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FINAL REPORT ON THE EVALUATION OF THE PROPOSED CENTER OF ADVANCED MANUFACTURING OF ELECTRONICS IN MEXICO

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1. INTRODUCTION

The Mexican government has set six priority issues to be addressed in the 1990's. They are:

(1) Telecommunications

(2) Microelectronics

(3) Biotechnology

(4) New materials

(5) Environmental controls

(6) Energy conservation

A series of meetings with government, industrial and academic experts has begun and to date nine documents containing a large number of proposals for achieving the goals and objectives of these six priorities have resulted.

One of these proposals outlines the creation of a Center for Advanced Manufacturing of Electronics. This proposed center, to be located in the MEXEL factory at Guadalajara, would be based on Surface Mount Technology (SMT), and would be a source of practical training in electronics manufacturing for the global marketplace. The evaluation of this particular proposal is the subject of this report.

2. MEXICO'S POTENTIAL FOR ELECTRONICS IN THE 1990'S

Mexico is frequently compared to the rapidly growing economies of the Pacific rim. Each region has approached manufacturing from different traditions. Japan and its neighbours, having few natural resources, quickly evolved an export strategy that included a protected home market for profit as well as product acceptance and improvement, a coordinated business group, and government assistance. In the electronics field, Malaysia is another example of how these factors can be combined to produce a successful expanding economy.

With the advent of standards, much of workstation electronics has been reduced to low margin, high volume commodities. Many U.S. companies have implicitly conceded these areas to the Pacific rim countries where world class factories with low labor costs provide a significant advantage. Further, with the new manufacturing processes and procedures based on highly integrated, information driven technology, we are seeing what some are referring to as winner-take-all markets. In these markets, the factories have such automated, high volume capacity, in terms of percent of total markets combined with high capital requirements and low margins, that only a few companies can successfully compete. Memory chips are one example where we have seen a four fold increase in capital requirement and a shorter product life cycle with each generation.

The following economic factors would indicate a potential for dramatic economic growth in Mexico:

(1) Mexico needs to export products to survive.

(2) Mexico has a free educational system with a large number of students in engineering and business.

(3) Mexico has access through free trade to the large North American markets, the European community and, through culture and language, to Central and South America.

All of these are positive factors that could position Mexico as an emerging economic force. What is holding it back?

This can be explained by a number of observations:

(1) Mexico lacks a compelling vision that native industry should create and own the intellectual rights to products rather than just manufacture products based on the ideas of other people.

(2) Venture capital needs to understand that research and development are necessary components of risk reduction in the overall portfolio of national investment. While high technology is, in general, riskier than real estate, etc., it is a way of diversifying the portfolio against business life cycles and other long term economic cycles.

(3) Mexico lacks an industrial infrastructure that would support the vision in an industry like electronics. However, all of the pieces are obtainable if a coordinated effort of private industry, education and government support could be marshalled.

(4) The success of the maquiladoras has created a state of inertia. Almost all of the new jobs in Mexico (some 500,000) were created in this sector of the economy during the 80's. This amounts to a quick fix for the economic crisis of the early 80's, but it is not a solution for providing high profit exports for the 90's.

(5) Free trade is rapidly opening up Mexico to all sorts of foreign products, many that are more advanced and of higher quality than the previously protected native industrial products. The native industry which never attracted large amounts of capital because its Mexican markets were too small, and are struggling to survive.

Given these circumstances, the question of how to overcome these drawbacks arises. The following steps are essential:

(1) Challenge the young Mexican engineering and business students and working professionals, to create ten new jobs in addition to creating their own over the next five years.

(2) Support this challenge by the creation of infrastructural centers that would facilitate the incubation of large numbers of new products and industry.

(3) Create an educational environment that would reward faculty and students for creating products as part of the educational process.

(4) Promote industrial, academic and government involvement in cutting edge activities that would promote the entrepreneur. These would include active involvement in international standards, trade shows and international consortia.

(5) Promote faculty and other expert exchanges by under-writing international meetings or training.

(6) Create a curriculum going from elementary school through graduate school that promotes industrial design. The model could be the one developed in Great Britain. Their Center for Industrial Design has an exhibit in downtown London to foster the export mentality. It features the best ideas for new products created by school age through college students.

The cost of this type of solution need not be high if human resources and barter are used.

3. BRIEF HISTORY OF THE MEXICAN ELECTRONICS INDUSTRY

In the 60's and 70's the Mexican electronics market was more or less closed, although some products were designed and produced by Mexican nationals for the national marketplace. However, the market was too small for efficient manufacturing; it lacked strong veature capital support due to a lack of vision to perceive research and development as an investment; and it was protected from the developing global competition that demanded quality products, rapid innovation, and a high level of customer service.

In the 80's the government entered into a series of free trade agreements that opened up the Mexican marketplace to the United States and Canada. The Mexican / U.S. border became the site of factories that were so-called "in bound" maquiladora factories providing goods and products for the U.S. marketplace. These factories, owned by multi-national corporations of the U.S., Europe and the Pacific Rim nations, have provided modest work for companies owned by Mexican nationals. The maquiladora industries account for 80% of the manufactured goods exported by Mexico and 40% of its total exports. Maquiladoras created 500,000 jobs during the 1980's which represent the majority of all new jobs in Mexico during that decade. Only a small percentage of these jobs are in electronics.

4. THE ELECTRONICS INDUSTRY TODAY

The electronics industry is central to modern society. Without modern telecommunications and information processing, manufacturing for export is hopelessly inefficient. The core of a democratic society is free access to channels of mass media. Cars, homes and industries need smarter, improved electronic control to reduce energy consumption and reduce pollution.

From electronic devices and components, to board level products, to complex electronic systems, electronics form a rainbow of industries and product opportunities. Given the rapid rise of standards and the need for massive capital investment, both in research and development, some corporations and countries have staked out claims to specific industrial sectors and markets and have reduced them to low margin commodities. Each generation of electronic device research has brought with it higher performance at significantly lower cost, leading to rapid product evolution and newer, more diversified markets. This rapid evolution has created economic opportunity and growth for many developing countries in the Pacific rim. Mexico, with its rapidly growing, educated workforce and evolving access to North and South American markets through aggressive free trade policies, would seem an ideal site for a similar scenario.

The electronics industry is also strongly linked to the software industry. In some industries the linkage is so strong that the production development cost is driven by the design and development of the software and vice versa. Electronic Computer Aided Design (ECAD), Computer Integrated Manufacturing (CIM) and Computer Aided Software

Engineering (CASE) software have spawned highly profitable, minimal pollution, multi-billion dollar industries.

Both the hardware and software sectors of the electronics industries offer significant opportunity for Mexico. First, they offer challenging jobs in creating new products and designs. These jobs can range in technical sophistication from low level systems integration to edge-of-the-art product development. Second, these industrial sectors will supply critical subsystems to enable the emergence of a modern telecommunication and transportation network. Third, creation of valuable, high profit margin exports based on native intellectual property will result. Fourth, this can be accomplished on modest capital and with minimum stress both to the environment and to worker health and safety, assuming proper attention is paid to toxics use reduction and the work environment.

