World Technology Evaluation Center

WTEC

WTEC Panel Report on

Electronics Manufacturing in the Pacific Rim

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William Boulton (Co-Chair and Principal Author)

May 1997

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WTEC PANEL ON ELECTRONICS MANUFACTURING IN THE PACIFIC RIM

Sponsored by the National Science Foundation and the Defense Advanced Research Projects Agency of the United States Government and by the National Electronics Manufacturing Initiative and employers of panelists from U.S. electronics companies.

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INTERNATIONAL TECHNOLOGY RESEARCH INSTITUTE
WTEC PROGRAM

The World Technology Evaluation Center (WTEC) at Loyola College (previously known as the Japanese Technology Evaluation Center, JTEC) provides assessments of foreign research and development in selected technologies under a cooperative agreement with the National Science Foundation (NSF). Loyola's International Technology Research Institute (ITRI), R.D. Shelton, Director, is the umbrella organization for WTEC. Paul Herer, Senior Advisor for Planning and Technology Evaluation at NSF's Engineering Directorate, is NSF Program Director for WTEC. Other U.S. government agencies that provide support for the program include the National Aeronautics and Space Administration, the Department of Energy, the Department of Commerce, and the Department of Defense.

WTEC's mission is to inform U.S. policymakers, strategic planners, and managers of the state of selected technologies in foreign countries in comparison to the United States. WTEC assessments cover basic research, advanced development, and applications/commercialization. Small panels of about six technical experts conduct WTEC assessments. Panelists are leading authorities in their field, technically active, and knowledgeable about U.S. and foreign research programs. As part of the assessment process, panels visit and carry out extensive discussions with foreign scientists and engineers in universities and in industry/government labs.

The ITRI staff at Loyola College help select topics, recruit expert panelists, arrange study visits to foreign laboratories, organize workshop presentations, and finally, edit and disseminate the final reports.

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FINAL REPORT

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ABSTRACT

This report reviews the status of electronics manufacturing capabilities of Hong Kong, Singapore, Malaysia, and Taiwan in comparison to the United States and Japan. Topics covered include government R&D programs and incentives for private investment, manufacturing and related technology infrastructure, regional economic cooperation, and relationships with the United States and Japan. Sources for the study included an extensive literature review (including Internet sources); visits to 28 key government agencies, research institutions, and manufacturing companies in the countries of interest; and an extensive review of the draft report by study panelists, site visit hosts, and study sponsors. The panel concluded that Pacific Rim countries have taken the lead in high-volume low-cost electronics manufacturing and are aggressively pursuing higher technology and higher value-added markets. While the United States and Japan retain technology leadership in electronic packaging for high performance and specialized applications, these technologies are being transferred rapidly to other Pacific Rim nations. The rapid development of electronics manufacturing infrastructure in East Asia poses a challenge to overall U.S. manufacturing competitiveness as the United States becomes increasingly dependent on Asian suppliers of key components, subsystems, and finished products.

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FOREWORD

The National Science Foundation (NSF) has been involved in funding technology assessments comparing the United States and foreign countries since 1983. A sizable proportion of this activity has been in the Japanese Technology Evaluation Center (JTEC) and World Technology Evaluation Center (WTEC) programs. NSF has supported more than 40 JTEC and WTEC studies over a wide range of technical topics. Both programs are now subsumed under the single name, WTEC, although the JTEC name still appears in some reports that cover only Japan.

As U.S. scientific and technological leadership is challenged in areas of previous dominance such as aeronautics, space, and nuclear power, many governmental and private organizations seek to set policies that will help maintain U.S. strengths. To do this effectively requires an understanding of the relative position of the United States and other countries. The purpose of the WTEC program is to assess research and development efforts in other countries in specific areas of technology, to compare these efforts and their results to U.S. research in the same areas, and to identify opportunities for international collaboration in precompetitive research.

Many U.S. organizations support substantial data gathering and analysis efforts directed at nations such as Japan. But often the results of these studies are not widely available. At the same time, government and privately sponsored studies that are in the public domain tend to be "input" studies; that is, they provide enumeration of inputs to the research and development process, such as monetary expenditures, personnel data, and facilities, but do not provide an assessment of the quality or quantity of the outputs obtained.

Studies of the outputs of the research and development process are more difficult to perform because they require a subjective analysis performed by individuals who are experts in the relevant technical fields. The NSF staff includes professionals with expertise in a wide range of disciplines. These individuals provide the technical expertise needed to assemble panels of experts who can perform competent, unbiased, technical reviews of research and development activities.

Specific technologies, such as telecommunications, biotechnology, microelectromechanical systems, and advanced materials, are selected for study by government agencies that have an interest in obtaining the results of an assessment and are able to contribute to its funding. A typical assessment is sponsored by two to four agencies. In the first few years of the program, most of the studies focused on Japan, reflecting concern over Japan’s growing economic prowess.

Beginning in 1990, we began to broaden the geographic focus of the studies. As interest in the European Community (now the European Union) grew, we added Europe as an area of study. With the breakup of the former Soviet Union, we began organizing visits to previously restricted research sites opening up there. These most recent WTEC studies have focused on identifying opportunities for cooperation with researchers and institutes in Russia, the Ukraine, and Belarus, rather than on assessing them from a competitive viewpoint. Most recently, studies have begun to focus also on emerging technological powers in Asia.

In the past several years, we also have begun to substantially expand our efforts to disseminate information. Attendance at WTEC workshops (in which panels present preliminary findings) has increased, especially industry participation. Representatives of U.S. industry now routinely number 50% or more of the total attendance, with a broad cross-section of government and academic representatives making up the remainder. Publications by JTEC and WTEC panel members based on our studies have increased, as have the number of presentations by panelists at professional society meetings.

The WTEC program will continue to evolve in response to changing conditions in the years to come. We are now implementing initiatives aimed at the following objectives:

- Disseminating the results of WTEC studies via the Internet. Fourteen of the most recent WTEC final reports are now available on the World Wide Web (http://itri.loyola.edu) or via anonymous FTP (ftp.wtec.loyola.edu/pub/). Viewgraphs from several recent workshops are also on the Web server.

- Expanding opportunities for the larger science and technology community to help define and organize studies
- Increasing industry sponsorship of JTEC and WTEC studies

The latter two objectives are now being served under the recently inaugurated WTEC Community-Initiated State-of-the-Art Reviews (CISAR) initiative. CISAR provides an opportunity for the U.S. R&D community to suggest and carry out studies that might not otherwise be funded solely at the initiative of the government. For example, WTEC has formed partnerships with university/industry teams, with partial funding from industry, to carry out three CISAR studies, covering the Korean semiconductor industry, electronics final assembly technologies in Pacific Rim countries, and civil infrastructure technologies in Pacific Rim countries, respectively. Several other topics are under consideration. Further information on the CISAR initiative is available on the WTEC WWW server (http://itri.loyola.edu/cisar.htm) or by contacting the WTEC office.

In the end, all government-funded programs must answer the question, How has this investment benefited the nation? A few of the benefits of the WTEC program follow:

- JTEC studies have contributed significantly to U.S. benchmarking of the growing prowess of Japan's technological enterprise. Some have estimated that JTEC has been responsible for over half the major Japanese technology benchmarking studies conducted in the United States in the past decade. JTEC reports have also been widely cited in various competitiveness studies.
- These studies have provided important input to policy makers in federal mission agencies. JTEC and WTEC panel chairs have given special briefings to senior officials of the Department of Energy and Commerce, to the National Aeronautics and Space Administration (NASA) administrator, and to the President's science advisor. Two recent studies on electronic packaging and related electronics manufacturing issues have had a particularly significant impact in this regard. The 1995 JTEC report on electronic manufacturing and packaging in Japan was cited by Secretary of Defense William Perry and Commerce Secretary Ronald Brown in their joint announcement of a $30-40 million government initiative to improve U.S. competitiveness in electronic packaging. The President's Office of Science and Technology Policy and two senior officials at the Department of Commerce have received briefings on a follow-on WTEC study covering electronic manufacturing in other Pacific Rim countries.
- Studies have been of keen interest to U.S. industry, providing managers with a sense of the competitive environment internationally. The director for external technology at a major U.S. high-technology firm recently told us that that he always looks for a relevant WTEC report first when beginning to investigate a technology for his company, because these reports provide a comprehensive understanding that includes R&D, process technology, and some information on commercial developments. The list of corporate users of the WTEC World Wide Web server includes virtually all of the nation's high-technology sector.

Not the least important is the educational benefit of the studies. Since 1983 over 200 scientists and engineers have participated as panelists in the studies. As a result of their experiences, many have changed their viewpoints on the significance and originality of foreign research. Some have also developed lasting relationships and ongoing exchanges of information with their foreign hosts as a result of their participation in these studies.

As we seek to refine the WTEC program in the coming years, improving the methodology and enhancing the impact, program organizers and participants will continue to operate from the same basic premise that has been behind the program from its inception: the United States can benefit from a better understanding of cutting-edge research that is being conducted outside its borders. Improved awareness of international developments can significantly enhance the scope and effectiveness of international collaboration and thus benefit all of the United States' international partners in collaborative research and development efforts.

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EXECUTIVE SUMMARY

In today's globally competitive business environment, electronics companies are under relentless pressure to provide innovative products in shorter time cycles, at reduced cost, and with improved quality. The electronics industry is driven by demands for products that are smaller, lighter, cheaper, and better than the ones they replace. In order to meet market requirements, industry has been moving to Asia, which is now the primary source of electronic components and is soon to become the primary market for consumer electronics.

Japan has been the undisputed leader in the Asian electronics manufacturing industry. This was clearly demonstrated in the JTEC report on manufacturing and packaging in Japan (Boulton 1995). With superior component and equipment capabilities, Japan continues to provide the technology needed to manufacture advanced electronic products throughout Asia. Korea and Taiwan are now competing for second and third place. The long-term strategies of Korea, Taiwan, and Singapore are to increase self-sufficiency by reducing dependency on foreign sources of materials, components, and equipment. The Korean government has provided continuing R&D support to industry in an effort to capture markets from Japan in such components as semiconductors and flat panel displays. The Taiwanese government has relied heavily on nationally funded research to develop and transfer semiconductor and packaging technologies into the private sector. Acer, Taiwan's largest computer maker, and Formosa Plastics, Taiwan's largest conglomerate, are attempting to become world leaders in computers and related components, respectively. As an aggressive new entrant in electronics, Singapore falls behind Korea and Taiwan in its breadth of capabilities, but it is attracting and subsidizing locally conducted R&D by foreign firms and gaining a strong reputation as the "intelligent island." While Hong Kong has significant experience in electronics, it appears to have fallen behind in the technology race and instead has chosen to invest heavily in China. Malaysia lags Singapore and Hong Kong in industrial capabilities but has growing strength in semiconductor and electronic component manufacturing.

Korea, Taiwan, and Singapore find themselves facing rapidly rising incomes and living standards that are pushing up labor costs. To maintain competitiveness, companies are rapidly transferring labor-intensive operations into neighboring countries like China, the Philippines, Thailand, and Indonesia. As the benchmark for low-cost manufacturing, China is forcing its Asian rivals to move into higher value-added products, to develop proprietary technologies, and to invest in capital-intensive businesses.

Korea, Taiwan, and Singapore are rapidly upgrading their production capabilities to utilize advanced component and process technologies. Governments in these three countries are committed to advancing electronics technologies by supporting developments in production equipment, related materials, and components. NatSteel in Singapore, Samsung in Korea, and Oriental Semiconductor Electronics (OSE) in Taiwan are among the many companies that have used government support to advance their production capabilities.

The transfer of operations from newly developed to developing countries has facilitated the creation of regional trade and the development of industrial trade zones as part of "regional polygons" or "regional triangles." There are currently eight growth polygons in East and Southeast Asia, and additional triangles are being planned. Four regional triangles have been established since 1989 involving parts of 11 countries. Regional cooperation provides a competitive model to attract investment and technology. The Southern Growth Triangle, known as SIJORI (Singapore, Johore State of Malaysia, and Riau Province of Indonesia), was formed in 1989 and covers a population of six million people. According to Singapore government officials, it attracted $10 billion in private sector investments during its first five years (1990-1995).

While these Asian nations are geographically and culturally distinct, each is in the process of improving its infrastructure to support product and process realization, from research and design though manufacturing and marketing. The high-quality jobs provided by the electronics industry provide the incentive to offer foreign companies substantial capital investment opportunities. The newly industrialized economies of Asia are making it attractive for foreign companies to move their most advanced technologies and most capital-intensive facilities there. This can only be followed by growing trade imbalances with the United States.

The rapid development of Asian nations is creating a large middle-class population of consumers in an area that includes nearly one-half of the world's population. It is projected that the Asian middle class (excluding Japan) could exceed 700 million people by the year 2010. The member countries of the Association of Southeast Asian Nations (ASEAN) alone represented a population of over 500 million by the end of 1996 (Tranzer 1996). China and India account for over 2 billion people. The electronics industries in these countries are growing at nearly 30% per year. The countries visited by the WTEC study teams are expected to prosper as major suppliers to these developing markets. It is further expected that technology transfer and the demand for increased production capacity will accelerate the creation of a very large middle class in Asia.

The United States and Japan will continue to play dominant roles in Asia as major sources of technology and as major markets for Asian products. Even while this report was being written, it was evident that Korea, Taiwan, Singapore, Hong Kong, and Malaysia no longer simply exploit technology from the United States, Japan, and Europe. They are working hard to become less dependent on external technology transfer. By developing its own intellectual property, Taiwan's Industrial Technology Research Institute is able to cross-license and obtain lower royalty rates on licenses for Taiwan's firms. National planning and implementation of long-term strategies in the countries of this study will make them less dependent on the United States and Japan and more competitive in global markets. At the same time, firms from the United States, Japan, and Europe will continue to invest in Asia and transfer their leading edge technologies in order to participate in these growth markets.

This report helps to explain the attractiveness of this migration of manufacturing operations. It is imperative that U.S. government and industry officials understand these trends and consider policies that will slow the outflow of capital and technology, if not reverse the trend. There is much concern that it may be too late. Table E.1 shows the current rankings of major Asian players compared to the United States. In electronics research and development, the United States and Japan are equally matched in innovating next-generation technologies. In product design, Japan has a clear lead over the United States and has been providing most of the new product concepts over the past several decades. There is little question, however, that Japan leads the United States in electronic manufacturing technologies, although the United States has several equipment makers that are producing leading-edge products. Japanese firms dominate the equipment market in Asia. The United States, with its strong brand names, continues to dominate global marketing and sales even as it continues to outsource a growing proportion of its design and manufacturing needs.

These comparisons with Japan are fairly well understood in the United States. What is less well known is how successfully Korea, Taiwan, and Singapore are competing in the marketplace for electronics products and components, or how intent China, Hong Kong, and Malaysia are on challenging the dominance of long-time leaders by rapidly increasing their competence in a wide range of electronics manufacturing fields.

Table E.1
Electronics Industry Capabilities of Asian Countries

Country	R&D	Design	Manufacturing	Marketing & Sales
USA	XXX	XX	XX	XXXX
Japan	XXX	XXX	XXXX	XXX
Korea	XX	XX	XX	X
Taiwan	X	XX	XX	X
Singapore	X	XX	XX	
Hong Kong		X	XX	
China			X	
Malaysia			X	

Note: More "X"s are better.

Table E.2 shows the panel's overall appraisal of Asian players' packaging technology capabilities, along with those of the United States and Japan.

Table E.2
Technology Leadership in Electronic Packaging

METRIC	TECHNOLOGY LEADERSHIP	FAST FOLLOWERS (Less than 1 year)	FOLLOWERS (More than 1 year)
Pin Grid Array pin count	Japan	Korea, Singapore	Taiwan
Quad Flat Pack lead pitch	Japan	Taiwan, Singapore	
Thin Small Outline Package thickness	Japan	Taiwan, Singapore	Korea
Ball Grid Array ball pitch	Japan	USA, Singapore	Taiwan, Singapore, China
Tape Automated Bonding-Outer Lead Bonding lead pitch	Japan, Taiwan	USA	Korea, Singapore, China
Multi Chip Module (high density)	USA	Japan, Taiwan	Korea, Singapore, China
Chip On Board	Japan	Hong Kong, China, Singapore	Taiwan, Korea, USA, Singapore
Flip Chip	USA	Japan	Taiwan, Korea
Chip-Scale Packaging (CSP)	Japan	USA	Taiwan, Korea, Singapore

It is important to recognize that the current status of electronic competitiveness is changing rapidly. The United States and Japan are likely to continue to be technological leaders. But with the rapid transfer of operations of U.S and Japanese firms into East Asia, the lag time in technology transfer is shrinking. Asian countries are moving upstream in the technology "food chain" by manufacturing more key components like semiconductors. They have already begun to produce new product designs and are becoming original design suppliers to global brand leaders like Compaq. Taiwanese and Korean producers like Acer and Samsung are already establishing their own brand names in the U.S. and Japanese markets.

As corporations assess their opportunities for expansion and investment, Asia is the most attractive alternative. As growth in local Asian markets increases the attractiveness of investing in the Pacific Rim, the U.S. economy cannot help but be affected. The United States is competing against countries with clearly articulated industrial strategies, long-term plans supported by appropriate investments, growing numbers of partnerships, and increasingly sophisticated and skilled workforces. The future standard of living of the U.S. workforce is integrally tied to the industrial dynamics that are reshaping the Pacific Rim. It is the hope of the authors of this report that the information provided here will serve to enlighten those making decisions in industrial boardrooms as well as the government officials who are making the policy decisions that affect the destiny of the nation.

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CHAPTER 1

INTRODUCTION

Michael J. Kelly

BACKGROUND TO THE STUDY

The JTEC panel report *Electronics Manufacturing and Packaging in Japan* (Boulton 1995) described the competitive advantages Japan has in electronics. When the study was conducted, it became evident that Japan, as well as the United States, was beginning to feel increased competitive pressure from other Asian countries. In particular, the newly industrialized nations, sometimes referred to as the four "tigers," Korea (i.e., the Republic of Korea), Taiwan, Hong Kong, and Singapore, were becoming a primary source of electronics manufacturing and, increasingly, of research and development. Malaysia may now be included in the list of rapidly industrialized Asian tigers that have strongly competitive electronics capabilities, and China is close behind, with even greater potential for economic strength.

As Henry Luce put it in 1941, the 20th century has been the "American century" (Luce 1941). The 21st century may well be the Asian (or Pacific) century. In addition to the established strength of Japan, the five Asian tigers and China are on a path that will make them world economic powers within 20 years, and expectations are that East Asia's percentage of the world economy will grow from 25% to 50% over the same time period. In an effort to better understand the dynamic developments among the five tigers and their Asian partners and their potential impact on U.S. competitiveness, the World Technology Evaluation Center (WTEC) at Loyola College organized this study of electronics manufacturing in the Pacific Rim as a follow-on to its 1994/5 study of Japan's electronics capabilities. Supporting this study were the National Science Foundation, the Defense Advanced Research Projects Agency, the U.S. National Electronics Manufacturing Initiative, and U.S. industry. The study had six goals:

- Evaluate electronic technology and manufacturing in the five countries
- Seek to understand the interdependencies among companies and countries
- Obtain information on the interactions between industry and government
- Understand the evolving production environment in the Pacific Rim
- Benchmark the Asian capabilities against similar activities in the United States
- Evaluate the elements of the supporting infrastructure that are drawing multinational companies to establish operations in Asia

STUDY METHODOLOGY

WTEC Study Teams

To meet these goals, the sponsors and WTEC selected Dr. Michael Kelly, who headed the Japan electronics study, and Dr. William Boulton, who was its primary author, as co-chairs of a panel to investigate electronics manufacturing in the Pacific Rim. This was followed by selection of other panel members: U.S. electronics experts with diverse areas of specialization. The panel then was organized into three study teams to visit Hong Kong, Singapore and Malaysia, and Taiwan. The panelists are listed below; Appendix A summarizes their professional experience. Other studies of Korea and China, also sponsored by WTEC, complement the work of this panel. The results of the China and Korea studies will soon be available on WTEC's Web site (http://itri.loyola.edu/#reports) or in the reports *Electronics Manufacturing in Korea and China* (Boulton, 1997, upcoming), and *The Korean Electronics Industry* (Pecht 1997). It is anticipated that further work will be done in the near future to better understand Korea, continuing developments in China, and the evolving participation of other Pacific Rim countries.

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Amalendu Sanyal, Digital Equipment Corporation
William Tucker, IBM
Sam Wennberg, Delco Electronics

Taiwan Study Team

William Boulton, Auburn University
H.M. Cheng, Universal Equipment Corporation
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Gordon Roberts, Lucent Technologies
Jan Vardaman, TechSearch International

After panelists completed their site visits and prepared their findings, WTEC hosted a workshop in Washington, DC, on July 18, 1996, to present the preliminary results of the study to the public.

Overview of the Report

This written report on the panel's findings is the final evaluation of the panel on the current state of electronics manufacturing in Asia. It consists of an overview of the areas studied and their electronics manufacturing capabilities (Chapter 2), and three chapters analyzing the electronics R&D and manufacturing capabilities of the separate regions visited by the study teams: Hong Kong and affiliated locations in South China (Chapter 3); Singapore and Malaysia (Chapter 4); and Taiwan (Chapter 5). Site reports on the organizations that the team visited are found in Appendix B (Hong Kong), Appendix C (Singapore), Appendix D (Malaysia), and Appendix E (Taiwan). All host organizations were given an opportunity to review the draft of the written report.

SIGNIFICANCE OF THE REPORT

This report helps to explain why locating electronics manufacturing operations in Asia is so attractive and why the resulting electronics manufacturing migration to the Pacific Rim may have a devastating impact on U.S. competitiveness. Panelists believe it is imperative that U.S. government and industry officials understand the trends and consider policies that will slow the outflow of capital and technology, if not reverse the trend. There is concern that it may be too late. The results of a survey of 300 leading manufacturers (Sachs 1996) found that "40% of their products were entirely made offshore; 42% were a combination of made in the USA and offshore; and 18% were 100% made in the USA…The latter group (18%) included a very high proportion of non-high-technology accessory products like fixtures, cabinets, shipping cases, and mounting brackets in contrast to electronic and digital products." The companies also said they "cannot get many key components of domestic origin because the items are either no longer made here, or if they are, they are not price- or quality-competitive compared to goods made off-shore." Of the manufacturers that assembled their end-products in the United States with imported components, virtually all reported that desired chips, resistors, capacitors, and potentiometers were not available domestically. Other scarce U.S.-made items include logic ICs, camera modules, liquid crystal display parts, mechanical/electrical devices, VCR parts, MOSFETS (metal oxide semiconductor field effect transistors), and digital signal plug connectors — all are critical components of electronics products. Understanding the implications of this finding is critical to maintaining the economic base of the United States. According to one major electronics company, the value added from key components generates 65% of total value added as compared to only 12% for final assembly. For every key component produced outside the United States, not only are jobs lost, but also higher incomes and tax base.

Asian National Independence and Regional Interdependence

As this study was underway, the five tigers already were becoming less dependent on technology transfers from the United States, Japan, and Europe. As these newly industrialized Asian nations expand their own research activities and attract the R&D activities of global electronics players, local technology availability is increasing at a rapid rate. While next-generation technologies are being developed in the West and Japan, much of their implementation is taking place in Korea, Taiwan, Singapore, Hong Kong, and Malaysia. As these countries develop their unique economic development strategies and target specific emerging industries, they also are providing investment incentives to develop infrastructures that can support long-term success. These nations are becoming increasingly sophisticated, and they are investing heavily to upgrade their own technical capabilities and move into product design to add greater value to their processes.

Even as their living standards and technical capabilities increase, the four countries covered in this report and Korea continue to be cost-competitive by shifting labor-intensive operations to neighboring countries with lower-cost labor. This has given rise to creation of regional economic trade and development zones known as economic "triangles" or "polygons." Singapore, Johore in Malaysia, and the Riau Islands in Indonesia established an early triangle (SIJORI), where Singapore provided technology and management expertise and Malaysia and Indonesia provided low-cost labor and local facilities. Such cooperative economic relationships across borders support domestic long-term economic growth while further developing the region. The growth in regional economic cooperation has accelerated the transfer of technology among participants and attracted important new investments. China has become a major focus of such cooperative efforts. The title "newly industrializing" is now shifting to China, Indonesia, Thailand, and the Philippines, and the process is continuing to cross borders into other Southeastern Asian nations (Laos, Cambodia, Vietnam, and Myanmar) as the search for lower-cost labor continues. Even Thailand, with wage rates as low as $5.75 per day, now finds itself less than competitive in the cost-driven electronics marketplace. In China, some factory workers work for $1.50 per day for a 12-hour day. Acceleration in competition between Asian nations, combined with their free trade and open borders, strengthens not only the members of Asia's largest alliance, the Association of Southeast Asian Nations (ASEAN), but also counties participating in the smaller triangles.

Electronics and Wealth Creation in Asia

The market potential of Asia is enormous. As the search for low-cost labor drives economic development across Asia at an increasing rate, development drives growing consumer purchasing power and expanding markets for electronics as well as other goods. Growth in living standards and consumer purchasing power among Asia's population of 3 billion provides significant market opportunities. By 2010, the middle class of Asia (excluding Japan) is expected to top 700 million people, thanks in large part to the contributions of manufacturing to each country's GDP. Such projections of inevitable market growth are driving multinational corporations to invest in Asia in hopes of capturing an early market position. In China today, less than 5% of the people own a dishwasher, clothes washer, vacuum cleaner, microwave oven, or car; there is one telephone for every 25 people, one fax for every 200 people, and one PC for every 400 people. At the same time, statistics published by *Forbes* (Tranzer, 1996) identified among the world's wealthiest business families 123 Asian families, of which 82 were non-Japanese. Wealth creation is likely to continue as Asian countries win major shares of their own newly developing markets. Recognition that technology transfer and increasing production capacity are expediting the creation of a very large Asian middle class may be more relevant to policymakers than the information presented in this report on the changing picture of technology transfer, the new sources of production being established throughout Asia, or the listings of component and product capabilities that the panel found.

Demand for all forms of infrastructure investments is driving corporate and national strategies. "East Asia is now capturing over 60% of the world's private capital flows to developing countries, an inflow worth $100 billion in fresh capital every year — not to mention managerial and technical expertise (East Asia central banks collectively hold more than $600 billion of foreign reserves)" (Tranzer 1996). The Asia-Pacific region, excluding Japan, is expected to spend a trillion dollars on infrastructure in the next decade, an investment that will shift Asian economic growth from a limited number of urban cities to a much wider geographical area. The most striking change will come from improving the telecommunication infrastructure. Indonesia, with its 13,000 islands, planned to invest $73 million in 1996-7 to improve its information infrastructure. Singapore's IT 2000 committee called for the creation of a national information network that will have all homes, schools, businesses, and government agencies interconnected in an electronic grid. Singapore is already one of the most highly networked societies in the world. China plans to spend more than $40 billion installing the equivalent of a Bell Canada-sized network each year until 2000. Besides helping to bring Asia into fuller involvement with the world community of nations, the telecommunication infrastructure being established there will foster greater collaboration among the Asian countries and offer new opportunities for them to capture the major share of local markets.

Asian Electronics Mastery

The information contained in this report demonstrates that Asia has mastered not only every electronic component technology but the systems design and integration technologies as well. It is also evident that Asian companies are adept at responding to changing needs of customers and the pressures of decreasing development cycle times. Their strategy of controlling all of the component technologies has provided them with added ability to meet cost, performance, and timing constraints. Asian countries that previously demonstrated success in electronic packaging and assembly are now actively engaged in research and development related to fusing technologies and acquiring the core competencies needed to excel as system integrators. Electronic components are increasingly being integrated onto the chip, flat panel display technology is being integrated with the electronic drivers, optics and electronics are becoming tightly coupled, and hardware and software are being integrated to produce optimal system solutions.

Much has been written about the globalization of the electronics industry, but it would be more accurate to speak about the concentration of the electronics industry in the Pacific Rim. In the past, U.S. companies like Intel, TI, Motorola, and IBM established facilities in Asia to exploit the opportunities for low-cost assembly and manufacturing. U.S. contract manufacturers such as Solectron and SCI now are establishing new facilities in Asia to be closer to their customers and to take advantage of infrastructures that are favorable to electronics manufacturing. In fact, all U.S. electronics companies are increasing their Asian investments in

R&D to take advantage of favorable industrial-government partnerships and engineering workforces that are highly motivated and well trained (frequently in the United States). While the Asian economies are admirably meeting the needs of foreign investors in the short term, their own long-term goal is to be able to call their own shots. So, as electronics technologies, products, and systems are undergoing explosive growth worldwide, the structures necessary to efficiently produce them are nowhere being as systematically and enthusiastically implemented as in Asia's emerging economies.

The dynamic changes taking place in Asia were very apparent to this WTEC panel on electronics manufacturing in the Pacific Rim; several panelists also participated in the 1994/5 JTEC study on electronics manufacturing and packaging in Japan. In the period between the two studies, there has been an accelerating shift in electronics manufacturing from the United States and Japan to Korea, Taiwan, Singapore, Malaysia, and China. Simultaneously, the infrastructures within these countries have continued to mature so that each country is now capable of participating in the full electronics product realization process. These countries have rapidly moved up the technology "food chain." Their firms have the capacity to produce name-brand products for their overseas customers while simultaneously marketing comparable products under their own names. As these five Asian nations continue to mature technically, the United States and Japan are increasingly dependent on their capabilities. It is also important to reiterate that the technology transfer process is continuing on to Indonesia, Thailand, the Philippines, and other Pacific Rim countries for the reasons described in this report.

Asia's Solid Position in the Global Electronics Manufacturing Environment

Manufacturing continues to be internationalized, with the objective of global rather than domestic business success. In some instances, the criteria for selecting manufacturing sites have shifted from low-cost labor to skilled-labor availability; from technology creation to processes used in technology exploitation; and from proximity to market to availability of transportation. Cost continues to be the primary consideration, but it is the cost of the *total process* from product conception to end-of-life that is the basis for management decisions.

The ability of nations to compete globally is not a function of size, as Korea, Taiwan, Singapore, Hong Kong, and Malaysia demonstrate. A primary source of wealth in these countries comes from the education and skill of their workers. In today's globally competitive environment, the best jobs go where the best-educated and most highly skilled workers are available. They are, in Lester Thurow's words (1992), "the dominant competitive weapon." On a more somber note Thurow writes, "In a global economy a worker has two things to offer — skills or the willingness to work for low wages." The countries of this study have worked hard to rapidly improve the education levels and skills of their workforces, enabling them now to engage in R&D, design, production, and marketing functions. Companies operating in these countries are generating economies of scale in the global market and designing products that are customized to the requirements of each market and an ever-changing mix of consumer preferences. They are globally successful businesses.

In order to gain greater access to the growing Asian market and take advantage of Asia's electronics competencies and attractive business climate, U.S., European, and Japanese companies are increasing their investments in Asia. This report identifies the following key factors that attract foreign investment to Asia:

- low-cost capital
- skilled and educated workforces, as well as low-cost workforces
- infrastructures that support rapid installation of new facilities
- local sources of all electronic components, and increased capability to support the total product realization process
- advanced telecommunication networks capable of supporting the global production enterprise
- new and improved transportation within and between the Asian countries
- tax laws favorable to business
- government programs that provide incentives to attract industry

- an infectious entrepreneurial “can do” spirit

The Changing U.S. Role in Asia’s Electronics Enterprises

What role will U.S. industry play in future development in Asia? The United States is an important trading partner in Asia, but the nature of that trade is changing. Whereas the United States once dominated the world markets for technologically advanced components and products, Asian nations have been aggressively acquiring from the United States intellectual and technical assets that empower them to compete strongly in those markets. Korea, for example, has 27 R&D facilities in the United States (Japan has 225); of these, 23 are focused on computers and electronics, and most of their research is applied and product-oriented. In addition, U.S. companies are moving research and development activities to Asia. Singapore ranked tenth for U.S. R&D investments abroad in 1993, and Hong Kong was sixteenth. Where Asian companies used to merely provide U.S. firms with cheap labor for labor-intensive component production and assembly, many are now becoming full system integrators and are selling their own brand name products. In Taiwan, Acer is one of the more notable among those companies that have successfully made this transition from contract manufacturer to original equipment manufacturer. It is a global federation of highly autonomous companies that makes almost everything itself and does assembly at 35 sites around the world.

Lewis M. Branscomb (1993) identifies the issues well:

> A leadership position in a technology, however exciting and important, does not, of itself, assure prosperity, a strong defense, or a clean environment. First, technologies must be mastered, reduced to practice, supported by cost-effective production processes, and introduced to the market. Then that market position must be sustained by appropriate complementary assets, by effective channels of distribution, and by responsive customer service. Even that, however, is not enough, for many innovative products have found strong initial markets, only to see other firms – sometimes in other nations – capture the lion’s share of market growth through incremental functional improvements, cost reductions, quality superiority, and better marketing and service….

The evolutionary and dynamic changes among the countries in East Asia are very accurately reflected in Branscomb’s statement.

The United States and Japan will continue to play dominant roles in Asia as long as they provide technology and provide significant markets for their products. Asian countries, however, are engaged in national planning and the implementation of long-term strategies that will make them less dependent on the United States and Japan and more capable of competing for an increased share of the global electronics market.

In every corporate boardroom, the question is being asked, “Where can we get the best deal?” In the electronics industry, the answer is “Asia.” This report helps to understand why and suggests that in order to improve the attractiveness of the United States as a country of choice for electronics manufacturing, U.S. leaders might benefit from the experience of the countries of this study in the following specific areas:

- improving government-industry partnering
- constructing a competitive educational system
- reducing the cost of capital for investors
- providing a more productive workforce
- improving investments in technology and exploitation of that technology
- attracting foreign investments through partnering in nationally-based production facilities

The following chapters provide information that will permit government and industry leaders to understand the need for improved collaboration to meet the global challenges to U.S. competitiveness, prosperity, and security that are presented by exponentially escalating Asian competence in electronics manufacturing. In the words of Winston Churchill we must come to realize that, "It is not enough to do our best; sometimes we have to do what is required." Readers of this report will hopefully better understand what is necessary to meet the associated challenges and then do what is required.

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CHAPTER 2

OVERVIEW OF ELECTRONICS MANUFACTURING IN THE PACIFIC RIM

William R. Boulton

INTRODUCTION

Electronics manufacturing technologies include all the materials, electronic components, assembly equipment, and processes required to produce electronic products. The range of technologies encompasses the design and packaging of semiconductor devices in both single and multichip configurations; the production of discrete and embedded passive devices and both flexible and rigid circuit boards used for mounting components; and the processes and equipment used for assembly and testing operations. The availability and configuration of these technologies determines the size, performance, cost, and style of the products that a firm can produce.

In a prior JTEC study published in 1995 (Boulton), it was clearly documented that low-cost electronics manufacturing provided the basis for Japan's past leadership in many of the key materials, components, and types of equipment used in the manufacture of electronic products. High-volume, low-cost electronic products are pushing the development of packaging-related component and process technologies far beyond their expected limits. Development of next-generation products has resulted in continued miniaturization with added functionality at existing cost levels. Today, miniaturization technologies that allow for increased functionality and higher-density assembly include multichip modules (MCM), ball grid array (BGA) chip packages, tape carrier packages (TCP), and direct chip attach processes.

Such process and component technologies are rapidly being globalized. U.S. semiconductor producers like Intel, Texas Instruments (TI), and Motorola have transferred significant R&D capabilities to countries in Southeast Asia. Leading U.S. contract manufacturers like SCI and Solectron have major production facilities in Singapore and Malaysia. Most major Japanese firms have established production operations throughout Asia. In addition to transfers of technologies into Southeast Asia by leading U.S. and Japanese firms, domestic companies in the Republic of Korea (hereafter referred to as "Korea"), Taiwan, Hong Kong, the People's Republic of China (PRC or simply "China" in this report), Singapore, and Malaysia all are fully exploiting advanced manufacturing technologies. Nam Tai in China and Inventec in Taiwan, for example, use wire bonding for inner lead chip attachment and tape carrier packages with outer lead chip attach processes to assemble personal digital assistants (PDAs). The rapid acquisition of these advanced production processes by Asian counterparts drives U.S. and Japanese electronics firms to continue to pursue new areas in which they can assert their technological leadership.

Low-cost manufacturing leadership of computers has now transferred to countries outside of Japan and the United States. For example, Hitachi, one of the world's technological leaders, has outsourced personal computer production, since this no longer requires "advanced technologies." In 1995, Taiwan's production share of computer components like motherboards, mice, and keyboards ranged from 64-72% of the world market. In newer technologies like network cards, CD-ROMs, graphic cards, and portable PCs, Taiwan's market share ranges from 11 to 38%. Three of the world's largest notebook computer makers, Acer, Inventec, and GVC, are Taiwanese companies. China's leading domestic producer of desktop computers, Legend's QDI, is headquartered in Hong Kong. Japanese firms, having lost their ability to economically assemble low-cost products, are now concentrating on exporting their advanced technologies in the form of electronics materials, components, and high-precision assembly equipment. Japan's surface mount technologies (SMT) are available globally. Taiwan also has benefited from its own technological capabilities. Its largest export destination, Hong Kong, accounted for over 26.2% of Taiwan's exports in 1995, with 60% being materials and components to be used in China.

Korea, Taiwan, and Singapore are rapidly upgrading their production capabilities to use advanced components and process technologies. Governments in these three countries are committed to advancing electronics technologies by supporting developments in production equipment and related materials and components. Samsung in Korea, Oriental Semiconductor Electronics (OSE) in Taiwan, and NatSteel in Singapore use government support to advance their production capabilities. Samsung, Korea's largest conglomerate and the world's leading producer of DRAMs, also produces SMT equipment. OSE designs and produces multichip modules in BGA packages, and assembles TCP cards for notebook daughter cards[1] and PCMCIA cards. NatSteel now uses TCP and SBB (stud bumping bonding) flip chip assembly processes.

These same advanced process technologies are now being moved into China. Nam Tai (headquartered in Hong Kong with production facilities in China) has acquired advanced wire bonding and TCP capabilities, along with top management techniques and Japanese and Taiwanese managers, to produce Sharp's low-end PDA in China. Wong's Electronics (headquartered in Hong Kong with production facilities in China) has cooperated with NEC to produce its newest Pentium desktop motherboard in China. Depending on a product's labor intensity, Wong's Electronics can cut product costs 30-70% by using Chinese products, parts, and assembly. Labor-intensive processes like through-hole insertion of components onto printed circuit boards (PCBs) are more economical in China due to use there of low-cost assembly workers rather than automated equipment. Companies throughout Asia are now transferring most of their PCB assembly of peripheral cards and motherboards for desktop computers to China, where factory workers earn about $65 per month for 72-hour work weeks, compared to $750 per month for 48-hour work weeks in Taiwan and $1,500 per month for 40-hour work weeks in Japan.[2] One Japanese customer now builds its prototypes in the WKK factory in Shenzhen.

COMPETITIVE PRODUCT REQUIREMENTS

Competition in electronics manufacturing is based on ability to deliver products that meet current market requirements. Requirements for electronic manufacturing are determined by (1) size and weight dimensions (millimeters and kilograms) of components and final products; (2) functionality and performance levels (number of functions, capacity and speed of operation, and energy consumption); (3) product shape (complex assembly using flexible or hard circuit boards to fit complex geometries), ergonomics, and aesthetics (use of precision plastics); and (4) cost of the final product (low-cost assembly and component sourcing).

1. Overall Size and Weight Limitations of the End Product

Portability increasingly is driving product demand and technological developments. Portable audio components accounted for 310,000 of 410,000 total domestic mini-disk and compact disk player shipments in Japan in 1994. In 1995, of an estimated 860,000 total units, 640,000 were portable (Yano 1994, 732). Sony pioneered production of portable consumer products like the Walkman, Handycam, and Discman. Each succeeding product generation has been smaller and lighter in weight. For example, Sony's first model of

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[1] Due to the rapid decline in microprocessor prices, notebook computer manufacturers have designed separate printed circuit boards to hold the Pentium microprocessor, which comes in a TCP format. These TCP cards are assembled on separate production lines and can be purchased separately by notebook manufacturers that lack TCP process technology.

[2] All dollar figures ($) are U.S. dollars, unless otherwise noted.

Handycam, released in 1985, weighed 1,970 grams; the models of ten years later weighed under 800 grams, a 60% reduction (Kaneda 1994). The drive to miniaturize products has spread from consumer products like video recorders and electronic games, to computers and to telecommunications and industrial products. Evolution of all handheld products like PDAs, palmtop computers, cellular telephones, walkie-talkies, and electronic testing equipment is driven by requirements for reduced size and weight.

Portability requires miniaturization technologies. MiniDisc for audio, made by Sony in 1994, achieved 73.8% coverage of the printed circuit board. This was a 40% improvement in SMT placement efficiency. The smallest resistors and condensers in use are 1005 (1.0 mm by 0.5 mm) and 1008 (1.0 mm by 0.8 mm), respectively. The primary applications include Handycams, cellular telephones, minidisks for audio, cameras, prepaid cards, and pagers. Cellular telephones and personal communication systems are now driving ongoing miniaturization efforts. Cellular telephones, over 1,100 cm^3 in 1985, have now reached 106 cm^3 in volume. IC (integrated circuit) circuit integration and high-density PCB assembly are common methods used to meet product miniaturization requirements.

Key electronic components are those that impact miniaturization, power savings, improved reliability, and lower costs. For example, smaller and lighter products require multilayer passive components like voltage-controlled crystal oscillators (VCO) with monolithic multicomponent ceramic substrates, tape-carrier packages, low-profile or thin quad flat packages, and small-sized, high-energy-density lithium ion batteries for consumer electronics. TDK reduced the size of its VCO for use in cellular phones by 96% in seven years, down from 26 x 17 x 10 mm to 10 x 7 x 2.5 mm (Okamoto 1994). The move to miniaturized components has resulted in lower power consumption. Lower energy consumption in today's electronic packages allows for smaller batteries and/or extended battery life. The growing demand for portability has also stimulated the demand for lower energy-consuming components like liquid crystal displays (LCDs). LCD screens are being developed from plastic rather than glass to reduce weight. Japan is the world leader in production of LCDs for lightweight, portable products.

Miniaturization has pushed traditional process and component technologies to their physical limits, requiring new materials and processes to be developed to provide ultra-small and ultra-lightweight components. Both epoxy and ceramic materials have been developed for alternative semiconductor packages. "Clean pellet" molding materials offer less volatility and better moldability. With the move to fine-pitch lead packages, new solder pastes have been developed using fine spherical-grain metal powders rather than irregular-grain powders. New materials and laminates have been developed for use in thinner and multilayer PCBs.

In parallel with materials developments, new processes and equipment have been developed for the production of smaller and thinner IC packages and their downstream assembly. Today's assembly requirements increase demands for advanced equipment. For example, the laser diodes used in CD players (0.2 x 0.25 x 0.12 mm in size) require ultra-precise mounting equipment to place the laser chip on a silicon wafer. Sharp's PDA uses TCP assembly for the microprocessor and wire bonding to attach its chip set directly to the PCB. Miniaturized components require higher-precision assembly technologies. Need for improved soldering performance has driven firms to move from wave soldering to reflow soldering methods. BGA components are becoming popular because of their larger pitch, which is less demanding and more robust in final assembly but allows for further downsizing of SMT devices.

The limits to miniaturization are determined by the size of constraining component technology. For example, the Walkman's or Discman's size is based on the dimensions of the cassette tape or CD used, the size of sub-notebook computers is limited by keyboard and monitor dimensions, and pen-based PDAs are limited by the dimension of their input screens. New component form factors, such as mini-cassettes, mini-CDs, butterfly keyboards, or pen-based LCDs, allow for "next-generation" products and lead to further demands for miniaturization. In fact, space limitations in most countries generate greater demand for smaller products than is the case in the United States. Desktop computers are still in large demand in the United States, while smaller notebook formats are the best sellers in Japan. In the United States, on the other hand, portable weapons systems, cellular telephones, and pagers have driven size and weight reductions. However, the demand for miniaturization is spreading across industries as technologies become more integrated.

2. Functionality and Performance of the End Product

Advanced performance and function have historically been driven by products like supercomputers and satellites. New products include advanced technologies and performance, i.e., global positioning systems, mobile satellite communication equipment, high-definition TV, and fuzzy-logic-controlled microwave ovens. The move into multimedia products will demand ever increasing functionality with integrated multiple technologies. For example, CD players and mini disk (MD) player/recorders use optical pickups and get their digital signal from laser diodes (Kaneda 1994).

