consumer products will account for 28.7 percent of China's IC market, 19.4 percent for telecom products and 18.9 percent for PCs and their peripheral products [Asia Pulse, 17 March 2000]. Besides PC and telecom products, the market for IC cards has shown tremendous

Table 2.1: Total IC Demand and Production in China (million units)

Year	Total IC Demand ¹	China's Total IC Output ²	IC Demand Met from Domestic Production (%)	Total Output of IC Products & Chips ³
1993	850	178	21	180
1994	1,000	245	24	250
1995	1,500	515	33	786
1996	2,200	758	34	1,149
1997*	2,800	800	29	N/A
2000 (forecasted)	4,200	2,000	~50	2,500

* Estimated

1. SEMI® estimates, Weng 1996 and CEInet China IT Market Report 1997. 2. China Electronics Industry Yearbook 1997, p.146. 3. CEInet China IT Market Report 1997.

development. IC cards were first introduced in China in 1995, and are mainly used in public telephone, bank, parking lot, purchase and personal ID. Their use is continuously increasing. More than 80 million IC cards were issued in 1998, a 200 percent increase over 1997. The total number of IC cards in circulation in 1999

was expected to exceed 150 million [Liu 1999a]. By the year 2000, it is expected that Chinese people will buy more than 250 million IC cards for use in 700,000 public telephones across the country, making it the largest IC card market in the world [Asia Pulse, 31 May 1999].

Table 2.2: China's IC* Import and Export Markets

Year	Import Units (billion)	Export Units (billion)	Import Value (\$billion)	Export Value (\$billion)
1995	5.9	0.9	2.2	0.37
1996	6.9	1.3	2.7	0.60
1997	9.6	2.5	3.5	0.86
1998	11.6	3.2	4.5	0.94

Including microelectronics components

Source: China Electronics Industry Yearbook 1997, p. 147, 1999, p. 211.

Table 2.3 China's IC Import and Export Product Type in 1999

Type	Import Volume (10 thousand)	Import Amount (10 thousand US \$)	Export Volume (10 thousand)	Export Amount (10 thousand US \$)
IC chip	4431	6798	1322	2277
MOS Technology Produce IC	52053	34535	1231163	31062
Bi-pole Technology Produce IC	13858	8013	8723	2258
Mix and other Technology Produce IC	285624	163831	56827	13856
Other Single Chip IC	1238718	393099	187667	55445
Mix IC	104676	134288	25619	70257
Microelectronics component	28684	12791	15302	13774
Total	1728046	753355	418576	188929

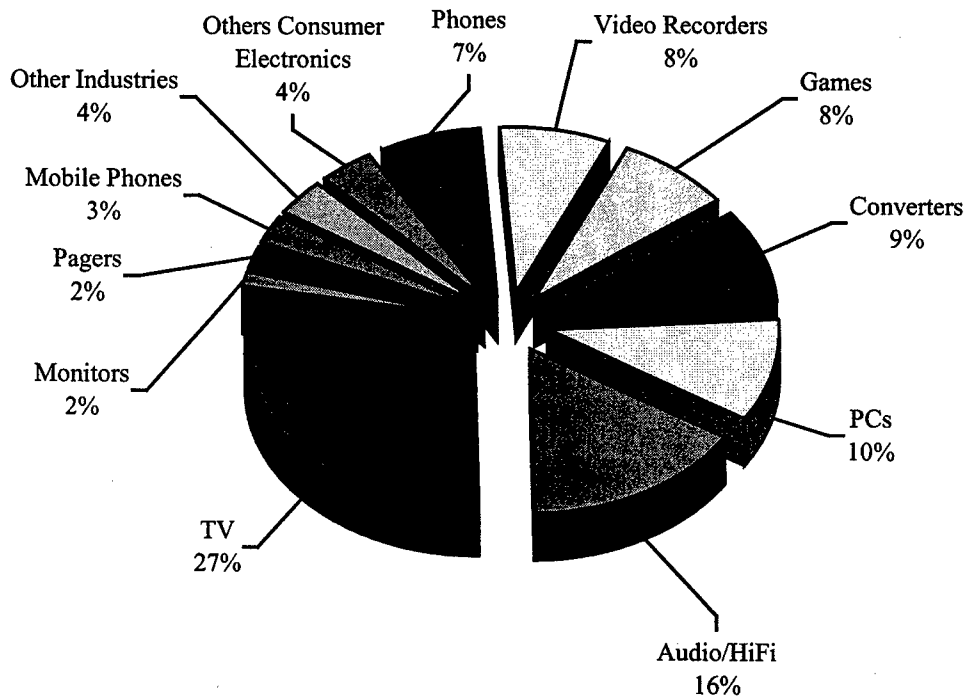
Source: Xiaotian Xu, Department of Electronics Information Product Management, Ministry of Information Industry, China, Date: 06/21/00

IC Design and Test

Until 1995 IC design was solely conducted within selected universities and research institutes. Fudan University in Shanghai, and Tsinghua University and Peking University in Beijing are some of the many institutions that actively support China's IC industry in design and testing. In 1986, the China IC Design Center (CIDC) was founded in Beijing as a state-owned enterprise. Its focus is primarily on ICCAD tools and

IC design. It has contract fabrication capabilities with foundry partners from the United States, Japan, Singapore, Hong Kong and Taiwan. The center has successfully designed an 8 bit CPU (CIU9102) for smart cards. It is the first smart card integrated circuit with wholly-owned intellectual property. The product was designed using 0.8 μm CMOS technology [China Electronics Industry Yearbook, 1999]. In 1998, the center began to develop MP3 decoders. Now the chips for MP3 decoders are in mass production. The Panda system, developed by the center, is the first complete VLSI CAD system. Seven versions have been released. A new EDA system, Panda 2000, was released in 1997 (version 1.0). The current version (4/2000) is 2.2. Panda 2000 provides a series of tools for high-level design, layout, verification, and layout migration. Capabilities of Panda 2.2 are claimed to be similar to those of the suite of VLSI design tools sold by Cadence Design Systems.

Figure 2.1: Breakdown of Chinese IC Applications



CIDC has advanced capabilities for testing mixed signals as well as analog and digital VLSI. It has purchased the Teradyne A580 mixed signal test system, the Electroglas EG2001CX automated wafer prober, and TSSI TDS software for design-to-test linking. In combination, these tools enable CIDC to do thorough prototype testing, as well as production testing on a limited scale.

With government support, CIDC has established itself as a leader in IC design and provides ongoing technical support to seven regional IC design centers. According to CIDC, non-Chinese customers for design services or Panda 2000 tools include C-Cubed, S3, Intel, National Semiconductor, Fujitsu, and NEC. CIDC has 180 employees with over 60 percent of its engineers having worked or been trained abroad [CIDC 2000]. Its revenues in 1999 were \$6 million; projected revenues in 2000 are \$10 million. CIDC is believed to be seeking approval to privatize through a public stock offering.

Another national design base is the National Engineering Center for ASIC Design (NECFAD) in Beijing. It was previously the Microelectronics Design Center of the Institute of Automation, Chinese Academy of Sciences. Its primary focus is on developing IC analysis tools, technologies and systems. An IC analysis system (versions 1.0 and 2.0) has been developed by the center. A more advanced analysis system is now under development, which can automatically analyze sub micron and deep-sub micron integrated circuits. The new system is planned to be released at the end of this year [NECFAD 2000].

As of 1998, there were Chinese claims of more than one hundred design houses and about one thousand experienced IC design engineers. According to a survey by the China IC-CAD Federation, about 26 percent of the design houses are independent IC design centers, 33 percent focus on connection technologies with universities and institutes, 12 percent belong to semiconductor facilities, 14 percent are subsidiaries of system assemblers, and the remaining 15 percent are new IC design houses created by foreign or Taiwanese investors [Liu 1998]. For example, as early as 1995, Shougang NEC in Beijing was sending its engineers to design ICs at NEC's facilities in Japan. Shanghai Belling has about thirty engineers designing ICs in-house, with a goal of fifteen to twenty new designs each year.

As market demand for IC products has increased, China's IC design industry is gathering government support and foreign investment. "Fabless" design is considered appropriate for China's IC industry by outsourcing fabrication. Project "909" calls for the establishment of as many as 20 design and development centers by the year 2000. More than US \$100 million was invested to create an IC design community in China. Shanghai Hua Hong Group has established design centers in Beijing, Shanghai, Suzhou, Shenzhen and even in the U.S.'s Silicon Valley in order to recruit excellent local experts and catch up with the latest design trends and technologies. On December 28, 1998, Guo Wei Electronics Co. Ltd. was founded through the joint investment of State Development and Investment Corp. and Shenzhen Advanced Science Enterprise Group. The two invested more than \$12 million in the joint project and shared equally the registered capital of \$7.7 million (U.S.). The company develops video frequency compressing products and 0.35-0.8 micron 8-inch silicon chips [CEInet 1998]. Shanghai Integrated Circuit Design Industrial Center (ICC) was opened in 2000 through the joint forces of China's Ministry of Science and Technology and the Shanghai municipal government. It is the first Chinese industrial park dedicated to IC design [Liu 2000a]. The local government initially invested \$12 million in the park's construction, which includes more than 215,000 square feet of office space with low rents. ICC also offers amenities designed to attract startups, including facilities equipped with the latest tools, workstations and test equipment that can be rented at low cost. The center also offers design houses and universities a multi-project wafer-processing capability that handles many designs with similar processing equipment. The approach aims to reduce layout and foundry costs for the prototype and low-volume products developed by local designers. So far, thirteen design houses have moved to the center. Total IC and system revenues are projected to reach \$250 million by 2005 [Liu 2000a]. Meanwhile, the Shanghai IC Design Research Center is under preparation.

The emergence of new design capabilities in China has created opportunities for foundries and EDA tool vendors. Leading U.S. EDA tool vendors have reported significant sales growth in China over these two years. CIDC alone claims to have spent about \$2 million to license design tools from major U.S. suppliers. Foundries including Hua Hong - NEC, CSMC - HJ and Hua Yue have provided their production services to local design houses, and are offering a variety of processing technologies together with tariff-free wafers. Meanwhile, local design houses are improving. CIDC (Beijing) has begun development of its own reuse tool at its Chinese and U.S. facilities. The development work is expected to yield Chinese-controlled intellectual property. Shenzhen State Microelectronics Co., Ltd., one of Hua Hong's design houses, is developing an MPEG-2 decoder and other IC designs. Hua Wei Technologies Co. Ltd, China's top telecommunication equipment manufacturer in Shenzhen, has developed a variety of advanced tools, and more than 160 engineers are working on ASICs. More than 10 ASIC designs have been used in Hua Wei systems [Liu 1999c].

Multinational companies are also making a concerted effort to enter the Chinese design market [Liu 1999d]. Intel, Motorola, Microchip, and NEC operate design houses in China. Microchips Technology Inc. plans to expand its presence in China by opening another three design centers in 2000, in Shenzhen, Chengdu and Fuzhou. Microchips is also planning to establish an Asian reference design center, possibly in Shenzhen [Leopold 2000]. By providing better benefits and higher salaries, these design firms are able to recruit excellent people. These companies also provide supporting and collaborate with universities and colleges on joint studies, and offer scholarships and education programs to college students - their future employees.

IC Technology and Product Development Status

Despite the rapid increase in production and technology, China's IC industry still lags far behind the technological levels of advanced countries. The Chinese Government is determined to push forward China's IC design and manufacturing capabilities through collaboration with global technology partners. Table 2.4

shows the status of IC technology development in China and several major technological cooperative ventures between foreign multinational corporations and domestic semiconductor companies in 2000.

In addition to cooperation with foreign partners to develop and transfer technologies, several organizations and research departments have been established over the years by government agencies and universities to advance domestic IC technology development and manufacturing capability. Table 2.5 presents eight research institutes and the corresponding IC technologies that are under development.

Table 2.4: IC Manufacturing Technology Status in China

Company (location)	Foreign Partner	Chinese Partner	Product Sector	Technology (monthly wafer capacity, in year 2000)
ASMC (Shanghai)	Philips Semi-conductors	Shanghai Belling	Wafer Foundry	5", 1.5 μ m Bipolar (25,000) 6", 0.6 μ m CMOS (15,000)
Shanghai Belling (Shanghai)	Alcatel (Belgium)	Shanghai Hua Hong/ Shanghai Bell Co.	Telecom IC Card Consumer	4", 1.2-2 μ m MOS 4", 3 μ m BiCMOS (total, 13,000)
Shougang-NEC (Beijing)	NEC (Japan)	Capital Iron & Steel Co.	4 Mbit DRAM, 64 Mbit DRAM, MCU	6", 0.35 μ m CMOS 6", 1.2 μ m MOS (total, 10,000)
Hua Jing (Wuxi)	-	State-owned	Consumer	4", 2-3 μ m Bipolar (15,000) 5", 2-3 μ m Bipolar (1,600) 5", 3 μ m MOS (10,000) 6", 0.6 μ m CMOS (10,000)
Hua Yue (Shaoxing)	-	Zhejiang Province	Consumer	3", 5 μ m Bipolar 4", 3-5 μ m Bipolar 5", 2 μ m Bipolar
Shanghai Hua Hong NEC (Shanghai)	NEC (Japan)	Hua Hong Electronics	64 Mbit DRAM Logic IC	8", 0.35 μ m CMOS (16,000) 8", 0.35 μ m logic chips (4,000)
CSMC-Hua Jing (Wuxi)	-	CSMC/Hua Jing	Wafer Foundry	5", 0.5 μ m CMOS (28,000) 6", 0.5 μ m CMOS (16,000)

Source: IEEE Spectrum, December 1995; D. Greene 1996; and Tsuda 1997; WSC study visit, 4/2000.

Microanalysis

China's technical capability for microanalysis of materials and electronic devices is concentrated at the National Microanalysis Center (NMC) at Fudan University, Shanghai. The center occupies its own modern facility on the university campus. The center owns and operates state-of-the-art analytical instruments for all major forms of microanalysis:

- Electron microscopy
- Atomic force microscopy
- Secondary ion mass spectroscopy (SIMS)

- Auger spectroscopy
- X-ray analysis
- Chemical analysis
- De-layering of semiconductor devices
- Electrical analysis
- Device and integrated circuit analysis
- Failure analysis
- Reverse engineering of semiconductor products

Table 2.5: IC Technology Development in China

Research Institution	IC Manufacturing Technologies R&D
Central Research Institute, Hua Jing Electronics Group Corp.	1 μ m (CSC245), 1M MASK ROM, DSP high-speed digital signal processing circuit, 256K SRAM
Microelectronics Research Center, Tsinghua University	1~1.5 μ m VLSI, 1M ROM
47 th Institute (Shenyang City), Ministry of Electronics Industry (MEI)	1.5 μ m
214 Institute, Weapon Industry Corp.	3 μ m ASIC
Microelectronics Research Center, Chinese Academy of Sciences (CAS)	0.8~1.2 μ m
ASC Shanghai Metallurgy Research Center	1 μ m
Microelectronics Technology Research and Training Center, Aerospace Industry Corp.	ASIC, GJB protocol microprocessing circuits
Institute of Microelectronics, Peking University	ASIC design, silicon-on-insulator

Source: Summarized from Weng 1996.

The NMC has a substantial core budget from the national and city governments, but a growing fraction of its revenue comes via contracts with industry. During the study tour in April 2000, we were shown examples of analytical micrographs obtained using several of the above analytical tools. Clearly the staffs of NMC have excellent skills in utilization of these sophisticated instruments. One staff member was to be an invited speaker at a meeting on microanalysis at NIST this year.

We saw examples of work performed under contract in which VLSI semiconductor devices were analyzed to determine the steps of the process sequence used to manufacture the devices. This is a form of reverse engineering also practiced in other countries. Other examples were a part of failure analysis of semiconductor devices. Overall, our impression was that the technical capabilities available at NMC are very comparable to those found in the U.S., Japan, and Europe.

DOMESTIC SEMICONDUCTOR MANUFACTURERS

Of China's current total of 330 semiconductor plants, 36 produce ICs and the rest produce discrete devices. Among the 36 IC manufacturers, only a few do wafer processing and IC fabrication; most of them focus on electronic packaging and test. The IC fabrication companies include Shanghai Hua Hong Group Corp.;

Shougang NEC, Beijing; Advanced Semiconductor Manufacturing Corp. (ASMC), Shanghai; Shanghai Belling Microelectronics Manufacturing Co. Ltd.; Hua Jing Electronics Group Co., Wuxi; and Hua Yue Microelectronics Co. Ltd.. Most of China's major semiconductor facilities are partly or wholly foreign-owned by companies such as NEC, Matsushita, SGS-Thomson, Philips, Northern Telecommunications, Samsung, Motorola, Harris, and Intel. China's state-of-the-art semiconductor technology at present is 0.35 μm with some still at a level of 2-3 μm , well behind the 0.18 μm or 0.13 μm of the West. Many advanced equipment makers are selling China their older machines for 1 to 1.5 μm specifications. Chinese facilities are making large deals to acquire foreign semiconductor manufacturing equipment, process software, and know-how for both common and state-of-the-art technologies. Although China's government is encouraging foreign investment as a means to hasten technology advancement, it is working on major projects to lessen its dependence on foreign chip suppliers. Several of China's largest and most advanced IC manufacturers are described below, in order of their founding (Table 2-6).

Hua Jing Electronics Group Corporation

Hua Jing Electronics Group Corporation is the largest of China's state-owned semiconductor plants and a subsidiary of China Electronics Corporation (CEC), a holding company that supports China's electronics industry. Hua Jing is located about 150 km west of Shanghai in the city of Wuxi in Jiangsu Province. It specializes in the R&D, wafer processing, packaging, and sales and marketing of two major categories of products: integrated circuits and discrete components. Hua Jing owns assets of \$360 million and has 1,200 engineers, 380 senior engineers, 39 professional senior engineers and one academician of the Engineering Academy of China. Hua Jing was consecutively picked out as a key enterprise for government investment during the nation's sixth, seventh and eighth five-year-plan periods, and also listed as one of the 512 state-owned large or medium-sized mainstay enterprises.

Hua Jing began with China's purchase in the early 1980s of a turnkey, second-hand, 3-inch line from the United States. Its principal business is the development and manufacture of discrete devices and both bipolar and CMOS integrated circuits [IEEE 1995], primarily for television sets and audio equipment. The annual capacity of bipolar devices is 180,000 4-inch and 20,000 5-inch wafers with 2-3 μm and 70 million packages for assembly. As of early 1997, Hua Jing had started production of 6-inch CMOS wafers with 0.6 μm design rules, with an annual capacity of 120,000 wafers. It also processes 120,000 5-inch CMOS wafers with 3 μm technology annually. In addition to its IC manufacturing lines, Hua Jing produces almost all of its own silicon wafers and maintains an R&D center that develops and tests new process technology.

Hua Jing relies heavily on the international semiconductor community for its technology support. The technology for 125 mm-diameter wafers was obtained from Siemens AG of Germany [IEEE 1995]. Support for bipolar technology comes from Toshiba Corporation (Japan), and manufacturing software comes from Promis Systems (Canada), including the ~\$0.5 million purchase in September 1996 of Promis' Manufacturing Executive System software. Technology transfer is also from AT&T, USA to construct the 6-inch wafer processing line as a part of the national "908" project [China Electronics Industry Yearbook, 1999]. In January 1998 Hua Jing completed a technology transfer from Lucent Technologies Microelectronics Group, which began in 1993 with an agreement between the State Council and Lucent, for worker training, processing technology, and related design tools for a 150 mm, 0.9 μm , single poly double metal complementary metal oxide semiconductor wafer [China Vista 1998]. The IC chips have been applied to the 5ESS systems made by Lucent's joint venture in Qingdao, Shangdong Province. According to a purchase contract signed recently, Lucent will also purchase telecom IC chips from Hua Jing [Asia Pulse, 3 April 2000]. Also, Intel has licensed Hua Jing as one of its testing and packaging partners for selected chips [Intel 1998].

Chinese authorities intend Hua Jing to be a "national champion" in the development of the country's semiconductor industry [Howell et al. 1995]. The Wuxi Hua Jing Expansion Project to upgrade the semiconductor manufacturing facilities and construct the IC research center was one of a handful of leading national projects considered to be essential to national development. The center has a Class 10 clean room that meets requirements for 0.8 μm ICs as well as those with 2 to 3 μm design rules.

Table 2.6: Summary of Chinese IC Fabs

Manufacturers	Technology	Silicon Chip Size (inch)	Produce Capacity (per month)	Remarks
China Huajing Electronics Group Co.	2-5u (bi-pole)	4-5	15000	Including the pre- and post- produce lines
	1.5-3u (CMOS)	5	12000	
	0.8-1u(CMOA)	6	6000	
Huayue Microelectronics Co. Ltd.	2-5u (bi-pole)	4-5	20000	Including the pre- and post- produce lines
Shanghai Belling Stocking Co. Ltd.	1.2-2u (MOS)	4	15000	Including the pre-produce line
Shanghai Pioneer Semiconductor Produce Co. Ltd.	2-3u (bi-pole)	5	12000	Including the pre-produce line
	0.8u (CMOS)	6	6000	
Shougang NEC Electronics Co Ltd.	0.5-3u(CMOS)	6	8000	Including the pre- and post- produce lines
Shanghai Huahong NEC Electronics Co. Ltd.	0.35u(CMOS)	8	20000	Including the pre-produce line
Hangzhou Youwang Electronics Co. Ltd.	2-3u (bi-pole)	4	1800	Including the pre-produce line

Source: Xiaotian Xu, Department of Electronics Information Product Management, Ministry of Information Industry, China, June 21, 2000.

In order to promote system innovation and corporation re-course, two subsidiary companies were founded in 2000. They are Wuxi Hua Jing Microelectronics Co. Ltd., and Wuxi Hua Jing - Gui Ke Microelectronics Co. Ltd. The primary business of the former will be front-end wafer processing of discrete and bipolar devices and production of silicon wafers. The company plans to issue A stocks in China in 2001. Hua Jing - Gui Ke was established mainly based on the Institute of Design and Test of the MOS Electronic Circuit Factory of the Group Corporation. Its business focuses on IC design and development. In September 1999, Hua Jing Group Corporation also issued a letter of intent to seek foreign partners for cooperation.

Shanghai Belling Stock Holding Co. Ltd.

Shanghai Belling Microelectronics Manufacturing Corporation was the first joint venture in semiconductor manufacturing in China. It was founded in September 1988 by Shanghai Electronics and Operation Instruments Holding Company, Radio Factory 14, and Shanghai Bell Telephone Equipment Manufacturing Company (itself a joint venture with Alcatel Bell, the Belgium branch of Alcatel). The total investment was \$82.4 million [Belling 1996]. By 2000, the total assets of the company had reached \$150 million. The company successfully issued stock in 1998, the first company in the IC industry to do so, and changed its name to Shanghai Belling Stock Holding Co. Ltd. Shanghai Hua Hong Group Co. Ltd. holds 38.45 percent of its shares and ranks the biggest shareholder of Shanghai Belling, followed by Shanghai Bell Co. with 25.64 percent of shares. For every year from 1994 to 1997, the company was rated as one of the top-500 foreign-invested enterprises and also one of the top-100 electronics enterprises in China. In 1999, Shanghai Belling 's revenue was \$49 million.

Shanghai Belling is located in Cao He Jing, a well-established, high-technology development zone in southwestern Shanghai. It has over five hundred employees, about 40 percent of whom are engineers and technicians. The company uses a Western-style, team-oriented management structure rather than a Chinese-style structure. Since its establishment, Shanghai Belling has built up three product categories: (1) specialized integrated circuits for telecommunications – each year up to ten million chips which support 5 to 6 million lines of exchange have been applied in China's fast-developing telecommunication network; (2) chips for IC cards; and (3) chips for intelligent control, including chips for electronic watt-hour meter, fuzzy logic MCU, etc. Most of Shanghai Belling's revenues come from ICs made for use in the private branch exchanges of Shanghai Bell Telephone, the first switch-maker in China to use locally made circuits [IEEE 1995]. The remainder comes from sales of micro-controllers and memory chips for use in such consumer products as appliances and remote control units for television sets and compact disk players. Shanghai Belling has independently designed and produced many kinds of IC card chips that have passed technical scrutiny. In 1999, with revenue for the 7442 IC card chips amounting to \$3.2 million, Shanghai Belling became the first manufacturer in China to mass produce IC card chips and thus ended China's situation of wholly relying on imported IC card chips. At present, Shanghai Belling is developing IC card chips of higher technical level such as contact less cards and CPU cards. Moreover, in 1999 the revenue for its fuzzy logic MCU chips was \$11.47 million, accounting for 90 percent of the domestic market. Shanghai Belling manages its quality system according to ISO 9001 standards.

Shanghai Belling Technical Center is a state-level enterprise technical center. The center was established in January 1995 and has been the leader in China's integrated circuit design field. The center is mainly responsible for marketing strategy studies, project scheduling, the design and development of new products, and research on new designing techniques, processing technologies and integrating techniques. Its major research and development covers the fields of integrated circuits for telecommunications systems, chips for IC cards and chips for intelligent consumer products, etc.

As of 1996, Shanghai Belling had one fabrication line, a 2000 m² Class 10 facility that annually produces over 160,000 1.2-3 μm bipolar and CMOS ICs on 100 mm (4 inch) wafers [Belling 1996]. Belling planned to upgrade its IC manufacturing technology to 6 inch, 0.8 μm by 1998 [Koo 1997.] and make ICs with 0.5 to 0.8 μm feature sizes on 200 mm (8 inch) wafers in the near future [IEEE 1995]. However, this project was cancelled by the company in 1999; instead, the company purchased 34 percent of stock shares of Shanghai Advanced Semiconductor Co. Ltd. for \$17 million to promote its wafer processing capacity. The new plan will be fulfilled in 2000. Also, the company purchased 25.5 percent of the shares of Shanghai Hong Ri International Electronics Co. Ltd. for \$1.6 million in order to improve its global sales network.

Advanced Semiconductor Manufacturing Corp. of Shanghai

Advanced Semiconductor Manufacturing Corporation of Shanghai (ASMC) was established in 1988 as a joint venture between Philips NV of the Netherlands and a group of Chinese investors. Northern Telecom, Ltd., (Nortel) of Canada joined the partnership in 1995, and its technology is the basis for ASMC's second line. However, Nortel dropped out of the partnership recently. ASMC, like Shanghai Belling, is situated in the Cao-He-Jing high technology park in southwestern Shanghai, which offers tax-free exports. The company draws most of its technical staffs from Fudan and Jiaotong Universities in Shanghai, two of China's premier universities. It employs over 450 people.

ASMC has two wafer fabrication lines. Fab I is a Class 10 fabrication plant able to process monthly 25,000 5-inch wafers for bipolar devices with a feature size of 1.5 μm . In 1997 ASMC processed more than 200,000 5-inch wafers and aimed to process about 250,000 in 1998. Fab II, which became operational in March 1997, is a Class 1 wafer fab able to process monthly 15,000 6-inch 0.6 μm CMOS wafers [ASMC 1998].

ASMC's product portfolio includes 3 μm bipolar, single/double metal bipolar devices up to 60V for TV and telephone applications; 3 μm low-voltage (1.5-9V) CMOS with EEPROM option for telecom and consumer applications; 1 μm single poly/double metal and double poly/double metal CMOS devices; 1.2 μm single poly/single metal SMOS devices with EEPROM option; and 1.5 μm , 0.8 μm single poly/single metal CMOS devices [ASMC 1998]. ASMC started strictly as a foundry and did not sell ICs of its own design, servicing IC manufacturers whose own fabrication lines were at capacity, as well as so-called "fabless" semiconductor

companies. Although this is still its primary market, it is working on coordinating design, assembly, and testing of its products. As proof of ASMC's growing status and capability in semiconductor manufacturing, it achieved ISO 9002 certification in January 1995, QS-9000 certification in February 1997, and it became the first ISO14001 certificated enterprise in the semiconductor manufacturing field in China in August 1998.

Hua Yue Microelectronics Corporation

Hua Yue is another state-owned semiconductor business controlled by CEC, but is less competitive. It sells its products on the merchant market and so is unlike either ASMC, which is a pure foundry, or Shanghai Belling, which sells most of its products to a single partner [IEEE 1995]. The company, located in the city of Shaoxing, manufactures bipolar ICs for television sets and telephones. In 1995-1996/7, Hua Yue started 15 to 17 thousand wafers with 3 to 5 μm feature sizes per month, of which seven thousand were 100 mm in diameter and the remainder were 75 mm [IEEE 1995, Koo 1997]. The company is expanding its capabilities to include 125 to 150 mm lines with 1.2 to 2 μm design rules that will enable it to produce ~50 million ICs per year [Howell et al. 1995, Tsuda 1997]. In 1998, Hua Yue purchased a 5-inch 2 μm bipolar manufacturing line from Fujitsu that is dedicated mostly to analog devices [Liu 1999d]. This line has been put into production, with the yield of the first two types of products over 90 percent [China Electronics Industry Yearbook, 1999]. Overall, Hua Yue has benefited less than Hua Jing from foreign technology, and has been searching unsuccessfully for a foreign partner [Koo 1997].

Shougang NEC Electronics Corporation

Shougang NEC, a joint venture of Japan's NEC Corporation and the Capital Iron and Steel Company of Beijing, was founded in Beijing in 1991. This company designs, fabricates, assembles, and tests a variety of ICs, including linear devices, memories, microprocessors, gate arrays, and communications chips. A new manufacturing plant, office, and dormitory building was completed in October 1993, assembly operations started in 1994, and wafer fabrication began in March 1995. The company employs over eight hundred persons, and most of the engineers are trained in Japan. As of 1996, the facility assembled a maximum of four million 16 Mbit DRAM units a month, and processed three to four thousand 6-inch, 1.2 μm wafers a month for 4 Mbit DRAMs, MCUs, and other ICs, corresponding to forty-seven million units, well above original projections [Tsuda 1997]. Ramp-up to five to eight thousand wafers a month was achieved in December 1996 as planned [Lammers 1997]. NEC provides production and management technology, including advanced LSI circuit diffusion and packaging production lines and testing equipment. The Chinese share in the joint venture started at 60 percent and has decreased to 49 percent; NEC's stake in the joint venture has risen from 40 percent to 51 percent. Total first-phase investment was about \$240 million for 4-bit micro-controllers as well as the 4 Mbit and 16 Mbit assembly operations. A further investment of over \$100 million was made for the production of 0.5 μm devices for 16 Mbit DRAMs [Tsuda 1997, Lammers 1997]. The ICs produced by Shougang-NEC have been used in remote control for color TVs, in air conditioners, VCDs, IC cards, clocks, and palm PCs. Now Shougang-NEC supplies 50 percent of the ICs for the domestic color-TV remote controls and clocks markets.

In the third quarter of 1998, Shougang NEC introduced the first 64 Mbit DRAMs [China Economic Information Net IT News, 19 August 1998]. In 1999, Shougang NEC invested around \$100 million to upgrade its wafer processing technology from 0.5 μm to 0.35 μm . Production volume is expected to increase from 8,000 wafers per month to 10,000 wafers per month. In 2001, monthly production volume will be raised to 15,000 wafers. Starting in 2000, Shougang NEC plans to construct an 8-inch 0.25 μm wafer processing line, with a monthly capacity of 20,000 [Shougang, 2000]. This indicates that China has made progress over the years to improve and upgrade its products and technologies in order to reach the world's advanced standards.

NEWER FABs

China is pushing plans for construction of several sub micron fabrication facilities with support from the government and foreign companies. This section presents some of the recent major efforts in China.

Motorola

Motorola has been the largest U.S. investor in China. By the end of 1999, it had committed more than \$1.5 billion in China. It has seven manufacturing operations in Tianjin and seven joint ventures in other parts of the country. With over \$900 million in export recorded by the end of 1997, Motorola was the largest exporter among foreign manufacturers in China.

In 1995, Motorola began to construct a wholly-owned sub micron fab in Xianing, south of Tianjin city, at an estimated total cost of \$1.2 billion. Under the plan, an 8-inch wafer-processing line was to be built to process devices with 0.8 μm technology in 1998 and 0.5 μm BiCMOS and CMOS technology in 1999. Monthly capacity was planned to reach about twelve thousand wafers per month. Major applications are telecommunications and automobile electronics [Tsuda 1997]. In May 1998, Motorola announced that would double the size of the Tianjin wafer-processing facility by spending \$2.6 billion to turn the site into a "superfab" and a linchpin in its Asian operations. The Tianjin manufacturing complex was planned to contain both high-volume, front-end, wafer-fab lines and advanced back-end chip-assembly operations. The second phase of the production plan called for a 0.35 μm fab line to come on line in 2000, doubling the silicon-processing capability of the site [Robertson 1998a]. Motorola also announced plans to advance the project to 8-inch and 0.25 μm technology [Liu 2000b]. However, as of April 2000, it appears that the project has been delayed.

In 1998, Motorola launched an advanced materials joint research program to investigate fundamental properties of ferroelectric thin-film materials. This class of materials has potential application for advanced non-volatile memory for cellular phones and smart cards. The program will draw upon the technology strength of the National Lab of Solid State Microstructures at Nanjing University and the technology application capability of Motorola [Semiconductor Business News, 2 April 1998].

In October 1999, Motorola Semiconductor Products Sector announced plans to open a chip design center in Suzhou, Jiangsu Province, focusing on microprocessors and IC technology for consumer electronics and telecommunications [EE Times, 1999]. The designs from the Suzhou center will be produced at Motorola's fab in Austin, Texas, with some outsourcing of production to foundries in Taiwan and South Korea. The center has 20 local engineers, and plans to expand the number to over 80 at the end of 2000 [Liu 2000b]. In the same year, Motorola Semiconductor Products Sector opened the China Predictive Technology Laboratory (CPTL), a research and development operation that will model the behavior of advanced silicon processes and systems in order to reduce cycle time to the customer. The laboratory is located at the Motorola North Asia Center, Beijing.

On November 3, 1999, Motorola Research Institute (China) was founded. It includes 18 R&D centers across China (including Hong Kong), and 650 researchers. The annual R&D funding amounts to \$150 million. Research areas include advanced semiconductors, micro controllers, CDMA and the "Will System," and software development [Huang Jing Reports, 4 April 2000].

Shanghai Hua Hong (Group) Co., Ltd.

Shanghai Hua Hong (Group) Co., Ltd. was founded by China Electronics Company (CEC), Shanghai Jiushi Company, and Shanghai Instruments Group in 1996. Now Shanghai Hua Hong owns six wholly-owned or stock-holding subsidiaries. They are Shanghai Hua Hong NEC Electronics Co. Ltd., Beijing Hua Hong IC Design Co. Ltd., Shanghai Hua Hong IC Co. Ltd., Shanghai Hua Hong International (USA) Co. Ltd., Shanghai Hong Ri International Electronics Co. Ltd., and Shanghai Hua Hong-Ji Tong Smart Card System Co. Ltd [Shanghai Hua Hong 2000].

Shanghai Hong Ri International Electronics Co., Ltd. was established in coordination with one of the nation's most significant projects, Project 909. Hong Ri is a joint venture funded by Shanghai Hua Hong (Group) Co., Ltd. and Tomen Japan, which undertakes the task of obtaining wafer processing orders for Hua Hong and expands both domestic and overseas markets for Hua Hong Products.

Shanghai Hua Hong International (USA) Co., Ltd. was established in 1997 in Silicon Valley, with registered capital of \$3 million. The major business of Hua Hong International (USA) Co., Ltd. is to provide not only

overseas processing orders for the integrated circuit production line of Hua Hong Group, but also to take advantages of its Silicon Valley location to collect information on market trends and international IC technology. Hua Hong International (USA) Co., Ltd. also participates in some venture capital projects. In December 1997, the company invested \$1.5 million to co-establish American New Wave Semiconductor Co., Ltd.

Shanghai Hua Hong - Ji Tong Smart Card System Co., Ltd. was established on the basis of Shanghai Ji Tong Smart Card System Co., Ltd., funded by Shanghai Hua Hong (Group) Co., Ltd. Hua Hong - Ji Tong mainly deals with the research, designation, and manufacture of IC card systems and IC reading devices.

