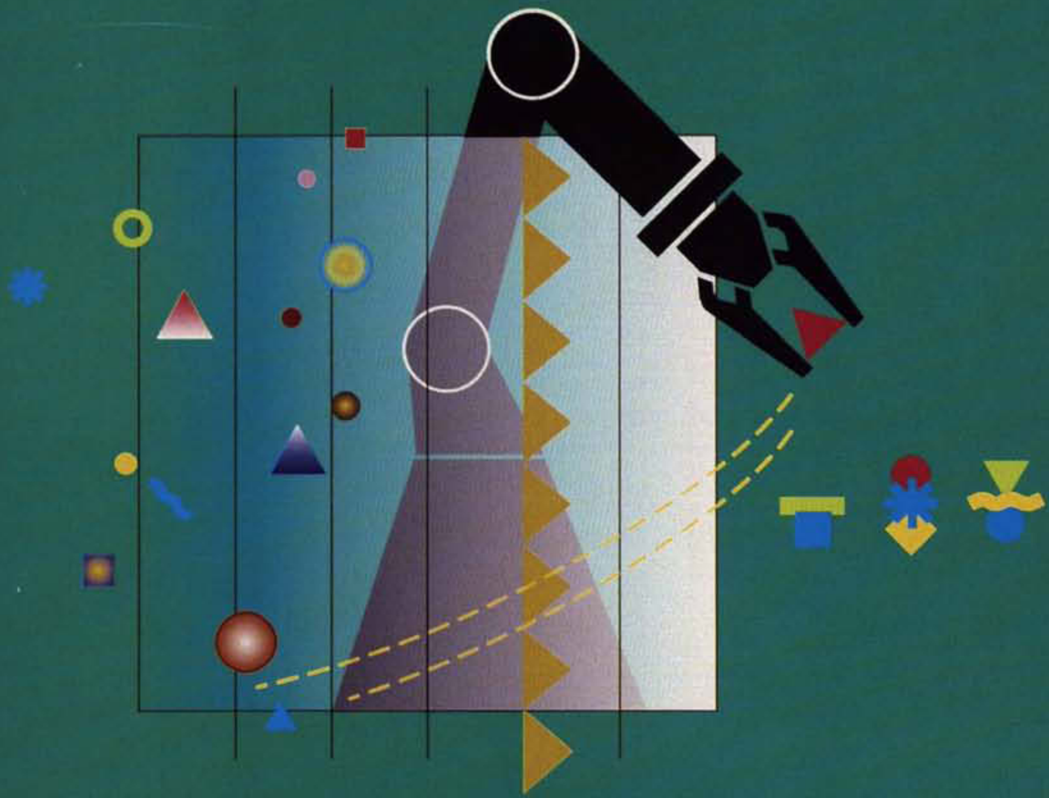
Industry, Science and Technology Canada

Industrie, Sciences et Technologie Canada



# Advanced Manufacturing Technologies



Canada

4

YEAR 2000

ADVANCED MANUFACTURING TECHNOLOGIES

# THE YEAR 2000



INDUSTRY, SCIENCE AND TECHNOLOGY CANADA

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## SECTION 5

# 1.0 EXECUTIVE SUMMARY

## 1.1 INTERNATIONAL TRENDS AND STRATEGIC ISSUES

### 1.1.1 COMPETITIVE FACTORS

World-class manufacturing is the basis of competition in the 1990s. In addition to advanced manufacturing technologies it involves management and people concepts including concurrent engineering, just-in-time (JIT) production, flexible manufacturing, supplier partnerships, employee empowerment and total quality management.

Customers are demanding world-class supplier performance in terms of products, service and support They are learning to look for the "best value", defined in terms of quality, variety, price and timeliness. Despite conventional wisdom that "you get what you pay for", customers are finding that they can often get high quality, wide variety, and quick delivery at reasonable prices.

World-class manufacturers are developing global reach. Trade barriers are diminishing. In general, world markets are open to "best value" suppliers. There are global opportunities for world-class manufacturers and home markets are threatened for those that don't measure up to that standard.