The simple integration of multimedia technologies into consumer products has begun to define Japan's future product strategy and is known as AVCCC — the combination of audio, visual, computers, communication, and controllers. For example, Sharp Corporation had introduced a wide-screen TV with on-demand news reports. Sharp's ViewCam has been introduced with a teleport for sending still pictures over analog telephone lines to other ViewCams. Sharp's Zaurus uses infrared light to send facsimiles or to provide wireless communications between computers and printers. Next-generation products can be expected to integrate more combinations of technologies into single products, like the combination printer-scanner-copier-facsimile machines introduced over the past several years, or Sharp's combination TV/VCR sets. Once integration occurs, the process of miniaturization and weight reduction continues. Technologies like voice recognition, superconducting circuits, medical lasers, terrestrial satellite navigation, and advanced security systems are promising to lead to even more advanced product possibilities.

3. Shape and Aesthetic Requirements of the End Product

Final end-users require advanced styling, such as seen in today's cameras and electronic games. The Japanese dominance of the single-reflex and video camera markets has led to the development of advanced flexible circuit boards that mold around a shapely camera body. Canon, Minolta, and Nikon cameras all use complex flexible circuit boards. Firms are developing multilayer flexible printed wiring boards (PWBs) to accommodate advanced product form factors. The latest Sega and Nintendo electronic games include stylish joystick controllers. New stereos utilize the latest materials and modular designs for maximum aesthetics.

4. Cost Requirements of the End Product

The United States has not been competitive in producing low-cost products like audio, video, or entertainment equipment. Advanced "Star Wars" technologies are typically expensive and seldom meet the cost requirements of high-volume, low-cost electronic products. Japan's leadership in low-cost consumer markets also has experienced some deterioration with the increasing value of the yen and rising cost structures. Products like personal computers and related components and products are highly cost-competitive. Sales of video players, electronic games, musical instruments, and home electronics rely on offering consumers ever increasing capabilities at continued low prices. Many Japanese firms now manufacture such products in China to stay competitive. Continued Japanese competitiveness is dependent on manufacturers being able to effectively redesign products and integrate components to reduce part counts in assembly. For example, Sony cut the number of parts in its optical pickup from 8 to 2, allowing drastic cuts in the unit's weight and cost. Innovative designs and high levels of electronic integration can typically cut costs from 30-70% (Kaneda 1994).

For labor-intensive electronics products requiring standard SMT assemblies, most Asian countries can now produce at lower cost than can Japan or the United States. The transfer of production from Japan or the United States to China allows for a further 30-70% in cost reductions derived from local parts sourcing and low-cost production. China is becoming the most competitive producer due to its extremely low labor costs combined with its access to advanced electronic manufacturing technologies. Over 8,000 foreign companies have already established facilities in China in an effort to stay competitive. Once a product begins production in China, market prices can be expected to rapidly decline, and, correspondingly, the profit margins of higher-cost producers can also be expected to decline.

ALTERNATIVE MANUFACTURING STRATEGIES

Manufacturing strategies depend on both product and process technologies, including materials, components, design, equipment, process type, operator skills, and economies of scale. Strategies also depend on the type of manufacturer: contract manufacturer (CM), original design manufacturer (ODM), or original equipment manufacturer (OEM). All three types exist in the countries of this WTEC study, and, in fact, are in a dynamic state of flux, some evolving rapidly from CM to ODM to OEM even as new contract manufacturers enter the market.

Roles of Contract Manufacturers, ODMs, and OEMs

Contract Manufacturers (CMs)

Contract manufacturers produce proprietary products for OEM customers. Many contract manufacturers began as suppliers of standard parts and components. By adding assembly equipment and test capabilities, these vendors can produce more advanced components, like motherboards, or completed products to meet OEM customers' specifications. As contract manufacturers increase their design capabilities, they seek to add additional value to their customer's products. Design for PCB assembly is a major step in developing overall product design capability. Japanese and U.S. firms are using experienced high-volume, low-cost contract manufacturers to redesign existing products for cost reduction. PCB design and decisions to outsource plastic and metal parts and other electronic components are being given to contract manufacturers, as shown in the Japanese flow chart below (Fig. 2.1). U.S. and Japanese firms still reserve the right to evaluate the end products and processes for quality and reliability. ISO 9000 certification of contract manufacturers helps to ensure consistency of results.

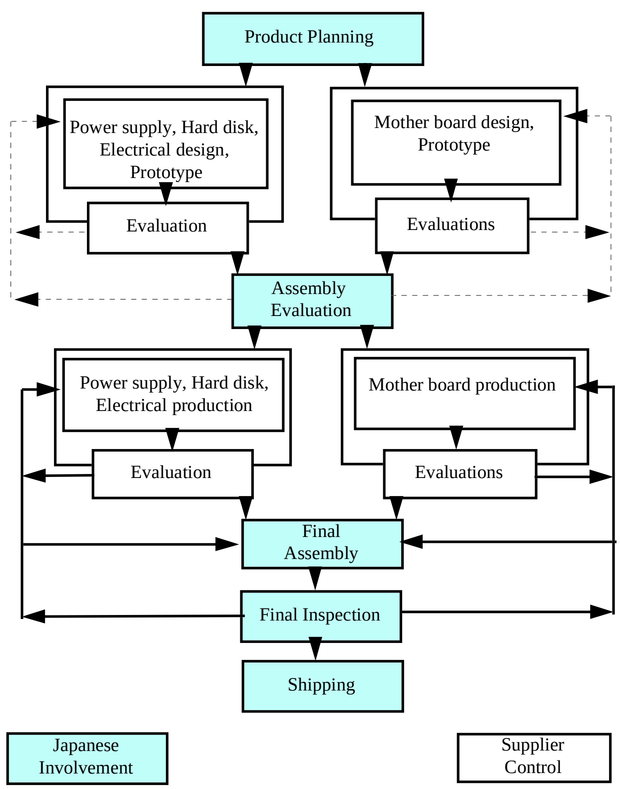

Fig. 2.1. Changing role of Japanese computer makers in component evaluation (*Nikkei Electronics* 1995, 88).

Original Design Manufacturers (ODMs)

ODMs are contract manufacturers with product design capabilities. ODM firms provide "ready to go" products for their OEM customers. Many Japanese firms, like Sharp, Hitachi, Canon, and NEC, and U.S. firms, like Xerox, Compaq, and Apple, began outsourcing production to contract manufacturers in order to reduce product costs. ODM firms can then reduce development time for new product models by creating "ready-to-go" products for their customers. The most advanced contract manufacturers get early signals about market shifts and technology development that they can integrate into advanced products. By the time OEM customers recognize the need for new product concepts, ODM firms already have products ready to market. ODM producers only need to add the customer's brand name and then proceed to manufacture in volume.

ODM competitors must be able to produce leading-edge products. In information products, leading-edge products require advanced component technologies like LCDs; TCP and PCMCIA cards for use in notebooks; high-density assembly using direct chip attach for personal computers and organizers; and high-density storage and memory devices. Multimedia products that combine scanners, printers, copiers, and facsimiles, for example, increase product complexity. With the growth in communications, products must be compatible across a broad range of software and hardware networks. Compatibility testing has become a critical requirement for firms supplying ODM products. The most aggressive ODM firms are developing products that incorporate the latest available technologies so that customers can cut development time for new product designs and production by three to six months. The availability of ready-to-go products gives the ODM competitor a definite advantage over the low-cost contract manufacturer in building close relationships with global customers. By also establishing low-cost facilities in China and the Philippines, ODM firms in Taiwan, for example, can further cut production costs for their customers.

Evolution from Contract Manufacturer to ODM

Growth of low-cost contract manufacturing in countries like China and the Philippines is forcing Korean, Taiwanese, and Singaporean vendors to increase their ability to add value through manufacturing of leading-edge products or advanced product design capabilities; that is, to assume the role of ODMs. Taiwan's Inventec, an ODM producer, makes Apple's Newton (PDA) and provides Compaq with its high-end LTE 5000 series notebook computers, both as ready-to-go products. GVC, another ODM vendor in Taiwan, grew from sales of $110 million in 1992 to $800 million in 1995, and, at the time of the WTEC visit, had plans to double sales in 1996. Design capabilities have allowed ODMs to produce higher-value-added products. Design is dependent upon highly trained and experienced design engineers who are fluent in the latest technologies and able to integrate a full range of electronic components and technologies.

Original Equipment Manufacturers (OEMs)

Fully integrated firms that design, manufacture, and sell their own "brands" under registered trademarks are referred to as original equipment manufacturers (OEMs). While such companies are well known in the United States, Europe, and Japan, OEMs are now growing in the rest of Asia. For example, VTech, the largest manufacturing firm based in Hong Kong, holds over 50% of the world's market in electronic learning aids and toys. Legend Holding's QDI subsidiary holds a 15% share of the Chinese personal computer market. QDI creates its own designs, test procedures, and process layouts for both computer add-on cards and motherboards. Acer, the largest and most well-known OEM producer of desktop and notebook computers in Taiwan, ranks eighth in the U.S. PC market. Samsung is the leading supplier of personal computers in Korea. Today, the vast infrastructure of Asian component and equipment makers has led to an increased number of new OEM companies throughout Asia.

<u>Brand Names</u>. Marketing and design skills are the primary domain of global firms whose brands are recognized throughout the world. Outsourcing to CM and ODM vendors still requires market research and channel management by global brand leaders. With growing costs of after-sales service, design for manufacture (DFM) requires tighter relationships between the OEM design teams and their vendors. The

increasing success of ODM vendors reduces the need for tight customer-vendor communications and allows the brand leader to focus more attention on gaining market access and share. In fact, contract manufacturers, like Nam Tai and Wong's Electronics in Hong Kong, ship finished goods directly to their customers' designated destinations.

Marketing and Sales. Global leaders command markets around the world with marketing channel control, brand reputation, and customer brand loyalty. Names like IBM, TI, and Compaq are well known. Only companies with the most advanced technologies, able to gain first mover advantages, are likely to break into established markets in the future. The value of recognized brands makes it difficult for new entry into established markets. However, Korea's Samsung and Goldstar are developing globally recognized names, as are Acer in Taiwan, and VTech in Hong Kong. Market leaders are driven by customer satisfaction and the continued development of market and related distribution channels. Market intelligence keeps them close to their customers and helps in forecasting product demand, planning production ramp-up, and minimizing related stockouts. The majority of contract manufacturers and ODM suppliers do not have recognizable brand names or direct access to markets or end users. They only serve as product providers. However, as brand leaders increase their dependence on ODM suppliers, they risk creating future competitors. Acer, for example, began as a contract manufacturer and now has a globally recognized brand name.

Customer Service. Brand reputation is based on the relative life and dependability of a firm's products. Rapid response to customer problems is an important competitive requirement. Customer service centers are required for branded products like copiers, computers, and automobiles that need repairs, servicing, or upgrading. Most manufacturers provide warranties and product replacements through national service centers of the brand holder. Effective communication is required to correct the source of market failures. Companies like GVC in Taiwan get daily feedback from U.S.-based engineers who analyze product failures. This information is used to take corrective action. To prevent serious field failures, OEM and ODM firms attempt to identify potential problems with products before they get shipped into the field. As a result, quality assurance activities are central to firms' long-term success.

COMPETITIVE CAPABILITIES

Across Asia, competitive strategies and technologies are driven by consumer product requirements. In assessing the levels of capabilities of electronics manufacturers in the countries that the WTEC panel visited, the following measures of capabilities proved to be useful: product design, process automation, next-generation technologies, communications, and capital.

Product Design

The firms visited during this WTEC study include contract manufacturers like WKK in Hong Kong, OSE in Taiwan, and NatSteel in Singapore; ODMs like GVC and Inventec in Taiwan; and OEMs like Legend in China, Acer in Taiwan, and Samsung in Korea. Contract manufacturers in Asia are experienced low-cost producers. However, rising labor and infrastructure costs are forcing contract manufacturers in Taiwan, Singapore, and Korea to increase their value-added activities. In their move to become ODM vendors, contract manufacturers like WKK and Wong's Electronics in Hong Kong are developing product designs in cooperation with their customers. More advanced ODM suppliers, like GVC and Inventec in Taiwan, design ready-to-go products. OEMs like Acer, Samsung, and Legend supply their own brands into the market. The movement from contract manufacturer to ODM is a long-term transition that requires significant upgrading of engineering talent and related design and materials technology. Inventec, for example, has used its technology to become the largest maker of electronic dictionaries in Taiwan and China, selling under its own "Besta" brand name.

Process Automation

The growth in competition based on low-cost labor requires increased automation and related capital investments by firms located in higher-cost countries. Sources of low-cost manufacturing have shifted over the years from the United States to Japan to the newly industrializing economies (NIEs) of Asia. Korea and Taiwan were the low-cost sources of labor in the 1970s, to be replaced in the early 1980s by Singapore and Malaysia, and in the late 1980s and 1990s by China and other less-developed countries of Asia.

As Hong Kong's labor costs increased, contract manufacturers moved their facilities into China in the mid-1980s, particularly for those labor-intensive processes where inexpensive manual labor is most cost-effective. For example, in China, most PCB assembly of through-hole components is done manually because Chinese factory workers earn such a low average wage. However, production of more advanced electronics products requires more sophisticated manufacturing technology and equipment than what can be produced solely with manual labor. Today's electronics products require surface mount devices (SMD) to achieve smaller product size and lower weight. While capital equipment investment is costly, SMD assembly cannot be done manually, so today, surface mount technology (SMT) is used throughout Asia. In the mid-1980s, Wong's Electronics was the first Hong Kong contract manufacturer to install surface mount assembly equipment in China. With increasing product sophistication, the amount of labor-intense through-hole assembly has declined. It is still used for most electronic toys and products not driven by miniaturization requirements.

Production in countries like Japan and the United States must be machine-intensive to minimize the content of high-cost labor. Increasing machine intensity requires using designs that minimize the number of through-hole components and/or using equipment with vision systems for placement of through-hole parts. Companies in Korea, Taiwan, and Singapore are making the transition from labor-intensive to machine-intensive operations. To stay cost-competitive, Taiwanese electronics manufacturers have installed capital-intensive "long-lines" (i.e., two chip-mounters and one chip-placement machine) for SMT assembly. Long lines are 50% more efficient than short lines. Final assembly remains labor-intensive, but through-hole assembly is minimized and automated. The most automated companies, like Inventec in Taiwan, are machine-intensive. For example, Inventec reduced the use of through-hole components using Universal placement equipment for its remaining through-hole placements that incorporates the equipment needed for remaining through-hole spot flow soldering. Throughput was increased by over 40%. Nan Ya Plastics' PCB fabrication facility has been fully automated with computer integrated manufacturing, except for visual inspections where cosmetics are critical to customer acceptance. Table 2.1 shows the general relationship between labor-intensive and machine-intensive production in countries capable of varying capital investment.

Table 2.1
Relationship Between Capital, Labor, and Machine Intensity

Capital Intensity Level	Labor Intensity	Machine Intensity
Level 1: Less developed countries	> 75%	< 25%
Level 2: Developing countries	50-75%	25-50%
Level 3: Newly industrialized countries	25-50%	50-75%
Level 4: Developed countries	< 25%	> 75%

VTech's assembly of electronic toys in China was virtually 100% manual at the time of this study. More advanced computer, telecommunication, and consumer electronics products were being assembled with SMT equipment. VTech, WKK, QDI, and Wong's Electronics all used SMT "short-lines" (i.e., one chip-mounter and one chip-placement machine) for advanced PCB assembly. SMT lines operated 24 hours per day using two 12-hour shifts, six days per week. It is by leveraging low labor costs with a minimum level of equipment investment that China maintains a minimum cost structure. To stay cost-competitive in China, Wong's Electronics is investing in dedicated SMT lines for high-volume customers.

Yamaha, Fuji, Panasert, and Universal SMT equipment is available across Asia. WKK is the agent for Yamaha SMT equipment in Hong Kong. Due to rapid growth in the Asian electronics industry, engineers are in short supply. China's close proximity to Hong Kong has allowed engineers to work in China during week days and return to Hong Kong and their families on the weekends. When technical problems occur, engineers can quickly be summoned within a day to help. WKK has provided a wide support system for its customers in Hong Kong and China. Once a process has been established, it can be operated by locally trained engineers in China, who earn about $260 per month.

Most Hong Kong SMT operations are being transferred to China. The concern for the future of jobs in Hong Kong has caused the government to provide incentives for local firms to upgrade their technologies and increase their process capabilities. China's continuing attraction of companies with advanced technologies is a serious threat to Hong Kong's competitiveness.

Taiwan is the largest market for SMT equipment and receives special discounts amounting to around 20%. Taiwanese firms have moved manufacturing of most of their more labor-intensive products, like desktop motherboard assemblies, to countries like China, Malaysia, and the Philippines. At the time of the WTEC visit about 25% of Taiwan's factory labor came from the Philippines. Increasingly, new facilities are being transferred to the Philippines to utilize its Taiwan-trained workforce.

Next-Generation Process Technologies

While SMT technology is mature and globally available, more advanced TAB and "direct chip attach" assembly technologies are not as widespread. Notebook computers, PDAs, and PC cards use TAB technology for miniaturization. The more advanced "direct-chip-attach" technology allows for further miniaturization. TAB technology was first used by Inventec in Taiwan in the assembly of Apple's Newton PDA. Hitachi recently announced that its next generation of thin and lightweight notebook computers will be produced in Japan using direct-chip-attach technology. TAB and direct-attach technologies require more sophisticated engineering capabilities. BGA packages were also being used for new Pentium chip sets at the time of the WTEC visits.

Access to advanced TAB and BGA components and assembly equipment determines the gap between production capabilities across Asia. These newest processes are engineering-intensive in their startup phase. Oriental Semiconductor Electronics (OSE) in Taiwan licensed TAB technology from Intel. OSE's engineers were trained at Intel, and then Intel's engineers provided on-site help at OSE. Due to early quality problems, these new technologies are generally established as independent engineering operations that require intensive levels of inspection and adjustments. NatSteel in Singapore uses SBB direct chip attach technology. Nam Tai in China uses TCP and inner lead wire bonding for direct attachment of chips.

While Taiwan once had the highest ratio of engineers to production workers of Asia's rapidly industrializing economies, Singapore now matches Taiwan, with about 16 new engineering graduates per 1,000 manufacturing employees. Korea is third with 10, and Hong Kong and China have under three engineers per 1,000 manufacturing employees.

To achieve the kind of technological leadership provided by Japan, countries must also develop the materials and components used in next-generation products. That requires much higher levels of R&D than is typically found in Hong Kong, China, or Malaysia; however, Korea, Taiwan, and Singapore are increasing domestic R&D in order to develop key electronics technologies. Future miniaturization requirements include direct chip mounting and multichip modules. In Taiwan, OSE is packaging MCMs and establishing four lines to produce BGA chip set packages as it climbs the technology ladder. Taiwan's Industrial Technology Research Institute (ITRI) has a research project for fine (.25 μm) line process technology. To meet finer pitch assembly requirements, Matsushita Kyushu and Toshiba have developed SMT and TAB equipment capable of assembling 0.15 mm-pin chips. Such fine pitch placement allows 800 pins on a 32 mm package, 1,000 pins on a 40 mm package, or 384 pins on a 16 mm package. Ceramic multicomponent modules (CMM) that integrate passive and active components are little larger than encapsulated ICs (Keizer and de Wild 1994).

Communications

No printed circuit board assembler can expect production to last over six months for today's products. Short life cycles are forcing firms to be more responsive in providing product quotes to and communicating with their global customers. Standard design software allows for rapid transfer of design data files between clients and vendors by electronic mail. Leading firms across Asia use leased lines and intranets between their operating units around the world to facilitate communications.

Capital

One barrier to competition is often capital; however, many of the countries of this WTEC study find themselves with excess financial resources to invest. Early investments in China allowed for sustained profit margins in high-growth industries like computers, telecommunications, and related parts and components. With growing competition, more capital-intensive strategies are now being pursued. In Taiwan, petrochemicals and semiconductor fabrication operations (fabs) are two industries with heavy investment requirements. Formosa Plastics, Taiwan's largest conglomerate and a world leader in high-quality textiles, is currently building a complex that will include an oil refinery, two naphtha cracking plants, and 27 chemical plants. The Singapore and Taiwan governments are providing additional incentives to build wafer fabrication facilities (fabs), where historical profits have been about 35%. By 2002, Singapore and Taiwan together plan to have over 40 wafer fabs, compared to 10 in 1995. At an estimated cost of around $1 billion per fab, these are truly capital-intensive investments. Hong Kong has discouraged such investments due to limited land availability.

ASIA'S ELECTRONICS MANUFACTURING INFRASTRUCTURE

Japan has been the undisputed leader in the Asian electronics manufacturing industry. With eminent components and equipment capabilities, Japan provides much of the technology needed for the manufacture of advanced electronics components and products. As shown in Fig. 2.2, Korea and Taiwan are much smaller second- and third-place followers in electronics. Singapore, China, Hong Kong, Malaysia, and Thailand follow, in that order. Each of these countries' governments plays an important role in defining and focusing economic development plans based in substantial measure on growing their national electronics industries.

Beginning in the mid-1980s, rising costs prompted Japan to transfer its electronics manufacturing base to the newly industrialized economies of Asia (Korea, Taiwan, Hong Kong, Singapore, and Malaysia), and that transfer process has continued in the region. As part of the Asian countries' development processes, they have worked out various kinds of cooperative agreements among themselves. Deregulation of international trade has been central to the development of cooperative "growth triangles" across Asia, which have been an integral part of the high levels of technology transfer and the corresponding rapid economic growth of the various national partners. Japanese overseas direct investment between 1986 and 1990 set the stage for much of the technology transfer that has taken place. During that time, Japan invested over $27 billion in the countries of the Association of Southeast Asian Nations (ASEAN), whose original members were Singapore, Malaysia, the Philippines, Indonesia, and Thailand. Indonesia received $11.5 billion, Singapore $6.5 billion, Thailand $4.4 billion, Malaysia $3.2 billion, and the Philippines $1.5 billion. Japan also invested $2.8 billion in China.

The earliest beneficiaries of Japan's technology transfer, Korea, Taiwan, and Singapore, now find themselves facing cost problems similar to those of Japan in the early 1990s. As rapidly rising incomes and living standards pushed up labor costs, initial attempts to maintain the manufacturing base in Korea and Taiwan led to heavy investment in factory automation and capital-intensive industries. Labor-intensive manufacturing, as mentioned earlier, is rapidly moving to China, the Philippines, Thailand, and Indonesia. As the current benchmark for low-cost manufacturing, China is forcing the NIEs to move into higher-value-added products, development of proprietary technologies, and investment in capital-intensive businesses such as IC wafer production, IC packaging, or precision manufacturing.

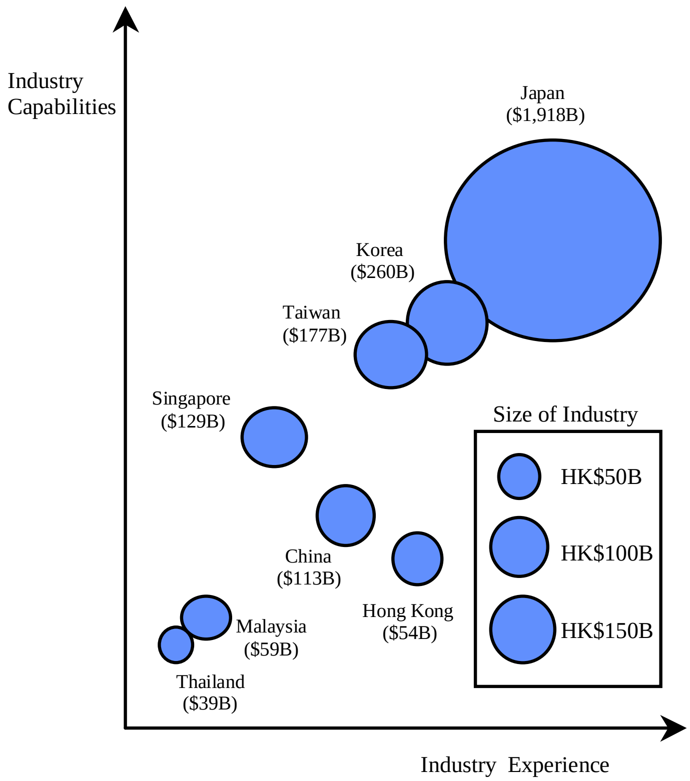

Fig. 2.2. Evolution of Asia's electronics industry (BCG 1994).

The shift from basic assembly, which has the lowest level of value-added, requires production of critical components and parts like semiconductors, LCDs, and precision assembly equipment. National policies have been established to subsidize R&D and encourage capital investments in automation and manufacturing facilities. Development of component technology and manufacturing ability provides for higher levels of value added and greater opportunities to gain market positions in global markets. The success of Asian industrialization is based on such value-added developments.

The long-term strategies of many of Asia's newly industrialized countries include (1) increasing their self-sufficiency, thereby reducing reliance on foreign, mostly Japanese, materials, components, and equipment imports; and (2) rapidly transferring labor-intensive operations into neighboring countries with lower labor costs, mostly to (but not limited to) China, which has over 1.2 billion people with average incomes under $400 per year. This movement has facilitated development of the regional economic trade and development zones known as economic polygons or triangles. At the same time, availability of advanced components and equipment on the open market allows China's (or other countries') firms to easily upgrade their production capabilities to sustain long-term competitiveness. The competitive pressures to upgrade technological capabilities directly challenge Japanese and U.S. high-technology leadership. Development of the Internet provides for even more rapid transfers of technology than in the past and will challenge even the best firms to keep pace.

Asia's Electronics Market Segments

The four major business segments in the electronics industry are (1) consumer electronics, (2) computers and peripherals, (3) telecommunications, and (4) parts and components. Table 2.2 shows the values of Asia's electronics industry segments in the early 1990s. Japan's production values in computers, peripherals, parts, and components accounted for 74% of its electronics production value; Korea's industrial products and parts and components accounted for 81% of electronics industry output; Taiwan's parts and components accounted for 50% of output, and computers and peripherals accounted for another 30%; Singapore concentrated on computers and peripherals (48%) and parts and components (30%); China produced mostly low-cost consumer electronics (45%) and related low-cost parts and components (38%); Malaysia concentrated on the parts and components business (57%); Hong Kong was balanced between consumer electronics (38%) and computers and peripherals (37%); and Thailand was focused on computers and peripherals (42%) and the parts and components business (30%). The recurrent emphasis on parts and components indicates the importance countries place on being able to locally supply their own parts and components, essential to being able to provide higher-value-added products and to limiting trade deficits due to importing the components required for final product assembly. Strong brand names do little to develop a strong economy if most components and end products are imported.

Table 2.2
Production Value by Electronics Industry Segment and by Country (1990-1992)

Country	Consumer Electronics	Computers & Peripherals	Telecom-munications	Parts and Components	Total Production (HK$ billions)
Japan	6%	38%	20%	36%	1,918
Korea	19	51%		30	260
Taiwan	10	30	10	50	177
Singapore	15	48	7	30	129
China	45	6	16	38	113
Malaysia	21	22%		57	59
Hong Kong	38	37	6	19	54
Thailand	17	42	11	30	39

Source: BCG 1994, 151-200.

Shortage of skilled labor in electronics businesses is a chronic problem across Asia. China has well-educated but inexperienced engineers. Only Japan and Taiwan have adequately skilled technicians. Shortages are most acute in Thailand, Korea, Malaysia, and Singapore. Lack of experience limits countries' capabilities in R&D and product design. According to the Boston Consulting Group (1994, 189), "Besides Japan, whose electronics industry is highly capable in all respects, only Taiwan and Korea can boast a significant sector of the industry with high-level capabilities in product innovation and design. Singapore is working hard toward this end, but is yet to reach the overall standard of these industries." While all countries have some value-adding capabilities, the majority of cost-based competitors are found in Thailand, Malaysia, China, and Hong Kong.

Asia's Electronics Capabilities

Production of electronics-based products has been growing in strength as a basis for industrial development throughout Asia. Japan and the United States have provided much of the technology needed for Asia's economic development in electronics businesses. This technological strength comes from long-term investments in R&D. Japan now invests 3% of its GDP in R&D, and the United States invests 2.7%. As a result, the majority of technology has come from Japan and the United States, with Korea and Taiwan only recently building technological strength. Korea and Taiwan are committed to building their technological strength as they increase their R&D investments, respectively, to 2% and 1.7% of GDP. Only France, Germany, and Britain have a comparable or a larger percentage of GDP invested in R&D than Korea. Other Asian nations still invest less then 1% of GDP in R&D.

In the area of fundamental research and development, Japanese electronics industries lead the world in technological innovations and new product introductions. The 1994 BCG study for the Hong Kong government assessed the areas of research and development, design, manufacturing, and marketing and sales capabilities for Asian nations (Table 2.3). Japan set the benchmark for these comparisons and was considered "leading edge" in all skill areas. According to the BCG study, Korea was ranked strong in R&D, design, and manufacturing, but only moderate in marketing and sales capabilities; Taiwan has capabilities similar to those of Korea (strong in design and manufacturing), but with only moderate R&D, marketing, and sales capabilities; Singapore was considered to be still weak in R&D, marketing, and sales, but with strengths similar to Korea and Taiwan in design and manufacturing (BCG 1994, 189).

Table 2.3
Electronics Industry Capabilities of Asian Countries

Country	R&D	Design	Manufacturing	Marketing & Sales
Japan	Leader	Leader	Leader	Leader
Korea	Strong	Strong	Strong	Moderate
Taiwan	Moderate	Strong	Strong	Moderate
Singapore	Weak	Strong	Strong	Weak
Hong Kong	Negligible	Moderate	Strong	Weak
China	Negligible	Weak	Moderate	Weak
Malaysia	Negligible	Weak	Moderate	Weak

Source: BCG 1994, 189.

Japanese, Korean, Taiwanese, and Singaporean strategies in electronic-based industries are focused on building value-based capabilities. Value-based competition is defined in the equipment and components capabilities of a country; Japan, Korea, Taiwan, and Singapore have invested heavily in these sectors. These strengths that require up-stream developments of technology are closely related to research and development of advanced manufacturing processes. Development of advanced materials and manufacturing processes are required in order to support leadership in components. Japan continues to be the primary source of many key components and equipment that are essential to the manufacturing of electronics products in Asia.

Governments in Korea, Taiwan, Singapore, and Malaysia have developed policies of technological self-sufficiency in basic materials and component areas. With support from the Korean government, Samsung Electronics, Goldstar, and Daewoo Electronics account for 45% of Korea's total sales and 20% of the domestic workforce in electronics. They are approaching world standards in their research capabilities. The Taiwanese government has been investing heavily in research in IC design, and Taiwan is approaching world standards in this area. Taiwan has made semiconductors a major priority and plans to have over 20 wafer fabs by the year 2000. Singapore also plans to expand in the fab business with 20 facilities by 2005. The Singaporean government is encouraging MNCs to locate R&D facilities in Singapore. Other countries, like Indonesia and Thailand, have little ability to develop new technology; to build basic capabilities they rely on imports of major components and equipment and on joint ventures with foreign firms.

GOVERNMENT STRATEGIES (BCG 1994)

While all Asian governments consider electronics industries key to their economic development, the level of government involvement and variety of support methods vary among nations. Table 2.4 summarizes the various mechanisms used by Asian governments. They include direct R&D investments, trade policies, technology transfers, tax incentives and investment subsidies, and training and consulting services. While some countries like Singapore provide a full range of programs, Malaysia and Taiwan offer much simpler and more focused programs. Hong Kong's approach is more general and passive (not wanting to pick winners and losers), while Singapore and Taiwan are more directive with targeted industries.

Table 2.4
Government Industrial Development Support in Asia

Government Programs	Japan	Korea	Taiwan	China	Hong Kong	S'pore	Malaysia
Government R&D	√	√	√	√	√	√	√
Direct R&D funding	√	√	√	√		√	√
Import controls		√		√			
Direct support for JVs/technology transfer				√	√	√	
Subsidized loans	√	√		√		√	
Tax incentives	√		√			√	√
Export promotion	√	√			√	√	√
Training support	√	√	√		√	√	√
Direct consulting/ strategic assistance					√	√	

Source: BCG 1994, 232.

Japan

As described in the BCG report (1994), the Japanese government funds collaborative research programs. With established leadership in most electronic technologies, efforts are increasing in basic research areas and in attracting foreign technologies to Japan. Export of electronics materials, parts, components and related assembly equipment provides strong earnings for Japan. For example, Taiwan's trade deficit with Japan has increased from $13 billion in 1991 to $18 billion in 1995 due primarily to increased imports of equipment and components required to support its growth in electronics manufacturing. Increasingly, however, the newly industrialized nations are working to reduce their dependence on Japan. Table 2.5 summarizes programs designed to make each country increasingly independent.

The Japanese government has traditionally focused resources and programs on development of strategic industries like electronics. Cooperative programs and research projects by government and quasi-government institutes are highly targeted. Japanese policies now set direction, focus on basic R&D, and promote cooperative research and foreign technology. Overall R&D is 3% of GDP.

China

The Chinese government has targeted electronics as a key industry for development. Its goal is to reduce dependence on imports of electronics and to build domestic production capacity. Labor-intensive products, including those requiring the most advanced SMT assembly equipment, are being rapidly moved to China where average factory workers earn about $65 per month, less than 10% of the wages earned by Taiwanese factory workers. While overall policy has been developed by the central government, policy implementation is carried out by the regional governments and is often developed within local industrial parks or free trade zones.

China's electronics industry, which surpassed $20 billion in sales in 1990, is growing at a rate of over 12% annually. The telecommunication (16%) and computer (11%) sectors are growing rapidly for both domestic sales and export. Revenues from parts and components (38%) and consumer electronics (44%) are from the most cost-competitive segments. To meet needs for increased assembly densities, flexibility, and short lead times, Chinese vendors now produce hybrid IC components for SMT applications. Yong Hong Electronic Device & Material Factory #749 is the leading producer of ICs in China, with sales of $18 million. Last year, 70 types of hybrid IC power converters were offered for a variety of applications. Facing stiff competition from monolithic ICs, Factory #749 designs and produces higher-density hybrid ICs for miniature electronic meters and instruments. Hongming Electronic Component Factory #715 exported over 100,000 hybrid ICs in 1994 and is developing integrated monolithic ICs for follow-on sales. A 30-member R&D department designs high-power, high-voltage, and high-precision new models of hybrid ICs (*Electronic Components* 1996, 316).

Table 2.5
Asian Government Programs in Support of the Electronics Industry

Country	General Programs	Specific Programs for Electronics
Japan		• Government ministries support basic research • Cooperative R&D projects • National Research Institutes
China	• Performance incentives for selected enterprises for sales/profit targets	• Direct R&D funding • Direct industry controls • Control of key parts/component imports to support domestic development • Support for JV/technology transfer in strategic industries
Taiwan		• R&D funding from government • ITRI-led R&D consortia • Lending to 10 targeted industries • Tax reduction on investment of 69 key products and components
Korea	• Government purchasing programs • Export incentive programs • Military service exemption programs	• G7 projects for technology development and private R&D support, and project funding • Electro 21 program to develop core technologies and increase self sufficiency in electronics
Singapore	• Direct consulting schemes	• R&D incubator programs • R&D assistance programs • Direct R&D funding • Technology transfer division • Management Productivity Center
Malaysia		• Direct R&D support
Hong Kong	• HKID promotes inward investment, technology development programs, quality programs, and infrastructure investment	

Source: BCG 1994, 201-237.

To support both the telecommunication and the computer industries, multilayer printed circuit boards are also produced locally. About 15 makers now produce multilayer PCBs, the majority producing boards of up to 8 layers. Shanghai Printronics Circuit Corp., a joint venture between Shanghai No. 20 Radio Factory and Australian Printronics Co., Ltd., can produce a maximum of 14 layers. Shenzhen Shennan Circuit Corp., a state-run company, produces from 4- to 16-layer boards, with capabilities to produce up to 20-layer boards of 100 mm lines, spacing, and hole dimensions, for applications in aerospace, computers, communication equipment, and instruments. Shenzhen Bestman Electronics Co., Ltd., a joint venture from Hong Kong, produces 4- to 10-layer boards and can produce up to 30-layer boards. Importing most raw materials from Hong Kong, Taiwan, and DuPont in the United States, Kintech Electronics Co., Ltd., from Taiwan established an FR laminate factory in Shanghai in 1995 to ensure its own supply and more competitive prices. It plans to establish a multilayer PCB plant in Guangzhou in 1997 (*Electronic Components* 1996).

Within the private sector, BCG found little R&D or product design capabilities in China. As Table 2.6 shows, the skills in electronics manufacturing are still only moderate. Nam Tai Electronics produces a range of the most advanced products using both inner and outer lead bonding technologies. QDI has demonstrated its ability to produce the highest-quality PCB boards in Asia. With a growing number of firms transferring operations into China, it can be expected that skill levels will rapidly improve. QDI, with 57 R&D staff, has excess capacity for PCB assembly designs. Within the government sector, the technology for defense production is at a high level.

Table 2.6
China Electronics Industry Capabilities (Private Sector Only)

Industry Sector	R&D	Design	Manufacturing	Marketing & Sales
Computers & Peripherals	Negligible	Weak	Moderate	Negligible
Consumer Electronics	Negligible	Weak	Moderate	Weak
Telecommunications	Negligible	Weak	Weak	Negligible
Parts & Components	Negligible	Negligible	Moderate	Negligible

Source: BCG 1994

With China's success in attracting firms to establish operations on the mainland, Asia's NIEs are facing a competitive challenge similar to that faced earlier by the United States and Japan. They are acutely aware that their future success is dependent on technology. They are racing to acquire and develop technologies that will allow their local industries to stay competitive by producing technology-intensive, higher-value-added, next-generation components and products.

Taiwan

Taiwan's Ministry of Economic Affairs has been actively carrying out a plan to develop Taiwan into a fully industrialized nation by 2000 and into the Asia-Pacific "Regional Operations Center," by promoting R&D, targeting high-tech and high-value-added product development, building "intelligent" industrial parts, and promoting capital-intensive investment projects. The Ministry of Economic Affairs has a very focused strategy to develop ten high-technology industries, including communications, information, consumer electronics, semiconductors, precision machinery, automation equipment, aerospace, and advanced materials. Technology-intensive industries have grown from nothing in 1976 to over 34% of the manufacturing base in Taiwan in 1995, and are projected to account for 40% of the manufacturing base by the year 2002. A broad range of programs provides incentives for research and development or investment in capacity to build Taiwan's self-reliance in key products and components. The government funds 80% of ITRI to conduct basic research, commercialize technologies, and obtain foreign technologies. ITRI was instrumental in developing the semiconductor industry in Taiwan. Plans are to increase the number of fabs from 4 to 20 by the year 2000. In support of the national strategy, R&D as a percentage of GNP reached 2%, or nearly $5 billion in 1994.

Taiwan's government development programs are extremely directed and have been especially targeted on IC and computer-related components and products. Programs allow for a 10-20% income tax credit for R&D investments, 50% funding or loans for major targeted investments, or up to 60% matching grants for training programs. The Industrial Zones Development Plan supports developments in 74 industrial zones. Table 2.7 summarizes BCG's appraisal of Taiwan's electronics capabilities (1994).

Table 2.7
Taiwan Electronics Industry Capabilities

Industry Sector	R&D	Design	Manufacturing	Marketing & Sales
Computers & Peripherals	Strong	Strong	Strong	Strong
Consumer Electronics	Weak	Moderate	Strong	Weak
Telecommunications	Weak	Moderate	Strong	Moderate
Parts & Components	Strong	Strong	Strong	Moderate

Source: BCG 1994, 151-200.

Korea

The Korean government provides a variety of programs for infant, competitive, and mature industries. Most are supportive of the major conglomerates Samsung, LG (formerly Goldstar), and Daewoo, which typically attempt to be low-cost, fast followers of Japan in high-technology businesses, thereby taking a major share of new and growing businesses. Due to restrictions on obtaining electronics materials and equipment in the 1980s, Korean companies have worked hard to develop their own electronic manufacturing equipment and components. They have been successful in their strategy to become the leading producers of such products as microwave ovens and DRAM ICs. Today, they are attempting to build a position in the LCD business.

For decades, the Korean government provided broad support to the three major industrial conglomerates rather than industry generally or electronics specifically. In order to increase the localization of parts and components to 75% by 1996, programs were directed at smaller manufacturers. The program "Electro-21" provided subsidies for private development of core electronic technologies. G7 funds supported research in high-end applied technologies. Major projects included high-definition TVs, very large scale integration, and high-end materials. A number of human resource educational programs supported development of manufacturing and engineering skills. The Engineer Training Institute is an engineering training program jointly subsidized by government and industry. Free training is offered to small- and medium-sized businesses in special areas. The Military Service Exemption program gives service exemptions to engineers working in the defense industry. Table 2.8 summarizes BCG's appraisal of Korea's electronics capabilities.

Table 2.8
Korea Electronics Industry Capabilities

Industry Sector	R&D	Design	Manufacturing	Marketing & Sales
Computers & Peripherals	Strong	Moderate	Strong	Moderate
Consumer Electronics	Strong	Strong	Strong	Moderate
Telecommunications	Moderate	Moderate	Strong	Moderate
Parts & Components	Strong	Strong	Strong	Moderate

Source: BCG 1994, 151-200.

Singapore

Singapore's government has the widest range of programs to support development of targeted industries such as semiconductors, communications, displays, and data storage businesses. Electronics accounted for 43.7% of Singapore's manufacturing output in 1992. Programs include both foreign and domestic incentives for locally conducted R&D, with infrastructure and human resource development programs to support high-end data storage, computing, and wafer fabrication technologies. Singapore had 6 fabs in 1996, but plans to have 20 by the year 2005.

Singapore government programs support a vision to surpass the United States in per capita GNP by 2030. The strategy is to create high-value-added activities, develop R&D capabilities, and train skilled workers. A full range of programs are provided to both domestic and foreign companies: R&D incentives, infrastructure initiatives, and human resource programs. Table 2.9 summarizes BCG's appraisal of Singapore's electronics capabilities (1994).

Table 2.9
Singapore Electronics Industry Capabilities

Industry Sector	R&D	Design	Manufacturing	Marketing & Sales
Computers & Peripherals	Moderate	Strong	Strong	Moderate
Consumer Electronics	Negligible	Moderate	Moderate	Weak
Telecommunications	Negligible	Weak	Strong	Weak
Parts & Components	Moderate	Moderate	Strong	Weak

Source: BCG 1994, 151-200.

Malaysia

The Malaysian government has provided guidance for overall economic growth and increased R&D investment. "Vision 2020" is the government's plan to accelerate industrialization through industry restructuring, technology upgrading, human resource development, and industry linkages.[3] Long-range goals include doubling GNP every 10 years and achieving global competitiveness in high-technology industries by the year 2020. The Malaysian Technology Development Corporation (MTDC) provides seed capital to develop and commercialize indigenous technologies, transfer university and institutional technologies, transfer technologies from abroad, and develop venture capital companies in Malaysia. The Malaysian Institute of Microelectronics Systems (MIMOS) invests in semiconductor technology, microprocessor engineering, radio frequency engineering, surface mounting technology, and digital signal processors. The Human Resource Development Fund, generated from 1% of employee wages, is styled after Singapore's Skill Development Fund to improve engineering and technical skills. Promoted investments obtain from 70-100% exemptions from income tax. Reinvestment programs obtain grants of up to 40% of the capital investment for production capacity. Overall R&D levels are about 1.5% of GDP.

Individual localities in Malaysia also focus public policy around rapid industrialization plans. The Penang Economic Council's Strategic Develop Plan was devised in 1991 in support of Vision 2020 to promote skill-intensive, technology-intensive, value-added industries and shift Malaysia's manufacturing competency from labor-intensive to capital-intensive manufacturing. Penang was successful in attracting firms like Hewlett-Packard, Intel, Siemens, and Seagate Technology (the world's largest disk drive maker). But with rising costs in Penang, new factories are being built further inland and in the state of Sarawak, on the island of Borneo (*Economist* 1996, 66). Table 2.10 summarizes BCG's appraisal of Malaysia's electronics capabilities (1994).

Table 2.10
Malaysia Electronics Industry Capabilities

Industry Sector	R&D	Design	Manufacturing	Marketing & Sales
Computers & Peripherals	Negligible	Negligible	Weak	Negligible
Consumer Electronics	Negligible	Negligible	Moderate	Weak
Telecommunications	Negligible	Weak	Moderate	Negligible
Parts & Components	Negligible	Negligible	Moderate	Weak

Source: BCG 1994, 151-200.

[3] This concept is fully defined in the book *Vision 2020* by Abdul Hamid Ahmad Sarji (1995).

