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LUCENT TECHNOLOGIES: GLOBAL SUPPLY CHAIN MANAGEMENT

For our business, traditional manufacturing is not strategic, but world-class supply and demand chain management and product reliability, are.
- George Foo, International Manufacturing Vice President, Lucent Technologies[1]

As they met in Hong Kong in early 2000, George Foo, International Manufacturing Vice President for Lucent Technologies, and his key staff reviewed with satisfaction the success their supply chain redesign for Lucent's flagship product, the 5ESS® digital switch. Four years earlier, Asia had been supplied almost exclusively from the United States—a costly and time-consuming approach. As they considered their redesign, they realized that they had dramatically cut costs and reduced product delivery times, as well as improved support for all Asian operations. More importantly, they had made significant improvements in customer satisfaction and increased market share. They had done this by moving much of the Asia-related manufacturing and material sourcing of the 5ESS® Switch to Asia, with Taiwan as the support hub. They had also become more involved in Lucent's bid and proposals process, helping the company secure additional business.

But they also realized that the Asian market had continued to grow rapidly, becoming an important part of Lucent's business, despite the currency crisis of 1997. Furthermore, the manufacturing infrastructures in Asian countries had matured substantially since the 1996 redesign. Was the current process still optimal, or did changing market and manufacturing conditions require continued evolution of the supply chain? Also, did their single-minded focus on cost and speed expose the supply chain to the major component shortage problems that had recently begun to plague the industry?

[1] "Value Creation Through Supply Chain Management," presentation at Annual Symposium of the Stanford Global Supply Chain Management Forum, Stanford University, June 11, 1998.

Research Associate David Hoyt prepared this case under the supervision of Professor Hau Lee as the basis for class discussion rather than to illustrate either effective or ineffective handling of an administrative situation.

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COMPANY BACKGROUND

Lucent's history goes back to the 1875 invention of the telephone by Alexander Graham Bell. American Telephone and Telegraph Corporation (now known as AT&T Corporation) was incorporated in 1885 as a subsidiary of Bell's original company, American Bell. Its charter was to build and operate the original long distance telephone network. AT&T became the parent of the Bell System, the regulated telephone monopoly for much of the United States until it was broken into eight companies in 1984 by an agreement with the U.S. Department of Justice that settled a major antitrust case. Lucent's genesis was the manufacturing company acquired by the Bell System in the 1800s. It largely supplied only its affiliated operating companies in the United States prior to the 1984 divestiture. International operations were a small part of its business.

From 1984 to 1996, AT&T was an integrated telecommunications services and equipment company, having divested its Bell System operating companies.[2] Its' 1995 revenues were $79.6 billion, of which nearly 60 percent was from services (i.e. phone bills). The United States continued to be the manufacturing arm's primary focus, accounting for 89 percent of 1995 sales, and all of the company's operating income.[3]

On September 20, 1995, AT&T announced its intention to restructure into three separate public companies. One of these companies was to focus on communications equipment, and would include AT&T's renowned research organization, Bell Labs. This company, later named Lucent Technologies, went public on April 4, 1996 when AT&T sold approximately 17.6 percent of its holdings for just over $3 billion, the largest initial public offering ever in the United States. In the company's first earnings release, on April 24, quarterly revenues were announced to be $4.6 billion.

The balance of AT&T's holdings in Lucent was distributed to shareholders on September 30, 1996 in the largest U.S. stock distribution in history.[4] Lucent grew steadily, with revenue increases of over 13 percent in each of the first two years of operation, led by its Network Systems unit, with growth of nearly 25 percent from 1995-1996, and over 18 percent from 1996-1997.

When it became independent in 1996, Lucent operated in more than ninety countries, and was organized into four units, the largest of which was Network Systems. This unit generated 57 percent of the total Lucent revenues for the first year of operation, and was the fastest growing part of the company. It provided networking systems and software to local and long distance telephone companies and cable companies. It was the market leader in the United States for switching systems, and was tied for market leadership in worldwide telecommunications infrastructure equipment. The Switching Solutions Group (SSG), which made the 5ESS® Switch, was part of the Network Systems organization.

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[2] AT&T history from AT&T web site: http://www.att.com/history/.

[3] AT&T Annual Report, 1995.

[4] Restructuring information from AT&T and Lucent Press Releases dated September 20, 1995 (http://www.lucent.com/press/0995/950920.cha.html), April 4, 1996 (http://www.lucent.com/press/0496.960404.cha.html), September 30, 1996 (http:www.lucent.com/press/0996/960930.com.html).

All of Lucent's operating units were supported by the research capabilities of Bell Laboratories, which had facilities in thirteen countries.[5]

THE 5ESS® SWITCH

Lucent's flagship product was the 5ESS® Switch. This was a large-scale, software based digital switching platform, which provided communications service for any type of signal over any medium. It connected end-users to central phone offices, and phone offices to each other. A full-sized 5ESS® Switch was capable of serving up to 250,000 subscriber lines (connecting a phone office to an end user), and over 100,000 trunk lines (connecting phone offices to each other). Customers included major telephone companies, which in some countries were state-owned. The 5ESS Switch was the world's most reliable and widely used switching system.

The 5ESS® Switch was based on a modular design, making it relatively simple to expand capacity. A Switching Module (SM) connected all external lines and trunks, providing switching functions and handling most call-processing tasks such as detection of phone off-hook, receiving dialed digits, and billing. The system could be expanded by adding Switching Modules (Exhibit 1).

A Communications Module (CM) handled functions between SMs; it could change from voice to data channels and provide communications between SMs or between an SM and an Administrative Module

The Administrative Module (AM) was a mainframe computer, responsible for resource allocation, global call processing, and administrative functions. It was the operations and maintenance interface for the technician.