### 1.1.2 ECONOMIC PATTERNS

World economic growth in the 1990s is expected to approximate that of the 1980s at about a 2.8% annual rate.

North America buys more than half of the AMT sold in the world at 53% in 1990, down from 60% in 1985. North American market growth over the past five years has been at 15% per annum while growth in Asia and Europe has been greater than 20% annually. The rest of the world grew at 25% per year from a very small base. Manufacturing investment in Europe in the 1990s will be driven by the opening of the East Bloc, EC92, and an aging labour force in the west.

Switzerland, U.S. and Canada are the top three countries in terms of worker productivity but Japan is closing the gap and the developing Asian nations are improving fast. Fundamental education is a problem in North America with U.S. and Canadian high school students scoring far lower on standard math tests than their counterparts in Asia and Europe

### 1.1.3 TECHNOLOGY TRENDS

Computing Technologies are a critical element in AMT. Artificial intelligence (AI) is becoming pervasive in advanced software. High speed computing architectures are becoming more prevalent. Integrated circuits (ICs) are advancing on all fronts (materials, processes, and architectures). Digital imaging will impact displays, image processing, and data input.

A key factor in reaping the benefits from new computing technologies is standards. Compatibility and connectability have become chief priorities of the user. Standards are a prerequisite to achieving these goals. The development and adoption of standards will play a critical role in utilizing the full potential of the advances in computing expected during the next ten years. These standards will enable computing and communications to become a utility that is readily available to users of AMT equipment at multiple locations, much like electric power or telephone service.

Smart sensors will become "brilliant" and more important to AMT. There is a continuing trend toward putting more processor functions onto sensor chips. Optoelectronic sensors are emerging that are fast and accurate and can withstand manufacturing environments. Discrete manufacturing is moving toward "process type" quality control techniques requiring sensor inputs for continuous machine status monitoring and control.

Advanced materials (e.g., high temperature ceramics, superconductors, and composites) will continue to impact manufacturing, both in terms of their use in AMT equipment and relative to the machinery and equipment needed to work the materials

Technology transfer works best on a one-to-one, experiential basis. Classroom and videotape programs are not as effective. Apprenticeship programs have been used in Germany and Sweden to promote widespread application of new technologies. Japanese joint development programs have proven to be effective tools for technology diffusion. The Japanese are also proficient at spreading technology to small plants.

### 1.1.4 MANAGEMENT ISSUES

Manufacturing management in North American apparently lacks an understanding of the competitive potential of world-class manufacturing and the related opportunities and threats. Management is often reluctant to apply AMT. It is not necessary to "bet the company"; low investment techniques (e.g., JIT) should be implemented first to get the benefits of inventory and cost reductions. Refusal to move ahead is more certainly fatal than potential mis-investment.

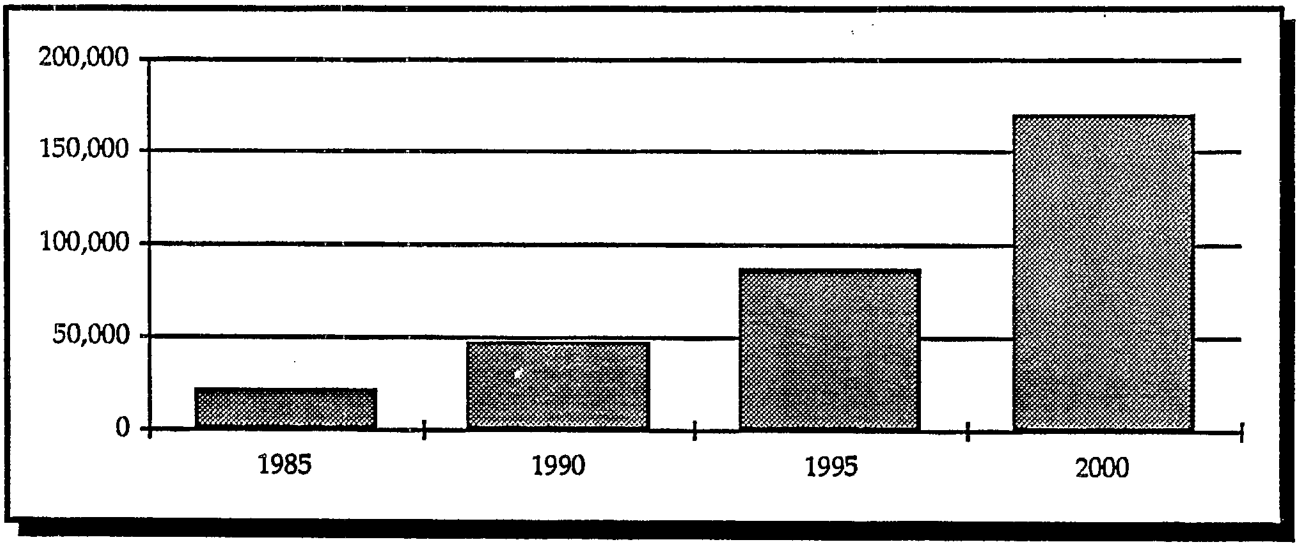
One basic tenet of competing on the strength of manufacturing capability is that a long term commitment to the business is required.