Shanghai Hua Hong NEC Electronics Co. Ltd. was jointly funded by Shanghai Hua Hong (Group) Co., Ltd. and Nippon Electronics Co., Ltd. (NEC). Hua Hong NEC was established on July 17, 1997, with registered capital of \$700 million and a sharing period of 20 years. As a vital step in the Chinese Government's ninth FYP Project 909 to establish an advanced semiconductor industry in China, it selected NEC in October 1996 as a joint venture partner with Chinese partners to design, manufacture, and market memory and logic semiconductors using 0.5 to 0.35 μm process technologies [NEC 1997]. The Hua Hong plant is 93,700 square meters in area, of which 62,000 square meters are for plant construction, and 5,000 square meters are for clean processing. The fab was built in Pudong, Shanghai, for a total investment of about \$1.2 billion. NEC holds 28.6 percent of the total, and Shanghai Hua Hong Group Co., Ltd.'s share is 71.4 percent. Employees were planned to number five hundred in 1999 and seven hundred by 2001. The fab started production at the beginning of 1999 with a capacity of 10,000 8-inch wafers a month for memory and logic ICs. The capacity will be doubled in 2000, among them 64-Mbit DRAMs will comprise 16,000 wafers per month, with 4,000 wafers devoted to logic chips for handheld cell phones and PDAs. All of the DRAMs are to be exported to Japan. At the end of 2000, the joint-venture operation will be upgraded to 0.25 μm processing equipment from 0.35 μm , enabling the fab to produce 128-Mbit DRAMs. NEC Corp. has received permission from the Japanese Government for the upgrade [Robertson 2000]. As part of the agreement, NEC is establishing a working partnership with MEI through which NEC can enter into other businesses in China, but must also negotiate financial and management arrangements such as product mix, where disagreements exist between the Chinese and Japanese investors.

Beijing Hua Hong IC Design Co., Ltd. was established in February 1998 between Beijing Electronic Information Industry (Group) Co., Ltd. and Shanghai Hua Hong (Group) Co. Ltd. with registered capital of \$18 million. The company undertakes contract design work for computer ICs, telecommunication ICs, consumer products ICs or special ICs, and system level ICs from both domestic and overseas customers. In order to learn the advanced experiences in integrated circuit manufacture and management from developed countries, and to expand its overseas market, Beijing Hua Hong IC Design Co., Ltd. has shared the investment of \$30 million with NEC to establish Beijing NEC IC Design Co., Ltd. Sixty percent of the overall investment in the company is owned by NEC and its affiliates, including Shougang NEC [Williams 1998]. The Beijing NEC IC Design Co., Ltd. aims to provide Project 909 with two hundred kinds of ICs and twenty thousand units of 8-inch silicon chips by 2001 [China Economic Information Net IT News, 11 September 1998]. It will focus on designing microcomputers, ASICs, IC cards, and other semiconductor products for use in applications in the areas of digital video and still cameras, consumer electronics, and mobile communications equipment. In addition, system on chip (SOC) devices will also be designed by the joint venture. Devices designed by the company will be produced at Shougang NEC or Shanghai Hua Hong NEC.

Shanghai Hua Hong IC Co., Ltd. is a research and design company for integrated circuit products, funded by Shanghai Hua Hong (Group) Co., Ltd., Shanghai Institute of Metallurgy Research, and Fudan University. The registered capital of the company is \$12 million. Equipped with advanced integrated circuit computer-aided design (ICCAD) instruments, the company mainly deals with research and design for several advanced integrated circuit products including IC card chipsets, chipsets for telecommunication products, and MCU for consumer products in coordination of Project 909's production line.

CSMC-Hua Jing

WuXi CSMC-Hua Jing Co., Ltd. is a joint venture between Central Semiconductor Manufacturing Co., Ltd. (CSMC) and Hua Jing Electronics Group Corp. It was established on August 1, 1999 and located at Wuxi

National Hi-Tech Industrial Development Zone. CSMC holds 51% of the equity and Hua Jing holds the other 49%. The joint venture leases facilities and equipment of Hua Jing's MOS wafer fabrication for MOS wafer foundry service [CSMC-Hua Jing 1999].

CSMC - Hua Jing provides both 5-inch and 6-inch wafer foundry service for the worldwide IC design centers and IDMs. It has a Class 10 clean room with an area of 3,400 square meters. The maximum throughput per month is 14,000 5-inch wafers and 8,000 6-inch wafers with 0.5 μm technology. During 1999, CSMC-Hua Jing intended to double the maximum throughput after resolving some equipment bottlenecks. The company had 279 employees (Mid-year 1999). Most of its key managers and engineers were trained in Toshiba's and Siemens' 2 and 3 μm production line and in Lucent's 0.9 μm production line.

Others

One of the major IC manufacturing projects in China recently is the Mitsubishi-Stone Semiconductor Co. Ltd. (MSSC), a joint venture of Japan's Mitsubishi Electric Corporation and Mitsui Co., Ltd., and the Beijing Stone Group Company. The company was founded in 1996 with registered capital of \$35 million. Total investment is \$2 billion, of which the Japanese side holds 70 percent and the Chinese side 30 percent of the shares. The primary products are MCU, ASIC, and SRAM with the technology goals of 0.28~0.35 μm and 8~10-inch wafers. The project is expected to produce 210 million ICs. The first phase of this project (back-end packaging and test) went into production in October 1998. The second phase (semiconductor design center) is in progress with a projected investment of \$110 million. [Stone Group, 2000].

Two new fabs are planned for construction in the special economic development zone of Shenzhen, near Hong Kong. The government is negotiating with STMicroelectronics to jointly build a fab in the special economic zone. The first fab will produce 30,000 6-inch wafers per month using a processing technology of 0.5 to 0.35 μm . The second fab will scale down to 0.2 μm , producing 25,000 wafers per month. The planned fabs will serve as foundries to supply devices for the country's telecommunications and consumer-electronics industries [Cataldo 1999]. The first phase of the project - Shenzhen Sai Yi Fa Microelectronics Co. Ltd. (back-end packaging and IC design center) -- was completed and put into production in 1997. The joint venture was co-funded by Shenzhen Saigew High-Tech Investment Stock Holding Co. Ltd. and STMicroelectronics with a total investment of \$115 million.

ROLE OF FOREIGN COMPANIES

In order to narrow the technological gap between China and other industrial nations, the Chinese Government is inviting foreign companies to set up manufacturing in China. They have set up various technologies parks with major tax incentives to entice companies. However, China generally seeks to maintain control over the direction and decision-making of companies operating in China, and this can be a problem for foreign companies doing business there. Other problems for foreign companies include lack of adequate protection for intellectual property and inconsistencies between different branches of the Chinese Government. For U.S. companies there is the additional problem of working within U.S. laws that govern export of "dual use" products and equipment that could be turned to military purposes considered detrimental to U.S. security interests.

Current U.S. trade policy toward China is to deny export and technology licenses for fabrication equipment that can produce ICs using below 0.35 μm process technology. The U.S. position is that export controls are needed to prevent the Chinese from making high-tech ICs for missile and nuclear weapon technologies. As a result, for China to become a significant player in the global IC market, it must extend the scope of international cooperation and speed up the current progress in indigenous technology development.

For a decade now, companies from the United States, Europe, and Asia have been building and equipping factories in China, training engineers and operators, and co-managing manufacturing operations, despite less than ideal conditions. Companies active in China's semiconductor industry, drawn by the low-wage labor force as well as by the huge potential Chinese market, include AT&T, IBM, Intel, Fujitsu, Motorola, Mitsubishi, National Semiconductor, NEC, Philips, Rockwell, Siemens, Texas Instruments, and Toshiba — all intensely competitive with one another. In addition, China is separately purchasing processing equipment

from the United States, Japan, and Europe to help expand production capacity, particularly in 0.8 to 1.0 μm and 6 inch technology, and there are opportunities for equipment suppliers offering 0.5 μm (and smaller) and 8-inch technology. The Motorola, Shougang-NEC, and Hua Hong-NEC plants already have given China some advanced chip making capabilities.

The Chinese Government, through the Ministry of Information Industries (MII), has listed the production of ICs as a priority development item. The Chinese Government is eager to seek technology transfer and investment from foreign countries – by giving investors preferential treatment and an opportunity to gain the inside track in China's huge market.

In 1998, the Chinese Government notified the U.S. Department of Commerce that it was ready to exempt tariffs on imported capital semiconductor equipment capable of making 0.25 μm or lower line technologies [Robertson 1998b]. In 1999, an agreement was reached by the Chinese Government and the U.S. Government on China's entry to the World Trade Organization (WTO). Under the terms of the agreement, China agrees to eliminate all tariffs on semiconductors, computers, and telecom products by 2005 and to adhere to global standards safeguarding intellectual property. China will also remove its requirement that the country's foreign chip fabs and assembly plants export most of their output [Robertson 1999]. The pact will open the way to greater direct investment in China and relax U.S export controls.

Compared with the United States, both Japan and Europe have greater freedom to approve the export of advanced semiconductor equipment, since a global system of controls called CoCom (Coordinating Committee on Export Controls) was eliminated several years ago [Robertson 2000]. NEC is the largest Japanese company to invest in the Chinese microelectronics industry. A new fab is in the plan as a joint venture between Mitsubishi (Japan) and Stone. Shenzhen Saigew Group is negotiating with STMicroelectronics (a joint venture between Italy and France) for construction of two IC foundries in Shenzhen.

Taiwan does not appear to have invested in IC fabrication in China. For Project 909, the Chinese Government initially planned to set up a foundry with TSMC [Lammers 1997], but it was unsuccessful. The primary investments of Taiwan companies are in printed circuit board production and component assembly, which require much less capital expenditure. The largest Taiwan investment in China so far has been the Acer Inc. computer main board plant; with a total investment of less than \$96 million, since the government of Taiwan only allows Acer to invest under \$30 million per year in any given project [Carroll 2000].

IC INDUSTRY ASSESSMENT

In 2000, the Chinese IC industry can be characterized by the following features:

- Inadequate capacity and low productivity. China can satisfy only 20 percent of its domestic needs.
- Strong competition. China must compete against Western and Asia-Pacific companies equipped with much better technologies and financial resources.
- Poor infrastructure. China's IC infrastructure is immature. Lack of peripheral industries (e.g., equipment manufacturing, assembly, and testing) is a major concern for future growth.
- Inadequate research and development. Most of the advanced technologies are acquired from foreign countries.
- Rapidly growing and sophisticated design capabilities. This may potentially negate the other problems.
- Strong government support.
- The major emphases in the development of China's semiconductor industry in the coming century will be seen in the following areas:

- IC design capabilities;
- Wafer preparation and chip manufacturing, including polysilicon, crystal silicon preparation and process, doping process, pattern micro fabrication, dielectric thin-film technology, metal thin-film technology, and clean room techniques;
- IC assembly, testing, and reliability.

The 64 Mbit DRAMs made recently by the Shougang NEC Electronics Co., Ltd. and Shanghai Hua Hong Group Co. Ltd., both of which are Sino-Japanese joint ventures, indicate that China's manufacturing technology of large ICs is on track to catch up to the level of industrialized nations. But China has yet to achieve mass production of ICs by using 0.35 μm process technology. Other areas targeted for major development efforts include 1Mb SRAM, 4 Mb ROM, IC cards containing EPROM, flash memory, 200k CMOS gate array, 300k CMOS standard cell, 50k BiCMOS gate array, and high-performance DSP. If the current pace of technological progress in China continues without disruption, it is expected that by the year 2005, 0.35 μm process technology will be implemented in mass production of ICs. By the year 2010, China may also expect to reach the technological level of 1M gate array, 250 K BiCMOS gate array, 4~16 Mb SRAM, 4~16 Mb flash memory, and 128 Mb DRAM.

China's party, governmental and industrial bureaucracies have held back the country's advance as an electronics consumer and manufacturer for decades. However the giant is awakening, and China will reshape the landscape of the global electronics industry as it assumes a role on the world stage. The power of a market consisting of 1.2 billion people cannot be ignored.

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CHAPTER 3

COMPUTERS IN CHINA

Michael Pecht and Weifeng Liu

Over the past ten years, Chinese-built computers have become nearly state-of-the-art devices and very competitive with the multinationals. China's personal computer (PC) market accounted for a 37 percent share in the Asia-Pacific region (Japan excluded) by the end of 1999. Top Chinese computer companies like Legend Group, China Great Wall Computer Group, and Beijing Founder Electronics are working diligently to establish a reputation for quality service and a brand-name prominence in not only the domestic market but also the world market. China's mainframe computers lag behind its PC development, but with technology and manufacturing advances, this difference will surely decrease.

HISTORY OF COMPUTERS IN CHINA

China's computer industry started in the late 1950s. In 1958, the first Chinese-made computer (a vacuum-tube computer called the 901) was manufactured at the Institute of Military Engineering within the prestigious University of Harbin. During this time, China received foreign aid from the former Soviet Union to assist in scientific research of computer technology. In the 1960s and 1970s, several computer systems were developed by China, including the 100 and 150 series. These were installed in universities, military laboratories, and some important industrial conglomerates, primarily to address national security. China developed these computers for its own large computer systems, including a navy command system, missile launching and satellite control systems, geological data analysis systems, production systems for oil fields, and similar operations [Zhang and Wang, 1995].

In the 1980s, with the open-door policy and economic reform, China reevaluated its computer development strategy, and switched from research and development of large-scale mainframe computers to the development of personal computers (PCs). In 1985, the State Computer Industrial Administration selected a group of core technicians to form a scientific research task force. By June 1985, the task force had successfully developed a personal computer, Great Wall 0520CH, which was the first PC using Chinese character generation and display technology, capable of processing information in Chinese.

The appearance of Great Wall 0520CH gave rise to the birth of China's PC industry. Soon after, Great Wall 0520CH began batch processing and gained a significant share of the domestic market. As of 1996, many Great Wall 0520CH computers purchased by China's General Customs Administration were still operating normally, storing large quantities of vouchers [Li, 1996].

The rapid development and diffusion of information and communications technology and products around the world have provided vast growth for the Chinese PC industry. However, domestic production has been unable to satisfy the increasing demand for PCs in China. Hence, relevant government agencies have opened the door to foreign enterprises in the hope that imported foreign information products will stimulate China's domestic PC technology development and accelerate the rate of domestic PC adoption. Notable name brands, such as Acer, AST, Compaq, and IBM, have set up sales offices or joint ventures in China.

NATIONAL DEVELOPMENT GOALS

In China's Ninth Five-Year National Development Plan (1996-2000), there were many goals devised to advance the domestic electronic information industry, including [China IT Market Report, 1997; Simon, 1996; Yang, 1997]:

- developing supercomputer systems with massive parallel processing (MPP) capability and computing speeds reaching fifty billion floating point operations per second;
- increasing the percentage of Chinese-made components in domestic computers, and the nation's capacity to produce peripherals, such as monitors, printers, floppy and hard disk drives, and printed circuit boards;
- achieving a computer penetration rate of one percent, 20 percent among urban families;
- developing two to three domestic microcomputer manufacturing enterprises with an annual production capacity of over \$1 million;
- applying computer products and techniques to the renovation of traditional industries;
- promoting industrialization of multimedia computers and supporting products, such as high-storage-capacity equipment and high-definition displays;
- developing a PC production licensing system and implementing uniform standards for standardizing the domestic microcomputer market and improving service and intellectual property protection.

These goals reflect the efforts of China's computer industry in the following four major areas. The first area is to build up domestic industrial capability of core computer technologies. China has determined that its computer industry should remain as a so-called "shell" industry, which lacks core technologies. An example involves China's zero capability of independently developing and manufacturing microprocessors, the heart of computers. The second area is to renovate and modernize the traditional industry, using computer technologies. The third includes an effort to consolidate the domestic computer industry to significantly improve its competitiveness both domestically and internationally and standardize the domestic market. The last is an effort to develop and master top computer technologies that no more than a few countries and companies in the world have so done. Typical examples of these kinds of technologies are those of super-computer technologies.

China has been applying a significant effort and has made remarkable progress in achieving its goals. In the early 1999, the National Research Center for Intelligent Computing Systems announced its success in developing a super server system capable of conducting 20 billion floating-point operations per second, which put China among the few nations in the world that is capable of developing high-performance servers [China Daily News 14 January 1999]. In early 2000, China's Great Wall Group put the first independently developed, high-performance 4.3GB and 6.8GB hard disk into the domestic market, representing the end of zero Chinese-developed hard disk in the domestic market [Great Wall Group News, 1999-2000]. By the end of 1999, there had already been an estimated 20 million PCs in operation in China, or one PC for less than 70 Chinese individuals. This indicates that China has already achieved its goal of developing a computer penetration rate of one percent set by the end of 2000. Regarding the effort in market standardization and industry consolidation, the government continuously supports the handful of players in the computer industry led by the Legend Group, initiated a strategic merger with its state-of-the-art motherboard manufacturing facility, being the fifth among the world's motherboard manufacturing giants in May 1999 [China Daily News 1 May 1999]. The number of the licenses issued by the government to PC OEMs during 1997-1999 is almost equal to the total number that had been issued before 1997. To improve the quality and competitiveness of domestically made computer products, the government is making a significant effort to enhance its licensing systems. In April 2000, two types of the Great Wall computers obtained the first electromagnetic compatibility (EMC) certificate issued by the Chinese government for PCs [Great Wall Group News 11 April 2000].

As the Ninth Five-Year period ends, China's Tenth Five-Year National Development Plan (2001-2005) will begin shortly. Since the agreement between China and the United States on China's accession to the World Trade Organization (WTO) was signed on November 15, 1999, China has accelerated its preparation process for its accession to the WTO. As the four areas mentioned earlier remain or become even more critical issues for China after its accession to the WTO, the ongoing effort in these areas is considered to still be the core of the Tenth Five-Year Plan on computer and other electronics developments [Xinhua News Agency 27 April 2000].

CHINA'S COMPUTER MARKET

The growth and use of PCs in China's midsize and small businesses, and the acceptance and need for graphical user environments, such as Windows and related applications, are the two specific factors contributing to the boom in the Asian PCs market [Forbes, 1997]. Since 1998, China's enterprise reform has been a driving force behind the big demand for computers. The Chinese computer market sold 2.1 million PCs in 1996 with a total value of \$3 billion (24.6 billion yuan), an increase of 47 percent since 1995 [China IT Market Report 1997]. In 1997, Chinese consumers bought 3 million personal computers, an increase of 40 percent over the previous year. The monetary value of 1997 PC sales was \$3.6 billion, up 17 percent from 1996, according to the data released by China's Ministry of Electronics Industry (MEI). In 1998 and 1999, although remaining healthy and robust, China's domestic market grew slower than what had been expected, due to the effect of the financial crisis in the Asia-Pacific region and weak domestic demand. In 1999, PC sales in China reached 4.5 million units with a total value of \$7.2 billion (60 billion yuan). It is estimated that it will grow at a faster pace to more than 7 million units sold in 2000 [Legend Internal Report, May 2000].

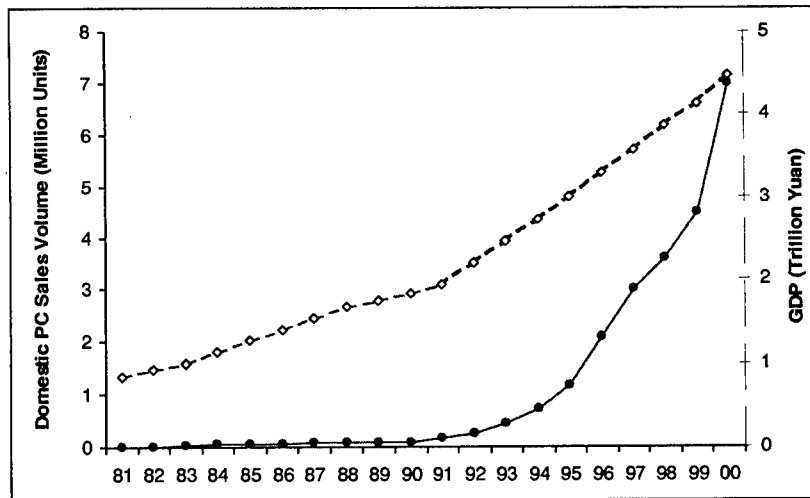
The increase of PC sales volume compared to the growth of China's gross domestic product (GDP) in the 1980s and 1990s are shown in Figure 1. Since 1991, the growth rate of domestic PC sales has far exceeded the GDP growth rate. Compared to the rapid growth rate of annual PC sales, the slower rate of increase in monetary value was due, at least in part, to the fact that there was intense competition among local vendors. This led to price cuts that averaged 15 percent for companies such as Legend and Founder. These price cuts caused prices that were almost 60 percent less than those of foreign competitors for similar products [China Telecommunications Weekly 3 March 1997]. In 1997 alone, Legend lowered its PC prices four times at an average of 15 percent each time [Lim and Trinh, 1998]. In 1999, responding to weak domestic needs, the war of price-cutting to promote sales among domestic PC vendors substantially escalated. Great Wall lowered the price of its Pentium II 400MHz computers three times in 1999 and the price of its Pentium III 500MHz computer just at the beginning of 2000 [Great Wall Group News 1999-2000]. In the list of the 1999 top 100 domestic electronic enterprises released by the Chinese government, Legend was ranked first in sales, but only tenth in terms of profit [China Daily News 3 April 1999].

Market Profile

Asia's recovering economy powered a distribution surge in the global PC market in 1999, and the Massachusetts-based International Data Co. (IDC) described the Asia-Pacific region as "the high-growth engine among the world's personal computer markets." China has already become the largest PC market in the region (Japan excluded) with a 37 percent share in 1999 compared to 26 percent in 1997 [China Daily News 1 December 1999]. In 1997, the number of 3 million personal computers that were sold in the domestic market made China the world's sixth largest PC market, following the United States, Japan, Germany, Britain, and France. China's PC market most likely surpasses Germany's to become the world's third largest computer producer, competing with Japan for second place in 2000, according to Liu, the chairman and CEO of the Legend Group.

The top five companies in the Asia-Pacific's PC market in 1996 were Legend, IBM, Compaq, AST, and HP [China IT Market Report, 1997], among which Legend, IBM, and Compaq remain the top three and close rivals in the region's PC market. In the first quarter of 1999, Legend led the market share of 8.5 percent in the Asia-Pacific region (Japan excluded), according to IDC, with IBM's 7.8 percent and Compaq's 7.4 percent. However, by the end of 1999, IBM reclaimed the market's top spot with a 8.4 percent market share followed by Compaq with 7.3 percent and Legend with 7.1 percent [IDC Market News 15 February 2000].

Figure 3.1. PC Sales Volume and Growth of GDP in China, 1983-2000



Sources: China IT Market Report, 1997 (1992-1996); *EE Times*, January 19, 1998 (1997); *Semiconductor Business News*, June 25, 1997; and China Daily Market News, 1998-1999 (2000 *forecast) for the PC sales volume. Zhang and Wang 1995, SCMP China Outlook, 2000 for China's GDP growth.

By the end of 1999, Legend remained the most popular brand in China, leading the domestic market share at around 20 percent compared to 10 percent or more in 1996-1997 [Wallace, 1998; China Daily News 1 December 1999]. Legend has been the top PC seller in China since 1996. Domestic vendors, led by Legend, whose PC sales surged to over 79 percent in 1999 [IDC Market News 15 February 2000], remain the dominant share of China's PC market. One of the negligible reasons is the strong presence of large domestic companies, such as Legend, Tontru, Great Wall, and Founder among government consumers, which, for example, accounted for about 85 percent of the total PC market in 1997 [China Daily News 4 February 1998]. Sales of PCs by Chinese companies accounted for over 60 percent of the total domestic market. Some statistical data for previous years are provided in Tables 3-1 and 3-2.

Table 3.1: Personal Computer Market in China (US\$ million)

	1996	1997	1998
Imported market	87	157	221
Local production	4,218	5,761	8,114
Exports	439	502	707
Total domestic market	3,866	5,416	7,628
Imports from U.S.	32	63	88

Notes: 1) Exchange rate: US \$1.00 = RMB 8.27

2) Total market equals imports plus local production minus exports

3) Source: Personal Computers and Peripherals, Lim and Trinh, 1998

Table 3-2: Personal Computer Sales in China by Brands (Unit sales: millions)

	1996	1997	1998
Foreign brands excluding U.S.	0.14	0.21	0.26
U.S. brands	0.65	0.77	0.95
Chinese brands	1.32	2.05	2.79
Total	2.11	3.03	4.00

Source: Personal Computers and Peripherals, Lim and Trinh, 1998

Business Computers in China

Computers bought by businesses still dominate China's computer market. Major customers include government, academic institutions, industry, grade schools, organizations, service enterprises, and the military. As mentioned earlier, in 1997, government purchases of PCs, which include those for government entities as well as for all state-owned enterprises and business, including education, accounted for about 85 percent of the domestic PC sales. Although rising incomes and purchase power in China, especially for the urban residents, are gradually bringing the market share of home computer purchases moving upwards in the domestic market, the dominance of computer purchases for business use has not changed significantly since then. The government purchase of PCs in 1999, for example, remained at approximately the same level as the market share was in 1997 [Lim and Trinh, 1998].

Computers for business use and those for home use are not clearly differentiated in China's computer market data. However, considering the income level of the average person in China, computer vendors generally target those classified as high-performance, high-price computers for business use and economic types, sometimes having convenient network connections and multimedia functions for home use. China's business computer market is expected to remain at a fast growth with the government's continuous effort in promoting industry renovation and education enhancement. For example, China's State Education Commission (SEC) has decided to equip its 800,000 primary and secondary schools with PCs at an annual rate of one percent. This raises a demand of about 200,000 more computers from the domestic markets each year [Lim and Trinh, 1998].

The series of government-directed projects on the construction of computer- and communication-network infrastructure is another significant contributor to the rapid expansion of China's business-computer market as well as the home PC market in recent years. The so-called "Golden Projects" are at the core of the efforts. The Golden Projects include the "Golden Bridge" (a national information network), the "Golden Card" (a nationwide banking network system linking China's banks), the "Golden Customs" (a communication network connecting foreign trade companies with China's Customs Bureau), and the "Golden Tax" (a computerized tax system). In addition, newly established information systems in government agencies have contributed to an increase in computer sales. China is planning to develop its own "Intelligent Card Program" for personal identification and registration. Computers are also being used as management tools in large projects, including air traffic control and road transportation and construction project management.

Home Computers in China

Enhanced capabilities, declining prices, and market focus on PCs, combined with rising incomes in China, have made computers attractive to home users. Almost non-existent before 1992, the number of PCs sold for home use was about 340,000 in 1996 and about 540,000 in 1997, which accounted for 15 percent to 18 percent of the total domestic PC market at the time [China IT Market Report, 1997]. In early 1998, the home PC market share in China went to a peak, approaching 30 percent of the total PC sales. Since then, especially entering 1999, China started to feel some effect of the financial crisis that occurred in the Asia-Pacific region, so the growth of China's entire computer market slowed down. In addition, with the government's ongoing effort in the reform of China's state-owned enterprises (SOEs), millions of workers were declared redundant and were laid off. In 1997 alone, an estimated 13.7 million workers, including those subject to forceful retirement, lost their jobs, adding to an already-worrisome nationwide unemployment problem. The loss of

income triggered a market depression with weak domestic needs, including those computers destined for home use. With the slowing growth of the domestic computer market, the market share of home PC sales was estimated around 20 percent in 1999 [Lim and Trinh, 1998].

Typical PC buyers in China are urban residents with incomes higher than the average in China. An investigation of China's Ministry of Electronic Industry (MEI) indicated that over 60 percent of all home PC owners had purchased their computers in the past two years [Carroll 1998b], and one out of ten urban families had put computers on their list of household essentials, along with color TVs, refrigerators, and washing machines [Lim and Trinh, 1998]. The New Century Group estimates that more than half of the PCs purchased by home users are bought primarily for children's education, approximately a third for entertainment, and a small portion for work at home. Although home purchases of computers generally represent a much larger investment for Chinese families than it is for the average families in more developed countries, the typical PCs purchased for home use in China are comparable in performance and functionality to those purchased in developed countries.

Brand-named PCs are replacing the low-priced, no-name domestic brands and store-assembled or clone PCs that were so popular for Chinese home PC consumers several years ago, indicating that the price of PCs is no longer the number-one factor influencing consumers' purchasing decisions [Home PC Market in China 1999]. The share of domestic name brands like Legend, Great Wall, Tontru, and Founder continuously increases, while the share of foreign name brands is declining.

China's cultural emphasis on education as a means to social betterment, the one-child norm, the prestige of home computer ownership, and rising personal incomes are expected to continue, driving home PC purchases to an annual growth rate of no less than 30 percent for several years. Despite this trend, a lack of quality software in Chinese language, as well as the cost and lack of consumer knowledge, still inhibit demand. Vendors are being pressed to reduce prices, improve software, and enhance support services, especially in remote areas. Influenced by these and other factors, the Chinese computer market has begun to place more emphasis on the value of software and services, as well as on hardware development and manufacturing.

Notebook Computers

There is much enthusiasm in the notebook or laptop computer market among a number of computer manufacturers in China. Firms with products in this market include Toshiba, MAX, IBM, Lunfei, AST, Compaq, Acer, NEC, Hewlett-Packard, Dell, DEC, Fujitsu, several Korean firms, and the domestic PC manufacturers: Legend, Great Wall, Founder, and Tontru.

The high price of notebook computers is a significant inhibiting factor [Roberts and Burbank, 1998]. Costs, however, are falling. The reduction in LCD monitor costs worldwide has helped to make notebook computers more cost competitive. Nonetheless, sales of notebook computers in China remain fairly slow. Users are still comparing prices and features with their desktop counterparts. About 220,000 notebook computers were sold in China in 1997—only about 6 percent of the sales of desktop computers, compared to about 40 percent of desktop sales in most developed countries [Li, 1998]. The notebook computer market in China grew more than 50 percent in 1998 to about 350,000 units sold [Lim and Trinh, 1998]. Taking into account China's gloomy market situation in 1999, the sales of notebook computers in China should have been lower than 10 percent of the desktop sales in 1999, remaining a relatively low percentage of China's computer market.

Overall, China still lacks the capability of independently developing notebook computers. Unlike the desktop market, where domestic brand names are dominant, the notebook computer market rarely sees domestic products. Since China does not allow foreign companies to engage directly in trade with China, aside from marketing goods manufactured in China, foreign computer companies have formed many joint ventures with local partners, such as Toshiba's with Legend, IBM's with Great Wall, and Compaq's with Founder, to provide notebook computers for China's market. China also hopes to obtain the notebook computer technologies and manufacturing know-how through joint ventures. Domestic companies have been working diligently to get their own notebook-computer design and manufacturing capability up to par, since notebook computers were first introduced to China's market in around 1996. Great Wall, for example, announced its acquisition of capability in developing high-resolution 21" and 29" TFT LCD flat panel displays in December 1999 [Great Wall Group News 28 December 1999].

MAJOR DOMESTIC COMPUTER MANUFACTURERS

China can be roughly divided into five different regions, centering around five major cities: the South (Guangzhou), the East (Shanghai), the North (Beijing), the Northeast (Shenyang), and Central China (Chengdu). China's major domestic PC manufacturers are the Legend Group, the Great Wall Group, the Tontru Group, the Founder Group, and the Stone Group, which subdivisions cover almost all areas in China.

Legend Group

The Legend Group was established in 1984 by eleven researchers from the Institute of Computing Technology, a branch of the Chinese Academy of Science [Zhang and Wang, 1995]. By the end of 1999, Legend had set up local headquarters in Beijing, Shanghai, Shenzhen in Guangdong Province, Shenyang in Liaoning Province, Xi'an in Shanxi Province, and Chengdu in Sichuan Province; there are over a hundred branches with over 8,000 employees covering China with twenty-one branches overseas [Legend Internal Report, May 2000].

Legend's major business areas include computers, system integration, network infrastructure, and software design. Computers, including desktop PCs, notebooks, handheld computers, printers, and other computer peripherals are the major products of Legend. In recent years, with the rapidly growing market of wireless communication systems in China, Legend has begun to expand its business into telecommunication areas, such as cellular telephone manufacture as well as communication network construction. Legend has consistently formed partnerships or joint ventures with foreign companies to acquire advanced technologies. Major companies having partnerships with Legend are Intel for manufacture of microprocessors, IBM in system integration, HP in the design and manufacture of computers and printers, Toshiba for the manufacture of notebook computers, Sun Microsystems in the development of server systems, Motorola in cellular phone manufacture, and Siemens in PC production.

Legend has been China's leading domestic information technology vendor since 1996. The company started its PC manufacture with 2,000 units in 1990. Eight years later, it shipped out 790,000 PCs, and boosted the number to about 1.3 million in 1999 for the domestic market, with the share doubled to more than 20 percent in 1999 from about 10 percent in 1997 (see Figure 3-2). For reaching the goal to become one of the world's top-10 PC makers in 2000, Legend already had the capacity of producing 1.5 million units annually and this capacity will reach 3 million in 2000 [China Daily News 1 June 1999]. Legend's total worldwide sales were \$2.12 billion in 1998. In the 1999, among the top-100 electronics firms, unveiled by China's Ministry of Information Industry (MII), Legend, which ranked the second in 1998, took the lead in 1999, surpassing Changhong, China's dominant TV supplier. Legend's ambitious goal is to achieve \$10 billion in sales by 2004, the 20th anniversary of its founding, five times more than 1998's figure, according to Liu, the group's president [China Daily News 28 September 1999].

In recent years, Legend has significantly strengthened its research teams and expanded its research facilities to accelerate the process of acquiring cutting-edge computer technology. In 1993, Legend became the first Chinese PC maker to open a design center in California's Silicon Valley [Dexter and Einhorn, 1997]. In 1998, Legend established the Legend Central Institute in association with the Institute of Computing Technology of the Chinese Academy of Science for research on computer technologies. This auspicious institute is so far the largest company-owned institute focusing on production technology in China [Legend Group News, 1998].

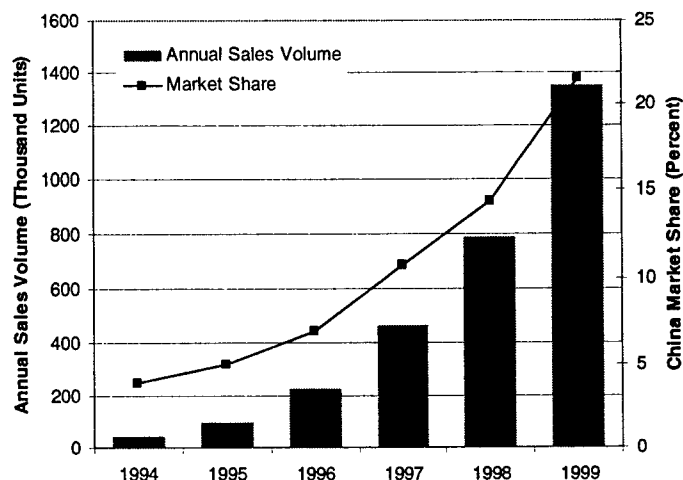
In component manufacturing, Legend has become an important supplier of PC motherboards worldwide. It exported motherboards to over forty countries, and its motherboard sales put the company in fifth place in the world in this market. To sharpen its competitive edge in the international market, in May 1999, Legend initiated a series of what it called strategic mergers, including the one with its state-of-the-art motherboard manufacturing facility, Quantum Design International Co. (QDI) [China Daily News 1 May 1999].

The China Great Wall Group

The Great Wall Group is a large state-owned enterprise with several significant subdivisions and joint ventures with IBM. One is the International Information Product Company, Ltd. (IIPC), founded in February

1994; another is GKI Electronic Product Company, Ltd., in operation since September 1995 [Dexter, 1996]. In addition, Great Wall signed a license deal with Intel in May 1996 to manufacture Pentium motherboards. Great Wall was also the first company in China to create a server series based on Intel's Pentium Pro processor.

Figure 3.2. Personal Computer Annual Sales of Legend Group Since 1994.



Note: The ranking of Legend Group, according to market share, was the third in China for 1994 and 1995, and has become the first since 1996. Source: Legend Internal Report, May 2000.

IIPC is one of IBM's six major PC production bases worldwide. It has five production lines, three offering IBM PCs labeled "Made in China," and two producing the Gold Great Wall series of PCs for domestic consumption [Li, 1996]. The number of IIPC PCs under the brand names of Gold Great Wall and IBM reached 100,000 in 1995. The second joint venture, GKI, was established, based on the cooperative experience on IIPC. GKI was equipped with the world's most advanced overall plane welding technology. The enterprise has an annual production capacity of two million boards [Li, 1996]. GKI thus became one of IBM PCs' major OEM suppliers.

The Great Wall Group is not only producing IBM brand name products, but is also developing its own brands. In 1995, Great Wall was able to develop large-scale production of computers and a sales alliance for the sale of monitors, terminals, disks, software drivers, video disk drivers, power disconnect switches, envelopes, and board cards [Li, 1996]. In 1997, Great Wall introduced an ultra-thin laptop computer configured with a Pentium 100 and a multimedia notebook PC, both in the low \$3,000 price range [China Telecommunications Weekly 24 March 1997]. In addition to producing parts and components for Great Wall PCs, the Great Wall Group also supplies domestic markets with monitors, software drivers, and battery backup systems and has become one of China's largest original equipment manufacturers (OEM) for do-it-yourself computers.