Hong Kong

The Hong Kong government is less directive than that of other Asian countries, but it does provide programs to support the movement into higher-value-added businesses. Most of Hong Kong's traditional businesses, like textiles, clothing, and plastics and metals fabrication, have become mature and are moving into China. The number of electronics firms, related employees, and facilities located in Hong Kong has also declined. There is a concern for the future economic status of Hong Kong and an understanding of the need to upgrade the technological base of its remaining firms to more value-added production. Since over 85% of HK electronics firms have annual revenues of under $500 million, they are considered small in comparison to global competitors and invest little in research and development. The HKPC (the Hong Kong Productivity Council) provides a "one-stop" center for technology transfer, educational programs, and technical services to support local companies. The Industrial and Technology Development Council funds technology development programs considered beneficial to Hong Kong. A new science industrial park provides incentives for firms to upgrade their technologies.

According to the BCG survey (1994), there was wide disparity between the levels of capability of companies in the various sectors of Hong Kong's electronics industry. The primary strength was in manufacturing, due to reliance on China's low-cost labor and land. Limited capabilities exist in other product design or market related activities. Because the majority of firms in Hong Kong are small, with under $100 million in annual sales, the range of capabilities is limited to manufacturing and design improvement restricted to board design for low-cost manufacturing, low-cost sourcing from China, and low-cost board assembly in China. Medium-sized firms, with $100- $500 million in sales, are more involved in design and brand management activities. Leading firms with annual revenues over $500 million have a full range of capabilities; Vtech's capabilities enabled it to capture 50% of the world market in electronic learning aids. Table 2.11 summarizes BCG's appraisal of Hong Kong's electronics capabilities (1994).

Table 2.11
Hong Kong Electronics Industry Capabilities

Industry Sector	R&D	Design	Manufacturing	Marketing & Sales	After Sales Service
Computers & Peripherals	Weak	Moderate	Strong	Weak	Negligible
Consumer Electronics	Negligible	Moderate	Moderate	Weak	Negligible
Telecom-munications	Negligible	Moderate	Strong	Moderate	Negligible
Parts & Components	Negligible	Negligible	Moderate (low end passives)	Weak (some niche firms)	Negligible

Source: BCG 1994, 151-200.

REGIONAL ECONOMIC COOPERATION

One of the most important developments in the world trade system in the 1990s has been the emergence of regional cooperation. The end of the Cold War reduced political tensions between countries in Asia as well as globalizing production processes and increasing vertical integration. Cities like Bangkok, Kuala Lumpur, and Singapore have been lifting their populations out of poverty in part through cooperative arrangements with neighboring countries. Transnational economic zones have utilized the different endowments of the various countries of East Asia, exploiting cooperative trade and development opportunities. Transfer of technology and manufacturing between nations has allowed them to develop sequentially. Information technology has improved linkages between economies and put remote regions in contact with the world. The private sector provides capital for investment; the public sector provides infrastructure, fiscal incentives, and the administrative framework to attract industry. Regional cooperation is now considered the means of enhancing economic development and providing economic security within the regions. Trade among ASEAN members accounted for more than 23% of all trade by member nations in 1994, topping that of any of the group's major trading partners.

Singapore has concentrated on becoming the technology center for Southeast Asia, sending labor-intensive operations to low-cost neighboring countries like Malaysia and Indonesia in special mutual cooperative trade and development arrangements known as growth triangles or growth polygons. The Southern Growth Triangle, also known as SIJORI (Singapore, the Johore state of Malaysia, and Riau Province of Indonesia), was formed in 1989 and covers a population of about 6 million people. It attracted $10 billion in private sector investments during its first five years. Such regional economic cooperation has occurred in other Asian regions as well, spurring economic development. Growth triangles are expected to be a continued driving force for growth in Asian economies throughout the 1990s. Four growth triangles have been established since 1989, involving parts of 11 countries. As shown on the map, Fig. 2.3, there are currently eight growth polygons in East and Southeast Asia, with additional triangles being planned. For example, Cambodia, Laos, Myanmar, Thailand, Vietnam, and China's Yunnan Province have been discussing ways to develop the Mekong area since 1992.

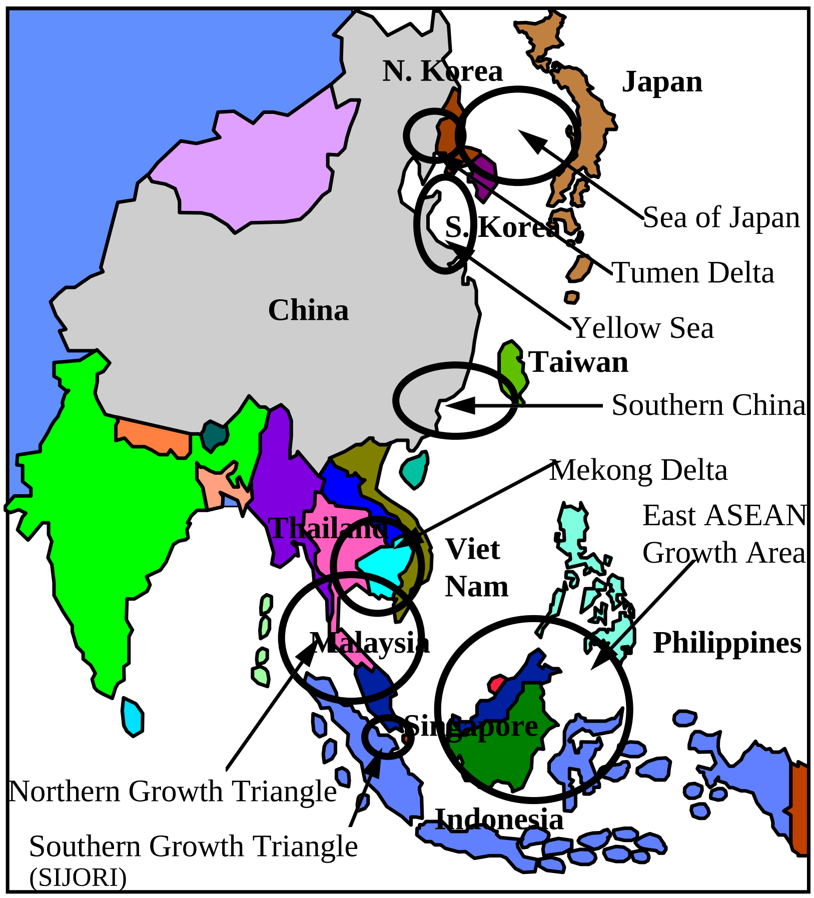

Fig. 2.3. Asia's growth "triangles."

Regional cooperation provides a competitive model to attract investment and technology. According to the secretary general of ASEAN, Ajit Singh, "These growth areas will have to be flexible to change where necessary, innovative, and always attentive to the needs of the investors and the businessmen. They also have to be aware that they are competing with much larger countries such as China and India, whose capacities for attracting investors are much greater than their own" (Kruger 1996, 17). Asian capital markets are now watching the global economy, and large companies recognize their need to be involved in this fastest growing region in the world.

The growth triangles typically group remote regions of the nations involved in an effort to exploit complementary assets within the groupings. For example, the Tumen Delta triangle integrates the capital and technology of Japan and the Republic of Korea with the natural resources of Russia and North Korea (i.e., the People's Democratic Republic of Korea) and the labor and agricultural resources of China. The governments of Brunei, East and West Kalimantan, and North Sulawesi of Indonesia; Sabah, Sarawak, and Labuan in Malaysia; and Mindanao and Palawan in the Philippines have given priority to expanding air and shipping routes within the East ASEAN Growth Area, another polygon. Where all parts of the polygon are at similar levels of development, growth is expected to be slower. Singapore has provided capital and technology for developments in Malaysia to support SIJORI. Thailand is expected to provide capital and experience in developing the Mekong polygon. It will encompass a population of over 400 million people offering low wages, rents, and land costs.

The Southern China Growth Triangle

The Southern China Growth area comprises Hong Kong, Taiwan, and the southern provinces of China (Thant et al. 1994). Because China lags behind Taiwan and Hong Kong considerably in economic development and has a very large population, growth in this triangle has enormous potential. Establishment of this triangle was spurred by market forces and private sector initiatives rather than by policy coordination among the countries. However, government policies have supported the economic links that were instituted. The PRC's economic reforms and open door policy initiated in 1978 laid the foundation for economic success in Guangdong and Fujian provinces. Establishment of China's first Special Economic Zone (SEZ) in 1980 provided for tax concessions, expanded land use rights, and simplified procedures for foreign investment. Policies for land use, finance, and trade were designed to reduce transaction costs and to provide greater access to the domestic as well as the world market. Policies formulated within the SEZs themselves have been even more liberal than those in other parts of the triangle. For China, the triangle has provided exports, foreign exchange, and employment as well as access to the larger global economy.

Rapid economic growth and higher incomes have occurred in Guangdong and Fujian Provinces with materials and components from Taiwan's manufacturing sectors and the support of Hong Kong's advanced services sector. Geographical proximity and common language are the most compelling factors for capital to move across the border from Hong Kong into Guangdong Province, or for investment to flow across the Formosa Strait from Taiwan to Fujian Province. Cantonese is a Chinese dialect spoken in both Hong Kong and Guangdong, while Fujianese is spoken in both Taiwan and Fujian. For Hong Kong and Taipei, the triangle has provided a means of implementing structural changes in manufacturing and export patterns at minimal cost. In spite of recent political posturing on the part of China, economic planners in Hong Kong and Taiwan are optimistic that economic logic will continue to drive regional integration.

Low-Cost Sourcing

As Japanese and U.S firms seek to reduce the cost of their latest innovations, they are outsourcing production to low-cost contract manufacturers. China has a growing number of low-cost parts and components suppliers. With a minimum of overhead and a large pool of low-cost labor in China, there is a growing list of high-quality vendors in China. The continuing miniaturization of products has lead to joint ventures with companies from Japan, the United States, Taiwan, Hong Kong, and other Asian countries. The success of these firms is dependent upon providing competitive value in a timely manner. Low-cost board assembly operations in China utilize the latest SMT equipment required by new computer and telecommunications products. Capital intensity will increase as IC packaging and SMT assembly operations are installed.

In the 1980s, Korea and Taiwan provided the first step in the cost reduction chain by providing the most advanced process capabilities. Singapore and Malaysia became additional sources for contract manufacturing with the establishment of global vendors like SCI and Solectron. Today, further cost reduction is possible by moving production to lower cost regions like China and the Philippines. Wong's Electronics in Hong Kong provides a three-step process for cost reduction that includes low-cost labor, low-cost sourcing, and low-cost production designs.

Hong Kong, Thailand, Malaysia, and China are considered the home of lowest-cost manufacturing competitors in the electronics industry today. They offer limited component technology or product design skills, but provide many low-cost suppliers of generic, low-technology components. Since low-cost manufacturing countries generally lack the technologies required to become industry leaders, they must follow the technology trends as quickly as possible. OEM competitors from Taiwan and Singapore are being forced to open branch plants in China or other Southeast Asian countries to produce the most labor-intensive, cost-driven products.

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CHAPTER 3

HONG KONG - SOUTH CHINA ELECTRONICS INDUSTRY

William R. Boulton

WTEC STUDY TEAM VISITING HONG KONG (MARCH 1996)

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INTRODUCTION

The rapid transfer of technologies and manufacturing activities to the People's Republic of China (PRC or simply, "China" in this report) has raised questions as to the future competitiveness of the newly industrialized Asian economies of Korea, Taiwan, Singapore, and Hong Kong. As most global companies scramble to (1) take advantage of low-cost manufacturing in China, and (2) get an early position in the Chinese market, the latest technologies are being rapidly located within China. Hong Kong, with its attractive living environment and close proximity to China, has been the primary channel for investments and support of operations located on the mainland. The majority of Hong Kong electronics manufacturers have placed operations in South China, making Hong Kong a source of low-cost manufacturing.

HONG KONG'S ELECTRONICS INDUSTRY

Hong Kong has a population of 6.3 million people. Its GDP for 1995 was $174.7 billion,[1] for a GDP per capita of $23,258. The economy's growth rate declined from 5.5% in 1993 to 4.6% in 1995 (Table 3.1). Hong Kong is a duty-free port. Exports from Hong Kong totaled $174.1 million in 1995; imports were $193.2 million, creating a trade deficit of $19.1 billion. According to the Hong Kong Industrial Department, in 1995, it ranked as the world's eighth-largest trading entity (one-quarter the size of U.S. trade), had the highest per capita GDP after Japan in Asia (greater than that of Canada, Australia, and the UK), had the largest throughput of any port in the world, had the 2nd busiest airport, and was one of the world's largest financial centers (fifth in external banking, sixth in foreign exchange, eighth in stock market capitalization). Major U.S. investors include Motorola, Digital Equipment Corp., Sea-land, Exxon, Citibank, Caltex, AT&T, IBM, Kodak, Bank of America, Dun and Bradstreet, American International Group, Coca-Cola, and Pepsi Co.

Hong Kong is a major center for regional headquarters. It provides much of the banking, distribution, and purchasing functions for companies in Asia, especially for those operations located in South China. The

[1] All dollar amounts ($) are U.S. dollars, unless otherwise noted.

number of regional headquarters and regional operations in Hong Kong, and the major foreign owners, are as follows:

- **Regional HQs (714 foreign)**
  - U.S. 198
  - Japan 116
  - UK 94
- **Regional Operations (1,132 foreign)**
  - Japan 303
  - U.S. 228
  - UK 132
  - China 81

Table 3.1
Hong Kong's Economy and Trade, 1993-1995

ECONOMY	**1993**	**1994**	**1995**
GDP ($ billions)	116.2	131.4	143.7
GDP Growth Rate (%)	5.5	5.0	4.6
GDP Per Capita ($)	19,386	21,750	23,258
Government Spending (% of GDP)	16.8	17.6	17.5
Inflation (%)	8.5	8.5	8.7
Unemployment (%)	2.1	2.0	3.2
Foreign Reserves ($ millions)	49,276	54,000	59,000
Average Exchange Rage (HK$/US$)	7.728	7.728	7.730
TRADE			
Total Exports ($ billions)	135.4	151.4	174.1
Total Imports ($ billions)	138.8	161.8	193.2
Current Trade Balance ($ billions)	-3.4	-10.4	-19.0

Source: www.ita.doc.gov/region/asia/pacific/fs-hkg.txt

Hong Kong's domestic manufacturing industry declined with the rapid migration of manufacturing across the border into the Pearl River Delta of Guangdong Province, China, between 1982 and 1994. In that period, Hong Kong's manufacturing workforce halved, while industry's contribution to GDP fell from 20% to just over 11%. Both real and nominal growth of Hong Kong's industry declined between 8 and 10% annually between 1988 and 1991, reaching $7.3 billion. In spite of this shift in industry structure, total employment increased from 2.4 to 2.9 million, an increase of 21%, as per capita GDP increased by 80% in real terms. In contrast, Guangdong-based industry grew 22% annually in the same period, with output worth $6.3 billion in 1992.

Industry Trends in Hong Kong

Hong Kong's success in recent years has been based on its ability to take advantage of China's low-cost labor. In Hong Kong's economy, textiles are most important; tourism is second. In electronics, Hong Kong is not known for any specific products, but some of its strengths are in electronic packaging designs. Funded by the government, the Hong Kong Electronics Industries Association is working together with the Hong Kong Productivity Council (HKPC) and the Hong Kong University of Science and Technology (HKUST) to develop a roadmap for Hong Kong electronics companies in packaging and assembly to complement China's low-cost manufacturing. HKPC is taking an important role in technology transfer in Hong Kong. In summing up Hong Kong's status in electronics, one HKPC official told WTEC panelists:

> Hong Kong was ahead of Taiwan and Singapore 15 years ago. The Chinese opportunity caused Hong Kong to chase cheap labor rather than high technology. Industry cannot continue to produce

> low-cost products, even in China. At some point, Mongolia will be even cheaper. China's move into technology will be fast. Probably 90% of SMT operations are now in China, only 10% in Hong Kong. The Japanese decline in electronics will give Taiwan and other Asian countries more of their market share. Now we are trying to catch up. In Hong Kong, we have a lot of good engineers that can be leveraged. We see the roadmap in technology following chip fabrication. We are followers in that. Hong Kong is not investing in wafer fabrication, which is the first level in the food chain. We are more involved in packaging and assembly activities, but there is no bumping facility in Hong Kong. They may not want to spend the money for technology, but they know they need it. It has been difficult to invest in cleanrooms, for example. We don't have much land.

Korea and Taiwan, in contrast to Hong Kong, have invested heavily in technology. Many Taiwanese engineers were trained in the United States, and Taiwanese firms have invested in wafer fabs and IC packaging of their own devices. Hong Kong hasn't done that; its investment in R&D, product development, and packaging technology is low. With primarily OEM customers from the United States, HK manufacturers continue to follow the needs of their customers. During the WTEC visits, it appeared that PCB assembly is a strength. TAB and BGA production technologies are seriously being considered. Manufacturers in Hong Kong were the second or third choice of firms attempting to cut the costs of their maturing products.

Globally, electronics companies are moving into more technology-intensive products. The shift in product manufacturing is from low-profit-margin, mass-produced, labor-intensive products to capital-intensive, equipment-intensive, high-value-added products. When one company recognizes a popular new product, its challenge is getting it into the market as quickly as possible. Japanese companies used to make some parts in Hong Kong and then ship them to Japan for final assembly. Now the Japanese are buying more completed products, including copier machines, from Hong Kong but more often from China. Xerox sends its quality managers and manufacturing people to audit one local company. Xerox has decided that its core process is the ability to meet the consumer's order requirements, not to manufacture all the products.

Hong Kong's Electronics Industry

In 1992/1993, the Hong Kong Government's Industry Department commissioned the Techno-Economic and Market Research Study of Hong Kong's Electronics Industry (BCG 1994). The study benchmarked eight countries including Hong Kong in an effort to identify strategies for Hong Kong manufacturing. The findings show that Hong Kong firms had focused too heavily on "mature" products that provided relatively low value-added. The study also concluded that the electronics industry was also providing a lower return on capital than the textile and garment industries, food and beverages industries, or non-electronics light manufacturing industries. Revenues from consumer electronics and telecommunication products had both been declining. Computers, peripherals, parts, and components had been growing but were only moderately profitable. As Table 2.11 (Chapter 2) shows, the study concluded that Hong Kong offers few electronics capabilities other than those conferred upon it by close proximity to low-cost manufacturing in the PRC. It concluded that Hong Kong, along with China, Malaysia, and Thailand, provides only low-cost competition.

According to the study, Hong Kong's strengths come from efficient low-cost manufacturing, consumer product trend identification, and aesthetic design capabilities. Weaknesses come from the lack of scale economies of small manufacturers, scarcity of R&D and technological innovations, lack of recognized brands, focus on mature products, and dependence on easily replicated skills. The primary opportunities are Hong Kong's proximity to China's land, labor, and markets; low-cost, large-scale operations in China; and the attraction of firms with high-order capabilities. An economic threat comes from land shortages in Hong Kong, skilled worker and management shortages in China, inadequate infrastructure, and ease of entry by other firms and countries. Overall recommendations for Hong Kong included the following:

1. Identify company competitive advantages
2. Develop strategies to move upstream into core supporting industries
3. Develop an institute for design and R&D engineering support for industry
4. Revise the role of the Technology Review Board to focus on technology transfer

5. Refocus the HK Technology Development Council to support marketing in China
6. Increase industry participation in the HK Industrial Department's Industrial Extension Services
7. Increase the scope of the Management Development Center to include Hong Kong and China
8. Establish a China Information Unit to coordinate and integrate Hong Kong and China efforts

Hong Kong's Electronics Infrastructure

HKPC officials told the WTEC study team that the electronics industry is seen as a conduit for developing globally competitive niches in newly developing markets. Asian governments have explicit objectives and industry policies to encourage electronics industry developments. Products requiring innovations and development are the focus of government policies in Korea, Taiwan, and Singapore. The Chinese government is heavily involved in the electronics industry in order to reduce dependence on imports and to increase production capacity. Policies in Malaysia and Hong Kong have been much less focused.

Hong Kong's acting finance secretary noted that the HK government did not intend to use interest rates, subsidies, imported labor, public spending, tax concessions, or tax incentives to direct industry behaviors. Instead, it attempted to provide the best business environment in the world by accelerating infrastructure investment. While refraining from interfering with either the pace or the direction of economic development, the government increased its industrial support fund from zero in 1993/94 to $180 million in 1994/95 and to $210 million in 1995/96. In addition, it spent $250 million to build the first Hong Kong Industrial Technology Center (HKITC), allocated an additional $180 million to operate it, and allocated a further $200 million to an applied research fund. With its open market and leading money management center, Hong Kong is a major center for capital in Asia. Hong Kong has expertise in financial and commercial services and has an excellent infrastructure, with good communications, roads, and utilities.

In June 1996, HKUST was completing a $50 million cleanroom in its Microelectronics Fabrication Center. Equipment includes a state-of-the-art e-beam system. HKUST operates the HK Telecom Institute of Information Technology, which studies lightwave, network, wireless, and video technologies. At the time of the WTEC visit, the university's Sino Software Research Center was developing low-cost Internet access, Chinese language interface support, and database management technology. The Advanced Materials Research Institute and the Institute for Micro Systems were developing advanced materials, micromechanical devices, flat panel display technology, nano technologies and devices, and integration of circuits and systems.

To further upgrade Hong Kong's technological infrastructure, government funds are being provided to Hong Kong's Applied Research Council to establish the Cooperative Applied Research and Development Scheme with research institutions in China. Feasibility studies have also been completed for a second technology center, a fourth industrial estate, and Hong Kong's first science park. The government's industry policy at the time of the WTEC visit was to assist the manufacturing sector in increasing real output per employee. Direct investment in manufacturing was left to the private sector. Policies were aimed at maintaining an infrastructure that enables manufacturing businesses to function efficiently, and at providing services that contribute to industrial development via productivity growth, quality improvement, and product innovations.

Human Resources Development

In the area of human resources development, education and training programs are provided through the Hong Kong Productivity Council, Hong Kong Polytechnic Industrial Center, universities, and the Vocational Training Center, as well as other commercial entities. Of the government's programs, few are heavily promoted. Educational and training programs had a higher level of awareness than other programs, according to the Boston Consulting Group's survey (BCG 1994). The Electronic Design Technology Training Center provided courses at rates of $25 to $40 per hour. The Vocational Training Council provided matching grants of up to $15,000 for local training and $37,500 for overseas training in new technologies. Over 15,000 students from Hong Kong study in the United States.

Technology

In technology, support is provided through the Hong Kong Productivity Council, Hong Kong Applied R&D Fund Co., Ltd., Design Innovation (HK), Ltd., Hong Kong Industrial Technology Center Corporation (started in 1993 with a government grant of $250 million), and the Technology Development Division of the Hong Kong Industry Department, which supports the Industry and Technology Development Council and Science Park developments. The Industry and Technology Development Council (ITDC) reviews proposals for projects that benefit Hong Kong's industries. The ITDC includes a number of committees, each of which has a representative from the Industry Department, 10 prominent industrialists, five academics, and vocational training representatives who stay on the council for two years. Of 40 proposals reviewed over the six months prior to the WTEC team's visit, money had been allocated to over 10 projects. The budget was about HK $300 million (approx. $39 million). ITDC identified BGA and TAB as technologies needed in Hong Kong. It approved a project to set up a radio frequency (RF) training center within HKPC.

Quality and Productivity

Quality and productivity are supported through the Hong Kong Productivity Council, the Hong Kong Quality Assurance Agency, and the Quality Service Division of the Hong Kong Industry Department, which provides ISO 9000 certification, standards and calibration, product standards, and laboratory accreditation.

New Business Development/Exports

New business development is supported by the Hong Kong Industry Department, the Hong Kong Industry and Technology Development Council, the Hong Kong Polytechnic Industrial Center, and the Hong Kong Industry Technology Center Corporation. The Hong Kong Development Council also supports export activities.

Automation Strategies

In June 1994, the Hong Kong government commissioned the Hong Kong Productivity Council to set up the Industrial Automation Task Force and implement a one-year pilot program to help 30 local manufacturers identify opportunities and develop industrial automation strategies. The pilot program was extended through the 1995-96 fiscal year. The task force works with firms to identify areas for automation and to map out automation strategies and implementation plans. This program resulted from a study by HKPC for the Industry Department of the Hong Kong Government to find key strategies to enable local manufacturers to become more competitive through improved quality, increased productivity, and high growth rates. HKPC was investigating new manufacturing technologies, and the HK government was developing the first science park in Hong Kong in hopes of encouraging R&D.

Hong Kong Productivity Council

HKPC is centrally located in Kowloon Tong, near the HKITC incubator for technology, City University, and the new Environmental Center. These three centers provide an important infrastructure for future technology developments. HKPC was established in 1967 to promote increased productivity and the use of more efficient production methods. Officials indicated that they want HKPC to become the strategy leader for Hong Kong. HKPC is a one-stop center for technology that provides consulting, training, product development, and technology transfer services aimed at strengthening the human resources and technology foundations of enterprises. For business, it provides training, consultation, and technical and laboratory-based services. For industry, it aims to identify new opportunities and carry out development projects. For government, HKPC provides advice on the factors affecting productivity in Hong Kong and carries out techno-economic studies. As explained by one official, HKPC focuses its attention on development of products, processes, people, and partnership:

> In the electronics area, we have about 45 people; about 35 are engineers. In terms of technology, we focus our efforts on the front end and back end of product development. On the front end, we will

> work with commercial clients on product development. The Design and Automation Branch has capabilities in the three areas of product design, process improvement, and people development. They assist in design of pagers, cordless and cellular telephones, palmtop computers and electronic organizers, hand-held data terminals for use by Hong Kong Telecom, multimedia kiosks using digital electronics, radio frequency circuit design, computer graphics, software engineering, and related manufacturing techniques. The pager was developed as a turnkey project, with a new production line, to help expand into higher-value-added products. HKPC designed a customized hand-held data terminal for use by Hong Kong Telephone Co., Ltd.'s, service team. Mr. Law has organized a club of component makers (switches, LCD, connectors, antenna, inductors, substrates, semiconductor packaging, and OEM subcontractors) that meet biweekly at HKPC. We are now leading a cooperative effort to develop the palmtop computer and a cordless phone for the home. Companies are beginning to cooperate more than in the past. No one company can do it all by itself.
>
> At the back end, the branch helps companies improve manufacturing processes through SMT and reliability and calibration centers. We look at how to manufacture the PCB assembly. We introduced SMT production several years ago. We continue to use a small batch line for product design so we can make sure that our designs work. It is also useful for small batch prototyping. Many companies will come to use that rather than change their own lines. The need for SMT training has been rapidly declining. Almost 90% of Hong Kong companies already use SMT equipment.
>
> We have other support facilities for product reliability and X-ray testing. We have a small group of engineers working in the IT [information technology] area to provide special services in that area. In the next several years, we will look for new technologies that can be transferred to Hong Kong. We have set up a production line for tape automated bonding (TAB) on LCD. A local LCD manufacturer just saved a trip to Japan to study TAB for LCDs by spending two hours at HKPC. We are encouraging local businesses to map out their automation strategies in support of their business goals. HKPC also provides help in ISO 9000 certifications.
>
> Companies are now moving towards more advanced processes like BGA. We have a proposal to install BGA and micro-BGA assembly and direct chip attach. We will look at the whole process, including attachment and inspection. We are investigating alternatives that might be considered. We are looking for suitable equipment for Hong Kong companies. ASAT packages semiconductors using BGA. Panasonic showed us their underfill process. Taiwanese firms produce a lot of notebooks and use TAB to reduce the board size and make the notebook very thin. We need to be able to produce these products in Hong Kong.

Since RF engineers are scarce in Hong Kong, HKPC planned to bring in experts and provide practical, hands-on training in this center. After acquiring the knowledge about RF technology, HKPC will transfer the technology to local industry through its engineers and labs.

CHINA'S ELECTRONICS INDUSTRY

The PRC has a number of important organizations that support electronics manufacturing, including the Ministry of Electronics Industry (MEI) and the State Science and Technology Commission (SSTC). Both organizations report directly to the State Council, the administrative arm of the National People's Congress. MEI and SSTC are involved in most activities relating to the electronics industry. MEI is one of 30 ministries in China. It oversees the computer and electronics industry, and it is increasingly involved in telecommunications. The Electronic Technology Information Research Institute, China Computer & Microelectronics Information Research Institute, China National Electronics Import Export Corporation, the Chengdu Electronics Research Institute, and the Great Wall Computing Corporation are arms of MEI. SSTC is one of 10 state commissions. It oversees the nation's R&D policy for high technology. SSTC has a number of affiliated research and development institutions, including the Chengdu Electronics Research Institute and the Chongqing Science & Technology Association. The Institute of Scientific and Technology Information of China (ISTIC) is a department within SSTC.

China has been quite successful in attracting advanced technologies. Table 3.2 shows a number of technologies that have been transferred to China from Japan over the past 15 years — technologies for products from supercomputers to VCRs and video cameras. Advanced electronic ICs, LEDs, and PCB technologies have supported the development of an electronics supplier base. Today, every major international component vendor, including Intel, is establishing advanced capabilities in China. Fiberoptic cables and switching technologies central to development of a telecommunications infrastructure are being provided by U.S. companies like AT&T and Motorola.

Table 3.2
Technologies Transferred From Japan to China in the 1980s & 1990s

Parts & Components	Consumer Electronics	Information	Telecommunication
Signal generators	CRTs	Hitac supercomputer	Microwave radios
Optical fibers and cables	VCR processing	Bar Code equipment	Radar
Capacitors	VCRs	Software development	Fiberoptic cable
LEDs	Digital recording		Ultrasonic diagnostics
Digital control systems	Video cameras		Switchboards
PCBs			
Image intensifier tubes			
Spectrophotometers			
Spectrometers			
Ceramic IC packaging			
Chip-mounting equipment			
Hybrid ceramic IC filters			
PCB-mounting/test equipment			
Transformers			
PCBs			
Motors			
Bipolar IC production			
Measuring instruments			
Panel meters			
Production single-loop controllers			

China's electronics industry capabilities were extremely weak in the early 1990s. As BCG summarized in its 1994 report (see also Table 2.6, Chapter 2), China's primary strength was low-cost manufacturing; it offered little else, but proved that its workforce was well disciplined. The five-year plan current at the time of the WTEC study aimed to have 85% of children complete a 9-year compulsory education and to reduce illiteracy among 15-45 year olds from 7% to 5% by 2000. In 1995, China invested ~$2 billion for R&D (compared to $35 billion for U.S. non-defense R&D), of which 7% was for basic research. Typical scientists in academia earned only $30-40 per month. Today, there are nearly 170,000 Chinese students seeking PhD degrees in the United States.

In 1991, there were 2,064 approved foreign-funded projects in China's special economic zones (SEZs), representing $6 billion in joint ventures, $2.1 billion in cooperative ventures with the government, and $3.7 billion in fully-owned foreign ventures. By 1992, ~850 electronics firms had moved manufacturing facilities to the Pearl River Delta area. By 1996, over 8,000 foreign firms had labor-intensive facilities in that area.

While still producing labor-intensive subassemblies, plants in China are now assembling a growing number of final products, including Scientific Atlanta's satellite decoders, Sharp's personal digital assistants, and a full range of electronic games, telephones, and stereo products.

In 1995, 41% of China's total exports came from joint ventures between foreign and Chinese interests. Growth in joint venture shares of PRC exports has largely been due to (1) the transfer of export-oriented factories to China by Hong Kong and Taiwan firms, and (2) increasing investment by Japanese firms to make goods for their home market. In April 1996, the PRC government imposed tariffs on imports of capital equipment by joint ventures that previously could be imported tax-free. This measure is expected to hurt foreign profits. Another adverse consequence of the increasing value of China's joint venture exports is the potential for significant trade imbalances. In 1996, China's trade surplus with the United States surpassed even that of Japan (Fig. 3.1).

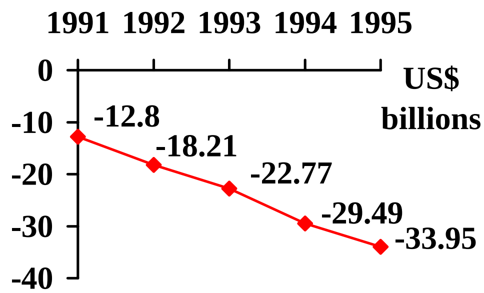

Fig. 3.1. The growing U.S. trade deficit with China

Physical Infrastructure Development in China

Development of China's infrastructure has taken place under a concept of "five opens" and "one leveling." Water supply, power supply, roads, navigation lines, and telecommunication are being opened, and land has been leveled to allow for construction. Beginning in 1986, expressways and railways were built to link the SEZs and the rest of Guangdong and Fujian Provinces, and air routes were established to provide links to the rest of China and the world. Continued development of such infrastructure projects ensures the future two-way flow of goods and services.

Labor Issues

Since most employees in Guangdong come from outside the province, factories include dormitories. Employees are mostly single and work 5.5 days per week, 8 hours regular time plus 4 hours overtime per day. Factory operators are paid about $65 per month with overtime. After New Year's, the turnover rate is 30-40% per year for operators and 10% for staff and engineers. Workers go home and often don't return after the holiday. They may stay out for a whole year. After getting rich (by local standards), they go home to their families where they may work for several years. VTech, for example, had 14,000 employees in five factories at its Chinese site; each year it requested 5,000 new employees from the government due to the attrition. To address this, the government is considering moving workers' families closer to Guangdong.

The Hong Kong Connection to China

Since China established its open-door policy in the late 1970s, the economies of Hong Kong and mainland China have become increasingly interdependent. China is Hong Kong's largest trading partner, and Hong Kong is China's second largest trading partner after Japan. Imports from China represented 36.2% of Hong Kong's total imports, compared to 14.8% from Japan, 8.7% from Taiwan, and 7.7% from the United States.

In 1995, two-way trade between Hong Kong and China grew 17%. Exports to China's economic zones are expected to grow at an annual average of 13%.

In Guangdong Province, which borders Hong Kong, the Pearl River Delta provides the Hong Kong electronics industry with an abundant supply of cheap land, subsidized factory leases, and low-cost labor. The Pearl River Delta encompasses eight cities: Guangzhou, Shenzhen, Zhuhai, Dongguan, Zhongshan, Foshan, Huizhou, and Jiangmen. Shenzhen, the area nearest Hong Kong, provides a seaport, airports, railways, roads, and communications lines to support the rapidly growing area. New power plants and reservoirs have been constructed to meet growing demands for power and water.

Monthly rentals for factory space in the Shenzhen SEZ were about $\$2$-$4/m^2$ compared to about $\$40/m^2$ in Hong Kong. In 1996, average monthly manufacturing wages in Hong Kong were over $820 as compared to about $125 in Shenzhen; outside of the Shenzhen SEZ, average manufacturing wages were closer to $65. These rates compared to about $750 per month for manufacturing wages in Taiwan, and $1,500 per month in Japan. An abundance of low-cost labor in these nearby areas allows economic restructuring and the relocation of Hong Kong's sunset industries and rationalization of production and distribution through vertical integration. Areas outside the Pearl River Delta in Guangdong Province were about 30% cheaper, and neighboring provinces of Fujian, Guangxi, Hunan, and Jiangxi had labor costs nearly half that of the Pearl River area. This difference, of course, attracts labor into the area.

Hong Kong's limited land area has restricted the development of its own manufacturing sector. Large-scale production, which is land-intensive, has not been feasible. Instead, Hong Kong has been the facilitator and financier of such investments in the PRC, and its manufacturing firms provide support services, such as the packaging, promotion, and design of products manufactured in the PRC, and direct technical assistance to transfer technology and management into China. Hong Kong also provides a high-quality living environment for senior management and engineers.

With China having labor costs about 10% of those in Hong Kong, cost savings of between 35-70%, depending on the labor-intensity of a product, can be achieved by sourcing parts and components and assembling products in China. As a result, most Hong Kong firms now have their major production operations in China, in terms of both space and numbers of workers. Relocation of Hong Kong's industry to China has provided first-mover access to the Chinese market. Legend, for example, distributes AST's personal computers in China alongside its own brand. AST holds 16% of the market, and Legend holds 8%.

Outsourcing to cut labor costs has made China a major center of foreign investment — most electronic firms now have some facilities or major supplier in China — but Hong Kong is China's largest external investor (Fig. 3.2). Hong Kong has accounted for about 60% of China's overall foreign direct investment this decade. Estimates set cumulative investments from Hong Kong at $233.6 billion through the end of 1995. Hong Kong companies employ over four million workers in Guangdong Province, 10 times the number of factory workers in HK manufacturing firms. China's investment in Hong Kong is estimated at $25 billion.

PRC exports to Hong Kong increased from $5.7 billion in 1981 to over $26.7 billion in 1991. Over the same period, Hong Kong component and equipment exports to the PRC increased from $1.9 billion to close to $17.5 billion. This is driving Hong Kong into capital-intensive, technology-intensive, and knowledge-intensive products. However, political uncertainty concerning Hong Kong's status after July 1, 1997, when political control of Hong Kong passes from the UK back to China, continues to be a threat to businesses.

China's Computer Industry

The worldwide market for computer systems grew from $145 billion in 1994 to $234 billion in 1995. From 1994 to 1995, the Asia-Pacific market, outside of Japan, increased its overall share from 7% or $10.15 billion to 11% or $25.74 billion. In PCs, Asia-Pacific nations outside of Japan accounted for 9% or $8.91 billion of the $94.83 billion worldwide market in 1994. The biggest markets were Korea ($3.01 billion) and China ($2.9 billion). PC penetration in the United States was 35%, followed by Australia (35%), Hong Kong

(32%), and Singapore (32%). Japan's penetration was 21%, followed by Malaysia (20%), India (8%), and China (7%). Of the 6.6 million Internet hosts worldwide in July 1995, only 229,854 were in Asia.

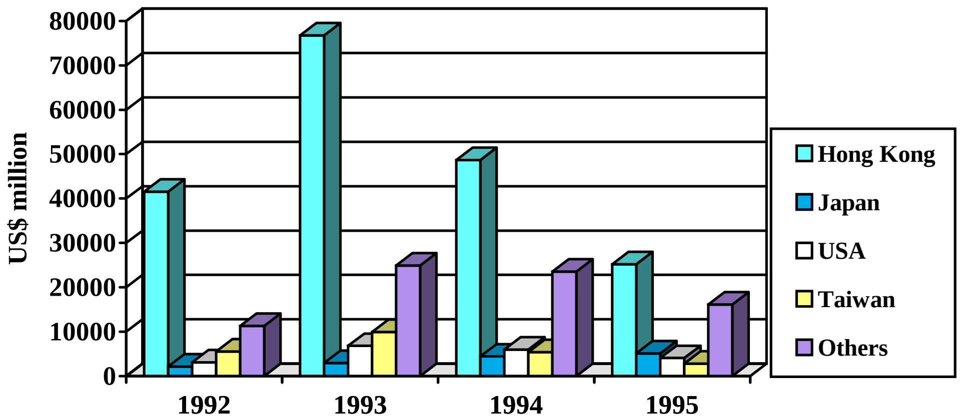

Fig. 3.2. Foreign direct investment in China (U.S.-China Business Council).

The size of China's computer and related industries has been growing explosively this decade. Imports of parts and components were worth $372 million in 1990, while exports of computers were worth only $200 million; by 1995, exports of computer products reached $3.78 billion. Software sales revenues were only $22 million in 1990 (due in part to software piracy); by 1995, software revenues reached $1.3 billion. In 1990 the Chinese computer industry had 191 hardware manufacturers, a few software and service firms, and a total workforce of 100,000 people. By the end of 1995, a total of over 300,000 people worked for 1,000 hardware manufacturers, 1,000 software houses, and 13,000 companies specializing in marketing and services, and there were an additional 1,500 workers in 50 R&D institutes (*China Infoworld 1995*). China's computer industry grew in output value from $921 million in 1990 to $6.37 billion in 1995. China's revenues from export of computers and input/output devices for computers grew from $150 million in 1989 to $3.6 billion in 1995.

Joint Ventures

China's domestic production of quality parts and components has been improved by joint ventures with companies like Hewlett-Packard (HP), AST, IBM, Unisys, Digital, and Compaq. In 1995 Compaq was the market leader in PCs, and Toshiba was the leader in portables with a 16% share. About 95% of the notebook market was assumed to be corporations. Compaq held 8.6% of the total market, followed by Samsung Electronics with 6.5% (concentrated in Korea), and Acer with 6.1%.

Sharp and Wuxi Municipal Electronic Instruments Company have invested $29.9 million in a black-and-white STN LCD factory. Intel has invested $30 million to build a factory to produce flash memory chips, microcontrollers and microprocessors, which is expected to go into production in 1997. IBM has moved its China headquarters from Hong Kong to Beijing and invested $10 million in a second joint venture PC assembly factory with Great Wall to supply domestic and overseas markets.

China's Domestic Market for Computers

In 1994 alone, 2.04 million PCs, 4.09 million monitors, 500,000 hard disk drives, 2.5 million floppy disk drives, and 6.05 million motherboards were made in China, most of which were exported. However, China has been a rapidly expanding market for computers in this decade, since there were few systems already in place, and servers have been needed to establish LANs for the growing number of new businesses. PC shipments in China grew from 100,000 units/yr. in 1990 to 1.08 million units in 1995, valued at $1.93 billion.

The Chinese PC market was estimated to be 1.4 million units in 1996. MEI estimates that by 2000 the Chinese output of PCs will reach 8 million units annually, with the majority sold domestically.

Legend is the best-selling domestic PC brand in mainland China. In 1995, Legend was in seventh place overall, with 8% of the market (by 1996, its share had reached 15%). AST was first with 16%, Compaq was second with 14%, and IBM was third with 9% of the market. The fourth, fifth, and sixth place players, respectively, were DEC in an alliance with the Founder Group, Hewlett-Packard, and Acer. The Chinese company Great Wall was number eight. The PC brand vendors were expected to get 80% of the home market. Acer was introducing a basic no-frills machine for around $500 for sales in developing markets.

Besides selling its own brands, Legend is also China's largest distributor for AST. It has over 200 outlets throughout China in which it sells brands like AST, IBM, and HP. Legend was the first vendor in China in 1995 to offer a Pentium 75 MHz PC for less than $1,200.

Intel commanded a 83.8% market share in China's CPU market, followed by AMD with 11.5%, and Cyrix at 3.2%. Pentium machines represented only 4% of the market in 1994 but over 45% in 1995. By the end of 1996, Pentium processors were predicted to increase from 20% to 74% of the market.

Joint Venture Semiconductor Investments

Since electronics is one of China's targeted industries, the semiconductor market in China is expected to grow dramatically, 40% per year, over the next 15 years from $4 billion in 1995 to $500 billion by 2010. According to HP, "Companies can't ignore China," in spite of its inadequate infrastructure, the government's control of the economy, unstable growth rates and investments, and deficits in state-owned enterprises. The following are just a few examples of China's escalating semiconductor endeavors:

- On March 19, 1996, China's Stone Group announced a joint venture with Mitsubishi Electric and Mitsui & Company from Japan to assemble integrated circuits in Beijing. Mitsubishi-Stone IC Company was to begin producing 5 million chips per month in June 1997, with an ultimate capacity of 120 million microchips and a value of $250 million. By 1998, $1.5 billion will be invested.
- On March 26, 1996, Hitachi announced its third operation to package and market memory chips in Suzhou Industrial Park. The investment will cost $40 million by the mid-1997 start up. Singapore's Economic Development Board will cover 30% of the cost, Hitachi 70%.
- NEC invested $104 million for a 40% stake in a semiconductor joint venture with the Shoudu Steel Works in Beijing. The plant produces 8,000 six-inch wafers per month and continues to expand its fabrication site near the capital.
- Motorola plans a $720 million semiconductor and telecommunication product plant in Tianjin. The semiconductor wafer plant will produce 3,000 submicron eight-inch wafers per week by 1998. The chips will be used in automotive, communication, PC, and consumer products.
- On May 7, 1996, Intel Corp. announced two separate agreements: a technology cooperation agreement with China's MEI for multimedia, telecommunications, enterprise computing, and training; and a license of Intel's latest Pentium motherboard designs to Beijing-based Great Wall Computer Group. Intel will continue its testing and packaging license for Pentium or Pentium Pro processors.