Managing new and changing business relationships will be a key factor. Understanding customer needs requires continuing detailed assessment of a broad set of needs and desires. Suppliers must be treated as partners, not adversaries. Employee teams must be empowered to make decisions. Investors and lenders must be convinced to take a long view. Alliances can be used to fill strategic product or market gaps. AMT users and suppliers must both learn to use system integrators effectively.

## 1.2 AMT MARKET FORECAST

Worldwide, purchases of AMT products are growing rapidly. Advanced manufacturing technology is one of the most dynamic areas of industrial investment in all regions of the world. From purchases of just over $20 billion (US) in 1985, the market is expected to expand to over $170 billion by the turn of the century. In the year 2000, total purchases of advanced manufacturing technology products and services are forecasted to be eight and a half times their 1985 level, having expanded at a compound annual rate of 15% over the last decade of the Twentieth century. From 1985 to 1990, purchases of AMT products and services are estimated to have grown at 18% annually. Although slowing somewhat, the growth rate is forecast to remain in double digits through the 1990s.

**CHART 1A**
**WORLDWIDE PURCHASES OF AMT PRODUCTS AND SERVICES**
**1985-2000**
**(In Millions of US Dollars)**




Source: Table 4-1

## 1.3 THE CANADIAN PERSPECTIVE

### 1.3.1 CANADIAN AMT INVESTMENT

Canadian manufacturers have invested substantially in AMT. However, their investment growth rate considerably lags that of their U.S., European, and Asian competitors. The trends are disturbing.

Canadian users of AMT are increasing their purchases at a much lower rate than the other major regions of the world. Within North America, Canada's growth rate is 11.9% and the U.S.'s is 15.3%. The overall difference is greatest when comparing Canada with Europe and Asia, where growth rates range in the upper teens and low twenties. Labour costs in Canada are high. Productivity must also be high for manufacturers to be competitive internationally. Although Canada's worker productivity is still among the highest in the world, Canada's productivity growth has become the slowest among the seven major industrialized nations. Japan may already have overtaken Canada's third place position in worker productivity and several other countries could pass Canada during the 1990s. Canadian manufacturers may find themselves at a considerable competitive disadvantage by the year 2000.

### 1.3.2 CANADIAN STRENGTHS AND WEAKNESSES

Canada has a major open market at its doorstep and successful Canadian companies consider the United States as part of their primary marketplace. In fact, some Canadian AMT suppliers have found acceptance in the U.S. market in advance of selling their products or services in Canada.

Some Canadian manufacturers of such diverse products as sportswear, lumber, integrated circuits, injection molding machines and automotive parts, as well as AMT suppliers, are competitive on a global basis and recognized outside of Canada as quality suppliers. Additionally, there is evidence that Canadians are viewed by offshore companies as easier to work with and less aggressive than Americans. Canadians have the vision, technological prowess and entrepreneurial spirit to start new businesses. Additionally, there is external recognition of Canada as possessing a skilled and cooperative labour force. Canada's extensive natural resources can contribute to its ability to be world-class as an AMT producer as those industries demand world-class performance from their suppliers.