5. TRENDS IN ADVANCED MANUFACTURING OF ELECTRONICS

5.1 Through Hole Manufacturing

SMT is gradually replacing Through Hole (TH) technology. With TH one can manufacture in a range of volumes from manual methods for small production runs to fully automated lines for the highest volumes. Thus companies like MEXEL, using modest investments and careful attention to quality, can find a profitable niche in the manual manufacture of low volume TH electronics.

In the TH technology, a Printed Circuit Board (PCB) is generated by taking art work, developed by the electronics design team using Electronic Computer Aided Design (ECAD) software, and etching metal into alternating layers of non-conductive plastic. These multi-layered boards (MLB) are next drilled through by a CAM program generated by the ECAD software. Multi-layer boards, of 2, 4, and 6 layers are common in TH. Next the "stuffing" operation is done either by machine or human labor. The leads (wires) need to be formed (shaped) and cut to correct length. Once the leads are formed, each electronic part is inserted through its prescribed holes in the PCB in an order determined by the manufacturing process engineer. The placement order of components is dictated by the assembly technology being used and their location on the board. once the component is inserted into the board the leads that now stick through the bottom of the board are cut and crimped (bent) to hold the component to the PCB. After each round of insertion the board is inspected for defects to determine if the components are correctly placed and oriented. Only one of the several possible orientations of the parts is typically correct. Finally, the board is run through a wave solder machine where the liquid metal wicks up the holes and forms a conductive path between the leads and the layers of wires etched in the PCB. When the metal cools and forms a hardened joint, the board is sometimes washed with to remove flux residue.

The final phase is to test the assembled board. Should the board fail the test it will need to go through a secondary operation that is much more expensive. In the secondary operation highly skilled technicians diagnose and repair the board's TH component joints and remove the solder and then replace and hand-solder in the new part.

5.2 Surface Mount Technology

On the surface the SMT process appears to be almost identical to the TH process. Yet, as we shall see, the technology is at best an order of difficulty more complex and unforgiving of minor mistakes. First, instead of components being applied to one side of a board we can apply them to both sides. This is possible because instead of drilling holes through the PCB we establish metal connections between the metal (wire) layers and also the two surfaces. These vertical wires, called vias when they are to connect a component lead, have a small pad of solder applied on top of the via as the first step of the assembly process. The solder actually is a mixture of solder and organic substance that will evaporate during the heating phase of solder reflow. The paste is applied in a manner similar to silk screening, i.e. a beryllium mask is aligned over the PCB. The paste is spread over the mask and a blade is put over the paste forcing the paste through the holes in the mask onto the board. The board and the mask must be aligned with the utmost accuracy and the solder mixture and the blade pressure accurately controlled in order for the pad to be of correct size on the correct location.

SMT has many other features to discuss. The electronic component is typically placed in a plastic or ceramic shell or package. The leads from the package come in several shapes. Two popular shapes are (1) J leads in which the lead is bent in the shape of a "j" with the loop under the bottom of the package and (2) gull-wings which are shaped as gull wings with the lead contact on the PCB being external to the base of the package. The distance between the lead centers is called the pitch and is measured in mils (thousandths of an inch). Current pitches are 50 mil and 25 mil. Any pitch below 25 mil is called fine pitch. As the pitch gets finer (smaller) the cost for the assembly equipment rises rapidly. one only has to examine a few 50 mil components and SMT boards to realize that manual assembly in any quantity is out of the question. The requirement of precise placement of components time after time on a board requires a robotic placement machine, a highly precise machine that has its parts delivered in tubes, reels and other automated feeder systems. After the board has been to the masking station it goes to the robot and the components are precisely placed over the pads and the downward pressure on the components forces the leads into the sticky solder paste. After all the parts are placed on the board, the board is inspected and taken to a solder reflow machine. The most common process is to use a complex infrared oven. The solder melts and wets (surrounds) the lead to form a metal joint. The SMT joint is subject to all sorts of mechanical and metallurgical forces that can cause failure. The finer the pitch the more carefully it must be controlled to get a satisfactory result. The greater the control, the more the process must be completely understood. SMT process technology requires a much more sophisticated Total quality Management (TQM) and an extensive process research support lab to detect and analyze the sources of process error.

5.2.1 SMT Versus HT

Why is SMT replacing the TH if it is so complex and costly? First as the pitch gets finer the parts get smaller and we get more electronics into a small area. Miniaturization is rapidly changing the nature of telecommunications, home electronics, portable and notebook computers, etc. The reduced size and requirements for electronics open vast opportunities for new products, new markets and new industries. Practically all of Mexico's major technological challenges will require some major development that will be based on SMT products.

5.2.2 SMT Is Unforgiving

As the number of components gets larger per square inch (in2) the number of leads rises dramatically. The PCB requires more and more layers in order to route (connect) resulting circuits. Thus the SMT board may have 12, 16, or 24 layers. When completed the SMT board may have thousands of joints on it. Every one must be perfect or else the board will fail at some point in its testing cycle. Each failed board means an expensive trip through the secondary diagnosis and repair loops. Each repair operation means another reheating and cooling of the PCB. Unlike HT's this PCB reheating does not come without risk. Each reheating and cooling causes thermal stress in the circuits. After four or five reheatings it becomes verv probable that the PCB will either delaminate (the lavers will separate) or the circuits will develop fine cracks and either cause intermittent failures or open circuits. This rule of thumb on reheating is the subject of much research and new products for reworking and repairing SMT boards are coming to market. In either case it is highly probable that it cannot be repaired and the board is a complete loss

This forces the manufacturer to use every quality tool available to insure that the SMT process runs at near perfection and that each process error is studied and eliminated. The TQM programs that work with relatively unskilled manual labor, where errors are measured in parts per hundred or thousand, become programs in robotic assembly with skilled technicians, with errors measured in parts per million with a goal of zero defects. TQM within SMT is an integral part of the process engineering.

5.3 Market and Technology Trends in Mexico

5.3.1 SMT Contract Assembly Market Potential Both Mexican and World Wide

In order to assess whether or not to proceed with this project one should at least have some concept of what the market is for SMT contract assembly. If the current proposal is funded, the MEXEL president, Mr. Castro, and the plant director, Mr. Ledesma, stated that there is sufficient SMT contract assembly business to support the project. The majority of this projected SMT assembly was to come from local maquiladora plants.

A more independent report on the global market can be found in the article by Marcoux [Marcoux 92]. The article cites three market data items from reliable sources:

1) "The electronic manufacturing services industry grew about 17 to 18 per cent"
Tony Hilvers, director of education and market research for the Institute for Interconnecting and Packaging Electronic Circuits (Lincolnwood, IL) (IPC) remark on U.S. market of members.

2) "our study estimated that the 1991 growth of this industry was 8.1 percent and that the average annual growth rate from 1989 to 1995 [will be] 8.4 percent" remark on the global market by Pam Gordon, President, Technology Forecasters, Berkeley, CA.

3) The Electronic Manufacturing Services Industry (EMSI) market was estimated by Gordon as $15.8 billion (U.S.) for 1991 worldwide.