Tontru Information Industrial Group

The Nanjing-based Tontru Information Industrial Group is part of the key Information Industrial Group for China's Ministry of Electronics Industry. Manufacturing and marketing PC-related products, the Tontru Group, by the end of 1996, had a full-line of PC series available on the market — a business PC (Tongshi series), a home PC (Tongle series), an education PC (Tongxue series), a PC server (Tongfei series) and a portable PC (Tonguin series). Tontru has also produced Intel-based MMX PCs, and as of 1998, Tontru had six production lines in Guangdong province and Nanjing that manufacture Pentium-type PCs, most using Intel chips, including the MMX chip, but some have 5X86 Cyrix chips. Tontru has twenty-eight offices and authorized maintenance centers throughout China. Half of its sales are in China's north and eastern regions [China Computer Trends 3 March 1997].

In 1997, Tontru had become the second largest PC vendor in China, behind Legend, with a selling capacity of more than 200,000 sets in domestic markets. Intel is Tontru's most important partner in China. In addition, the Tontru Group has developed close cooperation with Digital, Sunsoft, Samsung, LG, Leo, and Daewoo. The group has established six joint ventures and twelve branches and undertakes production of monitors, keyboards, cards, power supplies, and cases.

Others

The Founder Electronics Group, which is controlled by Beijing University, recruits top graduates for its three hundred-person research institute, which expects to add a hundred new employees annually during the nation's Ninth Five-Year Plan. As a leader in Chinese software, the Founder Group diversified into PCs in late 1995. In 1993, however, Founder was not among the top twenty PC vendors, but it zoomed to an eighth place ranking in 1997. An estimated 100,000 units of PCs were expected to be produced in 1997 [Dexter and Einhorn, 1997].

The Stone Group was established in the mid-1980s. It has ongoing cooperative relationships with Compaq and the Mitsubishi Corporation of Japan. In 1996, the Stone Group was classified by *Business Week* as one of China's PC champions [Dexter and Einhorn, 1997].

MAJOR FOREIGN COMPETITORS

China's PC market will remain competitive and challenging for both foreign and domestic producers. In 1998, major foreign computer manufacturers operating in China included IBM, AST, Compaq, Hewlett Packard, Dell, Gateway 2000, Apple, Sun Microsystems, Texas Instruments, and Packard Bell of the United States; NEC, Fujitsu, Hitachi, Casio, Oki, and Toshiba of Japan; Samsung of Korea. In June of 1999, Siemens, the number-one PC seller in Germany and one of the top ten distributors worldwide, also entered the Chinese market, joining hands with Legend [China Daily News 1 June 1999]. Figures 3 and 4 show the top ten PC vendors in China and the Asia-Pacific region, according to their market share. In China's market, foreign brands lag far behind domestic brands, which are led by Legend. IBM, Compaq, and HP are the top three foreign computer vendors in both China and the Asia-Pacific region.

IBM's business in China dates back to 1934, when the company first installed a bookkeeping machine for the Peking Union Hospital. IBM resumed its business in China in 1979 after the introduction of economic reform by the Chinese government. In 1992, it set up a wholly owned subsidiary in Beijing, IBM China, to manage and coordinate all of IBM's marketing and production activities in China. IBM has set up seven joint venture companies in China since 1994. There are three manufacturing joint ventures: IIPC in Beijing makes IBM and Great Wall brand PCs; Tianjin Advanced Information Products Corporation in Tianjin manufactures banking peripherals and point-of-sale terminals; and GKI Electronics in Shenzhen makes electronics cards and boards.

Compaq, one of the fastest growing PC suppliers in China, delivered 80,000 PCs to the Chinese market in 1993. Compaq was one of the leading PC vendors in 1996 with 7 percent of market share [China IT Market Report, 1997]. AST is a major collaborator with the Legend Group, and in 1993, it sold 140,000 desktop PCs in China, a market share of 30 percent. However, it only sold 145,000 PCs in 1996, which accounted for a market share of only 6.9 percent [China IT Market Report, 1997]. AST entered the Chinese market in 1985 and set up a factory in the city of Tianjin that reportedly produces more than 100,000 PCs annually [Zhang and Wang, 1995]. AST became the number-one PC supplier in 1995, but due to severe competition from both domestic OEM PC makers and foreign entries equipped with abundant resources and marketing skills, AST's significance in China's PC market has been reduced.

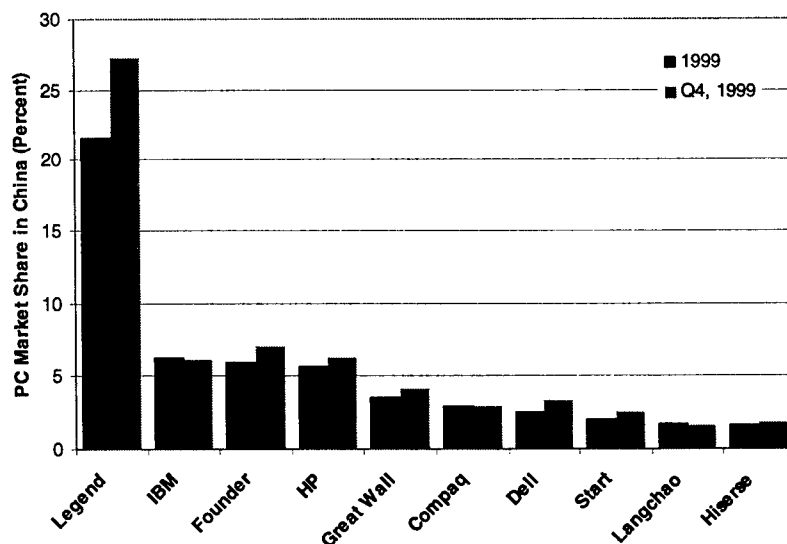
One of the fastest growing foreign computer companies in recent years is the U.S. giant Hewlett-Packard (HP) Corporation, which has started to challenge the position of Compaq and even IBM in both China and the Asia-Pacific region. In 1999, HP was already ranked the fourth biggest PC vendors in China, based on market share, following Legend, IBM, and Founder. HP even proceeded to third place, surpassing IBM in the fourth quarter of 1999 (see Figure 3-3). According to a senior company official, HP expected its China PC revenues to grow 30 percent, which is expected to be approximately five percent faster than the overall PC

market in China, spurred by the prospect of China's WTO entry and an Internet boom [Reuters Finance News, March 2000]. HP's China revenues exceeded \$1 billion in 1999 with more than a quarter coming from PCs, including commercial and consumer desktops, servers, and notebooks, as well as other contributors including printers, mini or hand-held computers, software, and consultation services [Reuters Finance News, March 2000].

PC DISTRIBUTION CHANNELS IN CHINA

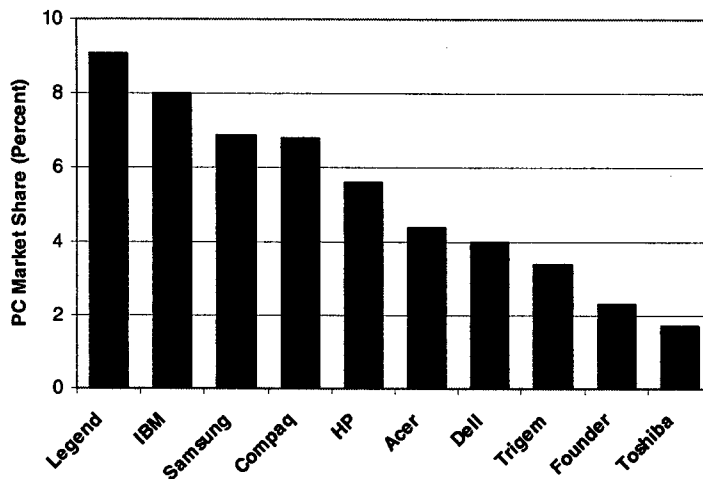
China was affected little by the Asian financial crisis in early 1998. However, especially entering 1999, China's computer industry suffered from the gloomy domestic economic situation and witnessed a dramatic drop in sales growth [China Daily News 1 March 1999]. Nevertheless, China is still a designated fast-growing area and stands as one of the few growth markets in the Asia-Pacific region for PCs. The main beneficiaries of the growth in the PC market are the domestically produced models, favored by local distributors, rather than foreign manufacturers [Carroll 1998b]. Local computer makers, particularly Legend, which has doubled its domestic share from about one tenth to more than one fifth of China's PC market in the recent three years, by 2000, have retained the lead in market share, while U.S. and other foreign OEMs in the region, such as Compaq and IBM, have seen their presence slide or remain stable at best.

Figure 3.3. Top 10 vendors and their PC market share in China for the fourth quarter and the whole year of 1999.



Note: The total sales volume of personal computers in China's market for 1999 was about 4.94 million units with 1.35 million units sold in the fourth quarter. Source: Legend Internal Report, May 2000.

Figure 3.4. Top 10 vendors and their PC market share in the Asia-Pacific Region, excluding Japan, for the fourth quarter of 1999.



Note: The total sales volume of personal computers in the region for the period was about 4.06 million unites. Source: Legend Internal Report, May 2000.

The critical issue is the implementation of a successful distribution channel strategy, especially in a place lacking well-established existing channels and trade transparency. As a result, foreign entries still rely on local distributors and dealers to sell their products, even if they have to set up their own representative offices locally. Establishing joint ventures or strategic alliances with local manufacturers or even competitors is one way to distribute products successfully in China. For example, Legend manufactures its own PCs and is also the largest distributor for AST. The Stone Computer Group produces its own brand-name PCs and also represents Compaq in China.

Personal connections are absolutely critical in all walks of life in China, particularly in business. Because of cultural reasons and an age-encrusted legal system, the Chinese prefer to deal with people with whom they have personal relationships. Thus, it is extraordinarily important for foreign companies to establish and maintain a close relationship with their Chinese counterparts in government and in the private sector.

The three basic avenues in which computer systems are being purchased in China are face-to-face meetings or discussions, customer walk-ins, and fax/telephone communications. The fax/tel method is not popular in China because customers and the communications infrastructure are generally less technologically sophisticated, while credit card ownership and acceptance is still uncommon. Understanding this kind of atmosphere, large domestic companies, such as Legend, the Great Wall, and Tontru have been expanding into the Internet. The China Great Wall Group, for example, unveiled an ambitious plan in September of 1999 to attract more Chinese people to the Internet and greatly promote online shopping. They will now provide a 5,900-yuan (about \$710) package, including a Great Wall 499 computer with a built-in 56k modem, three-year free Internet service, and 365-yuan (about \$44) worth of virtual cash for shopping on the Web.

The importance of channel partners is critical to doing business in a foreign country. Strong capability of providing local services and support is essential. Since the buying cycle tends to be lengthy in China, a sound financial background and the ability to finance purchases is also important. Overall, China's computer channel infrastructure is different from those used in industrialized nations. Face-to-face selling and buying methods continue to be the most comfortable and common method for many Chinese buyers.

ACKNOWLEDGEMENT

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CHAPTER 4

ELECTRONICS ASSEMBLY MANUFACTURING IN CHINA

E. Jan Vardaman

INTRODUCTION

The number of electronics manufacturing operations in China has increased dramatically over the last few years. Hong Kong and Shenzhen are well known for low-cost electronics assembly. Since China's opening in 1978, the majority of China's investments have gone through Hong Kong. The primary strategy of Hong Kong firms was to help firms reduce their costs by accessing China's low-cost labor. Some of those established in the early 1990s are shown in figure 4-1. Some of these facilities are traditional state-owned and operated enterprises while others belong to foreign companies.

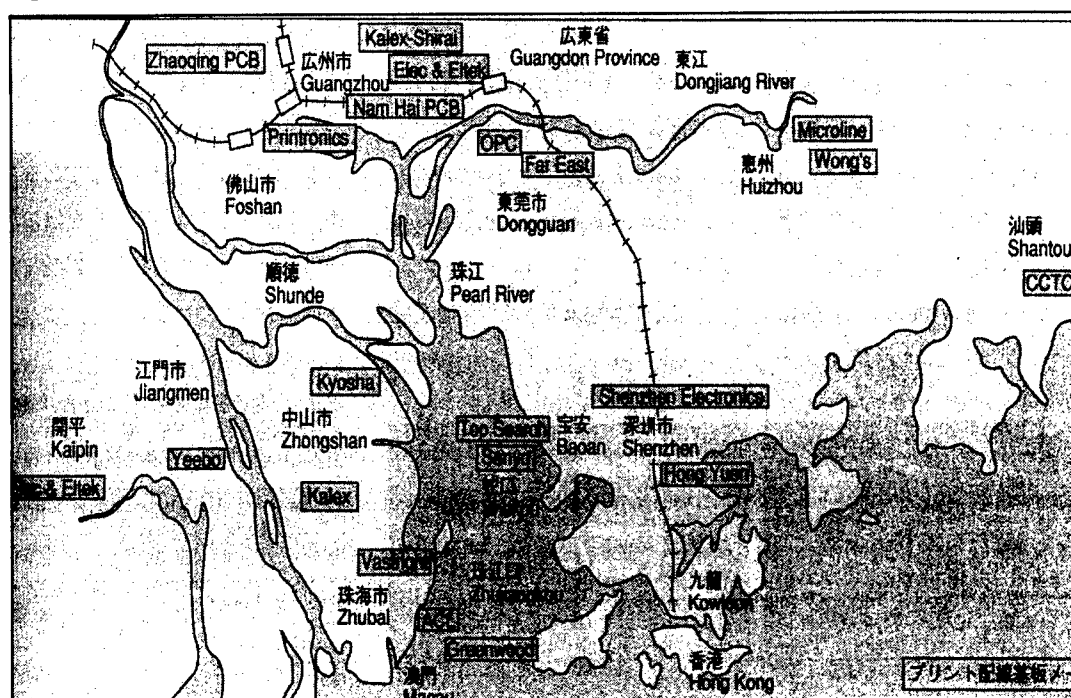
Over 5000 North American, European, and Japanese companies have also established manufacturing sites, some through joint ventures with existing domestic companies, a few with Chinese government cooperation, others with partners from Hong Kong. Surprising are the number of Taiwan-based companies with new manufacturing facilities. Drivers for the growth in new manufacturing facilities include the availability of low cost labor and the potential to market to one of the largest populations on the planet. Some of this growth is in the contract-manufacturing sector.

LOW COST LABOR: HOW LONG WILL IT LAST?

China is the new Mecca for low-cost electronics manufacturing. Wages for factory workers are low. Many of the factories pay production line workers \$50 to \$100 per month—even this is relatively high compared to a few years ago. In addition to wages, room and board—consisting of a room shared with at least three others—is provided. There are strict employment rules such as curfews for nightly return to the dorms. Regardless of the relatively strict employment rules there is no shortage of workers that are willing to fill these positions. Wafers offered by Chinese electronics manufacturing operations are higher than other sectors and the jobs are considered desirable.

The first workers at some of the contract manufacturing sites were not highly trained or even worldly. Workers came from the countryside far away from the manufacturing zones of Shenzhen or Shanghai. When one company opened its manufacturing facility in Shenzhen ten years ago it found workers marveling over the operation of ball point pens. Times have changed in the and the workers are more sophisticated. Today many workers have acquired highly prized skills and some companies are even constructing married family housing to encourage workers to stay with the company.

Figure 4.1: Contract Manufacturing Sites (1994)



Source: NT International.

While wages in China are low today, they are expected to rise over time—just as wages have historically risen in many of the world's formerly low-cost labor geographic regions. Variation in wages is already apparent in China's different economic regions. The closer one lives to Hong Kong, the higher the wage rate. As shown in table 4-1, Hong Kong's salaries are nearly five times those of China, causing problems for Hong Kong's competition in manufacturing. One must go to further and further inland in the southern economic zones to find the lowest wage structures.

Table 4.1: Salary differences

	HK vs. China	
• Head of Government	34,807	266
• Professor	16,287	453
• CEO	15,975	2,865
• Controller	11,022	2,457
• Manufacturing Director	10,150	1,866
• Sales Director	8,454	1,524
• Systems Engineer	3,774	746

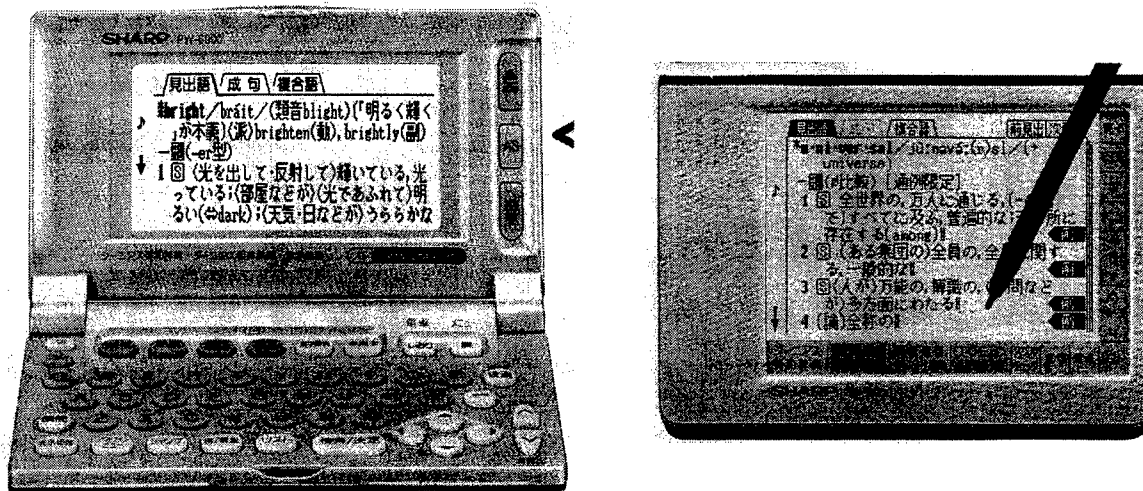
MOVEMENT INTO ADVANCED ELECTRONICS PRODUCTS

Japan's transition from producing transistor radios and cheap consumer products to the high-end, high quality producer of consumer products has been emulated by Taiwan, S. Korea and Singapore. Today, manufacturing operations in China are moving into more advanced products. For example, Namtai Electronics, a joint venture company with Hong Kong financing, Japanese management and technology, and China-based labor provides many advanced assembly services. The company started in 1975 and has moved from mainly calculator assembly to the assembly of products such palm-sized PCs, personal digital assistants (PDAs), electronic organizers and dictionaries, language translators, spell checkers, IC card readers, and

cordless phones as shown in Figure 4-2. The focus for the future is personal communications products; the most recent product is an electronic organizer with features similar to a Palm Pilot.

Surprising are the advanced equipment for product design. For example, one company is using a recently purchased NTT DATA CMET He-Cd laser rapid prototyping system that allows the company to make a prototype in 30 hours.

Figure 4.2: Recent Figure Product Developments



AUTOMATION AND THE EXPANSION INTO ADVANCED CONTRACT ASSEMBLY

One of the most striking differences between manufacturing in Japan, Taiwan, and North American is the amount of manual labor. Contract assembly factories contain rooms of semiautomatic aluminum wire bonders with a worker at each machine. Glob-top dispensing is done manually—by hand with a heated syringe. Many components are hand soldered and inspection is manual. While labor is cheap and capital is expensive, a surprising number of contract assembly houses are purchasing advanced assembly equipment capable of competing in the world market.

Just as contract assembly services around the world have moved into more advanced assembly operations over time, so will China. Whitways, a small contract assembly operation in Shenzhen, has already done BGA placement and even purchased an x-ray inspection system for use with its customer's product. Whitways offers a wide range of services and acquires whatever equipment is needed to service its customers. Table 4-2 provides a full list of equipment available just from Whitways.

Namtai provides component subassembly of small liquid crystal displays (LCDs) and chip on board (COB). Wire diameter of 25 μm and the bond pad pitch of 100 μm is common today. Namtai has just started moving to 75 μm pitch for COB. LCD modules are manufactured for cellular phones and home appliances. PCB assembly is provided for telephones, cellular communications, and microwave ovens. A tape automated

Table 4.2: Whitway's Equipment for Contract Manufacturing

Descriptions	Make	Quantity
SMT Pick and Place Machine	Fuji, Juki, Vitronics	10, 2, 6
Fine Pitch Placement System	Fuji	1
Hot-Air Reflow Oven	Fuji, Vitronics, Kince Worldwide	1, 1, 1
UV/IR Reflow Oven	Universal, Fuji	1, 2
Bonding Machine	ASM	8
Wave-Soldering Machine	Electrovert, Hollis	3, 2
Washing Machine	Electrovert	3
Auto-Insertion Machine (Axial)	Dynapert	4
Auto-Insertion Machine (Radial)	Universal	2
Component Sequencer	Dynapert, Universal	1, 1
Ultrasonic Welding Machine	Branson	2
Pad Printing Machine		7
Ultrasonic Cleaner		3
End Coil Winders 4 Head Single		2
End Coil Winders 4 Head Multiple		4

Plastic Injection and Tooling Fabrication

Descriptions	Make	Quantity
Plastic Injection Machine	Elite, Chun Hung	15, 4
Electric Discharge Machine	Elite	4
Computing Numerical Controller	FV-900SE	2
Milling Machine	100L	10
Drilling Machine		9
Precision Surface Grinding Machine	KEN	2
Measuring Profile Projector	Fuji	1

Major Equipment for Testing

Descriptions	Make	Quantity
Burn-in Chamber	Allen-Bradley	4
In-Circuit Tester	Test Research, Inc., Jet	2
Shield Rooms (For RF Products)		5
Acoustic Telephone Tester	Microtronics	1
Audio Analyzer	Meguro	2

bonding (TAB) and antistrophic conductive film (ACF) assembly business for LCDs started three years ago. Last year Namtai started a chip-on-glass (COG) operation for LCD modules. Chip-on-film (COF) is the next target. The company uses COG bonders from Japanese equipment suppliers for bond fine pitch parts—minimum pitch is 50 μm . Figure 4-3 shows small Japanese-made COG mounting equipment made for the Chinese market. This makes the latest technology available to Chinese firms in manual or semi-automated versions that can take advantage of China's low-cost labor markets.

Increasingly, pick and place lines are found running high volumes of boards per day. The throughput on these lines is high for SMT components. Rooms of manual labor handle the odd component placement while wave-soldering operations keep up with demand.

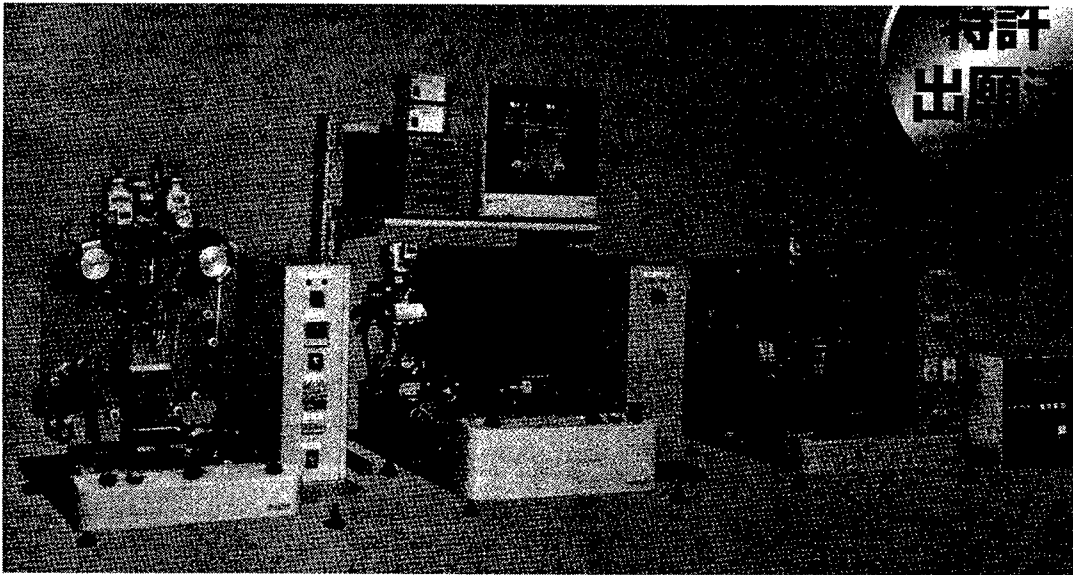


Figure 4.3: Small Chip-on-Glass Mounting Equipment for the Chinese Market

ACF Attachment

IC Alignment

Main Bonding

Reliability testing equipment similar to that found in many of the world's contract assembly operations are found in Chinese factories. Many contract manufacturing operations have test areas with ESPEC thermal shock chambers, vibration test, TABAI temperature/humidity chambers, freezers, and HAST ESPEC chamber, ESD test chambers, and high temperature storage equipment.

The level of technical capability and the use of software tools and programming is impressive. Whitways has a IC programming area with many workers programming 6,000 EEPROMs per day. The PCB layout area at many operations features some of the latest computer systems. Software for board designs including PROTEL or AUTOCAD.

There appears to be no restriction on the ability to purchase the necessary or desired manufacturing or test equipment for contract assembly operations in China.

ISO CERTIFICATIONS AND QUALITY CONTROL

Many companies have received ISO9002 and ISO9001 certification and expect to receive ISO14001 certification in the near future. Several companies are tracking defects and actively working to reduce the number of defects per production area.

Additional changes are expected to improve quality for all aspects of the assembly process. Even clean room technology has become more common in some of the more advanced contract assembly operations. Namtai's assembly operations take place in a clean room (class 10,000 to class 5,000). In more advanced

assembly plants, such as LCD and PCB production in China, tighter clean room standards are maintained. As shown in Table 4-3, firms do not need the same level of clean room environment for all applications. Some firms do not even have air conditioning. In fact, air conditioning (AC) causes added electro-static problems which have required firms to install AC with humidity controls. LCD applications require clean operating environments. Operators wear bunny suits and masks. While not all operations in China have clean rooms for assembly and good clean room practices a trend is expected to develop.

Table 4.3: Clean Room Requirements by Application (Firms A-F).

	Clean Level (Class)						
	<100	1K	10K	50K	ACH	AC	Non
COB		A	B	C	D	E	F
SMT					A	B	C
LCD	A	B	C	D			
LCM		A	B	C	D	E	F
PCB	A	B	C	D	E	F	G

Source: Grand Joint Technology, Ltd.

Many China-based manufacturing sites conduct 100 percent incoming inspection for all boards and components. PCB substrates at one contract assembly house go through a cleaning process for all incoming boards and glass for the displays are manually cleaned one-by-one with alcohol before assembly. Many companies noted that suppliers have improved their quality for components and PCBs. Quality improvements are expected to continue.

CHINA'S FUTURE AS AN ELECTRONICS MANUFACTURING POWERHOUSE

A visit to China's electronics manufacturing centers today is a reminder of the advances that have been made in North American and Japanese assembly operations. While many of the facilities are similar to the factories of the more advanced industrialized nations years ago, rapid progress is underway. Workers will become more skilled, the product mix will become more advanced, and labor rates will rise. China is clearly at the beginning of its rise to become a manufacturing giant in electronics assembly, and the rate of change is anticipated to be swifter than has been experienced by other geographic regions. Factors influencing this rapid growth include the tremendous influx of electronics manufacturing expertise from North America and Japan, the close proximity of Hong Kong with its advanced manufacturing operations and Western technology, the insatiable supply of labor, and the desire for rapid development of the electronics industry.

The global cell phone market has surpassed the computer industry for number of units sold and growth (Table 4-4). The four market leaders, Nokia, Motorola, Ericsson and Samsung have production facilities in China. More of the component suppliers are now producing in China. STN LCDs are already produced in China. STN LCD modules are now being produced in China. The leading supplier to the cell phone industry of LCD module, Epson, is planning to produce color STN in China in 2001. Kyocera plans optics for the cell phone video camera beginning in 2001 (Figure 4-4). China already has production of plastic optics for small camera lenses. The most advanced cell phones will be available from firms with manufacturing operations in China.

Table 4.4: Global cellular phone market (million units)

	1999	2000(Estimate)
Nokia	76.34(27%)	100
Motorola	47.82(17%)	61.5
Ericsson	29.79(11%)	41
Samsung	17.69(7%)	24.6
Panasonic	15.58(6%)	20
Others	96.38(32%)	164
Total	280 (100%)	411.1

Figure 4.4: Next Generation Cell Phones Production in China

Video Phone



Color STN Phone

Along with advanced cell phone technology, we can expect new forms of products to be developed within China and Hong Kong. With the advancements in hard disk drive technology, chip-scale-packages, mobile communication, and advanced microprocessors, firms are now being formed to create new products. With the change in basic components architecture, the playing field has been leveled. Neither Japan nor the U.S. necessarily has the advantage. Japan still supplies the critical manufacturing equipment, and the U.S., Japan, and Europe still have global brand leaders. But China is building its own capabilities and brand names, like Legend, that are proving to be successful competitors in the Chinese marketplace.

CHAPTER 5

SUMMARY FINDINGS OF CHINA'S ELECTRONICS INDUSTRY

William R. Boulton

As this report describes, China is rapidly closing the gap on technologies needed for electronics manufacturing. It can be expected that WTO membership combined with more aggressive incentives for foreign direct investment will lead to changes over the next five years that will be significantly greater than those of the past five years. The priorities described in Chapter 1 will continue and will result in a more competitive business environment. But without forecasting the future, we can summarize the present as follows.

TECHNOLOGY AND LABOR ARE COMPETITIVE

As this report has found, China has access to most of the technologies needed to manufacture today's products. Companies are already using leading edge manufacturing technologies for assembly that include chip-on-board, chip-on-glass, and chip-scale-packages. While the semiconductor industry lacks the capacity to meet domestic needs, China's IC design capabilities are competitive in the global marketplace. The design of ASICs for advanced products, like MP3 players and set-top boxes, has been well established. Such ASICs can be manufactured by any number of firms in Taiwan, Singapore, or Japan.

In combination with having access to leading edge manufacturing equipment, China has an unlimited supply of cheap labor. In Shenzhen and Shanghai, factory workers can cost as little as \$100 per month. In more rural areas, or in the western regions, labor can easily cost less than half the urban labor rates. With the new incentives in place to develop China's western regions, we can expect to see more investment in infrastructure and more foreign involvement in traditionally protected industries.

INCREASED INCENTIVE FOR FDI

The Ministry of Foreign Trade and Economic Cooperation (MOFTEC) has recently posted China's policies for trade and foreign direct investment. These policies are attached to this report as Appendix 1. They clearly state the incentives and describe the industries that are open for foreign direct investment, especially in the western regions.

ONE-CHINA POLICY

The consideration China's long-term electronics capabilities cannot ignore the current move for reunification of Taiwan with mainland China. Taiwan has been extremely successful in developing world market share in a wide range of electronics component technologies. In 11 years, Taiwan has gained 12.5% of the world's semiconductor market and hosts the world's leading semiconductor fab (TSMC). In key components, Taiwan appears able to gain a dominant market share in most segments that it enters. Previous reports describe Taiwan's successful strategy, a strategy that would support China upon reunification.

While the Chinese military is currently undergoing a dramatic restructuring (removing itself from commercial businesses), there is little evidence that military operations are able to compete with today's dynamic private sector. However, the continued privatization of state-owned-enterprises has the potential to generate significant capital. China Telecom and China Unicom have raised over US\$8 billion in the U.S. stock market. It is hoped that like amounts of capital can also be raised through the privatization of other leading firms.

The global trip of President Jiang Zemin proved successful in acquiring advanced technology from the former Soviet Union and Israel. The move to improve relations with China's neighbors, including India, suggest a strategy to build China's leadership in the region. The reunification of North and South Korea was the result of Chinese initiative. The entrance into WTO and the rapid move to meet WTO requirements will attract more investment. This combined with more incentives for FDI and the establishment of a legal system that meets global standards will make China an even more attractive investment site.

CONCLUSIONS

We should not underestimate the attractiveness of a marketplace with 1.3 billion people. What is more, this market provides unlimited low-cost labor (\$100/month for factory workers), world-class industrial parks (53 high-tech industrial parks) that provide tax incentives for up to 8 years and maximum corporate taxes of 15%, and a rapidly opening marketplace (WTO agreements). While there are significant risks and uncertainties that relate to political corruption and weak legal systems, the government appears committed to utilize foreign direct investment to help build its western regions (added investment opportunities and tax incentives). Such a commitment requires that the government build a business-friendly environment. If this does not happen, it is unlikely that the government can generate the new jobs needed to support continued restructuring of its economy, and the closure of many state-owned-enterprises that are not competitive in a free market economy.

In conclusion, the panel was impressed with the basic capabilities found in China. Many are considered equivalent to western or Japanese firms. Where capabilities are lacking, it is primarily due to the lack of investment, such as in semiconductors, where capacity costs are extreme. Over the next five years, IC capacity should nearly double. Even then, this will only meet about 25% of internal demand. Resolution of conflicts with Taiwan could rapidly improve this situation, making this a continuing political priority. Following the evolution of a "one China" reality could rapidly change the real status of Chinese technology capabilities, especially in electronics.

APPENDICES

APPENDIX A. BASIC POLICIES GOVERNING CHINA'S FOREIGN TRADE AND ECONOMIC COOPERATION (WWW.MOFTEC.GOV.CN)

I. Stick to the policy of opening up in all directions and expanding foreign trade in all forms.

We shall speed up the pace of opening to the outside world, fully utilize the international and domestic markets and these two resources. Additionally, we will actively participate in international competition and international economic cooperation, bring into play China's comparative economic advantage, forge an open economy and make the domestic economy integrate with and complement the international economy. We also need to continue to move ahead with the opening drive in the special economic zones, coastal open cities, coastal open areas and key cities along borders, rivers and in inland areas, and fully bring into play the influencing and driving role of the open areas. And we should speed up the development and opening of areas along major transport lines. encourage the mid-western areas to expand opening both externally and internally, accelerate the exploitation and utilization of natural resources, bring into full play advantages in terms of labor and markets and promote economic development. We must formulate an overall plan, operate well economic and technical development zones and bonded areas and form an all-directional, multi-layered and varied opening pattern. Finally we must continue to expand the scope of foreign trade and economic cooperation, promote the development of the trade in services and further open the domestic market.

China's opening drive is oriented towards the whole world, including both the developed and the developing countries, under the guidance of market diversification strategy for foreign trade and economic cooperation. We are willing to develop the economic and trade relations with various countries and regions in the world and intensify the multilateral cooperation with the organizations of the UN development system as well as other international economic and trade establishments based on the principle of equality and mutual benefit. As a developing country with a huge population, China will develop its economy mainly by relying on its own capital accumulation, domestic resources, domestic market and the intellectual abilities and creativeness of its own people. We uphold the principle of independence and self-reliance, but in no way exclude international division of labor and exchanges.

II. Stick to the policy of deepening the reform of the foreign trade and economic cooperation regime and, with the momentum of the reform, promote the sustained, rapid and healthy development of the foreign trade and economic cooperation sector.

This reform calls for compliance with the requirements of establishing the socialist market economic system and adaptability to international economic and trade norms in the course of establishing an operating mechanism satisfying globally prevalent economic rules. We must stick to the reform direction characterized by uniform policies, liberalized operations, equitable competition, self-responsibility for profits or losses, combination of industry and trade and pursuit of the agent system. The State will mainly resort to such economic tools as the exchange rate, tariff rate, taxation and credit in regulating foreign-economic activities, bring down the overall tariff level, appropriately adjust the tariff structure, revamp the import and export administrative regime to achieve its standardization and scientification, and bring into play the role of chambers of commerce in coordination, guidance, and advisory services.

The transformation of the operating mechanisms of foreign trade and economic enterprises will be speeded up. In accordance with the modern enterprise system, state-owned foreign trade and economic cooperation enterprises will be restructured so that they can genuinely become operating entities which are autonomous in their operations, responsible for their own profits or losses, self-developing and self-restraining. We should bring into full play the initiatives of these enterprises and their staff members, continuously expand import and export trade and foreign economic and technical cooperation, ensure the preservation and appreciation of the value of state-owned assets and strengthen these enterprises.

Qualified foreign trade and economic cooperation enterprises must gradually be transformed into standardized limited liability companies or joint stock limited companies. On the basis of equality and mutual benefit, we will encourage the formation of a group of large industrial-trading enterprise conglomerates with foreign trade and economic cooperation as the spearhead and integrating trade with industry, agriculture and technology or with productive enterprises as the core through investment, equity participation and etc. It is not permitted to interfere with the voluntary merger or acquisition between enterprises.

We will speed up the endowment of foreign trade right to the qualified state-owned production enterprises, distributing and retailing enterprises and scientific research units. We will also deepen the reform on the system of foreign economic and technical cooperation and improve the comprehensive operating capabilities and overall benefits. The management system and modalities of foreign assistance will be reformed. Corresponding reforms will be conducted on the operating administration system of other economic and trade activities.

III. Stick to the principle of equality and mutual benefit and "Honoring Contracts and Standing by Reputation."

In all foreign trade and economic cooperation activities, China has always upheld the principle of equality and mutual benefit and made consistent efforts to respect each other and consult with each other on an equal footing. We oppose the attachment of any unfair and unreasonable conditions. We maintain that pricing should be as fair as possible and beneficial to both parties and that all economic and trade activities must meet the needs and capabilities of the parties concerned. We oppose any party to use certain advantages to gain unreasonably huge profits. Trading terms and conditions, methods of payment, commodity inspection, customs, transport, insurance and arbitration should follow international norms and practices. While placing importance on the development of economic and trade relations with the developed world, China also actively forges economic and trade ties with the developing world and work with these developing countries towards the establishment of a new international economic order. The Chinese government requires all departments, enterprises and individuals engaged in foreign trade and economic activities to follow the principle of "Honoring Contracts and Standing by Reputation" and set up sound regulations and rules to ensure the implementation of this principle.