From a manufacturing perspective, the 5ESS® Switch modules consisted of several types of assemblies: printed circuit boards (called "circuit packs" by Lucent), cables, power supplies, and other assorted electrical and mechanical components that were mounted in cabinets. Most of these assemblies could be built with generally available parts, using Lucent proprietary assembly drawings. Some, however, contained Lucent proprietary components. A typical system, selling in the range of $1 million, might consist of 6–7 cabinets full of circuits and cables.

A 5ESS® Switch "office" (consisting of an AM, CM, and SM) contained two hundred unique circuit pack assemblies. Some of these were used in high quantity, while others were relatively infrequently used. Some could be assembled from standard industry components, while others required Lucent proprietary ASICs (applications specific integrated circuits) and other proprietary components. In addition, some of the circuit packs required specialized test fixtures. Due to the wide range of specialized needs of customers, the 5ESS® Switch was a custom configured, engineered-to-order product with an almost unlimited number of configurations. As a result, only a portion of its assemblies could be built to stock (Exhibit 2).

[5] Corporate structure and growth information from Lucent Press Release dated September 30, 1996, and the company's 1996 and 1997 Annual Reports.

ASIAN JOINT VENTURES: FORMATION AND ROLE

Four joint ventures had been established in Asia in response to requirements from customers—generally government-owned telephone operating companies. In some cases, receipt of an order (which could be hundreds of thousands, or tens of millions of dollars) depended on providing local jobs and bringing technology into the country. This was done by forming a joint venture with a telephone operating company or a major local company that had a strong influence in the telecommunications industry. Thus, establishment of joint ventures had been a market entry vehicle, not part of a manufacturing strategy. The first such joint venture was in Taiwan in 1985, followed by Indonesia (1991), China (1993), and India (1993). The Taiwan joint venture was 85 percent owned by Lucent, and 15 percent owned by Chunghwa Telecom Co., Ltd. (CHT)—a government-owned operating company that was privatized in the mid-1990s—and other local investors.

Once a joint venture was established, most manufacturing continued to be done in the United States. It was believed that the high volume of production in Oklahoma City led to the lowest product costs through economies of scale. The process of supplying the joint ventures was called "infeeding." Oklahoma City selected the materials, and fed them to the Asian joint ventures for assembly and testing. Marking up infed material sold to a joint venture was one mechanism that Lucent used to recover expenses for R&D, marketing, support, as well as generate a profit. AT&T retained all profits from direct sales to end-users and to joint ventures, but profits from joint venture sales to end-users were split between the joint venture partners.

In the early 1990s, Asia was becoming an important part of Lucent's business. With its huge population and relatively small base of installed telephones (less than two phones per one hundred people in China,[6] and just fourteen per one hundred people in the rest of Asia[7]), the region promised tremendous future growth. Beginning in 1995, Asia was the fastest growing region for the 5ESS® Switch. The scale of opportunity can be seen by comparing the installed base of relatively less developed Asian countries with their more developed counterparts (Exhibit 3).

Two critical competitive issues were emerging: cost and delivery time. The existence of multiple suppliers, such as Lucent, Alcatel, Siemens, and others created tremendous cost pressure for large contracts. Delivery time was important because many countries were rapidly developing their infrastructures, and tight delivery schedules were necessary to meet their growth requirements. In some cases, quick delivery became a more important factor than price. For instance, in 1990 there was a boom in the Taiwan stock market, and the telephone volume to the exchange increased dramatically as investors hurried to place orders. More switching capacity was needed, and the most important competitive factor in selecting a switch supplier was fast delivery.

In addition to these regional trends, additional factors were affecting the competitive situation in Taiwan. The telecommunications market was being deregulated, so new carriers were emerging to compete for customers. Before this liberalization, customers had to wait for service until the phone company could expand to add lines. Delay in adding capacity only meant that new service was delayed. With the emergence of competition, delay meant that new business would

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[6] Communications Daily, June 21, 1993 (http://ptg.djnr.com/ccroot/asp/publib/story.asp).
[7] Lucent Press Release, February 27, 1997 (http://www.lucent.com/press/0297/970227.coa.html).

go to another telephone company, if that company could provide the service. The new carriers, as well as the newly privatized CHT, required large numbers of switches to service their customers, and fast deployment was a high priority.

Many contracts included penalty clauses for late customer delivery. These penalties might be as high as 30 percent of the contract value. In some cases, joint ventures were known to have chartered 747s in order to get products from the United States to their customers on time. While this was an expensive solution, it was cheaper than incurring penalty costs.

THE 5ESS® SWITCH SUPPLY CHAIN BEFORE THE 1996 REDESIGN

In 1995, most production for Asian customers was done in Oklahoma City. The parts and subassemblies were then shipped to a staging center in Rocklin, California before being sent on to Asia. The Asian joint ventures performed final assembly and test for shipments to customers in their countries. Shipments to customers in Asian countries without joint ventures were made directly from the United States (Exhibit 4).

While the Asian joint ventures' primary role was market access, by 1996 they had developed a varying range of manufacturing capability. Joint ventures had been able to increase their local content by having locally purchased parts certified by Bell Labs, then using them in their production. Taiwan was the most mature, having started some local procurement in 1992. This allowed the Taiwanese to lower their costs by leveraging the advantage of lower cost material originating in Asia. The joint ventures in China, India, and Indonesia used fewer locally produced parts.

The 1995 production process was initiated by orders that came from Asia in one of two ways. For countries without local joint venture companies, orders were placed with AT&T's offices in New Jersey. For countries with local joint ventures, the order was placed with the joint venture, which forwarded the order to New Jersey. In either case, Asian customers were far removed from the order processing and manufacturing activities.