China's Telecommunications Industry

China's current five-year plan calls for spending no less than $60 billion by 2000 on the country's communications infrastructure, more than doubling its telephone switching capacity to 150 million from the 71 million lines it had in 1995. China's telecommunications industry is a state-owned monopoly which is operated solely by the Chinese government (Ministry of Posts and Telecommunications, MPT). Market access by foreign firms is limited to experimental joint venture projects in which the Chinese side holds majority ownership. China does need capital to modernize its network, however. MPT has allowed some value-added licenses to Singapore Telecom, a number of Hong Kong cellular companies, and United

Telecommunications Corp. (Unicom) to develop cellular and paging networks in China. The Directorate General of Telecommunications intends to allow foreign businesses to take part in some specific telecom projects on a joint basis. Nextel Communications and Shanghai Unicom own 23% of a Shanghai GMMS digital cellular telephone system. “Wireless local loops” that serve fixed locations can be installed faster than wired systems and in 1995 cost less than copper phone lines. Motorola and Ericsson completed connecting China’s cellular phone networks across 26 provinces; this is now the largest cellular network in the world. While there are currently only 3 million subscribers, it is expected to reach 13 million subscribers by 2000. MPT adopted Motorola’s high-speed Flex system as China’s national paging standard for 30 million existing customers, with 70 million customers expected by 2000.

China’s primary telecommunications-related exports in 1994 included wire telephone sets, stored program controlled telephone switchboards, radio and TV transmitting equipment, fax machines, radio pagers, radio walkie-talkies, and satellite earthstation equipment. Telecommunications products accounted for only 5.3% of total Chinese exports in 1995, generating foreign exchange revenues of about $2 billion.

Foreign companies with operations in China in early 1995 included AT&T (terminals and modems), Motorola (switching systems), Siemens (base stations and terminals), BTM (LSI sets), Ericsson (base stations and telephone switching stations), and NEC (terminals), in addition to Goldstar, Samsung, Fujitsu, and Northern Telecom. Primary imports included wire and wireless hand-held telephone sets and spare parts, fax machines and parts, walkie-talkies and parts, switchboards, and radar equipment. The market in 1995 (Table 3.3) was expected to be over 25 million lines for local area switchboards, over 19 million telephone sets, between 2.3 and 2.5 million switchboards, 1 million mobile telephone sets, 9 million pagers, 1.6 million mobile communication switchboards, 1 million long-distance switchboards, 600,000 fax machines, and 14,000 satellite communication earthstations.

Table 3.3
Forecast of China’s Communication Equipment Demand for 1995

Product	Units	Quantity
Local area switchboards	million lines	25-28.7
Customer switchboards	million lines	2.3-2.5
Telephone sets	million sets	19-25.8
Mobile telephone sets	million sets	1-1.1
Radio pagers	million sets	8.6-9.7
Mobile communication switchboards	million sets	1.62
Long-distance switchboards	million ports	.95-1.13
Long-distance optical cables	million kilometers	5.1-6
Optical terminal units	1,000 ports	6.8
Fax machines	1,000 sets	600
Satellite communication earth stations	1,000 sets	14

Source: PRC Ministry of Posts and Telecommunications, 5/12/95

HONG KONG - CHINA COMPETITIVENESS

Substantial foreign investment in China is raising the country’s technology and manufacturing capabilities to globally competitive levels, and this trend should continue. It seems likely that much of the manufacturing and technical base will continue to shift to mainland China as foreign corporations transfer their leading-edge technologies. Despite the fast-approaching 1997 return of Hong Kong to the PRC, Hong Kong’s capitalist economic and trade systems, the free movement of goods and capital, and the free port and separate customs territory are supposed to continue via a concept the Chinese call "one country, two systems." In spite of the high turnover of factory personnel in China, the Chinese have proven that high-quality, high-technology products can be produced in China with little difficulty because of workers' strong discipline and training. As China continues to develop an infrastructure for the electronics industry, Hong Kong is expected to continue to perform an important interface between mainland China and the outside world. Its lifestyle offerings and business support activities will continue to be important.

Both optimism and anxiety can be expected to continue in Hong Kong before the actual political transformation is complete. Hong Kong companies are now trying to determine their core competencies for the future. They need to determine what in-house capabilities can provide future competitive advantages as China's capabilities increase. Companies are trying to identify products and markets that offer future growth opportunities. There is a search for technologies that are required to build next-generation products and gain market position. Because of the focus on taking advantage of China's cheap labor, HK firms delayed funding their own technology development. Fewer than 60% of firms in Hong Kong spend over 3% of revenues for R&D. The lack of R&D and technology investment has left Hong Kong behind Korea, Taiwan, and Singapore in electronic technologies. Wafer fabrication or IC packaging facilities seem to be moving to mainland China rather than to Hong Kong.

Low Cost Design and Production (Wong's International Companies)

Hong Kong-based companies have been very successful at finding low-cost manufacturing sources for firms desiring to cut their production costs. One source is Wong's International (Holdings), Ltd., a parent company for electronics-product-related companies accounting for 5,500 employees and sales revenues of $315 million in 1995. Wong's Circuit (P&E) produces single-sided PCB for low-cost, high-volume consumer products with manufacturing in Hong Kong and in Huizhou (a joint venture with the city government) and Dongguan, China. Wong's Circuit (PTH) produces double-sided, up to 14-layer PCBs with factories in Hong Kong and a joint venture with the Huizhou city government. Wong's Electronics Co., Ltd. (WEC), assembles PCBs in Hong Kong, China, and Malaysia. Season Industries produces plastic molded parts next to WEC's PCBA factory in Shenzhen, China. A joint venture with Japan's Tomiyama makes precision sheet metal stamping. At the time of the panel's visit, the group had 7 factories totaling 1.1 million $ft.^2$ of manufacturing space.

WEC manufactures high-end electronics products and systems. Sales are divided between computers (35%), peripherals (25%), telecommunications (25%) and other office equipment, medical electronics, and industrial products (15%). WEC tries to offer customers a total manufacturing solution. WEC offers a "three-step" cost-reduction program that uses its vertically integrated PCB supply, plastics and metal parts supply, and electronics assembly, combined with global manufacturing, procurement, and sales:

1. Move production to China where lower labor cost, lower overhead, and lower land cost automatically cut product costs. If assembly is 10% of the product cost, WEC can achieve 30% savings in assembly cost, cutting overall costs 3%, by finding alternative sources for parts of equal specification, equal quality, and lower costs from established WEC vendors in China and other places in Asia. Most mechanical parts like switches, connectors, cables, speakers, passives, plastic and metal parts are sourced in China. WEC also provides component engineering services to support its supply line management strategy.
2. Reengineer products to cut manufacturing steps and reduce defects. Reengineering reduces board size to cut cost and waste and changes designs to reduce numbers of board layers, often from double- to single-sided boards. WEC uses Cadnetic and Pads2000 CAD software for PCB layout.
3. Create original product designs for customers.

In China, WEC produces Pentium PCBA subassemblies for NEC, hard disk drives for Conner, and cordless and cellular telephones for Toshiba. WEC also makes power supplies for ABB in Europe and PCB assemblies for Xerox office equipment worldwide.

Prototyping and Design Services (WEC, WKK, and Legend's QDI)

Lead times required for new product designs are typically six months. Companies like WEC and WKK provide on-site prototyping capabilities for their customers. WEC provides a prototyping SMT line at its Hong Kong facilities in order to make certain that production processes and product designs are proven before sending them to its factory in China. One of WKK's major customers does its actual prototyping in WKK's factory. In other cases, small outside firms handle prototyping of small volumes of a product for use in reliability testing and low-volume market testing.

WEC and WKK both have limited ability to develop new designs for their customers. The short life cycles of most computer-related products makes it difficult for a company to keep up with the changes taking place in the market. At the time of the WTEC visit, WEC had designed some notebook computers for several Japanese customers and had recently supported the design of NEC's new Pentium motherboard. WKK had recently designed a component stereo set for a Japanese customer. With a relatively small number of engineers, WKK has to select its projects carefully.

Legend's QDI, with a staff of 57, had the most extensive design capability for computers that panelists observed. QDI is one of the top-ten suppliers in the world for design, manufacture, and distribution of motherboard and add-on cards, mostly for VGA and MPEG video cards. In 1994, QDI sold 1 million motherboards and 3 million add-on cards and had the capacity to produce 300,000 motherboards or 580,000 add-on cards per month. Sales grew from $10 million in 1991 to $249 million in 1995. QDI representatives indicated the company was looking for new customers:

> We are now looking for new OEM customers to fill our excess capacity. At the Hanover fair in Germany, we introduced our OEM capabilities. We have contacted IBM, HP, NEC, and other PC makers. We offer cost-reduction opportunities through our strong sourcing and purchasing power, effective manufacturing, PCB supply, and simple organization. Our OEM group offers a single window to our customer, is very responsive, and has effective communication through electronic mail and international offices. We are ISO 9001 certified since 1994. We have won many awards for our product quality. It is our policy to never be late, try to beat our delivery commitments by MRP management, and continuously reduce our manufacturing cycle time. We also offer strong R&D and engineering support teams. It takes between 8 and 12 weeks to design a board. We are considering ODM business since we can help to design boards for U.S. companies.

Advanced Assembly Skills (Nam Tai)

The trend several years ago was for advanced Japanese and U.S. electronics companies to shift production to Korea or Taiwan where advanced manufacturing capabilities are available. Today, advanced production capabilities are also available in China. For example, Nam Tai Electronic (Shenzhen) Co., Ltd., produces miniaturized products like calculators, databanks, personal organizers, electronic dictionaries, IC card readers, LCD modules, and COB and SMT assemblies for customers like Canon, Sharp, Seiko Instruments, and Texas Instruments. Nam Tai utilizes the relative advantages of China's low labor cost, Japan's advanced assembly technology and management methods, and Hong Kong's gateway to China. Nam Tai's CEO noted to panelists that the company introduced the most advanced technology and production equipment in Southeast Asia, including wire bonding, SMT, OLB (outer lead bonding), and fine-pitch heat seal. It competed to produce high-tech products that require SMT, OLB, high-speed assembly, or next-generation chip-on-board. Nam Tai was looking to produce multimedia products using LCD displays. It was also developing MPEG 2 and MPEG 4 software for products five years into the future. A new $25 million factory that opened in April 1996 doubles previous capacity. Nam Tai obtained ISO 9002 in 1993 and ISO 9001 in 1996.

Nam Tai's new factory incorporates high-density micro assembly technology, including wire bonding in a class-10,000 cleanroom. The fourth floor has SMT and OLB. The third floor is for final assembly. New COB facilities and processes allow 130 µm fine pitch with high-speed and accurate coating and semiautomated die attach machines. By 1997, it was planned that the factory would wire bond 100 µm fine-pitch ICs. OLB will allow for 281 pin/240 µm pitch TAB. Assembly will allow 500 pin count/200 µm pitch TAB parts and BGA. SMT will allow for 500 µm fine pitch in the new factory, and 300 µm pitch by 1997. In 1997, chip on glass (COG) technology and multichip module (MCM) assemblies using BGA, CSP, and flip chip were planned. Table 3.4 shows Nam Tai's electronics technology roadmap.

Table 3.4
Nam Tai's Technology Roadmap

	1995	1996	1997	1998
PRODUCTS	Calculators, organizers, data banks, electronic dictionaries	PDA, Handy media module	Palmtop computers, electronic educational PRD, PHS, IC card reader	Intelligent network system, communication devices
COB (chip on board)	140 µm	→ fine pitch 130 µm →	120µm → 100µm	
OLB (outer lead bonding)	281 pin/280 µm	→ 281 pin/240 µm	→ 500pin/200 µm	→ 1,000pin/100 µm
SMT (surface mount technology)		small component 500 µm →	→ BGA 300 µm	
Heat Seal	420 µm	fine pitch → 350 µm		
ACF (anisotropic conductive film)		4-inch X—XX—100 µm →	6-inch 80 µm →	60 µm
COG (chip on glass)			X → XX →	→ XXX
MCM (multichip module)			BGA, CSP, flip X →	chip XX → XXX

According to Nam Tai's CEO:

> We are using 140 micron pad pitch wire bonding, but will use finer and longer wire in the future with higher pin counts. By 1997, we will use 130 micron pad pitch wire bonding by using higher level ASM wire bonders. The new equipment's limit is 100 micron pitch and 1,000 pin count. Computers require more pins. The products that must be thin and light will use this approach. Pocket-sized products must be thin and light. Computers can use large formats. We will be using OLB technology, COB technology, and SMT technology. The next step is COG technology for the LCD module connection system. After that, we need flip chip technology. The basic technologies are COG and OLB. By 1997, we will be producing flip chip.

Integrating Product Technologies (VTech)

VTech Corporation, with 1995 global sales of $631 million, is Hong Kong's largest manufacturer. It has been especially successful in integrating computer and telecommunications technologies in its new products. VTech effectively merged technologies from computers (30% of its sales in PCs) and telecom (23.7% of sales) into its electronic toys and learning aids (46.3% of sales). VTech made proprietary ASIC designs and was the first company in Hong Kong to design ASICs for PCs. VTech's Toys & Electronics division makes compact ASICs for use with more primitive microprocessors like the 8088 or 68000. Learning aids look like notebook computers or cars or telephones. Over 50% are sold in the United States.

VTech invests about $20 million in R&D annually, with 350 engineers in Hong Kong, 300 in China, and 100 overseas. Electronics products are dependent on key components like motherboards, video cards, and sound cards. VTech makes the ASICs and electronic assemblies that go into its products. Translation products use a proprietary CD ROM, which sells under the VTech name. In telecom products, VTech adds RF technology.

Wireless modems that code data into radio signals are expected to be integrated into PC products. With expertise in developing key electronics components, VTech is able to rapidly transfer PC and telecom technologies into its toy and learning aid business. As the world leader, VTech has over 100 design engineers in Hong Kong and over 30 new product designs on the drawing boards. It takes about six months to get new designs into production.

Design Capabilities in Shenzhen (Legend's QDI)

Legend's QDI also has extensive design capabilities for circuit boards, including 57 staff members. Most design staff are from famous universities in China. The product development group has 29 people, including 7 people in motherboards and diagnostics, 6 in VGA boards, 4 in IDE I/O, 4 in CAD for layout, and 7 in the BIOS and driver development area. QDI has the source code to allow for BIOS and driver modifications. Of 8 people in the product quality control group's product support department, 4 people are located in Shenzhen, 2 in Hong Kong, and one in Taiwan to aid in sourcing and preparation of manuals and documentation. The chip sets and BIOS come from Taiwan. The manufacturing engineering support group has 3 people to provide the interface between R&D and manufacturing and load the MRP for products. The administrative staff includes 4 members, and there are 3 staff in accounting.

QDI's product development process has ISO 9001 certification. The product design process includes specific steps for placement, placement approval, release of the Gerber file, prototyping, release of the bill of materials, and handling customer complaints. Fig. 3.3 shows the process.

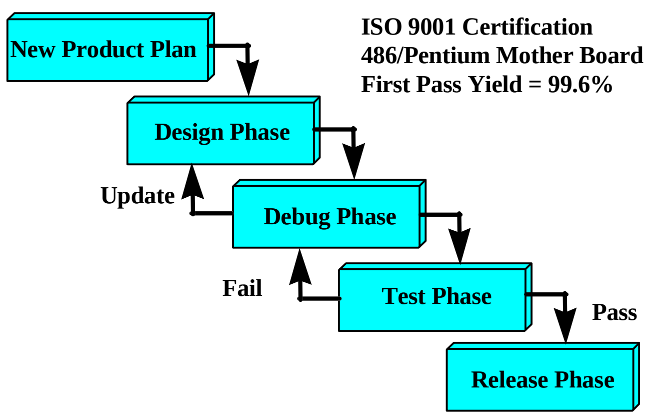

Fig. 3.3. Legend QDI's product design and test flow chart.

As one QDI official explained (February 1996):

> We do the product quality control [PQC] here and build our own test boards. After product development debugs its own product, it is passed to product QC. PQC checks the product carefully to find bugs. They will then send it back to product design to fix the product. Most problems are fixed after one review. After [the product] passes this process, it is tested further and then released for production. If [the product is passed], it is released to manufacturing. We make sure it is compatible with all the popular software drivers. We use the standard tests set up by outside organizations. This group also provides the documentation.
>
> We are the only beta test site for Intel in Hong Kong. There is no other equivalent company in Hong Kong. We see our competitors as being in Taiwan, not in China or Hong Kong. This is the product design flow chart. From the new product study phase; design, debugging, testing, to release takes from one to two months. Some motherboards take more than three months because of the time needed for debugging and testing. We produce over 150,000 motherboards per month and over 250,000 VGA cards per month. We are one of the largest producers of VGA cards in Asia. We

have several 486 boards, and three Pentium boards in production. We have just finished the P-6 motherboard. Not many companies can do this. We will begin production of the Pentium Pro board in May 1996. It includes BGA packages. We released the BGA information to manufacturing to get ready for that. We have an ICT test pad that checks the leads coming out from this chip. We created our own software for motherboard tests. We use Trident chip sets. Whatever chip sets they produce, we make the card.

SUMMARY

Mitsubishi Electronics, Hitachi, and NEC are all expanding IC production and packaging capabilities in China. Intel is establishing a flash memory factory in China. Not to be outdone, companies like AST and IBM have installed their most advanced production facilities in China. The expected growth in Chinese PC production to 8 million units annually by 2000 provides a major incentive. The extensive supply base available in China is reducing the need for imports as exports gain market share in overseas markets like the United States and Japan.

Hong Kong continues to provide an important support base for Chinese electronics industry developments. The rapid development of capabilities in China has already matched most manufacturing capabilities in Hong Kong. The attempt to upgrade technologies in Hong Kong appears to be limited, since most companies from the United States and Japan are placing operations and transferring the latest technologies directly to China. Companies like WKK and Wong's Electronics have specialized in helping companies cut their product costs through sourcing and production in China. Hong Kong's long-term advantage continues to be its living environment and support activities such as engineering, finance, purchasing, distribution, and communications. High cost of labor and limited availability of land provide little incentive to expand HK manufacturing operations.

At the same time, companies like VTech continue to expand operations in China, utilizing advanced ASIC technology to transfer computer and communications technologies into their advanced learning aids. Ability to embed their latest technologies into a chip, and then use the lowest cost labor to assemble their products, gives the company a strong leadership role in the world market for learning aids. Nam Tai produces the most advanced consumer products requiring miniaturization technologies, using Hong Kong as its sales, purchasing and distribution center. Legend's QDI considers itself a competitor with companies like Acer in Taiwan, offering the highest quality and most advanced desktop computers in China. Such development will put further pressure on Korea, Taiwan, and Singapore to push their technologies to more advanced levels.

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CHAPTER 4

SINGAPOREAN AND MALAYSIAN ELECTRONICS INDUSTRIES

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WTEC STUDY TEAM VISITING SINGAPORE AND MALAYSIA (APRIL 1996)

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RESEARCH METHODOLOGY AND REPORT

This chapter consists of a brief overview of Singapore and Malaysia with emphasis on their electronics industries and then a set of key observations. The team visited the 16 government agencies, institutions, and companies listed in Table 4.1. Summary reports on each of the sites visited may be found in Appendices C and D. During the visits, the team had the opportunity to discuss technology and manufacturing with leaders from the respective companies and agencies.

INTRODUCTION

Singapore and Malaysia are leaders in Southeast Asia. They are forging economic relations between members of the Association of Southeast Asian Nations (ASEAN) to further the region's development. Transformation of these economies has been fostered by industry and government cooperation. These countries have good trade balances, sound economies, positive capital flows, are internationally competitive, have diversified their industries, and are expanding into world markets. Singapore is classified as a more advanced developing country; Malaysia trails Singapore by only 5-10 years in its economic development. A major portion of their trade expansion is occurring in the electronics manufacturing sector. As a combined force, Singapore and Malaysia are the largest assemblers of IC packaging in the world.

Singapore and Malaysia started in the electronics business in the late 1970s by exploiting their cheap labor to assemble final products and subsystems. In the mid-1980s, Singapore and Malaysia's labor rates lost this competitive advantage to neighboring countries with lower wage rates. Changing economic realities caused

Table 4.1
Sites Visited by WTEC Team in Singapore and Malaysia

Site	Country	Focus	Type
Chartered Electronics Industries (CEI)	Singapore	Contract manufacturing	Local
Economic Development Board (EDB)	Singapore		Govt. agency
GINTIC Institute of Manufacturing Technology	Singapore		Govt. institute
Hewlett-Packard	Singapore	Ink jet printing	MNC
Institute of Microelectronics (IME)	Singapore		Govt. institute
Intel	Malaysia	IC packaging	MNC
LIKOM	Malaysia	Contract manufacturing	Local
Motorola Microcontroler Technology Group	Malaysia	IC packaging	MNC
National Science & Technology Board (NSTB)	Singapore		Govt. agency
NatSteel Electronics	Singapore	Contract manufacturing	Local
NatSteel Technologies	Malaysia	Contract manufacturing	Local
SCI Manufacturing	Singapore	Contract manufacturing	MNC
Solectron	Malaysia	Contract manufacturing	MNC
ST Assembly Test Services (STATS)	Singapore	IC packaging/Test service	Local
Texas Instruments	Singapore	IC memory packaging	MNC
Venture Manufacturing	Singapore	Contract manufacturing	Local

Local - locally owned company; MNC - multinational corporation

the governments to put together economic programs to modernize their nations and move to the next level of industrialization. Being single-party states with centralized decision-making structures allowed them to direct their resources to achieve aggressive economic development goals. Programs were directed towards export-oriented industries. Government-industry partnerships supported continued GDP growth of 8% per year with an inflation rate of less than 4%. Companies and government agencies provided clear goals to improve living standards as measured by GDP growth rate. The goal of Singapore's EDP 2000 plan is to achieve an unrivaled standard of living by the year 2000; Malaysia's plan, Vision 2020,[1] aims to achieve the same goal by 2020.

These plans support short- and long-term economic development programs. The electronics industry is playing an increasing role in elevating GNP with advanced manufacturing and end-assembly operations. The leaders of Singapore and Malaysia recognize that they can no longer improve their citizens' life styles by promoting labor-intensive industries: they no longer have low-cost labor. Singapore is the most expensive of newly developed and developing countries. Engineers' salaries in Singapore compare with U.S. salary levels. Surrounding countries like Indonesia, Myanmar, Laos, Cambodia, Vietnam, and China have far lower labor rates. To keep the standard of living up, more advanced technology and capital-intensive industries are required. Both countries are competing for high-technology and capital-intensive industries.

ASEAN PROFILE

Regionalization is important to all the countries in Southeast Asia. ASEAN, formed in 1967, now consists of Singapore, Malaysia, Thailand, Indonesia, the Philippines, Brunei, and Vietnam. The ASEAN region covers

[1] This plan is fully defined in the book by the same name by Abdul Hamid Ahmad Sarji (1995).

a total land area of 1.2 million square miles and a growing and youthful population of 425 million people. The region has an abundance of natural resources, particularly land, petroleum, and minerals. It is one of the fastest-growing economic regions in the world and has become a center for manufacturing excellence for many multinational corporations (MNCs) around the world. It is expected to include Myanmar, Laos, and Cambodia in the near future. The total ASEAN population will then exceed 500 million.

In the ASEAN founding declaration, members affirmed their interest in promoting economic growth, social progress, and cultural development among themselves to promote peace and stability. Functionally, the association is working as a clearing house for agreements to reduce internal barriers to trade and to standardize tariffs. ASEAN has provided preferential treatment in unilateral trade relations among member nations by enhancing each nation's capability to leverage technologies that it has "acquired" by allowing the free flow of capital and knowledge through free trade. The U.S. Department of Commerce added ASEAN to its "emerging markets" list in recognition of the significance to the U.S. economy of U.S. exports to ASEAN. The companies visited by the WTEC study team typically had operations in other ASEAN countries. As Table 4.2 shows, contract manufacturers had operations in a number of countries. (Solectron has recently announced plans to build operations in China.)

Table 4.2
Operations of Contract Manufacturers in Other Asian Countries

Country / Company	Singapore	Malaysia	Indonesia	China	Thailand
NatSteel	Y	Y	Y	Y	Y
SCI	Y	Y			Y
Venture	Y	Y	Y	Y	
Chartered	Y		Y	Y	
Solectron		Y		(Y)	
Likom	Y				

Y = yes

SINGAPORE

Singapore is an island city state 26 miles long by 14 miles at its widest point, with a land area of 240 square miles, approximately the size of Washington D.C. The population of 3.3 million including permanent residents and foreigners is growing. Singapore has virtually no unemployment and imports about 450,000 Malaysian workers (commuters) daily. According to Philip Yeo, Chairman of the Economic Development Board (EDB), Singapore's goal is to "Provide our youth and future generations with meaningful jobs, a high standard of living, and a quality of life second to none."

Singapore's strategy to improve the population's standard of living is to utilize foreign trade and to continuously increase its GDP. The leaders have developed a comprehensive plan to diversify the economy into greater-value-added products and services. They continue to identify emerging industries that they can target for growth and areas where they can leverage their resources. Their integrated strategy (Fig. 4.1) supports continued growth in GDP. The government has built a solid economic base and long-range plan ("E 2000") to support continued development.

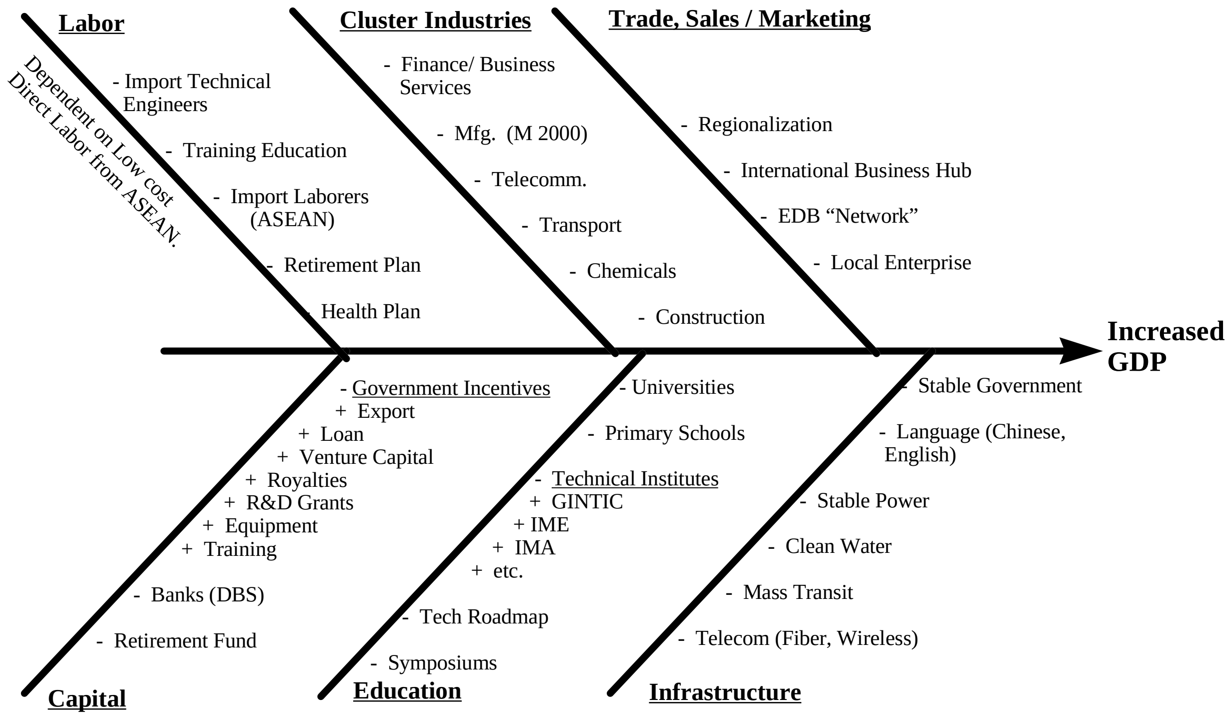

Fig. 4.1. Integrated strategies for economic development.

The government has set very specific goals for annual growth of 8% in GDP, with manufacturing at 25% of total GDP. The GDP increased 9.9% in 1993, 10.1% in 1994, and 8.5% in 1995. Singapore's per capita income is approximately $22,000.[2] Singapore was the United States' ninth-largest export market ($15 billion) in 1994. The country boasts one of the world's most highly developed industrial, commercial, financial, and consumer economies. Major exports are refined petroleum products, electronics (primarily disk drives and computer-related products), and services. Inflation remains low at 2-4%, and 1994 new investments totaled $2.4 billion.

Singapore's infrastructure supports continued economic development. Its telecommunications system is completely digital and uses the most modern technology. There is already fiber in every home, which is reflected in Singapore's reputation as the "intelligent island." Individuals are surfing the Internet on T1 cables. Singapore boasts an extensive road network and a modern mass transit system that utilizes bus, train, and light rail systems to serve major business, manufacturing, shopping, and residential areas. Its deep seaports and airport are ranked among the world's best facilities. Centrally located in Southeast Asia, Singapore provides a focal point for commerce, development, and communication activities among ASEAN countries. In concert with Malaysia and Indonesia, Singapore has established stable but increasingly expensive regional supplies of power and water.

Singapore has focused the entire country's organizational structure to support its growth. Every institution, from parliament to the finance and capital markets, from educational institutions to the transport authority, share common goals. They have created monetary exchange control regulations that are business-friendly but regulated. They offer attractive tax incentives for promoted investments ranging from pioneer status (partial exemption from income tax payments) to investment tax allowances. Rebates, deductions, R&D training, and incentive programs for skills training are many, and taxation has steadily been reduced over the last five years, with Singapore's tax rate being the lowest in the region. Recently the government has introduced a general

[2] All dollar amounts ($) are U.S. dollars, unless otherwise noted.

service tax (GST), which is a value-added tax system; this is expected to further reduce overall taxation on the individual as well as corporations. Capital gains are not taxed, nor are citizens who are stationed overseas.

Recognizing that future growth will depend upon overcoming resource limitations and a small domestic market, Singapore's government has taken the following key strategic steps:

- encourage multinationals to select Singapore as their Asian headquarters
- invest in nearby developing countries (China, India, Malaysia, Indonesia) to obtain market access
- promote foreign investment in leading-edge and higher-value-added technology development

A shortage of labor is leading Singapore to cooperate more fully with its neighbors, transferring labor-intensive operations out of Singapore and upgrading its own level of technology and labor.

The government of Singapore is preparing the workforce for the future through industrial and educational cooperation. The government works to increase research efforts within universities for industrial research. The government has used incentives to attract multinationals and their technology and to increase the skills of the local workforce. Industry provides the monetary support and establishes R&D facilities that help train students and workers. Industry obtains government assistance in R&D for product and process developments.

As Fig. 4.2 shows, Singapore also recruits technical engineers overseas. Training is a major part of Singapore's strategy for development. If there is a technology that a local company needs, the government will identify a source and bring it into Singapore from anywhere in the world. Technical training includes foreign education, foreign experts, multinational corporate training, and a variety of technical training programs and institutes. All of these activities are supported by the government in order to improve the quality and capabilities of the nation's work force.

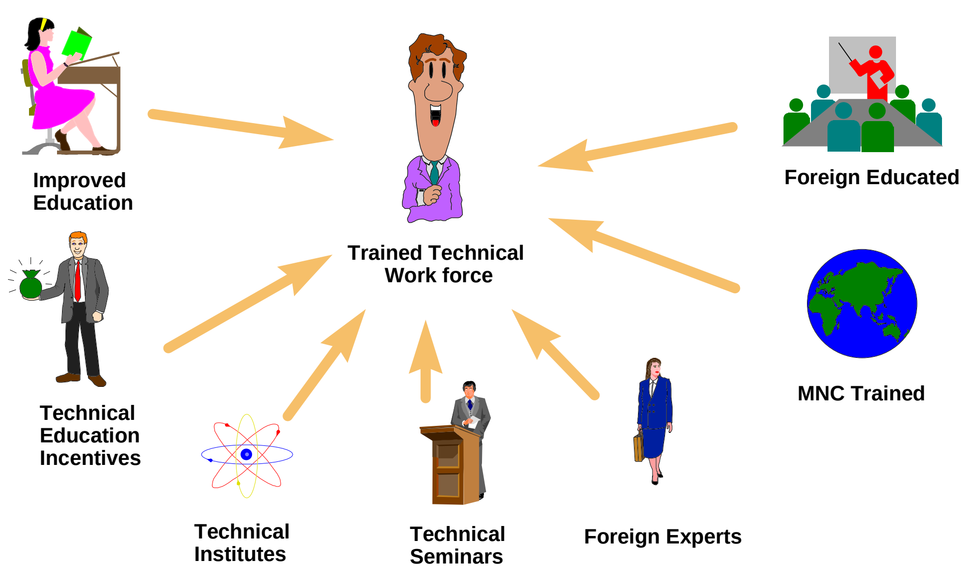

Fig. 4.2. Sources of technical know-how.

An integrated and efficient infrastructure (power, water, roads, etc.) allows international companies to move in and set up easily. Singapore competes with capital, not labor. Its capital investment incentives include the following:

- Investment allowance
- Expansion incentive
- Export of services
- Approved foreign loan scheme
- Approved royalties
- Overseas enterprise incentive
- Warehousing and logistics incentive
- Overseas investment incentive
- Venture capital incentive
- Operational headquarters incentive
- Business headquarters
- Double deduction for R&D expenses
- Double deduction for overseas investment development expenditure
- Research incentive scheme
- Research & development assistance scheme
- Coinvestment

Manufacturing incentives in 1994 reached about $1.1 billion, an increase of 49% over 1993. Japan and the United States are heavy investors in Singapore (and Malaysia). Japan's rising wages and high yen value have caused its companies to move offshore. Singapore's ease of investment and technology support has been increasingly attractive since the mid-1980s. In addition, the country's strong and cohesive infrastructure offers investors core competencies in the following areas:

- education
- technical institutes
- trade, sales/marketing
- telecommunications (fiber, wireless)
- mass transit
- imported technical experts
- imported laborers (Bangladesh, Indonesia, Philippines, etc.)
- technical associations
- technical consortia (e.g., ball grid array)
- research institutes and centers

Other countries have asked Singapore to set up and operate industrial parks and economic zones.

Singapore's EDB has $1 billion in a cluster development fund to support the growth of manufacturing GDP and achievement of the country's development goals. These are investments that don't require a return-on-investment justification but are assumed essential for future developments. If a firm has a need for technology, the government will find funding to support it. The Singapore government currently runs a $10 billion budget surplus, so EDB has the funds for such investment.

EDB is empowered to represent the many constituents of the Singapore government, thus reducing the confusion of "doing business" in Singapore. To facilitate investment, EDB works closely with a variety of organizations, including Jurong Town Corporation, JTC (responsible for land and factory space); the Development Bank of Singapore, DBS (responsible for capital and financing); the National Science and Technology Board, NSTB (responsible for technology development and transfer), the Productivity Standards Board, PSB (responsible for standards, measurements, and testing); and the Trade Development Board, TDB (responsible for export trade).

Singapore's National Strategies

Singapore's government officials view themselves as capitalists responsible for business formation. They have focused on six development strategies: (1) developing industry clusters, (2) making Singapore into a business hub for the region, (3) promoting regional development, (4) developing business councils to recruit industrial partners, (5) supporting evolution of companies into MNCs through product and market developments, and (6) collective marketing to sell Singapore's government, corporate sector, and academic goals.

Twelve business clusters are central to Singapore's business development strategy. The national objective is to generate at least 25% of GDP from manufacturing. If government officials don't maintain this goal, they will lose their jobs. The government established the NSTB in 1991 to develop Singapore into a center of excellence in selected areas of science and technology in order to enhance national competitiveness in both the industrial and services sectors. NSTB's activities support the following clusters:

1. Commodity trading to develop Singapore into a leading international trading hub with competence in offshore trading, transshipment and reexport trading. The Trade Development Board is responsible.
2. Shipping to strengthen and broaden Singapore's position as a leading maritime hub, a regional headquarters for shipping and ship management activities, and a leading feeder for shipping lines. The Port of Singapore Authority is responsible.
3. Precision engineering to become a premier designer, manufacturer, and marketer of niche high-end precision components and systems, where Singapore enjoys a competitive advantage. The Economic Development Board is responsible.
4. Electronics to excel in selected specialized technologies and establish Singapore as a high-value-added electronic products/component supplier as well as an R&D and product management center for the Asia-Pacific region. The Economic Development Board is responsible.
5. Information technology to support Singapore as an effective exploiter of information technology and to be a competitive exporter of software products and services focusing on strategic sectors and capitalizing on niche technologies. The National Computer Board is responsible.
6. Petroleum and petrochemicals to develop Singapore into a world-scale integrated petroleum and petrochemical hub. The Economic Development Board is responsible.
7. Construction to enhance competitiveness in construction services and establish Singapore as one of the centers for construction services for the Asia Pacific region. The Construction Industry Development Board is responsible.
8. Heavy engineering to maintain Singapore's position as a major center for ship repair and oil rig construction and to develop it into a major center for manufacturing and servicing of oil and gas field equipment. The Economic Development Board is responsible.
9. Finance to become a major international financial and financial news center. The Monetary Authority of Singapore is responsible.
10. Insurance to establish Singapore as a regional insurance and reinsurance center and to increase the insurance coverage of the population to the levels of industrialized nations. The Monetary Authority of Singapore is responsible.
11. General supporting industries to establish Singapore as a one-stop service center and regional center for internationally competitive and high-quality products and services. The Economic Development Board is responsible.
12. Tourism to establish Singapore as a premier visitor destination with universal appeal and a leading international hub for aviation, convention/exhibition, and travel/tourism-related services. Singapore Tourist Promotion Board is responsible.

The Aerospace cluster has now been added to the strategy. Singapore's core service competencies cut across these clusters. Telecommunications, finance, shipping, and insurance support the manufacturing industries. Singapore's information technology supports its shipping activities by allowing it to be the most automated port in the world. In manufacturing, the clusters shown in Fig. 4.3 are central to Singapore's strategic plan.

Singapore plans to become a hub of regional headquarters for the region, and attract higher-value-added activities, which will effectively utilize its relatively small population.

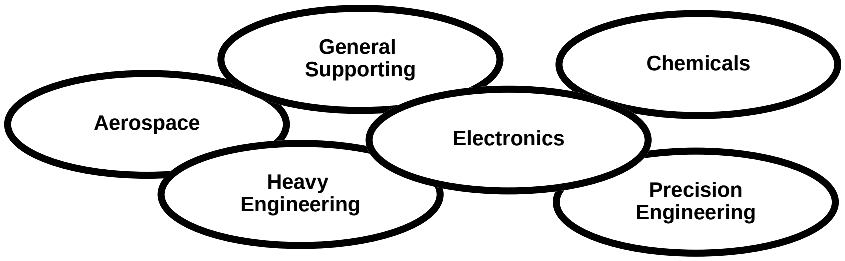

Fig. 4.3. Singapore's core clusters to support manufacturing.

Singapore's Electronics Industry

Electronics plays a major role in Singapore's "E 2000" cluster plan. The Singapore electronics industry had a 1995 output of over $45 billion, a growth of 19% from 1994. Electronics accounts for 51% of Singapore's GDP. The electronics industry makes up 43.7% of the total manufacturing output of Singapore. Its cluster includes consumer electronics, communications, semiconductors, electrical supporting industries, computers, and mass storage and peripherals. The electronics industry in Singapore is not growing in the area of consumer electronics, but is growing in the very latest and most advanced products and technologies such as data storage, computing, and wafer fabrication. Fig.4.4 shows the major product segments that make up Singapore's electronics output.

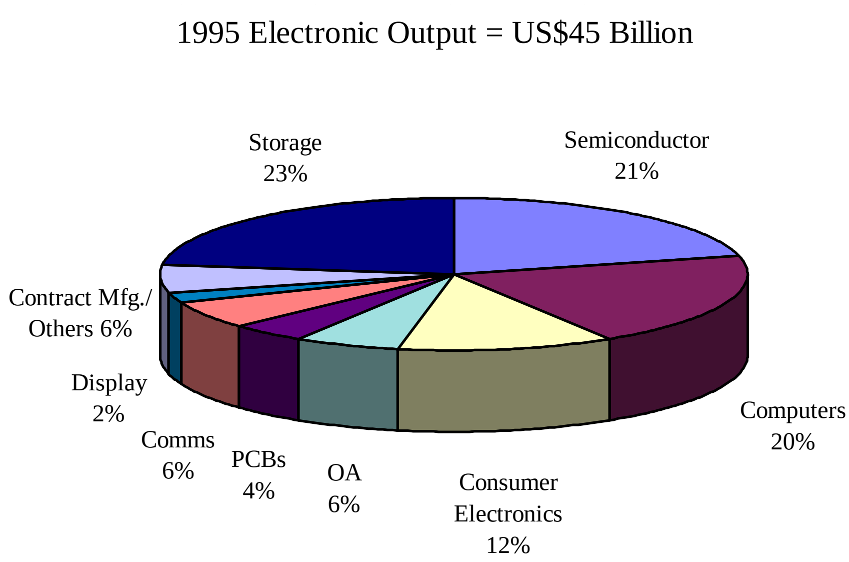

Fig. 4.4. Key electronics sectors, 1995 Singapore economy.

Storage products (hard disk drives), semiconductors, computers, and consumer electronics are the dominant product segments and represent about 76% of the $45 billion in electronics output. Table 4.3 shows the growth of key segments. Between 1994 and 1995, data storage devices grew 20%; semiconductors grew 53%; computers grew 10%; consumer electronics declined 3%; communications grew 34%; office automation products grew 17%; passive components and printed circuit boards grew 10%; display devices grew 21%; and contract manufacturing and others retained the same level of output. Contract manufacturing and printed circuit board production are not cost-effective in Singapore for low-end products and require higher levels of production technologies.

Semiconductors are considered a key enabler for all electronic businesses. EDB has been successful in deploying this technology and is planning for 20 wafer fabrication operations (fabs) to be operating in Singapore by the year 2005. Fig. 4.4 and Table 4.3 indicate the size and importance of Singapore's semiconductor industry. Between 1994 and 1995, semiconductor revenues grew 53% to about $2.2 billion. What is impressive about this growth is that it was zero five years earlier. The infrastructure for the future wafer fabs is in place and ready for development. The American School has been moved near the industrial park for future wafer fabs to encourage Americans families in Singapore to move closer to the industrial park.

Table 4.3.
Growth in Singapore's Key Components

	1995 (S$B) [3]	1994 (S$B) [3]	% Growth 95/94
Data storage	13.5	11.3	20
Semiconductors	12.2	8	53
Computers	11.5	10.4	10
Consumer electronics	7.2	7.4	-3
Communications	3.7	2.7	34
Office automation	3.4	2.9	17
Passive cpts. & PCBs	2.1	2	10
Display devices	1.3	1	21
Contract mfg. & others	3.3	3.3	0
TOTAL	58.2	49	19

The boxes shown in the electronics cluster in Fig. 4.5 represent the strategic products that are needed for future growth: multimedia products, personal digital assistants, direct satellite systems, and set-top boxes for cable and satellite receivers. Communications represents a new growth opportunity, and displays are required for next-generation multimedia products. Government officials are pushing hard to make sure they are growing in those product areas. They ensure that supporting technologies like semiconductors are in place. They see lithium ion polymer batteries as future products that will be available within the next several years. Tantalum capacitors for wireless products and optical mass storage technologies also have been identified as essential technologies for future products. If any company wishes to bring its R&D activities to Singapore to develop these technologies, the government will begin negotiations to fund 50% of the research and development expenses. It is aggressively seeking access to the technologies required for future growth.

At one point in the WTEC trip to Singapore, government officials showed a slide that one of the team members had developed about three years earlier for the U.S. National Electronics Manufacturing Initiative (NEMI) (Fig. 4.6). They were quite capable in explaining it, and it is apparent that Singapore is closely following world technology trends.

[3] The approximate rate of exchange is S$5.3 to U.S.$1.