IV. Stick to the principle of success through quality.

Quality is the pass to the international marketplace and the lifeline of enterprises. All foreign trade and economic cooperation activities must center around the idea of quality first in order to attain a good reputation on international markets. We will choose well-performing enterprises as designed ones, organize production, perfect quality check and acceptance system, implement total quality management, improve the quality of export goods, and realize economic benefits by way of quality and variety. Projects with foreign investment should comply with the State's industrial policy, increase the percentage of technologically advanced and export-oriented enterprises and the ratio of success of these projects. In contracting overseas engineering projects, it is imperative to execute the quality standards as stipulated in the contract so as to foster a bigger number of quality projects; it is also necessary to enhance training of labor services personnel to improve their quality. It is also vital to bring into play the international spirit and, with a high sense of responsibility, succeed in every foreign assistance project so that those projects can generate due economic and social benefits.

V. Implement the "Macro Foreign Trade and Economic Cooperation" Strategy in this sector.

Since the adoption of the reform and opening policy, China's foreign trade and economic cooperation sector has gradually formed a multi-channel, multi-layer and multi-modality pattern combining commodity, technology, capital and labor services. In order to satisfy the needs of establishing China's socialist market economy, on the basis of the already-formed foreign trade and economic cooperation pattern, it is an inevitable trend to carry out the "Macro Foreign Trade and Economic Cooperation" strategy. To do so, we mean that under the macro environment of the socialist market economy, we must strenuously advance the advance the combination of foreign trade, foreign economic cooperation and foreign investment, promote the alliance of foreign trade and economic cooperation with agriculture, technology and commerce, embark on the path of industrialization, conglomeration and globalization. Development of bilateral economic and trade

relations with all countries in the world is the basis of China's all-directional opening policy and the priority of China's foreign trade and economic cooperation policy. China adheres to the principle of combining bilateral economic and trade relations with multilateral economic and trade relations to tap the international marketplace in different forms so as to facilitate the sustainable, rapid and healthy development of China's foreign trade and economic cooperation.

VI. Enhance the uniformity and transparency of policies.

The legislation system for foreign trade and economic cooperation shall be improved upon and all types of foreign trade and economic operations should be administered in accordance with laws and regulations. Foreign trade and economic departments, enterprises and professionals shall enhance their legal awareness, level of law enforcement and consciousness of abiding by laws and regulations. A uniform nationwide foreign trade and economic policy is also necessitated by the objective requirements of the establishment of a unified domestic market and is in line with the international norms. In an effort to ensure the uniformity of China's foreign trade and economic policies, systems, laws and regulations, except those that should be promulgated by the National People's Congress and its Standing Committee or the State Council, the State Council has already authorized the Ministry of Foreign Trade and Economic Cooperation to publicize, in a unified manner, systems and laws and regulations concerning foreign trade and economic cooperation and organize for their implementation. All the foreign trade and economic laws and regulations, policies and systems and relevant rules, shall be made public. The previous internal documents shall be sorted out and those which remain valid shall be published in order to raise transparency.

VII. Foreign Trade Policies.

1. It is the fundamental policy of China's foreign trade to maintain a balance between import and export. The export expansion is aimed at importing the advanced technology and equipment needed in the economic construction, the materials in short supply domestically and necessary consumer goods. Under the circumstance of too rapid increase in import, anemic growth of export and the emergence of trade deficit, we try to reach a balance through the active export expansion instead of passive import reduction.

2. Enterprises are encouraged to constantly raise the quality and grade of the export products by means of deeper processing. In the optimization of export composite, the shift from mainly exporting roughly processed products to finely processed products shall be promoted in a bid to export more high value-added products. We shall, in accordance with the trend of international trade development, give full play to the advantages of labor resources, technical and natural resources, increase marketable export commodities, and boost the business activities of inward processing.

3. We shall adopt the policies and measures of export encouragement. We shall promote export growth and improve the export tax refunding system to ensure adequate and timely rebate with simplified procedures and at the same time, to firmly guard against tax fraudulence through seriously combating law violations. An export commodities development fund shall be established for a few numbers of commodities vulnerable to great price fluctuations in international market so as to offset losses with profits and be self-responsible for profits and losses in a bid to ensure a steady increase of export and production capabilities. A credit policy favorable to export development shall be adopted so as to give priority guarantee for the export loans of various foreign trade enterprises and to ensure the growth of loan scale match with export growth. And also a state import and export bank needs to be set up to provide credit support and risk guarantee for export.

4. We shall, while increasing foreign exchange earnings through export to ensure necessary foreign exchange reserves, actively expand export according to the principle of striking a balance between import and export. The priorities for import are: the import of important materials required by national economic development and the import of advanced technology, equipment and important raw materials in short supply domestically. We shall protect our infant industries according to international trade practice and adopt necessary trade safeguard measures; exercise statutory inspection of some imported goods by using the advanced inspection facilities and improve the inspection methods so as to facilitate import and export. Necessary quota and licensing administration shall be adopted for a few important imported products. China will never practice trade protectionism and China market will be open to countries and regions all over the world. Foreign

commodities, so long as they are competitive and conform to China's industrial policy, are blessed with abundant opportunities to enter China market.

5. Import and export trade shall be liberalized under macro control. Joint companies shall be established to exercise unified and joint transaction over a few especially important commodities which concern state economy people's inclined to be monopolized in international markets and which take predominant role in international market, while other import and export goods shall be liberalized for transaction by companies with foreign trade rights. Administration commodities subject to aggregate quantity control shall be exercised in accordance with the principle of efficiency, impartiality and transparency, with the quotas subject to bidding, auction or standardized allocation. The Ministry of Foreign Trade and Economic Cooperation (MOFTEC) is responsible for the formulation of relevant regulations and the supervision over the implementation, whereas the specific procedures are to be organized by import and export chambers of commerce concerned. In meeting with the requirements of economic system and reforms of foreign trade regime, import and export trade shall be regulated mainly by economic means while supplemented by necessary administrative measures, with interest rates, exchange rates, tariffs and so on as the major leverages.

6. We shall follow the principle of diversification of trade practices and methods. Flexible and diversified trade measures and practices shall be adopted according to different market situation. At the same time when cash trade is being expanded, we shall also pay heed to the development of barter trade, entreat trade chartering and leasing trade, counter trade, multilateral trade and border trade with other economic and technological cooperation activities and boost such businesses as processing with imported materials, processing according to supplied samples and assembling of imported parts and components.

7. We shall strengthen the coordinated service mechanism of foreign trade so as to give a full play to the role of coordinated guidance and consulting service by the import and export chambers of commerce in foreign trade activities. The import and export chambers of commerce are the sectoral self-disciplined organization to exercise coordination with in the sectors and to offer service for enterprises, with the major functions as the following: to maintain foreign trade business order and to safeguard the interests of the member enterprises; to organize the responding to the anti-dumping cases filed by foreign countries; to provide information and consulting service for member enterprises; to refer the requests and opinions of the enterprises to the government and to put forward proposals to the government for the formulation of policies; to supervise and guide the enterprises to abide by laws and regulations in their business activities; to organize the quota bidding for export commodities within the authorization as conferred by competent authorities; to inflict economic punishment upon enterprises who violate the coordinated decisions of the chambers or to offer other punishment recommendations to the competent authorities. And the government has granted the chambers of commerce with the rights of supervision, examination and veto.

A social intermediate service system shall be established so as to give full play to the information service functions of various research and consulting institutions, various academics and associations. In this way, a sound, nationwide information service network can be formed. It is also necessary to set up law firms, accounting and auditing agencies in order to supply the enterprises with services related to foreign trade and to exercise social supervision over the operation of the enterprises.

VIII. Policies Concerning the Absorption of Foreign Capital.

1. Foreign businessmen are allowed to make investment either in the form of physical materials such as currencies, machines, raw materials and transportation tools or in the invisible assets such as industrial properties or proprietary technologies;

2. There is no ceiling for the equities held by foreign businesses in a joint venture and wholly foreign-owned enterprises are allowed to be established;

3. Foreign-invested enterprises are permitted to purchase raw materials and sell their own products directly in the international market. Enterprises are encouraged to export their products and can also be allowed to sell the products in domestic market;

4. Through consultation, either the Chinese or the foreign side of a Sino-foreign equity joint venture or Sino-foreign cooperative joint venture can hold the post of chairman. Foreign-invested enterprises are encouraged to employ local employees and they are also allowed to engage expatriate technical experts and senior managerial personnel;

5. Preferential treatments in taxation, land use and provision of raw materials are offered for foreign-invested export-oriented enterprises or those with advanced technology;

6. Foreign businesses are encouraged to channel funds into the following sectors in accordance with the state industrial policies: (1) projects of agricultural technology development, transportation, energy and important raw materials projects in urgent need by the country; (2) projects which involve the introduction of foreign technologies urgently needed by the country, which may renovate the functions of the products, save energy and raw material, reduce pollution, upgrade the products, explore the international market and expand export; (3) projects involving new equipments and new materials which may fill the void in the country and which are marketable; (4) projects of new technologies and equipments which allow the comprehensive utilization of domestic resources and recycled resources.

7. Foreign investment is restricted in the following sectors: projects which have been developed or to which technologies have been more than once introduced with the production capacity already satisfying the demands in the domestic market or the projects simply involving the assembling with imported parts and components for sales at the home market; projects involving the production of China's traditional native products and traditional export products and other projects alike. Foreign investment is forbidden in the following areas: projects which involve state security, detrimental to national economy and social development; projects which harm natural environment.

8. Preferential taxation treatments are granted to foreign investment. The main items are as follows:

The National People's Congress, in 1991, adopted the "Income Tax Law for Enterprises with Foreign Investment and Foreign Enterprises", and then the State Council enacted the "Detailed Rules for the Implementation of the Income Tax Law for Enterprises with Foreign Investment and Foreign Enterprises", which stipulates that the income tax for enterprises with foreign investment is levied at a rate of 30%, local income tax at 3%, totally 33%. The income tax on enterprises with foreign investment established in Special Economic Zones and enterprises with foreign investment established in Special Economic Zones and enterprises with foreign investment of a production nature in the Economic and Technological Development Zones is levied at a reduced rate of 15%. Enterprises with foreign investment of a production nature established in coastal Economic and Technological Development Zones shall be levied at a reduced rate of 24%. Enterprises with foreign investment established in coastal economic open areas, in the old urban districts of cities where Economic and Technological Development Zones are located or in other regions designated by the State Council, within the scope of energy, communication, ports and harbors, wharfs or other projects encouraged by shall be levied at the reduced rate of 15%.

Any enterprise with foreign investment of a production nature, scheduled to operate for a period of no less than 10 years shall, from the year beginning to make profits be exempted from income tax for the first and second year and allowed a 50% reduction in the third to the fifth years.

Export-oriented enterprises with foreign investment may, upon the expiration of the tax exemption and reduction period as provided for in the Tax Law, further enjoy the 50% reduction the corporate income tax based on the rate stipulated by the Tax Law, if the value of their export products of the year exceeds 70% of the total value of products of the year.

Any foreign investor of the enterprises with foreign investment who reinvest its share of profit obtained from the enterprise directly into that enterprise by increasing its capital, or uses the profit as capital investment to establish other foreign-invested enterprises to operate for a period of no less than five years shall, upon approval by the taxation authorities of an application filed by the investor, be refunded 40% of the income tax already paid on the reinvested portion.

Enterprises with foreign investment shall, to import machinery, equipment, parts and components and the materials needed for the establishment of factories, for the installation and fortification of the machinery and

equipments within the total investment value and the added capital amount; to import machinery, equipments, spare parts and components and materials directly used in exploration and exploitation for offshore petroleum cooperative development project and to import parts and components and materials needed for manufacturing offshore oil exploitation machinery and equipments, be exempt from customs duties and value-added tax levied in the import links.

9. While energetically attracting direct foreign investment, China is active in utilizing foreign loans. However, the following principles are to be abided by in raising foreign debts: (1) appropriate size, rational structure and adequate growth. Debts should be controlled in such a size that the annual payment of principal plus interests shall not exceed 20% of the foreign exchange earnings through export and commercial credit shall not exceed 20% of the total debt. (2) Utilization of foreign debt should be commensurate with the industrial restructuring. (3) Attention shall be paid to the utilization efficiency of the foreign debts. Rate of investment return (or the comprehensive economic efficiency) shall be higher than the rate of loan repayment. (4) The overall management over foreign debt shall be strengthened. In order to guarantee the repayment, both the central and local authorities shall gradually establish various levels of redemption fund.

IX. Policies Concerning Foreign Technology Trade.

1. In technology trade, we shall abide by international norms and practices and protect intellectual property rights according to law so as to safeguard the legitimate rights and interests of the cooperative parties. We shall introduce and learn the advanced technology and experience of other countries so as to promote domestic economic development. We shall encourage the active exploration of technology export market and extensively participate in international division of labor in an effort to gradually make China's technology-intensive industries one of the important links of the international industrial technology chain.

2. We shall develop foreign technology trade in various flexible manners. In terms of technology introduction, various ways may be adopted such as licensing trade, cooperative production, cooperative design, technological service, consultancy and importing key equipments and complete plants, while the specific method of introduction will be adopted according to the specific situation. The key point of importing technologies is to renovate the existing enterprises and we encourage the import of techniques of the products designing, processing, manufacturing and production management. In terms of technology export, we encourage the export of mature industrialized techniques.

3. We shall speed up the work of combining trade with scientific research and industrial production so as to establish a new type of scientific research and development system. We shall greatly accelerate the integration of trade with scientific research and industrial production, increase the capital input and scientific research and development and enhance digesting, absorptive and innovative capabilities of the introduced technologies. In this way, scientific research and development can be gradually transformed from being mainly managed by the state to managed by the enterprises. We shall establish a R&D system which is conducive to the industrialization and commercialization of the introduced technologies so as to give the best play to the introduced technology.

4. We shall pay attention to the sophistication and the applicability of the imported technologies so as to yield better economic and social returns through digestion and absorption. By sophistication of the technologies, we mean the sustainability of the technologies and the competitiveness of the products, while the applicability means that the level technologies is commensurate with the general technical level in the country, which can be quickly mastered and implemented.

5. We shall raise funds from various channels so as to support the development of technological trade with foreign countries. In the field of technology import, we shall strive to make use of foreign governmental loans, mixed loans, export credit, loans from international financial organizations and commercial loans. The state shall place priority on financial arrangement and offer preferential interest rate so as to safeguard the construction of these key projects in urgent need by the nation's economic development. In the field of technology export, the state applies the internationally prevailing credit policy in supporting technology export by establishing seller's credit and buyer's credit for the export of technologies and complete plants. Banks, based on the principle of granting loans, place priority on the financial arrangement for technology export and offer preferential interest rate.

6. Preferential taxation policies are granted to the enterprises engaging in technology trade. In technological introduction, the policy of pegging the introduced technology to technological contents is adopted. And the strategy of introducing technologies mainly for leading industries (machine-building, electronics, chemical industries and so on) is practiced. We shall reduce and exempt the customs duties on the equipment in the contract in accordance with the technical content in the technology import contract; import with high technical content will enjoy more tariff reduction and exemption and vice versa. With regard to the provision of advanced technologies in some important areas such as industry, agriculture, forestry, fishery and animal husbandry by foreign countries, the reduction or exemption of enterprise income tax will be granted. In the field of technology export, those companies and enterprises which import raw materials, components and spare parts needed for technical upgrade and for the export of complete plants and new and high technologies will enjoy preferential treatment according to the relevant stipulations concerning processing with imported materials.

7. The state will mainly rely on legal and economic means to exercise macro control over technology trade and classify the technology trade projects as prohibited, restricted, allowed and encouraged. The state will only apply the guidance plans to major technology import projects which have a bearing upon the economic development and technology export projects which involve significant interests of the country.

8. The combination of technology trade and investment shall be encouraged. Technology may be taken as equity investment to establish joint ventures so as to realize technology transfer. Foreign enterprises, when making investment in China and at the same time bringing in sophisticated technologies, may enjoy various preferences in accordance with relevant laws and relations. It is still in the trial stage for China to make overseas investment and provide the recipient countries with advanced technology. However, China enjoys a promising prospect to develop technology trade in the way of making overseas investment.

X. Policies Concerning Overseas Contracting Projects and Labor Cooperation.

1. China follows the guideline of equality and mutual benefit, pursuing practical results, adopting various ways and seeking common development in developing overseas contracting projects and labor cooperation undertakings.

2. Enterprises which satisfy the following conditions are eligible to apply for the rights in dealing with overseas contracting and labor cooperation: economic entities which exercise independent management, assume independent accounting and be solely responsible for profits and losses;

3. Economic entities equipped with relevant personnel, adequate funds and technology in conducting overseas business activities;

4. Economic entities blessed with the track record and credibility of conducting cooperation with those enterprises already granted with the said rights to develop business activities abroad.

5. China practices an organized manner in dispatching its personnel to undertake overseas contracting projects and labor cooperation. These people will return to China after the fulfillment of the contracts and therefore will not bring social problems or employment pressure to the host country. The government has established the training and examination system for these people and requests departments and enterprises concerned to examine the ethics, technical level and health condition of these dispatched people so as to raise their quality and the government strictly prohibits illegal emigration and unlawful activities by using the channel of official labor service provision.

6. The government shall constantly improve the coordinated administration mechanism, and shall strengthen the coordinated service for the enterprises engaging in overseas contracting and labor cooperation via intermediate organizations such as chambers of commerce.

7. The Chinese government actively supports and encourages the development of overseas contracting and labor cooperation undertakings and has formulated corresponding preferential policies and measures in providing preferential loans, tax exemption or reduction and guarantee.

8. The Chinese government actively supports and guides the enterprises which undertake overseas contracting and labor cooperation to develop various forms of international economic cooperation, to embark on the road of conducting multiple business while centering on one main business line and to stride toward industrialization, conglomeration and internationalization.

XI. Policies Concerning Overseas Investment.

1. China's principle in making overseas investment and setting up enterprises abroad is equality and mutual benefit, pursuing practical results, conducting various forms and seeking common development.

In establishing overseas enterprises. China sticks to the principle of equality and mutual benefit, respects the sovereignty of the host country, does not interfere with the internal affairs of the country and attaches no political conditions. Overseas Chinese-invested enterprises and staff working abroad shall abide by the local laws, respect local customs and habits. The Chinese side shall take full consideration of the possible conditions and the actual needs of both sides and fully exploit their respective advantages and potentiality. The ratio of investment, the way of investment and the manner of conducting business shall be decided in line with the specific conditions of the host country and the cooperative partners so that not only investment partners are able to gain profits, but also China and the host country may achieve direct or indirect economic and social returns through joint investment and joint management.

2. Supportive Policies.

Being a developing country, it is impossible for China to develop large size overseas investment. Currently, the major task is to support and encourage those powerful enterprises to make proper overseas investment based on needs and possibilities.

In a bid to promote export enterprises (referring to foreign trade companies, industrial and trading companies, export-oriented production enterprises, enterprise groupings, enterprises of high and new technologies and other qualified economic entities) to actively tap the international market and raise the competitiveness of the Chinese-made machinery and electronic products on international market, these enterprises are encouraged to set up manufacturing enterprises and service network aimed at export expansion through overseas investment.

Manufacturing enterprises and domestic investors which have sponsored comparatively large amount of development projects of overseas resources or make comparatively large investment abroad may apply to the state banks for preferential loans (including foreign exchanges and Chinese RMB yuan) in addition to raising part of the funds themselves.

Domestic investors, when they receive the share of the after-tax profits (no matter whether China has signed the agreement on the avoidance of dual taxation with the host countries of the overseas enterprises), may retain all the money and are exempted from income tax within five years starting from the date of the establishment of the enterprises and thereafter, shall pay income tax according to tax ratio set by the state.

3. Sectoral Guidance Policies

The industrial orientation of the overseas investment enterprises is decided by the requirement of China's economic development and international economic environment. The overseas Chinese-invested enterprises shall generate more foreign exchange earnings for the country, participate in international competition and division of labor and bring benefits to the development of the national economy. Overseas investment in the following sectors is encouraged at present: manufacturing sector of the processing and assembling type, development of natural resources, development of high technologies and sciences, contracting projects and service sector.

XII. Policies concerning Foreign Assistance.

The Eight Principles governing foreign assistance are the fundamental principles in China's foreign assistance. In July of 1979, Comrade Deng Xiaoping pointed out: "We should give positive assessment to the previous assistance offered to the third world. Though China has economic difficulties, we still must earmark

certain necessary amount of foreign assistance appropriation and we shall keep this in mind. In providing foreign assistance, we should persist in the eight principles which we have had. Basically, the eight principles remain to be our foreign assistance guidelines, but some modifications must be made on the specific methods so as to truly benefit the recipient countries. These Remarks have set forth correct guidelines for the development and reforms of the foreign assistance in the new period.

In the new period, the principle of China's foreign assistance is to help recipient countries develop small and medium-sized projects which can meet the local needs and can be supported by local resources and to make a combination of developing bilateral and multilateral economic and trade relations as well as mutually beneficial cooperation. In this way, we can make the foreign assistance appropriations generate greater returns for the recipient countries so as to achieve common development for these countries and China. This can be manifested in the following aspects:

1. Diversification in providing Foreign Assistance. We shall, based on the real situation, different conditions and different needs in different countries, provide foreign assistance funds with different contents in different ways and of different nature to different recipient countries while taking into consideration the capabilities of our country. The governments of the recipient countries are permitted to re-lend the loans granted by the Chinese government to enterprises cosponsored by the two sides or just by one side.
2. In accordance with the requirements of the recipient countries, we shall discuss with them to select those small and medium-sized projects which they can construct and operate and which are commensurate with their economic development, e.g. industrial and agricultural production projects, processing and assembling projects, commodity distribution centers, bonded warehouses and department stores, etc. We encourage enterprises from both sides to establish equity or cooperative joint ventures in production projects, and we should strengthen various forms of technical assistance.
3. The provision of material assistance to foreign countries should serve the development of the foreign trade market apart from serving the purpose of disaster relief. We should ensure the quality of the assistance materials and offer a good service after the provision. We should both meet the needs of the recipient countries and bring benefits to the expansion of bilateral trade.
4. We shall support foreign trade, overseas investment and other forms of mutually-beneficial cooperation. Apart from relending governmental loans to the enterprises, certain amount can also be appropriated from fund for foreign assistance to support, in the form of credit, Chinese enterprises to establish joint ventures and undertake overseas projects in the developing countries. The assistance fund can also be used in the cooperation in resource survey or the prospecting and design of the projects.
5. We shall continue to adopt flexible and timely forms of foreign assistance and provide small volume of grant (material, technical assistance and small projects) to the recipient countries so as to help them surmount certain difficulties.
6. We shall strengthen multilateral cooperation. We can combine some aid fund with the funds from UN and other multilateral development institutions in order to carry out economic and technical cooperation in developing countries.
7. The ways and practices in foreign assistance shall both carry our own characteristics and be consistent with the internationally prevailing practices and rules. The contents of the contracts of assistance in the form of projects and materials shall be in line with the international norms so that different recipient countries will be willing to accept.
8. The recipient countries are allowed to repay our loans in various forms.

XIII. Policies on International Trade and Economic Cooperation.

1. With regard to the relations with international organizations for multilateral economic and trade cooperation, our principle is to strengthen trade and economic contacts with all members of international multilateral organizations on the basis of mutual respect, equality and mutual benefit so as to promote common development. We are of the view that economic development and common prosperity can not be

achieved without constantly strengthened cooperation and coordination as well as exchange of needed goods and complementing each other on the basis of equality and mutual benefit. We shall strictly abide by this principle in the relevant activities in GATT, WTO, UNCTAD and APEC.

2. With regard to the development of regional blocs in the world economy, it is our view that regional economic blocs should be open rather than exclusive and be conducive to the establishment of a new international economic order. Given the different conditions in the countries and regions, it is impossible to have just one form of cooperation, the countries and regions concerned may choose a suitable mode of cooperation in the light of their actual conditions. We are willing to consult with the countries concerned and carry out various forms of regions economic and trade cooperation according to the needs and possibilities.

3. With respect to the resumption of china's GATT contracting party status, China is willing to enjoy the equal rights that it is entitled to and to perform the obligations commensurate with the level of economic development in China along with other contracting parties on the basis of balance between rights and obligations. Our purpose is to, through the participation in multilateral trade system, introduce proper competition mechanism into our country, deepen the reform of the domestic economic and trade system, promote the development of domestic industries, create a more favorable and stable international trade environment for the development of China's foreign economic relations and trade and the establishment of a new world economic order. In the light of these principles and targets, while bearing the obligation to open more domestic market, we will also demand our trading partners to reduce and eventually eliminate those discriminatory tariff and non-tariff measures against China, reduce trade barriers and improve the environment for China's foreign trade.

4. The Asia-Pacific region is the most dynamic region in the world economy today. As a member in APEC, China attaches great importance to the activities of this Organization. In November 1994 at the informal meeting of APEC leaders held in Bogor, Indonesia, President Jiang Zemin clearly stated that diversity and interdependence were the reality of the Asia-Pacific region. Based on this perception, he put forward five principles for the future development of economic cooperation in the Asia-Pacific region, which are mutual respect, consensus through consultations; progressive and steady development; openness to each other and non-exclusion; extensive cooperation and mutual benefit; narrowing differences and achieving common prosperity. These five principles are also China's principles for dealing with other regional economic organizations. APEC should be an open, flexible and pragmatic forum and a consultative body and not an inward-looking economic and trade bloc. The Asia-Pacific countries and regions should open their markets to each other and to the rest of the world as well.

5. China's principle for bilateral and multilateral assistance is "give and take". In 1982, we began to receive the economic assistance from some developed countries and international organizations. We shall take into consideration the capacity of the donor countries and our priority needs in the economic construction and do our utmost to obtain more grants and advanced technologies so as to promote the economic development in our country. At the same time, we shall provide assistance to other countries within our capacity through international organizations.

APPENDIX B. BIOGRAPHIES OF PANEL MEMBERS

Name: Dr. William R. Boulton (Panel Chair)
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Dr. Boulton is the C.G. Mills Professor of Strategic Management in the College of Business at Auburn University. His research is focused on Global, Technology-based Competition. Dr. Boulton was Visiting Professor at Germany's premier executive development institute, Universitätsseminar der Wirtschaft at Schloss Gracht, in Erfstadt, Germany during 1999. He was a Visiting Scholar at the prestigious Institute for Fiscal and Financial Policy of Japan's Ministry of Finance in 1993. He has also been Visiting Professor at Keio Business School in Japan in 1992 and 1993, where he was also hosted as a Fulbright Research Scholar in 1986.

Dr. Boulton is the chair of a new Asian Electronic Manufacturing Update study beginning in September 1999. Since 1992, he has conducted three research studies for U.S. government agencies on electronic manufacturing technologies and industrial development policies of Asian countries. The studies include Electronic Manufacturing and Packaging in Japan (1995), and Semiconductor and Electronic Manufacturing in the Pacific Rim (1997), and Information Technologies in the Development Strategies of Asia (1999).

Dr. Boulton is author of numerous articles and cases covering topics of competitive strategy, technology and innovation management, boards of directors, and strategic planning. He developed The Resource Guide for the Management of Innovation and Technology for the AACSB in 1993, and wrote a case and textbook, Business Policy: The Art of Strategic Management in 1984.

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David A. Hodges is a Professor in the Graduate School and the Daniel M. Tellep Distinguished Professor Emeritus at the University of California at Berkeley. He earned the B.E.E. degree at Cornell University in 1960 and the M.S. and Ph.D. degrees from Berkeley in 1961 and 1966. From 1966 to 1970 he worked at Bell Telephone Laboratories at Murray Hill and Holmdel, N.J. Since 1970 he has been a member of the faculty in Electrical Engineering and Computer Sciences at UC Berkeley. Following a year as Chair of the EECS Department, he served as Dean of Berkeley's College of Engineering from July 1990 through June 1996. He was appointed Professor in the Graduate School after retiring from regular teaching duties in July 1998.

From 1970-90 Professor Hodges was active in teaching and research on microelectronics technology and design. With colleagues he developed Berkeley's electrical engineering courses on bipolar and MOS digital integrated circuits. With H. G. Jackson, he co-authored the McGraw-Hill textbook *Analysis and Design of Digital Integrated Circuits*, which has been used by more than 50,000 students in two English language and several translated editions. He is an author and/or editor for two IEEE Press books, and author or co-author of more than 130 contributions to IEEE and other refereed archival publications, including several conference papers that won "best paper" awards.

In the 1960s and 1970s, Professor Hodges was active in research on semiconductor memories, signal processing circuits, and MOS data converters and filters. Since 1985 his research has centered on semiconductor manufacturing systems. He has supervised 27 completed doctoral dissertations and 90 completed master's degrees. Since 1991, he and Professor R. C. Leachman have led Berkeley's interdisciplinary research program on Competitive Semiconductor Manufacturing, the first U.S. academic program of its kind.

Professor Hodges was the founding Editor of the *IEEE Transactions on Semiconductor Manufacturing*, a past Editor of the *IEEE Journal of Solid-State Circuits*, and a past General Chairman of the IEEE International Solid-State Circuits Conference. With Professors R. W. Brodersen and P. R. Gray, he received the 1983 IEEE Morris N. Liebmann Award for pioneering work on switched-capacitor circuits. He was the winner of the 1997 IEEE Education Medal and the 1999 ASEE Benjamin Garver Lamme Award. Professor Hodges is a Fellow of the IEEE and of the American Association for the Advancement of Science, and a Member of the U.S. National Academy of Engineering. He serves as a Director of Mentor Graphics Corporation, Silicon Image, Inc., and as a Trustee of the International Computer Science Institute.

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Michael Pecht is the Director of the CALCE Electronic Products and Systems Center at the University of Maryland and a Full Professor. Dr. Pecht has a BS in Acoustics, a MS in Electrical Engineering and a MS and PhD in Engineering Mechanics from the University of Wisconsin. He is a Professional Engineer, an IEEE Fellow and an ASME Fellow and a Westinghouse Fellow. He has written eleven books on electronics products development. He served as chief editor of the *IEEE Transactions on Reliability* for eight years and on the advisory board of *IEEE Spectrum*. He is currently the chief editor for *Microelectronics Reliability International*. He serves on the board of advisors for various companies and provides expertise in design, test and reliability assessment of electronics products and systems.

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E. Jan Vardaman received her B.A. in Economics and Business from Mercer University in 1979 and her M.A. in Economics from the University of Texas in 1981. She worked on the corporate staff of Microelectronics and Computer Technology Corporation in Austin, Texas where she analyzed international developments in software including artificial intelligence and semiconductor packaging and assembly. In 1987 she founded TechSearch International, Inc., providing licensing and consulting services in semiconductor packaging and is the president.

She is the editor of *Surface Mount Technology: Recent Japanese Developments*, published by IEEE. She is a columnist with *Circuits Assembly* magazine, and author of numerous publications on emerging trends in semiconductor packaging and assembly. She served on the NSF sponsored World Technology Evaluation Center (WTEC) study team involved in investigating electronics manufacturing in Asia. She is a member of IEEE's CPMT society, IMAPS, and SMTA. In 1991 she received a technical contribution award for an outstanding technical lecture delivered at the SHM International Internecon Joint seminar held on January 22, 1991. She has served on the program committee for numerous IEEE conferences and workshops including the International Electronics Manufacturing Technology (IEMT) Symposium, the IEEE Computer

Packaging Workshop in Santa Cruz, and the Electronics Components and Technology Conference (ECTC). She was the Vice Chair of the IEEE CPMT International Electronics Manufacturing Technology Symposium in 1995 and the General Chair in 1996. In 1997 she received an appreciation award for the many years of technical guidance and management provided to the IEMTS. She served as the U.S. liaison to the IEMT Japan conference from 1989 until its merger with IMC, where she continues her liaison duties. She served on the board of directors of IEPS and worked on the merger of IEPS and ISHM to create a combined society and received an appreciation award in 1997. She has been a course instructor at the ECTC since 1995.

Jan's specialty is analyzing international developments in the field of semiconductor packaging and assembly. She has been an invited speaker for IEMT/IMC in Japan, IMAPS/Nordic in Finland, Singapore, the 30th Anniversary of IMAPS France, and the opening of the Fraunhofer Institute in Berlin, Germany. She has authored more than 100 technical papers and made more than 90 presentations worldwide.

APPENDIX C: SITE REPORTS

Site: **Hong Kong University of Science and Technology**
Clear Water Bay
Kowloon, Hong Kong

Date Visited: 9 April 2000

Host: Dr. Ping K. Ko
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Dr. Ko is taking leave of absence from UST as director of a new start-up that will design products for wireless communication. Today, you only need a hard drive, processor, wireless, and ISP.

Hong Kong Opportunity

HK has the opportunity to provide the "front end" design function for product development. China is focused on "back end" design of products for the Chinese market. The market for cell phones, for example, has reached 16 million units in 1999, compared to 1 million in HK. That is enough to focus company attention on the internal market and its product needs.

There was a plan completed in 1999 to give HK a high tech focus. It established ASTRI (Applied S&T Research Institute) as a way to attract people who have serious business proposals. They would join the networked center for two years to complete pre-incubation planning to reduce start-up times. The implementation plan was completed in June 1999, but the government has not released funds. It is not needed now, since spin-offs have taken off without it.

Richard Lee started Cyberport. It is a real estate development project that was sold to HK officials to attract high tech firms. Only Yahoo has committed to doing R&D there. It has already achieved its function by getting global attention. The offices are subsidized at \$8/sqft compared to \$40 in town. The money will be made on the residential developments nearby that are tied to the project. It is the only development land left in HK, and needed a "hook" to get government support.

HK's situation is this:

- Many of those for or against a high tech focus don't understand the basic issues on either side.
- HK has been successful by staying ahead of China and making money doing it, like with the container port. They charge a premium for their services.
- The Chinese market has reached an income level that will support products that cost between \$50 and \$1000 US. To show the potential 5% of the population, or 60 million, are saving 45% of their incomes. Cell phone sales reached 17 million in 1999 and are growing 100%/year, compared to 1 million in HK. That is a self-sustaining market.
- If HK can stay ahead and participate in the market, it will do well. S. China is competent in prototyping, but has limited "font end design" capability. For example, 70% of the consumer product designs done in South China are for the internal market. That means that those projects will not have a serious export market, except for places like Eastern Europe and Africa. HK can do "front end design" and transfer the "back end design" and "prototyping" to China. Then products can be exported.

HKPC

HKPC was established to help industry in HK, but it is bureaucratic and inefficient. They made some contributions in the area of metals, but has failed in most electronics projects. HKPC responds to the needs of industry, but that is only after industry is already behind. Then HKPC is too slow to move, and is usually too late to be of help. They have led the development of several products, like the notebook, but have failed to make a difference. Many of their engineers come from the UK and lack the experience for the products they develop. Their notebook was too heavy and large for the market since they lack component expertise. Once they hire these highly paid engineers, they are stuck with them and must find ways of generating funds to pay for them.

HKPC is involved in the proposing research projects and bidding for them. This is one way for the government to channel funds to PC. It is a conflict of interest that has developed some negative feeling with the Grand Assessment Council.

Research Funding

Funding for research is political in China. City University has many local government people on its council. UST has bankers and industry people on its council. This has given them some political advantage. Young faculty are now getting signing bonuses, equipment, etc. With increasing pay in China, they are doing well with PPI rankings. Engineers are now making over \$400 per month. Young professors will be getting over \$2000 per month.

We set up a joint research program between the Research Grants Council/HK and the National Science Council in China to fund joint proposals. In the Phase 1 process, we reviewed the simple proposals. UST sent theirs for outside reviews. China reviewed theirs internally and selected those with the big names on them. We found that the English version needed to be well written, but the Chinese version needed the right names.

HK University of Science and Technology

UST is in need of champions who focus attention on an area and get things done. The current leadership is spread too thin. UST lacks a driver at present.

- UST recruited 19 of the top students from Tsing Hwa, Beijing, and Fudan universities in 1999. They stay for six months, and then transfer into our programs. We are still working out the policy issues with the government. We have 19 more coming in 2000. 7 of 12 in engineering were on the Dean's List. We have been limited by the number of scholarships we have, but now some parents in Shenzhen want to pay to send their kids. We will add 12 more of them this year.
- UST is a totally networked campus with lots of computers. We have top faculty and are the only representatives to world conferences from Chinese universities. We have a strong undergraduate program that includes labs for students.
- Chinese universities (Tsing Hwa and Beijing will increase salaries of young faculty to \$2000 per month. They need to keep good faculty. This will spread to other universities.