As the Asian electronics industry grew in the early 1980s, AT&T began to use parts produced in the region, which were shipped to Oklahoma City for assembly. This resulted in long lead times, as well as high costs associated with maintaining a parts pipeline extending from Asia to the United States and back again. By the late 1990s, more than 90 percent of all integrated circuits consumed in the world were packaged in Asia.

THE 1996 SUPPLY CHAIN REDESIGN

Before Lucent became independent in 1996, the Asian supply chain had not been a high priority. AT&T had been primarily U.S.-centric in its outlook, and Asia had not been a significant part of its business. Also, AT&T's large cash flow from phone bills had insulated its manufacturing arm from the consequences of inefficient asset management and long delivery times. When Lucent became independent it lost the deep pockets of AT&T, and became a manufacturing company. Asset management, product lead time, and supply chain efficiency took on new importance.

From a marketing perspective, the rapid growth of communications infrastructures in Asian countries provided an important opportunity. Not only was there a great need for improved telephone infrastructure, but Asia was also in the midst of tremendous economic growth. If Lucent was to get a substantial share of this market, it needed to compete on price, delivery, technology, and support. Order cycles that started by going to the United States, that required products to be built in the United States, and that required support from the half-way around the world, inhibited Lucent's competitiveness in Asia.

From a supply chain perspective, Asian manufacturers were producing more and more of the component parts used in the 5ESS® Switch. By 1996, 60 percent (by value) of parts used in the 5ESS® Switch originated in Asia (Exhibit 5). In addition, a substantial contract assembly industry had developed worldwide, and was particularly strong in Asia. Local companies had developed that could assemble basic electronic products, such as cables and printed circuit boards (Exhibit 6).

In addition, the fact that the 5ESS® Switch was a highly configured, engineered-to-order product imposed challenges on the supply chain. In many cases, customers made changes to orders after they were placed, or placed orders at the last minute, demanding fast delivery and rapid response to changes. Furthermore, engineering an order to meet customer requirements, and implement any subsequent changes, was done in Asia. This created major disruptions in the supply chain, which was focused on the needs of the United States. Structural changes in the supply chain were required in order to succeed in this environment.

Lucent's independence from AT&T, the booming Asian marketplace, significant price erosion for telecommunications equipment, original parts sourcing, and manufacturing capabilities suggested that a redesign of the Asian supply chain was needed. Foo, Ben Nan (manufacturing planning director), Gaylord Huang (operations vice president, Taiwan), and their team set about to do this in 1996.

Their solution was to change from the U.S.-centric supply model to a "hub-and-spoke" approach. In this model, Taiwan would be the hub of the Asian supply chain. Orders were placed with Taiwan, rather than New Jersey. Custom engineering and manufacturing of Asian orders would be done in Taiwan. Infeeding, the supply of parts to Asian joint ventures, would come from Taiwan, as would technical support (Exhibit 7).

An important consideration was how much of the product to build in each of the Asian joint ventures. This was heavily dependent on the production volume of each joint venture. At very low volumes, it was most efficient to do only final assembly and testing using materials supplied from Taiwan. As volume increased, the level of local production content increased. First, cable assemblies would be outsourced to local suppliers. Then simple circuit boards would be outsourced locally. As volumes continued to increase, these tasks would be brought in-house by the joint ventures.

By 1999, Taiwan was the most mature of the joint ventures, building ninety-five of the two hundred unique circuit pack assemblies, and accounting for 85 percent of the circuit pack value. Qingdao, China built 50–60 circuit packs locally. Production of circuit packs in Indonesia and India was outsourced to local contract manufacturers, since the volume levels did not support the investment required for a circuit pack production line.

Parts procurement was also changed. Components that originated in Asia were identified and shipped directly to Taiwan rather than the United States ("direct procurement"). The joint ventures also sought out additional local suppliers to build assemblies from Lucent drawings ("local procurement").

When changing the sourcing, quality control was essential. New parts selected from Asian suppliers were subjected to a stringent qualification process, conducted by a Lucent support group independent of the local manufacturing organization. Candidate components were shipped to Bell Labs for certification. New assemblies made in Asia were built using the same drawings, manufacturing standards, test fixtures, and quality measurements that were used in Oklahoma City.

When a joint venture wanted to add more local manufacturing content, it prepared a simple make/buy business case by evaluating the current costs compared with the costs if produced locally and considering the necessary investments. Cost justification resulted in medium and high volume assemblies being built in Taiwan. Low volume assemblies remained in Oklahoma City, where costs could be spread over world-wide production. Assemblies that required expensive, specialized tooling or test fixtures also remained in the United States.

BARRIERS TO THE 1996 REDESIGN

The biggest barrier that the team encountered was employees' natural discomfort with change. The redesign required that many functions in the United States would be reduced, and workers were afraid of losing control and perhaps their jobs. This was the case in the Oklahoma City manufacturing facility and the New Jersey order processing operation. This resistance was offset somewhat by the help of the U.S. management teams, who supported the changes. However, until the new process was proven to be a success, employees were reluctant to give up their accustomed responsibilities.

Another source of resistance was from the Lucent Product Management organization. It was concerned that the transfer of production to the joint ventures would reduce company profits. Since Lucent received only that portion of the profits from sales made by a joint venture to a customer, there was a potential for reduced profits as production moved to joint ventures, which could only be made up by increased volume and improved margins.