Although there are disadvantages to manufacturing in Canada and to being in the AMT business from a Canadian base, none appear to be so serious that they are insurmountable barriers.

Disadvantages related to a small home market disappear when the home market is defined as North America. The inclusion of the United States as part of the home market provides access not only to a large consumption area but to technology as well. The computer industry and semiconductor industry in the U.S. are as geographically accessible to the major industrial centres in Canada as they are to many sections of the U.S.

The cost of capital in Canada is high, putting Canadian companies at a competitive disadvantage. Venture capital firms in Canada have generally been more conservative than those in the U.S. In today's environment, it is even more difficult to acquire venture capital on reasonable terms. Partially offsetting the difficulties in raising private sector funds is the availability of financial assistance from various Government programs, including provincial programs, however in recent years these programs have been cutback substantially.

Canada's labour rates are high. However, in most manufacturing plants the cost of direct labour runs between 5% and 10% of total costs, so the cost of labour may not be as much of a disadvantage as it appears to be. Generally, Canadian companies do not attempt to compete in markets where a low labour cost factor is a requirement. By focusing on high value-added products Canadian companies can offset labour cost rates via an emphasis on quality and productivity.

### 1.3.3 MARKET OPPORTUNITIES AND THREATS FOR CANADIAN COMPANIES

Although the U.S. market has always been reasonably open to Canadians, the FTA enhances that. New market opportunities are developing on other continents as well. Europe is going to be more open as a result of EC92. The opening of the East Bloc and an aging labour force should drive the growth of AMT and other manufactured products. Except for Germany, EC countries are relatively receptive to North American suppliers. The emerging economies of Southeast Asia have needs in terms of AMT and those requirements, which will be increasing throughout the decade, will be filled by products and systems offering the best value, from whatever country or continent they may originate.

The FTA is a double-edged sword. An open North American marketplace offers the potential of increased business for Canadian manufacturers, however, it also represents a serious threat when coupled with a declining relative level of productivity.

Canadian manufacturers have the opportunity to turn the productivity curve upward through the use of advanced manufacturing techniques and technologies, coupled with effective human resource programs.

## 1.4 RECOMMENDATIONS

### 1.4.1 RECOMMENDED ACTIONS FOR AMT USERS

❶ Define the Home Market to Include all of North America

If Canadian companies don't take advantage of their status as a partner in the world's largest market, then they will experience only the negative effects of FTA as they lose large portions of their domestic market to aggressive U.S. competitors.

❷ Adopt a Global Perspective

Canadian manufacturers may or may not develop a strategy to operate globally; but their scanning horizons must be global. Global scanning is needed to stay abreast of technical, competitive, and economic developments that could represent opportunities or threats.

❸ Analyze the Competitive Environment

Determining who the competitors are and are likely to be on a worldwide basis is a necessary step. This includes understanding competitors' product lines, manufacturing methods, marketing strategies, distribution channels, pricing policies, territorial strengths as well as growth patterns and goals.

❹ Assess Customer Needs and Desires

Understanding what customers expect and what they are getting from their suppliers is imperative to developing a manufacturing strategy including the use of AMT. This includes competitors' customers. Information needed includes expectations of quality, price, variety, service and delivery as well as levels of satisfaction with current suppliers.

❺ Forecast Technology Changes

Technology development must be monitored regularly on a global basis; the next generation of product or process technology may come from any where in the world.

❻ Conduct a Critical Self Evaluation

How does your company stack up against competitors in terms of satisfying critical customer requirements? Are your products as technologically advanced as those of the other suppliers (whether or not they are currently competitors in your market)? How well prepared are you for the next wave of technological product advancements? What is your relative status in terms of process technology? Are you as productive as the best in the world? Are you as customer oriented, as timely, as quality conscious? Does your product mix meet customer needs? Are your distribution channels serving customers as completely and conscientiously as you expect? What are your critical core competencies and how do they differ from those of the other suppliers? What are your relative strengths and weaknesses? Where and what are your opportunities and threats?