UST has good faculty in areas like LCD sensors. China produces 60% of the world's LCDs, at the low end. UST is strong in microelectronics and represents China in international conferences. We are strong in wireless communication, video, and automation. We have a good language and internet technology group.

UST has developed industry cooperation. UST is now doing front end design projects and turning them over to OEMs. UST developed a DVD digital jukebox using a CSP chip with coding and designing the final box. There are about 15 design houses in HK now, and another 7 being developed that cover a full range of technologies and products. They have been funded mostly by HK investors. HK will invest in anything that can make money.

UST started its incubator center in November 1999. It provides a structure with policies and guidelines for participation and faculty involvement. It does not require university ownership, like City University. If results come from NSF-type research, then it is intended for publication and is in the public domain. If it is industry funded, and is intended to be patented, then it can be licensed. Faculty can be directors or part-timers, or can take leave.

UST has an entrepreneurial program that allows participants to pay 3% of stock or up to 300,000 shares to participate in the incubator center. It also has operations in S. China to facilitate "back end" design. They are located in a high tech industrial park and have special status. The HK-Shenzhen Research Study Center can hire anyone in China and move them to Shenzhen without having to pay \$20,000 fee to the government. That has made companies want to join our center, but not stay in HK.

China Business Situation

The gap between HK and China design capabilities is closing fast. Hardware, software, and firmware designs are getting better fast. All capabilities in China are being raised rapidly, as firms with young CEOs are becoming common.

No one is overly concerned about the loss of engineers to overseas. When the opportunities develop at home, they will return, like they did in Taiwan. The time for development won't take as long as in Taiwan.

SOEs are hopeless. "None of them will make it." They are in a strange situation. If they are successful and make a profit, the state will increase the profit goal by 50%. One CEO said that if he were too successful, someone who wanted access to the money and power of a profitable organization would replace him.

Vtech computers was spun off from Vtech Holdings. It was losing too much money. I don't know if it will survive.

Legend has been successful since one of its founders was from HK and understood customer service. He has been able to deliver to customers on his promises. Competitors like Great Wall have lost position to Legend because they come from the "old" Chinese organizational culture.

Legend is subsidized by the state. The state wants a successful computer company in China and requires agencies to buy from them. That may hurt them long term.

909 project with NEC won't transfer technology. NEC has agreed to do what the bureaucrats wanted them to do. It is guaranteed not to be a loss making operation, and the price of output was fixed.

Beiling and Advanced Semiconductor are unable to get additional investment funding for expansion and upgrading technology. Hua Hong was losing money until Taiwanese investors came in and made it a foundry. That was a change in business model.

Shenzhen and Shanghai governments are more efficient and responsive than the HK government by ten times. They are both paranoid of the other winning and move quickly. They make things happen fast. In one day they determined a location and facilities for one company it introduced. Official from Shenzhen come from outside the area and are rewarded for performance and cooperation.

Souzhou Industrial Park is considered a failure. Firms are now moving out into neighboring parks. They alienated everyone by running a colony.

Huawei builds Cisco-type routers in Shenzhen. They started with low-end switches using outside chips. They are now selling between \$1-2 billion US for the local market. They say they have the largest number of PhDs in China. They still do little export.

China GNP/capita is \$800, Shenzhen is \$3700, Shanghai is \$3500, and Beijing is \$2730. These are the manufacturing centers.

Shenzhen has about 3 million people, with about 1.3 registered residents. Others are immigrant workers without access to schools. If they work for firms in high tech parks, they can get residency status. Shenzhen imports about 15,000 university grads per year, out of the 40,000 that graduate. The major multinational electronic firms are located in Shenzhen. This is the most professionally run government.

Guangdong region has 60 million people and only two universities. It has never been supported by the central government, so the state was poor and no SOEs were located here.

Donguang now has mostly Taiwanese firms, over 8000. The government builds to fit with low rent. It is the PC and peripheral center in China. 70% of the companies are Chinese.

They are trying to grow Canton now. It annexed the Nansha area with its new industrial park along the Pearl River. The key to growth is being within six hours from Hong Kong. As the infrastructure gets better, the distance will increase. The key is to have a one-day trip from HK. That will become a 100 to 200 mile radius. That allows a 10x increase in growth.

Shanghai will attract more multinationals, but they will have to have manufacturing in Shenzhen.

Most SOEs are in the North and North East. They are having the most economic problems and have pollution and logistics problems. They have good education. They started from mining and military operations. They will have to move south to survive.

DVD is becoming the standard for China. It has taken off faster than expected and will leave the VCR tape behind.

The rate of change in China is accelerating. Success will depend on talent and money. We are starting to see them come together.

Written by William R. Boulton

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Compass's mission is *"To be the best among world class suppliers of high density interconnect IC assembly packaging materials.* We recognize all associates are our corporation's most valuable assets. We will continuously invest in them to improve the productivity and quality. Embodying TQM in everything we do, we practice Continuous Improvements in all business processes by implementing Best in Class practice, new skills and technology to achieve the Best in Quality, Speed, Productivity, Technology and Services." The company's advantages include:

- Hong Kong production flexibility combined with Japanese manufacturing technology and quality.
- World-class clean room facilities designed at class 1K for sub-micron lithography.
- Training and developing resources to carry out hi-tech research and development.
- Customer oriented organization.
- Focus on continuous improvement of quality, technology and speed.

Introduction

Compass manufactures TAB tape used for IC package substrates. The focus is on tape for CSPs and TBGAs. Adhesive-based tape is fabricated in 35mm and 48mm widths. Compass intends to sell flexible device substrates in 35, 48 and 70 mm widths. A new production area for 70mm width tape is in the process of being installed. Today's production is one copper metal layer.

The highest pin counts in production is greater than 400 leads. Tape with up to 800 leads has been fabricated. The minimum line and space in production is 25 μm . The minimum pitch in production is 50 μm . Fifty percent of the company's customers request heat sink attachment. The company's heat sink attach operation takes place in a clean room.

The business model is to stay as close to the customer as possible. Since freight costs are 12-14% of sales, and response times are critical for customers of device substrates, physical location is important to their service strategy. The company is focused on selling value and response time to its customers. It delivers prototypes in three weeks and delivers product two weeks later. Singapore will become a second operation and provide customers with a second source of supply. ASAT is the primary customer that has given Compass the ability to deliver what the customer needs.

Compass History

Compass started in 1997 with HK\$335.4 million (\$42 million) in capital, including 4 VCs such as GEMS (\$10 million) and General Oriental in Hong Kong. Nearly \$300 million has been invested. Founders include Chee W. Cheung, and Edmond K.S. Poon. Prior to founding Compass, Chee worked at QPL, one of the world's largest lead frame makers.

The company is housed in a 148,000 square foot facility and has 463 employees from ten countries with an average age of 28. Of the total employees, 81.8 percent are in manufacturing, 2.6 percent in design (7 PhDs in research and development), and the remainder is administrative. Sixty percent of the employees have secondary education or better. Compass has 7,735 square feet of Class 1,000 clean room space, and 19,679 square feet of Class 5,000. The TAB technology is from Japan. Production materials and equipment are also Japanese.

Production began in August 1998. Production of commercial shipments started in January 1999. Compass is currently producing 35 and 48 mm tape for use in micro BGA, CSP, TBGA and MCM packages. It will start two metal layers in June, and plans flip chip tape and multiplayer flex substrates for the future. By 2002, capacity will reach 250,000 meters of tape.

TAB tape market

The capacity for flexible circuit substrate for TAB applications is currently filled in the world market. Compass views its primary competitors as Shindo, Shinko, and CMK. Shindo and Shinko are currently at capacity and expansions will require some time. CMK started production for wide web tape, which requires high precision machinery. It can use old stepper equipment for this application.

Singapore Expansion

In August 1999 Singapore expansion was initiated, and the first U.S. order was received, which was worth \$1.85 million. This project will greatly increase the company's manufacturing capacity and at the same time strategically enhance our customers' time-to-market capability. The Singapore plant is expected to commence operations in the 4Q of 2000. With this additional facility in place, it will effectively increase the company's total capacity by 150%. Compass has representatives in Asia and the United States. The company recently received an additional \$26 million for expansion of a new plant in Singapore. Compass is considering building a production facility in Shanghai in two to three years.

Materials Problems

The major strategic problem is the source of raw materials. Eighty percent of the materials and equipment is from Japan. Most equipment is Japanese built, but the copper plating and desmear lines are built by local Hong Kong companies. The Japanese equipment is modified to improve speed as much as 50%. HK lacks the infrastructure needed to support operations. Compass contends that Japan's strategy is to ship lower grade materials that potentially hurt yields, and to ship shorter rolls that increase setup costs. Compass also believes that Japanese suppliers also price above market rates for some materials. In purchasing raw tape, Japanese companies do not provide the lengths needed for efficient production (350 meters is ordered, but lengths as short as 70 meters are received). Short rolls lose efficiency in setup time. Also, some Japanese suppliers do not ship "A" graded material (which is sold to Japanese firms and used internally). There is a 15-20% loss in yield due to the poor quality of materials (it is not possible to use the outer edges of the tape).

The typical copper thickness is between 25 to 35 μm , with some 18- μm copper in production. In the future Compass may use 12 μm thick copper. Mitsui Metal & Mining supplies copper. Polyamide (UPILEX) thickness is 50 to 75 μm and is supplied by Ube Industries. Toray or Tomogawa adhesive is used. Tape inspection is manual. In addition, some material is not available. Compass could not purchase the wet photo resist material from the Japanese supplier that it wanted to use. According to Cheung, this puts Compass at a slight yield disadvantage from the start, but this is made up by the advantages of being close to the customer.

Compass is developing two-metal and multilayer tape. The two-metal process will be an adhesive less process. Via fabrication is by CO₂ laser. Compass is also developing a gold-bump-on-tape technology. The process is a direct copper plate, nickel, palladium, and gold process. In evaluation low flow under fill materials the company is working with Dr. C.P. Wong of Georgia Tech.

One metal tape production capacity is 150,000 linear meters per month (65 percent is 35mm tape, the remainder is 48mm width). Monthly production capacity is planned for 350,000 linear meters per month in 2002, and 600,000 linear meters per month in 2003.

Structure of TAB Tape

	2000	2002
Polyamide Thickness (μm)	50, 75	50, 75
Cu thickness (μm)	18	18, 12
Min. Line/Space (μm)	30/30	20/20
Min. Iner lead pitch (μm)	50	40
Number of Metal Layers	1, 2	1, 2

Source: TechSearch International, Inc.

Process for TAB Tape

	2000	2002
Polyamide Type	Upilex	Upilex
Starting Material	Polyamide	Polyamide
Subtraction or Addition	Subtractive	Subtractive
Process Format	Reel	Reel
Format Size	35, 48, 70mm	35, 48, 70mm
Via Formation Method	Punch, laser	Punch, laser

Source: TechSearch International, Inc.

University Relations

Compass relies on technical cooperation from local universities to develop new technologies. These universities and government research organizations include Hong Kong Polytechnic University, City University of Hong Kong, and the Hong Kong Productivity Council (HKPC). Compass works closely with City University for failure analysis and reliability testing. It is working with HK Polytechnic University on CO₂ laser drilling capabilities, since tape is now being sent to Japan for drilling. Compass Technology committed to donate HK\$1 million in cash and HK\$1.62 million in plating facility and manpower support. In addition, the company will participate in PolyU's Teaching Company Scheme. It also has an exchange agreement with Georgia Tech on advanced packaging materials. UST is used in material science. UST has a 9-5 mentality, which limits access to their facilities after hours. City's labs are more open and provide Compass personnel with access cards. City University is the most successful model in HK for helping companies. Training is also provided by HKPC and includes SPC, Taguchi method, World Class

Manufacturing Practices, and Supervision Management. International cooperation includes consulting from professors at the Georgia Institute of Technology.

Hong Kong Locations

The cost in HK is about 10 times what it would be in China. HK gives no subsidies. Singapore provides tax incentives and training grants. HK's training is too complex and high cost. They interview the workers to check the training. It costs too much. Since 1997, Compass is the only manufacturing startup in HK and is the "pride and joy" since the takeover by China. As a result, China would have provided a more cost competitive location since nearly 80 people are used in quality inspection.

Written by William R. Boulton and Jan Vardaman

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Mission and Strategy

The mission of the Hong Kong Productivity Council (HKPC) is to promote productivity excellence through the provision of professional services to achieve a more effective utilization of available resources and to enhance the value-added content of products and services. Hong Kong firms receive access and services on a preferred basis, even if manufacturing operations are principally or wholly carried out in mainland China. Foreign firms can purchase services at (much higher) market rates, but it appears that little such business is done.

Electronics Manufacturing

About two years ago, the Electronics Manufacturing Technology Unit was moved from the Electronics Services Division to the Automation Systems Division. Staffing level for electronics manufacturing technology unit has remained about the same, nine professionals and five others.

The Electronics Manufacturing Technology Unit continues to focus on manufacturing technology for Electronic Packaging and Assembly (EPA), including:

- Fine-pitch printed circuit boards
- Micro via formation in boards
- Tape automated bonding (TAB)
- Surface mount technology (SMT)
- Ball grid array (BGA) chip attachment
- Solder bumped flip chip to PCB attachment
- Chip on glass (COG) for liquid crystal displays
- Chip scale packaging (CSP)

Laboratories

We saw laboratory facilities that can perform most of these operations on prototype scale. Equipment investment may approximate \$2M USD, but capabilities seem not to have been upgraded on a regular basis.

It appeared that overall utilization is light. A former service for rapid prototyping of single and double side printed circuit boards has been discontinued in face of little demand.

Microanalysis services are offered, including materials analysis, scanning electron microscopy, and sectioning of boards and electronic components. There is much more utilization of these services than the assembly services listed above.

The Electromagnetic Compatibility Center remains organizationally a part of the Electronics Division. It is well equipped and formally qualified to evaluate and certify electronic equipment as conforming to international standards. Investment in facilities exceeds \$2M USD. Hong Kong firms heavily utilize the Center's services.

Funding of research programs via the Industrial Support Fund complement HKPC efforts on electronics manufacturing. A new initiative, the Applied Science & Technology Research Institute, was authorized in mid-1999, but a director has yet to be appointed.

The HKPC provides training and assistance to firms seeking ISO 9000 and other ISO qualification approvals, now essential for acceptance in world markets. Reference standards and calibration services are offered as a part of this activity. Training is also offered on environmentally friendly manufacturing processes (e.g. solvent management, lead-free soldering), in response to growing demands.

Roadmap Study

An HKPC professional was among the members of the committee that produced the "Microelectronics Packaging and Assembly (EPA) Roadmap Study" (January 2000, 173 pp.). The report is a very detailed assessment of new technologies and expected technical and market directions out to 2012. Among the recommendations is one that urges the Hong Kong government to seek establishment of semiconductor wafer manufacturing in Hong Kong within the next few years, based upon government-offered incentives to stimulate the needed investment from overseas.

In summary, the Hong Kong Productivity Council continues to provide valuable assistance to Hong Kong manufacturers. Its specific activities have evolved to meet changing needs. HKPC is a catalyst for cooperative activity among Hong Kong manufacturers and academic institutions that appears to benefit all participants.

Written by David A. Hodges and Joanne Maurice

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Introduction

Nam Tai Electronics, Inc. is a consumer electronics design and manufacturing service provider to some of the world's leading original equipment manufacturers. Nam Tai manufactures telecommunication products, palm-sized PCs, personal digital assistants, linguistic products, calculators, smart card readers and various components including LCD modules and, in the near future, rechargeable lithium ion battery packs, which are used in cellular phones, laptop computers, electronic toys and household appliances. The company utilizes advanced production technologies such as chip on board ("COB"), chip on glass ("COG"), surface mount technology ("SMT"), tape automated bonding ("TAB") and TAB outer lead bonding ("OLB") technologies and anisotropic conductive film ("ACF") heat seal technology.

Mission Statement

"Stay one step ahead of customer satisfaction" and

"To be the preferred supplier of manufacturing services to a group of leading OEM and ODM customers in the electronics manufacturing services industry."

Net sales for the year ended December 31, 1999 increased by 42.7% to a record high of \$145.1 million from \$101.6 million for 1998. Operating income for the year ended December 31, 1999 decreased 4.8% to \$8.0 million from \$8.4 million for 1998. Net income for the year ended December 31, 1999 increased 234% to \$11.8 million from \$3.5 million for 1998. Basic earnings per share for the year ended December 31, 1999 were \$1.26 compared to \$0.34 for the prior year period. Diluted earnings per share were \$1.25 compared to \$0.34 for the prior year period.

Background

Namtai was started in 1975. It is publicly traded and listed on the NASDAQ. The company is an ODM subcontract assembly operation with a 310,000 square foot production in two factories. An additional 160,000 square foot factory is planned for May 1996. The company has 2,868 employees (2,418 in manufacturing and 450 in management and staff). Customers include Canon, Epson, Legend, Matsushita Electronics, Nitsuko, Optrex, Seiko Instruments, Sharp, Sony, and Texas Instruments. Namtai reports \$145 million in sales for 1999.

Namtai has received ISO9002 and ISO9001 certification and expects to receive ISO14001 certification this year. Namtai reports good quality performance with only 166 PPM defects for 1999. The goal for this year is 99-PPM defects. Five years ago, price was the primary criteria for sales. Today, networked products require six-sigma quality. Namtai won TI's supplier excellence award between 1995 and 1998. It is given to 8 firms per year, out of 3000 vendors.

Namtai Products

Namtai originally concentrated its business on the production of calculators. In 1998 calculator production was 55 percent of total production, but dropped to 35 percent in 1999, and is expected to be 25 percent in 2000. This shift was required as the market for calculators saturated and prices fell. Namtai's customers include Japanese, Europeans, and Chinese firms.

LCD modules for cell phones have increased in business. The company provides component subassembly of liquid crystal display modules for cellular phones and home appliances. Approximately 2 million sets per month are assembled. In June 1999, Namtai Telecom was started in June 1999 to produce the 900 MHz cordless phone for the European market. Major customers include Casio, Asahi Corporation, and the Family Radio System for the United States. Sales to Daewoo had declined and were discontinued. The first order was to produce over 170,000 units for Family Radio Systems in the U.S. market with delivery requested in the months of April and May 2000. Cell phone sales in 1999 increased to 300 million units. Sales are expected to reach 400 million units in 2000. Nokia sold 150 million sets in 1999. Namtai provides 65% of Epson's requirements for LCD modules. Other modules are being supplied to Sharp Thailand for microwave ovens.

PCB assembly is provided for telephones, cellular communications, and microwave ovens. Nickel Hydride battery packs are also being produced with technology from Toshiba. Next year Namtai expects to start assembly with CSPs or BGAs. Namtai's Phase II expansion is being designed and is expected to begin operation in February 2001. It will include five floors (see Appendix I).

Namtek, Namtai's software company, developed an electric dictionary using a single chip. This is an ODM product with production of 2.8 million units in 1999. Key customers included Seiko, Sony and Sharp.

Namtai's Development and Service department is being changed to the Research and Development Department as more ODM products are being developed. They will focus on developing small, personal sized products, adding the personal computers and communication line. Namtai is providing ODM assembly services for a PDA for Legend Computers. Future products will focus on personal communications.

1. CTI/CTI+ Cordless Phones for Europe

The company has successfully finalized the development of NTP 2000 (a new 900 MHz cordless phone model) and obtained type approval in Germany. Orders for this new model were received from Metro MGE Einkauf GmbH ("Metro") for the German market. Metro is Europe's largest telephone distribution company. Orders were also received from Master S.P.A. of Italy; however, type approval for Italy is still in process.

The company also confirmed that it continues decreasing its inventory of finished goods for Daewoo Electronics Deutschland GmbH, and the outstanding balance will be shipped out within two months to totally resolve the inventory build-up of these products.

2. Family Radio System

The company has received initial orders from Korean company Headline Electronics Co., Ltd. for 177,000 Family Radio System ("FRS") units to be sold in the North American market to Radio Shack, a Division of Tandy Corporation, and Midland Consumer Radio Ltd. One million units for Radio Shack and 600,000 units for Midland order forecasts for one year have been received.

3. Digitally Enhanced Cordless Telephones ("DECT")

The Company has finalized cosmetic designs for two DECT models and orders have been received from Master S.P.A. in Italy.

NAMTAI TELECOMMUNICATION BUSINESS PLAN 1999-2000	
1999	2000
900MHz, Europe	
FRS	
LMR	
	DECT
	900MHz SST
Target Sales :	4 - 5 million units

Production capabilities

Namtai performs 100 percent incoming inspection. All boards and glass for the displays are cleaned before assembly. These operations are manual.

Namtai's major strength is COB capabilities, being best in China. The COB operation consists of die attach, wire bond, and epoxy resin coating. The COB operation has a high labor content—there is a person for every bonder. Namtai uses ASM semiautomatic Al wire bonders. The wire diameter is 25 μm and the bond pad pitch is down from 100 μm to 75 μm today. Capacity is 4,000,000 COBs per month (with approximately 150 wires/PCB). Namtai claims that today's wire bonding operations in Japan are too automated today. Unlike Japan, where is now difficult to find high quality workers for manufacturing jobs, Namtai has access to top quality people in China. Workers are flexible and can handle a wide variability of chip sizes. At Namtai, yield is improved in bonding since testing is carried out after the bonding is completed. Yields are 99.85%. If there is a problem, Namtai can catch it quickly.

Namtai has a tape automated bonding (TAB) outer lead bonding (OLB) operation. The company's three bonders were not running at the time of visit.

Namtai has 10 surface mount technology (SMT) lines. The SMT lines have KME and JUKI equipment (Japanese suppliers). The theory is that SMT is used for boards with over 100 parts. While most Japanese firms use a full-automation strategy to reduce labor costs, Namtai can use a mixed assembly model that uses labor to assemble under 100 parts.

Technology / Machines	Current	Plan
•COB - Wire Bonding Machine	82 sets	+ 8 sets
•OLB - Outer Lead Bonding Machine	3 sets	
•SMT - Surface Mount Assembly	10 systems	
•TAB - Tape Automated Bonding Machine (TAB with ACF)	7 systems	
•COG - Chip On Glass Machine	2 systems	+ 1 system
•Fine Pitch Heat Seal Machine	8 sets	
•Heat Seal Machine	75 sets	

The TAB and antistrophic conductive film (ACF) business started three years ago. In 1999, Namtai started a chip-on-glass (COG) operation. Chip-on-film (COF) is the next target. The company uses COG bonders from Toray Engineering and Ohashi—both Japanese equipment suppliers.

There are 20 machines for TAB bonding (also called tape carrier package—TCP). The TCP process requires 25 seconds per part and is capable of minimum pitch of 200 μm . Capacity for LCD modules is 1,000,000 per month. COG capacity is 1,000,000 units per month. The maximum display size is 150 mm x 150 mm. The bond time is 5 seconds and minimum pitch is 50 μm .

For rapid prototyping, Namtai has a NTT DATA CMET He-Cd laser system. The use of this system allows the company to make a prototype in 30 hours.

Namtai has an extensive test area with ESPEC thermal shock chamber, vibration test, TABAI temperature/humidity chamber, freezer, and HAST ESPEC chamber, ESD test, and high temperature storage equipment.

Assembly operations take place in a clean room (class 1,000 to class 5,000). Operators wear bunny suits and masks.

New Capabilities

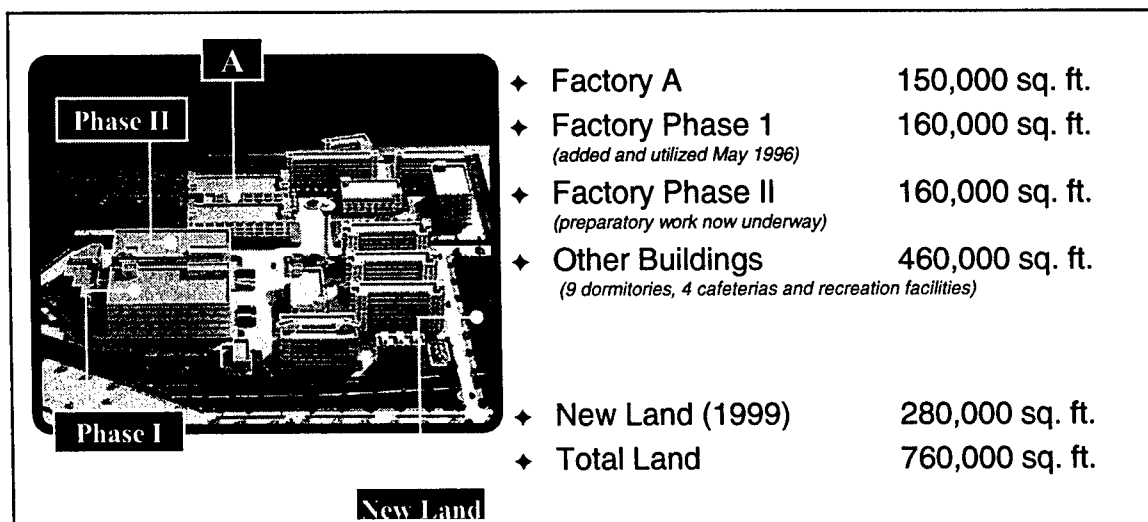
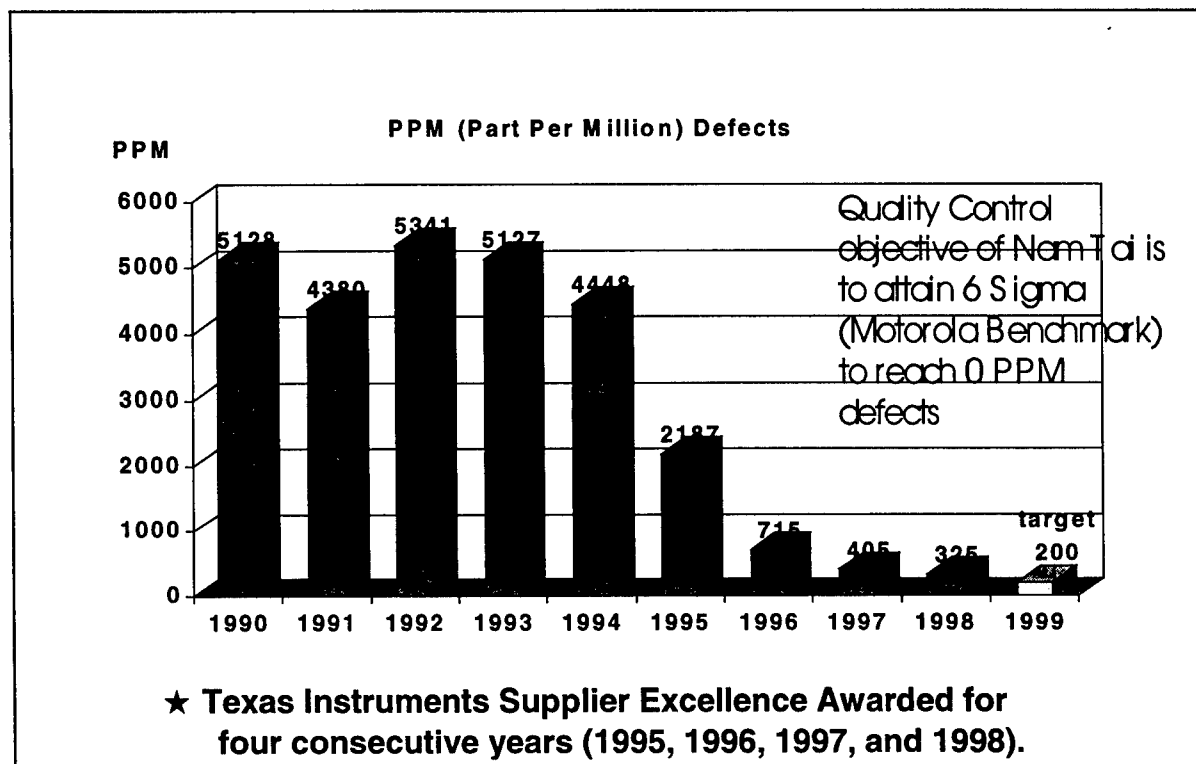
Nam Tai Electronics, Inc. developed advanced MP3 decoder technologies in its subsidiary companies, Shenzhen Namtek Co. Ltd. ("Namtek") and Zastron Plastic & Metal Products (Shenzhen) Ltd. ("Zastron"). The demo board will help Nam Tai demonstrate to its customers its ability to integrate MP3 technology. Eventually, Nam Tai would like to integrate MP3 functionality into a variety of hand-held electronic products for its customers including PDA's and Palm-sized PC's.

Namtek implemented the compression (encoder) and decompression (decoder) technology (specified in the ITU standard G.729A) on PC and NEC 32bit RISC CPU intended for speaking dictionary type products. Applications such as teleconferencing, visual telephony, voice over Internet, cellular phones and other wireless applications, where quality, delay, and bandwidth are important, will benefit immediately from this technology. G.729 is also used for speech recording applications such as digital speech recorder and telephone answering machine.

Zastron announced the successful development of three new technologies. First are electro-luminescent (EL) panels used as LCD backlighting for LCD modules, notebook computers, games, electronic dictionaries, LCD watches, and many other uses. Second, it has successfully developed a touch panel, which can be incorporated into PDA products, home appliances, and other products. Third is the development of double-edged flexible printed circuits: new precise wire products. These advanced technologies were developed as Zastron received requests from its customers to increase its emphasis on higher technology products.

Nam Tai acquired just under 50% of Red Net, a Silicon Valley Internet firm located in Shanghai. Red Net aims to make <http://www.echolaw.com> the largest legal affairs website in China, contributing to help build and strengthen the legal infrastructure and institutions in China. <http://www.echolaw.com> is currently

available in Chinese and English, with a Japanese version now under development. Nam Tai will develop hardware (PDA) products in the future for this business.



Namtai's New Factory/Facilities

Labor rates

The labor rate for operators is \$100 per month—approximately 10 percent more than other companies. Room and board is provided in the company dorms. There is a 2,000-hour limit (168 hours per month). In some cases workers have 4-hour on/off shift. Work is typically 5 to 6 days per week.

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Raymond Lai, Project Manager
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Introduction

Whitways is an OEM factory with no ODM work. It generates between \$2.5 and \$3 million per year in value added revenues. Whitways reputation is for QPS: namely Quality assurance, competitive Price and on-time delivery Services. The company is extremely flexible in attempting to get business in the 200,000 square foot factory. It is like a job shop. The motto for Whitways might be, "We can do anything." Products include the Talking Globe, remote control toys, laser pointers, and an electronic compass (see Appendix I for customer/product list). Pet products include electric pet controls (fence) and training devices. The company has B.A.B.T certified in telecommunications products for ISO9002.

Background

Whitways is a sole proprietorship. Mr. W.Y. Hui, the founder and owner, is from Hong Kong and was one of the early Fairchild employees. He likes challenges, and buys equipment needed to make a customer's products. The company started its operations in Hong Kong in 1978 as a manufacturer of toys and watches. In 1988 the company moved its manufacturing facilities to Dong Guan, China (20 miles from the border of Hong Kong). The cost of labor and rents were too high in Hong Kong. The strategy for China is to utilize US technology, improved QC, and lower labor costs. Salaries are only 10 to 15% of those in HK, around 500 RMB per month. The facility includes accommodations for customers and managers staying at the factory. Today, engineering, purchasing and warehousing are still carried out in Hong Kong. Whitways has opened a new marketing & sales office in Fremont, California.

Whitways has 900 employees, and hires about 10 university graduates per year for training. The company is building a dormitory for families. Employees have a 11 pm curfew. Employees with yellow badges are not allowed to take their badges out of the factory, since they get recruited for a 1000 RMB salary increase. Whitways has 5% employee turnover per year.

Operations

Whitways has 25 departments, including manufacturing, engineering, quality, production, metalworking, plastic injection molding, spray-painting, and silk screening (see Appendix II for an equipment list). The company assembles everything from dog doors and feeders to games, light sensors, laser pointers, and phones. Early customers include Commodore and Atari with joysticks. One of the main customers today is dialing machine assembly for Viking - a Swedish company. Whitways provides assembly service of a dialing machine to route calls. Until Philips started its own phone factory in Shenzhen two years ago, Whitways provided it with phone and answering machine assembly services.

Whitways has two warehouses in Hong Kong—one for finished goods, the other for raw materials. Material at the factory is caged for each customer. There is a large incoming inspection area both for quality and to check for the correct shipment quantity. QC is 100% on critical components. If a vendor fails inspection three times, they are replaced. Over time, suppliers' quality has improved significantly. All IC and valuable components are kept in safes to prevent employee theft. The factory receives daily deliveries from HK, holding only three days of inventory in the plant. For critical, high cost components, the stock is only 1-2 days.

Whitways sets up separate factory areas for each customer's assembly. The company has 5 SMT lines with Fuji CPIII and CPIV. The company has a Universal Instruments ominplace machine. There are hot air ovens and IR reflow (Vitronics). Single sided and double sided solder wave ovens are located in the facility. Whitways also has auto insertion equipment. The company had one job that required BGA placement and purchased an X-ray system for inspection.

The mold shop has 19 molding machines for plastic injection molding. This operation typically runs 7 days per week, 24 hours per day. A new 600-ton molding injection molding machine will be operational for the pet feeder.

The COB operation uses 8 ASM A1 ultrasonic wire bonders. Six are semiautomatic and two are automatic with up to 340 wires for LCD drivers used for a thermometer. COB assembly is for SIMMs and other products. There are no clean rooms and no facemasks worn by employees in the COB area.

Whitways has a IC programming area with many workers programming EEPROMs. Volume is 6,000 per day.

The PCB layout area features some of the latest computer systems. Software includes PROTEL and AUTOCAD. They do 100% in-circuit testing, and 100% functional testing.

Written by William R. Boulton and Jan Vardaman

Appendix I: Product and Customer List

Customer	Product(s)
ABB	Power Supplies
ACTIX SYSTEMS INC.	Graphics Cards
ADAPTEC	CD-ROM Drive Interfaces
ADVANCED DIGITAL INC.	Pentium Main boards
ALCOM COMMUNICATIONS LIMITED	Telephones
ASANTE TECHNOLOGIES, INC.	Ethernet Modem Cards
ATARI CORPORATION	520/ 1040 Computers
CAD CAM INDUSTRIES	900 MHz Cordless Phones
CASTLESPRINGS ENTERPRISES LIMITED	Educational Toys
CHAMPION CORPORATION	Sprinkler Systems
COMSET INTERNATIONAL INC.	Network Computers
DREAMLAND	Electric Blanket Controls
EASTEK INTERNATIONAL	Power Supplies & Electronic Directories
EDUCATIONAL INSIGHTS	Toys
EFTA CORP.	Electronic Games
FUTURE DOMAIN INC.	CD-ROM Drive Interfaces
GARRETT COMMUNICATIONS, INC.	Stackable Personal Hubs
HONKONY INTERNATIONAL LIMITED	Electronic Games
INNOVATIONS INTERNATIONAL LIMITED	Alkaline Battery Recharges
LANSTAR SEMICONDUCTOR INC.	SIMM Board
M TECH	Electronic Timers
MEGA TECHNICAL LIMITED	Personal Alarms
MICROMARK	Passive Infra-Red Sensor Alarms
NEWFORD COMPANY LIMITED	Personal Alarms
NIGHTHAWK INDUSTRIES INC.	Carbon Monoxide Detectors
NIXXO/ SHUM YIP	Pagers
PAGER REPAIRS	Cellular Batteries
PHILIPS COMMUNICATIONS SYSTEMS	Telephones & Answering Machines
PHILIPS LASER MAGNETIC SYSTEMS	Computer Cards
PRECISION NAVIGATION	Electronic Compasses
PROTON TECHNOLOGY CORP.	Power Supplies & Accessories Boards
RADIO SYSTEMS CORP.	Pet Control Devices
RIMCO RESOURCES INC.	Thermostats
SILICON VISION	Desktop Digital Camera
SHARPER IMAGE	Infra-Red Light Controls
STAR MULTIMEDIA	Wavetable Sound Cards
VIKING TELECOMMUNICATION	Automatic Line Switching Devices
More Products	Laser Pointers, Data Banks, Translators, French Tutor, Infra-Red Remote Controller, Joy pads, Arcade Style Joysticks and Ski Secure Alarms

Appendix II: Major Equipment for Full Turnkey Manufacturing

Descriptions	Make	Quantity
SMT Pick and Place Machine ☐	Fuji, Juki, Vitronics	10, 2, 6
Fine Pitch Placement System	Fuji	1
Hot-Air Reflow Oven	Fuji, Vitronics, Kince Worldwide	1, 1, 1
UV/IR Reflow Oven	Universal, Fuji	1, 2
Bonding Machine ☐	ASM	8
Wave-Soldering Machine ☐	Electrovert, Hollis	3, 2
Washing Machine	Electrovert	3
Auto-Insertion Machine (Axial) ☐	Dynapert	4
Auto-Insertion Machine (Radial) ☐	Universal	2
Component Sequencer ☐	Dynapert, Universal	1, 1
Ultrasonic Welding Machine	Branson	2
Pad Printing Machine		7
Ultrasonic Cleaner		3
End Coil Winders 4 Head Single		2
End Coil Winders 4 Head Multiple		4

Plastic Injection and Tooling Fabrication

Descriptions	Make	Quantity
Plastic Injection Machine ☐	Elite, Chun Hung	15, 4
Electric Discharge Machine ☐	Elite	4
Computing Numerical Controller	FV-900SE	2
Milling Machine	100L	10
Drilling Machine		9
Precision Surface Grinding Machine	KEN	2
Measuring Profile Projector	Fuji	1

Major Equipment for Testing

Descriptions	Make	Quantity
Burn-in Chamber	Allen-Bradley	4
In-Circuit Tester	Test Research, Inc., Jet	2
Shield Rooms (For RF Products)		5
Acoustic Telephone Tester	Microtronics	1
Audio Analyzer	Meguro	2
Spectrum Analyzer	HP	7
Oscilloscope		70
Frequency Counter		28
Telephone Analyzer		50
Signal Generator		31

Site: **The Legend Group**

Date Visited: 11 April 2000

Hosts: Chris Yang
Legend Computer Systems, Ltd.
Legend Science Park Sun
Huiyang GuangDong, P.R. China
yangxin@legend.com.cn
Tel: (0752) 3500450 (0752) 3500417

Garry Gao, Product Manager
Product Marketing Dept.
Legend Computer Systems, Ltd.
10/F Investment Bldg.,
4009 of Shen Nan Ave.
Fu Tian District, Shenzhen 518026 P.R. China
gaoyu@legend.com.cn
(755) 2712 288 (755) 2712 585

Wong Pui Ki, General Manager
Hui Yang Legend Computer Co., Ltd.
Legend Science Park
Sun City, Hui Yang, Guang Dong 516213 P.R. China
(86 752) 350 0250) huangpj@legend.com.cn

China can be roughly divided into five different regions centering around five major cities: the South (Guangzhou), the East (Shanghai), the North (Beijing), the Northeast (Shenyang), and the Central China (Chengdu). China's major domestic PC manufacturers are Legend Group, Great Wall Group, Tontru Group, Founder Group, and Stone Group. These groups cover almost all areas in China.