This concern was overcome when Ben Nan and the Asia management group worked with the Product Management organization to understand the actual costs of the assemblies, and the impact of inter-company mark-ups on Lucent's competitive position. When high mark-ups were added to products shipped to joint ventures, and additional mark-ups added to the customer's price, it made the product relatively expensive to purchase. The high transfer price inhibited overall sales. Long delivery times also inhibited sales. Reducing total costs and slashing delivery times by redesigning the supply chain would result in increased total revenues, and thus boost profits for both Lucent and the joint ventures.

Since it was not economical to supply Asian customers with Asian parts that were assembled in the United States, it made more sense for Lucent to concentrate on shipping parts that were truly proprietary, or which were costly to obtain locally. Thus, the revenue recovery model became a

"Coke syrup" approach, where higher mark-ups were applied to critical, proprietary components and assemblies that were retained for manufacture in the United States.

In addition, a dramatic change to the joint venture business model greatly reduced the reliance on parts supply for profit generation. Previously, profits and losses were determined by a joint venture's performance, as it purchased parts from Lucent and resold finished products to customers. This led joint venture partners to feel vulnerable to Lucent's parts pricing, and created animosity among the partners. Lucent agreed to pay their partners a fixed return on their capital. Thus, the need to use a markup on supplied parts for recovering profits was unnecessary and a more efficient supply chain could be designed.

Finally, there was resistance from the sales and support organizations in Asian countries. While they did not like having to deal with the United States for all order processing, production, and support issues, this was a system that was well established, and they were concerned about the loss of a "made in USA" label. They were reluctant to change until Taiwan proved its ability to provide parts to the joint ventures and support to all Asian countries. Also, they were not convinced that sourcing in Taiwan would be more cost effective, since they felt that Oklahoma City, despite paying higher wages, had the advantage of economies of scale.

All of these barriers to change were addressed by focusing on the benefits to be gained, with strong management support in the critical organizations. Development of alternative strategies, such as the "Coke syrup" approach to profit recovery (which supported the redesign), were also important in overcoming barriers. However, resistance would never be truly overcome until the success of the new approach was demonstrated.

EFFECT OF THE 1996 REDESIGN

The "hub-and-spoke" model was implemented beginning in November 1996. Shipments from Taiwan began in May 1997, and by late 1998 all Asian orders were being processed in Taiwan. Supply of parts for Asian joint ventures came from Taiwan, and all direct shipments to customers were being made from Taiwan.

The results of the change were dramatic. By 1999, 82 percent of parts, by value, were being sourced within Asia. The remaining parts were sent from Oklahoma City to Taiwan, which prepared the parts kits for the other joint ventures.

In order to efficiently accommodate its increased responsibilities, Gaylord Huang led the Lucent Taiwan team's effort to reengineer its factory. Lucent switched from push to pull manufacturing, reorganized the shop floor for better materials flow, attacked bottlenecks, and focused on productivity. The team implemented leading edge procurement practices, including consignment and vendor managed inventory arrangements. They outsourced the production processes that the company did not do well, but also served as a contract manufacturer for other companies for those processes that it did well, thus sharing its fixed overhead with others. The result of these measures was that the factory was about three times as productive in 1998 as it had been in 1995.

Product manufacturing throughput time decreased from over five weeks in 1995 to one week by 1997. This had a significant effect on delivery performance. In Indonesia, for instance, Lucent's on-time delivery performance had been so poor that its continued business in the country had

been in jeopardy. From June through October 1997 there were few orders, but most were delivered on time. In November and December, there was a surge of year-end orders, of which over 80 percent were delivered on time.

Significant improvements were also realized in profitability and asset management measures. Margins improved by more than 10 percentage points, and inventory days of sales fell by more than half. Costs per termination, the most important competitive measure of product costs for the 5ESS® Switch, were cut in half.

Support of Asian joint ventures and customers improved. Since all support was now provided within Asia, the time differences and long distances that had inhibited responsiveness were eliminated. The "bullwhip effect"—information distortion within a supply chain—was greatly mitigated. Sales people that had been skeptical of the change were quickly convinced of its benefits. In fact, they were so enthusiastic that they asked other Lucent business units to implement this approach. By 1999, the Taiwan joint venture had begun to manufacture data access and wireless products for other business units. Furthermore, since the Taiwan factory was in greater control of the cost elements of the 5ESS® Switch, it became a critical member of the bids and proposals process for winning new business in Asia. In several instances the factory, because of its intimate knowledge of product costs, was able to steer bids towards configurations in which the 5ESS® Switch had the greatest cost advantage compared with competitors' products, providing the competitive advantage needed to win the bids. This would not have been possible if the product continued to be manufactured in the United States, since the difference in time zones prevented close collaboration.

These effects combined to greatly improve the competitiveness of Lucent's Asian operations. In Indonesia, shipments doubled in 1997. In 1998, and again in 2000, Lucent captured 100 percent of the Taiwan telecommunications switch market, as no other company could compete with Lucent's cost structure. In China, the most competitive switch market in the world, Lucent's market share increased and the company achieved profitability in the country. In India, Lucent captured the largest market share in 2000. To support this increased business, Taiwan's output nearly tripled from 1997 to 2000.

THE SITUATION IN 2000

As the joint venture operations developed to meet their new responsibilities, Lucent found that each major production site had unique strengths that could provide benefits beyond those envisioned in the hub-and-spoke concept. Qingdao, China provided products at the lowest cost. Its products had been redesigned to incorporate low cost Chinese-made parts, and local labor was relatively less expensive than in other countries. Taiwan, with its outstanding personal computer industry, engineering and manufacturing infrastructure, was best at delivering custom products and rapidly engineering new designs. Oklahoma City was best suited for extremely high volume orders.