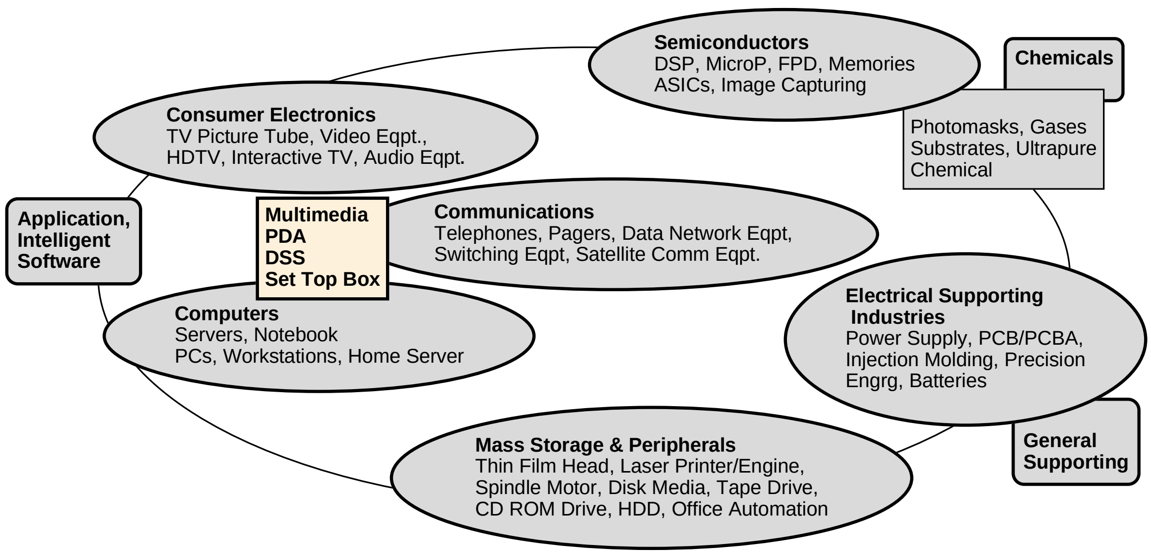

Fig. 4.5. Singapore's electronic manufacturing clusters.

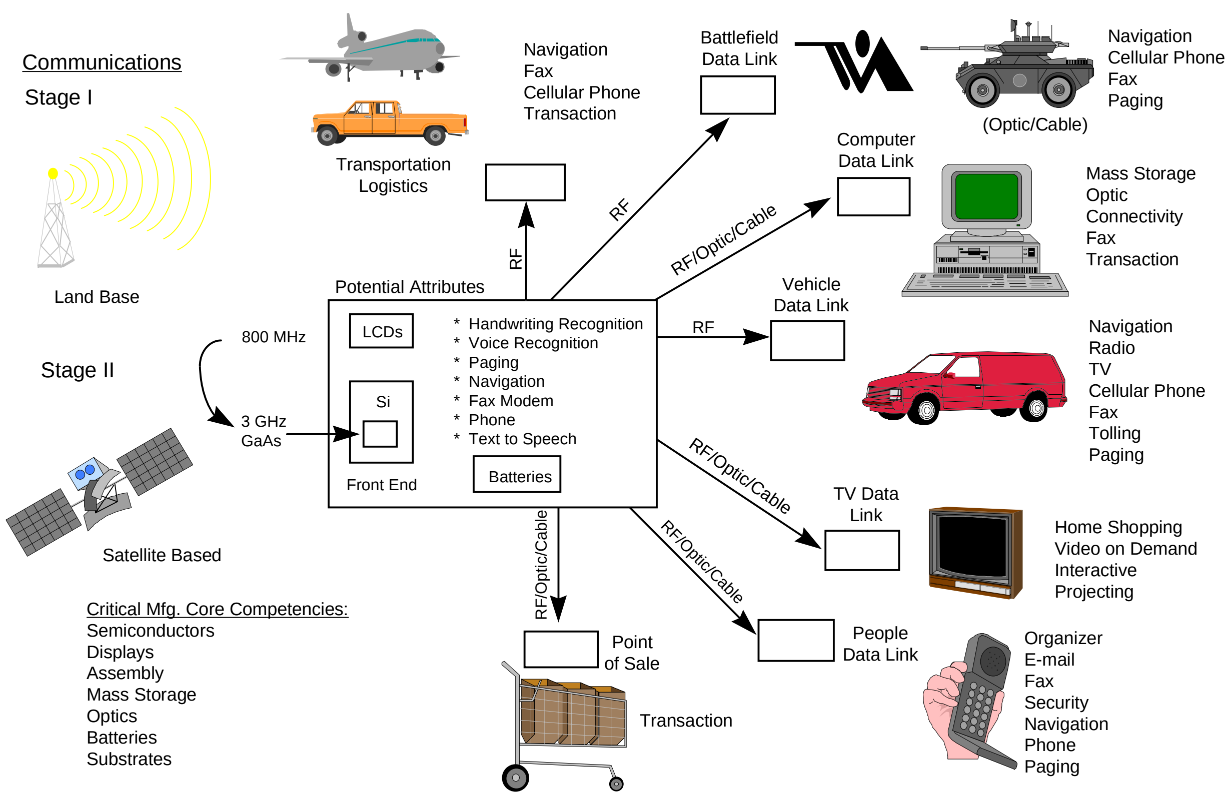

Fig. 4.6. NEMI vision of technology deployment.

Singapore has shifted its core competence from just manufacturing to component design. Table 4.4 identifies many firms that have made investment commitments to Singapore's electronics industry. IC fabrication of silicon semiconductors has had the highest priority. Singapore has established the infrastructure to support 20 wafer fabrication facilities by 2005, with designated land, installed utilities, schools, and logistics to support such growth in fabs. Sharp, Siemens, and SGS-Thompson are providing IC designs. IC assembly and testing, photomask equipment, and automation technologies are being developed in Singapore. A number of firms have operations in Singapore for disk media, wireless communications, computers, and other key components. Texas Instruments' research and development and memory manufacturing is all controlled from Singapore.

Table 4.4
Foreign Firms Investing in Singapore's Electronics Industry

Growing Electronics Capabilities		Foreign Companies Involved
• Semiconductor - Wafer Fab	→	CSM-3, Tech-2, HNSC
• Digitization - IC Design	→	Sharp, Siemens, SGS-Thompson
• IC Assembly & Test	→	Brooktree, Seiko-Epson, Stats
• Supporting Industry- Photomask, Equipment	→	Photronics, ESEC, Sumitomo Bakelite
• Automation	→	Sony Display, Hitachi, Siemens
• Key Components - Disk Media	→	StorMedia, Hoya, Seagate, Conner Mitsubishi Chemical
• Wireless Communications	→	Motorola, Philips, Kenwood, Goldtron
• Computer	→	Adaptec, Apple, Compaq
• Key Modules / Components	→	Sony, Philips, MESA

The WTEC study team visited government agencies and institutes where the brightest graduates are employed. The Singapore Economic Development Board guides and nurtures industrial investments. Leaders in the electronic packaging industry assemble, develop, and conduct research in the region. GINTIC is a government institute of technology which, along with the Institute of Microelectronics, supports manufacturing and technology in electronics. The National Science and Technology Board assures that research activities are linked and relevant to the industry.

CONCLUSION

Singapore's long-range goal is to surpass the U.S. per capita GNP by 2030. Singapore's future activities are based on its E 2000 plan to move into more advanced production capabilities. The upgrading of technology is essential to address the rising cost of labor and to improve living standards. The plan stresses working relationships between government, industry, and academia. It includes a wide range of programs to support the development of semiconductors, communications, display, and data storage businesses across Southeast Asia. ASEAN's members are reinvesting to improve their core competencies at all levels of the supply chain. Singapore alone invested $28 billion in 1993 in countries throughout the region. The strategy is intended to increase higher-value-added products, develop greater R&D activities, create a better trained workforce, and further develop Singapore's regional role as the leader of its immediate geographical area and gateway to that area for MNCs, technology transfer, investment, and so forth.

MALAYSIA

Malaysia is on its way to becoming the fifth so-called “tiger,” or newly industrialized economy, of East Asia, along with Taiwan, Korea, Hong Kong, and Singapore. The country has averaged a real 9.6% growth in GDP over the past eight years. Its goal is to increase trade at an average annual rate of 8.5%. While Malaysia is somewhat behind Singapore in its development, it has a clear vision of its goal for the year 2020. Malaysia has a population of 20 million people producing an adjusted GDP of $171 billion. It has a free market economy with an 8-9% growth each year (GDP growth for 1995 was 9.6%). At the time of the WTEC team’s visit, the country had an inflation rate of 3.4-4% and an unemployment rate of 2.5% for its labor force of 9 million.

Malaysia is larger, more geographically dispersed, and richer in natural resources than Singapore. It has a total land area of 329.8 square kilometers and consists of a peninsular area (East Malaysia) and Sabah and Sarawak (West Malaysia) on the island of Borneo. Malaysia is a multilingual culture. The major languages are Bahasa Malaysian and English (the official business language), with Chinese, Tamil, and Hindi also spoken by many of its residents. Malaysia is an Islamic state that has succeeded in balancing religious fundamentalism with pragmatism in application of its laws and business environment. Malaysia practices parliamentary democracy and has been a stable, single government since achieving independence in 1957.

Malaysia enjoys a unique situation at this point of its development history. It currently enjoys trade benefits through GATT’s Generalized System of Preferences (GSP) and unilateral trade agreements, and it now has the infrastructure, technological expertise, and manufacturing diversity to meet the demands for high quality of its firms’ customers and pass the content hurdles set out in the international trade agreements. The confluence of these events supports capital investment from a variety of sources (the United States, Japan, and Europe, as well as other Asian countries such as Taiwan). Malaysia is working with Singapore and Indonesia to further develop and refine supplies of water and power for the region. Malaysia’s petroleum reserves are adequate to supply domestic needs and still export.

Malaysia’s Industrial Strategy

Malaysia’s geographic location, deep-water ports, modern airports and transportation system, telecommunications, and reliable power and water facilities provide investors with an attractive infrastructure backed by an investment-friendly environment that allows up to 100% foreign ownership. The main economic growth segments are manufacturing, agriculture, and tourism. Malaysia is among the world’s leading exporters of semiconductors, air conditioners, rubber gloves, and consumer electronics. The country has 11 Free Trade Zones (FTZs) as incentives to develop specific geographic areas. Within the FTZs, companies are subject to minimum customs formalities and are exempt from import duties on raw material, machinery, and component parts. The government has created monetary exchange control regulations that ease the transfer of funds for approved projects. It offers attractive tax incentives for promoted investments, ranging from “pioneer status” (partial exemption from income tax payments) to investment tax allowances and abatements for exports and deductions for R&D training. Operations must provide partial ownership to indigenous peoples (*Bumiputra*) before listing on the stock market can occur.

Penang, the second smallest state in Malaysia, has a manufacturing economy that accounts for nearly half of the country’s GDP. There are currently six different industrial parks in Penang to support Malaysian manufacturing industry. Through the Penang Development Corporation, Penang has developed significant investment for the past 20+ years, primarily in electronics. In terms of technology deployment in advanced electronics manufacturing, a summary of Solectron’s operations in Malaysia vs. other locations (Table 4.5) indicates there is virtually no delay time in getting the latest technologies in Penang. Although California is the leader in U.S. electronics technology, Solectron in Malaysia will have some capability before its California operations begin. As another indicator, Intel Corporation has invested $800 million in its Penang facility.

Table 4.5
Solectron's Electronics Capabilities in Penang, Malaysia, and Other Locations

Technology	California	Washington	N. Carolina	Penang	Bordeaux	Dunferm
0.3 mm Mass Reflow	C		C	D	C	C
0.4 mm Mass Reflow	P	C	P	P	P	P
0.5 mm Mass Relow	P	P	P	P	P	P
BGA:<225 I/O	P		D	P	D	D
BGA:>225 I/O	P		D	P	D	D
Entek Boards	P		P	P	P	P
TAB	P		C			
Flip - Chip	D					
Chip On FR4	C			C	P	
Chip On Flex	P			P	D	
Chip On Ceramic	D					
Chip On Glass	D			D		
Selective Wave	P	P	P	P	P	P
No Clean	P	C	P	P	P	P
VOC Free No Clean	P	D	C	P	C	C
SLR Paste in Hole	P			P		
LCD Mod. Assembly	D			C		

C = being considered, D = being deployed, P = in production

The Malaysian Technology Development Corporation (MTDC) provides seed capital to companies interested in investing in Malaysia. The MTDC also provides capital to Malaysian companies that are involved in technology-based operations, in order to enhance their competitiveness. The objectives of the MTDC are (1) to develop indigenous technology, (2) to facilitate the absorption of technology developed by universities and institutions, (3) to transfer technology to local companies by gaining access to foreign technologies, and (4) to develop venture capital activities in Malaysia. Like Singapore, Malaysia also emphasizes interregional investment and technology transfers. The goal is to develop new markets and sources of low-end products.

Malaysia's Vision 2020

The government of Malaysia has provided a clear vision to its companies and their employees: to reach the standard of living of industrialized countries by the year 2020. This plan, called Vision 2020,[4] is accelerating Malaysia's shift to high-technology industries. Specific objectives include accelerated industrial restructuring, technological upgrading, human resource development, and industrial linking. Malaysia's seventh development plan emphasizes the capabilities of its manufacturing sector by producing higher-value-added products and developing workers better capable of meeting the requirements of more sophisticated manufacturing processes. The plan focuses on development of industry, academic, and government relationships. The government is developing preemployment schools to train employees with strong work ethics and loyalty to company and country. It has also developed high-tech industrial parks to allow for the concentration of industry, research and development, and academic institutions. The government is also supporting industry with technical training programs and research programs at universities.

The Penang Economic Council drafted the Penang Strategic Development Plan in 1991 to support Vision 2020. Specific strategies included the promotion of skill-intensive, technology-intensive, and high-value-added industries through building an R&D infrastructure, including technology parks, and a supportive culture with a qualified workforce. In order to attract skilled workers from other states and countries, Penang is creating a competitive wage policy that will change its manufacturing core competence from labor-

[4] See footnote 1.

intensive to capital-intensive manufacturing. Companies from Japan, the United States, Taiwan, Singapore, Hong Kong, and Germany invested over RM[5] 15 billion (about $6 billion) in 1995. Malaysia continues to follow in the path of Singapore, developing close relationships with foreign and local industry participants. For example, Intel assembles its Pentium chips and does much of its packaging research and development in Malaysia, and Motorola has its premier packaging group in Malaysia.

Malaysia is a founding member of and plays a strong leadership role in ASEAN. The country is also involved in the General Agreement on Trade and Tariffs (GATT) and the World Trade Organization (WTO). Among the newly industrialized economies of East Asia, only Malaysia enjoys preferences under the General System of Preferences (GSP). GSP was intended to help developing countries grow their economies. It provides special access to first-world countries' markets, and industry protection measures that give local companies a competitive advantage. To attract companies and investments, Malaysia is reducing corporate tax rates from 32% to 30%. It will also reduce withholding taxes from 20% to 15% on interest payments made to nonresidents, and reduce the taxes on technical fees and royalties from 15% to 10%. Import duties are being reduced on more than 2,600 items, and sales tax on machinery parts and components and imported heavy machinery will be abolished.

Malaysia's Electronics Industry

The electronics industry plays a major role in Malaysia's development plan. It grew 29% in 1995 and 21.6% in 1994. Malaysia is a major producer of ICs, semiconductors, capacitors, and wafers. More than 80 companies produce PC-based components, subassemblies, or peripherals there. As a leading exporter of electronic components, the government is committed to increasing the value-added level of products. Under the Action Plan for Industrial Technology Development, it has targeted both upstream and downstream industries for development with the goal of becoming an R&D center. Downstream, motherboards and non-CRT displays are targeted. A major upstream project in Kulim Hi-Tech Park (financed by U.S. investments) will emphasize production of software, IC and wafer fabrication, including multilayer, coextruded, electron-beam cross-linked polyolefins, shrink films, and high definition displays (HDD). HDD has been designated as a strategic industry with a 10-year tax holiday. R&D incentives provide 5-year pioneer status and tax allowances on R&D investments. Matching grants and industrial building allowances of 10% are available. Capital allowances, tax exemptions on machinery and equipment for R&D, and relaxed tax conditions for expatriate and foreign workers support investment. In addition, seven of Malaysia's 11 FTZs are devoted to electronics: Batu Berendam (Malacca), Ulu Klang (KL), Bayan Lepas (Penang), Prai (Penang), Technology Park (KL), Kulim Hi-Tech Park (Kedah), Shah Alam (Selangor), and Subang Hi-Tech Park (Selangor).

In conclusion, Malaysia has the infrastructure, technology, manufacturing capabilities, and trade advantages that ensure its continued development. To reach a developed status by 2020, the targets are to increase domestic investments, to continue to diversify the economic base, to continue to develop and advance technological innovations, and to continue to develop R&D in education, training, and technology centers. The country's seventh development plan supports the goals of Vision 2020. The Technology Park of Malaysia will accelerate R&D developments in information technology, biotechnology, electronics, microelectronics, resource-based technology, telecommunications technology, aerospace, defense, and materials technologies. The government supports increased education, technical institutes, trade, telecommunications, mass transit, and recruitment of technical experts. The country is exporting its labor-intensive industries and importing laborers from countries like Bangladesh, Indonesia, and the Philippines. Technical agreements and consortia are being developed for advanced technologies like ball grid arrays. The goal of the manufacturing sector is to grow 10.5% annually and contribute 37.2% to GDP and account for 82% of total export earnings by 2000. Improved education, advanced technology, and ASEAN cooperation and investment are all expected to help make Malaysia a major world force in electronics.

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[5] RM is abbreviation for Malaysian currency, ringgits.

SINGAPORE & MALAYSIA'S GROWING COMPETITIVE CAPABILITIES

Singapore and Malaysia have natural strategic advantages from their locations as gateways to Asia. They have used their location to become major financial centers, and they provide tax incentives to encourage the transfer and development of technological and intellectual property. Both governments are committed to high levels of GNP growth. They recognize that technology and product development are required to move beyond their strength in manufacturing. The governments actively follow and track the technology roadmaps developed in advanced nations that conduct cutting-edge research and development, and they quickly develop complementary approaches to attract local participation. Commonly shared visions by government officials facilitate their ability to make quick decisions, a key factor in their success.

The primary goals of Singapore and Malaysia are to become totally self-sufficient and self-sustaining economies while maintaining high standards of living. In terms of electronics technologies, they have acquired and are importing the additional technologies and intellectual property required to achieve independence from foreign sources. Their strengths include the following:

- Government and industry work closely together to optimize for GDP growth
- They strongly emphasize technology and innovation (moving up the value chain)
- ASEAN is reinvesting to improve core competencies in all levels of the supply chain
- Singapore and Malaysia have clearly defined plans to ensure they will be a force in electronics for the long term

In some cases, the governments have provided nearly 100% financing and investment to multinationals that could enhance technology transfer. Multinationals are transferring state-of-the-art development and manufacturing to take advantage of the financial incentives offered by Singapore and Malaysia. In addition, the governments are subsidizing R&D activities for advanced technologies. As a result, the old model of technology movement from the United States and Japan into Singapore and Malaysia is changing.

As shown in Table 4.6, as Singapore and Malaysia move towards increased research, with high-volume, low-cost manufacturers, the United States is most likely to become a technology follower. They are moving rapidly into design and development and are increasing their investments in research in all areas of electronics. They are well established in production of ICs, IC packaging, PCB fabrication, and PCB assembly. The Singapore and Malaysia PCBA industry is on par with (or slightly behind) the United States in terms of technology. Both countries have increasing design capabilities in all of these areas and are moving into basic materials research to support next-generation component developments.

Table 4.6
Model of Singaporean/Malaysian Electronics Technology Development

Product Technologies → → →

Technology Stages	Integrated Circuit	IC Package	PCB Assembly	PCB	
Research	Cell Design	Materials	Materials	Materials Plating Wet Chemistry	
Design	Logic Design	Mechanical Characterization	Circuit Design		**Some Capable**
	Module Layout	Package Design	Layout	Layout	
Deployment	Production Engr.	Production Engr.	Production Engr.	Production Engr.	**All Capable**

The work ethic and regional loyalty in Singapore and Malaysia are high due to such labor benefits as the governments' effective health care and retirement programs. A strong desire for personal advancement, stimulated by a high demand for talent, results in a great deal of job hopping and thus "technology transfer" throughout the region. The governments attract high-value-added capabilities by being able to establish new expertise. Government institutes focus on training future engineers, presenting a shared vision of technology directions, and providing centralized facilities for use by local companies. While the research of these organizations is insignificant, their product deployment capabilities are well utilized. Deployment of leading technologies for mass production (bare chip attachment, BGA, etc.) is ongoing.

The United States is clearly more advanced than Singapore and Malaysia in conducting both basic and applied research; is slightly ahead of Singapore and Malaysia in terms of process development; is on par with Singapore and Malaysia in terms of process deployment; and is behind Singapore and Malaysia in continuous improvement of mass production. But in the minds of officials in Singapore and Malaysia, it will not be long before their countries are on par with or ahead of the United States as they rapidly move into design and development and eventually into basic research with a number of consortia. Government and industry work closely together to keep up the rapid growth rate. There is a strong emphasis on technological innovation and development of core competencies. These two countries plan to be long-term leaders as they continuously seek the next application for high-volume production in order to gain economies of scale. Based on their vision and strengths, Singapore and Malaysia will remain world leaders in the area of electronics.

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CHAPTER 5

TAIWAN'S ELECTRONICS INDUSTRY

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WTEC STUDY TEAM VISITING TAIWAN (MARCH 1996)

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INTRODUCTION

Taiwan ranked behind Japan, China, Korea, and India in its overall gross domestic product (GDP) in 1995; Taiwan's GDP rose 3.7% in that year to $250 billion.[1] With a population of 21 million, per capita GDP was $11,882. Exports totaled $108.4 billion, and imports were $101.4 billion, giving Taiwan an overall trade surplus of $7 billion. Electronics and machinery represented about 41% and 31% of exports, respectively. With the growth of Taiwan's electronics industry, imports of key components and equipment have generated a deficit in trade with Japan. Between 1990 and 1995, the trade deficit with Japan increased from $13 to $18 billion. As a result, Taiwan's government has developed a strategy to localize production of a greater percentage of electronics components and equipment. As Table 5.1 shows, Taiwan's manufacturing segment declined from 33.3% to 28.1% of total GDP in the first half of this decade; at the same time, electronics manufacturing increased from 12.7% to 18.4% of GDP. The government wants to stimulate industry growth in order to provide jobs and taxes. Focus on high-technology industries has resulted in their generating 33.5% of manufacturing revenues. Taiwan's national goal is to attain fully developed status by 2002.

Taiwan's strategy is to become the "Asia-Pacific Regional Operations Center (APROC)." Announced on January 5, 1995, the APROC plan seeks to transform the Taiwanese economy by fostering freer flow of goods, services, human capital, funds, and information. According to Premier Lien Chan, "The plan demonstrates our commitment to integrate with regional economies and become a full member of the international community."

The strategy attempts to utilize Taiwan's geographic location, growing domestic market, entrepreneurial spirit, well-educated workforce, abundant capital, maturing technologies, modern management skills, global trading network, and cultural bonds with mainland China and other Asian markets. The plan calls for Taiwan to become the hub for regional manufacturing, sea transportation, air transportation, and financial, telecommunications, and media activities.

[1] All dollars symbols ($) denote U.S. dollars, unless otherwise noted.

Table 5.1
Taiwan's Electronics Manufacturing Industry

	1990	1991	1992	1993	1994	1995
GDP (US$ billion)	$160.2	$179.3	$212.3	$222.6	$241.0	$250.0
GDP/Capita (US$)	7978.0	8769.0	10271.0	10411.0	11456.0	11882.0
Manufacturing/GDP (%)	*33.3*	*33.3*	*31.7*	*30.5*	*29.0*	*28.1*
Export Value (US$ billion)	$67.2	$76.2	$81.5	$85.1	$ 93.0	$108.4
Import Value (US$ billion)	54.7	62.9	72.0	77.1	85.3	101.4
Electronic Mfg/GDP (%)	*12.7*	*13.7*	*13.6*	*14.4*	*15.1*	*18.4*
Electronic Exports (US$ billion)	$17.9	$20.3	$22.2	$19.1	$20.9	--
Electronic Export (%)	*20.3*	*19.4*	*19.8*	*20.7*	*21.4*	*23.3*
Electronic Imports (US$ billion)	$7.7	$8.1	$9.3	$10.6	$11.9	--
Electronic Import (%)	*14.7*	*14.8*	*16.0*	*16.4*	*17.1*	*18.4*

Sources: Executive Yuan; Taiwan Customs; ERSO/ITRI ITIS Project

According to Chan, "In the future, we will rely on competition rather than industrial development planning to guide our economic strategies. All economic measures should be facilitative and constructive, rather than regulatory and restrictive. Where the government regulates a market segment, it should not own or manage business in that sector. We also understand that market efficiency and national competitiveness can be enhanced through aggressive deregulation. To this end, I have instructed our government staff to reduce paperwork and streamline the bureaucratic review and approval process. By the same token, we have adopted a policy that government measures and rules should be simple and transparent." To meet Taiwan's goals, high-technology industrial parks have been established to allow for "one-stop" shopping for new investment permits. Special incentive programs have been established to encourage R&D and facilities investments in high-priority industries, products, components, and technologies. Relationships with mainland China are also being improved to encourage economic activity.

Strategic Technology Investments

Government funds are used to support industry development and are directed through ministries and various councils to research institutes like the Industrial Technology Research Institute (ITRI), university research programs, and industry to stimulate technology development and facilitate its diffusion in order to encourage economic growth. As Fig. 5.1 shows, the Ministry of Economic Affairs (MOEA) and the National Science Council direct the majority of technology-based programs. The National Science Council has oversight of the science-based industrial parks and national laboratories and supports academic research programs. MOEA has oversight of the development center of biotech, ITRI, funding of technology development programs, and provides incentives (tax and matching funds) for industry investments. Additional science and technology programs are carried out by the Atomic Energy Council, Council of Agriculture, Ministry of Transportation and Communication, Ministry of National Defense, Ministry of Education, Department of Health, and the Environmental Protection Agency.

Ten strategic industries, 8 key technologies, and 69 key parts and products have been given priority for development. With low-interest loans and technology support from the government, these industries are expected to rekindle economic development. Research institutes are responsible for developing core technologies and key components, such as a common engine for automobiles or LCDs for computers.

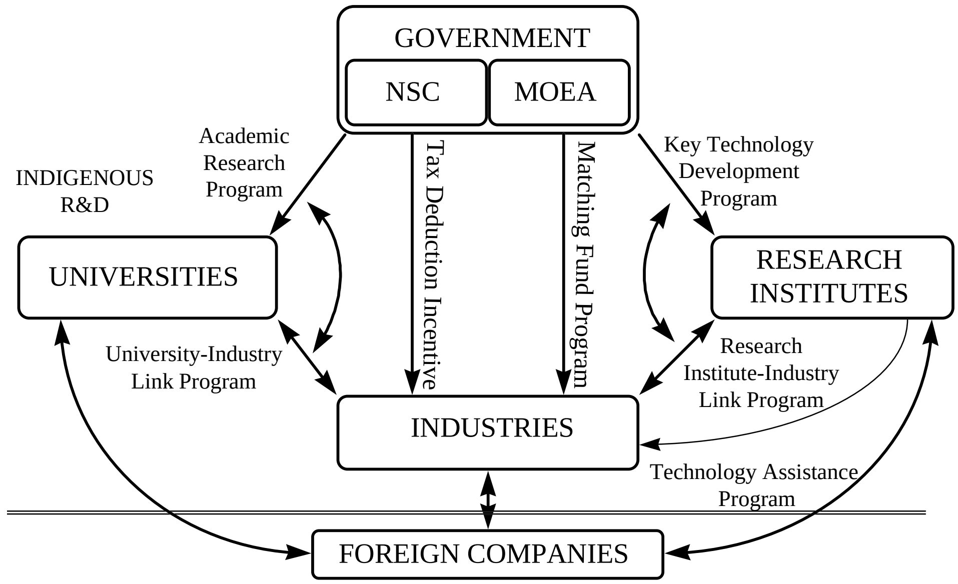


Fig. 5.1. Taiwan's technology development programs (ERSO/ITRI).

ITRI plays a key role in technology policy and has provided the basic support for developing high-tech industries like semiconductors. It has also upgraded traditional industries and provided pollution control in the livestock industry. Research institutes also provide basic infrastructure for technology development by such as testing centers for electronic products and automobiles. ITRI further provides technical assistance, coordinates international cooperation, and provides information to industry. New industry developments then stimulate production and sales in both domestic and overseas markets. Technology-intensive industries have grown from nothing in 1976 to over 34% of the manufacturing base in Taiwan in 1995. They are projected to account for 40% of the manufacturing base by the year 2002. Between 1976 and 2002, traditional industries will fall in importance from 52% to 25% of the manufacturing base in Taiwan.

Taiwan's government contracted with ITRI to identify ten emerging growth industries that should receive incentives and support. The priority emerging industries ITRI identified are communications, information, consumer electronics, semiconductors, precision machinery and automation equipment, aerospace, advanced materials, specialty chemicals and pharmaceuticals, medical and health care, and pollution control and treatment industries. Growth in these industries is projected to increase production value from $27.3 billion in 1992 to $94.2 billion in 2002, a yearly growth rate of 13.2%. By 2002, information, precision machinery, and specialty chemical industries are expected to be Taiwan's leading industries.

For priority industries, the government's strategy includes the following:

1. Provide R&D and plant investment assistance for selected products
2. Encourage R&D and technology transfer to ensure self-reliance in key technologies
3. Create a favorable climate for high-value-added and low-cost R&D, production, and marketing
4. Strengthen upstream industries to support middle- and downstream development systems and vertical industry integration
5. Utilize government purchasing projects to obtain foreign expertise and technology
6. Encourage fair competition in the domestic market with updated laws and regulations
7. Coordinate agencies to establish development plans for top ten key industries; develop five-year plans designed to stimulate industrial automation, industrial design capabilities, quality programs, product image, satellite factories, technology diffusion, high-technology workforce, and cooperative efforts in emerging industries

Incentives apply to any company located in Taiwan; those that invest in priority industries and technologies get a 5-year tax holiday from the time they start making money. Individual investors get a 20% tax reduction.

In 1980, the government established the Science-based Industrial Park in Hsinchu to encourage high-tech industry. The park has over 1,500 developed acres and is close to the international airport and harbors, two national universities, and ITRI. There were 170 firms operating there in 1995, about 25% of which were foreign-owned. Annual sales were $6.4 billion in 1994. Within the park, there were 51 semiconductor firms, 39 PC/peripheral firms, 30 telecommunication firms, and 25 optoelectronic firms. In addition, there were 16 precision machinery and 9 biotechnology companies. High-tech companies that locate in the science and industrial parks are provided one-stop permitting and special incentives, including a 5-year corporate income tax exemption, low-interest loans, and tax credits for investments in R&D, factory automation, and human resource development support. In addition, no duties are levied on imported equipment, components, and materials. The total number of employees in the park in 1995 was 36,000. The number of these parks is growing rapidly across Taiwan. A new science park was planned to open in 1997. ITRI will establish a second campus for new programs that will be located within the new science park.

Critical Components Strategy

With the growth in Taiwan's electronics manufacturing industry came a growth in electronics exports from 20.3% in 1990 to 23.3% of total exports in 1995, while imports grew from 14.7% to 18.4%. Meanwhile, Taiwan's trade deficit with Japan grew from $13 billion in 1992 to $18 billion in 1995. A study showed that 90% of the deficit was due to the import of materials and key components. In response, government set a priority to balance the trade with Japan. MOEA established a program for the development of critical components and products. For example, by the year 2000, Taiwan plans to have 20 wafer fabs, although only one company grows silicon crystals in Taiwan. A joint venture was planned to start in July 1996 to supply 6-inch and 8-inch crystals, but most material will still be imported. This analysis resulted in formation of MOEA's Industrial Development Bureau to develop key components like CPUs, DRAMs, and LCDs. The aim is to centralize the resources of the government and private sectors and acquire technology for investment and production, replacing imports with domestic production, improving the industrial structure, and developing the newly emerging high-technology industries within the shortest possible time.

As of February 1995, MOEA's critical components program listed 48 critical components and 24 critical products, as shown in Table 5.2. These were classified into three groups. In the A group, a research institute like ITRI would be entrusted to develop the technology or product. In the B group, MOEA would employ government assistance in the development of targeted leading products and the program for application, promotion, and assistance of strategic technology for qualified manufacturers to conduct the development plan. In the C group, the government would provide investment incentives such as tax credits, acquisition of industrial land, government participation in investments, favorable loans and training of professional personnel, and special duties and import regulations. Examples of critical products include HDTV, digital audio tape recorders, electronic still cameras, and a variety of computer peripherals and manufacturing automation equipment. Critical components included as group A projects are fuzzy ICs, LCDs, high-density static and dynamic RAM, and a variety of RF (radio frequency) ICs, LEDs, and CCDs. Many of these are also open to group B and C incentives. Silicon wafer production was a group C priority.

Industrial Technology Research Institute (ITRI)

ITRI is a nonprofit government-sponsored organization with a mission to promote development of high-tech industries, improve domestic product design and processing technologies, provide technical services to industry, and assist in development of defense technologies and industry. Most Taiwanese companies are too small to afford R&D, so ITRI is their sole source of R&D. ITRI has about 5,700 young and energetic engineers. In the past, there were as many as 10,000 engineers working at ITRI.

Table 5.2
MOEA's Critical Components and Products List

Critical Products	Critical Components	
Improved/Enhanced Definition TV*	Fuzzy IC*	Micro Fiber
Digital Audio Tape Recorder	Converter*	Aspherical Molded Lens*
Projection TV*	>25" CRT	Anti-Vibration Rubber*
Electronic Still Camera*	Si Wafer	High Pressure Rubber Hose
Multifunction Clinical Analyzer*	LCD Display*	Build-in Main Spindle*
Ultrasonic Diagnostic and Medical Equipment*	DAT Mechanism*	Jet Engine Compressor/Turbine Blade
Engineering Workstation*	DRAM >4M*	Aircraft Parts
Multi-Processor System*	SRAM >1M*	Etching Ai Foil*
High Resolution Page Printer*	DSP IC*	AF Zoom Lens*
High Performance Scanner	RF IC*	Watch Movement
Optical Disk Drive*	Thin Film Disk	Automobile Transmission*
Micro Disk Drive*	CCD*	Transmission/Brake for Bicycle*
Digital Mobile Phone*	LED*	Electronic Control for Auto*
Aircraft	High Resolution Laser Engineer*	4-Stroke Engine for Auto*
IC Memory	Lithium Battery*	3-Cyanopyridine
Digital Storage Oscillator > 100MHz	5 1/2 bit A/D Converter	Si-Electrical Steel Sheet
Wire Cutting Machines	32 bit CPU*	Linear Guide
Robots	System Software & Tools	Automatic Coin Machine
NC Controlled Injection Molding	Thermal Print Head	4-stroke Motocycle Engine
High Speed Shuttleless Loom	ISDN Interface IC*	7-Aminocyphalosporamic Acid
Co-Generation Equipment	Micromotor	p-HydroPhenyl Glycine
Multimedia System*	Thin Film Disk Head	CNC Controller*
B-Carotene**	Copper Sheet for Lead Frame**	Scroll Refrigerant Compressor **
Breathable Fabric & Product**	Broadband Communications IC**	
	Laser Diode Chip **	

*ITRI-planned or on-going development program; **New item

With the recent uncertainty created across the Taiwan Straits in the People's Republic of China (PRC, or, simply, China), government funding growth has been curtailed. ITRI's current budget is about $260 million annually: about 80% of the funding comes from government (55% from MOEA and 25% from defense), and the goal is to increase support from industry to 25%. That means ITRI gets about $65 million per year from the private sector. Some of the divisions have already achieved this balance in funding.

Taiwan's small companies lack the resources to build a strong R&D position; ITRI therefore plays an important role in coordinating efforts to develop new industries. It is very good in the area of applied research. In the past, ITRI worked to improve the ability of companies to do product development. It has an incubator facility that can be utilized by companies that have worked on joint projects with ITRI, and it built a pilot production line that was then transferred to a private company. ITRI is also concerned about quality and has obtained ISO 9001 certification for its labs.

ITRI's policy is to be involved in MOEA's A group technologies where it can apply its own technologies. B group areas have only a limited number of companies capable of making early investments. ITRI's policy is to reduce its involvement in B area developments to only 10% by the end of 1996. Instead of being directly involved, ITRI will develop consortia or joint ventures with foreign companies to take advantage of their quick responses to market changes. C group areas have a lot of foreign companies that have technology. In the past, ITRI helped transfer technology to Taiwan in C-type industries. Wireless telecommunication is an area now targeted in this group. Companies like Acer form their own alliances with foreign companies to transfer technologies.

ITRI started by helping companies get new products out quickly. Companies are now able to do that well, so ITRI is less involved. ITRI now concentrates its efforts on development of key components that are middle- and long-term projects requiring over five years. ITRI moves a product from the laboratory to pilot production and then terminates its direct participation and funding. The government gets dividends after the business generates adequate revenues.

ITRI has 7 laboratories and 3 centers. The range of technologies is quite broad, with about half of ITRI's efforts going to support electronics technologies. With the growth in computers and communication, a lot of engineers have returned from U.S. companies like AT&T, IBM, Belcore, and Star Labs; over 200 engineers who formerly worked at IBM and AT&T now work at ITRI. The Institute's divisions include the computer and communications research laboratory (once part of ERSO – see next page), which is now researching broadband ISDN and HDTV. This lab has adopted MPEG II for image compression and is capable of 2-way interaction for "video on demand" delivery. ITRI also has mechanical, material, and energy research labs, and offices in Taipei, Tokyo, the United States, and Russia. Finally, it has centers for developing measurement standards, pollution control technology, and aviation and space technology.

The Electronics Research and Services Organization (ERSO) was established in 1974 within ITRI. Its mission is to develop and diffuse electronics technologies. Its major foci are semiconductor IC devices, display devices, microwave components, and electronic packaging. ERSO is committed to building Taiwan's high-tech industry base. Its strategy is to develop key electronic components and subsystems. Employing about 600 engineers, ERSO does the research and technology development for the government. The key is to transfer technologies into the market as quickly as possible. After four years, programs are spun off. The optoelectronics and systems lab was spun off from ERSO in 1985, and the computer and communication research lab was spun off in 1990 once its technical base was adequate. In addition, ERSO established consortia for PC computers in 1983 and 1984, submicron process development in 1991 and 1992, and LCD development in 1993.

ITRI has a planning department for technology forecasting and market research that proposes development projects to the Ministry of Economic Affairs and then carries them out. ITRI provides services for private companies to generate internal revenues for additional research projects. Pilot production allows transfer of operating capabilities into the private sector. ITRI's computer and communications laboratory looks at complete systems. ITRI developed a 3.5-inch hard disk drive and licensed it to three companies, but development was not fast enough to be successful – new products were being introduced every 6 months as product life cycles shortened.

Technology Diffusion Strategy

The Industrial Technology Investment Corporation aids technology transfer from ITRI/ERSO to the private sector. After market research and technology forecasts, proposals are made for applied research, technology development, and pilot production. Once projects are completed, technology is diffused through spin-offs, investment, technology transfers, talent transfer (over its lifetime, ITRI has transferred 11,000 people to other organizations and companies), workshops, industrial services, and/or joint ventures. As with ICs, this has resulted in the creation of new industries. Other traditional industries are targeted to be upgraded. Companies come to ITRI if they have problems and need access to technology or technology development.

ITRI licenses technologies from foreign companies like IBM, AT&T, TI, and Intel for use in Taiwan. ITRI uses the technology to develop local industry and generate revenues. At the same time, ITRI has been rapidly increasing its own patents and encouraging local companies to apply for patents. Taiwanese patents are used for cross-licenses with foreign companies to reduce the royalties required by Taiwanese companies. ITRI has negotiated an umbrella agreement with companies like AT&T and IBM for technologies using a flat royalty rate. These arrangements reduce product costs and the risk of law suits against Taiwanese companies. This encourages firms to accumulate patents for use in negotiations with foreign firms.

The Taiwan Connection to China

In Taiwan, government controls on imports from mainland China, as well as on exports to and investment in the PRC, have been gradually liberalized since 1985. In the 1970s, Taiwan began its industrial restructuring with the move into high-tech and capital-intensive industries like chemicals and pharmaceuticals. At the same time, labor-intensive semi-manufactured products fell by over 30%. By the late 1980s, an economic slowdown drove the government to launch its new six-year development plan, which included $300 billion for infrastructure developments. Accounting for 34% of GDP in 1990, Taiwan's manufacturing sector was its strength. Heavy chemical products accounted for 47% of GDP in 1991, and other high-technology products represented 36%. The share of exports of primary products, consumer goods, and processed food declined while exports of components and capital goods increased.

With its roots in both the language and culture of China, Taiwan invested its surplus capital in the PRC. Relocation of manufacturing to the PRC also facilitated industrial and economic restructuring of Taiwan's mature footwear, plastics, and apparel industries. Dirty industries also found their way to the PRC. As of June 1993, Taiwan had invested over $2.9 billion in the PRC, including $364 million in electrical and electronic machinery. This has created concern in Taiwan over possible dependence on the PRC's resources, markets, and political influence.

TAIWAN'S ELECTRONICS INDUSTRY

Taiwanese government officials consider Taiwan's primary strengths to be in electronics manufacturing. While Japan has been Asia's benchmark in electronics' R&D, design, manufacturing, marketing, and sales, Taiwan has been strongest in all areas of computers and in component technologies. According to a 1993 study (BCG 1994), Taiwan is relatively weak in consumer and telecommunication products (see Table 2.7, Chapter 2).

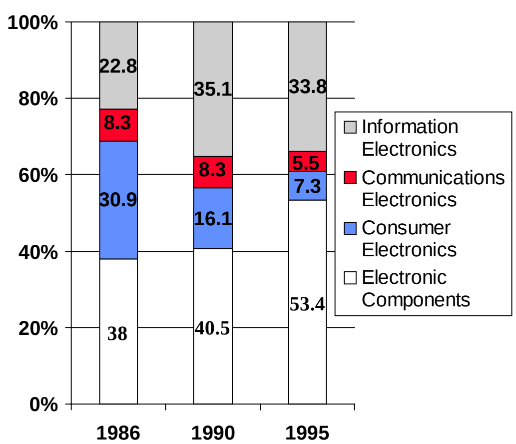
Taiwan developed its electronics manufacturing capabilities over the past four decades (Table 5.3). In the 1960s, Taiwan assembled such products as transistor radios, tape recorders, and some transistor packaging. In the 1970s, Taiwanese firms entered the component manufacturing business with CRTs, IC pilot production of ICs (via ERSO), electronic watch production, and VCR magnetic drum developments. In the 1980s, Taiwan entered into computer manufacturing with United Microelectronics Corporation's (UMC's) semiconductors, the IBM-compatible PC, 256K DRAM development, color monitor production, and establishment of Taiwan Semiconductor Manufacturing Company (TSMC). Electronics became the number one export and Taiwan became the fifth-largest supplier of PCs. In the 1990s, Taiwan moved into microelectronics manufacturing and became the number one supplier of motherboards, monitors, scanners, and mice. In 1995, Taiwan became the number three supplier of computers, with a value of $19.7 billion. In 1995, Taiwan produced $3.3 billion in semiconductors, began mass production of 16 Mbit DRAMs, and opened four of 20 planned 8-inch wafer fab operations. Today, Taiwan is targeting the markets for semiconductors, optoelectronics, displays, and packaging.

Taiwan's government decided to get out of electronic games and toys, considered intellectually unhealthy for children. As Fig. 5.2 shows, the shift into computers and related components has been extremely successful. While communications electronics has remained a small proportion of output, it is targeted as an emerging growth industry for the future. Consumer electronics fell from 30.9% to 7.3% of Taiwan's electronics output between 1986 and 1995; information products grew from 22.8% to 33.8% during the same period. Related electronic components also increased from 38% to 53.4%.

Table 5.3
Taiwan's Evolution in Electronics Manufacturing

Electronics Assembly	Components Manufacturing	Computer Manufacturing	Microelectronics Manufacturing
60s	**70s**	**80s**	**90s**
• Transistor radio production • 1963 B/W TV production • 1966 Tape recorder production • 1969 Color TV production • 1969 First favorable balance in electronic product trading	• 1970 B/W CRT production • 1974 Establishment of ERSO • 1977 CMOS IC pilot production • 1978 Electronic watch production • 1979 VCR magnetic drum developed by Tatung	• 1982 UMC starts IC production • 1982 Tatung VCR delivered; color monitor production • 1985 ERSO develops IBM PC/AT • 1985 256K DRAM developed • 1986 Color monitor production • 1987 Fifth PC supplier • 1987 TSMC established	• 1991 No. 1 supplier of motherboards, monitors, scanners, and mice • 1995 No. 3 in computers production value (US$ 19.7B) • 1995 IC production value US$ 3.3B • 1995 16 M DRAM mass production • 1995 4 (8") fabs start operation; 10 (8") fabs under construction; 5 (8") fabs planned

Source: ERSO/ITRI ITIS Program

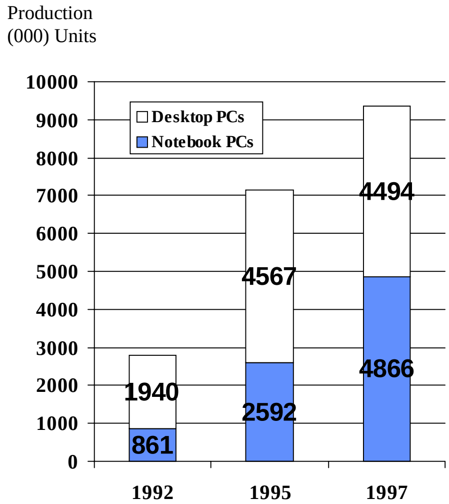


- Electronics Industry growth
  ('90-'95) = 12.4%
  - Information = 11.7%
  - Communication = 3.4%
  - Consumer Electronics = -4.1%
  - Electronic Components = 18.9%
- Information & Electronic Components Products are mainly in PC and IC businesses.
- Product integration is growing.
- Value added comes from enabling components and software.