The Legend Group was established in 1984 by eleven research staff members from the Institute of Computing Technology, a branch of the Chinese Academy of Science [Zhang and Wang 1995]. By the end of 1999, Legend had set up local headquarters in Beijing, Shanghai, Shenzhen in Guangdong, Shenyang in Liaoning Xi'an in Shanxi, and Chengdu in Sichuan; over a hundred branches with over 8,000 employees around China; and twenty-one branches overseas.

Legend's major business areas include computer, system integration and network infrastructure, and software. Computers, including desktop personal computers, notebook computers, handheld computers, printers, and other computer peripherals, are the major products of Legend. In recent year, with the rapidly growing market of wireless communication systems in China, Legend began to expand its business into telecommunication area like cellular phone manufacture and communication network construction as well. Legend has formed partnerships with foreign companies to acquire advanced technologies. Major companies having partnership with Legend are Intel in the manufacture of microprocessors, IBM in system integration, HP in the design and manufacture of computers and printers, Toshiba in the manufacture of notebook computers, Sun Microsystems in the development of server systems, Motorola in cellular phone manufacture, and Siemens in PC manufacture.

Legend has been China's leading domestic information technology vendor since 1996. Legend started its PC manufacture with 2,000 units in 1990. Eight years later, it shipped out 790,000 PCs, and boosted the number to about 1.3 million in 1999 for the domestic market, with the share doubled to more than 20 percent in 1999 from about 10 percent in 1997 (Figure 1). To reach the goal to become one of the world's top 10 PC makers in 2000, Legend built a capacity to produce 1.5 million units annually. This capacity will reach 3 million in 2000 [China Daily News 1 June 1999]. Legend's total worldwide sales were \$2.12 billion in 1998. According to the 1999 top 100 electronics firms listed by China's Ministry of Information Industry (MII), Legend moved to the first place in 1999 (see Figures 2 and 3) from second place in 1998, surpassing Changhong, China's dominant TV supplier. According to Chuanzhi Liu, the group president, Legend's goal

is to achieve \$10 billion sales in 2004, the 20th anniversary of its founding, five time more than the 1998 sales figure [China Daily News 28 September 1999].

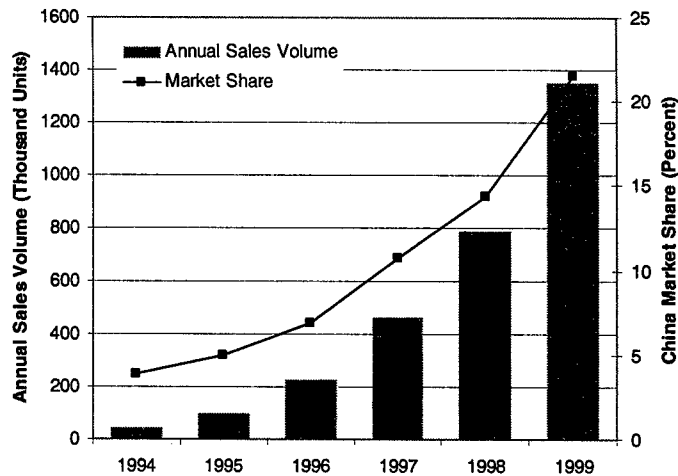


Figure 1. Personal computer annual sales of Legend Group since 1994. The ranking of Legend Group, according to market share, was the third in China for 1994 and 1995, and has become the first since 1996. [Legend, 2000]

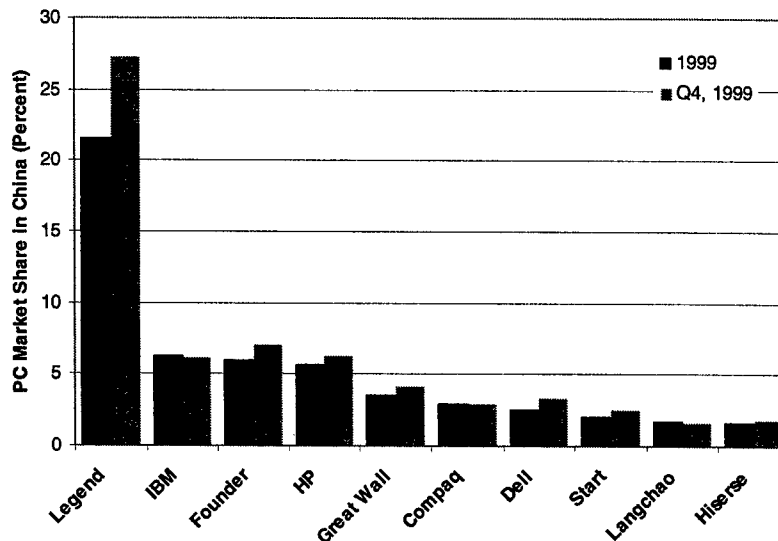


Figure 2. Top 10 vendors and their PC market share in China for the whole and the fourth quarter of 1999. The total sales volume of personal computers in China's market for 1999 was about 4.94 million units with 1.35 million units sold in the fourth quarter. [Legend, 2000]

In recent years, Legend has significantly strengthened its research team and expanded its research facilities to accelerate the process of acquiring cutting-edge computer technologies. In 1993, Legend became the first Chinese PC maker to open a design center in California's Silicon Valley [Dexter and Einhorn 1997]. In 1998, Legend established the Legend Central Institute with the Institute of Computing Technology of the Chinese Academy of Science for research on computer technologies. This institute is so far the largest company-owned institute focusing on product technologies in China [Legend Group News 1998].

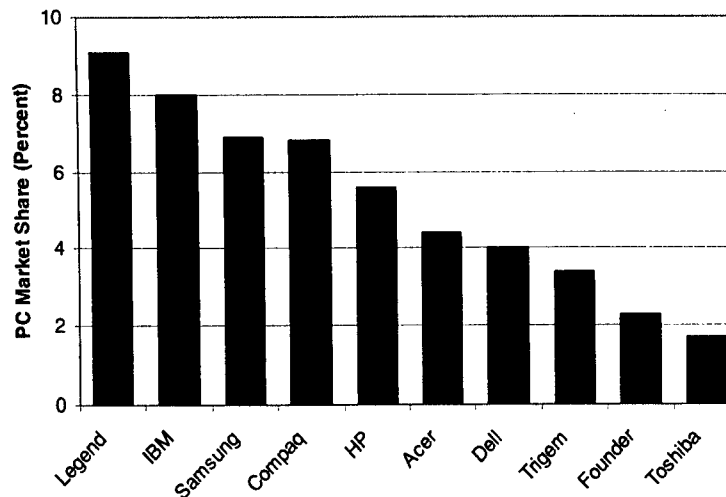


Figure 3. Top 10 vendors and their PC market share in Asia-Pacific region excluding Japan for the fourth quarter of 1999. The total sales volume of personal computers in the region for the period was about 4.06 million units. [Legend, 2000]

In component manufacturing, Legend has become an important supplier of PC motherboards worldwide. It exported motherboards to over forty countries, and its motherboard sales put the company in fifth place in the world in this market. To sharpen its competitive edge in the international market, Legend initiated a series of strategic mergers including the one with its state-of-the-art motherboard manufacturing facility, Quantum Design International Co. (QDI), in May of 1999 [China Daily News 1 May 1999].

Reference

China Daily News, "Legend initiates strategic merger," May 1, 1999.

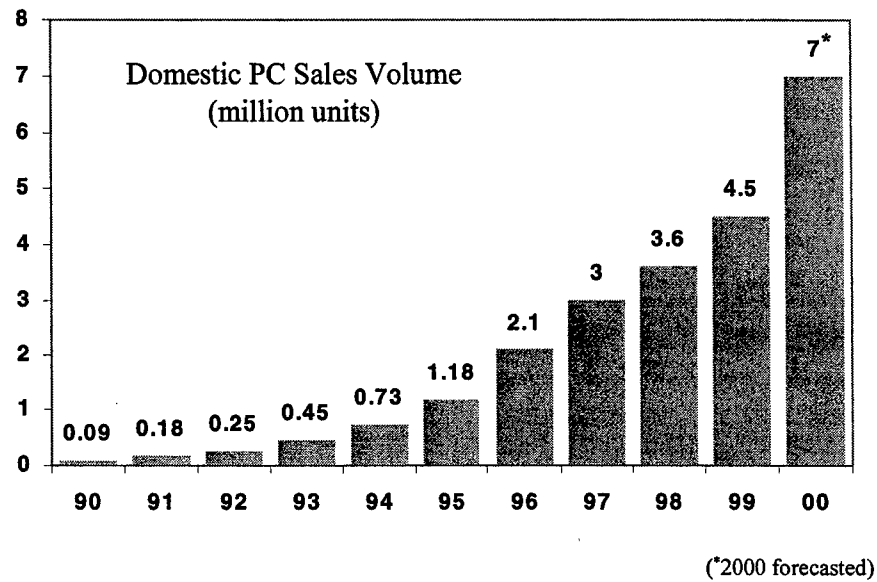
Dexter, R., and Einhorn, B., "Going Toe-to-Toe with Big Blue and Compaq," Business Week, April 14, 1997.

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Zhang, J.X., and Wang, Y., The Emerging Market of China's Computer industry, Greenwood Publishing Group, Westport, CT 1995

Profile of China's Computer Market

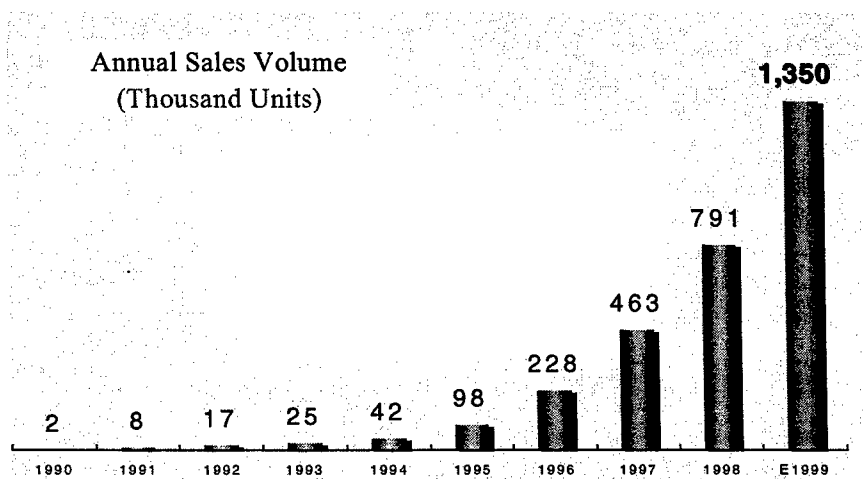


5

Site:

National Microanalysis Center

Legend Group



Source: IDC, Legend Research May 2000

8

**Fudan University
20 Handan Road
Shanghai 200433**

Date Visited: 12 April 2000

Host: Dr. Chang Xu
Postdoctoral Researcher
sauxchang@etang.com

Dr. Chang, who earned his Ph.D. at NMC in 1998, was our host. Prof. Wang Jiapi, who was to have been our host, was called to a meeting out of town. Dean Zong Xiang-Fu was unavailable to meet us. The NMC is now located in a new building that was occupied about 1997. Clean shoe-covers are the only specific provision aimed at maintaining clean-room conditions. The analytical capabilities and operating practices of the Center are similar to those reported from the 1996 site visit. NMC has continued to host periodic technical meetings of the Asia-Pacific Microanalysis Association.

Analytical Capabilities

Dr. Chang presented slides that described the Center's analytical capabilities and examples of complex projects undertaken in response to contracts from industry. The Center has a complete up-to-date complement of microanalysis equipment and capabilities, including:

- Electron microscopy
- Atomic force microscopy
- Secondary ion mass spectroscopy (SIMS)
- Auger spectroscopy
- X-ray analysis
- Chemical analysis
- De-layering of semiconductor devices
- Electrical analysis
- Device and integrated circuit analysis
- Failure analysis
- Reverse engineering of semiconductor products

The overall analytical capabilities of NMC appear to be comparable to those of very good laboratories in Japan and the United States.

Reverse Engineering

Government funding for fundamental studies is declining, while the volume and value of contract work for Chinese industry is increasing. Contract work includes failure analysis studies and reverse-engineering studies of processes and materials employed in semiconductor components such as nonvolatile "flash" memory chips. Dr. Chang showed us many microphotographs he had taken. Clearly he is very skilled in obtaining excellent results from the sophisticated analytical tools listed above. He will be reporting on some of his work in a paper accepted for presentation at an international meeting on microanalysis to be held at NIST in Washington in mid-June, 2000.

Dr. Chang is not involved in other work of NMC on sensors, displays, polymers, and organic materials, so we were unable to learn anything about those activities.

David A. Hodges, Joanne Maurice

Site: **Parlex (Shanghai) Circuit Co., Ltd.**
711 Yi Shan road, Shanghai 200233, China
Voice (86) 21-6436-3464, Ext. 25
Fax (86) 21-6470-2138

Date Visited: 12 April 2000

Hosts: Alan W. Wong, General Manager, email: awong@parlex.com
Stanley Gu, Operations Manager, email: sgu@parlex.com
Darrell Sen, Sales & Marketing Manager, email: dsen@parlex.com
Richard E. Martos, Engineering Manager, email: rmartos@parlex.com

Introduction

Parlex (Shanghai) is four years old, and has grown to 600 people. It plans to have 1000 employees by 2001. Sales in 1999 were \$67 million, and the company plans for \$100 million in 2000. The current facility is 50,000 sq. ft, but uses about 40,000 sq ft. A new 100,000 sq. ft. facility is being designed. Parlex Shanghai has no R&D. They had \$2 million in 1996 revenues, \$5 million in 1997, \$7.5 million in 1998, and \$15 million in 1999, with profits of \$2.5 million. They project revenues of \$25-30 million in 2000. About 70% is exported. They had 2 years tax free, and three years of 50% tax (7.5%). They are located in a high tech park, whose occupants pay a maximum tax of 15%. Parlex invested \$3 million in 2000.

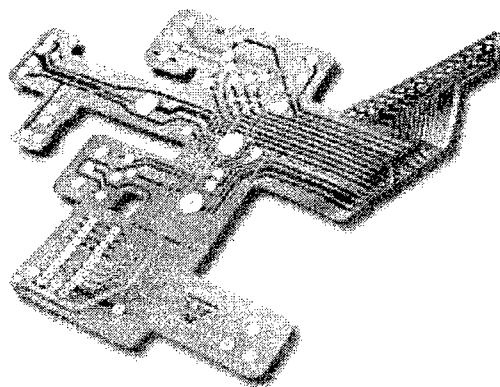
The Institute for Interconnecting and Packaging of Electronic Circuits

("IPC"), an international trade organization, estimates that worldwide sales of flexible circuits in 1999 exceeded \$2.5 billion. The IPC has reported that the flexible circuit industry in North American has grown at rates between 12% and 19% in each of the past three years. The principal competitors for flexible circuits are Sheldahl (automotive), AdFlex (telecommunications), M-Flex (computer) and Flex Circuits, Inc. (aerospace). For laminated cable, the principal competitors are Axon (a French company) and Fujikura Ltd. (a Japanese company). There are about 28 flex circuit firms currently in China with three more planning to enter. The flex circuit firm, World Circuits, was a JV failure in China. M-Flex is an aggressive competitor, but is small and independent. Sony Chemical is larger and has more technology, but is captive to Sony.

Parlex Corporation and Technology

Parlex Corporation is a world leader in the design and manufacture of flexible interconnect products. Parlex produces custom flexible circuits and laminated cables utilizing proprietary processes and patented technologies, which are designed to satisfy the unique requirements of, sophisticated electronics. The company's objective is to be the supplier of choice for key customers in markets where cost-effective flexible interconnects provide added value to the customers' products. Within its targeted market segments, the company believes that its ability to develop strategic customer relationships and provide a broad product offering serves as a competitive advantage. These relationships have enabled the company to work closely with its customers from the design phase through production to ensure that its customers' flexible interconnect requirements are met. In fiscal 1999, the company's top customers in terms of revenues were Nortel, Motorola, Amp, Raytheon, and Allied Signal.

Parlex Flex Circuits



Flexible circuits are lightweight and compact; fit easily into 3-dimensional packaging; offer improved thermal management; and can support high signal speeds. Parlex's flexible circuit products are utilized in applications for the automotive, telecommunications, computer, medical, industrial, consumer, and military-

aerospace industries. Some of these applications include: engine control units, cellular phones, networking systems, patient monitoring devices, postage meters, and navigational/flight controls.

Substrates can be categorized in terms of flex, rigid and flex-rigid boards, and whether the product is single sided, double sided or multi-layer. In general, the more complex, the higher the technology. The flex circuit is a mid-level technology, compared to most of today's rigid circuit card technologies. Nevertheless, flex circuit applications are growing, especially in the telecommunications industry.

Parlex History

Parlex is considered the "grandfather" of flex circuits. It has had some of the earliest patents and is the technical flex circuit leader with 25 patents. It was the first to produce double sided flex, multilayer flex, and high power flex systems. Parlex developed the PALFlex® adhesive less material for the manufacture of flexible circuits. In addition, Parlex developed and produced ultra-thin PALCore® rigid-flex circuits. Parlex has also patented a process to produce shielded impedance controlled circuitry for high-speed digital applications. Parlex future product development is in micro-vias. It is the third largest flex circuit company in the US, behind F-flex and Sheldaul. Many consider it to be the most profitable.

Parlex started on the US East Coast, with its main plant in Massachusetts. Parlex moved from being private in the 1970s, to public in the 1980s. Initially Parlex was a supplier to the US military, but transitioned to commercial products when military acquisition reform took place. As Japanese firms took over low-end business, Parlex began losing money in the late 1980s, forcing the company to shift to a competitive commercial focus and reduce costs. They focused on the auto industry with high quality requirements and moved to Shanghai. Its facilities are located in Methuen, Massachusetts; Salem, New Hampshire; Shanghai, China; and Empalme, Mexico (see Appendix I). Parlex has over 500,000 sq. ft. of factory space, produces FFC laminated cable, does assembly in Mexico, prototyping in California, and polyflex in the UK.

In 1995, the Company established Parlex (Shanghai) Circuit Co., Ltd. ("Parlex Shanghai"), a joint venture in China designed to serve the Asian market with flexible circuits as well as to produce certain products more cost-effectively for North

The company has opened an interconnect finishing facility in Empalme, Mexico, which began to ship product in fiscal year 1999. The company has also established logistic support capabilities in Singapore and France. In April of 1999 the company purchased Dynaflex, a division of Hadco Corporation. Dynaflex, strategically located in San Jose, California, which produces a full range of flexible circuits in limited quantities in order to meet the requirement for short lead times usually associated with prototype products. Today their customers include various automotive and telecommunications companies.

Types of Flexible Circuits Manufactured by Parlex. Parlex's capabilities include the manufacture of single-sided, double-sided, and multi-layer flexible circuits. Table 1 describes applications for the various circuits described below.

Single-Sided Flexible Circuit. A single-sided flexible circuit has an etched conductor pattern (usually copper) on one side of a dielectric base film. A dielectric covering, such as solder mask or cover layer, is usually applied to protect the conductors and to dictate component placement areas. Stiffeners or backers can also be added to create selective rigid sections.

Double-Sided Flexible Circuit. A double-sided flexible circuit has a single etched conductive pattern on two sides of a dielectric base film. Electrical conductivity from side to side is achieved through plated through holes. A dielectric covering, such as solder mask or cover layer, is usually applied to both sides to protect the conductors and to dictate component placement areas. Stiffeners or backers can also be added to create selective rigid sections.

Multi-Layer Flexible Circuit. A multi-layer flexible circuit is a combination of single- or double-sided flexible circuits laminated together and processed through drill and plating to form plated through holes that create conductive paths between the various layers. This technology allows for increased circuit densities and layer shielding that can provide highly reliable interconnect solutions.

Multi-Layer Rigid Flexible Circuit. Although it is similar to a multi-layer flexible circuit, a multi-layer rigid flexible circuit also utilizes rigid board inner-layers and / or outer-layers. This creates a multi-layer board, which is both a hardboard in the component mounting area and a flexible circuit in the bend sections. The technology enables a designer to create a single board that meets all of the interconnection requirements.

Table 1: Parlex Product Applications

Product	Applications
Flexible Circuits:	
Single-Sided	Automotive Displays Batteries for Cell Phones Printers Computer Networks
Double-Sided	Engine Controls Laptop Computers Cellular Phones Engine Sensors
Multilayer & Rigid-Flexible	Computer Networks Telecom Switching Systems Aircraft Displays Automotive Transmission Systems
Laminated Cables	Postage Meters Automotive Sound Systems Laptop Computers Industrial Controls Electronic Scales

Hybrid Flexible Circuit / Laminated Cable. A hybrid incorporates a flexible circuit with a laminated cable, which creates a cost-effective solution to many interconnect needs. Parallel conductor runs are manufactured from laminated cable, while variable pattern conductors at the termination ends are constructed from either a flexible circuit or a traditional rigid board.

Parlex Shanghai Joint Venture. In 1995, the company established a joint venture company in China, Parlex Shanghai, to manufacture and sell flexible circuits. The participants in Parlex Shanghai are the company (50.1% equity), Jin Ling, Inc., a Chinese company (40.0% equity), and Mascon, Inc., a Massachusetts-based international marketing and manufacturing company (9.9% equity). The company established Parlex Shanghai to better serve customers and potential customers that have manufacturing facilities in Asia and to more cost effectively manufacture certain products for worldwide distribution. In fiscal year 1999, 34% of Parlex Shanghai's products were sold to Chinese customers, 33% to other Asian customers, and 33% to North American customers.

The original joint venture partner was #20 Radio Factory. It produced single sided PCBs products. The Radio Factory obtained flex technology from Pentropix in a JV, but had not been able to get the factory operating. Jin Ling bought out the Radio Factory's 40% ownership in 1997. Jin Ling was a cooperative that was developed after the Cultural Revolution and had to compete to survive. It is a listed company. Parlex added about 50% of the equipment needed for final operation, and was making a profit within 4 months by

responding to customer needs. Parlex (Shanghai) developed a flex board for the VW Santana that generates nearly \$2 million in annual revenues.

Customers

Parlex is close to the auto customers in Asia, both VW in Shanghai and GM's Delco. GM produces the Buick Century in China with the first automatic transmission made in China. It sells for around \$40,000, but is newer technology than the VW. It is a good customer, and has local protection from the Shanghai government. Parlex can respond to these customers in 2 to 3 days. Parlex Shanghai value is focused on customer specific products. They do not develop high technology items, with 4x4 mil lines being their most sophisticated. PALFlex is Parlex's (US) roll-to-roll double-sided flex technology. This will be transferred to Shanghai for high volume applications.

JVs in China

- 1) JVs typically do not succeed in China. Chinese can't market or manage. There is also trouble fighting over who gets the profits.
- 2) What is necessary to succeed: The JVs must have controlling interest in order to have the incentive to transfer technology, and provide marketing expertise. They require good staff, customers, and a good partner.
- 3) Parlex example as a JV: The Radio Factory had good staff of which 60 out of 150 employees were selected for the new company. Parlex added the synergy needed for the business to take off. To attract and keep good employees, they offer relatively high salaries, 2-week vacations, and pay 1.5 times for overtime on Sunday, and 2 times for Holidays. They claim not to discriminate. Employees don't have to pay tax on income up to 1000 RMB and have low turnover. They also have the right to fire people.

In Shanghai, the Shanghai Instrument Bureau has JVs with over 100 firms.

State-owned Enterprises

SOEs will continue in oil, steel as state monopolies. They have had the resources to acquire the expertise, and are downsizing now. They still lack competition, but lack competitive advantage by not being able to trade freely. Other industries are increasing the number of private competitors. Shanghai now allows sole proprietorships that can form stock companies. This will be allowed in both Shanghai and Beijing. With WTO, China will have to open import/export regulations. In 1999, foreign trading companies are allowed to do business.

Business Environment

Shanghai is more open to foreigners, since it is a port. Beijing is known for its bureaucrats. Hong Kong is strong in procurement and marketing. The stock market is a source of capital. You buy it in China from Hong Kong companies. Hong Kong is behind in technology, since they do not have the best engineers. In Shanghai, the best students come from Fudan and JiaoTung University.

China's weakness is in information. The Yellow Pages reference is poor, and data is hard to get. It has poor labor markets, since classified ads are not well developed. Taiwan and HK are the information brokers and financial markets for China. They are much more sophisticated than China. Chinese markets are too risky, since there are no regulations.

Singapore has close relations with China. They have the same political style and managed market economy. Japan, Taiwan, and Singapore are looked at as the source of technology. Taiwan and Hong Kong are the leading investors in China. Japan is second, and the US is third. Chinese have a free spirit similar to Americans. They are more creative than other Asians.

Labor Costs

Labor costs about 40 RMB per day (\$5US) or \$100 per month for factory workers in Shanghai. The cost is about double that with burden: 32% tax to the government, 14% medical, 2% employee association, and 10% to 50% bonus. In China, there are 10 public holidays and a 5 workday week.

Value-added Taxes

The government doesn't worry about income taxes. For products that are to be made and sold within China, there is both an import tax and a value-added tax (VAT). The import tax ranges from 10-40% on materials. The tax is VAT of 17%. It is the main income for the government, and evasion of this tax can mean the death penalty. If a product is exported, then the import and VAT do not apply. Thus, if a Chinese company wants to purchase a Chinese made sub-product, the sub-product will be shipped to Hong Kong to avoid the taxes, and purchased from Hong Kong. In summary, most companies consider it generally better to import than to produce for the Chinese market.

Manufacturing Facilities

Parlex's manufacturing facilities are located in Methuen, Massachusetts; Salem, New Hampshire; San Jose, California, Shanghai, China; and Empalme, Sonora, Mexico. The company also has regional offices throughout the United States, as well as strategic alliances and logistic support centers in Europe, and Singapore.

Corporate Headquarters &
Flexible Circuit Products
Parlex Corporation
One Parlex Place
Methuen, MA 01844
Tel: (978) 685-4341
Fax: (978) 685-8809
E-Mail: flexcircuits@parlex.com

Capabilities:

Services: Design and Production

Products: Single-Sided Flexible Circuits, Double-Sided Flexible Circuits, Multi-Layer Flexible Circuits, Rigid-Flex, and Hybrid Assemblies

Technology: PALCoat[®], PALFlex[®], PALCore[®], PALCon[™], Polyamber, H S I +, White Immersion Tin

Area: 188,000 SF

Laminated Cable Products
Parlex Corporation
7 Industrial Way
Salem, NH 03079
Tel: (603) 893-0040
Fax: (603) 894-5684
E-Mail: lamcable@parlex.com

Capabilities:

Services: Design and Production

Products: Standard Jumpers, ZIF Jumpers, and Crimp Style Connectors

Technology: U-Flex[®], PALCon[™], Ultra Flex, High Density Cable, Hybrid Assemblies, Shielded Cable, Autoline Cable

Area: 46,000 SF

Parlex Corporation
1756 Junction Avenue
Suite D
San Jose, CA 95112
Tel: (408) 441-8713
Fax: (408) 441-8734
Email: dynaflex@parlex.com

Capabilities:

Flexible Circuit & Assembly, Quickturns

Products: Single-Sided Flex, Double-Sided Flex, Multi-Layer Flex, Rigid-Layer Flex

Technology: Polyamide, Polyester, Polyamber

Area: 19,000 SF

Parlex (Shanghai) Circuit Co., Ltd.
711 Yi Shan Road
Shanghai, People's Republic of China
Post Code 200233
Tel: 86-21-6408-2771
Fax: 86-21-6470-3128
E-Mail: pscc@parlex.com

Capabilities:

Services: Prototype, Production, and Low-Cost Turnkey Assemblies

Products: Single-Sided Flexible Circuits, Double-Sided Flexible Circuits

Technology: Polyamber, Polyamide, Polyester

Area: 35,000 SF

Mexico Operations
Parlex Corporation
Carretera International, Km. 1969
Guadalajara - Nogales Km. 2
Empalme, Sonora, Mexico
Tel: (52) 622-3-22-22
Fax: (52) 622-3-30-40
E-Mail: mailto:mexico@parlex.com

Capabilities:

Services: Circuit Finishing and Assembly, System Box Builds

Area: 16,000 SF

U.S. Regional Offices

Parlex offers its unique interconnect technology to the many electronics manufacturers in the western and southeastern regions of the United States through a customer support function located in close proximity to their operations. The presence of these offices is part of Parlex's strategic direction to provide the highest level of service in the flexible interconnects industry.

Western Regional Office
Parlex Corporation
1747 Crescent Knolls Glen
Escondido, CA 92092
Tel: (760) 480-0025
Fax: (760) 480-0068
E-Mail: mailto:west@parlex.com

Southeastern Regional Office
Parlex Corporation
900-B Hillsborough Road
Chapel Hill, NC 27516
Tel: (919) 968-4970
Fax: (919) 968-0129
E-Mail: southeast@parlex.com

Southwestern Regional Office
Parlex Corporation
6201 Snrrd Cove Road
#1535
Austin, TX 78744
Tel: (512) 325-8698
E-Mail: southwest@parlex.com

Strategic Alliances and Logistics Support Centers

Singapore

Parlex has a logistics support capability through YCH Group of Singapore. Customers are able to receive products within hours and Parlex and its customers monitor inventory levels electronically.

Europe

Parlex has established itself as a major supplier of flexible circuits and laminated cables for the European market. Parlex supports this effort through a logistical support capability similar to the Singapore model but located in Southern France. The company also works through a distributor in Germany and has created alliances with other interconnect companies in the region.

Written by William R. Boulton

Site: **Shanghai Huahong (Group) Co., Ltd.**
18/F Jiushi Renaissance Mansion
918 Huai Hai Zhong Rd.
Shanghai 200020, China

Date Visited: 13 April 2000

Host: Mr. Xia Zhongrui, President

Ms. Gao Huan, Interpreter

Several members of the management team were present who did not participate in our discussion. Professor Wang Jiaji of Fudan University, who also holds a technical management position with Huahong NEC, had arranged our visit. We met for one hour in a conference room in corporate headquarters. We had no opportunity to visit the Huahong NEC manufacturing facility.

Background

NEC is the second largest semiconductor vendor in the world (Table 1). The Huahong NEC facility is part of China's Project 909. The project was formally launched in Shanghai in July 1, 1996. The national budget for the project was approximately \$1.2 billion, with an emphasis on the enhancement and development of IC technology and industry in China. It consists mainly of two components:

1. Production of IC chips
2. Design and development of IC chips.

Shanghai Hua Hong and NEC established Shanghai Hua Hong NEC Electronics on July 17th 1997. With the completion of construction in February 1999, the facility is the most advanced semiconductor production site in China, utilizing a 0.35-micron design rule for fabrication of 8-inch wafers. Though its initial monthly production is approximately 5,000 wafers, it is expected to gradually expand to 20,000 wafers per month, and employ approximately 800 people in the year 2000.

Table 1

Top 10 Worldwide Semiconductor Vendors by Revenue Estimates (Millions of U.S. Dollars)

1998 Rank	1999 Rank	Company	1998 Revenue	1999 Revenue	1999 Market Share (%)	1998-1999 Growth (%)
1	1	Intel	22,784	25,810	16.1	13.3
2	2	NEC	8,227	9,216	5.8	12.0
4	3	Toshiba	5,913	7,594	4.7	28.4
6	4	Samsung	4,743	7,095	4.4	49.5
5	4	Texas Instruments	5,820	7,095	4.4	22.0
3	6	Motorola	7,088	6,425	4.0	-9.4
7	7	Hitachi	4,668	5,521	3.4	18.3
9	8	STMicroelectronics N.V.	4,199	5,080	3.2	21.0
8	9	Philips	4,448	5,065	3.2	13.9
10	10	Infineon	3,909	5,010	3.1	28.2
		Others	64,359	76,222	47.6	18.4
		Total Market	136,158	160,133	100.0	17.6

Source: Dataquest (January 2000)

Shanghai Hua Hong NEC, the show-piece of China's 909 project, will begin using licensed 0.35-micron technology and move to a 0.24-micron process for 128-Mbit DRAM production (Table 2). NEC is investing about \$200 million in the \$1.2 billion Shanghai Hua Hong NEC Electronics fab. Shanghai Hua Hong NEC Electronics is NEC's second wafer fabrication plant in China, and the company's fourth overseas wafer fabrication base. Shougang-NEC Electronics Co., Ltd., NEC's first wafer fabrication plant in China, was established in Beijing in December 1991. Shanghai Hua Hong NEC Electronics is NEC's 17th semiconductor manufacturing company, of which eight are located outside Japan. NEC employs about 5,000 people in

China at 14 different companies in the computer, telecommunications, and semiconductor fields, and says it is the largest employer among Japanese companies in China.

Shanghai Hua Hong NEC Electronics will produce 64Mb (megabit) dynamic random access memory (DRAM) devices as well as logic ICs (integrated circuits) aimed at the future for the custom market in China and the ASEAN region, with plans to eventually manufacture for world markets. NEC intends to utilize the plant not only to provide advanced semiconductor manufacturing support to the Chinese market but also as a strategic global manufacturing base supporting development of its global semiconductor business.

Outline of the new plant

Land area:	209,750 m ²
Floor space:	77,046 m ²
Products to be manufactured	64Mb DRAMs, logic ICs, among others
Production capacity:	Fabrication of 20,000 8-inch wafers per month

NEC also established an integrated circuit design company, Beijing Hua Hong NEC IC Design Co., Ltd. in June 1998. The design and sales company is a joint venture between NEC and Beijing Hua Hong Integrated Circuit Design Co. It is a subsidiary of Hua Hong Group. About \$30 million will be invested in the design and sales operation, and staffing will increase from about 120 in 1999 to 320 by 2003. It will design microcomputers, application-specific ICs, coder/decoders, IC cards, and systems on a chip for consumer products, mobile communications, and digital cameras.

Table 2: Outline of Shanghai Hua Hong NEC Electronics Co., Ltd.

Location:	No.1188 Chuanqiao Rd., Pudong, Shanghai, China	
Type of company:	Limited liability company	
Business:	Development, manufacture and marketing of semiconductor devices	
Capital:	US\$700 million	
Capital ratio:	Shanghai Hua Hong Group Co., Ltd.	US\$500 million (71.4%)
	NEC Corporation	US\$130 million (18.6%)
	NEC (China) Co., Ltd.	US\$70 million (10.0%)
Executives:	10 (7 from Shanghai Hua Hong, 3 from NEC)	
	Chairman:	Zhang Wenyi, Vice Chairman of the Board, Shanghai Hua Hong Group Co., Ltd.
	President	Toshihiko Kuniyoshi,
Employees:	1999	700 approximately
	End 2000	880 approximately

Key points

Hua Hong has established six subsidiaries (Appendix 1 describes the Hua Hong Group) covering the design, production and sales of integrated circuits. Its name has been changed from Shanghai Hua Hong Microelectronics Co., Ltd. into Shanghai Hua Hong (Group) Co., Ltd. The Huahong Group has controlling or major interests in three semiconductor manufacturers, ASMC, Belling, and Huahong NEC all in Shanghai.