The numbers would indicate a healthy market even within a major recession.

In a separate article, McCabe discusses why subcontracting of circuit board assembly is growing worldwide [McCabe 92]. He cites five reasons for this:

(1) An increase in percentage growth of SMT and mixed technology, i.e. 44% of $11.2B (U.S.) in 1988 to an estimated 56% of $18.0B (U.S) in 1993.

(2) The reluctance of the Original Equipment Manufacture (OEM) to invest in expensive SMT capital projects.

(3) Reduced product life cycles.

(4) Lack of OEM engineering skills.

(5) The cost effectiveness of the subcontractor.

MCabe also forecasts that the largest increases in this contract assembly will occur in the Asian Market. Malaysia has made rapid strides and is both attracting multinational corporate investment and experiencing a rapid rise in its own nationals becoming subcontractors. Manufacturing Miracles by Gereffi and Wyman provides some insight as to how the outward looking export orientation of the Asian countries accounts for this growth and compares it to the historic pattern of inward protected market approach of the Mexican government [Gereffi 90]. While it is true that there is currently a worldwide surplus of capacity in many areas of electronics and that the Asian countries are further building capacity, there are two trends that bode well for the proposed project. The first is that Asian manufacturing is designed for the high volume, commodity electronics markets, thus leaving a considerable market for the subcontractor in special niche markets or those subject to rapid product evolution. Second, the tendency to "make it where one sells it" gives Mexico the edge in North and South America and to a lesser extent in Europe.

Based on discussions that the author has had with industry experts, HT technology is beginning to phase out rapidly. Fine pitch and, within 5 years, ultra-fine pitch SMT will be the principle technology and Tape Automated Binding (TAB) will become common in world markets in approximately five to ten years. Japanese equipment manufacturers are beginning to show TAB equipment at trade shows and are beginning to do trial manufacturing within their home markets.

Marcoux also makes some other points that are worth commenting on within the context of the proposed models [Marcoux 92]:

1) Turnkey assembly (in which the PCA buys and inventories all product material, builds the assembly, and tests it) is done by the largest and most financially stable of PCAs, since 70 to 90 per cent of cost is in the components.

2) The normal situation is that PCAs provide only assembly and limited testing. The PCAs are just now beginning to move to SMT and fine pitch assembly.

3) Few PCAs provide design services.

Finally, Marcoux points out a major theme throughout this report. When the PCAs are examined on pricing, both for U.S. domestic and foreign manufacturers, the difference is no more than 5 percent. This small difference is due to the increasing automation of the assembly process, and one can conjecture that it will decrease as the SMT process begins to dominate. The impact of this is that local PCA vendors will be desired if quality issues are met. Further, delays and other hidden costs of off-shore manufacturing will help drive the process in favor of domestic production.

6. CURRENT PROPOSAL BY MEXEL

The original proposal by MEXEL represents a project that is of short term duration (one year) and modest capital requirements ($250,000 to $1 million U.S.). The proposal components consist of the following:

(1) An SMT line would be set up based on equipment purchased from a variety of vendors rather than a single source;
(2) Equipment designed for 50 mil (thousandth of an inch) centers would be purchased
(3) The SMT line would be set up within the Mexel Guadalajara factory
(4) Equipment purchase, set-up and trial production would require six months, after which orders would be taken for SMT assembly
(5) Students from universities would be accepted for training about one year after install; and
(6) At some future time other MEXEL competitors would be allowed to take training.

6.? Strengths of MEXEL Proposal

A working factory already exists in Guadalajara. It is a highly efficient, small business which is very cost conscience and provides a supportive work environment. They have instituted a first phase of TOM which is very effective. The factory uses Just-In-Time (JIT), Statistically Quality Control (SQC), and Materials Requirements Planning (MRP) and teaches these principles to the employees. It employs these principles correctly resulting in a very competitive manufacturing environment.

MEXEL has an energetic and creative manager and staff and an effective workforce. They employ an appropriate level of automation. Also, they u·· a quality circle or team of employees who continuously improve the · eration and competitiveness of the factory.

6.2 Weaknesses of MEXEL Proposal

There are several areas of concern in regard to the MEXEL proposal. The business plan and its goal of beginning the transition from HT to SMT assembly are clearly necessary if MEXEL and other Mexican PCAs are to remain competitive. The decision to purchase equipment from a variety of manufacturers may indeed result in a lower initial capital requirement. However, one must also consider that systems integration is expensive; training and support for maintenance becomes an issue start-up time is longer; and equipment or process issues require negotiations with multiple companies.

The decision to begin with 50 mil pitch equipment and ease into the SMT process to lower the capital requirements may be argued as only a short term solution at best. The plan of doing a few 25 mil components by manual means is also of some risk due to reheating. The program for TOM has not yet been established. The SMT process is approached as a simple extension of HT and one that could be set up in a matter of a few months. Most of the larger micro-computer and work station companies in the United States spent six months to a year debugging their SMT processes.

The education experience was stressed to be hands-on and real world. There was very little evidence of formal industrial training or evidence of an academic plan or affiliation. The project did not mention whether the women who occupy the low wage manual assembly positions would be upgraded to SMT process technicians.

The role of the MEXEL center in educating other PCAs in SMT methodology was also very vague and would not be started until well after MEXEL had established its capability.

The role of a MEXEL center to foster or incubate new Mexican electronic industries was not addressed. Nor was the preparation for or the demonstration of such concepts as concurrent engineering, CIM, or intelligent manufacturing.

While it is clearly a legitimate project as conceived, with clear goals and objectives, the project was designed to resolve one company's need to have a competitive future. The education dimension was a device to justify getting a UNDP grant or other international money to pay for all or part of the project and to get some inexpensive labor (students) in exchange for training. Thus without a great deal of modification, including a greatly expanded education plan and guarantees that would diffuse the benefit to the Mexican economy, it would seem to be a project for a standard industrial development loan and not a project that would be supported by the U.N.

7. REVIEW OF CONCEPTUAL MODELS FOR MANUFACTURING DEMONSTRATION CENTERS

What will form the basis of this report's recommendation is what shall be called center models. These models represent alternative templates upon which the Center for the Advanced Manufacture of Electronics could be based. The three alternatives are:

(1) The industrial center of excellence

(2) The educational-industrial collaborative for advanced electronic manufacturing; and

(3) The infrastructural center for advanced electronics. This model is based on real projects in which this reviewer's Center for Productivity Enhancement (CPE) has participated.

Each of the three models has quite different goals and associated scopes and each will be addressed separately and in detail.

7.1 Paradigm U.S. Centers Representing Each Model

The Commonwealth of Massachusetts, is one of several sites with a major concentration of electronic industries within the United States. These industries sprang up after World War II based on government sponsored research done at major research universities and laboratories. This research funding continued during the cold war, spawning among others the space and defense electronics industry, the computer and medical instruments industries and the basis for home electronics.