❼ Develop Target Market Plan

A marketing strategy focused on specific geographic and industry targets should be developed based on the evaluation of customer needs as well as competitive strengths, weaknesses, opportunities and threats. The marketing plan defines key manufacturing issues including the product variety and volumes to be produced, thus defining manufacturing strategy and the application of AMT.

❽ Select and Prepare Distribution Channels

The correct form of distribution is a function of several variables. The variables include the territory to be covered, the technical complexity of the product being sold, the size of the average sale or the annual sales value of the average customer, the technical competence of the customer, the nature of the customer (e.g., end-user vs. reseller), the size of the market in the territory being covered, local buying preferences, the competitive environment, and the relative market position of the supplier company. An analysis of the variables is required to determine the appropriate channel. The nature of the distribution channel may suggest benefits that can be designed and built into the product. Training is a key issue, both in terms of finding a channel with people technically capable of being trained in the product line and making distribution channel personnel available for training.

⑨ Study World-Class Manufacturing

From the CEO down, the company must learn what it takes to be world-class. Top executives must be deeply involved; those who don't get involved don't understand the stakes. Visits to world-class manufacturing plants with similar processes and problems are important to develop ideas and to benefit from the experience of others. Employees, including top management, should take advantage of the several means available to learn about AMT applications; these include professional or trade association meetings, conferences and trade shows.

⑩ Strive for World-class Manufacturer Status

Implement a manufacturing program to meet the marketing plan, striving to meet or beat the best in the world. Establish benchmarks as to current standing as well as long and short-term goals based on the evaluations of customer needs and competitors' performance. The program should operate on three general levels of activity: Management Practices, Human Resources, Application of AMT.

### 1.4.2 CAUTIONARY POINTS FOR PROSPECTIVE AMT USERS

- Don't try to automate what doesn't work well manually
- Don't attempt to apply AMT to an overly complex product design; first, redesign to simplify and standardize components
- Don't apply flexible automation techniques to high volume requirements
- Don't bite off more than you can chew; start with relatively simple projects
- Don't deal with more variables than necessary at one time; if a project can be implemented in stages, get stage one working before moving ahead with stage two

- Don't attempt to implement AMT without employee participation and cooperation at all levels and in all affected departments

- Don't skimp on employee training; make sure everyone gets sufficient training, including operators, supervisors and maintenance personnel

- Don't wait too long to get started; chances are that some competitor somewhere already has

### 1.4.3 STRATEGIES FOR AMT SUPPLIERS

❶ Define the Home Market to Include all of North America

As with AMT users, Canadian AMT suppliers must target the U.S. as part of their home market. This will be necessary to achieve a critical mass of sales volume, to toughen their competitive skills, to expand their application base, and to gain an additional window on technical trends.

❷ Adopt a Global Perspective

Canadian AMT suppliers may or may not decide to operate globally, but their scanning horizons must be global. A global technology and market information base must be actively developed and managed. This involves participation in standard-setting bodies as well as active participation in industry associations and international trade fairs. Periodic market research must be conducted in key markets in order to identify trends in competitive position and customer needs and requirements.

❸ Use Regional Roll-out to Achieve Direct Selling in North America

In the long run a direct sales force targeting key customers and industries will be necessary for sustained competitive growth in several product classes. Otherwise, the supplier becomes virtually a private labeler for the entity controlling the marketing and sales function. North America is a large continent with many pockets of industrial activity. It will likely not be economically feasible for smaller suppliers to institute a direct sales force in all areas simultaneously. Thus, a regional roll-out (i.e., establishing a direct sales presence in one or two markets at a time, leading to complete geographical coverage over a period of several years) may be the best way to focus limited resources, establish a direct salesforce and penetrate the market.

❹ Leverage Home Market Customers into Global Accounts

Canadian AMT suppliers can leverage their North American customer base to help reach global markets. Valued suppliers can build on their track record with North American customers to identify overseas opportunities with respect to timing and project scope, establish key buyer contacts and introductions, and determine important purchase criteria. A strategic effort is needed to identify, understand, track, and market these global sales opportunities.