The Shanghai Hua Hong Group's strategy is to combine the design, production, sales, and whole-unit application of integrated circuits to fully utilize the integral advantage of the 909 Project. The goal of Hua Hong Group is to build a market-oriented company based on its continuous upgrading production lines, its worldwide high-quality sales network, and its first-rate management team. Hua Hong Group will devote itself to the design, production, and sale of the integrated circuit and combines itself with the whole-unit development. Hua Hong Group will actively open up the overseas and domestic markets to make its contributions to the development of the semi-conductor industry in China.

Our discussion only focused on the Huahong NEC. Huahong NEC manufactures 8" wafers with 0.35 μm minimum feature size. The principal product is 64 MB synchronous dynamic random access memory (SDRAM). Production began in February 1999 and now has reached 10,000 wafers per month. At present, all output is shipped to NEC, in accord with NEC's contract with Huahong Group for this production facility. Huahong Group hopes to obtain from NEC some opportunity for marketing of these semiconductor products within China.

According to President Xia, existing production equipment has sufficient capacity to increase output to 20,000 wafers per month. This is the goal for production rate by the end of 2000. Future plans include a goal of offering foundry service for Chinese and export markets, and further development of Huahong Group's skills in new semiconductor product definition and design.

Written by David A. Hodges, Michael Pecht, Joanne Maurice, and William R. Boulton

Appendix 1: Shanghai Hua Hong (Group) Co., Ltd.

Shanghai Hua Hong (Group) Co. Ltd. (Hua Hong) has undertaken the largest project in the electronics industry of China, known as the 909 Project, with a total investment amounting to 10 billion RMB. Established on April 9, 1996, the company has a registered capital of 4.87 billion RMB. The Chairman of the Board is Hu Qili, Deputy Chairman of the Board, Chen Liangyu and Zhang WenYi, and President Xia Zhongrui.

Hua Hong is jointly funded by Chinese Electric Information Industry (Group) Co., Ltd., Shanghai Jiu Shi Co., Ltd., and Shanghai Meter and Electronics (Group) Co. Ltd. Based on the advanced technology and scientific management system, Hua Hong manufactures and sells high-quality Integrated Circuit products and other relevant products. Hua Hong also invests in relevant high-tech industries and in other industries, through which the company is rapidly expanding to be a large enterprise group, including designation, manufacture, and marketing in Chinese Microelectronics Industry.

Hua Hong has now developed seven subsidiaries since its establishment in 1996. They are: Shanghai Hua Hong NEC Electronics Co., Ltd. with a registered capital of 700 million RMB, which possesses the nation's most advanced 0.35 -- 0.5 micron integrated circuit production line; Shanghai Hong Ri International Electronics Co., Ltd., which undertakes the global sales network establishment of Hua Hong Group; Shanghai Hua Hong International (USA) Co., Ltd, which emphasizes its major task on the expansion of overseas market of Hua Hong Group; Beijing Hua Hong IC Design Co., Ltd and Shanghai Hua Hong IC Co., Ltd., whose major business is to design the Integrated Circuit, and to provide the processing order for Hua Hong NEC production line; Shanghai Hua Hong - Ji Tong Smart Card System Co., Ltd., whose main business scope is to design and develop IC card system; and Shanghai Belling Co., Ltd., a public company listed at Shanghai Stock Exchange, whose market value is over 9 billion RMB. Based on the seven subsidiaries, Hua Hong Group will unify the developing strategy within the group to improve the reasonable exchange of the essential manufacturing factors and the configuration of the resources so that the company may utilize its group advantages as well as its comprehensive functions to expand its domestic and overseas market share and to reach its business goal.

The goal of Hua Hong Group is to build a market-oriented company based on its continuous upgrading production lines, its worldwide high-quality sales network, and its first-rate management team. Hua Hong Group will devote itself to the design, production, and sale of the integrated circuit and combines itself with the whole-unit development. Hua Hong Group will actively open up the overseas and domestic markets to make its contributions to the development of the semi-conductor industry in China.

Shanghai Hua Hong NEC Electronics Co. Ltd. is jointly funded by Shanghai Hua Hong Microelectronics Co., Ltd. (Hua Hong) and Nippon Electronics Co., Ltd. (NEC). Hua Hong NEC was established on July 17, 1997, with a registered capital of 700 million USD and a sharing period of 20 years. Hua Hong NEC is located in 46 Block of Shanghai JinQiao Export Processing Region, with an area of 200 thousands square meters including 13 thousand square meters Clean Room. The scope of Hua Hong NEC's business is the manufacture and sales of Integrated Circuit productions. Integrated Circuit industry has become a basic industry of the nation with some strategic importance due to its enormous information, its rapid development,

and its strong infiltration. IC industry exists in all electronics system productions and is applied in almost all fields of the nation's economy. 65% of the increase in General Domestic Product (GDP) have relationship with IC industry. Hua Hong NEC is the core of the 909 Project, a significant project in the nation's semiconductor industry, builds a 8-inch wafer fab at 0.35 -- 0.5 μ m tech. level. The pre-estimated monthly product of the fab is 20 thousand wafer.

The major product of Hua Hong NEC is 64M DRAM, and other logical electronic products. DRAM is a kind of VLSI, in order to produce such productions, it may need hundreds of processes. Hua Hong NEC has applied many advanced techniques like double silicide; double metal; CMP and others new processes to manufacture such VLSI. Its products can be widely applied in computer, telecommunication system, IC card, and consumptive electronic device industries as memories or integrated circuits with logic capability.

Beijing Hua Hong IC Design Co., Ltd. is jointly funded by Shanghai Hua Hong Microelectronics Co., Ltd. and Beijing Electronic Information Industry (Group) Co., Ltd.. The company is one of the important undertakers of national electronic project, 909 Project, mainly dealing with the integrated circuit products design.

Beijing Hua Hong IC Design Co., Ltd. is founded on February 18, 1998 with a registered capital of 150 million RMB after the foundation of the largest micro-electronic enterprise, Shanghai Hua Hong Microelectronics Co., Ltd.

Based on the solid fund basis of Hua Hong Group, as well as the advantages in intelligence, technique, and market in Beijing, the company devotes itself to the designation, research, entrusted manufacture, and marketing of semi-conductor integrated circuit and other relevant products required by the customers. The company undertakes the entrusted designing work for computer IC, telecommunication IC, consumptive or special IC, and System level IC from both domestic and overseas customers. Through independent designation, cooperative designation, and entrusted designation, the company provides the 909 Project production line with chipset designation, and develops advanced information technology products and integrated circuit products with independent intellectual property.

With the scientific management style and modern operation system, Beijing Hua Hong IC Design Co., Ltd. exerts much attention on attracting more talents to build a keen and high efficient work force of management and technology. Over 80% of the company employees are IC designing experts or specialists.

In order to learn the advanced experiences in integrated circuit manufacture and management from developed countries, and to expand the overseas market, Beijing Hua Hong IC Design Co., Ltd. has shared the investment of 30 million USD with NEC to establish Beijing Hua Hong NEC IC Design Co., Ltd.

Emphasizing both the social and economic results as the principle, Beijing Hua Hong IC Design Co., Ltd. will continue to design, research, manufacture (by entrustment), and sell the advanced high-quality IC or relevant products by adopting the modern enterprise operation system and flexible talent-attraction strategy, and by the aids from all munificent policies issued from the government of Beijing and the country to the high-tech industry

Beijing Hua Hong IC Design Co., Ltd. will devote itself to serve the development of the electronic-information industry and the domestic economy of the nation with its first-rate talents, techniques, and services.

Shanghai Hua Hong IC Co., Ltd. is a research and design company for Integrated Circuit products, funded by Shanghai Hua Hong Microelectronic Co., Ltd., Shanghai Metallurgy Research Institute, and Fudan University. The registered capital of the company is 100 million RMB.

Shanghai Hua Hong IC Co., Ltd. is a large integrated circuit research and designing company in coordination of 909 Project's production line. Equipped with advanced ICCAD (Integrated Circuit Computer-Aided Designing) instruments, the company mainly deals with the researching and designing work for several advanced integrated circuit products including IC card chipset, chipset for tele-communication products, and MCU for consumptive products. With the integral advantage of Hua Hong Group, the company will devote itself to build a first-rate market-oriented integrated circuit products designing and research company in the

world, by fully utilizing the intellectual advantage from Shanghai Metallurgy Research Institute and Fudan University, and by actively seeking for its business partners.

Shanghai Hua Hong IC Co., Ltd. is another company independently designing and researching integrated circuit products besides Beijing Hua Hong IC Design Co., Ltd.. The establishment of the company has some significances to Hua Hong's market-oriented future growth coordinated with the development of the application of whole unit. IC designing serves as a bridge connecting the 2 large market, chipset and entire machine. Shanghai Hua Hong IC Co., Ltd. will continue to develop, by combining the manufacture, research, and academic knowledge together, to promote the industrialization of high-tech in Shanghai and the formation of information technology industrial chain.

Shanghai Hua Hong International (USA) Co., Ltd., a subsidiary of Shanghai Hua Hong (Group) Co., Ltd., was established on December 4, 1997 in the Silicon Valley, CA, USA, with a registered capital of 6 million USD. The Chairman of the board is Mr. Yang Guang, and the President and Chief Executive Officer, Mr. Lu Dechun.

The major business of Hua Hong International (USA) Co., Ltd. is to provide not only overseas processing order for the Integrated Circuit Production Line of Hua Hong Group, but market trends of international Integrated Circuit Technology, by fully utilizing the advantages of Silicon Valley.

Hua Hong International (USA) Co., Ltd. also participates some risk investment projects. In December 1997, the company shared 1.5 million USD to establish American New Wave Semiconductor Co., Ltd.

Shanghai Hong Ri International Electronics Co., Ltd. (Hong Ri) was established in coordination with one of the nation significant project, 909 Project. Hong Ri is a joint venture funded by Shanghai Hua Hong Microelectronics co., Ltd (Hua Hong) and Tomen Japan (Tomen), which undertakes the great task of obtaining wafer processing order for Hua Hong and expands both domestic and overseas markets for Hua Hong Products.

By fully utilizing Tomen's advantage in distribution network covering more than 100 main cities all over the world and its rich experiences in management of interflow of commodities, Hong Ri is trying its every effort to provide its customers with first-rate services. Since its establishment in August 1997, the turnover of Hong Ri has been ever increasing, which may lay a sound foundation for its further business expansion in coordination with the whole development strategy of Hua Hong. Hong Ri is able to provide customers with various of high-quality services including the settlement of accounts in RMB, for instance, the excellent quality assurance system, the timely logistic services, the overall supports in the fields of purchasing, designation, and development from Japan, and etc. The present major business of Hong Ri includes the import of integrated circuits, the import and domestic sales of other electric components and products, the supply of domestic sales network with design-in, the supply of semi-conductor components, quick delivery services, and etc. At the same time, Hong Ri provides relevant market information of the world with its advantageous sales network.

Hong Ri has established stable relationship with many famous domestic electronic manufacturers so far, and is going to exert more effort on further market expansion to realize its future long-term target. Shanghai Hua Hong -- Ji Tong Smart Card System Co., Ltd. (Hua Hong-Ji Tong) is established on the basis of Shanghai Ji Tong Smart Card System co., Ltd., funded by Shanghai Hua Hong (Group) Co., Ltd. Hua Hong -Ji Tong mainly deals with the research, designation, and manufacture of IC card system and IC reading devices. Since the later part of 1996, the company has successively finished several research projects like Non-contact IC Card POS Device, and Electronic Ticket System for Public Transportation. The company undertakes the whole developing and service work for the project of electronic ticket system for public transportation, which is the first to apply this advanced technique to the public transportation field. Nearly one thousand devices has been used on over 800 buses of 25 lines in Shanghai so far. The company is now designing the non-contact IC card POS Device for the public transportation service in Shunde, Guangdong, and Bei Hai, Guangxi.

Besides, the company undertakes the research, designing, and service work of Purchasing System for Friendship Shopping Center, IC Card Read System for Shanghai Refueling Station, Postal Service Green

Card for Shanghai Postal Service Bureau, and the IC Card System for Shanghai Niwota Chain Restaunt Co. Recently, the company has won the project of Non-contact IC Card Multi-functions System for Taiyuan Highway in Shanxi Province. The system is planned to start operation in May 1999. Furthermore, the company will expand its business to the high-intellective residence areas or buildings by popularizing the usage of IC card system.

On the basis of Hua Hong Group's comprehensive advantages, Shanghai Hua Hong - Ji Tong Smart Card System Co., Ltd. will further its business in the IC card system and IC card reading devices field according to the developing strategy of Hua Hong Group. By building the chain-services capability for IC card system, the company aims at the promotion in both social and economic results.

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Date Visited: 13 April 2000

Host: Teng Jing Xin, Chief Engineer

Huajing has a website, www.huajing.com.cn but it has had slow access. The company is switching from the Wuxi S&T Agency to the post office for better Internet support.

Background

China Huajing Electronics Group Corporation (Huajing) is one of the microelectronics industrial leaders in China specializing in R&D, volume production and sales and marketing of two major categories of products: integrated circuits and discrete components. Huajing has assets of around RMB3 billion (\$350 million). Huajing was founded in 1989 in a merger of the Ministry of Electronics Industry's Wuxi 24 Research Institute and Electric Factory 742. Huajing has been a targeted enterprise for government investment during the nation's sixth, seventh and eight five-year plans, and is listed as one of the 512 state-owned large or medium government enterprises with preferential support. Huajing was the leader in China in the production and technology of ICs. In the past four years, the industry has changed. The new Hua Hong NEC plant is now the benchmark in China.

Product-Market Focus

Huajing plans to focus on three areas: discrete, bipolar, and MOS products. Huajing develops and produces diversified products listed below:

- ICs and transistors
- Analog HF/UHF
- ASIC (full/semi custom), microwave, low-noise
- MPU & micro-controllers, high-voltage high-power
- Memories high-speed switching
- BiCMOS power MOS
- Thick-film hybrid

Huajing is the leader in China in discrete product variety and throughput. The company is planning heavy investment in this area to increase technology levels. Huajing plans to produce 0.4 micron lines by 2001. Keeping its leadership is the top priority. Huajing products have found extensive domestic applications in the consumer electronics sector (TV, telephone, audio entertainment system, energy saving lighting, clock and watch, toy, calculator and VCR, etc.), satellite & mobile communication, smart card assembly and electromechanical integration. Huajing sells DSP products for 32-bit switches and controllers to communications firms. They sell products for automobiles, telephones, TV, stereo systems, watches, calculators, and voice products.

Thanks to its long-standing quality assurance system, Huajing was registered with ISO9001 Quality Certification System and granted the certificate of qualified manufacturers in 1994.

Key Operations

The company includes an R&D center, three manufacturing plants (discrete, bipolar and MOS), five support facilities (mask making, silicon material preparation, tooling & machining, parts making and utilities), and two centers for technical support and information processing. It includes 5200 employees with 1200 engineers, 380 senior engineers, 39 professional senior engineers and 1 Academy of China engineer.

The central R&D lab is furnished with two state-of-the-art pilot lines and staffed with numerous engineering talents in different technical fields, devoted to microelectronics basic research, IC product designing and new process development.

The discrete plant has grown into a leading supplier of discrete components in China through its drastic innovation in the past four decades. Presently, it operates a high-volume line of Japanese origin at an annual production capacity of 150,000 3" and 10,000 4" wafers for wafer processing and 90 million packages for assembly, and accomplishes development and design finalization of at least 20 prototypes every year.

In analog bipolar products, Huajing has the best design capabilities in 1- to 1.5-micron products. The company plans to maintain this leadership. The bipolar plant, backed up by its 30 years experiences in linear IC fabrication, has increased its annual capacity to 180,000 4" and 20,000 5" wafers for wafer processing with 2~3 μ m technology and 70 million packages for assembly. It takes the leading position in China for its unique ANSA, PCT and multi-layer interconnection technologies, and its products available in the marketplace exceed 200 types.

As a key national construction project during the seventh and the eighth five-year-plan periods, the joint venture with TSMC of Taiwan provides a MOS plant capable of processing 120,000 5" wafers with 3 micron technology and 120,000 6" wafers with 0.6 micron technology and assembling 20 million packages each year. It obtained from Intel a certificate for its successful assembly and testing of Intel products in 1997.

The mask shop was built by DAW Technology of the United States and contains a clean room totaling 1,080m² rated up to class 10 in the process area and class 100 elsewhere. The entire clean room mechanism is fully computerized to accommodate high-precision mask making tools such as E-beam exposure, optical exposure and automatic reticle inspection & repair, etc. The mask shop produces 3,000 sets of working masks and 300 sets of masters every year.

The silicon material plant includes a complete line of modern equipment and advanced technology for monocrystal pulling (high, medium or low resistivity), ingot slicing, wafer grinding & polishing and epi-layer growing (high, medium or low resistivity) at an annual throughput of 6 tons of monocrystal ingots of diameters ranging from ϕ 2.5" to ϕ 5", 300,000 polished wafers and 200,000 epi wafers of 5" or 4".

The utilities plant distributes high-quality water, power, air, gas and air conditioning constantly and reliably to the R&D lab and all production sites.

The tooling, molding and machining plant and parts making plant are both primarily engaged in the manufacture of lead frames, lead frame stamping dies and plastic encapsulating dies used for a variety of ICs and transistors, and in the silver, tin or tin-lead alloy plating of diversified lead frames. Also, they assemble semiconductor manufacturing equipment and testing instrument and undertake equipment installation and maintenance.

The Huajing site covers an area of 360,000 m² in construction and 40,000 m² available for new production line set-up.

Technical Capabilities

Huajing has imported high-voltage power transistor technology, perfect crystal techniques, advanced nitride self-align techniques and 0.8 micron silicon-gate MOS technology on 6" wafers. In MOS, the company will have front-end foundry, and fabless design capability. It began with technology from Lucent, and created a JV with TSMC Corp. of Taiwan to build a MOS fab in 1998. It will be a large foundry for 6" wafers producing 20,000 wafers per month. It will product 0.6 to 0.8 micron line width, with plans to produce 0.5

micron in 2 years. The company established Semico, a design company, in early 2000. It includes test facilities and works closely with universities in Nanjing, Beijing, and a new technical university. It is looking for new partners.

Future Directions

Huajing is a state owned enterprise that is now moving to privatize. Government officials recognize the importance of the electronics industry and are planning new policies for development of this sector. The government plans to liberalize the sector in software and microelectronics. The government is deregulating SOEs. Many white papers have been written about this. They plan to exit some areas, and encourage foreign investment in others. Huajing is in the process of restructuring to implement its strategy. The attitude in the company is changing as management is putting each plant on its own, like a company. They expect that WTO rules will require such change for survival.

Huajing is advertising on its website for partners in the microelectronics business. Huajing seeks to enter into cooperation with companies in any mode, either cooperative production or joint ventures, allowing investment by cash or technology. They seek the transplant of existing 5" or 6" IC production lines as a means of cooperation with Huajing or build a new line on the reserved land within Huajing's compound. In their words, the mode of our anticipated cooperation is flexible.

China's Electronics Centers

China has three areas in which electronics is critical.

1. The Yangtze River Delta area has the concentration of semiconductor operations. The "Golden Triangle" is considered to include Nanjing, Wuxi, and Shanghai.
2. In the North, Beijing represents the second area with the Capital Steel-NEC joint venture. Key institutions include Beijing University, Tsinghua University, the Academy of Sciences Research Institute, CIDC, and Motorola Tianjin.
3. The Shenzhen/Canton area is newly recognized as a microelectronics/semiconductor area and is developing rapidly. It has a good business environment with open-door policies to foreign firms.
4. In western China, the Xian area is expected to become the fourth center of electronics. It has several famous universities and colleges with emphasis in electronics.

There are several different cultural areas in China. One is based on traditional Confucian philosophy that supports central control. This is strongest in Beijing. The coastal culture has been open to the outside world. The Hong Kong and Shenzhen area is most open and has a better understanding of foreign cultures and business practices. It is becoming the second "golden triangle". Shanghai is a coastal culture, but was also the center of the planned economy. As a result, Deng Zao Ping decided to begin opening China in the more southern area of Shenzhen. If it failed, it would not reflect badly on the central government since the south had a reputation of being independent. It had a good location and good resource base in Hong Kong.

Information is also an important part of electronics. As a result, universities are considered an important part of any electronics area. Shanghai, Beijing, and Xian have good universities. As a result, the industry developed first in Shanghai, then Beijing, and then Shenzhen. The Yangtze River Delta is the leader in production scale and technology. There are many new production facilities in the Pudong High Technology Zone. Many electronics firms are beginning to relocate their production facilities in this area. The Souchou Industrial Park is the assembly and design center. MOSEL from Taiwan is planning to build a new front-end wafer fab there. It will have a JV in R&D, and a wholly owned wafer fab. SG Thompson has delayed plans to put a fab in Hong Kong.

Huajing considers the 17% VAT tax to be a competitive disadvantage in the industry. Huajing is the fourth largest taxpayer in Wuxi. The government is considering reducing the VAT tax on IC products and software.

Written by William R. Boulton

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"In the process of a rapid development leading to the future society, microelectronics, with IC as its centerpiece, has penetrated into various fields of national economy and social life. It gradually changes the traditional style of life and way of thinking. Its great effect and impact can never be overestimated. Today's world has stepped into a new era in which electronic information and microelectronics form the core. ICs, especially ASICs along with IC fabrication, design and application, form the two wings for the take-off of microelectronics industry. As a key player in this field, CIDC is dedicated to the design of IC device in various fields and their applications.

"We are also active in the research of ICCAD tools and IC design methodology, which will help us support the technical improvement and product development for various industries, both domestically and abroad. High concentration of "Qualified Personnel", "Technical Expertise", and "Advanced Tools" is the pre-condition of our success. Protection of customer's interests, quick response to market demands and excellent service are what we have been struggling for.

Wang Qingsheng, Chair

Introduction

CIDC was founded in 1986. It is 100% state-owned, but aims to become a public limited liability company within a year. It is the leading Chinese-owned chip design firm and electronic design automation (EDA) provider. It has grown steadily and now has 180 employees, mostly degreed electronics and software professionals. Its main products are in three categories: integrated circuits, EDA software, and system products. In 1999, revenues were US \$6 million and are expected to increase to US \$10 million in 2000.

Integrated circuit products

CIDC defines, designs, and sells integrated circuits and PC cards, operating as a "fabless" semiconductor enterprise similar to many in the US. Manufacturing is contracted to foundries including Huajing, Chartered Semiconductor, Fujitsu, and Samsung. CIDC has capability for testing chips at wafer level and as finished products, using three modern mixed-signal testers purchased from Teradyne Corp. of the US. Further, CIDC provides application-specific integrated circuit (ASIC) design services to more than 60 clients in China. CIDC's capabilities include:

- Implementation by CIDC starting from high-level logic design to the supply of qualified IC products based on the functional description and specifications of the system provided by the customer.

- Logic verification, testability analysis and qualified final product by CIDC while system design and logic design by the customer.
- Configuration of the chip design, layout analysis and qualified IC product by CIDC while logic design and logic verification using CIDC's various ICCAD systems by the customer themselves.
- Designing at CIDC by the customer, CIDC is responsible for testability analysis, layout design and PG-tape supply.
- Implementation of all the design process by the customer alone by using CIDC's various ICCAD systems and database until PG-tape acquisition.
- PCB schematics or sample chips and their application specifications concerned by customer only, CIDC completes logic optimization and verification, layout design and final IC products that meet the requirement.
- PCB schematics or sample chips and their application specifications concerned by customer only, CIDC responsible for logic optimization and verification and providing EPLD/FPGA samples and/or ASIC products.

Electronic design automation products

In the 1980s, US export restrictions prevented CIDC from purchasing Electronic Design Automation (EDA) software from US firms. Therefore CIDC independently developed and has continued to improve the "Panda" EDA software package. Panda now provides much of the capability of EDA software sold by Cadence Design Systems. There are 30 customers in China and about 10 outside China, including Japanese and US firms that use Panda. Panda lacks important features found in US products such as logic synthesis. However, advantages include pricing (1/3 that of Cadence's product), flexibility for customization, local support (in China), and an available version for the Linux operating system.

US export restrictions eventually were relaxed. Subsequently, CIDC purchased or leased EDA software from Synopsis, Cadence Design, Mentor Graphics, and Avant! to obtain features beyond those of Panda and to assure compatibility with CIDC customer designs. CIDC spent US \$2 million acquiring EDA software, mostly from US firms, in 1999. Current capabilities include:

- Full-custom software development for Electronic Design Automation (EDA)
- System design, consulting and implementation on EDA
- Technical cooperation with companies domestically and abroad, engaging in software development and distribution
- Development of software application on various software and hardware platforms and system integration
- Providing software training services on EDA

CIDC founded Beijing Benda Information Engineering Company (Benda) in 1992 to develop its proprietary EDA system. In November 1997 it released the Zeni EDA system. In Nov 1998, Zeni V2.0A was released (see Appendix 1 for details).

Electronic System Engineering Development

In the past few years, CIDC has begun to develop complete consumer electronic products such as television set-top boxes for cable and satellite, and MP3 players for digital music. Products are aimed at both Chinese and world markets. They are marketed and distributed by other firms. CIDC has begun development of

chips for CDMA cell phones, in anticipation of future introduction of CDMA service in China. CDMA cell phones could become future products of CIDC.

Telecommunication related systems include CDMA Wireless Local Loop, PABX and boards of computerized communication systems.

- Control system design (mainly micro controller)
- Intelligent instrument design
- Logic design for user's system integration
- Development of consumer product
- Consultations services in design methods for technical enhancement
- Domestic and international projects for electronic devices and system engineering

Gold-Card Project

CIDC developed the Smart card IC, IC card and IC card application series:

- BIGS series IC card reader and writer for general purpose
- Multi-functional IC card management systems include:
 - attendance management system
 - book service system
 - precharged system
 - medical care system
- Toll collection system
- Pre-charged systems on household electricity, water and gas consumptions
- Other variety of IC card applications

The smart card has been delayed, but is still in the Government's plan. There are concerns for security and the cost of implementation. Some 100 million cards were in use in 1999, with 200 million cards expected for 2000. In Beijing, drivers must carry smart cards to register fines and keep records. It can be used for bank ATMs. The card companies are pushing this. Beginning in April 2000, people must use their own names for bank accounts in an effort to stop graft. The smart cards are supposed to ensure this, but people can still buy counterfeits.

CIDC pioneers the high level IC testing capability in CHINA

- The most advanced Teradyne (USA) A580 Mixed Signal Test System.
- Complete set of Logic Master XL60 High Performance Test Station with mixed signal test solution made by IMS (USA) is the most complete set in China today.
- EG2001CX Wafer Prober produced by Electroglas Co. (USA) in the overhead connection with the A580 test head ensuring a high speed and precise wafer testing.
- TSSI's TDS software system makes design-to-test linking an easy thing and conversions between the current world EDA tools and ATE available, enabling speedy and complete testing programs and test pattern generation.
- A team of IC test engineers with years' experience in testing technology and special training abroad.

Opportunities and limitations

Electronics markets are growing rapidly in China. CIDC believes it has the opportunity to double its revenues each year. To do so will require rapid growth of staffing, additional capital, and more flexibility in professional compensation. Because CIDC now is a state-owned enterprise, staff salaries are fixed substantially lower than those offered by foreign competitors such as Intel and Motorola operating in China. (At the current exchange rate, CIDC salaries are about 1/8 of those prevailing in the US.) Thus CIDC cannot hire and retain enough highly qualified engineers to meet growth needs. Transformation to a limited liability public corporation is seen as the action required to provide the capital and operational flexibility needed for rapid growth.

Chinese firms are trying to do everything. Big companies are spinning off weak operations. New high-tech products that are registered with the government get preferential treatment. They must renew their registration each year and can get lower tax rates for three years.

Product Distributor

CIDC is trade representative of such semiconductor companies as Fujitsu as:

- ASIC Design Agent
- Micro controller IC Agent
- Various memory circuits
- Other ICs

Being the number one fabless design house in China, CIDC is the only enterprise with integration of ICCAD tool development, IC design and entrusted fabrication capability that forms the profile and superiority of its business.

The smoothly running foundry partners from the United States, Japan, Singapore, Hong Kong and Taiwan ensured qualified products.

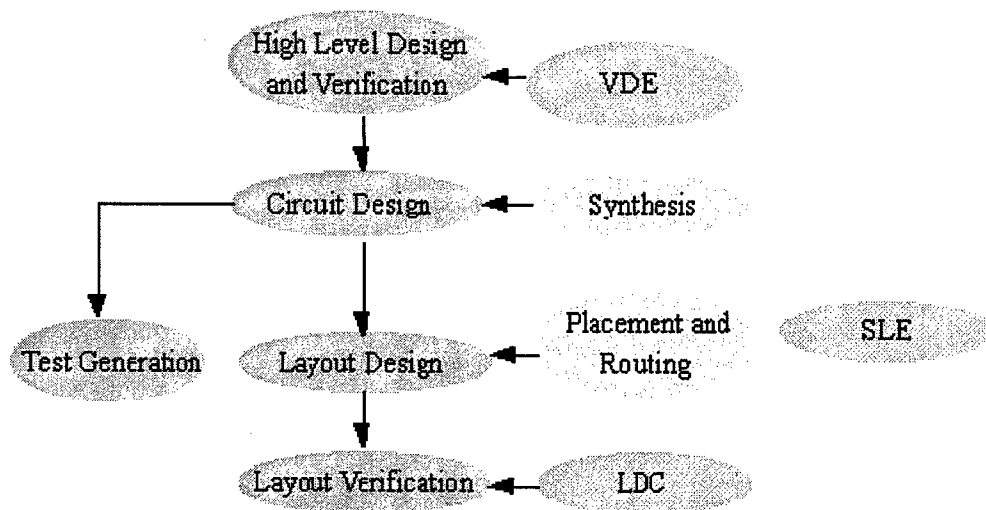
The dedicated engineers and the most sophisticated design environment are the promise of the most excellent EDA tool development and the most efficient IC design.

Written by David A. Hodges, William Boulton, Michael Pecht, Joanne Maurice

Appendix 1: Beijing Benda Information Engineering Company

Beijing Benda Information Engineering Company (Benda) was founded in 1992 by the leading IC industry enterprise China IC Design Center. Benda has been developing our proprietary EDA system. In November 1997, she released Zeni EDA system. In Nov 1998, V2.0A of Zeni was released.

The Zeni is a VLSI CAD system, which provides a series excellent tools for design engineers, including high-level design and verification tools, layout editor and verification tools, etc.



ZeniVDE: based on graphical entry interface, enables designers to realize their design idea without sacrifice of the versatility of HDL description. PandaVDE also contains functions as compiler and simulator for VHDL/Verilog design means. The tight combination of compiler and simulator tools can create an environment that makes design modulation an easy play.

ZeniSLE: an interactive IC layout editor, supports full hierarchical, multi-view/cell editing and is able to handle layouts with millions of elements.

ZeniLDC: a layout verification tool that handles designs with over 10 million elements, includes physical design rule checking (DRC), netlist extraction (NE), electrical rule checking (ERC) and layout versus schematic comparing (LVS) functions.

Site: **Ministry of Information Industry**
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Date Visited: 14 April 200

Hosts: Zhu Chongjin, Director, First Division of International Cooperation
email: hezuoyichu@mii.gov.cn
Xun Xiangyun, First Division of International Cooperation
Xhou Dai Qun, Director, Broadcasting & TV Division, Dept. of Electronics & IT Products

Professor Zhou described the status of the electronics industry. While many numbers were presented, no printed material was provided. The following numbers could be in error since they were communicated verbally in translation.

Introduction

The Chinese government realizes that IT is a pillar industry and should lead the country's development. It sees the combination of industrialization and "informization." The development challenge is in building the needed infrastructure, which is not yet developed. The IT and Internet capabilities are still weak. Phone penetration in the 1980s was only 0.43%, and reached 1.1% penetration in 1990. In 1999, it reached 13%. This compares to 80-90% for developed countries. With 1.3 billion people, the goal is to reach 60% penetration. The telecom infrastructure is also a challenge for Chinese manufacturing firms. It restricts the informization of older industries.

MII

The Ministries of Electronics and of Posts and Telecommunications have been merged into MII. There is now one minister, but the merging is underway. Primary focus is on manufacturing sectors. MII covers products like computers, software, broadcasting and home electronics, IC components, and equipment.

IT is the fastest growing area with 20-30%/year increases per year. In 1999, IT reached a milestone by becoming the most important segment in China. Internet surfers reached 8.9 million in 1999. There were 4 million PCs sold. SINA.com was just listed on the NASDAQ.

Electronics Industry

Electronic manufacturing is leading China's development. About 90% of electronic output comes from 11 of China's 31 provinces, including Taiwan. There was over 20 billion RMB in sales. The leading 100 companies provide 42% of the output.

In the 1980s, consumer products accounted for 70-80% of electronics sales. In 1990s, this has fallen to 28%, with investment products accounting for 41.8% and components accounting for 30.1%. Consumer products include cameras, recorders and players for DVD and VCD, and A/V equipment for home electronics. Investment products include computers and telecommunications products, workstations, and mainframes. Components include IC, manufacturing equipment, and instruments. Non-consumer areas are growing at over 30% per year.

Electronics manufacturing has changed from a quantity to quality focused in output, from analog to digital products, and to more advanced products and infrastructure. Since China is lacking world-class infrastructure in many areas, it can start from white paper planning, and can jump to next generation technologies. For example, the ATM transmission protocol will be the standard for China.

The IT industry structure is changing as more private enterprises enter rapidly and drive advancements. Products that cost \$1000 five years ago cost 1000 RMB today. Telephones are a key product, with over 38.5 million lines installed, up 99% over 1998. Cell phone production of mobile phones was 23 million, up 102%

over 1998. Sales were 19.2 million, up 37%. Exports were 7.9 million units, up 137.6%. GMS 900 and 1800 are the standard. Some people have 3-4 phones with different colors and styles.

PC production reached 3.97 million units in 1999, with sales of 3.2 million. Consumer products, like VCD and DVD players produced 10.2 million units (DVD products were 2 million units, up from 300,000 units in 1998) with 50% exported.

China is weak in IC and software development. The government is focusing on this area and plans to provide preferential policies for IC and software segments. It is expected that the VAT tax will be reduced to make it more competitive with imports. The PC industry is already competitive and doesn't need any special support.

Written by William R. Boulton

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Presentation

Professor Wu is director of the National CIMS Engineering Research Center, and chief scientist for the National High Tech Program for Automation Technology. He is also a member of the Chinese Academy of Engineering.

1. Much of the CIMS research is funded through the National 863 High Tech Program, which was initiated in 1986. It involves over 3000 researchers, 650 research projects, and 250 company applications. There are seven engineering labs involved in CIMS programs (including Beijing, Shanghai, Nanjing, Xian, Shengyang). There are 10 training centers. CIMSNET was developed to aid in interactive design and manufacturing activities that occur in different cities/locations. More than 200 firms have used it.
2. Systems and Information Technology is another focus. They have used a variety of modeling and design tools, MRPII, CRM, and tools to support implementation of IT networks. These tools have been applied to a number of corporations to achieve significant improvements in, for example (one company):
 - Reduction of product development times (18 to 10 months)
 - Quality problems (reduced 80%)
 - Delivery times (reduced 40%)
 - Reduced capital needs (50%)
 - Lower operating costs (doubled productivity)
 - Improved sales
 - Improved profits

The application of CIMS projects for firms is sponsored 10% by government and 90% by companies. The Ministry of Science and Technology and local governments provide support.

3. Process reengineering and optimization activities include design for manufacturing, design for cost and quality, design for assembly, design for virtual manufacturing, and integration of JIT and MRP systems with feedback. Optimization teams have been used in different application projects. Aviation, space, and other industrial organizations have been using concurrent engineering.
4. Agile manufacturing is a project to improve Time, Quality, Cost, and Service levels (see Appendix I). Agile manufacturing will be based on the use of IT (CIMSNET) and management technologies to allow for virtual engineering by using the Internet. They have used simulation and plan to use virtual reality to design advanced manufacturing and automation systems.
5. Over the next 10 years, there will be increasing emphasis on new management concepts and technologies. Management is important, and reengineering through e-logistics and e-commerce. Tsinghua has five pilot projects in this area. Universities are expected to spin off companies to

support such activities. Professors are being encouraged to open companies. Consulting is just starting in China. The government wants to encourage increased entrepreneurship.