Massachusetts was the site of the industrial revolution in the U.S. From its beginnings in water driven mills in Lowell, MA., it has seen industries rise, mature, and die over its nearly two hundred year history. The lessons based on riding these business cycles have been dearly learned. In recent years both state and federal government have begun experimenting with private industry and educational institutions to create programs that address economic and societal issues resulting from the cyclical business climate.

One such program was the creation of the University of Massachusetts Lowell (UMass Lowell) during the recession of the 1970's. Its mission was to supply the critical resources for sustained economic growth of the region's high technology. The ULowell Center for Productivity Enhancement (CPE), of which the author is the director, was a major attempt to provide start up companies, as well as mature high tech companies, with industrial partnerships enabling them to be competitive. The CPE was designed to develop young entrepreneurs and new products and processes for industry. Further, it was realized that human capital was the state's most important resource, so the CPE addressed issues of worker health and safety, toxic use reduction, and work and technology issues such as skill-based automation. New products and new ideas are the well- spring of new industry and hence the CPE undertakes advanced materials research. Business to business marketing research is also a key program.

The CPE is mentioned to provide a point of reference. The CPE is a microcosm of the six priority issues being undertaken by Mexico, and it has been deeply involved in the long term competitiveness of the region's electronics industry. As might be expected, each of the proposed center models has a prototype in Massachusetts and each will be discussed here as a case history to provide relevant experience and concepts. Certainly there are other centers that might have been cited, but the author's firsthand experience with these particular centers was considered important.

The industrial center of excellence model is similar to MEXEL's proposal except it incorporates the concurrent design of electronics within its scope. It seeks to address issues such as Time to Market, Concurrent Engineering, Design for Manufacture, and Intelligent Manufacturing.

The educational-industrial collaborative sets up a pilot plant laboratory with limited scale production facilities that produces a low volume of actual products or prototypes. The goal is the generation of industrially qualified manufacturing technicians and manufacturing engineers through a vocational technician program. Training materials are developed in collaboration between industries and universities.

Although the infrastructural center presented here does not currently exist as the reviewer proposes, it is one that is evolving rapidly. Central to the concept developed here is the idea that industries do not exist without a governmental infrastructure in the form of transportation and telecommunication systems, a nurturing set of laws, and a supportive business and social climate. The public infrastructure provides a large labor pool that is educated and well- motivated. Further, in industrialized countries it is also recognized that an essential ingredient supporting an industry such as electronics is an infrastructure of industrial suppliers of basic materials and services as well as financial services. In recent years the cost of research and/or the cost of some leading edge facilities has been so large that not even the largest, wealthiest corporations can afford them. The result has been the formation either of private consortia or quasi-private centers that undertake the task.

Both the United States and Canada have seen the creation of silicon foundries as centers for research and process training, design experience, and software development. The MCC in Austin, Texas and MITI in Japan are examples of collaborative research centers that industry subscribes to for the knowledge that affects their future products. The Center for Productivity Enhancement (CPE) belongs to the Massachusetts Microelectronics Center (MMC), which is a center to promulgate the theory and design of semi-conductors and the theory and practice of their production, i.e. an operational silicon foundry. The original partnership between the state and local industry was a 50 per cent sharing of cost. As the MCC has evolved, the cost of operation has forced a shift in operational budget sharing. The educational burden is now approximately 20% of operating cost and is shared by government, universities and industry, while the remaining 80% will now be paid for out of production of chips for private industry.

The Mexican electronics industry will always remain fragile. i.e.. subject to economic and tariff decisions and to technology that needs cheap labor. unless it creates an electronics industry in a holistic sense. encompassing is meant the creation of the original electronic design. the manufacture. and the international export and distribution of the product. Both the industrial model and the educational industrial collaborative address the immediate problem of introducing SMT to Mexican industry and the latter also addresses the national goal of providing the necessary technicians and manufacturing engineers. The infrastructural center addresses the larger problem. Mexico has a young and growing population. It is adding one year on to its high school and one year on to its college curriculum as a means of dealing with its lack of employment opportunities. A native electronic and software industry could potentially absorb vast numbers of educated professionals in high value added jobs. It should be noted that electronics and the software industry to support electronics are low pollution and low environmental stress industries which should be encouraged in the Mexican economy. Electronics is one of the new fundamental industries necessary for everything from micro-electronics and telecommunications to consumer and durable goods.

Ideally the infrastructural center would be sited within an incubator environment that would supply the market for its limited production runs. have strong industrial support and a strong commitment to education. and provide proactive support to member universities and technical colleges.

In the case of Mexico, the center could be quasi-private with the government assisting in part with the operating cost and in the educational programs. International funding from World Bank. UNDP and perhaps Inter American Development would also be sought and justified if foreign universities and small businesses could participate. The operation of the center would be a joint board of the stakeholders and the day to day operation either done by the consortia or by a private contractor. The goal is to provide all the necessary and sufficient infrastructure to develop and support an electronics industry in Mexico. In today's terms that means it must produce a world class product both for domestic and international markets.

7.1.1 The Industrial Center of Excellence For Manufacturing in Electronics

In this case study. which is similar to the MEXEL proposal. the industrial center is set up as an actual assembly line to demonstrate the corporation's leadership in such areas as total quality. productivity. and competitiveness. UMass Lowell's CPE was involved with an industrial partner in such a start up center. The concept is to demonstrate that the industrial sponsor's computers can be used to create a concurrent engineering design environment that allows the engineering design team to address issues such as:

1. Providing E-CAD tools to design. simulate. and analyze the micro-computer electronics

2. Designing the manufacturing database. all the artwork. CAD/CAM. and the component source files. Address costing and manufacturing issues at the time of design rather than during manufacturing phase;

3. Creating all the automated software for the robotics and other assembly equipment;

4. Creating the Automated Test Equipment vectors; and

5. Addressing total quality in the planning phase. design for manufacture. and the creation of a strategic manufacture plan.

The goals are to minimize the Time to Market issues and the engineering change orders. improve the TQM. and create a lights out manufacturing SMT assembly line. This center was designed to demonstrate that a U.S. micro-computer company can produce an edge-of-the-art world class manufacturing process.

Funding for this center came primarily from the corporation with some support from NASA (government).

The roles of each partner were as follows:

(1) The corporation was primarily responsible for the purchase and installation of the SMT assembly. the physical plant. and products produced. They supply engineering design and manufacturing teams.

(2) The CPE supplied artificial intelligence software for the lights out factory. software integration or various commercial ECAD tools, and the manufacturing CIM environment. The CPE also

- provided training for students. corporation engineering and manufacturing staff. and researchers.

- researched SMT technical issue.

- examined the toxic use reduction in the production of the PCB board. SMT assembly. and other manufacturing processes.

History:

During the early 1980's this corporation was rapidly growing and successful. The corporation's products enjoyed wide spread acceptance and their closed solution technology locked in long term customers and high profit margins. The CPE was frequently brought in to discuss manufacturing issues and problems. The CPE provided a variety of insights concerning the direction of the computer industry toward international standards and open systems. the need to address TQM and cut down the corporations massive work in progress inventory and its frequent engineering change orders. These insights. while supported by middle management. were rejected by upper management in manufacturing. Generally the reason for rejection was that the company continued to be profitable. In other words. if it's not broken don't fix it. Recent autobiographies suggest that the founder and his family were not accessible to those who needed to carry the message. Further. the products under development didn't materialize in time.