Fig. 5.2. The changing structure of Taiwan's electronics industry (ERSO/ITRI ITIS Project).

Computer Development Strategy

In 1983-84, ERSO and local companies launched a project to shorten the product development cycle of IBM-compatible PCs. The first commercial products took 12 months to develop, provided the model for rapid product development, and enhanced the global competitiveness of Taiwan's information products. Since then, other computer-related product development consortia have included printers, Winchester disk drives, notebook PCs, SPARC workstations, handheld PCs, submicron SRAM and DRAM semiconductors, and CAD magnetic circuit design prototyping. Fig. 5.3 shows the growth in computer output and the time required for product development. While China is a growing source of motherboards and desktop computers, Taiwan continues to be a major supplier of notebooks. By 1997, Taiwan's worldwide market share of notebook PCs is expected to reach 38.7% and 8.9% for desktop PCs.



- 1995 PC Production Value/ Information Hardware ($19.7B)=28.7%
- Time Lag Shortened
  - 2 months, May 1993, Pentium
  - 6 months, Sep. 1989, 486DX
  - 1.5 years, Dec. 1986, 386DX
  - 3 years, July, 1985, 286
- Current Imported Key Components
  - CPU
  - DRAM
  - LCD

Global Share			
Notebook PC	18.2%	27.0%	38.7%
Desktop PC	7.5%	10.0%	8.9%

Fig. 5.3. Taiwan's computer development (ERSO/ITRI ITIS Project).

Taiwan's leading PC makers are now primary suppliers to original equipment manufacturers (OEMs) like Compaq, IBM, Apple, Packard Bell, NEC, AST, and Dell (Table 5.4). The speed with which Taiwanese computer makers can now design and deliver advanced PC notebooks makes them a major source of original notebook PC designs. Inventec designed and produces Compaq's high-end LTE 5000 series of notebook computers, and it began producing Apple's Newton in 1992 using Apple's latest tape automated bonding technology to miniaturize the Newton's motherboard. Most recently, it has designed and produced Compaq's new personal digital assistant (PDA). Inventec considers itself a 100% original design manufacturer (ODM) because it produces only products that it designs. GVC supplies about 60% ODM products to firms like Packard Bell and NEC. It targets the top-ten PC companies as its primary customer base for ODM products.

Table 5.4
Taiwan's Leading PC Vendors

Top Ten PC Companies	Taiwan Suppliers	Notebook PC	Desktop PC
1. Compaq	**Inventec Electronics**	x	--
2. IBM	**ASE**	x	--
3. Apple	**Acer**	x	--
4. Packard Bell	**Inventec Electronics/** **Tatung/GVC Corp.**	x --	-- x
5. NEC	**First Int. Company** **Elite Group** **GVC Corp.**	x x --	-- -- x
6. AST	**Quanta Corp.** **AST**	x --	-- x
7. Dell	**Quanta Corp.**	x	--
8. Toshiba	**--**	--	--
9. HP	**Twin Head**	x	--
10. Acer	**Acer**	x	x

Source: GVC

Taiwan can now supply all of the components for the computers it assembles, except hard disk drives. Table 5.5 shows Taiwan's success in moving into critical component areas. By 1995 monitors had become a $7.2 billion business for Taiwan, with a world market share of 57%. Taiwanese companies held 65% of the world markets in motherboards and keyboards, 64% in scanners, 38% in network cards, 35% in power supplies, 32% in graphic cards, 27% in portable PCs, 11% in CD-ROMs, and 72% in computer mice. The time required for Taiwanese companies to introduce new models has fallen sharply: it took them 3 years to introduce their first IBM-compatible 286 computer in 1985, but it took them only two months to produce their first Pentium-based system in 1993. By 1996, most Japanese firms were outsourcing notebook computers to Taiwanese firms.

Table 5.5
Taiwan's Top Ten Information Technology Products, 1995

Product	Value ($US million)	% change 95/94	Volume (million)	Worldwide Market Share
Monitors	$7,271	38%	31.3	57%
Notebook PCs	3,339	22	2.6	27
Desktop PCs	2,314	48	4.6	10
Motherboards	2,046	21	20.8	65
Power Supplies	895	22	34.3	35
Scanners	540	37	2.5	64
Graphic cards	516	7	9.3	32
Keyboards	358	32	32.8	65
CD-ROM drives	305	1,906	3.7	11
Network cards	298	41	10.3	38
Others	1,785	51	na	na
Total	**9,667**	**35**	**na**	**na**

Figures include offshore production; Source: Market Intelligence Center

Taiwan Electronics Infrastructure

Taiwan's electronics infrastructure is outlined in Fig. 5.4. With over a decade of experience in printed wire or circuit board assembly and total systems fabrication, electronic packaging is a core competency of Taiwan. Taiwan has been adding IC packaging, IC wafer fabrication, and LCD assembly to its capabilities.

Technology Development Strategy

ERSO's strategy is to develop key devices, components, and related process technologies essential to information input, signal processing, and output of information. Process developments are required for CCDs (charge-coupled devices) and RF IC input devices. Displays and related drivers require process developments for thin film transfer (TFT), micromachining, and power devices. In signal processing, submicron CMOS process development is required for CPU, digital signal processing (DSP), and memory devices.

ERSO's packaging focus is on multichip modules (MCM), single chip packaging, assembly technologies, high-density printed circuit boards (PCBs), systems packaging designs, and materials development for double-sided TAB, organic solder paste, molding compounds, liquid encapsulants, lead frame materials, and high-T_g substrates. Chip on glass (COG) and tape automated bonding (TAB) for LCD applications have been developed. TAB, COG, and MCM require integrated packaging and assembly technologies and the development of new methods for failure analysis, testability design, and reliability testing. ERSO established a simulation design department to work in these areas. Extensive simulation and analysis software for electrical, thermal, and mechanical design of packaging was developed for in-house as well as external customer applications. ITRI was developing a five-year roadmap for technologies to be completed within 1996. ITRI then planned to develop a strategy for the packaging area.

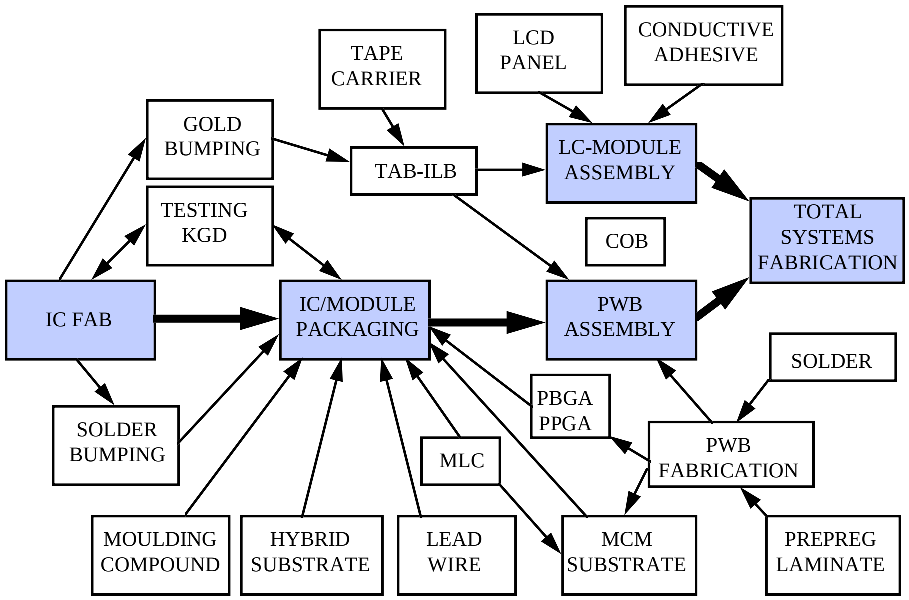


Fig. 5.4. Taiwan's electronic packaging industry infrastructure (ERSO/ITRI).

Future success for Taiwan will depend on the development of technologies that can be commercialized and produce revenues. Micromachining is thought to offer future opportunities, as are other technologies related to mechatronics, materials science, and biotechnology. A preliminary study of both surface and bulk micromachining processes is being conducted by ITRI. According to one ITRI official,

> For the past three years, we have developed some technologies. Now we are trying to apply them to products. We hope to market a pressure sensor within two years. We are also developing a room-temperature thermal imager. We have a team that includes four companies and a professor as project manager. They are designing the complete package. We are also developing the lead frame for high pin counts. The complexity comes in tool fabrication. We are trying to use this in infrared technology for the medical industry. We are also considering areas like bioelectronics. One researcher recently synthesized a protein that acts as a biosensor. It looks interesting and fits with our experience in CCD sensor technology. ITRI will continue to look for new technologies and new industries in which it can play a role.

Materials Development

ITRI's Materials Research Laboratory (MRL) is responsible for materials and process developments. With a staff of 600 engineers, MRL helps mostly small firms solve manufacturing problems and add value to existing products through development of cost-effective materials and processing techniques. Taiwan produces most of the materials used for desktop computers, but notebook computers' flat panel displays and batteries were mostly imported from Japan at the time of the WTEC visit. MRL was working to develop lithium batteries, color filters, physical and chemical sensors, and aluminum foil capacitors.

MRL is developing a range of materials to industrial specifications. Primary areas of interest are those in which it can integrate backwards into materials currently being imported. Such imports can determine the future success or even survival of these industries. Examples include electronic polymers like photo-resist and solder masks, permanent magnets and recording media, photoconductive toners, organic composites like carbon fiber for bicycle parts, ceramics, and superconducting wires and films. Because of Taiwan's hot and humid climate, compounded by pollution, MRL does extensive research on corrosion protection technologies. MRL is recognized in areas of life assessment technology, corrosion monitoring and protection engineering, and environmental assisted corrosion.

Processing Technology

The metal processing technologies under development by ITRI are metal melting and rolling techniques for lead frames, powder injection molding technology, continuous casting of copper wire, and composite design. MRL deploys intelligent processing of material for cost-effectiveness. The chemical and mechanical labs are also involved in equipment and process developments. They are now looking for better ways to coordinate and integrate these various programs. This is especially critical in the packaging areas that require integration of materials and process technology and components.

Printed Circuit Boards

PCB fabrication technology, started at ITRI, is now mature. Two hundred firms produced PCBs valued at $1.7 billion in 1995. Taiwan had six of the top 100 PCB manufacturers providing multilayer and double-sided boards. In 1994, Taiwan ranked third in the global PCB market. One new player entered in 1995 with flexible PCB and TAB tape carrier substrates. Between 1991 and 1994, PC board sales grew from $710 million to $1.2 billion. In the PCB sector, there are a lot of very small, specialized companies that do only drilling or plating of boards, allowing PCB companies to subcontract when needed to increase their capacity by as much as 200%. While Taiwan is the king of wire bonding and has a strong product reputation as the number-one producer of PCBs and motherboards, it lacks the high-end materials and equipment capabilities at the next level up the value chain.

Single and double-sided boards have remained flat in Taiwan as new facilities have moved to China. Multilayer boards accounted for 36% of capacity in 1995 and were projected to increase to 45% of Taiwan's capacity by 1997. In 1997, about 42% of the capacity was expected to be FR-4 materials, 44% paper-based materials, and 14% CEM-based materials. ITRI has programs to develop advanced VG materials in its materials research laboratories. Taiwan's technical capabilities included the following at the time of the WTEC panel's visit:

- Line width/spaces of 4 mil/4 mil in mass production (U.S./Japan have 2 mil/2 mil in R&D)
- Drilling diameters of 13.5 mil in mass production (U.S./Japan mass-produce 13.5 mil, have 6 mil in R&D)
- Blind vias of 10 mil in mass production (U.S./Japan mass-produce 10 mil and have 4 mil in R&D)
- Layer thicknesses of 24 mil in mass production (U.S./Japan mass-produce 24 mil, have 12 mil in R&D)
- SM pitch of 0.4 mm in mass production (U.S./Japan mass-produce 0.4 mm and have 0.25 mm in R&D)
- Aspect ratios of 5 in mass production (U.S./Japan mass-produce 5 and have 8 in R&D)

Packaging Technology

Twenty-three firms assembled motherboards valued at $2 billion in 1995. Taiwan has held over 65% market share in computer motherboard assemblies. Taiwan's technological capabilities are shown in Table 5.6. Intel is providing TAB process technology for assembling P-6 microprocessors for notebooks using tape carrier packages (TCP). It requires a separate "daughter" board using super-solder technology. As companies produce daughterboards to supply OEM orders, they can also begin production of notebook computers and a variety of PCMCIA cards. Areas of major investment now include wafer fabrication and LCD production, which are critical technologies and components for information products.

Table 5.6
Status of Taiwan's Packaging Technology

CATEGORY	METRIC	TAIWAN TECHNOLOGY LEVEL	TECHNOLOGY LEADERSHIP	LEADING TECHNOLOGY LEVEL
PACKAGE				
• PGA	Pin Count	172 pin mass production	USA, Japan	Mass production >300 pin
• QFP	Lead Pitch	0.4-0.5 mm mass production	Japan	Mass production 0.25-0.4 mm
• TSOP	Thickness	1.0 mm mass production	USA, Japan	Mass production 1.0 mm, R&D 0.5 mm
• BGA	Ball Pitch	50 mm mass production, 40 mm R&D	USA	Mass production 50 mil, R&D 40 mil
• TAB	Lead Pitch	9.8 mil mass production	Japan	Mass production 9.8 mil, R&D 8 mil
• MCM		Pilot line	USA	Applied to product packages
PCB	Line width	5/5mil mass production	USA, Japan	R&D 2mil/2mil
	Drilling diameter	13.5 mil mass production	"	mass production 13.5 mil, R&D 6 mil
	Blind via	10 mil mass production	"	Mass production 10 mil, R&D 4 mil
	Laser thickness	24 mil mass production	"	Mass production 24 mil, R&D 12 mil
	S.M. pitch	0.4 mm mass production	"	Mass production 0.4 mm, R&D 0.25 mm

Source: ERSO/ITRI

ERSO's director of packaging had been the vice president of a U.S. packaging company. In electronic packaging, ERSO is focusing research on three areas:

1. Passive device process and chip bonding technology: passive device thin film processing, flip chip bonding, tape automated bonding, and chip on glass
2. Module packaging technology: MCM design, substrate processing, and module packaging
3. System packaging design and analysis technology: structural analysis and design, and electrical engineering analysis and design

As electronic products have become smaller and lighter, electronic packaging has become one of the most important concerns for the microelectronics industry. Many design houses have started to invest in testing and packaging areas. There are 21 companies in Taiwan that package ICs, with revenues valued at $2.6 billion in 1995. At the IC level, there is rapid expansion with production of PQFP (plastic quad flat packages), TSOP (thin small outline packages), PPGA (plastic pin grid arrays), BGA (ball grid arrays), MCM-L (multichip module-laminate), and flip chip. Integrating packaging and testing is under development. Taiwan's packaging technology capabilities include the following:

- PGA with 172 pins in mass production (United States/Japan mass-produce over 300 pins).
- QFP is mass produced with lead pitch of 0.4-0.5 mm (Japan mass-produces 0.25-0.4 mm pitch).
- TSOP in mass production has a thickness is 1.0 mm (United States/Japan mass-produce 1.0 mm and have 0.5 mm in R&D).
- BGA with 50 mil ball pitch is mass-produced, and 40 mil is in R&D (United States mass-produces 50 mil and has 40 mil in R&D).
- TAB-OLB (tape automated bond - outer lead bond) is mass-produced with 9.8 mil pitch (Japan mass-produces 9.8 mil and has 8 mil in R&D)
- MCM is in pilot production (United States is producing and employing MCMs)

Development of chip-scale packaging was planned through a component consortium and technology licensing.

MCM Packaging Center

ERSO established the multichip module (MCM) service center to provide technologies needed to make MCM prototypes. Design, fabrication, and testing of MCM-Ds using silicon substrate materials were developed. Low-cost integrated resistor and capacitor networks are two features of ERSO's MCM technology. Technical services begin with a discussion with customers. Electrical designs, including signal integrity analysis, physical layout design, and a chip placement design are based on customer product specifications. Combined with electrical and physical design, a computer 3D simulation of thermal dissipation guarantees module reliability. Module temperature distributions are checked against the thermal simulation. At the time of the WTEC study trip, this project was moving to pilot scale production and private investors were being sought to commercialize the process.

ERSO has low-cost MCM-D substrate packaging, flip-chip bonding, thin-film resistor array, ceramic ball grid array, and plastic ball grid array capabilities. The substrate, which consists of up to five layers of aluminum interconnecting lines and polyimide dielectrics, is 100%-tested before module assembly. Automatic pick-and-place equipment positions known-good-bare-die onto the substrate for high-speed wire bonding. Since the substrate is made of polyimide, the wire bonding is under a tight process control. The wire-bonded module is tested before delivery. The Taiwan Known Good Die (KGD) Alliance was established to develop testing techniques for bare IC dies and to promote overall improvement of Taiwan's MCM packaging industry.

Imports of process and testing equipment, molding compounds, and molding facilities are still required. In 1995, Taiwan's molding compound market demand was $85 million, all of which was imported. Of that, $66 million (78%) was used for IC products, which market was growing about 40% annually. ITRI has supported polymer development at the Union Chemical Laboratory. The 1995 lead frame market was $281 million, of which 77% was imported ($215 million) and 23% was supplied locally. Molding equipment sales in 1994 were 262 units ($27 million), of which 28% was locally supported.

Microelectronics Technology

In 1995, domestic suppliers provided 19.1% of Taiwan's IC requirements. This is projected to reach 37.8% by the year 2000. Beginning with acquisition of 7-micron CMOS technology in the mid-1970s, ERSO has been instrumental in building Taiwan's IC industry. It is now identifying additional areas to develop. Strategic alliances with both domestic and foreign companies are actively pursued, as shown in Fig. 5.5. Primary research areas at ERSO include the following:

- Semiconductor process technology: deep sub-micron lithography, etching, device, and thin film development; high-frequency process integration
- Design technology: mixed signal IC, RF IC, and CCD
- IC testing technology

United Microelectronics Corporation (UMC) was ERSO's first Taiwanese IC spin-off in 1979. Most capital came from government and local banks. The Electronics Testing Center was spun off in 1982. The Taiwan Semiconductor Manufacturing Company (TSMC) IC foundry was the third spin-off from ERSO. All technical people initially came from ERSO. The Taiwan Mask Corporation (TMC), the first domestic mask manufacturer, and EMMT System Corporation were spun off in 1988. In 1994, Vanguard International Semiconductor (VIS) was spun-off as the first 8-inch wafer fab in Taiwan, specializing in sub-micron memory IC manufacturing. In 1995, there were 26 Taiwanese companies involved in IC design with total revenues of $593 million, and 12 firms producing ICs with total revenues of $4 billion. There are four 8-inch fabs in operation, 10 under construction, and 6 in the planning phase. By the year 2000, 20 wafer fabs are to be operating. As shown in Table 5.7, 19 fabs would account for over $16.5 billion in investment and provide capacity of 4.8 million pieces per month. With new fab capacity being added across Asia, overcapacity is a potential problem. While prices were down in 1996, past margins – for some firms as great as 50% – were considered high. Such high margins are not considered good for the industry.

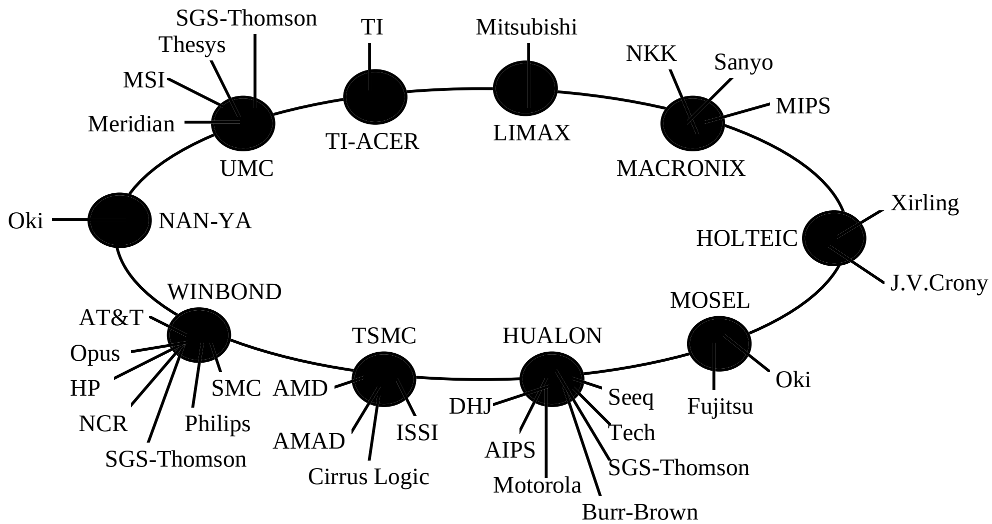


Fig. 5.5. Strategic alliances in Taiwan's IC industry (MIC, ERSO/ITRI ITIS Project). See also Table 5.7.

Table 5.7
Taiwan's 8-inch Fab Investments

Companies	**Factory**	**Investment (US$ M)**	**Ground breaking**	**Completion**	**Capacity (K pc/M**	**Major Product**
Vanguard	Fab I-A	680		1994	150	DRAM, SRAM
	Fab I-B	750	1995	1996	150	
TSMC	Fab III	1000	1993	1995	250	Foundry
	Fab IV	1000	1995	1996	300	
	Fab V	1000	1995	1997	250	
TI-Acer	Fab I-B	500	1994	1996	150	DRAM
	Fab II	1100	1994	1997	400	
UMC	Fab III	1000	1995	1995	250	CPU, SRAM, Foundry
US	Fab I	1000	1994	1996	250	Foundry
UC	Fab I	1000	1995	1997	250	Foundry
UR	Fab I	1000	1995	1997	250	Foundry
Nanya	Fab I	750	1995	1996	240	DRAM
Powerchip	Fab I	750	1995	1996	250	DRAM
HMC	Fab I	400	1994	1996	150	Memory, ASIC
Macronix	Fab II	1100	1995	1997	350	NV Memory, Logic
Winbond	Fab III	1100	1995	1997	400	SRAM, Logic
Mosel-Vitelic	Fab II	1100	1995	1997	250	DRAM, SRAM, Logic
AS	Fab I	750	n.a.	1997	300	Foundry (DRAM, Logic)
Holtek	Fab II	750	1996	1997	250	MCU, ASIC
Total		**16730**			**4840**	

Source: MIC, ERSO/ITRI ITIS Project

In the production of SRAMs, Taiwan was already the low-cost producer at the time of the WTEC visit (Taiwan's relative SRAM cost = 1, Korea = 1.14, Japan = 1.43, and the United States = 1.6). By 2000, Taiwan wants a 39.8% share of the global IC foundry market. To support these market goals, an alliance of companies is developing deep submicron process capabilities in the 0.25-0.18 µm range. Eight companies are working on 12-inch wafer development with expected mass production in the year 2000. National Chip

Implementation Center projects also include e-beam equipment and PCVD etching equipment developments. ITRI is developing packaging equipment, light-resistor, and Si-resin materials.

Table 5.8 shows Taiwan's IC capabilities. After completing 0.5 µm CMOS technology development, ERSO is now working on various 0.25 µm technology modules jointly with local IC manufacturers. Because mixed-signal ICs, such as data converters and phase locked loops, are well developed, ERSO is moving towards high-frequency ICs (including monolithic microwave ICs) and low-power ICs for applications like wireless communications and mobile personal equipment. Complete chip sets for CCDs, along with relevant system technology, have been developed for applications such as security monitors, video phones, scanners, and digital video storage systems.

Table 5.8
Taiwan's IC Technology Status

ITEM	METRIC	TAIWAN TECHNOLOGY LEVEL	TECHNOLOGY LEADERSHIP	LEADING TECHNOLOGY LEVEL
Process				
• CMOS	µm	Mass production 0.5µm, R&D 0.35 µm	Japan, USA	Mass production 0.35, R&D 0.25 µm
• BiCMOS	µm	Mass production 1.0 µm	Japan	Mass production 0.5 µm, R&D 0.3 µm
• Bipolar	µm	Mass production 3.0 µm	Japan	0.8 µm 4K ECL SRAM
Product				
• DRAM	Byte	16M mass production, R&D 64M	Japan, Korea Japan	64M mass production, 256M production, 1G paper
• SRAM	Byte	1M mass production, prototype 4M	USA, Japan	1M mass production, 4M/16M production, 64 M paper
• Flash	Byte	4m mass production, pilot 16M	USA	16M mass production, 32 production, 256M R&D
• MCU	Byte	4 bit - 8 bit production	USA	16 bit - 32 bit production
• MPU	Byte Frequency	486 - 32 bit RISC production	USA, Europe, Japan	Intel P-Pro 64 bit – 200 MIPs
• A/D	Byte Frequency	10 bit 20 MHz (5V), R&D 40 MHz	USA, Europe,	10 bit 40 MHz (2.7V), 8bit 45 MHz (3.3V)
• D/A	Byte Frequency	8 bit 135 MHz (5V), 10 bit 80 MHz (5V)	Japan	8 bit - 100 MHz
• Gate Array	Gate Count	up to 60K	USA, Japan	More than 100K, 1,600K prototype
Design				
• St. Cell	µm	0.8 µm CMOS	USA	0.5 µm CMOS
• Si	inch	8" fabs under construction	Japan, Germany, USA	12" R&D

Source: ERSO/ITRI ITIS Project

Taiwan's electronic equipment industry was worth $4.4 billion in 1995 and is currently supplied by only a few countries. Taiwan's market forecast for the 1995-2000 period for IC packaging equipment follows:

- wafer slicing/polishing machines 500/1,200 units
- mounting machines 930
- wire-bonding machines 5,400
- plastic sealing machines 730
- molding machines 2,000
- stamping machines 1,500
- others 300

Even though Taiwan is a major market for semiconductor production equipment, it is weak in equipment production. Since Taiwan lacks an equipment industry to leverage, it would require outside participation in order to establish a Taiwanese capability. ITRI officials are considering establishing a consortium similar to SEMATECH. The industry's research lab has developed a wire bonding machine, but it lacks the proven reliability needed for low-cost manufacturing. However, a tax incentive is offered for purchasing equipment from local producers. To keep their Taiwanese equipment business, foreign suppliers give Taiwanese firms a 20% discount on most equipment, giving Taiwanese companies a cost advantage over other countries.

Flat Panel Displays

In 1995, Japanese suppliers provided 100% of the 10-inch STN and TFT LCDs for notebook PCs produced in Taiwan. Local LCD vendors provided 90% of the screens used in electronic dictionaries, though 90% of the materials used to produce them were imported. Japanese firms also provided 87% of the high-resolution CRT monitors and 30% of the mid-resolution monitors used in Taiwan. Local CRT vendors produced 20% of the mid-resolution monitors and 80% of the low-resolution monitors, though 40% of materials were imported.

As Table 5.9 shows, Taiwan mass-produced CRTs up to 21 inches at the time of the WTEC visit; was in pilot production of CRTs over 28 inches; and was developing 16:9 ratio CRTs for use in HDTV. In LEDs, 10-inch color STN and TFT LCDs were in pilot production; TFTs over 10 inches were in development. Color filter driver ICs were imported. Taiwan is a close follower in high-luminance LEDs and is developing the blue LED at ITRI.

Table 5.9
Taiwan's Display Technology

		Technology Development		
Category	**Size**	**R&D**	**Pilot Production**	**Mass Production**
CRT	14" CRT			**X**
	15" FS			**X**
	21" CRT			**X**
	Over 28"		**X**	
	16:9 WST	**X**		
LCD	STN 3-10" B/W			**X**
	STN 10" color		**X**	
	TFT under 6"			**X**
	TFT 10" color		**X**	
	TFT over 10"	**X**		

Source: ERSO/ITRI ITIS Project

The thin film transistor liquid crystal display (TFT LCD) has been the preferred flat panel display technology since about 1989. ERSO had previously developed 3-inch and 6-inch color panels for both direct view and projection applications, and demonstrated wide viewing angle and quick response displays in 1996. The first 10.4-inch panels were displayed in 1996 for use in notebook computers. In 1995, two firms were producing TFT LCDs in Taiwan, and 13 firms were producing STN displays. Nan Ya Plastics produces 30,000 medium and small STN units per month. CPT began producing 10-inch STN LCDs for mobile PCs in 1995. Unipac produces 5,000 TFT LCDs per month ranging from 3-inch to 5.6-inch. In 1996, it planned to produce 30,000 units of large TFT LCDs per month. Prime View began producing 120,000 units/yr. of medium and small TFT LCDs in 1995 and was planning to product large units in the near future. Table 5.10 summarizes these companies' LCD investments and production plans.

In flat panel displays, ERSO is focusing its attention on four areas:

- TFT LCD technology: thin film device and circuit processing, color filters, and module integration
- LCD projection technology: module integration and optical system development
- Field emission display technology
- Plasma display panel technology

Table 5.10
Taiwan's LCD Investments

Company	Investment Amount	Completion	Production Plan
Nan Ya Plastics	$44.4 million	1994	Medium-small STN, 30,000 pcs./mo.
CPT	$111 million	1995	STN LCD for PC
Unipac	$30 million $370 million	1994 1996	3"-5.6" TFT LCD, 5,000 pcs./mo. Large TFT LCD for PC, 30,000 pcs./mo.
Prime View	$111 million $259 million	1995 --	Med.-small TFT LCD, 120,000 pcs./mo. Large TFT LCD for PC, 20,000 pcs./mo.

Field emission display (FED) technology development includes the combination of CRTs and microelectronics into 3-inch color panels. At the time the WTEC team visited Taiwan, ERSO was developing the pilot plant to produce them.

COMPANY STRATEGIES

The WTEC study team found evolving developments in the level of capabilities and strategies of the companies it visited in Taiwan, as shown in Table 5.11. The site report summaries in Appendix E describe each company's strategy and capabilities. Most companies are strong in contract manufacturing (CM) of electronic components and systems, using standard "long-lines" for SMT assembly. Some firms have moved beyond contract manufacturing and are designing original products for their customers. These original design manufacturers (ODM) are growing rapidly. Tatung, one of Taiwan's oldest brands and most established original equipment manufacturers (OEM), also sells products designed for major customers (ODM), and provides contract manufacturing (CM) for high-end notebook computers. The WTEC study team visited the production line for notebook motherboard and final assembly operations. The company was strong in all skills, but had limited sales and distribution capabilities outside of Taiwan.

Table 5.11
Evolution of Taiwan's Strategies and Capabilities

Taiwan Companies Visited	Competitive Strategies	Critical Skills
Tatung (notebooks)	OEM/ODM/CM	R&D, design, manufacturing, distribution
Inventec (notebooks)	OEM/ODM	Design, manufacturing, distribution
GVC (desktops, motherboards)	ODM/CM	Design, manufacturing
OSE (IC packaging/board assy.)	CM	Manufacturing
Nan Ya Plastics (PCB fabrication)	CM	Manufacturing

OEM - original equipment manufacturer; ODM - original design manufacturer; CM - contract manufacturer

Inventec has developed excellent manufacturing skills and is designing most of its customers' products. Inventec has used its capabilities to establish its own BESTA brand for Chinese electronic dictionaries. The BESTA dictionary dominates the Taiwanese market and is growing rapidly in mainland China. In 1996, the company had been producing Apple's Newton-based PDA for nearly four years. The company uses advanced TAB equipment for assembly of its PDAs and daughter cards. Inventec designed and produces Compaq's high-end LTE 5000 series notebook computers. Inventec's SMT production lines are the most advanced visited by the study team. The lines include automated through-hole placement and selective soldering machines.

GVC is becoming heavily involved in the design of multimedia computers for major OEM customers, targeting the top ten brand names in computers and developing new designs for companies like Packard Bell. GVC's long-line SMT assembly was typical of those seen in Taiwan.

OSE was the only fully integrated electronics manufacturer the team visited. OSE packages a full line of semiconductor products and assembles a wide range of motherboards and PCMCIA cards. The company has begun to package BGA and MCM products and is beginning to produce daughter cards for notebook computers. The company is also assembling completed notebooks.

Nan Ya is a fully automated PCB fabricator with world-class production facilities. Operations use CIM technologies for inventory and production control, and major investments have been made to maximize productivity gains. At the time of the WTEC visit, a new factory was being built to double capacity using the most advanced technologies and practices.

Overall, the WTEC team found Taiwanese companies to be well-managed and aggressive competitors. They are moving labor-intensive operation offshore, to China, Malaysia, and the Philippines, while they upgrade their own technologies and capabilities to stay competitive. The overall strategy is to ensure that Taiwanese contract manufacturers (CM) can produce the most advanced products and components, and can stay competitive in costs with offshore production. In addition, many companies are seeking to add increased value by creating original product designs for their customers. By designing "ready to go" products in advance of their customers' needs, Inventec and GVC are growing rapidly, at rates of over 50% annually. More and more companies are looking at developing ODM capabilities, but are restricted by the shortage of design engineers. The National Chip Implementation Center is training 300 professors and 1,000 IC designers each year in an attempt to address this shortage.

Taiwan's Labor Market

The Taiwanese government places heavy emphasis on education, encouraging everyone to get at least a high school degree. A BERI report ranked Taiwan's labor force number one among 17 newly industrialized nations. Much is invested in education, and many students go overseas for degrees in engineering. Due to a shortage of factory workers, the structure of the local labor market is changing. Nearly 25% of the factory workforce is composed of foreign workers. Most companies recruit Philippine employees because of their English language skills, excellent education, and strong work ethic. They earn around $750 per month plus dormitory costs.

In Taiwan, two 12-hour shifts are used instead of three to maximize productivity. Four shifts rotate two days on, for 12 hours per day, and then two days off. For sophisticated equipment like semiconductor equipment, it takes 30 minutes to an hour to make the transition. Three shifts loses significant productivity due to shift changeovers.

SUMMARY

It is obvious from the WTEC team's research that the Taiwanese government is strongly committed to ensuring long-term industrial growth. Emerging industries are targeted for future growth, programs are in place to ensure that supporting technologies will be available, and incentives are provided for industry to invest in and expand facilities in order to obtain global market share. Taiwan's strong global market position in electronic components suggests that the strategy is succeeding.

Companies are aware of government programs and are taking advantage of ITRI's supporting activities. To maintain competitiveness, companies are upgrading technologies for advanced manufacturing processes and are adding design capabilities to their manufacturing strengths. GVC and Inventec produce in-house designs for the world's top computer companies. Taiwan's record leaves little doubt that it will continue to take a leadership role in all areas of electronic packaging. Taiwan offers a full range of IC packages and assemblies, including MCM chip sets, high-end motherboards, and PCMCIA cards. Twenty IC wafer fabs are planned to be in place by 2000.

With the rapid development of China's electronics industry, established products are increasingly becoming commodities, and competition is based on price. As Taiwan's costs escalate, the government is committed to supporting leading-edge technologies and providing incentives for firms to enter emerging high-technology industries. The major competitive risks to Taiwan and its companies come from a shortage of leading-edge technologies. Taiwan has been less concerned with the development of new technologies than with the rapid transfer of technologies in time for volume production. With China's rapid entry into electronics, there are few barriers to technology transfer across Asia. The ability to maintain competitiveness is now dependent upon development of technologies more rapidly and having an adequate engineering and design capability to utilize technologies early. At present, Taiwan and Singapore have the advantage in engineering talent. The question is whether this will be adequate to provide leadership ahead of China and other rapidly industrializing nations like Vietnam and the Philippines.

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APPENDICES

APPENDIX A. PROFESSIONAL EXPERIENCE OF PANEL MEMBERS

Michael J. Kelly (Panel Co-Chair)

Affiliation: School of Engineering and Technology, California State University, Los Angeles
Address: 5151 State University Drive
Los Angeles CA 90032

Mike Kelly occupies the Northrop Grumman Endowed Chair of Manufacturing and Design at California State University, Los Angeles. Before accepting that position in 1996, he was a professor in the Georgia Tech School of Management, Public Policy, and International Affairs. He also held the position of Director of the Georgia Tech Manufacturing Research Center. Prior to accepting that position in October 1991, he was Director of the Defense Manufacturing Office at the Defense Advanced Research Projects Agency (DARPA), during which time he was also the Executive Director of the National Advisory Committee on Semiconductors. He came to DARPA in January 1989 from the New Jersey Institute of Technology, where he was Director of Computer Integrated Manufacturing and Technology Transfer.

Dr. Kelly worked at IBM for 17 years beginning in 1969. Prior to that, he was an associate professor of electrical and mechanical engineering, and Director of the Engineering Case Program at Stanford University. His other academic experiences included three years of teaching at the University of Detroit, where he also served as director of the university's computer center, and four years of teaching and administration at Marist College.

Mike holds a BA degree from Marist college; a BEE and MEE from Catholic University; and a Doctor of Engineering degree from the University of Detroit

William R. Boulton (Panel Co-Chair and Principal Author)

Affiliation: Department of Management, Auburn University
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Auburn, AL 36849

Dr. Boulton is the Olan Mills Professor of Strategic Management in the College of Business at Auburn University. He was the director of Auburn University's Center for International Commerce from 1990-1994. He was a Fulbright Scholar in 1986 and Visiting Professor in 1992 and 1993 at Keio University's Graduate Business School in Japan. He was also a visiting scholar at the Institute for Fiscal and Financial Policy of Japan's Ministry of Finance in 1993.

Dr. Boulton's current research is involved with global technology-based competition. His reports cover numerous companies, institutes, universities, and government organizations in Japan, Taiwan, Hong Kong, China, Singapore, and Malaysia. Current activities extensively cover South Korea and China. Dr. Boulton has focused attention on the speed of technology transfer into Asia and the support programs of Asian governments in support of industrial development and growth. Dr. Boulton is author of numerous articles covering topics of competitive strategy, strategic planning, boards of directors, and technology and innovation management. He has published *Business Policy: The Art of Strategic Management* (1984), *The Resource Guide for the Management of Innovation and Technology* (1993), and edited *The JTEC Panel Report on Electronic Manufacturing and Packaging in Japan* (1995).

Dr. Boulton received his doctorate from the Harvard Business School in 1977 in the field of business policy and strategy. He previously worked with GTE International Corporation and Singer Corporation in Asia.

Dieter Bergman

Affiliation: Director of Technology Transfer
Institute of Interconnecting and Packaging Electronic Circuits (IPC)
Address: 2215 Sanders Road, Northbrook, IL 60062-6165

Dieter Bergman began his career in 1956 as a designer for Philco Ford in Philadelphia, PA. He assumed the position of supervisor of the printed circuit design group in 1967, and joined the company's advanced technology group where he specialized in printed circuit computer-aided design. In 1962, while at Philco Ford, he became the company's official representative to the IPC. As a member, he received the IPC "President's Award" in 1968 and in the same year assumed the responsibilities of chairman of the Design Committee. He served as chairman of the committee for seven years and during his tenure was the recipient of the IPC "Outstanding Achievement" award for his work in developing the *Design Guide*.

Bergman was elected Chairman of the IPC Technical Activities Executive Committee in 1974, and later that year joined the IPC as Technical Director. In 1985, he was named to the IPC Hall of Fame, one of the IPC's highest awards.

As Technical Director, he was responsible for the coordination of standards, specifications, and guidelines development; round robin test programs; establishment of workshops and seminars; government and intersociety liaison; and IPC activities in Europe and Asia. As Director of Technology Transfer, he is responsible for moving the information developed by IPC Technical Committees into the manufacturing infrastructure.

He is Chairman of TC52, Printed Circuits of the International Electrotechnical Commission (IEC) and U.S. Technical Advisor to TC91 on Surface Mount Technology. He attended Temple University.

Bipin Chadha

Affiliation: Lead Member, Engineering Staff
Lockheed Martin Advanced Technology Laboratories
Address: One Federal Street, Camden, NJ 08102

Dr. Chadha is the Technical Lead for the information and process management strategy on the RASSP program, as well as the principal investigator on multiple enterprise engineering, supply chain integration, and process improvement initiatives within Lockheed Martin. Prior to joining Lockheed Martin, Dr. Chadha was an information technology and process improvement consultant for Intergraph Corporation, and a manufacturing information system developer for AT&T. His key areas of technical expertise include large-scale product data management, workflow and document management, expert systems, and business process reengineering. Dr. Chadha is a member of the ASME Engineering Information Management Committee, the Supply Chain Council, and Lockheed Martin-92s PDM subcouncil. Dr. Chadha has published many technical articles and presented his work at a variety of national and international conferences.

Dr. Chadha received his PhD in Mechanical Engineering from Georgia Institute of Technology, a Master's degree in Mechanical Engineering from Southern Illinois University, and a Bachelor's degree in Mechanical Engineering from the University of Roorkee, India.

Nicholas J. Naclerio

Affiliation: Director of Strategy for New Enterprises, Motorola
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Dr. Naclerio heads a team whose mission is to identify emerging industries and develop market entry strategies for Motorola. Prior to joining Motorola in November 1996, Nick was assistant director of the Electronics Technology Office at DARPA. While at DARPA, he initiated and led major programs in simulation and modeling, electronic packaging, and electronic systems manufacturing. He also served as the government representative on the SEMATECH Board of Directors and Executive Director of the National Advisory Committee on Semiconductors.

In 1994, Dr. Naclerio's contributions to the semiconductor industry were recognized with the Arthur S. Fleming award for exceptional public service. He holds a BS degree in Electrical Engineering and Computer Science from Duke University, a Master's equivalent in Materials Science from Cambridge University, and a PhD in Electrical Engineering from the University of Maryland.

Michael Pecht

Affiliation: Director, Computer-Aided Life-Cycle Engineering (CALCE), Electronic Packaging Research Center (EPRC), University of Maryland
Address: College Park, Maryland 20742

Michael Pecht is the Director of the CALCE Electronic Packaging Research Center at the University of Maryland and a full professor with a three-way joint appointment in Mechanical Engineering, Engineering Research, and Systems Research. 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, 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 the *IEEE Transactions on Components, Packaging, and Manufacturing Technology; SAE Reliability, Maintainability and Supportability Journal;* and the *International Microelectronics Journal*, and is on the advisory board of the *Journal of Electronics Manufacturing.* He serves on the board of advisors for various companies and consults for the U.S. government, providing expertise in strategic planning in the area of electronics products development and marketing.

The CALCE EPRC at the University of Maryland is sponsored by the National Science Foundation and over 40 industry and government members. The Center is a leading research facility in the design, manufacture, and test of reliable, cost-effective electronic products. The CALCE EPRC provides a resource base to support the development of competitive electronic products and systems in a timely manner. The resource base includes design methods, simulation techniques, models, guidelines, instructional information, and future engineers and technical leaders.

Gordon Roberts

Affiliation: Technical Manager, Lucent Technologies Engineering Research Center
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Dr. Gordon Roberts joined the Lucent Technologies Engineering Research Center in 1977 and participated in the development of low-cost plastic packages for CMOS and bipolar integrated circuits. During the 1980s he led the Lucent Technologies program in surface mount technology. His responsibilities included management of materials and manufacturing process development, equipment design, and technology deployment into Lucent factories both in the United States and overseas. More recently, Dr. Roberts led the Lucent program to develop assembly technologies for application in miniaturized portable products. In his current position he is responsible for the application of breakthrough technologies to electronic switching systems. Dr. Roberts has a BS in Chemistry and a PhD in Physical Chemistry from the University of Aston, Birmingham, England.

Amalendu Sanyal

Affiliation: Principal Engineer, Module Manufacturing Operation
Digital Equipment Corporation
Address: 24 Porter Road, LJO1-1/H2
Littleton, MA 01460-1446

Amalendu Sanyal is the principal engineer reporting to Digital Equipment Corporation's module manufacturing technology manager in Littleton, Mass. This is part of the central manufacturing group supporting module (electronic assembly) plants located in Canada, Scotland, Singapore, and Taiwan.