❺ Address The Western European Market Excluding Germany

The several forces driving European countries to invest in AMT make this an attractive market. Within Europe, Canadian companies should concentrate on markets in the U.K., France, Italy and Spain, which are generally open to outsiders. Germany is the largest, single country market in Europe, but is generally inhospitable to outside sources of supply, especially with regard to technical products. Germany has made a major commitment to its eastern sector which may divert the resouces of world-class German suppliers from competing as effectively in other established markets within Europe.

❻ Use Reciprocal Partnerships to Penetrate Asian Markets

Canadian companies possess valuable access to the North American market. The Asian markets, especially Japan, are best penetrated via marketing partnerships. To the extent possible, these relationships should be chosen in such a way that they also provide complementary product and technology for sale in the North American market. In addition to the obvious sales revenue impact of this strategy, it will provide a Canadian company with leverage on its partner, i.e., each side is hostage to the good will and best efforts of the other.

❼ Focus on Packaged Software Products for Standard Platforms

Standard computer hardware platforms and standard operating systems represent a major opportunity for growth by AMT software suppliers. Software offered in a transportable form (e.g., Unix) will reach several times the number of customers as software developed for a proprietary computer. AMT software suppliers that wish to expand outside North America should avoid support-intensive applications. They must develop software which is internally complete.

❽ Offer Specialized Machine Controls Based on Advanced Sensors

New sensor technologies offer opportunities that can be capitalized upon by Canadian AMT suppliers who posess in-depth understanding of machines and processes. Improved sensors and related controls are needed in each of the machinery product categories. Successful product development will rely on the convergence of sensor technology with machine technology. The goal will be to incorporate sensors to develop machines that achieve zero defects on an inherent quality basis, i.e., make products so reliably that no inspection or test is required.

❾ Build Training Into The Product

A breakthrough is needed with respect to AMT training. Most AMT products include a computer or controller with one or more processors that can be programmed for multiple functions. The opportunity exists, using this processing power, to build the training into the product. To be most effective the training approach should be interactive and allow the trainee to move at his/her own speed.

❿ Develop Telecomputer Product Support Systems

Canadian AMT suppliers should take advantage of telecomputer technology to establish systems linking designers, application engineers, service support staff, sales force, marketing partners and customers around the world. This type of approach has proven to be a powerful competitive tool for those who have implemented it. It can be used to support sales staff, as well as to provide customer application support, maintenance information, and software product upgrades.

# 2.0 INTRODUCTION

## 2.1 BACKGROUND

Industry, Science and Technology Canada (ISTC) has undertaken a targeted initiative to develop the Canadian advanced manufacturing technologies (AMT) sector. For the purposes of this project, AMT is considered to include factory automation equipment and software used in discrete manufacturing applications.

The study phase of this effort involves detailed analysis of market and technology trends, profiles of sector companies, strategic analysis, and consultations with companies to identify opportunities and means to promote sector growth. This study forms part of the ISTC initiative.

## 2.2 PROJECT OBJECTIVES

### 2.2.1 MAJOR OBJECTIVES

The two major objectives of this report are to:

- Identify opportunities for small and medium-sized Canadian supplier and user companies within the Advanced Manufacturing Technologies (AMT) market as it will exist in the year 2000

- Recommend strategic approaches by which Canadian AMT suppliers and users may capitalize on those opportunities

### 2.2.2 SUBSIDIARY OBJECTIVES

A number of subsidiary objectives underlie the primary objectives:

- Interpret current technology trends to predict the availability and acceptance of new AMT products and services in the year 2000, as well as identifying the principal sources of new technologies

- Analyze international political and economic patterns and forces to predict the state of the economies of the major regions and key areas within those regions for the year 2000

- Based on the projected technological and economic environment, forecast the market for AMT in 1995 and 2000 and analyze the growth patterns leading to that market forecast