In 2000, Lucent had four facilities in Taiwan, with over 1,200 employees. Its manufacturing facility was located in Hsin Chu Industrial Park, a center for technology, whose 300 companies and more than 80,000 employees generated over $20 billion in annual revenues. The employees of Lucent's Taiwan joint venture had been with the company for an average of more than five

years. Three-quarters of them had some college education, and almost half had either undergraduate or graduate degrees.

Lucent had started to take advantage of some of these strengths outside of Asia. For instance, when Oklahoma City was faced with a surge in orders beyond its delivery capacity, Taiwan would supply the required additional production. Taiwan and Qingdao were also secondary suppliers for Brazil, which was normally supplied by Lucent's Spanish factory. From 1997 to 2000, Taiwan's sales to other Lucent factories more than doubled. In order to take advantage of Qindao's low cost structure, Qingdao became the hub for supplying India.

As Foo, Nan, and Huang reviewed the Asian situation in 2000, they realized that rapid changes were taking place, and that the situation had dramatically changed in the past few years.

The year 2000 was an extremely challenging year for all manufacturers in the electronics industry. Due to unprecedented growth in the cellular and Internet sectors, component demand far outstripped supply, and unprecedented material shortages developed. Leading edge procurement arrangements were sorely tested, and in some cases broke down.

The supply chain redesign had focused on cost and speed. Parts availability had not been a problem in the past, and therefore not been a consideration. With the focus on costs in China and Taiwan, several Asian vendors did not make needed investments in new capacity. Lucent, like many electronics manufacturers, was vulnerable to this imbalance in supply. The problems could be broken down into five areas:

1. Sole-sourced component lead times more than doubled.
2. Inventories increased by about 25 percent, as assemblies could not be completed.
3. The Taiwan factory had to commit to early parts delivery to ensure availability.
4. Product shipments to customers were jeopardized, and orders were at risk due to an inability to ship on time.
5. Premium prices were required in order to obtain expedited shipments of missing parts.

While they tried to systematically identify high-risk items and mitigate these risks, this was a difficult management process, and vulnerable to forces outside Lucent's control. Lucent viewed the supply issue as its single biggest challenge.

The Internet and the improvement of information technology tools were causing fundamental changes in business models and traditional customer-supplier relationships. Contract manufacturing companies had expanded internationally, providing world-class capabilities for an increased portion of manufacturing and logistics responsibilities. Product life cycles were shortening, and telecommunications technology was progressing at an ever-increasing rate. The investment community was placing an even higher value on growth and the ability to respond to opportunity.

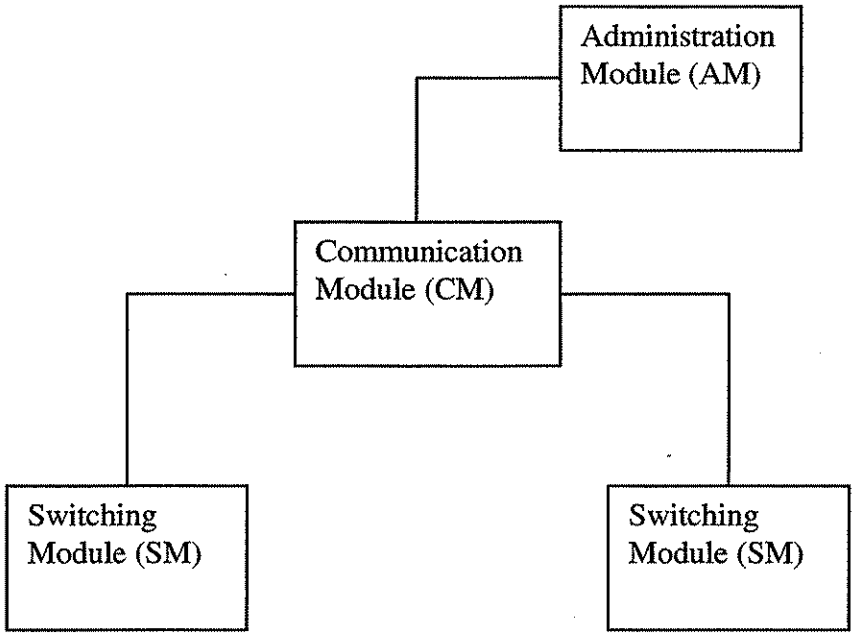
Contract manufacturers, for years a major force in Asia in the production of toys, apparel, and consumer electronics, were starting to get more involved in sophisticated telecommunications electronics. Within Lucent, questions were being raised as to whether the company should continue to devote scarce capital to developing its own manufacturing assets and inventories rather than using contract manufacturers.

The Asian markets, despite the setback from the currency crisis in 1997, were growing rapidly, offering significant opportunities to Lucent and its competitors.

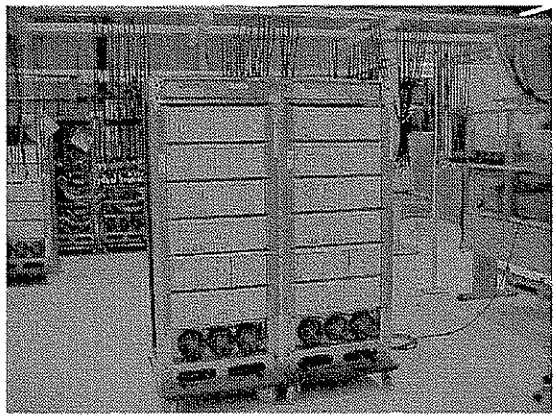
The 5ESS® Switch was also reaching the mature part of its product life cycle. It had been based on circuit switch technology that was efficient for voice networks, but that was now being challenged by alternative technologies and products based on packet switching technology and the demand for data networks.