Prior to joining Digital, Sanyal worked as a manufacturing engineer at Bell & Howell's communication division in Burlington, Mass. At Bell & Howell, he was responsible for new product introduction and supported manufacturing processes for the pager and communication products. He joined Digital at its high-volume manufacturing plant and supported the module assembly operation. In 1979 he joined the Complex Module business at Digital in Massachusetts.

Sanyal was part of the team responsible for developing the SMT process for Digital plants. He designed and published the *SMT Land Pattern Guide* for manufacturing (an internal publication). He managed a group of development engineers and technicians involved in advanced development of future module assembly interconnect technologies, and developed and managed delivery of SMT process to manufacturing plants. In 1992 he provided leadership for the technology forecast project aimed at providing inputs to various technology groups on important technical development and recommended technology investment options.

Currently Sanyal is responsible for benchmarking, comparative analysis, and technology forecasting for the module assembly business. He is a joint owner of a patent on "step-stencil." Sanyal has an MS in mechanical engineering and an MS in engineering management. He is a member of SMTA.

William A. Tucker

Affiliation: Senior Technical Staff Member, IBM Personal Computer Company
Address: 11400 Burnet Road, Austin, TX 78758

Mr. Tucker joined IBM in 1969 at the Boca Raton, Florida, Development Laboratory, where he held several technical and managerial positions in both engineering and programming development of the IBM System/7. In 1977, he transferred to the Austin, Texas, Development Laboratory, where he was responsible for design of the document distribution hardware and microcode for the IBM 5520 Administrative System. He subsequently was named senior programming manager responsible for all software support of the IBM 5520 administrative system. In 1983, he was named assistant to the vice president, Office Systems and Programmable Workstations, for the Communications Products Division in White Plains, New York. Later that year he was promoted to manager of quality assurance for Entry Systems Division in Austin, Texas, responsible for logic board assemblies and box manufacturing for the Austin site, which included qualification of surface mount technology (SMT) within IBM.

From 1986 until 1991 Mr. Tucker held several management positions responsible for worldwide new product introduction and manufacturability of electronic card assemblies. In 1992, he established the Austin OEM electronic card manufacturing business. Mr. Tucker served as Global Procurement Program manager responsible for ensuring worldwide competitive sourcing of electronic card assemblies from 1993 through 1995. He was appointed to his current position in September 1995.

Mr. Tucker has made many contributions to IBM in the areas of hardware design and development, software design and development, and manufacturing of electronic card assemblies. He has authored several technical reports and outside papers. He is one of the pioneers in implementing surface mount technology within IBM Corporation and is a leader in the corporation on competitive manufacturing costs of electronic assemblies.

Mr. Tucker received a Bachelor of Science degree in Industrial Engineering from Auburn University in 1969 and a Masters of Business Administration degree from the University of Texas in 1991.

E. Jan Vardaman

Affiliation: President, TechSearch International, Inc.
Address: 9430 Research Blvd., Bldg. 4, Suite 400
Austin, TX 98759

E. Jan Vardaman received her Bachelor of Arts in Economics and Business in 1979 from Mercer University and her Master’s degree in Economics in 1981 from the University of Texas. After working as a government computer industry analyst, she joined the corporate staff of Microelectronics and Computer Technology Corporation (MCC) in 1984, where she analyzed developments in semiconductor packaging and assembly.

In 1987, she founded TechSearch International, providing services in licensing electronics technology and reporting technical information on international developments in the electronics industry. She is the editor of *Surface Mount Technology: Recent Japanese Developments,* is a columnist for *Circuits Assembly* magazine, is on the editorial board of *Advanced Packaging Magazine*, and is author of numerous publications on emerging trends in semiconductor packaging and assembly. She has made presentations on developments in TAB, flip chip, ball grid array packages, chip size packaging, and multichip modules in Asia, the United States, and Europe. She is a member of IEEE’s CPMT society and ISHM/IEPS. She was the 1996 General Chair of IEEE’s International Electronics Manufacturing Technology Symposium held at Semicon Southwest.

Samuel Robert Wennberg

Affiliation: Manager, Technology Assessment and Acquisition
Delco Electronics, General Motors Corporation
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Mr. Wennberg has worked 17 years for Delco Electronics, a subsidiary of General Motors. In the 17 years he has worked in product design, finance, quality, production readiness, manufacturing engineering, and research and development. Mr. Wennberg is the founder and leader of the Delco Electronics’ Advanced Manufacturing Engineering team, which led the effort to develop the next generation of electronic manufacturing technology being deployed within Delco Electronics and throughout the electronics industry. The Advanced Manufacturing Engineering team was formed to develop this new technology and consisted of 50 engineers and scientists located in Singapore and the United States.

Based on his industry reputation Mr. Wennberg was asked in 1995 to launch the National Electronics Manufacturing Initiative (NEMI), as the first director of operations. NEMI is an organization that works with U.S. electronics industry manufacturers, associations, and the U.S. government to improve the electronics manufacturing infrastructure in the United States. NEMI was successfully launched and is in the process of publishing its manufacturing technology roadmap for the electronics industry. Since his return to Delco Electronics, Mr. Wennberg has assumed the position of manager for technology assessment and acquisition. Current technical areas of interest and study include multimedia, communications, system and software processes, manufacturing and packaging, and vehicle system integration.

APPENDIX B. HONG KONG SITE REPORTS (MARCH 1996 VISITS)

Site: **Hong Kong Productivity Council (HKPC)**
HKPC Building, 78 Tat Chee Ave., Kowloon, Hong Kong
Tel: (852) 2788-5678; Fax: (852) 2788-5900; e-mail: www.hkpc.org

Participants: Thomas Chow, Advanced Manufacturing Technology Manager, Electronics Services Division
Dr. Stephen Cheung, General Manager, Electronics Services Division
Charles E. Chapman, Executive Director, Hong Kong Electronics Industry Association
Mr. S. L. Law, Advisor, Senior Principal Consultant, Electronics Division

Mission and Strategy

HKPC is a multidisciplinary organization established by statute in 1967 to promote increased productivity and efficient production methods in Hong Kong's business sector. HKPC provides consultation, training, product development, and technology transfer services to strengthen human resources and enterprise technologies. It provides a wide range of services and training to over 4,000 companies per year.

Key Elements of Presentation

- Helping Hong Kong companies make a transition from labor-intensive to high-value-added production. Major emphasis is on identifying product and process technologies that need to be transferred to HK.
- Some major projects on technology transfer are funded by the Industry Technology Development Council.
- In the electronics area, it has about 45 people, about 35 of whom are engineers. Products developed via consortia include pager, palm top computer, and cordless/cellular phones.

Key Elements of Tour

- Facilities include auto-mold software and hardware for parts prototyping. CAD is used with surface tracing to input 3-D digital information.
- RF design unit has engineers developing cordless phones.
- SMT lab proves design concepts for PCB assembly and allows low-volume prototyping.
- New TAB equipment demonstrates outer lead bonding for TCP on LCD.
- HKPC has a 4-day turnaround calibration laboratory and a strong reliability laboratory with the SEM for bare PCB and semiconductors, high/low temperature and humidity chambers, random vibration system and micro-sectioning capabilities. A new EMC chamber is now under construction at the ground floor.

Core Competencies

- Excellent new facilities and location have been funded by the government. A new flying probe bare PCB tester was installed in the SMT laboratory.
- Large theater, training facilities supported with consulting services and labs and engineers open to industry.
- About 280 staff cover disciplines like electronics, mechanical, software, and textiles.
- Publications are available to membership on training and technology issues.

Conclusions

- Some HKPC projects are supported by ITDC to move local companies into higher-value-added businesses.
- HKPC, along with Hong Kong Electronics Industries Association and Hong Kong University of Science and Technology, is developing a technology roadmap for packaging to provide direction for future efforts.
- HKPC focuses on product and process developments needed to keep local firms competitive.

Site: **Nam Tai Electronic & Electrical Products Ltd.**
Unit 513-520, 5/F., No. 1 Hung To Road, Kwun Tong, Kowloon, Hong Kong
Tel: (852) 2341-0273; Fax: (852) 2341-4164

Participants: Tadao Murakami, Chairman and President, Nam Tai Electronic & Electrical Products, Ltd.
Tetsuya Onishi, Chief Engineering Manager, Nam Tai Electronic (Shenzhen) Co., Ltd.

Mission and Strategy

- Nam Tai utilizes the relative advantages of China's low labor cost, Japan's advanced technology and management system, and Hong Kong's gateway between China and other countries. Its objective is to stay "one step ahead for customer satisfaction."
- Nam Tai is targeting Japanese firms looking for low-cost production of high-tech consumer electronic products. Products include calculators, databank, personal organizers, electronic dictionaries, IC card readers, LCD modules, COB assembly, and SMT assembly.
- Key customers include Canon, Sharp, Seiko Instruments, Matsushita Battery, Texas Instruments, Optrex, Toshiba, Nintendo through Sharp, and Seiko-Epson.
- Nam Tai aims to be China's top-quality company. It obtained ISO 9002 in 1993 and ISO 9001 in 1996.

Key Elements of Presentation

- New COB facilities and processes allow 130 mm fine pitch with high-speed and accurate coating and semi automated die attach machines. By 1997, Nam Tai will be able to wire bond 100 mm fine pitch ICs.
- OLB will allow for 281 pin/240 mm pitch TAB. By 1997, Nam Tai will be able to assemble 500 pin count/200 mm pitch TAB parts and BGA.
- SMT will allow for 500 mm fine pitch in the new factory, and 300 mm pitch by 1997.
- Nam Tai will introduce chip on glass in 1997 and begin MCM assemblies using BGA, CSP, and flip chip.

Key Elements of Tour

- PCBs are 100% inspected due to high cost of chips.
- Nam Tai has 80 sets of wire bonding equipment, 3 SMT systems, 3 sets of TCP assembly machines (OLB), and 2 sets of automatic heat seat machines.
- Wire bonding machines do 200 million wires per month with at 0.3 to 0.4 seconds per wire, 4 to 5 million LSI per month or 2 million pieces with 4 or 5 chips per piece.
- SMT uses KME's CM82C high-speed chip-mounter, 0.15 second placement, using 1005 parts.
- Sharp's mini-Taurus are produced weighing 110 grams.
- All future products will be lightweight and thin, requiring COB and OLB processes. Nam Tai attaches 280 mm pitch tab chips with 281 pins for the Sharp organizer. Chips placed on the board are 0.42 mm pitch.

Core Competencies

- Quality. ISO 9001 certification. The OLB quality is 99.6% throughput.
- Experienced managers are from Japan and Taiwan.
- Wire bonding, SMT, OLB (TAB), and fine-pitch heat seal processes.

Conclusions

- Nam Tai can make any high-tech consumer products coming out of Japan.
- Low cost labor and local suppliers, plus high-tech processes are a strong combination.
- Recruiting of top managers from around the world is its major strength for the future.

Site: **Wong's Electronics Company, Ltd. (WEC)**
Wong's Ind. Centre, 180 Wai Yip St., Kwun Tong, Kowloon, Hong Kong
Tel: (852) 2345-0111; Fax: (852) 2797-8119

Participants: Sunny Chau, Assistant General Manager, Sales and Marketing
Ricky Siu, General Manager, Welco China Limited
Simon Au, Engineering Manager, R&D Department
Clarence Wong, Senior Manager, Concurrent Engineering Department

Mission and Strategy

- WEC manufactures high-end OEM and ODM electronics products and systems. WEC provides a total manufacturing solution, being vertically integrated into PCB supply, plastics and metal parts supply, electronic assembly, with global procurement, manufacturing, and sales.
- Customers seek cost-reduction and reengineering of first-generation products. WEC goes through a "three-step" process to cut vendor costs, production costs, and design costs. Any cost improvement after production begins is shared 50-50 with customers.
- Sales in 1994 were divided among computers (35%), peripherals (25%), telecommunications (25%), and other office equipment, medical electronics, and industrial products (15%). Sales were divided among North America (55%), Japan (25%), Europe, and Southeast Asia (10% each). The percentage for 1995 decreased some for North America and increased for Japan.
- WEC makes Pentium 5 PCBs for NEC in China as an ODM joint development project to reduce costs; hard disk drives for Conner; printers; PCB subassemblies for Xerox office equipment worldwide; small PBXs for Executone in the United States; U.S. cordless and cellular telephones for Toshiba; and power supplies for ABB in Europe. The computer sector is decreasing with the growth in other areas.
- The Hong Kong factory was ISO 9001 certified in 1994, the Malaysia factory was ISO 9002 certified in 1993, and the China factory was ISO 9002 certified in 1996.

Key Elements of Presentation

- Wong's International (Holdings), Ltd., is the parent company for electronics product-related companies accounting for 5,500 employees and sales revenues of $315 million in 1995. WEC had total revenues in 1994 of $190 million, 60% of the group's sales. 7 factories have 1.1 million ft^2 of manufacturing space.
- WEC began assembling electronic products in 1977; it established a joint venture in 1980 with Atari in China for games and toys, and a manufacturing facility in 1990 in Johore Bahru, Malaysia, to diversify risks.
- Key components are produced by Wong's Circuits (PCBs), Season Industries (plastic parts), and Tomiyama Wong's (precision sheet metal). Wong's International China is a sales distribution company that helps customers enter the China market.
- Five strategic business units have production lines, warehouses, and engineers.

Key Elements of Tour

- Prototype production is done in Hong Kong and transferred to China.
- The China factory has 1,500 workers, 160 staff, 60 supervisors, and 40 HK staff. There are 2 main factory buildings (210,000 ft^2) plus plastics/metal parts supplier factories.
- Conner's line is mature and has only a 3% cumulative defect rate.
- WEC has 9 Fuji CP2/3/4 and two new Fuji CP6 high-speed chip-mounting machines; 15 Yamaha YM-100VP IC-mounting machines accurate to 15 mil QFP; plus a new Universal GSM-1 IC mounting machine for 12 mil placement required for assembly of 2.5-inch hard drive assembly and BGA placement.

Core Competencies

- WEC has 8 sets of Micro Cadam Plus and two sets of 3D Cadkey stations and designs to international standards. It has limited ODM capabilities.
- Equipment is standardized in factories for SMT, through-hole, and testing.
- It has a variety of Genrad and Teradyne testing equipment. Average pin count for testing is 1,200; maximum is 3,584.

Conclusions

- WEC helps Japanese firms cut costs via Chinese sourcing and production.
- It is reorganizing to handle higher-volume customers with dedicated SMT lines.

Site: **Wong's Circuits (PTH), Ltd., (WC)**
Wong's Ind. Centre, G/F-3/f, 180A Wai Yip St., Kwun Tong, Kowloon, Hong Kong
Tel: (852) 2357-8111; Fax: (852) 2343-7799; e-mail: wongspth@hk.super.net

Participants: M. Hasukawa, General Manager
W. Y. Yip, Assistant General Manager
Adam Chung, Senior Sales Engineer, Marketing Department

Mission and Strategy

- WC is a PCB manufacturer. It keeps a balance between four business areas: about 35% in personal computers, 10% in office automation, 40% in telecommunications, and 15% in automotive devices, aiming for a balance between these of about 25% each.
- In Hong Kong, 85-90% of production is 4- to 16-layer boards. Double-sided boards are 10 to 15%. In China, 60-70% of production is for double-sided boards, with 30-40% being 4- to 6-layer boards. The expansion in China will lead to 8-layer board production. The hope is to increase high-end customers by 50% by supplying companies like Apple, IBM, and NEC.
- About 45% of sales are in North America, 10% in Europe, 15% in Japan, 10% in Hong Kong, and 20% in Singapore and Malaysia.
- High-volume scale requires 30,000-40,000 units (30 or 40 m^2) per month.
- Changing customer needs require increased materials variety; increased performance through automation; reduced consumption of water, energy, and chemicals through recycling; and flexibility. Sales can increase 20 or 30% per year using existing employees with unit automation.
- New technologies include high-layer-count panels of 18-24 layers; rigid-flex multilayer PCBs, thin PCMCIA cards with alternative finishes and ultrafine-line microcircuits for the computer industry. This results from new investments and R&D efforts at new materials evaluation, new process implementation, and new equipment installation.

Key Elements of Presentation

- Wong's Circuits sales were $90 million in 1995, up from $56.1 million in 1991. With expansion in China, the forecast for 1996 was $110 million, and $160 million for 1997 after the Hong Kong expansion.
- Wong's began producing single-sided boards in 1962, but Wong's Circuits (PTH), Ltd., was actually established in 1975. In March 1997, the Hong Kong site was scheduled to move to Junk Bay Industrial Estate, a new industrial park for high-tech manufacturing. The factory area would increase from 156,000 ft^2 to 337,500 ft^2 in Hong Kong at a cost of $35 million, with $38 million of new equipment.
- In 1990, Wong's Circuits (Huizhou), Ltd., was established in China. In March 1996, that factory was expanded from 97,500 to 150,500 ft^2.

Key Elements of Tour

- WC produces 5,500 (2.6 ft^2/panel) panels (14,300 ft^2) in Hong Kong, and 2,800 (2.3 ft^2 panel) panels (6,440 ft^2) in China. Output will double after expansion to 5,000 panels per week in China and 11,000 panels in Hong Kong.
- An Excellon drill press is run by a CNC unit, loaded from a CAM station. The drill runs at a speed of 10,000 rpm to 0.35 mm. That has stabilized for computer boards in order to minimize costs. Engineers think it will work to 0.25 mm in mass production.

Core Competencies

- WC has the capability of producing in volume, 4-, 6-, 8-, 10-, 12-, 14-, and 16-layer PCBs. Ten-layer board production is well advanced, and 14-layer boards are being produced in mass quantities. WC can build very thin panels for PCMCIA cards for notebook computers that have a minimum thickness of 0.35 mm.
- Some employees have over 20 years of service.

Conclusions

- WC is aggressively investing in high-end product manufacturing and automation.
- Quality levels are improving through training and automation.
- Prices are becoming global.

Site: **WKK Industries, Ltd.**
WKK Bldg., 9/F, 418A Kwun Tong Road, Kowloon, Hong Kong
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Participants: L. H. Choi, Senior Manager, Sales and Marketing
Patrick K. K. Lee, Assistant General Manger, Engineering
Shu Tim Liu, General Manager, Shajin Factory, China

Mission and Strategy

- WKK provides both OEM and ODM services. WKK is the manufacturing arm for customers and produces a wide variety of high-quality products, in both large and small volumes, sourcing all components and subassemblies plus packaging and shipping.
- About 20% of current sales are ODM. The customer provides conceptual design and sketch or mockup; WKK designs the cosmetics and shape and produces the mechanical and PCBA. Depending on the product, a firm quote takes two to six weeks.
- WKK has 8 years' experience with Japanese customers: it produces Sega color LCD games, Universal remote controllers, Casio calculators, NEC color printer boards and 486 motherboards, Yamaha mini hi-fis, Scientific Atlanta's cable TV decoder, and cordless telephones for Seiko and Kenwood (including pilot runs).
- WKK will make Sharp's PDA, using 0.3 mm parts, Internet, and CD ROM cards. WKK produces the 16-bit Sega Genesis and will produce the new 32-bit game machine using a CD ROM player and PCMCIA cards.
- WKK was ISO 9001 certified in 1994.

Key Elements of Presentation

- The WKK group is headed by Wong's Kong King International (Holdings), Ltd. Total revenues for 1995 were over $122 million, an increase of 41% over 1994.
- WKK has operations in China, Singapore, Malaysia, Thailand, Japan, and California. The China factory will be moved to a new site in 1997 with Nissin precision parts joint venture.
- China has five operating groups (digital/game, audio and SMT manufacturing, personnel/administration, and engineering). Hong Kong handles R&D, QA, and marketing.
- China has 17 managers, 11 engineers, and 3 supervisors from Hong Kong; 6 managers, 58 engineers, and 49 staff from China, plus 1,679 direct laborers, including 135 quality inspectors. Assembly operations run one shift. SMT runs 24 hours per day.
- The average monthly salary for engineers in China is $275, compared to $2,055 in Hong Kong. Factory workers take home $65 per month. Benefits run $65 for administration fees and local taxes. HK factory workers cost HK$825 per month. The turnover rate is as high as 50% in China.

Key Elements of Tour

- SMT lines include 8 Yamaha lines sold by WKK with assembly time of 0.3-0.4 sec. per component, and 5 KME lines with 0.15 sec. assembly time per component for runs of over 1,500 units per day. 10 stand-alone machines do batch production. The finest pitch currently in mass production at WKK is 0.5 mm pitch. The Yamaha can handle 0.3 mm.
- Genrad, Tescon Point, and Test Research machines are used for ICT as required.
- 900 Casio calculators are produced each hour, 9,000 per day.
- Japanese management methods and innovative assembly practices are pervasive.

Core Competencies

- Two 64-bit lease lines for voice and data keep WKK linked via voice and e-mail between China, Hong Kong, Japan, and the United States.
- WKK has engineering expertise in mechanical, digital electronics, telecommunication, and document control for designs and drawings.
- WKK is the agent for Yamaha and has access/know-how for the latest equipment.

Conclusions

- WKK has food computer and communications systems.
- Highly innovative and experienced factory management in China; produces wide variety of products.
- Strong Japanese customers with leading game, phone, and PDA technology products.
- It has strong SMT capabilities, with Yamaha agency and engineering expertise.

Site: **VTech Computers, Ltd.**
23/F, Tai Ping Industrial Centre, Block 1, 57 Ting Kok Road, Tai Po, N.T., Hong Kong
Tel: (852) 2665-5266; Fax: (852) 2680-1120; e-mail: kan_leung@VTech.com.hk

Participants: Kan W. K. Leung, General Manager, PC Division
Kenneth K. W. Leung, Quality Assurance Manager, PC Division

Mission and Strategy

- VTech Holdings, registered in Bermuda, is Hong Kong's largest manufacturer. VTech's mission is to provide innovative and high-value products to consumers through the application of technology to electronic learning, telecommunication, and computing products.
- VTech's three product divisions are electronic toys and games, telecom products, and personal computers. Its strategy is to design, develop, and manufacturer a wide range of high-quality, innovative electronics products and components that fulfill the integrated learning, entertainment, telecommunication, and computing needs of its customers.
- The 1995 multinational sales were $631 million (46.3% in toys and games, 30% in PCs, and 23.7% in telecom products). The United States accounted for 50.2%, Europe for 29.3%, Canada for 3.6%, and Asia for 16.9% of sales. Offices are in 13 countries with expansions in India, Mexico, and South America.
- VTech invests $20 million in R&D annually, with 350 engineers in HK, 300 in China, and 100 overseas.

Key Elements of Presentation

- VTech's HQ and production facilities are in Hong Kong and China. VTech grew from a small manufacturer of single-chip microprocessor video games into a consumer electronics business. It has 10 years of ASIC experience.
- VTech's home segment of SOHO (small office, home office) and parents concerned about children's education and learning is expected to triple by 1997.
- Company strengths are in five key areas within the group: ability to apply technology to new product development; well-established distribution channels; strong alliances with business partners; sophisticated customer service and support; and a cost-efficient manufacturing base.

Key Elements of Tour

- VTech's product showroom displayed PCs, toys/games, and cordless telephones, cable set decoders, and satellite receivers, ranging from low-end toys to high-end computers.
- VTech and Playteck toys and games include the Talking Whiz Kid Genius, Super Color Whiz, and Alphabet Desk, which use human voice synthesizers and interactive response. AT&T and Toshiba are OEM customers of its 900 MHz cordless phone.
- Computer products are sold under VTech's own Laser and VTech brands, plus OEM. Computer products include desktops, notebook and servers, video display cards, motherboards, and ASIC chips. ICs in PQFP, SOL, and PLCC packages use 300 I/Os.
- The Dongguan, China, factory site is 2 million ft^2 with 14,000 employees. The company has ISO 9001 and ISO 9002 certifications.

Core Competencies

- VTech has a global network of research, engineering, and manufacturing expertise, supported by worldwide marketing and sales teams and distributors.
- It pioneered the use of microprocessor technology in design and production of electronic toys and learning aids.
- It has over 700 product development people worldwide in R&D facilities in the United States, Canada, UK, Hong Kong, and China. It averages 65 new products each year.

Conclusions

- VTech's commitment to customers is to provide the most innovative products and highest value. Its market share of electronic learning aids is 70% in the U.S. and 80% in the UK.
- It designed and produced the world's first digital 900 MHz cordless telephone (Tropez 900DX), capturing 50% of U.S. market share.

APPENDIX C. SINGAPORE SITE REPORTS (APRIL 1996 VISITS)

Site: **Singapore National Science & Technology Board (NSTB)**
Singapore Science Park, 16 Science Park Dr., #01-03 The Pasteur, Singapore 118227

Participants: David Lim Dah Chee, Manager, Manufacturing Technology Group
Low Kiam Cheow, Manager, Electronics/MicroE/Elect Systems
Loh Oi Kang, Senior Officer
Robert Chen

Mission and Strategy

The National Technology Plan (NTP) was established in 1991. The goal is to upgrade technology in support of upgrading industries to increase GDP. NTP objectives were:

- To create a world-class industry and service cluster.
- To develop core competence and technologies to support higher value-added activities.
- To improve competitiveness through innovation and economically relevant R&D. The NSTB provides the primary link between NTP's key initiatives and this economic upgrading. To support NTP objectives, the NSTB initiatives include:
  - Encouraging private sector R&D through loans and grants.
  - Identifying and recruiting the manpower and technologies needed to build long-term sustainable advantage in R&D.
  - Supporting and financing institutes and centers to meet the R&D needs of companies.

Key Elements of Presentation

R&D expenditures have increased dramatically in all sectors. Primary R&D policies include:

- Match R&D investments in areas of competition.
- Share risks with industry to encourage company R&D.
- Establish specialized research institutions focused on industry clusters and generic technologies.
- Develop research manpower.
- Deepen capability in identifying industry relevant technologies.
- Foster culture of technology innovation and entrepreneurship. A new 5-year plan was to be finalized in July of 1996. It is expected that the next five years of NTP funding will exceed the current five-year budget of $1.27 billion. Strategies include:
  - provide incentives and other assistance to private sector
  - develop technology and knowledge infrastructure
  - develop R&D manpower
  - support commercialization

Key Elements of Tour

Measures used by the NSTB to evaluate progress in implementing the NTP include:

- R&D spending targeted at 2% of GDP (GERD/GDP)
- (Research Scientists & Engineers) per 10,000 labor force
- Private sector share of R&D (target is half, or 1% of GDP).

Key Results

The progress at the end of 1994 against these objectives was:

- R&D spending of 1.13% of GDPC (GERD/GDP).
- 477 RSEs per 10,000 labor force.
- Private sector share of R&D spending was more than 64.5%.

Conclusions

In support of Singapore's objective to become the regional hub, or gateway, for R&D in electronics:

- Singapore is graduating 3,500 engineers and scientists each year from the local universities.
- In the electronics area, NSTB funds the Institute of Microelectronics (IME) to support the development of integrated circuits and micro-machining, and GINTIC Institute of Manufacturing Technology to support manufacturing automation and integration.

Site: **Institute of Microelectronics (IME)**
11 Science Park Rd., Singapore Science Park II, Singapore 117685

Participants: Dr. Robert C. F. Tsai, Associate Director
Wallace Lim, Senior Marketing Officer
Dr. S. Navin Bhandarkar, Technical Staff

Mission and Strategy

NSTB started IME in 1991. IME's mission and objectives are to help increasing value-added from electronics industries in Singapore by engaging in relevant R&D over selected (strategic) fields in microelectronics, supporting and partnering with electronics industries, and developing skilled R&D personnel.

Key Elements of Presentation

IME focuses on 4 areas of activities across 6 business units:

ACTIVITIES

1. Advanced services
2. Silicon microelectronics applications
3. Miniaturization for portable electronics
4. Training

BUSINESS UNITS

1. Optical and magnetic
2. Micromachining and sensors
3. Mixed-signal designs
4. Advanced packaging development
5. Deep sub micron
6. VLSI

Key elements

IME currently has a team of 140 scientists and staff (two-thirds of whom have post-graduate degrees) and $26 million of equipment. IME actively recruits talent from around the world, including the U.S., but has a difficult time retaining top level researchers due to the high demand in the local region for this skill level.

Key results

Advanced packaging activities focus on flip chip, ball grid array, and chip size packages.

Conclusions

IME has failure analysis equipment including focused ion beam, transmission electron microscope, and atomic force microscope. Skills to operate and interpret the results have been obtained from Motorola, Bell Labs., etc.

Site: **GINTIC Institute of Manufacturing Technology**
Nanyang Technological University, 71 Nanyang Dr., Singapore 638075

Participants: Ho Nai Choon, Division Director
James Ling Kwong Ung, Director
Dr. Lim Beng Siong, Senior Manager
Stephen Wong Chee Khuen, Group Manager
Dr. Sanjay Jain, Research Fellow

Mission and strategy

GINTIC is responsible for enabling the manufacturing community to contribute 25% of the GDP. It keeps a current 5-year strategy on how to help local manufacturing by exploiting existing manufacturing and systems technologies and developing new technologies.

Key Elements of Presentation

GINTIC is operated under funding from the NSTB and has a staff of 250 people growing to 300. They focus on information technology, process technology, and automation technology (including material handling) to support manufacturing by Singapore firms throughout the region.

Key Elements of Tour

GINTIC provides the reliability analysis, cost analysis, prototype assembly, and process definition to support the transfer of technology to member companies.

Key Results

Advanced electronic packaging activities include no clean flux, paste in hole, organic surface preparation, and flip chip on glass. Facilities are adequate to demonstrate technology capability, help with product deployment.

Conclusions

The information technology group has a new project focusing on virtual factory simulation and cycle time analysis. There are no current activities underway to support flat panel manufacturing or card level testing.

Site: **Economic Development Board - Singapore**
250 North Bridge Rd., #24-00 Raffles City Tower, Singapore 179101

Participants: Koh Yong Boon, Senior Officer
Yun Kok Siong, Senior Officer

Mission and Strategy

- The Economic Development Board (EDB) was established in 1961 under the Minister of Trade.
- The 1995 mission statement of the EDB is to develop Singapore into a global city with total business capabilities. EDB's original mission was to attract multinational corporations (MNCs) to Singapore for the purpose of achieving full employment, which was achieved in the early 1980s.
- In the mid-1980s, Singapore experienced a recession since their total production costs were too high for the production technology deployed within Singapore. EDB took the lead in establishing plans to diversify the economy and to move up the value chain as labor costs increased. The National Technology Plan (NTP) and Economy Plan (E2000) were thus formulated.
- The goal is to grow in new technology markets that can improve Singapore's long-term standard of living.

Key Elements of Presentation

EDB set up a variety of government organizations to insure that the Economic Growth Process achieved a minimum GDP of 8% per annum with an inflation rate less than 4%. Infrastructure agencies that were spun off from EDB include:

- JTC Land and factory space available for start-up and small companies.
- DBS Banks Capital and Financing
- NSTB National Science Technology Board
- SISIR Standards, measurements and test
- TDB Trade encouragement

Key Elements of Tour

Current EDB initiatives include:

- M2000: Target at least 25% of GDP in manufacturing.
- IBH2000: Attract 80 to 100 regional headquarters in Singapore
- PLE2000: Encourage 50 to 70 local enterprises to reach $100 million in sales.
- LIVP: Local industry upgrade program.
- Region2000: Participate in growth of the rest of Asia through direct investments in infrastructure, manufacturing and service
- IDS: Innovative Development Incentive

Key Results

- EDB works closely with NSTB, Ministry of Finance (TEMASEK), and other Singapore agencies to identify strategic markets and to invest as necessary to develop an infrastructure within Singapore to support the new initiatives. The EDB has a $1 billion Cluster Development Fund to invest in key "Clusters of Technology."
- In the wireless technology cluster, EDB is actively working with other government agencies to establish an infrastructure to support the wireless market. The technology infrastructure includes projects to support tantalum capacitors, TFT LCDs, and Li-ion-polymer batteries. A recent investment was made in a new $1.3 billion wafer plant with the capability of generating 0.2 micron geometries.

Conclusions

EDB has set up specific funds for various initiatives. However with Singapore's yearly budget surplus of $10 billion, budgets are not an issue. Basically, EDB targets high-value-added markets that will provide long-term economic benefit. The EDB has been very successful since the mid-1980s in transforming the economy from a labor-based economy into a capital-based economy.

Site: **NatSteel Electronics - Singapore**
138 Joo Seng Rd. #07-00, Singapore 368361

Participants: Chester C. Lin, NatSteel Chief Executive Officer
C. Y. Shaw, NatSteel Chief Operating Officer
Ng Hock Ching, Marketing Director
Tio Wee Seeng, NatSteel Senior Marketing Executive
Andy Yeo, Engineering Manager

Mission and Strategy

- Established in 1963, NatSteel, Ltd., includes the NatSteel Technologies group with NatSteel Electronics; Broadway Industrial for plastic injection molding and metal stamping in China; B.J. Industries for precision machine parts in Singapore and Batam; Engineering Computer Services for software and system integration in Singapore; and Multiwave Innovation, a multimedia company in Singapore.
- NatSteel Electronics was started in 1981. Its revenue grew from $80 million in 1992 to $500 million in 1995, with $600 million projected in 1996.
- NatSteel's customer base for computer and peripheral cards includes BMI, Chicony, Compaq, Diamond Multimedia, Hewlett-Packard, IBM, JTS, Multiwave, Video Logic, and Western Digital. Its customer base for telecommunications include Nortel, Hewlett-Packard, Supra, and Yupiteru. It is providing consumer electronics for Delta, Giken, Hipro, Hewlett-Packard, Litton, Sumitomo, and TEAC. It also manufactures RF electronics for General Instrument and Wireless Access. Complete products that it currently manufactures include 2-way pagers, set-top products, and calculators.
- NatSteel representatives stated that contract manufacturers make their money by effective utilization of capital. They operate their Singapore facility 3 shifts per day, 5 days per week, at 85% utilization.
- NatSteel is a contract manufacturer for both low-volume/high-mix and high-volume/low -mix products.

Key Elements of Presentation

NatSteel Electronics has several facilities:

Location	*Sq. Ft.*	*Employees*	*SMT Lines*	*Auto Insertion*	*ISO 9002*
Singapore	80,000	750	12		1993
Penang	160,000	800	18	7	1995
Bantam	70,000	750	7		1996
Shenzhen	75,000	100	2	2	1996
Bangkok	15,000	200	0	8	Open

- Each facility is operated as a profit center with its own manpower and scheduling.
- The Singapore facility has separate floors for the different volumes of businesses.
- Low-volume lines use a screener, MV2C chip placer, MPA3 module placer, IR, inspection, HP3070 ICT, and function test. A complete line changeover of products can be achieved in 2 hours, with another 2 hours to run sample parts before beginning volume production. Each operation uses statistical process control.
- High-volume lines are set up for double reflow products and have a screener, manual connector insertion, MV2C chip placement, MPA module placement, IR oven, screener, manual place PTH in paste, MV2C chip placement, MPA module placement, IR oven, cleaner, ICT, burn-in, functional test, visual inspection, then ship. NatSteel achieves 96% yield at ICT, 98% at functional. It has a 3-day average cycle time using batch build.
- The company is considering an acquisition to enter North America or Mexico.

Key Elements of Tour

- NatSteel Electronics provides infrastructure support from Singapore to all its facilities for process technology, materials, and finance. NatSteel has agreements with both Panasert and Hewlett-Packard to obtain additional equipment in a two-week timeframe.
- All component pricing is negotiated by the Singapore facility.
- Its MRP system is run once a week. Each facility approves the MRP volume input, takes responsibility for inventory, and either places outside purchase orders or buys from Singapore. They stock all components under customer part numbers and can run a partial MRP by customer at any time.
- It achieves 11-12 inventory turns. Its materials stockroom has limited access; expensive parts are locked inside an inner stockroom within the stockroom. The stockroom is run like a "supermarket." Material handlers get a shopping list from the batch floor release and collect parts from the shopping list. When

they leave the stockroom the parts are charged out to each line. Any overages (full reels, etc.) must be accounted for within 48 hours after removal from the stockroom.

- The process engineering department works with GINTIC for joint development of technology processes. NatSteel also works heavily with Panasert in Japan.

Key Results

- NastSteel is qualifying TCP attachment using a Panasert OLB machine and has qualified flip-chip-on-glass using stud-bumping-bonding (SBB) and anisotropic conductive film (ACF). It has qualified and is building volume products using organic coating, 15 mil QFP, and TAB.
- Its officials are watching the evolution of packaging technology and work with Panasert for placement equipment and GINTIC for process development. The next focus is test development by working with HP, Teradyne, and GENRAD.

Conclusions

NatSteel Electronics has a strategy to fill its factories and to win business by providing higher value-added services including system build and ODM products. It had just won a major product build contract for a major manufacturer at the time of the WTEC team's visit.

Site: **SCI Manufacturing - Singapore**
3 Depot Close, Singapore 109840

Participants: Kenneth H. F. Kwong, Marketing Manager
S. Chan, Manufacturing Operations Manager
Soh Siang Loh, M. E. Manager

Mission and Strategy

- SCI, started as an R&D company in 1961, entered commercial contract manufacturing in 1977. It is the largest contract manufacturer, with 22 facilities worldwide, which are ISO 9002 certified. It locates its facilities near its customers. Revenues have grown from $2 billion in 1994 to a projected $4 billion in 1996. SCI's objectives are to provide capability, speed/flexibility, value, and synergy to support its customers.
- Its Far East operations include Singapore, Thailand, and Penang, which operate at 150 million placements/mo.

Key Elements of Presentation

- SCI Singapore's customers include Hewlett-Packard, Seagate, Singapore Technologies, Compaq, Texas Instruments, Exabyte, NEC Semiconductors, Baxter, and Apple.
- SCI Singapore builds PC motherboards, LAN cards, printer cards, SIMMS, disk drive cards, modem cards, tape drive cards, and video tuner cards.
- The Singapore facility has 18 SMT lines using Fuji equipment with 85%-90% ICT yield and 92%-95% functional test yield. Test equipment includes Hewlett-Packard, Genrad, Zentel, and Fairchild. The company is achieving 11 inventory turns.
- SCI Singapore performs failure analysis to the component level but leverages GINTIC's local facilities for component failure analysis, obtaining local perspectives and networking among local manufacturers. SCI Singapore is not working with GINTIC on BGA qualification because BGA qualification is being done by SCI in Huntsville for the corporation.

Key Elements of Tour

- SCI is experiencing a turnover rate of 3% per month for its operators. New operators are given a 3-day basic course and must pass an examination before they begin one month of on-the-job training. SCI provides good benefits and quarterly profit sharing.
- Professional staff have lower turnover but leave for better opportunity jobs. This is especially true for engineers who have been out of college for 5 years or less.
- Approximately 82% of SCI Singapore's workforce are operators, and 30% of the operators are Malaysians who are picked up by bus on a daily basis. SCI also employs many operators from China, for whom SCI provides dormitory housing.

Key Results

SCI Singapore generated $330 million in revenues in 1995.

Conclusions

- SCI obtains advanced manufacturing process technology from Huntsville, AL, and does concurrent engineering, including PCB layout and process implementation, locally.
- SCI has global purchasing centers for selected corporate commodity management in Huntsville, Singapore, and Irvine, Scotland.

Site: **Venture Manufacturing - Singapore**
5006 Ang Mo Kio Ave. 5 405-01/12, Tech Place II, Singapore 2056

Participants: Tan Choon Huat, General Manager

Mission and Strategy

- Venture Manufacturing was established in 1984 with venture capital. It was listed as a public company in 1992 and had revenues of $121 million in 1994, an increase of 83% over 1993.
- Some key customers include Hewlett-Packard, Apple, Sony, Compaq, Iomega, Adaptec, and Astvich. It builds complete products like bar code printers, portable printers, and global positioning satellite systems.
- Product/customer diversification is one of the key elements of Venture's strategy. Venture was one of the fastest growing electronic companies in the region with facilities in Singapore, Johore Bahru (Malaysia), Batam (Indonesia), and China.

Key Elements of Presentation

- The Singapore facility is an ISO 9002 facility located in an industrial park managed by Jurong Town Corporation, which is a government subsidized facility.
- Venture has 15 SMT lines in Singapore and 4 SMT lines in a new factory in Batam. Their lines use Fuji placement equipment with a DEK265 screener, two Fuji CP-4 chip placement machines, one Fuji IP-II module placement machine, and either a Heller 1500 or a BTU reflow oven. The lines are hard coupled and utilize NUTEK board handling equipment manufactured in Singapore. They operate at cycle time of 3 hours and achieve inventory turns of 4 for low-volume products, 30 for high-volume products.

Key Elements of Tour

- Venture provides PCBA and final product assembly services with turnkey (90% of business) and consignment (10% of business) for multiple customers at low costs. The goal is to provide cost-effective manufacturing approaches for customers while providing high-value services such as concurrent engineering, new product prototyping, and value engineering. It also provides concurrent engineering for customers to achieve the lowest possible manufacturing cost.
- Venture also provides customers prototyping support. Hosts quoted cycle times of 3-5 months from start of product to completed manufacturing release package, then 4 weeks to volume production. The company is considering establishing a prototype facility in the United States, potentially as a joint venture.
- At the time of the WTEC team's visit, 30% of Venture's labor force came from Malaysia and it was experiencing very low attrition. New operators undergo a 2-day generalized training followed by OJT for specialized operations. All employees participate in profit sharing on a quarterly basis.

Key Results

Venture is making 8 - 10% gross profit for this portfolio.

Conclusions

Venture works with GINTIC to obtain useful information in the area of shop floor scheduling, test improvements, design rules, BGA process and no-clean process. EDB has provided assistance in financing, capital and consultation.

Site: **Hewlett-Packard - Singapore (HP-Singapore)**
1150 Depot Rd., Singapore 0410

Participants: Lim Chuin Kiat, Printer R&D Manager
Frederick Cheong, IC Development Technology Manager (via phone)

Mission and Strategy

HP has R&D facilities around the globe. Singapore has R&D for inkjet technology, IC packaging, networking solutions, and PC products; inkjet R&D takes place in San Diego, Vancouver, Barcelona, and Singapore (Deskjet 340).

Key Elements of Presentation

- HP selected Singapore for competence in providing low-cost solutions, productivity, tax advantages.
- There are approximately 40 people located in Singapore working on lower-cost inkjet printer designs.

Key Elements of Tour

IC packaging R&D for Hewlett-Packard is split between Palo Alto (DCA and flip chip) and Singapore (enhanced BGA and fine pitch).

Key Results

The Singapore lab leverages technology from other divisions in Hewlett-Packard and cost-reduces the technology for use in its products.

Conclusions

This organization leverages IME capability, Hewlett-Packard capability, and the capability of the silicon package vendor to produce lower-cost and smaller IC packages.

Site: **Chartered Electronics Industries (CEI) - Singapore**
19 Tal Seng Drive, Singapore 535222

Participants: S. K. Gan, Assistant General Manager
Peter Loh Kum Pui, Manager, Product Marketing
T. Y. Heng, Head, Manufacturing Engineering

Mission and strategy

- Chartered Electronics Industries is a member of Singapore Technologies, which is a large government-sponsored holding group with strategic business areas (SBA) ranging from ordnance to semiconductors.
- Chartered Electronics was established in 1980 with government-sponsored venture capital to provide electronic manufacturing value-added services. It is part of the electronics SBA. Its strategy is to move into total box production and to provide higher-value-added services.
- The products it manufactures include telecommunications (10%), industrial (36%), PC products (34%) and office equipment (20%). Its customer base includes Compaq, Allied Telesystems, Packard Bell, Oce, Planer, IPC, Creative, Aztech, Philips, Fuji, and Xerox.

Key Elements of Presentation

- Chartered Electronics' core business is divided into 5 areas: (1) contract manufacturing; (2) turnkey, semi-turnkey, and consignment electronics manufacturing; (3) complete product manufacturing; (4) PCBA assembly for other members of Singapore Technologies; and (5) thick film hybrid assembly.
- Charter Electronics has 3 locations:

Location	Sq. Ft.	Employees	SMT
Singapore	50,000	438	5
Batam	33,000	200	2
China (Suzhou)		182	

- CEI provides complete product build for a portable language translator it is manufacturing. CEI representatives also quoted a cost redesign activity where they were able to redesign a product and move it to their Batam facility with lower labor rates and provide customers with a 20-30% cost reduction.
- CEI utilized its Batam facility to assembly PCBAs that have higher labor content.

Key Elements of Tour

CEI's manufacturing labor force is made up of Singaporeans, Malays, and Chinese. The turnover rate in Singapore is 10% per year but almost zero in Batam since the laborers in Batam sign a two-year contract.