During the middle 1980's things began to turn sour. Profits fell and competition began to appear from larger competitors with greater resources and better marketing. Standards and open solutions began to take hold. At this point, manufacturing costs became an issue. While the company's volumes were large enough to justify highly automated robotic HT processes, including mobile robots, its assembly processes were largely manual labor intensive (most minimum wage jobs held by women) and massive rework lines of male technicians.

The company set up a manufacturing research lab to study installation of a completely automated SMT line. They installed what could be called a phase one TOM program. The creation of quality circles forecast ideas that had been suggested earlier. In less than a year the adoption of such techniques as Statistical Quality Control (SQC), Just-In-Time (JIT) practices, and U Line assembly techniques had a rapid and much larger than expected improvement in both quality and reduced costs.

The team that had pulled off this rapid turn around was then rapidly promoted and replaced upper manufacturing management. The new manufacturing executives revisited plans and projects suggested by the CPE. The corporation had realized that TOM tends to follow the 80/20 rule. That is 80 per cent of the benefit is derived from the first 20 per cent of effort. An industrial center of manufacturing excellence in electronics would be created. A five year plan to address concurrent engineering, TOM, and Time To Market product development was created. Project teams between the CPE and the cooperation were set up. Funding was estimated to be about $2.5 million (U.S.) a year. Additional funding from the NASA Technology Utilization Program was obtained to transfer the CPE's intelligent manufacturing software developed under NASA contract.

Just as the program was launched the corporation was hit by a wave of red ink. The combination of new competition, failure to produce a timely product, and a loss of key personnel due to disputes with the founder, were partial causes. In any case, the financial markets and the consumer lost faith causing the company to shut down plants and create massive lay offs. New executives were recruited and the founder resigned.

Result:

The projects that were scheduled for the first year were undertaken. The SMT line did go into production. However, production levels were dropped and key engineers were turning over rapidly. Progress was slow to nonexistent and finally the corporation dropped its manufacturing strategy to be a distributor of another company's hardware and became a value-added software re-seller.

Conclusion:

While this case is a pessimistic and cautionary tale, it does point out a valuable lesson. There is a window of opportunity for every investment. Technology and markets move rapidly and when the window closes it can slam shut. Further, the MEXEL proposal is a limited one year, quick fix. Assembly technology is rapidly evolving and the

Industrial Center model needs a long term plan to acquire and absorb this evolution.

7.1.2 Educational/Industrial Collaborative Center for Advanced Electronic Manufacturing

In this case study a vertical education consortium consists of:

a. Minuteman Vocational Technical High School
b. Manufacturing engineering college programs at UMass Lowell and MIT
c. University research labs - CPE and MIT Lincoln Labs and a collection of private industries:
    a. Workstation manufacturer - Digital Equipment Corporation (DEC)
    b. Defense contractor - Raytheon
    c. Electro-mechanical assemble - Polaroid

combining to form a manufacturing center.

The goal is to set up an assembly line within the vocational high school that would make a limited number of real manufactured goods. The assembly line would be a hybrid assembly of SMT and HT. The students would take a three year sequence of courses toward a career in electronic manufacturing technician certificate in addition to the normal vocational high school program.

The corporations and universities will supply course material development for inclusion within the curriculum. UMass Lowell will set up a program with itself and a community college to attract the vocational tech graduates to go into a career in manufacturing engineering. The research labs and the private industries will provide summer jobs for vocational tech faculty and students in challenging positions. The concept is to provide Massachusetts with well trained technicians and manufacturing engineers.

The Project Manufacturing Lab:

The three corporate members will donate all the assembly equipment. The vocational technical high school will supply space and staff. UMass Lowell will provide some teaching and research assistants to assist the faculty. The Lab will produce about 50 DECTALK units per month. DECTALK is a low volume product that is used in children's hospitals across the U. S. for work with the handicapped. Digital Equipment frequently donates this equipment but it is a real product.

Digital will audit the quality and the manufacturers will provide consulting and deal with SMT process problems.

Funding:
All equipment will be donated by the corporate members as well as all manufacturing supplies and components. The National Science Foundation will supply $150,000 (U.S.) for development of the three year curriculum and the course and training materials. Further funding is being sought for a two-way interactive television network that involves daisy-chaining community cable TV in a star network to connect other regional vocational tech high schools. This interactive television technique has

been used by UMass Lowell for a variety of high school/university joint labs. The students can perform a series of experiments on expensive university equipment using both interactive TV and telephone connected workstations and FAX. The concept is to provide high school students and faculty with a challenging hands-on science and math experience.

History:

MIT Lincoln Labs was the convenor of the collaborative. The collaborative has been meeting approximately once every two months over lunch for the last year. Lincoln Labs has a program where they offer a sabbatical to a high school science teacher to undertake research at the lab over a year's time. The teacher, from the Acton, MA. high school, acts as the coordinator and, along with the Minuteman vocational faculty, wrote and won the $150,000 NSF funding for curriculum development.

The NSF funding was approved in the fall of 1991 and the first students will begin taking courses in the spring of 1992. Most of the laboratory manufacturing equipment will be supplied by DEC from its surplus equipment. It will be current 50 mil center but will not be its latest 20 mil line equipment All three corporations have manufacturing research laboratories that are working on even more advanced robotic assembly processes. Polaroid also has a fully automatic (robotic) assembly line of its current camera that assembles a full range of electro-mechanical mechanisms that includes springs and motors.

The goal of the project is to develop technicians who can go to work immediately and not take the 6 months to 2 years of industrial training now required. Further, it is hoped that a large number of students will elect to go on to careers in manufacturing engineering at schools like UMass Lowell or MIT, and that the best and brightest will go on to be entrepreneurs by doing graduate work at UMass Lowell and/or MIT in engineering and manufacturing management.

UMass Lowell has inaugurated a new curriculum in manufacturing engineering and will work with Minuteman and the local community college to provide advanced placement of the graduates of Minuteman. This first term will supply 26-30 students and it is anticipated that 80-100 students will enter each year. The Production Lab is designed to provide 52 hours of hands-on exposure.

DEC, Polaroid, and Raytheon will supply some of their industrial training staff and a full range of their training materials.

Comment:

The educational/industrial collaborative model is one that has the educational component that would develop human capital in a very structured manner, an aspect which is missing from the MEXEL proposal. Further it could be a model for turning out technicians in other areas of manufacturing. MEXEL does not believe that the lab would be realistic enough training.

While 50 units a month is lower than the collaborative industrial members wanted, it was one with which vocational technical faculty felt comfortable. Higher volume of either product or increased range of products will be revisited after the first year of operation.

The shortage of well trained technicians is a distinct threat to the long range health of the Massachusetts economy. DEC in its personnel planning realizes that it must attract higher percentages of women and minorities to careers in the high paying skilled end of manufacturing if it is to meet its needs, and thus justify its commitment of valuable human and capital resources.