- Characterize the AMT competitive environment as anticipated in the year 2000

- Identify projected weaknesses or gaps in the products or services being supplied to meet AMT requirements in 2000

- Determine areas of relative strength or competitive advantage exhibited by Canadian AMT product or service suppliers

- Identify product or service segments where Canadian AMT suppliers can be focused to fill a projected unmet need, resulting in areas of opportunity

- Develop a series of strategies by which these opportunity areas can be exploited by small to medium-sized Canadian companies

- Identify the resources and capabilities required for AMT producers to implement these strategies, including:

  - Human resources (education/training requirements)
  - Capital requirements
  - Distribution channel structure
  - Strategic alliances
  - Technologies to be mastered
  - Management techniques

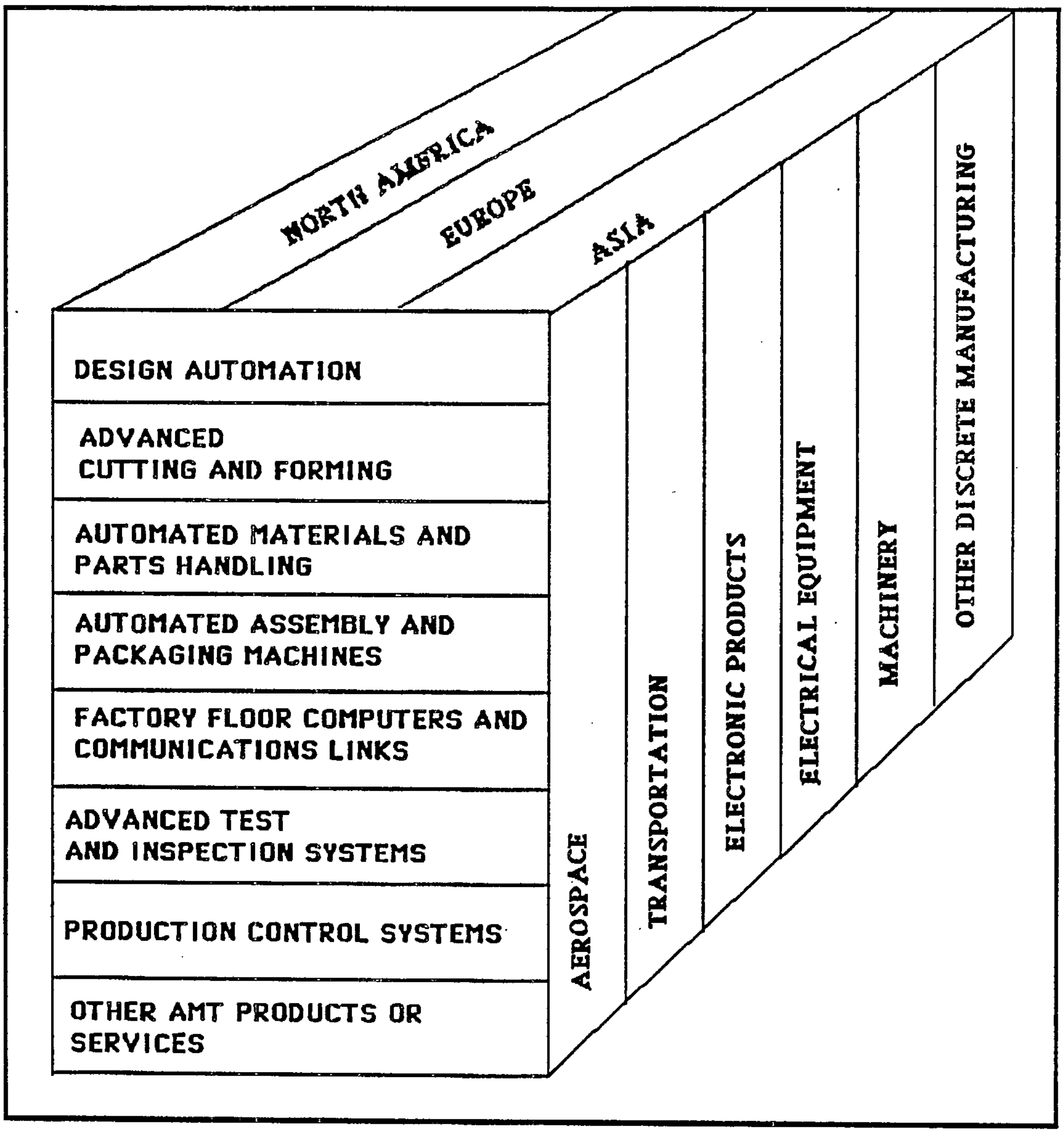
- Identify the resources and capabilities required for manufacturing users to be more competitive based on the state of AMT in 2000; identify potential problem areas in user implementation of AMT