Foo and his team wrestled with these issues. They had designed and implemented a highly efficient manufacturing operation that delivered a competitive advantage. But the world was changing. Was the hub-and-spoke process, despite its success, the right model for this evolving environment? How could they take advantage of the maturing resources within and outside Lucent? What could Lucent do to mitigate exposure to material shortages without increasing inventory? Was today's leading edge procurement effective for future environments? Should they continue to drive internal breakthrough improvements, or should they "harvest" their previous supply chain investments and direct their attention towards outsourcing for their future needs?

Exhibit 1
5ESS® Switch Product Diagram and Photographs



An Administrative Module, Communication Module, and Switching Module are required for a complete 5ESS® Switch system. Additional capacity is provided by adding more Switching Modules.



5ESS® Switch, front view

5ESS® Switch, rear view

Source: Lucent Technologies.

Exhibit 2
5ESS® Switch Components and Assemblies

The following components were used in the 5ESS® Switch. The primary change in components between 1996 and 2000 was from through-hole components on printed circuit boards to surface mounted devices.

Components Used in the 5ESS® Switch

Component Type	# of type	Required Manufacturing Capability
Integrated Circuit	508	Mature
Power Module	21	Mature
Printed Circuit Board	69	Mature
Other Active	131	Mature
Capacitor	144	Simple
Resistor	504	Simple
Other Passive	268	Simple
Metal Parts	832	Simple
Backplane	32	Mature
Cable/Wire	588	Simple

Components Used in Line Pack[8]

Component Type	# of type	Qty	Qty %	Value %
Integrated Circuit	14	83	11.1%	72.30%
Power Module	1	1	0.1%	3.07%
Printed Circuit Board	1	1	0.1%	5.41%
Other Active	2	5	0.7%	0.04%
Capacitor	9	360	48.0%	3.20%
Resistor	23	211	28.1%	0.18%
Other Passive	6	78	10.4%	13.37%
Metal Parts	8	11	1.5%	2.43%
Total	64	750	100%	100%

Source: Lucent Technologies.

[8] A "line pack" is the highest usage circuit board in the 5ESS. Its function is to connect to the individual telephone line.

Exhibit 3
Teledensity in Asian Countries

A. Fixed-line teledensity (telephones per capita, in percent).

	1996	1997	1998	1999	2000	2001	2002	2003
Australia		51.9	53.2	54.4	51.4	51.6	51.7	51.6
India	1.4	1.7	2.1	2.5	3.0	3.6	4.2	4.8
Indonesia	2.1	2.4	2.7	2.9	3.1	3.4	3.7	4.1
Japan	49.0	49.0	49.0	49.0	49.4	49.4	49.3	49.3
Korea	43.1	44.5	43.3	46.2	47.5	49.0	50.6	52.1
Malaysia	18.1	20.0	20.5	20.3	23.0	25.2	27.9	30.9
New Zealand		46.5	50.2	51.3	53.7	54.2	56.9	57.3
Philippines	2.6	3.3	3.5	3.7	4.0	4.6	5.1	5.5
Singapore	50.2	53.5	55.4	57.4	63.0	64.1	65.0	66.8
Taiwan	46.7	50.2	53.1	54.9	58.8	61.8	64.7	67.5
Thailand	7.1	8.0	8.4	8.5	9.6	10.4	11.5	12.8
China		5.7	7.0	8.6				

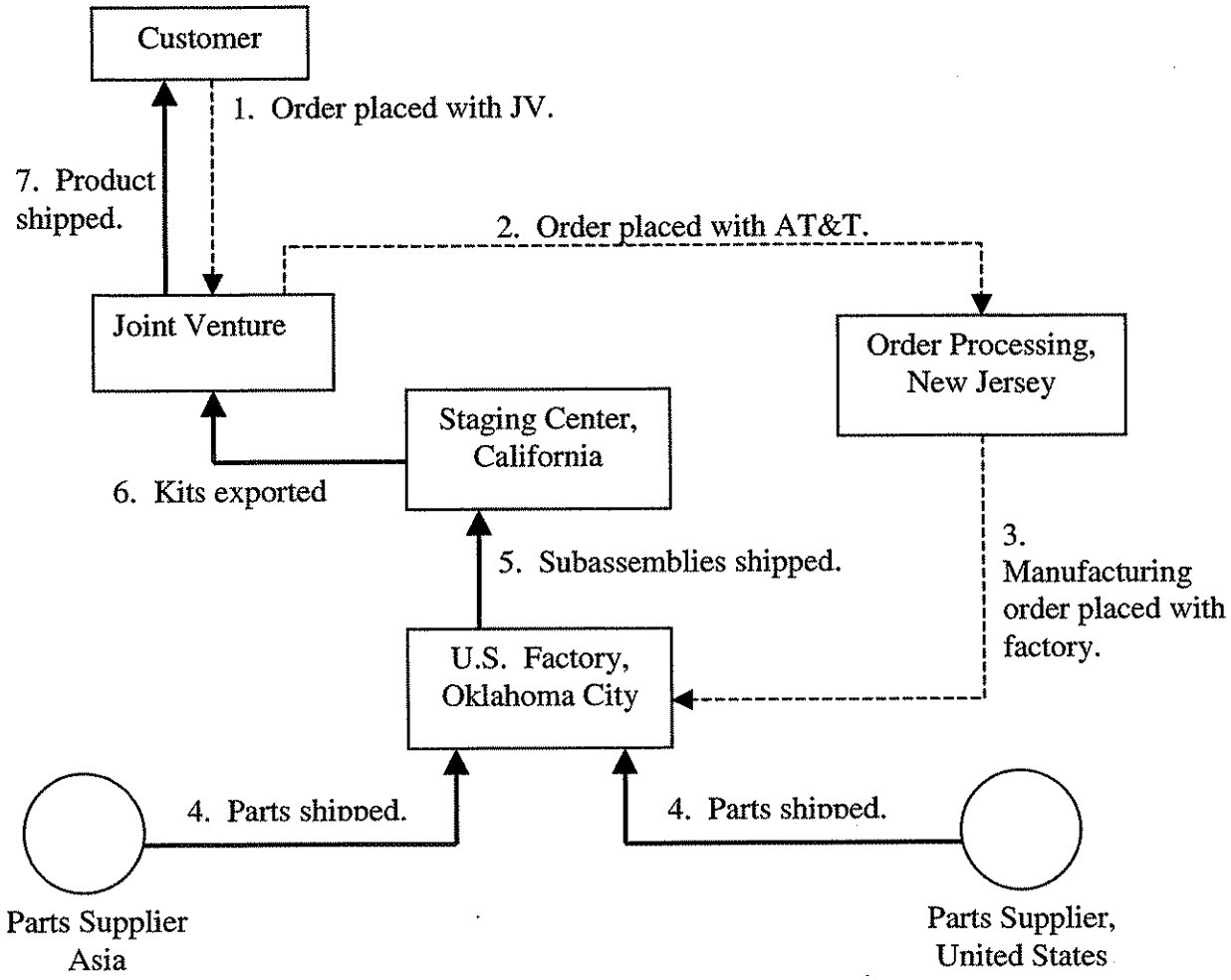
B. Wireless penetration (mobile phones per capita, in percent).