7.1.3 Infra-structural Center for Additional Electronics Based on Current Concepts and Future Trends

The center as envisioned as the infra-structural paradigm is based on two experiences. The first comes from the CPE's attempt to understand issues such as how to create a young entrepreneur, how industry can get a project to market faster, and how to translate the concept of concurrent engineering into industrial practice.

The Creation of the Electronic Entrepreneur:

The CPE encourages students to form business groups. They develop a product concept and a business plan, and find an industrial partner with the help of the CPE's participation in trade shows where it either has a booth or shares a booth with an industrial partner. The students and faculty, who in the lab are treated on a peer level, then perform the research and development, often in conjunction with the industrial partner. The projects of direct relevance are those where the students have elected to create a variety of graphics and imaging hardware devices.

Based on our first attempts we quickly found use of simple inexpensive CAD tools, wire wrap prototypes, and third party board layout and routing to be slow, time-wasting, and inefficient. The review of the first complete board led us to seek an infrastructure partner. The industrial partner produces personal and home computers. They were ideal as an industrial partner. They had a small but highly talented engineering staff that used the latest in ECAD technology. They needed new products and did not have the staff to work on them. Moreover they had a complete manufacturing capacity from prototype PCB boards, to assembly, to sophisticated testing for the various UL and FCC approvals. Finally they had a chief operating officer who understood the needs and limitations of a university partner.

To date two board level products have been developed:

(1) a dataflow imaging board based on the NEC 7281 chip which was sold only in limited quantities to research labs, and

(2) a recently released, high resolution graphics card based on the TI 34010 graphics chip which forms the basis for the product.

The MCC and its university partnership:

The MCC was created during the mid-1980's as a consortium of the Commonwealth of Massachusetts, private industry, and the major engineering universities in the state. The university members represent ten private and public institutions. The original capital investment was $20 million (U.S.) with DEC, Data General, and Prime donating a significant portion of their share in mini-computers, UNIX workstations, and plotters. The MMC would provide the following services:

1) An ECAD software clearing house and porting facility manned by MCC staff and graduate students.

2) Training in the ECAD tools, VLSI design theory, and research topics for industrial members and teaching faculty.

3) Training in VLSI manufacturing operations, including the appropriate control and maintenance of the individual equipment, the operation of the clean room environment, and TQM.

4) The MMC operates a 1.8 micron silicon foundry that will soon be up-graded to 1.2 micron. The foundry provides a ten week turn around production for faculty and student prototype VLSI designs. The MMC also manufactures VLSI chips for private industry and other out of state universities at a nominal cost.

5) Computer equipment and public domain VLSI design tools are distributed to university members based on the number of students involved in VLSI design classes. The university in return would pay for the maintenance and provide systems support. In addition, the university would also provide graduate students to intern at the MMC.

6) The MMC would establish at three university sites, a clean room and all of the unit operation equipment found at the silicon foundry. The resulting laboratory would be shared with two-four other schools. The cost of maintenance, materials, and systems technicians would be the responsibility of the university participants.

The university would also supply qualified Electrical Engineering and Computer Science faculty who would undertake training at MMC in the theory and design practice of VLSI and the theory and manufacturing practices of the foundry's operation. The university would identify and train several hundred students per year in VLSI design and manufacturing. The goal is to supply local industry with designers that could be productive upon job entry rather than require two-three years of training at industries' expense.

The initial concept and goals would appear to be similar to the previous educational/industrial collaborative, i.e. to develop the human capital to meet the needs of the region's growing computer, defense, and electronics industry. However, as the 1980's draw to a close and the MMC's foundry came on line, it became clear that its mission and scope would have to be expanded. First, as the faculty and graduate student support staff invested large amounts of time in becoming qualified as experts, they wanted more return on their investment than just undergraduate teaching would allow. They began to want university recognition for the intellectual property they had created in their software tools and chip designs. This is mirrored in NSF supported workshops where faculty from the nations engineering schools recommended a software clearing house be set-up and asked that their schools be recognized for the important software tool development in the tenure and promotion process. Second, the recession and other economic forces caused the MMC to see itself as an incubator for small VLSI start-ups and also as a production house. Thus, as the 1990's began, its character is that of an infrastructual center that supplies a wide range of goods and services to the region's micro electronics industry as well as an educational resource.

Lessons learned:

1) An infrastructural center can operate a world class manufacturing site with a sophisticated TOM program.

2) That university faculty, graduate, and undergraduate students can be trained to use the complex ECAD design tools and produce sophisticated VLSI parts. However, it has taken three-five years to reach this plateau.

3) The operational plan would have been less traumatic if the foundry had been originally conceived as an infrastructual center with a clear mission to produce rapid turn-around prototypes and production volume tasks for industry.

4) The educational scope originally was to train undergraduates. Faculty and graduate students quickly sought to expand it, create novel designs, and Ph.D. research topics. Products, patents, and software royalty streams based on their new intellectual property, are now beginning to appear. It again would have been prudent to have anticipated this need.

5) The greatest turn-over is not surprising in the personnel associated with the manufacturing technicians who form the heart and soul of the TOM efforts. Recruitment, training, and retention of manufacturing technicians are important TOM issues.

6) Since the original goal was undergraduate based, the software chosen was inexpensive public domain tools. As the MCC progresses, the scales are shifting toward commercial packages (the Canadian center already uses them).

Many of these lessons should be considered in planning the scope and the financing of the recommended solution. It should be noted that design training is an interactive process that requires several years before it is productive.

The University Incubator:

The CPE has been very active in graphics and imaging standards and has chaired a number of American National Standards Institute (ANSI) committees, and participated in a variety of International Standards organization (ISO) standards related to graphics, imaging, multi-media, operating systems and computer acquisition and logistical systems (CALS). The university has created a center within Management Science dedicated to industrial policy and industrial competitiveness, and an Institute for

Plastic Innovation (IPI) based on its leadership in plastics engineering. With the aid of loans from the Massachusetts Government Land Bank and the assistance of its research labs and center, UMass Lowell has begun an infrastructural center type incubator for plastics graphics, and imaging. The first industrial clients will be accepted sometime this summer.

Entrepreneurial Educational Programs:

In closing it must be stated that many hold the belief that an entrepreneur is born not created through education. Further risk taking, creative vision, and the courage to successfully develop a start up company cannot be taught or instilled by the educational environment. A program that directly flies in the face of this conventional wisdom was undertaken by the university some five years ago. While it is far too early to assess the success or failure of the project, its structure would appear to offer some insights for the recommendations to follow.

The program called a Doctor of Engineering (D.Engr.) is designed to produce an industrial leader in engineering with a strong background in management. Currently, Ph.D. programs in engineering have been evolving since the late 1950's into research programs in Applied Sciences and Physics. The D.Engr. does not follow this trend. Instead it requires 30 semester hours of advanced engineering past the bachelor's degree and 18 semester hours of intensive management science, plus a year's industrial experience and a thesis. The management science is designed to be a survivor's course in operating a small business start up. The course is intensive and demanding and it is hoped, inspires creative engineers with a clear concept of what is a product and how to develop it successfully.