Key Results

KME placement equipment is used in the SMT lines and CEI has a cycle time of 3 - 4 days.

Conclusions

CEI leverages GINTIC resources and government incentive programs to lower its cost of process development.

Site: **Texas Instruments - Singapore**
990 Bendemeer Rd., Singapore 1233

Participants: Goh Geok Ling, Managing Director
Goh Jing Sua, Manager, Advanced Package Development
Ignatius Yeo, Manager, Site QRA
Swee Yong Khim, Manager, Failure Analysis & Chemical Lab

Mission and Strategy

- TI has multiple facilities in Singapore, which include TECH Semiconductor (consortium with TI, EDB, Canon and Hewlett-Packard), TI distribution center, TI Software, process automation center (design and manufacturing of IC assembly and test equipment) and the Bendemeer IC assembly and test facility.
- The TI Singapore mission statement is, “Be the leading semiconductor company in Singapore and the preferred supplier of those customers and markets we target.”
- TI Singapore has a very obvious customer focus on quality and delivery. It had a 99.5% on-time delivery record for the first quarter of 1996. Understanding of the customers’ volumetric needs, quality needs, and reliability needs enables it to develop new IC packaging technology to support its customer base at a competitive total cost of ownership.

Key Elements of Presentation

TI on a global basis has located its facilities near its customers and has reduced its customer base and product focus. The TI Asian locations each have been assigned specific IC packaging missions:

Malaysia	Bi-polar logic
Philippines	ASICs
Taiwan	Linear products
Singapore	Memory

Key Elements of Tour

- The TI Singapore IC packaging facility is TI’s only large-scale DRAM packaging facility (it assembles and tests well in excess of 95% of its worldwide DRAM production, although there is a small facility in Japan that produces a small amount of specialized DRAMs for the Japanese market.) The facility was established in 1968 to package transistors/logic/bipolar products. The plant was in production 50 days after the signing of the contract with the Singapore government. It began producing DRAMs in 1974.
- It employs 2,200 people with 58% direct labor, 24% non-exempt, and 18% exempt. The workforce consists of Chinese (67%), Malay (21%), and others (12%). Their attrition is average for the area, and most of the employees who leave have been with the company for a short time. This is manifested by the fact that 41% of their employees have less than 5 years of service.

Key Results

- Initially the packaging technology was developed in the United States, then product-specific packaging was done in Singapore. Today all DRAM packing responsibility for TI resides in Singapore. NSTB gave a $1.27 million packaging award to TI Singapore.
- TI Singapore leverages three forces in the improvement of IC packaging technology. These are (1) continuous miniaturization, (2) density improvement driven by component integration, and (3) the development of IC packaging at the assembly site. IME failure analysis facilities are leveraged for quick turnaround on sample production. As a result of all this leverage, TI has not had a packaging related qualification failure since 1989.

Conclusions

- The TI Singapore IC packaging facility is very capital-intensive with $1.1 billion total assets and an annual investment of over $55 million. This facility has achieved a competitive edge in IC packaging costs, even with more expensive labor, due to its core skills that facilitate test time reduction, rapid time to yield, high yields, and a high degree of automation.
- TI Singapore has achieved a competitive edge in IC packaging cost even with more expensive Singapore labor. This competitive edge is due to a 1% - 2% yield benefit resulting from the core skill base that facilitates good yields, quick time to yield, lots of automated equipment, and reduction in process and test times.

Site: **ST Assembly Test Services (STATS) - Singapore**

Participants: J. C. Lee, General Manager

Mission and Strategy

- STATS was incorporated in January of 1995. The shareholders of STATS include Singapore Technologies, EDB, and Seiko-Epson in Japan. STATS has an approved capital plan of $317.75 million and it currently has $76.25 million of installed equipment.
- Other members of the semiconductor group are TriTech Microelectronics International (IC design), Chartered Semiconductor Manufacturing (wafer fab), and CiNERGi Technology & Devices (distribution).
- ST Assembly Test Services provides one-stop service to customers for assembly and testing of ICs.
- Customers include 20 electronic companies, many of which obtain fab services from Chartered Semiconductor. Seiko-Epson provides technology transfer and obtains packaging capacity and preferential pricing.
- STATS offers customers total cost reduction and reduced cycle time. It provides a 2.5-day turnaround on samples at no extra charge.

Key Elements of Presentation

- First assembly started in August 1995 and the first profitable month was December 1995
- STATS leased 60,000 square feet from Jurong Town Corporation in 1995. It also utilizes 30,000 square feet at Chartered Semiconductor for IC test. It will occupy a new 500,000 square foot facility, currently under construction, within the next year.
- STATS is considering establishing a prototype facility within the United States.

Key Elements of Tour

- The key management team for STATS includes many years of experience with TI, Fairchild, National, and AMD.
- It currently has 410 employees, growing to 600 by the end of 1996.

Key Results

- STATS’ new capital investment provides highly automated and faster equipment that provides better quality and shorter cycle times than existing competitors who have a “mixed bag” of equipment.
- The Singapore free port allows faster shipment to customers than competitors in Taiwan who require customs clearance.

Conclusions

STATS’ current IC packaging menu focuses on higher-value-added, larger-pin-count packages of QFP and PLCC devices. Its planned packages include the addition of BGA, TQFP, and TSOP devices.

APPENDIX D. MALAYSIA SITE REPORTS (APRIL 1996 VISITS)

Site: **NatSteel Technologies - Penang, Malaysia**
(see NatSteel Singapore site report for contact address)

Participants: Cliff Chu, Vice President - Operations
Victor Ng, General Manager
Ng Hock Ching, Marketing Director
S. C. Hoon, Marketing & Business Development Manager

Mission and Strategy

- NatSteel Penang is a wholly owned subsidiary of NatSteel Electronics and has been operating since 1992 in the Penang area.
- NatSteel plans to expand its value-added services offered in Singapore to include PCB layout and wiring.
- NatSteel Penang participates on a corporate technology council.

Key Elements of Presentation

- NatSteel Penang moved to a new 160,000 ft^2 two-story building in 1994 located on 9 acres of land. This includes 110,000 square feet of manufacturing space and 31,000 square feet of high bay storage.
- NatSteel Penang uses Panasert SMT equipment and had been adding one line per month at the time of the WTEC visit. It has 16 SMT lines doing 8 million placements per day and has 90% equipment utilization.
- 3 rotating shifts are run per day, 20 shifts per week; 11 inventory turns with 4.6 asset turns are achieved.

Key Elements of Tour

- When this facility was ISO-certified in March of 1995, it had spent 6 months modifying the basic procedures from Singapore to meet specific local Malaysian requirements. It also expended 8,000 hours of training deployment to prepare for this certification.
- Process yields are design-dependent but average 98% at ICT and 99% at functional.

Key Results

- Customer returns (production line plus field) are 2,000 ppm with 1,000 ppm for ASICs, 600 ppm for no fault found, 200 ppm for SMT related, and 200 ppm for ECO/test.
- Penang has failure analysis capability to the component level and utilizes Malaysian government facilities for component/IC failure analysis.

Conclusions

New SMT processes are developed in Singapore and migrated to Penang, but Penang does product startup for all products that are slated for volume production in Penang.

Site: **Solectron Technology Sdn. Bhd. - Penang, Malaysia**
Plot 13, Phase IV, Pral Industrial Estate, 19600 Pral, Penang, Malaysia

Participants: Kong Siew Mui, General Manager
James C. K. Chuen, Director, Business Development
Riwayat B. Mansor, Director, Quality and Engineering
Mohana Krishnan, Business Unit Director
Sundra Raj, Senior Engineering Manager

Mission and Strategy

- Solectron is a U.S. company established in 1977. It is the world's third-largest contract manufacturer.
- Solectron has 8 facilities across three continents employing approximately 13,000 employees. It achieved over $2 billion in revenue in 1995.
- Solectron is a key supplier to major global customers such as IBM, Sun Microsystems, Apple, Hewlett-Packard, SCI, Philips, Maxtor, and Toshiba.
- Solectron Penang was established in 1991 as a foreign subsidiary. Solectron has a corporate culture to share the best production methods among lines at each site and between sites. The Penang facility has 22 engineers devoted to process development and introduction of new products.

Key Elements of Presentation

- It has a total of 28 Fuji lines, 6 flex circuit lines, and one chip on flex line in a class 10K cleanroom that place a total of 275 million components per month.
- Solectron provides concurrent engineering and design services including electronic information interchange direct with its customers through the Internet.
- Solectron Penang has 5 different business units, including one dedicated for Intel that consists of 12 SMT lines (segments). At the current time, only 8 lines are being used. Its SMT lines are all identical hard-coupled lines with a Fuji GSP-III screener, one Fuji CP-6 chip placer, one Fuji CP-4 chip placer, a Fuji IP-II module placer, and a BTU oven with nitrogen reflow.
- Solectron has 199,000 ft^2 and 2,700 employees. It hires local labor with 9th-11th grade education. It provides new workers with 1 month of training, 2 weeks in classroom and 2 weeks under direct OJT supervision. It runs 17 8-hr shifts per week (the same as 3 shifts for 5½ days per week). Shifts rotate weekly. Solectron can work its labor force up to 4 hours overtime per day, so it has significant labor force flexibility. It is experiencing 2% attrition/mo. for operators. It provides good benefits and quarterly profit sharing.
- Solectron Penang participates in a corporate technology council that manages the introduction of advanced process technology.

Key Elements of Tour

- The company was ISO 9002 qualified in 1993.
- The facility is 100% Malaysian managed.
- It is experiencing from 12 to 35 inventory turns, depending upon the product.

Key Results

- Penang was selected as the site to proliferate Solectron manufacturing technology to future Asian sites.
- It has already established a program office in Japan that provides access to Japanese technology roadmaps. Investigation has begun for possible expansion into China.
- Solectron Milpitas has historically been the site to provide advanced technology development to other Solectron sites for implementation and deployment. Solectron Penang has begun to share in the development of advanced process technology, especially for chip on glass and chip on flex. The Milpitas facility is used for cross-sectioning and process failure analysis at a corporate level.

Conclusions

Solectron Penang is establishing a manufacturing facility for active matrix TFT color LCD. It is importing this technology with the assistance of its customers. Some of the specific equipment has been jointly designed by Solectron and its customers. Processes required to support this technology include:

- Precision taping and heating of anisotropic contact film
- TAB-IC punching from reel
- Hot-bar / gang soldering of TAB onto PCB
- Solectron Penang has developed a unique program to encourage sharing of creative ideas. The program is called the C.A.T. program and encourages copying of ideas across the entire facility.

Site: **Intel Technology Sdn. Bhd. - Penang, Malaysia**
Bayan Lepas Free Industrial Zone, 11900 Penang, Malaysia

Participants: David B. Marsing, Vice President/Managing Director
Theoh Swee Thye, General Manager

Mission and Strategy

- Intel Penang was established in 1972 as the first Intel offshore assembly plant focusing on low-cost, labor-intensive, low-technical content products.
- Intel Penang's portfolio includes the 80486DX4, 80486DX2, Pentium and Pentium Pro microprocessors; 8-bit, 16 bit and 32 bit microcontrolers; Pentium core logic chipsets; and communication devices.
- Capital investment has grown from $4 million in 1972 to the current level of $800 million. This capital investment combined with a trained work force have been the key to its growth in this region.

Key Elements of Presentation

- Intel-Penang has migrated over time to become a highly automated, capital-intensive IC assembly and test facility with its own packaging R&D activity. This growth was accomplished by adding test activities in 1978 followed by the addition of a customer warehouse and process and product capability in the early 1980s. By 1990, it had assumed the customer interface responsibility and R&D responsibility for microprocessor product packaging, process and silicon design capability supported by computer aided manufacturing (CAM).
- The facility in Penang occupies 60 acres and has 3,700 employees.

Key Elements of Tour

- This facility experiences approximately 1% monthly attrition of its employees, down from a previous high of 38%. This improved retention is credited to programs such as a corporate profit sharing program, employee stock purchase plan, after work recreation programs, recognition of Malaysian cultural diversity, and the establishment of the first company-sponsored kindergarten in Malaysia.
- It supports multiple package types ranging from large-pin-count ceramic PGAs to QFPs, PLCCs, and PDIPs. Profit and loss responsibility for the 8 bit family of microcontrollers is now owned by Intel Penang.

Key Results

- Intel Penang has been the most productive facility inside Intel. This is attributed to its 20-year investment in knowledge and several cultural differences such as better work ethics among its employees and the desire to learn more and understand more. Intel has also imbedded TQM into its work ethics. The facility is highly automated and many of the pieces of equipment have been locally designed. Test development is the responsibility of Intel Penang.
- It now has the packaging R&D responsibility for all Intel microprocessors except the TCP package, which is the responsibility of the Intel facility in Chandler, Arizona. It has the silicon design responsibility for microcontrolers and the product engineering responsibility for all of its products. This total R&D activity is supported by 120 designers and engineers in Penang.
- Its product engineering team has been responsible for many of the Intel microprocessor speed enhancements by identifying speed critical circuits and paths and submitting recommendations to the microprocessor design teams in the United States.

Conclusions

The packaging R&D has been transferred over time from the United States to Intel Penang.

Site: **Motorola Microcontroler Technology Group - Kuala Lumpur, Malaysia**
#2, Jalan SS 8/2, Sungei Way Free Trade Zone, 47300 Petaling Jaya, Selangor Darul Ehsan
P.O. Box 1001, Jalan Semangat, 46960 Petaling Jaya, Malaysia

Participants: Roger Bertelson, Vice President, Managing Director, Country Manager
A. Lew, Assistant General Manager
C. Liew, CIM Manager, Factory Automation
H. Yang, Manager, Reliability & Quality Assurance
Latifah M. Daud, Organization Development Manager

Mission and Strategy

The Kuala Lumpur facility is the largest Motorola IC packaging facility in the world and employs 5,000 people. The Motorola R&D model is to co-locate the IC packaging development with the design center, thus Austin develops the microprocessor and DRAM packaging. Kuala Lumpur is responsible for volume production, which includes product engineering responsible for process qualification, yield management, and product qualification. New product prototyping is performed at the U.S. facilities. Kuala Lumpur builds QFP, DIPs, SOJs, TSOPS, and ceramic packages. It is working on implementing BGA but has no plans for flip chip technology in Kuala Lumpur.

Key Elements of Presentation

4 Motorola facilities in Malaysia employ a total of 13,000 employees:

- Penang — Design center for walkie-talkies
- Serban — Assembly/test of discrete devices, wafer fab for FET and Bipolar
- Philips JV — Assembly/test of discrete devices
- Kuala Lumpur — Assembly/test of DRAMS, SRAMS, microprocessors, and analog devices.

Motorola has had a facility in Kuala Lumpur for 23 years and has manufactured there for the last 22 years.

Key Elements of Tour

- The Kuala Lumpur facility is very automated and has become a capital-intensive factory. It is investing in CIM and has developed a strategy and roadmap that its managers believe will make them the leader in Motorola within 5 years.
- There is an extensive in-house training program for all employees, with 40 hours per employee per year
- Cycle time is 2 days for assembly, and test depends upon the device (8 hours to 4 days).

Key Results

Kuala Lumpur is the leader within Motorola for reliability and quality while maintaining competitive yields for more complex package types.

Conclusions

The Kuala Lumpur factory shows visible signs of the Motorola 6 sigma and 10X quality activities.

Site: **LIKOM PCB Sdn. Bhd. - Malacca, Malaysia**
Kawasan Perindustrian Cheng, Fasa III, Mukim Cheng, Daerah Melaka Tengah
75250 Melaka, Malaysia

Participants: Francis Khoo T. C., Assistant General Manager
William Loo, International Marketing Executive
Frankie Ng, International Marketing Executive
Choy Kok Leong, Project Manager

Mission and Strategy

- LIKOM is part of Lion Land, which is a member of the Lion Corporation, an investment and services group with over $2.5 billion capitalization. The Lion Corporation has a wide variety of companies, including steel manufacturing, assembly and marketing of automobiles, life insurance, container manufacturing, property construction, chocolate manufacturing, and trading.
- LIKOM, established in 1992, calls itself "the biggest OEM technopolis in Asia." Its current capitalization is over $100 million and supports a vertically integrated facility with the following capabilities:
  - design and manufacturing of color monitors
  - design and manufacturing of switching power supplies, keyboards, casings, and precision plastics
  - design and manufacturing of motherboards, PCB assemblies, multimedia and PC system unit assemblies
  - tooling design for plastic injection molding
  - metal stamping and complete spray painting process for computer casings
  - double and multilayer PCB fabrication
- The first customer of LIKOM in 1992 was Apple Computer. Today 75% - 80% of LIKOM's customer base consists of Japanese companies.

Key Elements of Presentation

- LIKOM occupies 1.1 million square feet on 92 acres located in Malacca Technology Park. The Malacca location offers abundant industrial land, close proximity to air and sea ports, licensed manufacturing warehouse (duty free trade zone), and favorable support from government and local authorities.
- Malaysia offers duty advantages under GSP for the United States and Europe, dependent upon the amount of local content, and there are several major component and subsystem manufacturers located close within Malaysia: Intel, TI, National Semiconductor, TEAC, Mitsumi, Seagate, Conner, and Astec.

Key Elements of Tour

- LIKOM provides hostels, meals and transportation for its local employees. It also has 1,500 work permits approved for foreign workers who are provided housing, meals and transportation.
- Lion Tech and Shamrock Technology in Taiwan design keyboards and monitors, respectively.
- LIKOM PCB is a technology transfer agreement with Mommers Print Service of Holland.
- Lion Plastic Industries receives technical assistance and continuous upgrading from Ishihara Plastic and Sannoh Ginken from Japan.

Key Results

The motherboard design is from Lion Computer Technology (USA), multimedia products and CD ROM designs are from Lion Optics Corporation (USA), and power supply designs are from 3Y Power Technologies (USA).

Conclusions

LIKOM's facility is highly automated. Many of the manufacturing technologies contained in LIKOM were technology transfers from other companies.

Site: **Electronic Research & Service Organization (ERSO)**
Industrial Technology Research Institute (ITRI)
R200, 195-4, Sec. 4, Chung Hsing Rd., Chutung, Hsinchu, Taiwan 310
Tel: 886-35-917007; Fax: 886-35-918022; e-mail: scl@erso.itri.org.tw

Participants: Sebastian Shyi-Ching Liau, Design Development Manager, Electronic Packaging Tech. Div.
Fei-Jain Wu, Sr. Asst. to General Director, Electronic Packaging Technology Div.
Dr. Min-Shyong Lin, Executive Vice President, ITRI
Dr. Wenbin Hsu, Deputy General Director, ITRI
Li-Chung Lee, Vice President & MRL General Director, ITRI
Choung-Lin Lo, Consultant, MRL, ITRI

Mission and strategy
- ITRI is a nonprofit, government-sponsored organization chartered to promote the development of high-tech. industries, to improve domestic product design and processing technologies, to provide technical services to industry, and to assist in the development of defense technologies and industry.
- ITRI is the sole source of R&D for small firms in Taiwan.
- ITRI is concentrating on developing key components that are imported and cause a trade deficit.
- ITRI moves products from the laboratory to pilot production, and into private industry.
- ERSO was established in 1974 to develop and diffuse electronic technologies. It focuses on semiconductor IC devices, display devices, microwave components, and electronic packaging. ERSO also provides technical services to industry.
- ERSO developed low-cost MCM-D substrate packaging, flip-chip bonding, thin-film resistor array, ceramic ball grid array, and plastic ball grid array capabilities.

Key elements of presentation
- ITRI's budget of NT$7 billion comes from government (55% from MOEA and 25% from defense) and industry (20%). ITRI has seven laboratories and three centers. The range of technologies is quite broad, with about half of ITRI's efforts going to support electronics technologies.
- ITRI has about 5,700 young and energetic engineers, over 200 from IBM and ATT.
- ITRI played a key role in creating the semiconductor industry in Taiwan. ITRI research accounts for about 1% of the revenues that have been generated from ITRI semiconductor spin-offs. In 1995, there were 26 companies involved in IC design with total revenues of $593 million, 12 firms producing IC with total revenues of $4 billion, 21 companies that package ICs with revenues valued at $2.6 billion, 200 firms producing PCBs valued at $1.7 billion, and 23 firms that assemble motherboards valued at $2 billion. There are four 8-inch fabs in operation in Taiwan, 10 under construction, and 6 in the planning phase. In 1995, domestic suppliers provided 19.1% of Taiwan's IC requirements. This is projected to reach 37.8% by the year 2000.
- ERSO established consortiums for PC computers in 1983 and 1984, submicron process development in 1991 and 1992, and LCD development in 1993.

Key elements of tour
- IC research focuses on deep sub-micron lithography, etching, device, and thin film development, high-frequency process integration, and design of mixed signal IC, RF ICs, and CCDs.
- Packaging research focuses on passive device thin film processing, flip chip bonding, tape automated bonding, chip on glass, MCM designs, substrate processing, and module packaging.
- Flat panel display research focuses on thin film LCD device and circuit processing, color filters, module integration, and optical systems.
- ITRI's strength is transferring technology into the commercial world.

Taiwan technology levels
IC process capabilities include:
- Process capabilities in CMOS are 0.5 mm in mass production and 0.35 mm in R&D (U.S./Japan mass-produce at the 0.35 mm level and have 0.25 mm in R&D).
- 16 MB DRAM are in mass production and 64 MB in R&D (Japan/Korea mass-produce 64 MB and are introducing 256 MB, and have published a paper on 1 GB).

- 4 MB Flash memory is mass-produced and 16 MB in pilot production (In U.S./Japan, 16 MB is mass-produced, 32 MB in production, and 256 MB in R&D).
- Gate arrays up to 60K are produced in Taiwan (Japan/U.S. produce 100K, and have 1,600K prototypes).
- 8-in. silicon is in production (Japan/Germany/U.S. have 12-inch in R&D).
- In SRAMs, Taiwan is the low-cost producer (SRAM cost in Taiwan = 1, Korea = 1.14, Japan = 1.43, and the U.S. = 1.6).

Packaging capabilities include:

- PGA with 172 pins in mass production (U.S./Japan mass-produce over 300 pins).
- QFP is mass produced with lead pitch of 0.4-0.5 mm (Japan mass-produces 0.25-0.4 mm pitch).
- TSOP in mass production with thickness 1.0 mm (U.S./Japan mass-produce 1.0 mm, have 0.5 mm in R&D).
- BGA with 50 mil ball pitch is mass produced and 40 mil is in R&D (U.S. mass-produces 50 mil and has 40 mil in R&D).
- TAB-OLB is mass produced with 9.8 mil pitch (Japan mass-produces 9.8 mil and has 8 mil in R&D).
- MCM is in pilot production (U.S. is producing packages).

Developments are targeted at substrate and fine pitch/small via technology. Taiwan's technical capabilities include:

- Line width/spaces of 4 mil/4 mil are in mass production (U.S./Japan have 2 mil/2 mil in R&D).
- Drilling diameters of 13.5 mil are in mass production (U.S./Japan mass-produce 13.5 mil and have 6 mil in R&D).
- Blind vias of 10 mil are in mass production (U.S./Japan mass-produce 10 mil and have 4 mil in R&D).
- Layer thicknesses of 24 mil are in mass production (U.S./Japan produce 24 mil and have 12 mil in R&D).
- Pitches of 0.4 mm are in mass production (U.S./Japan produce 0.4 mm and have 0.25 mm in R&D).
- Aspect ratios of 5 are in mass production (U.S./Japan mass-produce 5 and have 8 in R&D).

Conclusions

- Taiwan has been successful in moving into critical component areas. For example, in 1995, Taiwan companies held 72% of the worldwide market in the computer mouse, 65% in motherboards and keyboards, 64% in scanners, 57% in monitors, 38% in network cards, 35% in power supplies, 32% in graphic cards, 27% in portable PCs, and 11% in CD-ROMs.
- 6 of the world's top 100 PCB manufacturers are in Taiwan.

Site: **Inventec Corporation**
Inventec Building, 66 Hou-Kang St., Shih-Lin District, Taipei, Taiwan
Tel: 886-2-881-0721; Fax: 886-2-881-1288

Participants: Chen-Pang Lin, Vice President, Manufacturing Division
H. K. Chang, Senior Manger, Automation Engineering Department
Chime Chang, Senior Manager, Surface Mounting Department

Mission and strategy

- Inventec produces notebook computers, phones, personal digital assistants, calculators, electronic dictionaries, and facsimile machines.
- Inventec is a 100% ODM manufacturer with exception of electronic Chinese language dictionaries sold under its own BESTA brand name. Inventec has 60% market share in Taiwan for electronic dictionaries.
- Notebook production is 50,000 per month with planned 100,000 per month in 1997. It claims to have the largest notebook revenues in Taiwan (Acer has more unit volume). Principal customer was Compaq's LTE 5000 series notebook, designed and manufactured by Inventec.

Key elements of presentation

- Established 20 years ago as board level contract manufacturer. Inventec now combines contract design and manufacturing capability for computer and communication products.
- Revenues for Inventec Taiwan were NT$14 billion with 5,000 employees. Inventec group revenues were NT$20 billion. Projection for 1996 is NT$35 billion.
- Inventec has three factories in Taiwan: WooKu for PDAs and TI's graphic card, Linko for computer docking stations, and Taipei for notebook computers. A joint venture with Toshiba in Malaysia produces fax machines. In 1991, a factory was build in Shanghai, China (1,300 employees including 500 software programmers).

Key elements of tour

- The Taipei factory has 6 SMT long lines with MPM screen printers, Camelot 3800 glue dispensers, Panasonic MV2C, MV2F, MSH2, and MPA chip placement machines, one Universal GSM system for through-hole insertion.
- Furukawa, EXCEL ER-1000, and Electrovert nitrogen reflow ovens have improved quality 60%.
- Inventec is the only Taiwanese firm (with three machines) using selective solder lines for through-hole components.
- Inventec has produced TCP for three years in making Apple Newton PDA boards. It uses two Universal hot bar bonders for TCP.
- In 1996, PBGA with 420 I/Os and 320 I/Os are planned for assembly.
- SMT defect goal of 20 ppm (98%) yield has been reached. Component defect rate for TAB is 500 ppm.
- SMT operates 24 hours with two days on, then two days off. The shifts run from 7:20 to 7:40 giving 40 minutes of overlap per day.

Core competencies

- Design for ODM includes minimum through-hole components for maximum automation.
- Desire to eliminate ICT testing as quality levels increase. Focus on reliability testing.
- Dedicated Panasonic equipment and component customer for SMT. Produces 208 lead QFP on SMT line.
- Selective solder system for through-hole components.

Conclusions

- Well-planned and clean SMT and assembly operations.
- Notebook for Compaq is high-end product.

Site: **GVC Corporation**
14/F, No. 76, Sec. 2, Tun Hwa S. Rd., Taipei, Taiwan
Tel: 886-2-755-2226; Fax: 886-2-755-2513; e-mail: T.G.wang@mailx.gvc.com.tw

Participants: T. G. Wang, Vice President
Nelson Wang, Senior Vice President, Computer Business Area
Philip Liu, Manager, Sales and Marketing Department, Computer Business Unit

Mission and strategy

- GVC is dedicated to the integration of computers and communications.
- Primary products include modems (25% world market share), monitors, PCs and notebook computers.
- GVC is committed to becoming its customer's most reliable partner. The company's motto is "The customer's wish is our command." and "Make the impossible, possible."
- Strategy is based on speed of response, quality, cost and service, and "ready to go" products (ODM).
- GVC bases its corporate culture on the 5 "Es": electronics, evolution, education, enjoyment & eternity.

Key elements of presentation

- Revenues were $770 million in 1995; up from $110 in 1992; and estimated at $1.2 billion for 1996.
- 95% of GVC's sales are contract manufacturing for top ten (tier 1) brands like IBM, Compaq, Acer, AST and Packard Bell.
- Shorter product life cycles have led to increased ODM sales (60%) of "ready-to-go" products. The remaining 40% of contract sales are OEM.
- GVC sells bare bones motherboards and ODM motherboards. Advanced technology development is done in the United States, low-cost manufacturing of motherboards (two-thirds of GVC output) in China and, beginning in 1996, the Philippines using Fuji and U.S. equipment (a total of five factories). Expansion is expected in Ireland and the United States.

Key elements of tour

- GVC has 18 assembly lines with 8 at the factory visited. Fuji lines and software make setup of lines easy. Assembly is conducted in a class 10,000 cleanroom.
- GVC uses long lines for SMT: 2 high-speed chip shooters with one flexible chip placement machine to obtain 1.5 times capacity of short lines. Line includes MPM stencil printer, Fuji CPVI chip shooters, IP 3 placement machines, and Furukawa reflow (IR-nitrogen system) ovens.
- 100% ICT on Genrad test yields 97% on 5-month-old board. Typical board life is six months. Quotes take three months. Line optimization takes one month to 98% yields.
- Wave soldering uses active flux followed by DI water rinse for board cleaning.
- Boards get 100% 8-hour static test at 55°C, the 1% gets 72-hour reliability stress test ESS -5°C to 40°C at end.
- Through-hole components were being manually inserted. Board assembly done on moving conveyor system.
- Production was 150,000 per month of 10 desktop models at the time of the WTEC visit.
- 25% of factory workers are Filipinos who can stay only two years.

Core competencies

- GVC produces BGA and TCP components in notebook assembly.
- GVC has strong relationships with Japanese component suppliers.
- Product design is key strength for ODM, and low-cost, high-volume manufacturing with flexible Fuji production systems is key to meeting customer needs.

Conclusions

- GVC enjoys a growing strength with large global customers by providing ODM products.
- GVC's management attitude is you can't compete if you work less than 12 hours per day. Fast response and meeting customer deadlines will keep customers loyal.

Site: **Orient Semiconductor Electronics, Ltd. (OSE)**
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W.L. Shieh, R&D Department Manager, Semiconductor Group
C.M. Wu, Director of Operations, Semiconductor Group
C.Y. Lin, Assistant Vice President, Finished Products Group
Allen K. Lin, Account Manager, Desktop Computer Group, Finished Products Group
N.C. Chiang, Director Customer Service Division, Finished Products Group
Wayne W.F. Fu, Group Leader, Notebook Computer Group, Finished Products Group

Mission and strategy

- OSE produces IC packages and PCB assemblies and finished products (FP) for OEM customers. The strategy is to become the manufacturing arm for customers.
- OSE Semiconductors specializes in plastic and hermetic IC packaging and testing. OSE designs the printed circuit layout of substrates for BGA assembly. New products include thin packages, P-BGA, and MCM-L packages.
- OSE finished products are 100% OEM for PCB assemblies and finished products for desktop computers (40%), notebook computers (5%), PCMCIA/TCP cards (20%), network cards (15%), and industrial controls (5%). Motherboards, network cards, and PCMCIA cards account for 80% of sales.
- As desktop motherboards move to China and India, OSE is focusing on BGA, TCP, and SMT technologies for PCMCIA cards and notebook motherboards.

Key elements of presentation

- OSE has 25 years of IC and assembly experience. 1995 revenues were over $230 million.
- OSE employs about 2,332 people, 729 in finished products, 1,528 in semiconductor group, and 75 in finance, administration, and EDP.
- Of sales, Taiwan represents 40%, Europe represents 15%, and the U.S. 45%.
- 10 customers account for 85% of IC sales; 3 customers account for 80% of FP sales.
- IC packaging production includes PDIP from 8 pin to 42 pin, PLCC from 20 to 84 pin count, SOJ-28 pin for SRAM and DRAM, SOP from 150 mil to 500 mil, and 150 mil (.3mm) SSOP design. TSSOP and TSOP with 1.0 mm body thickness began mass-production in 1995. They are used for PCMCIA cards and notebooks. QFP have pin counts from 44 to 256; LQFP have a 1.4 mm body thickness with pin counts from 48-176.
- Leased lines (128K) to the United States allow for rapid communication and e-mail.
- OSE has had ISO 9002 certification for both semiconductor and finished product assembly since 1993.

Key elements of tour

- 310 wire bonders get a 99.8 or 99.9% yield, with 70% expansion to 560 wire bonders in a class 10 cleanroom in 1996. One operator handles 12 bonders. A second operator focuses on quality. There is automatic detection of failures, and a no-rework policy.
- Packaging of BGA with 328 I/O in pilot phase with 1,800,000 per month capacity in 1996. Prototype MCM-L with four chips and 500 I/O under development.
- 100,000 desktop motherboards are produced per month. Long SMT lines include two Fuji high-speed chip shooters (CP-6 has 0.09 seconds placement) of 0603 components. Dual head Fuji machine places two QFPs at one time, or 320 pin count BGA devices.
- TCP notebook daughter cards with Pentium CPU are produced with Intel technology.

Core competencies

- 35 million completed chips are produced per month with 25% having high pin counts (over 100 pins) using 145 different types of lead frames.
- OSE develops its own loading and off-loading equipment and related tools and jigs.
- IC packaging and assembly technologies include BGA, TCP, and MCM developments.
- OSE keeps excess capacity and flexibility to meet customer's demands.

Conclusions

- OSE has semiconductor design capability for new packages, lead frames, heat dissipation, and BGA/MCM substrates; and tooling and equipment design capabilities for loading-unloading, mold-dejunk-trim and form-singulation of die sets, UV and laser marking, and in-line integration of marker and form-singulation equipment.
- Combined IC packaging and PCB assembly with equipment capability has synergy.

Site: **Nan Ya Plastics Corporation, PCB Division**
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Mission and strategy

- Nan Ya is a division of Formosa Plastics, a $10 billion conglomerate. Nan Ya's PCB factory opened in Taiwan in 1985 with HP technology. It now has $100 million invested in PCB manufacturing facilities.
- Nan Ya is an OEM PCB shop and does not design boards for customers.
- Nan Ya's goals are to provide customers with high-quality, highly reliable printed circuit boards, at the lowest possible assembled cost, and to grow with its customers.
- As a manufacturing leader, the Formosa group tries to be lowest-cost producer through large-scale production, automation, quality control, product design, power generation, and internal manufacturing of equipment.
- Computer and telecom boards account for 77% and 18% of PCB sales, respectively.
- The company's quality, cost, and timely delivery are key to its success.
- Laminates and resins are provided by group companies.

Key elements of presentation

- Sales include the U.S.A. (42.9%), S.E. Asia (23.7%), Europe (20.6%), Canada (4.1%), Taiwan (3.4%) and others, including Japan (5.3%). In 1995, 77% of PCBs were used in PCs and peripherals, 18.1% in telecommunications, 3.5% in automobiles, and 1.4% in medical products. PC-related sales have fallen to about 62%, while automobile-related sales increased to 12% in the first quarter of 1996.
- Major customers include Apple, Delco, HP, IBM, Intel, Motorola, Nokia and Nortel.
- Two plants produced 640,000 ft^2 per month in 1995 of FR-4 and tetra PC boards with $240 million in 1995 sales. Plant 3 will have a capacity of 750,000 ft^2. 1995 capacity was 8.0 million ft^2, increasing to 18 million by 2000.
- 1,400 people are employed, increasing to 2,000 with completion of the third factory.
- 4- & 6-layer boards comprise 80% of current production. 8-layer boards are mass produced and 14-layer boards are in sample production.

Key elements of tour

- Nan Ya imposes rigid standards on the management of the manufacturing process. The shop floor CIM tracks product and quality through the manufacturing process.
- In February of 1993, the Nan Ya PCB division received ISO 9002 certification.
- PCB process capabilities include 4 mil line, 5 mil space, and 10 mil pitch SMD. Smallest finished hole size is 8 mil. Blind and buried via technology will be introduced in 1996.
- Surface finishes include electroless Ni/Au, Entec, hot air soldering leveling (hasl). Super solder precoating will begin 2Q96 for TCP requirements.
- 44 automatic drilling machines are automatically loaded and unloaded. About 145 boards are processed at once using a universal fixture to handle any sized panel. Nan Ya currently drills about 11 mil holes, but can handle 8 mil holes.
- High-layer, high-density boards have 100% automatic optical inspection against model.

Core competencies

- The third plant will be most advanced. Current production is up to 14 layers.
- Net yield at final inspection is 93% with goals to improve to 95% in 1996.
- CIM controls and automation capabilities are very strong with vertical integration.
- The management model is TQRDC plus 5M and 5S for total customer satisfaction.

Conclusions

- Impressive facility with high levels of automation and quality control.
- One of the top PCB companies in Taiwan.

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Mission and Strategy

- Tatung Company produces a wide range of products, including color TVs, home appliances, and a full range of power generators, transformers, and substations. The VCR plant produces magnetic drums with precision equipment. The audio plant produces a complete line of stereo equipment. Tatung is the largest producer of refrigerators in Taiwan. Its refrigerators are available in all sizes, serve all industries, and are sold around the world. The company builds telecommunications products, including multifunction facsimile machines. The company also supplies compressors to other manufacturers. Tatung's electronic and multifunction rice cookers are famous throughout the world. Tatung also produces washers, dryers, and new supersonic dish washers. The company produces window air conditioners and dehumidifiers. It also provides a full range of office furniture.
- Tatung produces much of the materials, components, and equipment used to manufacture its products, including silicon rods and wafers for semiconductors. The company also does its own circuit design and fine printing. The chemical materials center produces copper clad laminates and insulating varnish. A magnet plant produces high quality magnets as part of the company's vertical manufacturing strategy. The optical storage center produces CD-ROMs. The company is a leading producer of wires, optical fiber, and power cables. Components also include electronic type modulators, magnetic heads, computer keyboard switches, and volume controls.
- The Tatung Institute of Technology has a full range of engineering programs, including mechanical, electrical, chemical, and materials engineering departments that provide undergraduate and master's degrees. Mechanical, electrical, and chemical engineering programs are PhD granting departments. Other programs include business administration and information sciences.
- The company is decentralized into 25 units and 80 profit centers around the world. Total sales were over $4.5 billion in 1995. It has subsidiaries in Thailand to make monitors, in Malaysia to make CRTs, in Indonesia to make motors, in China to make monochrome monitors, in the UK to make monitors and TVs, and three other subsidiaries. It has one of the largest color and monochrome monitor plants in the world.

Key Elements of Presentation

- The Computer Division makes computers, including notebooks, desktops, and advanced workstations. Sales were about $400 million in 1995. About 20% is Tatung brand, of which 35% are notebooks. OEM and ODM are both about 40% of the business, including monitors, PCs, and soundcards. The computer plant includes about 1,150 people. There are about 200 in R&D. It has 270 Philippine workers. There are four production lines: SMT, notebook, moniputer (monitor plus computer in a single box), and desktop. SMT runs three shifts per day, seven days per week. The moniputer line is two shifts per day.
- The Computer Plant produces about 50,000 motherboards per month. The plant has 5 SMT lines using Panasonic equipment and 6 manual insertion lines. SMT lines have two high speed mounters. The follow-on line is for through-hole insertion. About 10% of the components are done by hand insertion. Moniputers use auto insertion equipment. Final assembly lines include 3 PC lines and 4 moniputer lines that produce about 100,000 units per month, one workstation line that produces about 1,000 units per month, and 2 notebook lines that produce 20,000 units per month. The plant obtained ISO 9001 certification in December 1992.

Key Elements of Tour

- Tatung began assembling BGA in 1995 by producing the PowerPC with IBM and Motorola. SMT will be upgraded in the future to include TAB and flip chip. One OEM's notebook uses 352-pin BGA chip sets. Double-sided, four-layer boards were put into production in 1991. Ceramic BGA chips were introduced in 1992.
- SMT operations are enclosed in a cleanroom environment. Visitors walk around the operation rather than entering it. The dual SMT lines begin with solder paste and then go to two high speed Panasonic chip shooters that place 0.4 mm pitch parts on notebook boards. Water soluble flux is used with DI

water cleaning. After completing the process for one side, the boards are sent to the second line for the reverse side assembly. If the second line is not available, they can reset the first line and run it through.

- There is 100% in circuit testing. Tatung uses GenRad's 2284 model and does internal software development for tests. After through-hole components are placed, the board is preheated before soldering. Some components can't pass through the wave solder and are placed at the end of the line. After SMT processing, the first pass yield is 95-98%.
- Tatung utilizes Japanese TQM and TPM methods for quality improvement and machine maintenance. Final assembly has each station worker sign off on the task completed as the notebook moves down the line. The LCD is sourced from Toshiba and Hitachi, although a local subsidiary is developing an LCD. One shift produces 600 notebooks per day. Each notebook goes through vibration testing and then burn-in. Dynamic testing for two to three hours is then completed during burn-in using infrared controls. The functional tests are carried out with testing software developed by Tatung. It can take 8 to 10 minutes to complete all the tests. There is 100% QA test at the end of the line to follow a checklist. There are then customized QA tests.

Conclusions

- Motherboards take about 4 to 5 days from order to delivery. It takes 20 days from order to delivery for notebook systems. The actual production time depends on the testing procedures required, and that depends on the configuration and customer requirements.
- Rapid price declines in components are making it difficult to manage profitability. Unlike desktops, notebooks install the CPU and DRAM. In the first quarter of 1996, the DRAM prices dropped quickly. The same happened with LCD prices. Production and inventory scheduling is critical to reduce risks from price decreases.

APPENDIX F. GLOSSARY

ACF	Anisotropic conductive film
ASIC	Application specific integrated circuit
ASM	ASM International (materials-related professional society formerly known as the American Society for Metals)
BGA	Ball grid array
CAM	Computer-assisted manufacturing
CCDs	Charge-coupled devices
CD	Compact disk
CD-ROM	Compact disk-read-only memory
CEM-based materials	A grade of motherboard material
CIM	Computer-integrated manufacturing
CM	Contract manufacturer
CMM	Ceramic multicomponent modules
CMOS	Complementary metal oxide semiconductor
CNC	Computer numerical control
COB	Chip on board
COG	Chip on glass
CPU	Central processing unit
CRT	Cathode ray tube
CSP	Chip-scale packaging
DIP	Dual in-line package
DRAM	Dynamic random access memory
DSP	Digital signal processing
DSS	Direct satellite systems
EMC	Electromagnetic compatibility
ERSO	Electronics Research and Services Organization (Taiwan)
Fab	Semiconductor (wafer) fabrication facility
FED	Field emission display
FR	Flame-retardant
FTZ	Free trade zone
GDP	Gross domestic product
GNP	Gross national product
HDD	High-definition displays
HDTV	High-definition television
HKPC	Hong Kong Productivity Council
I/O	Input/output
IC	Integrated circuit
IDE	Integrated drive electronics (hard drive interface for personal computers; standard developed by Western Digital in 1986)
ISDN	Integrated services digital network
IT	Information technology
ITDC	Industry and Technology Development Council (HK)
ITRI	Industrial Technology Research Institute (Taiwan)
KME	Kyushu Matsushita Electric (branch of Matsushita)
LCD	Liquid crystal display
LED	Light-emitting diode
LSI	Large-scale integration
MCM	Multichip module
MCM-D	Multichip module-thin film dielectric
MCM-L	Multichip module-laminate
MD	Mini disk

MEI	Ministry of Electronics Industry (PRC)
MNC	Multinational corporation
MOEA	Ministry of Economic Affairs (Taiwan)
MPEG	Moving Pictures Experts Group (standard for coding audio-visual information in a digital compressed format)
NIE	Newly industrializing/ed economy/ies
ODM	Original Design Manufacturer
OEM	Original Equipment Manufacturer
OLB	Outer lead bonding
OSE	Oriental Semiconductor Electronics
PC	Personal computer
PCB	Printed circuit board
PCBA	Printed circuit board assembly
PCMCIA	Personal Computer Memory Card International Association (interface standard for portable personal computer peripherals, now called "PC Card")
PDA	Personal digital assistant
PDIP	Plastic dual in-line package
PDP	Plasma display panel
PHS	Personal handyphone system
PLCC	Plastic leaded chip carrier
PPGA	Plastic pin grid array
PQFP	Plastic quad flat package
PRC	People’s Republic of China
PWB	Printed wiring boards
QFP	Quad flat package
RF	Radio frequency
ROI	Return on Investment
SBB	Stud bumping bonding
SEM	Scanning electron microscope
SEZ	Special Economic Zone
SMD	Surface mount devices
SMT	Surface mount technology
SOJ	Small outline “J” type package
SRAMs	Static random-access memory
SSTC	State Science and Technology Commission (PRC)
STN	Super-twisted nematic
TAB	Tape-automated bonding
TCP	Tape carrier package
TFT	Thin-film transfer
TFT LCD	Thin-film transistor liquid crystal display
TSOP	Thin small outline packages
VCO	Voltage-controlled crystal oscillators
VCR	Video cassette recorder
VG	Video graphics
VGA	Video graphics adapter