	1996	1997	1998	1999	2000	2001	2002	2003
Australia				37.0	49.8	59.2	67.4	73.4
India	0	0.1	0.1	0.2	0.3	0.4	0.6	0.7
Indonesia	0.3	0.5	0.6	1.1	1.5	2.0	2.5	3.1
Japan	18.4	28.3	35.5	42.6	48.5	53.6	58.0	62.4
Korea	7.0	14.9	30.2	50.1	65.2	72.3	76.2	80.5
Malaysia	6.7	9.8	10.0	12.9	16.0	17.6	19.4	21.3
New Zealand				29.0	35.4	45.3	61.4	66.8
Philippines	1.3	1.8	2.4	3.8	6.7	9.0	11.9	15.1
Singapore	13.5	23.9	33.0	45.6	65.0	70.0	75.0	80.0
Taiwan	5.1	6.9	21.2	47.0	62.9	72.6	77.2	80.4
Thailand	2.9	3.5	3.4	3.9	5.2	6.4	7.9	9.3
China		1.1	2.0	3.4				

Sources:

China: Ministry of Information Industry, People's Republic of China.
All other data and forecasts: Lucent Technologies.

Exhibit 4
Asia Supply Chain, 1995



For sales to Asian countries without joint ventures, the local sales representative placed the order directly with New Jersey, and the shipment from California was made directly to the customer.

Source: Lucent Technologies.

Exhibit 5
Component Sourcing, 1996 and 2000

Asian sourcing of components in 1996 and 2000, by type:

		1996 Asian Source		2000 Asian Source	
Component Type	**# of type**	**Parts %**	**Value %**	**Parts %**	**Value %**
Integrated Circuit	508	47%	60%	83%	96%
Power Module	21	22%	39%	31%	55%
Printed Circuit Board	69	15%	21%	72%	77%
Other Active	131	23%	32%	75%	92%
Capacitor	144	51%	72%	81%	91%
Resistor	504	73%	88%	98%	99%
Other Passive	268	63%	85%	98%	99%
Metal Parts	832	74%	86%	95%	98%
Backplane	32	0%	0%	39%	61%
Cable/Wire	588	57%	76%	99%	99%

Source: Lucent Technologies.

Exhibit 6
Development of Taiwan High Technology Manufacturing

The electronics manufacturing capability within Taiwan grew rapidly in the 1990s. As an example, consider the Hsin Chu Industrial Park, where Lucent's Taiwan manufacturing facilities were located. In 1999, it housed 292 high technology companies, with 82,822 employees. This represented a capital investment of US$18.5 billion, with annual revenue of US$16.6 billion and per employee revenue of US$200,000.

The growth of Hsin Chu Industrial Park had been dramatic, as illustrated below.

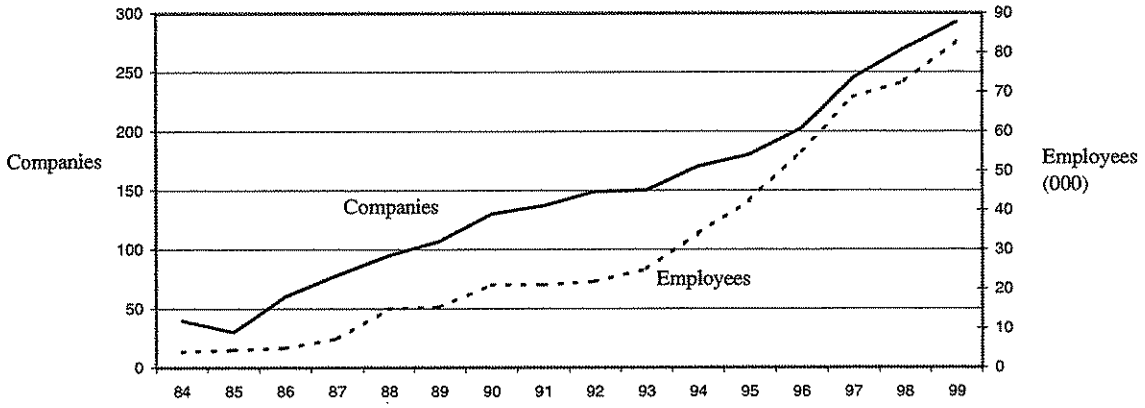


Figure 1. Company and Employee Growth, 1984–1999.