Summary:

The concept of an infrastructual center is just now beginning to emerge. The key concept is that all the necessary and sufficient components to support start up companies must be at hand if the start up is to have a significant prospect of success. For the more complex industrial start ups with high intellectual property contents, this requires something more than funding and physical plant. This type of start up requires a complex incubator environment involving skilful partnership between educating government, and private organizations.

8. RECOMMENDATIONS FOR THE CREATION OF A MEXICAN INFRASTRUCTURAL CENTER FOR ELECTRONICS (MICE)

In the MEXEL proposal we identified a number of shortcomings that limit the benefits to Mexico in terms of human capital and long range economic development. In the material to follow a project is recommended that is at once more aggressive in terms of its approach to the development of the electronics and software industry with what will be high, long term economic development. The project will address the need to create jobs at all levels of society ranging from professional, such as engineering, industrial designer, and manufacturing management to technicians for laboratory and manufacturing. The shop floor jobs that will be created will be healthier and safer and will offer career development paths that the current $1/hour assembly jobs do not. Since in the electronics field these assembly jobs are occupied by women these will create a new path to economic job parity with men.

The creation of a Mexican Infrastructural Center for Electronics (MICE) will also accelerate Mexico's development of entrepreneur and increase the probability of the successful incubation of high technology, export driven start-ups. Assuming that the center also helps to foster an educational environment that produces a more balanced engineering theory, curriculum with a solid design and product development experience will produce a generation of entrepreneur.

The vision here is of a five to ten year development. The project, to be viable, will have to establish a series of realistic short term deliverables to establish credibility both in the private and international development sectors. Further, it will require capital and support from many sources and establish ground-breaking collaboration if it is to be funded to reach its full potential.

Since this project, in its complete form, is significantly beyond the scope and the funding requirements of the original proposal, we shall offer a series of alternatives that will allow the participants to seek to match scope to available resources. Ultimately, if the educational and private sector leadership of Mexico undertakes this project in a timely manner, the benefits will quickly become apparent and resources will be found.

8.1 The Infrastructural Center

We shall briefly describe how one might create a center that would:

(1) foster the nucleation and growth of electronics and related software start-ups;
(2) develop a young entrepreneurial engineering and management team that seeks to create jobs and exports;
(3) create a humane, skills-based, automation shop floor
(4) transfer technology developed internationally to Mexico's universities and industry; and
(5) transfer this technology to other developing countries in Central and South America.

The concept of an infrastructural center for electronics is as follows:

1) The center should be sited in such a fashion as to have broad access to all its stake holders.

2) The center should, as a minimum, support a broad range of training and industrial practices in such areas as:

a. Concurrent engineering of electronics i.e. the concurrent development of the electronic design, manufacturing plan and the logistics of acquisition of components and product distribution.

b. TOM and the ISO 9000 series of standards to assure world class manufacturing quality and competitiveness.

c. Entrepreneurial training and development including courses in modern business to business marketing, exporting, and financing the venture.

d. The technical backbone courses in Electronic Computer Aided Design (ECAD), SMT manufacturing, Robotics, Computer Integrated Manufacturing (CIM), etc.

e. Courses in the current and developing standards and how they impact design and manufacturing of electronics. The rapid rise in open systems i.e. products based on international standards or de facto standards requires an expanding and evolving knowledge of standards.

f. Environmental issues that effect electronics. This should be a cradle (concept) to grave (disposal) holistic approach, starting with protecting the worker and engineers' health and safety through training, proper ergonomic design, ventilation, hazardous materials handling, and safe practices. It should also include modern toxic use reduction in areas such as PCB manufacturing by moving away from current wet practices to dry processes i.e. reducing the need for etching and other chemical processors the effects of air pollution and other environmental conditions that reduce yields and quality and how to deal with them; and finally, a theory of design for disposal.

g. Theory of innovation, invention, and industrial design coupled with an active seminar series of resource, results in electronic devices and commercial product development to stimulate in the short term the rapid evolution of commercially viable products. This long term goal is to stimulate and help focus both academic and industrial scientists to provide results that will give Mexico a true quantum jump in competitiveness.

3) The infrastructural center should offer a full range of manufacturing processes and consulting services to incubate new companies and products. The concept would be to reduce the fixed cost of the start-up in order to generate as many new companies and products as possible. Further, in order to increase the total quality of the products, it is suggested that a staff of center consultants be made available to review design and manufacturing practices. The manufacturing facilities should be designed to handle sufficient volume to be able eventually to be self-supporting and have a flexible and sophisticated management system to produce very low volume prototypes rapidly. Such an incubator component would include:

(a) A ECAD design facility that would offer access to a full range of ECAD design tools and technical support;

(b) An information resource center that would gather industrial trends, standards, technical data, and market intelligence. More than a library and/or information network, this resource would have a significant staff to attend trade shows, standards meetings, and other international meetings that had bearing on the direction and technical needs of electronic product development.

(c) The development of SMT electronics which requires:

(1) A PCB manufacturing facility that can produce the high quality PC boards needed for SMT. This facility should be a demonstration site for reduced toxic material use, and

(2) A SMT assembly facility capable of fine pitch assembly with a plan to move to ultra-fine pitch as the market develops.

(d) An enterprise institute to assist in the development of business plans, export and other financial documents, and legal services.

(e) Communication support between education, business, and international members. This facility should eventually allow for interactive multimedia video conferences.

4) The center should provide university programs and graduate research support to advance the theory and design of ECAD, CIM, CASE and other software tools that would advance the state of design and manufacturing of electronics.

5) A Software Engineering Institute to teach theory and industrial practice of modern software development.

6) An International Fellowship Program that would allow international faculty and graduate students and industrial leaders to:

(a) Interact and study at the Centers and the associated university laboratories and design centers.

(b) Work in the incubator's start-up or at the more mature electronics firms.

(c) Set up an interactive, multimedia, video link for international technology transfer to remote classroom and industrial sites.

(d) Identify and exchange industrial fellows who are recognized experts in design and manufacturing.

8.1.1 The Educational and Industrial Training Issues

The issue of human capital development is of primary importance to the funders of international development. The wider and more diffuse this development is throughout society, the greater the potential for an equitable distribution of wealth and social benefits. The typical educational institution is based on a tradition of individual scholarship and merit. The training in universities is on theory, social values and culture. At the world's better educational institutions students are blended for their life's experiences. Due to the high cost of these institutions a large portion are from rich, successful families that have mastered the complex social and business codes that baffle the outsider.

The social networking that goes on informally at these institutions widens and modifies the codes and protocols for the next generation.

In large part, the attraction of the large city to the rural native, is hope of serving an apprenticeship in learning those skills. Every street corner in Mexico City has entrepreneurs supplying an amazing array of goods, services and handcrafts. The maquiladora factories have also shown that, given fair pay and opportunity, Mexico can meet and exceed world class standards. Mexico, having lived in protected markets for so long and only recently been exposed to worldwide consumer and industrial goods, has not yet made the adjustment on how to compete, not only in its own markets but also those of exports. To accomplish this transition and to achieve the aforementioned goals the educational issue should be broken down into three components:

(1) The MICE should be responsible for industrial training of entrepreneurs, engineers, manufacturing management, and trainees. University faculty and vocational educator training would also be carried out. Course material for university classes could be done by the Center (Canadian model) or by individual faculty (U. S. model).