6. The Agile Supply Chain Management System is another project supported by the 863 Program to improve costs and delivery times (see Appendix II). It is one of the National Hi-Tech Key Projects focused on collaboration, cooperation, and coordination of supply chain interactions. Three companies are prototypes for object-based simulations in building materials, costume, and electronic businesses. The real challenge for the future is in responding to the lack of information, coordination, and collaboration. Chinese firms have too small a scale and are lagging in MIS capabilities. There is need for global alliances to improve speed. B2B is a key emphasis.
7. Management is a problem. Shenzhen and Shanghai have good management systems. Shanghai has a better commercial culture for improvements. They are creating famous brands and developing strategies of international cooperation. North China and West China have most state-owned enterprises (SOEs). They need a new model to survive. They must change their product line structures and use the Internet to facilitate design and sales activities. The Internet is currently weak in China, but is growing very rapidly and is the key to company survival.

The west (Xi'an and Chongqing, Chengdau) will be the next government priority for development. The government will encourage JV. Local leaders understand the need for outside help and resources.

Written by William R. Boulton

Appendix I: Background of the Concept of Agile Manufacturing

As human beings are striding into 21st century, we are faced with a more fiercely competitive and living environment. The ever-flooding emergence of new knowledge and concept, the fast changing of new products and techniques accelerate the changing process of market. Here the competition-environment-changes include market requirement changing, deploy technology changing, competitor's situation changing and organization management changing; while the respected adjustments are composed of competition strategy adjustment, organization structure adjustment, production process adjustment and supply/distributor relationship adjustment etc. All enterprises have been met ever-tougher challenge due to the quick changing international competition environment since 1990. The most significant characteristic of this challenge is

"the changing speed of the competition environment is too fast that our own adjustment could not keep up".

The ever fast, persistent and non-predictable changing of competition environment puts new demands on the enterprises' management and product development process. To grasp chances and win, enterprises should possess the ability of quick response to changes, and the ability of exploiting and guiding markets through new technologies and new products.

The concept of Agile Manufacturing was put forward just in conformance with this new kind of competitive environment in 1991 by American government-sponsored research effort at Lehigh University. The CTPID's new project, sponsored by the Advanced Research Project Agency and the U.S. Air Force, and in partnership with Lehigh, aims to "put meat on the bones" of the Agile concept articulated at Lehigh.

In the business world, to be "agile" is to master change and uncertainty and to integrate a business' employees and information tools in all aspects of production. For the consumer, agility translates as customer enrichment. The goal of an agile manufacturer is to present a solution to its customer's needs -- and not just a product. A producer does this by learning what a consumer needs now and will need in the future.

For businesses, agility translates as cooperation that enhances competitiveness. An agile community crosses company borders and works together. A company that can best perform a particular business function shares that knowledge with the other companies in the industry.

Key Problems of Agile Manufacturing

Before 1970's, the lifecycle of a product was long, techniques of developing it is comparatively simple. When a new product went to the market, other factory might create products with the same functions of it soon later. Therefore, the competition was mainly around how to enhancing productivity of labor, so large-scale fixed production lines emerged at that time. This kind of lines were based on the standardization of parts and normalization of processes, and utilizing the Management Theory of Taylor to restrain workers to do simple and efficient operations, in such a way the productivity was lift up greatly. In midst and lateness of 1970's, and 1980's, along with the fast progress of techniques and people's need for personalized products, the forms of production were gradually transmitted into multi-variety and small-batch. The competition in market cried for flexibility and cost reduction in production and the need was endowed with more new content as the time went on.

In 1990's, the processes of technology progress and product evolution were speeded up more and more. The product lifecycle was reduced further. The competition was largely around development of new product. The law of value tells us that the price of a new product is always higher than its value. So only developing new product that is unique and needed in the market, can an enterprises profit from it. This reflects the basic characteristic of the competition of this time: the competition of unique technologies.

The nature of information era is the creation, transmission, and application of knowledge. Seizing the chance of market and applying the potential technologies to promote new products have become the main means of winning.

Due to continued competition, the lifecycle of a product is shorter and shorter, the manufacturing technique is more and more complex, and the production batches are smaller and smaller. So former fixed production lines for large-scale fabrications are not qualified for this environment. Environment compels enterprises to change the mode of its fixed lines into agile modes, to reengineer its organization, in order to response the market quickly and produce products users needed. Along with the progress of information technology, quick response can be implemented through cooperation with other factories on the Internet/Extranet, from multi-function developing group to virtual enterprises.

Agility Research in Shanghai, China

The Agility concept was first introduced into China by the SSTCC (State Science & Technology Commission of China) in 1992. After that, agility study in China has been mainly pushed forward by the CIMS expert group and the Chinese National Science Foundation. It is now one of the most important areas in the advanced manufacturing technology related research and application.

Although AGILITY is a new concept to most of the Chinese enterprises, its basic philosophy and methodology has been widely accepted. In fact, many Chinese enterprises are practicing that with/without intention and benefit from that.

Start in 1994, we have conducted a series survey on best agile practice on variety Chinese enterprises. After a survey conducted on different enterprises, we found that many of those enterprises, especially those who did well in today's competition environment, have some agility practice underway. Following is two examples in Shanghai:

Shanghai Artificial Joint Replacement Center:

This center focuses on human body joint replacement. The traditional method is for each patient, selecting a best available joint to do the replacement. Since every patient is different, this method has many problems. As medical technology, computer technology and advanced manufacturing technology merging together, there is a possibility that we could quickly manufacture a specialized joint for each patient without greatly increases the cost. That is the goal of this center when it is founded. This center located in Shanghai Jiao Tong University. Using SHENET and SHRNET, this center is directly connected to 3 major local hospitals and 7 manufacturing plants with CNC machines and different RP machines. This is a loosely associated, contract-based corporation. When there is case, (it could be started either by the center or by one of the hospitals) the center will contact other partner to form a virtual organization. CT image scanned at a hospital

will transmit to the center directly, where a solid model is rendered from the scanned CT images. Though video telecommunication the model is being discussed and refined. After the model has confirmed, it is send to a RP machine for making a quick prototype or to a CNC machine directly to make a metal joint. When the joint placement is over, the center also serves as a recovery center. All the patients are closely monitored so that later design could be adjusted from those previously collected data.

This is an excellent example of virtual organization. It is also a good way to connecting academic and enterprises to speed up technology transfer between universities to industry.

They cannot get enough contracts. The success of CAC pointed them a way to improve that.

Shanghai Yadie Fashions Co. Ltd.

Shanghai Yadie Fashions Co., Ltd. (SHYF), jointly founded by Shanghai Yadie and Wacoal Japan in 1992, is a small apparel manufacturer in Shanghai. Although it is a small labor intensive sewing manufacturer, and does not have fascinated computer and NC machines to facilitate the manufacturing process, it also find its way to approach agile by using available computer and communication technology. Instead of using federal express and airplane to send working orders and working samples as it has been doing for 4 years, SHYF recently jointed MATIC project. By implementing MATIC project, it will be able to receive its working order as well as all technical documents required to produce new fashions from Wacoal via computer network. With an automatic translator and SGML editor, it will quickly translate all the technical documents into Chinese and edit them for production use. With this, it can shorten a new product's lead-time by 30%-40% almost no extra cost.

This example shows us that agility itself does not require big investment, nor really high technology. This example also suggests that build up a good nation-wide information infrastructure could greatly help many Chinese enterprises to enter the world market.

Appendix II: Virtual Enterprises and Agile Supply Chain Management

All enterprises have been met ever-tougher challenge due to the quick changing international competition environment since 1990. The most significant characteristic of this challenge is "the changing speed of the competition environment is too fast that our own adjustment could not keep up". Here the competition environment changes include market requirement changing, deploy technology changing, competitor's situation changing and organization management changing; while the own adjustments are composed of competition strategy adjustment, organization structure adjustment, production process adjustment and supply/distributor relationship adjustment etc.

The ever fast, persistent and non-predictable changing of competition environment puts new demands on the enterprises' management and product development process. On one hand, the quick decision-making and faster turn over time asking; downsizing; while on the other hand, an enterprise got to have more exclusive knowledge and strong risk resistant capability. The commonly accepted paradigm for this requirement is so called "win-win principle based virtual enterprises", which is built on global base. We analyze and discuss how to deploy this new manufacturing paradigm to Chinese enterprises, including its requirement, imperatives and characteristics. Based on the analysis, we focus on the study of agile supply chain management technology, which is one of the key technologies for optimization and management of virtual enterprises. Finally, a proposed architecture for achieving agility requirement of supply chain management system is presented for reference.

Agile Competition Needs Virtual Enterprises

It is approved from the experience of last decade that downsizing and virtual organization are the effective way to increase the agility of an enterprise. IBM, AT&T, FORD and many other giant companies have spun off many of their subsidiaries by intention. By doing so, not on only this company could have more energy and budget focus on their core competencies, but also good for those spun off companies. They get more freedom to decide what to do and how to do in order to meet the market requirement. How, getting smaller is not the purpose, the final goal of the company, to get more profit and market share has never being changed. To deliver required products and service to customers faster, better with appropriate cost, those primary

trading partner (PTP) has to more closely working with their partners, including suppliers, subcontractors, and distributors. They have to share their profit as well as risk with their partners. But this time, they are not bounded to their own subsidiaries. They could freely choose their partner worldwide. This global agile manufacturing paradigm is what we called virtual enterprises. Besides win-win principle, dynamic is another major characteristic of virtual enterprise. It is created corresponding to a new market chance or a new technology introduction and it is terminated when such pre-requirement has changed.

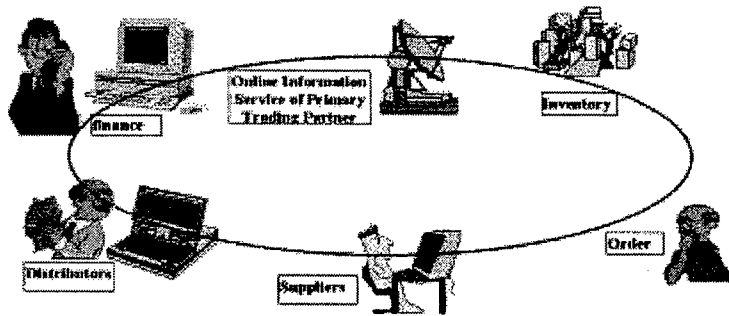
It is needed to point out that the concept of virtual enterprises is quite different from the traditional giant company. It is more flexibility, dynamically reconfigurable and thereafter, more agile. The core principle of a virtual enterprise is that every company in the organization should focus on its core competency only and left other for its partners. In other words, companies form a virtual enterprises should have the same market motivation but different core competencies. Otherwise they will be more competitions other than cooperation. All the companies in the virtual enterprises are willing to share risks because they understand they will share profit too. This kind of new organization paradigm could make those international companies put more effects on new product development and market expending. It will also bring other manufacturing type companies (especially those from developing countries like China) more chance to get into the international market. Take MD as an example. By cooperating with several Chinese Airplane Companies, MD effectively increased its productivity and International market share without buying any new equipment, build single square meter of new plant, nor recruit one new labor. At the same time, by working on those orders, the Chinese airplane manufacturer not only indirectly entered the international market, but also learned a lot of important lessons, accumulated many priceless experiences. It is this kind of experience makes Chinese believe that they could build their own airplane in the next decade. This is a typical win-win case of virtual enterprises.

Different from normal work style of a company, a virtual company emphasizes on "dynamic" and "alliance" characteristics. "Dynamic" reflect the characteristics of the ever faster changing competition environment, while "alliance" represents core competency compensation based new organization structure. Although cooperation is not a new concept, in fact, it is always an important issue ever since human had organized production activities. But what we are talking today about the cooperation within virtual enterprises is far more than what we used to understand. Taking supply/distribution problems of an enterprise as an example. Most of companies (if not all) have their purchasing and sales department to handle their supply and distribution problems. In fact, by exploring the operation flow within a company, we could say there is also a supply chain problem across departments and divisions. Today, all necessary cooperation among suppliers and distributors are governed by contracts, orders and billing papers, which are handled by telephones, faxes or express mails. A primary trading partner will make their production along with their purchasing and sales plan according to the sales information collected for last season or last year, plus the information from the customer meeting conference (1 or 2 time a year). Its suppliers will then make their production plan according to orders they got from their primary trading partners. This kind of planned production system and cooperation strategy can certainly not meet today's fast changing market requirements. Virtual enterprises concept calls all the partners cooperating in a more active, more tacit fashion. Still take supply/distributor problems of an enterprise as an example. Virtual enterprises concept asks primary trading partner and its alliances forms a direct market profit driven company so that they could work more tacitly and smoothly. Distributors will send all the related market information back to the primary trading partner in real time (via internet for example). The primary trading partner could use this information to adjust their production plan and sales strategy on weekly or even daily bases. These adjustments include product category and structure adjustment, batch number and delivery date adjustment, technology used and enterprise resource usage adjustment and so on. By means of Intranet/Extranet, all the adjustments and related documents are published on line and all the suppliers could browser it at their convenient time and make their adjustment accordingly. In this way, every one in the organization is continuously making self adjustment to make sure that it can serve the community better and could achieve its ultimate profit goal (Figure 1).

Virtual enterprises Paradigm and Its Chinese deployment

Although many Chinese enterprise leaders many not familiar the work of "virtual enterprise" and they may not quite understand about the real meaning of agile competition. But from their business practice, especially after going though the excitement and painful experience the open door policy brought to them. It does not only bring new chance, new technology, and new management concept, but also bring new and ever strong

Figure 1. Supply Chain within Virtual Enterprise



competition. They all realize that "We should not only concentrate on internal technology and management improvement, but also trying our best to help our partners to improve their process cycle"; "We will get more profit only if the entire value chain is optimized"; "On time collecting of accurate market information and production states of our suppliers are critical to make right decisions". Therefore, the concept of virtual enterprises is very easy for them to accept.

However, the acceptance of the concept does not mean they have the correct understanding. We must acknowledge that, many years of planned economy and those years of extensive style competition makes our enterprise more favor of competition instead of collaboration. In many people's mind, He is in charge of his own company and that is all he cares about. The improvements of other partners are their business although they may affect his business. He did realize that they have some common interest but did not thinking how to solve the overall optimization problem. The resulting situation is, the primary trading partners often complain about suppliers can not deliver right product in right time and right quality and about distributors does not provide accurate and on time market information without think how to help them solve these problems; The suppliers complain most about the frequent changes of orders without thinking how to change his production style this reactive mode to proactive mode; The distributors complain cannot get their orders delivered in a faster cycle but did not think of how to improve the running of the supply chain system. Therefore, in order to achieve the goal of shifting our economic development style from extensive to intensive style. We need to reeducate our business managers that they have to look things from the value chain point of view and consider new characteristics of international competitions. That is, they have to put more effects on improving their collaboration environment and learn how they can effectively cooperate with others. This may be the way of quickly get most benefit with minimum investment.

Value Chain and Agile Supply Chain Management (ASCM)

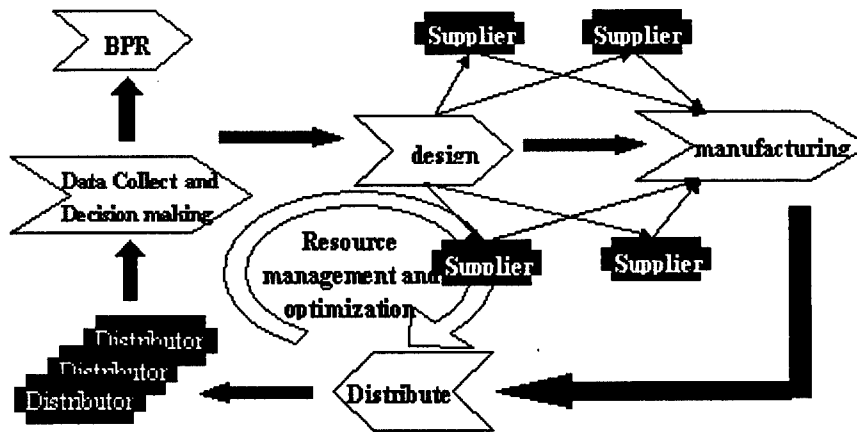
A value chain of a product described the detail capital flow of the entire product life cycle, from concept design to manufacturing, from inventory storage to customer delivery (figure 2).

In this process, agile supply chain plays a role as a lubricant. Agile supply chain is a concept of combination of agility and supply chain management. A supply chain management system is different from most of those existing MRPII/ERP systems by focusing on the information and automation perspective of the supply chain problems, while most of MRPII/ERP systems are devoted themselves to information process and management of manufacturing process.

Today's supply chain management solution emphasizes on function enhancement to those existing MRPII systems of their primary trading partners. They did not give enough emphasize to meet requirements of suppliers and distributors; neither to the integration of those distributed heterogeneous information systems existed on different alliances.

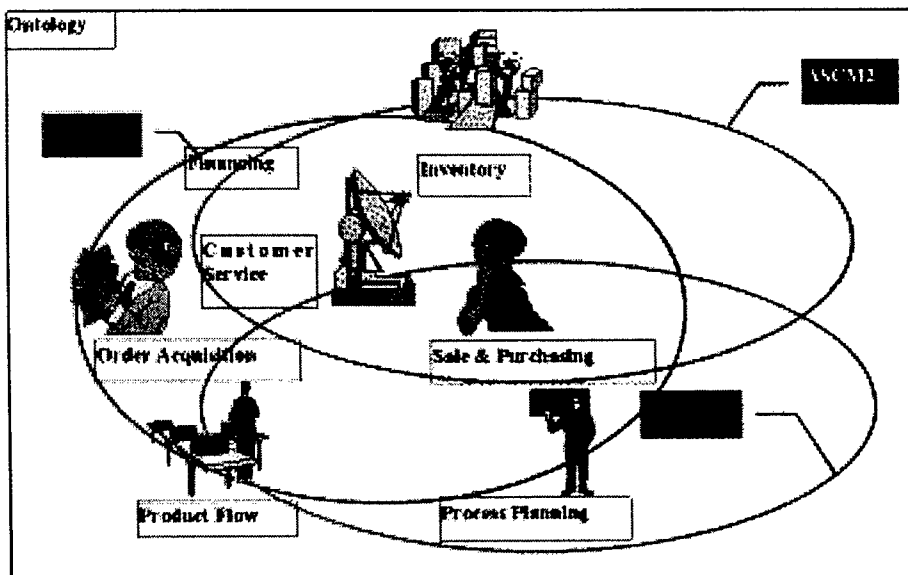
□

Figure 2. Value chain and Supply Chain



1. The dynamic feature of virtual enterprises determined the dynamic feature of agile supply chain management. As the market condition and product structure changes, the number and contents of alliance could change. It requires the coordination facilitator-the supply chain management system can be easily reconfigured and reconstructed to accommodate these changes. It is this reconfiguration capability demands a new infrastructure of the agile supply chain management system (Figure 3).

Figure 3. Reconfigurability of ASCM



2. The win-win principle of virtual enterprises asks the agile supply chain system should not only fulfill the requirements of a primary trading partner, but also other partners' interests. Therefore, on one hand, it should be able to help primary trading partners to collect the first hand market information and acting upon it; help them by browsing distributors' sales records and suppliers' inventory to adjust its purchasing and sales strategy. On the other hand, it can help distributors by browsing different PTP's production plans and sales information of other distributors to adjust his own market strategy; help suppliers by browsing PTPs' inventory information and production plans

to actively adjust his production schedule. These requirements also put some special functionality to the agile supply chain management system.

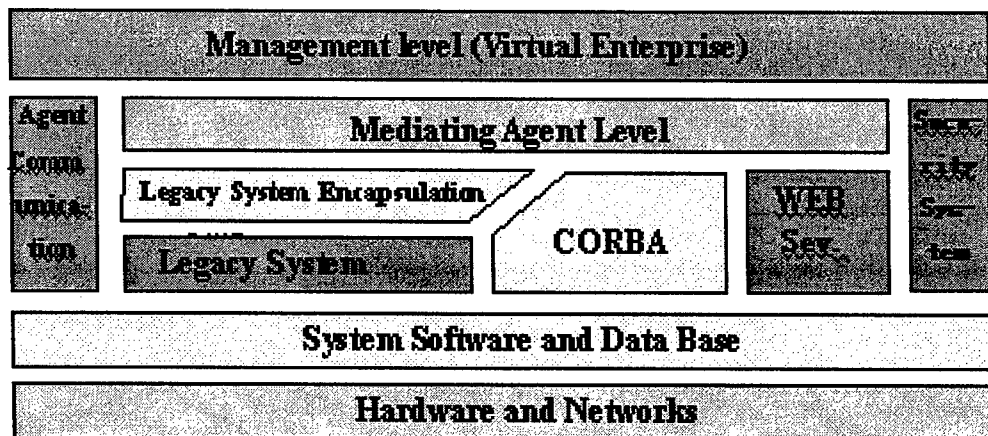
3. Heterogeneous integration is another challenge an ASCM must solve. The characteristics of virtual enterprises ask an ASCM handles information integration problems of different partners in an equally fashion. In other words, we could not ask other partners to modify their information system to integrate with PTP's one. It is neither a good integration strategy, nor a healthy collaboration relationship. We must set up a neutral mechanism to handle the integration requirements of different heterogeneous system possessed by different partners of the organization. It is this mechanism that enable supplier to participate different virtual enterprises without modify his original information system. With the support of this mechanism, every enterprise can freely choose its best partners to grasp every market opportunity without worry about heterogeneous problem (figure 4).

The Architecture of Agile Supply Chain Management System

Based on the analysis above, we designed a new architecture for agile supply chain management system (figure 5). In this architecture, we emphasize the agility of the system, its reconfigurability and fast encapsulation capability for different legacy systems.

In this architecture, the reconstruction of an ASCM is achieved by reconfiguring a set of predefined mediating agents. The detail about mediating agents and reconfiguration is, however, beyond the scope of we. Since the agent communication is implemented based on CORBA standard and WEB technology, it can be used to integrate heterogeneous systems. By encapsulating legacy systems with different mediating

Figure 5. Architecture of ASCM



agents, we get a neutral mechanism for system integration.

Prospect

The 90's quick changing international competition environment asking companies to make changes in their organization management as well as production paradigm. Virtual enterprises, as a new advanced manufacturing paradigm, a new organization structure of agile competition has been widely accepted by industries and academics worldwide. We analyzed how to deploy this new manufacturing paradigm to Chinese enterprises. Then it focuses on the study of agile supply chain management technology and proposes

architecture for achieving agility requirement of supply chain management system. Currently, the development of an ASCM system based on this idea has been supported by 863/CIMS's key R&D project called "Agile Supply Chain Management System and Related Technology Based on Reconfigurable Architecture". Within this project, we will try to deploy the research results to a number of big Chinese companies like Jincheng, Kelong, Jinbei as well as some merchandise chain stores.

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Date Visited: 15 April 2000

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Kurt W. Tong, Counselor, ESAT

Introduction

Singapore provides the model for China. It is a one party system with a lot of government oversight. While Chinese can move locations to escape government interference, the government is very strict. There is a lot of uncertainty in this system.

The legal framework for doing business in China is still lacking. It is expected that WTO will allow the world court to adjudicate legal problems. This is not too popular with the Chinese government, but will provide a framework for foreign firms.

Capital Issues

Financial controls limit firms from participating in capital markets. Taiwan is an important part of China's future development. Taiwan has capital, speaks the language, and has technology. Capital controls are a key tool for government, like Japan's MITI controlled industry investments in the 1970s. MII will implement its strategy through capital allocations. MII's strategy is "CCC" (communications, computers, and consumer electronics). The government is reallocating capital to SOEs. Some successful firms that have gone to the public capital markets include Haier, which like IRICO, makes consumer products.

The military is not getting the efficiency of private firms like Legend. They can't keep up with private firms. Their employees are demoralized due to poor pay. They don't keep the best people. They can't keep up their equipment. The technology is changing too fast, and they are not hooked into the market. CIDC's development of PANDA software was due to the US export controls. It is one-third the price, offers local service, and can be customized. But they can send ASICs to Taiwan for production. TI sells DSPs. They go into the labs and show how to use it (TI and DaTang Telecom). Hua Hong's output goes to NEC for use by NTT. It was part of the requirement to ensure that Hua Hong would be profitable.

Universities have been short of money, like Harbin Engineering Institute. They invest in factories. Universities started Legend, Founder, and Stone. Beijing University and Tsing Hwa are building western style housing for new faculty. There are building infrastructure to attract young faculty. UST has the highest paid faculty.

Telecommunications Issues

There is some debate as to how much investment will go to expand telephone wire, and how much will go to wireless cell phones. Cable TV is outside of MII's scope, but cable offers an alternative route to the Internet. There are experiments being done in large cities outside of Beijing. Shanghai Bell is experimenting with video on demand. Cable offerings are different between foreign and Chinese housing. Foreign access is open, while Chinese access is closed. There are some additions of HBO and CNN. The military is receiving Taiwan's satellite leads and reselling it. The Ministry of State Security is looking at this.

iMode phones will be a standard in Japan, but may not export successfully. The Asian market can communicate a lot of information using characters on devices. Motorola is using Linux. Palm Pilot uses its own format for the Internet.

There was a White Paper that compared China's use of ATM technology to the USA's use of TCP/IP. Since China Telecom is a government monopoly, bureaucrats run it and they can deliver universal cell phones. The rail lines are competing by installing fiber to cover business's communications needs. But city usage is growing faster than capacity, and performance is poor. Small cities don't have the same problems. They are doing CDMA experiments for 3.0. There is a policy implementation problem. The state council has to make decisions, since there was conflict between ministries. MII was set up to merge MPT and MEI to limit the number of decisions that had to go to the State Council. The Minister of Rails has set up two companies to expand bandwidth, one is China Netcom.

FDI

The buzzword for the future is "WOFE" (wholly owned foreign enterprises). Everyone wants to own their own shop. There are virtually no successful US joint ventures except IBM (Shanghai). Most firms in the north have failed due to too much oversight by the government. Intel's flash memory operation is successful and plans to double size. They are doing R&D for natural language and are one of the most prominent companies with a JV.

Unicom will have a 49% cap on foreign ownership of telecommunications.

Key points from trip:

- International awareness and engagement in private industry is high.
- CIDC is only one step from meeting world standards (Panda, MP3). They have integrated capability, are able to retain employees, and have Internet access even if they can't travel.
- Fudan's analytic capabilities are excellent.
- IC technology is one-two generations behind, but they are learning. They need more investment to close the gap. The market is open for equipment they need. This needs privatization before it will move.
- Most organizations are investing several millions of dollars per year to keep up, not \$100 million like in the West. They don't want foreign control, but lack the capital to stay in the game.
- Datung website is <http://192.160.1.2/english/default.htm>

Written by William R. Boulton

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Date Visited: 17 April 2000

Host: Zhang Junhua, Deputy General Manager, Xianyang Factory email: ch2@irico.com.cn

IRICO produces tubes for televisions. We visited the 25" color picture tube factory in a three-story building. Production flows appeared to be steady. There was no indication of quality management methods or improvement processes. Management had not implemented team activities, or other improvement methods.

IRICO uses supplier companies, both in-house and out, for glass and shadow masks. The original technology came from Toshiba, with whom they still have a technical relationship. The base line for technology is considered fairly low. IRICO is a component supplier. Their customers produce TV sets under their own brand names.

IRICO was listed on the Shanghai stock exchange on May 2, 1996. Employees were given stock, but most have sold it and lost the gains that have occurred since then. The company was forced to become "orderly" in going public. A Board of Directors and Management Committee were established.

Written by William R. Boulton

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Date: 18 April 2000

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Xi'an Orient Software Co., Ltd. (Xi'an Orient)

Founded in 1988, SO!Tech (Shanghai Orient) is the Bunka Orient Group entry into the Chinese market. Xi'an Orient Software Co. Ltd. (Xian Orient) was founded in October 1988 as Future Electronics Co. (FEC) Ltd., located in Xian High-Tech Development Zone. Future was originally a JV between two Japanese firms, one university, and the government. Today, it is wholly owned by BOC (Bunka Orient Corp.). BOC has operations in Sendai, Tokyo, Osaka, Shanghai, Beijing, Xian, Canton, New Delhi, Bangalore, and Mongolia. The branch names are being changed to Orient for standardization purposes. The government is paying to develop a network for the banking systems. BOC has a JV with a local company in Mongolia.

Xi'an Orient specializes in the development of computer software and hardware solutions. It owns a wing of the Incubator Center, in the Xian High Tech Economic Zone. The Xi'an offices are spacious and modern, equipped with up-to-date facilities, and staffed with a team of Microsoft Certified System Engineers and Microsoft Certified Solution Developers. The Xian facility provides a capability to extend services to multinationals and nationwide enterprises that need support and maintenance in China's vast interior.

Xi'an Orient employs 30 development engineers, and plans to double that number in 2000. Over 20 of their staff in the company have been trained in Japan. Xi'an Orient offer services such as consulting, training, software development, hardware integration and system maintenance services to multinationals and nationwide enterprises based on Microsoft product families - Windows 95, BackOffice, Exchange Server, MS Access, Visual Basic, and Visual C++.

Xian Orient has developed a Chinese accounting system - Orient Financial System, which conforms to the exact standards of the Chinese National Accounting Association.

Currently, 95% of our engineers are Microsoft Certified with a MCSE (Microsoft Certified System Engineers) and/or a MCSA (Microsoft Certified Solution Designer) certificate. With these outstanding skill sets and technologies, FEC was chosen as their MCSP (Microsoft Certified Solution Provider), ATC (Authorized Training Center) and Authorized Dealer.

The staff in Xian is comparable in ability to any other in the region. Many of these engineers have written software for corporations, universities and government agencies in Japan and the USA. Today, 80% of the development projects are from Japan or the US. The QA is in place, the output has improved so they can take on good projects, and they have sales teams in the US and Japan. They provide higher salaries than competitors, give an additional 10 days of vacation time (adding 1 day per year of service), and give bonuses after a project has been completed and evaluated in Japan.

Xian Orient made its first profit in 1999. They now enjoy a two-year tax holiday, and then will have six years of 50% taxes (15%). That was just increased from three years. Future gets audited from Japan. The company's policy is to not make bribes, so they don't get much local work. However, the US and Japan contracts have higher prices.

Bunka Orient Corp

Founded in 1983, Bunka Orient Corp. of Japan is now the leading supplier of ActiveX components in Japan. With over 20,000 companies and government agencies as customers, including almost every major corporation in Japan, its products are being used by tens of thousands of developers to help build better Windows applications quickly and inexpensively.

Bunka Orient is also the number one developer and vendor of School Management Software for private schools in Japan. With an estimated share of over 70% of the market, its systems have been deployed in over one thousand private schools throughout Japan. Its Accounting System for Schools is the only private school accounting system to be officially recognized by the National CPA Association of Japan.

Bunka Orient is a Microsoft Solution Provider providing consulting and development services for Client/Server, Internet, and Intranet systems using Microsoft NT and the BackOffice family of products. Bunka Orient has been a co-sponsor with Microsoft of several technical seminars in Japan on the development of software for Windows.

Future's Products

Future has developed a shrink-wrapped financial accounting package for the Chinese market using the Future brand. It is also developing an ERP system for the local market that will target the middle layer of firms. Being developed in China, it can also be customized for specific company needs.

Xian Area

Xian was an interesting location because of its historical significance, and the good universities and research labs there. Xian Jiaotong University was moved from Shanghai to Xian in 1959. It has 10 schools and 72 laboratories, of which 10 are key National Labs. Xian Electronic Science and Technology University (Xidian) has six institutes covering communication engineering, electronic engineering, computer science, electronic mechanics, economical management, and adult education. Xidian grew out of the Radio School for the Central Military Commission. Under the National Seventh Five Year Plan, Xidian has received about \$30 million for 2200 research projects, for which they have received 200 awards. Universities have their own application labs, and have established some companies.

Xian has a lower turnover rate than Shanghai, and a 20-30% wage advantage for software development people. The company provides six months to one year of training to developers, and then sends them to Japan once they become skilled. Japan is a faster moving environment that shows them what can be done. Qian Hua, the Director-Deputy General Manager, runs the local operation. Future has established a QA program and is working to speed delivery. They review all programs after completion to learn and improve the development process. They are currently completing a program for Microsoft that will be checked in Japan and delivered to California.

The government is trying to increase incentive for software development. Most universities have established computer science departments. It has sent a lot of people to Bangalore for training. It is also working hard to improve the Internet bandwidth, but usage is growing faster than lines can be installed. The current Internet is slow and sites get blocked for political reasons, like cnn.com. They have also increased the time for tax incentives.

WTO is going to cause rapid change. The local and state government has greatly improved the Xian infrastructure since 1993. The education is better. People wear better clothes and it even shows in the way they walk. The government has committed to making the NW catch up with the coast in its development.

Written by William R. Boulton

Appendix 1: Shanghai Orient Technologies [Excerpts from Company Brochure]

Founded in 1988, SO!Tech is the Bunka Orient Group entry into the Chinese market. Our goal is to provide **complete business solutions** to foreign and local companies in China. Utilizing high skills and advanced technologies, we aim to consistently satisfy and exceed the expectations of our customers.

Our Mission

Shanghai Orient Technologies (SO!Tech) was established in May 1993, and is fast becoming known in the Chinese market as a leader in software technology.

Our mission is to ensure the success of our customers' business by providing quality software solutions that they can depend on.

Customers For Life: This is the philosophy that is the driving force behind all of our policies. Whatever their computing needs, our goal is to consistently satisfy and exceed the expectations of our customers.

Business Application "MRP9000" Manufactory Control System

Software: "Pivotal Relationship" Customer Relationship Management System
"OFS" Orient Financial Management System

Software Development Tools: ActiveX/Java Controls (PowerTools"Series)

Technologies: Architectures: Client/Server, Internet/Intranet, Windows DNA
Development Tools: Visual Basic, Visual C++, Visual InterDev, Visual FoxPro, Visual J++, VB Script, VBA, Office 2000 Developers Edition, ActiveX Controls
Databases: SQL Server, MS Access, Oracle
Platforms: Windows NT, Windows 98/95, Microsoft BackOffice
Languages: Chinese, English, Japanese

Capabilities: System Developers *
ERP Consultants + Specialists
CRM Consultants + Specialists
Trainers - Microsoft products - Business solution systems
IT Technical Support Specialists - Enterprise Premier Support - On-line / On-site support

Qualifications: Microsoft Certified Solution Providers Partner (MCSP Partner)
Microsoft Authorized Training Center
Microsoft Authorized Support Center
MSDN Regional Director
IMS Certified Implementation Service Provider
Pivotal Alliance Member

* Over 85% of our engineers are certified as Microsoft Certified Systems Engineers (MCSE) and/or Microsoft Certified Solution Developers (MCSD); the largest team of MS Certified Engineers in China.

SO!Tech Hong Kong

Tel: (+852)-28080344/(+852)-28080444
Fax: (+852)-28080544

SO!Tech Guangzhou

Tel: 86-20-8755-2099
Fax: 86-20-8755-3424

SO!Tech Beijing

SO!Tech's modern office in Beijing, serves as a support and liaison base in the north to further extend our

services to multinationals and nationwide enterprises in that area. This office is networked with our Shanghai and Xian facilities to give us instantaneous integration of our entire Chinese staff of engineers. This means that our highly trained engineers can quickly and flexibly meet your needs anywhere in China.

Tel: 86-20-8755-2099

Fax: 86-20-8755-3424

SO!Tech Xi'an (Xi'an Orient)

The Xi'an offices of SO!Tech are spacious and modern, equipped with the most up-to-date facilities, and staffed with a team of Microsoft Certified System Engineers and Microsoft Certified Solution Developers. Many of these engineers have written software for corporations, universities and government agencies in Japan.

This facility in Xian gives SO!Tech the capability to extend services to multinationals and nationwide enterprises who need support and maintenance in China's vast interior. We are confident that our staff in Xian is equal or superior in ability and qualification to any other in the region.

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Technology Transfer (TTEC) Division

The Technology Transfer (TTEC) Division of Loyola College in Maryland is a division of Loyola's International Technology Research Institute (ITRI). It was originally established in April 1993 with funding from the U.S. Department of Transportation to conduct a series of assessments of foreign transportation technology. Under DoT funding, eight delegations of U.S. experts visited developed countries in Europe and the Pacific Rim to gather information on technological innovations and research advancements in the transportation area. In 1996 TTEC broadened its scope to include a variety of foreign technology transfer services.

The Department of Transportation developed the International Technology Scanning Program in response to Section 6003 of the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991. Under this program, TTEC conducted a number of "scanning" tours for DoT. As applied in this program, the term "scanning" referred to the approach generally known as benchmarking.

TTEC assembled delegations of U.S. professionals, composed of representatives from Federal, State, and city planning levels, from academia, and from the private sector. They identified foreign transportation experts in governments, universities, and the private sector, established contact, coordinated meetings, and provided logistical arrangements. Upon completion of the study tour, a member of the delegation compiled the information collected into a report of results. TTEC also disseminated the results to the highway community through workshops and technical presentations.

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