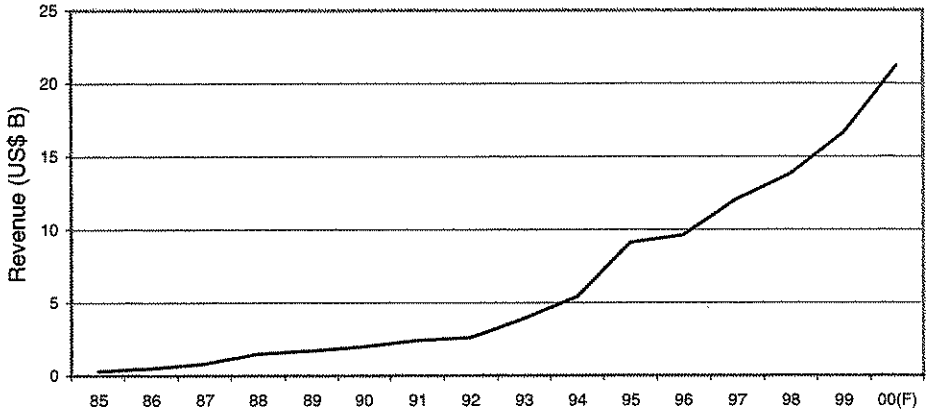
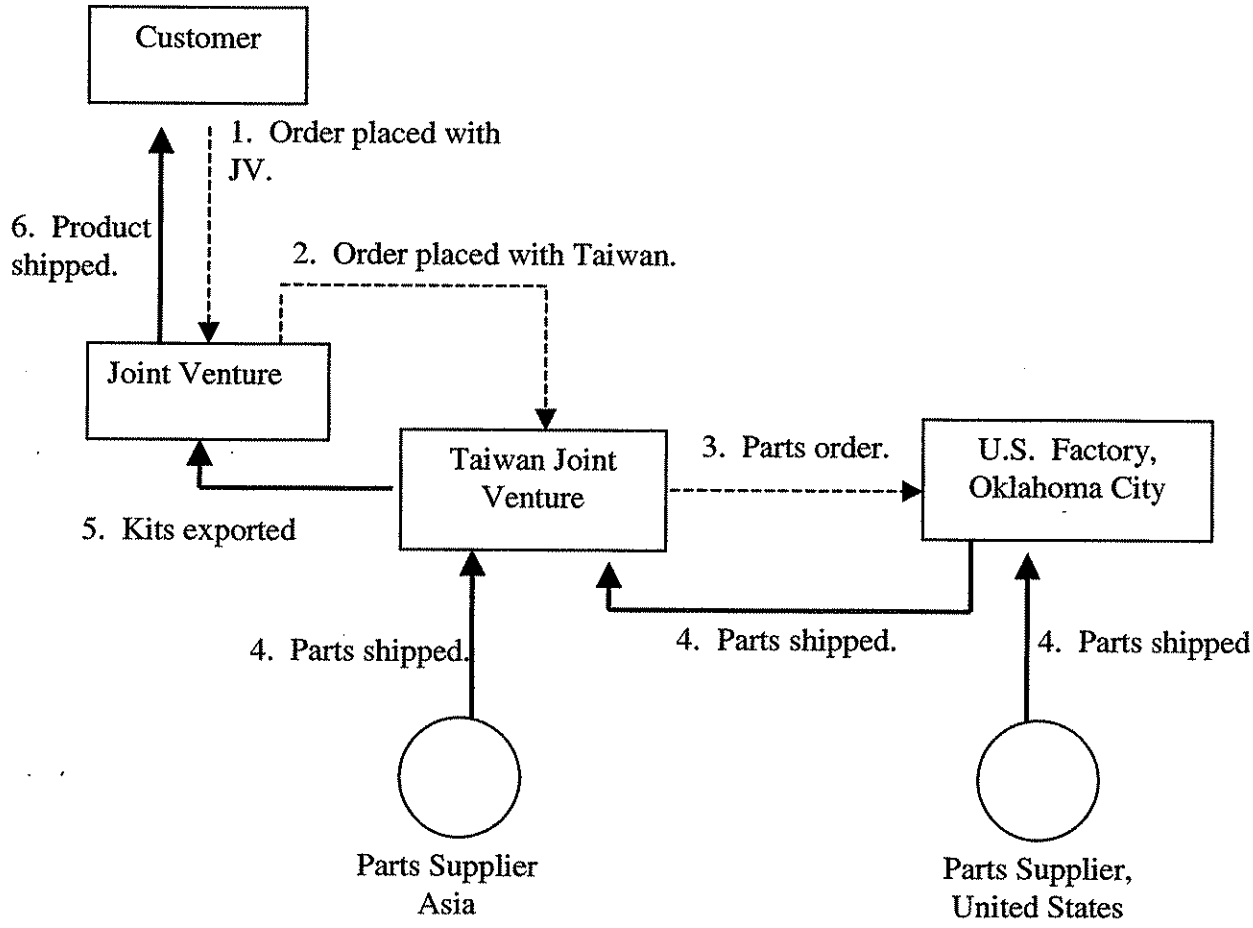


Figure 2. Hsin Chu Industrial Park revenue growth, 1985–2000 (forecast).

Source: Lucent Technologies.

Exhibit 7
Asia Supply Chain After 1996 Redesign



For orders from Taiwan, or from customers in countries without joint ventures, orders were placed directly with the Taiwan joint venture, and shipped directly from it to the customer.

Source: Lucent Technologies.