(2) The university would be given responsibility for developing specialized laboratories for advanced manufacturing research, toxic use reduction in SMT processes, and ECAD research. The university would examine their course requirements in engineering and business to incorporate basic business principles in how to start up and run a company. Principles of design, TQM, and project management could also be included. Since the undergraduate experience is being extended by a year, this could be one potential way to modify the curriculum. Finally, the schools participating in the project should provide a Center for Electronic Design and Product Development.

(3) The technician training should be undertaken by an educational/industrial collaborative. The training should address the full range of technician needs of the industrial sectors.

Project 1 - Technician Training through an Educational-Industrial Collaborative

The development of this training could follow a variety of models. The technician training and development could actually follow the example of the educational/industrial collaborative model. The current world recession and resultant over capacity documented by the IPC and others in the large multi-material manufactures of commodity micro-electronics, suggests that maquiladoras owned by IBM, WANG, DEC, etc. might be approached to sponsor a regional network of Production Technology Training Labs. Like the Minute Man model the corporations would be asked to donate current operational equipment and educational material and training consultants to get the project off the ground. It should be noted that donations of equipment needs careful screening. The experts consulted by this author claim that SMT equipment does not store well 90-120 days out of production was the suggested limit. Also, equipment too out of date or worn out is too expensive to maintain. Since the electronics industry will be largely maquiladora over the near term they could at nominal cost support this phase and get a significantly larger and higher quality labor pool. Further, it is suggested that this be a regional network of technical schools and universities coordinated by the infrastructural center because at the present time, according to Dr. Mendez, Director General of the Instituto Mexicano De Comunicaciones (IMC), the need for technicians is not being met by the Mexican educational system and only one college is addressing the need. Further, the largest numerical needs in terms of total personnel is in technician support fields. Support programs for automobile electronics near the U.S. border, microelectronics in Guadalajara, and the incubator at Cuernovaca would suggest three or more regional centers. A board of directors for this regional network should include: representatives from the infrastructural center, educators, a balanced representation of the maquiladoras and Mexican electronics firms such as MEXEL and CEMIT. If Mr. Antonio Castro were willing to expand his vision to a regional network and could identify his counterparts at a local maquiladora as an educational coordinator, it would be a very powerful and highly motivated driver to kick start the first regional site. The economic benefit of such regional centers could be significant. The larger and better educated the labor pool of technicians, the more competitive and compelling is the attraction and retention of the maquiladora and more likely that the national PCA's and PCB manufacturers will be able to qualify as world class manufacturers. By inviting the multi-national corporations into this phase as partners, one develops goodwill that can be used by the government to seek continued investment in plant and labor instead of seeking cheaper, newer sites at some future time. In addition, as the MEXEL's etc. are able to become qualified suppliers with the multi-nationals their opportunity for export is greatly increased.

8.2 Funding

The cost for the total MICE project is still in the concept phase and the key participants would have to work out such fundamental issues as:

(1) Where the MICE would be housed and whether the building would be supplied or purchased.
(2) What level of SMT production capability is desired?
Would it be only for training or limited prototype production or for sufficient production jobs to pay for the cost of operation?
(3) Should the manufacturing capability include PCB's or SMT assembly or both?
(4) Will the funding from the international development banks allow private industrial membership in the MICE and will Mexico seek to include multinational corporation support in the form of donations of equipment and technical support?
(5) Will the MICE seek to stay on the cutting edge of technology?

The answers to the above and many more questions will come when the project begins to be fleshed out and the key leadership evolves to push the project to completion. For purposes of this early phase we will assume that:

(1) Space is being made available.
(2) All manufacturing equipment for the MICE needs to be purchased.
(3) Workstations and software systems are supplied at 50% discounts (half donated).
(4) Equipment has a useful life of 3-5 years and that replacement will be at least as expensive as the current price.

(5) Manufacturing capability is sufficient to support break-even operation at one shift per day and that sufficient market will exist for production within two years.

Our options. in order of increasing cost. are:

PROJECT 1
Fund the SMT Technician Training Center with the MICE location having a complete state-of-the-art production line and four regional centers with current equipment.
Initial Capital Cost:$1-1.5 Million (U.S.)
Yearly Operational Cost:$0.5 Million (U.S.)

PROJECT 2
Fund the PCB manufacturing capability and the MICE design center and the university participation.
Initial Capital Cost:$2-3 Million (U.S.)
Yearly Operational Cost:$1-1.5 Million (U.S.)

PROJECT 3
Fund the MICE to include the remaining options to operate as a comprehensive services incubator and as an inter-American training site.
Initial Capital Cost:$1-1.5 Million (U.S.)
Yearly operational Cost:$1-1.5 Million (U.S.)

Project 1 will provide an immediate benefit to the Mexican economy by supplying the critical technicians to transform the current manual assembly process to the SMT automation contract assembly that will dominate the requirements within the next two years.

Project 2 assumes that Project 1 is also undertaken and that the goal of Project 2 is to supply designs and manufacturing managers to support the maquiladora industries as well as its own electronics firms. Results will begin to appear in 3-5 years. University prepared students going through this program will be able to begin productive work almost immediately. After 3-5 years faculty and students will begin to turn out state-of-the-art designs and toward the end of the fifth year some initial products will begin to seek venture capital or license.

The PCB manufacturing could be deleted or delayed until a dry process is available. The SMT PCB boards for prototype could be farmed out to private facilities that could supply 3-4 week turnaround. The costs for Project 2 would be reduced by 50% if this were carried out.

Project 3 assumes that Projects 1 and 2 are undertaken. The clear desire for this project would be to put in place an incubator that would signal Mexico's desire to create a favorable environment for export. The goal would be to create significant job growth over a five to ten year period and an export product stream. The funding for some portions of Project 3 could come from Mexican national venture capital sources and by joint ventures of the industrial members in a fashion similar to the MCC. The remainder would come from international development sources

8.3 Summary

Clearly the Project 1 funds must be found if Mexico is to support her own national PCA's in making the transition to SMT assembly. The most likely sources are the World Bank and the Inter-American Development Bank. The transition will generate new jobs that will employ higher paying technicians but it will be at the expense of many more low paying entry level positions. The transition is inevitable and the attempt should be made to retrain the manual assemblers as manufacturing technicians whenever possible.

Both Projects 2 and 3 are required if the Mexican engineering graduates are to have a long term future. Two schools, the Advanced Center for Research and Education of Ensenada and the Center for Advanced Research and Studies of the National Polytechnical Institute, have already expressed significant interest in participating. The investment, if done with appropriate public relations and support of the private industrial leaders and venture capitalists, will spark the imagination and the drive of thousands of entrepreneurs. The total project will require some patience since new products and high tech ventures are risky under ideal conditions. The key to long term success will be to learn from every failure, to reduce start-up stress, and to encourage innovation and invention.

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