## 2.3 PROJECT SCOPE

This study is defined along four dimensions: one dimension is product and service categories, the second is end-user industry, the third is geographic region and the fourth dimension is time. Market estimates are provided for 1990, forecasts and growth rates for 1995 and 2000.

A graphic presentation of main groupings covered is shown below.

**FIGURE 2A**
**MARKET BREAKDOWN FOR EACH REPORTED YEAR**



## 2.4 RESEARCH METHODOLOGY AND INFORMATION SOURCES

### 2.4.1 DATA COLLECTION

The research conducted for this project is of the nature of secondary data collection. The information used includes publications by governments, universities, trade organisations, corporate entities, economic planning bodies, standards development committees, market research firms and privately-funded research institutes. The bibliography (Appendix D) provides a detailed listing of the sources used in this project.

### 2.4.2 CORRESPONDENT RELATIONSHIPS

To supplement and complement the experience of the core project team, cooperation has been obtained from other research organisations that specialize in regional markets or specific product and service classes. These firms have provided their insights relative to the economic, product, technology, competitive and general market trends in the product classes, industry segments and geographic regions in which they conduct market research.

## 2.5 PROJECT STRUCTURE

The project has been divided into three phases:

| | |
|---|---|
| Phase 1 | Major International Trends and Strategic Issues |
| Phase 2 | Strategic Issues for Canadian AMT Producers and Users |
| Phase 3 | Market Characteristics and Specific Recommendations |

Reports on Phases 1 and 2 have previously been submitted. This Phase 3 Report is the final project report and summarizes the information and conclusions drawn from all three phases of activity.

## 2.6 REPORT ORGANISATION

Section 1 - Executive Summary

International trends are presented in summary form. The forecast of the AMT world market is presented for 1995 and 2000 and compared to market size in 1985 and1990. A view of the Canadian AMT market is given as well as a summary of strengths, weaknesses, opportunities and threats seen in viewing the Canadian market. Recommended strategies for AMT users and suppliers are enumerated as well as cautionary points for users contemplating AMT implementation.

Section 2 - Introduction

The background, objectives and scope of the, project are discussed, as well as the project structure and the research and data collection methods used. A general outline of the organisation of the report is also provided.

Section 3 - Driving and Inhibiting Forces

International competitive, economic, technological, and management trends are discussed and the strategic issues analyzed.

Section 4 - AMT Market Forecast

The market for AMT products is projected for 1995 and 2000. Projections by geographic region, product classification, and end-user industry are presented and discussed.

Section 5 - The Canadian Perspective

Canadian purchases of AMT products and services are examined and related to those in other industrial countries. Productivity growth in Canada is also reviewed and compared. The relative advantages of manufacturers and AMT suppliers operating in Canada are discussed.and related to the case studies performed in Phase 2 of the project and included in this report as Appendix C.

Section 6 - Strategies for AMT Users

Key strategic issues are recapped and strategic recomendations are made. Points of caution for companies considering the implementation of AMT are listed.

Section 7 - Strategies for AMT Suppliers

The competitive environment is reviewed from a product, market, and geographic perspective. Implementation issues are discussed and strategic recommendations for AMT suppliers are made.

Appendix A - Tables

This section contains tables relating to the market forecast detailed by product, end-user industry and geographic region.and covering the actual, estimated and projected markets for the years 1985, 1990, 1995, and 2000.

Appendix B - Standards

The international organisations which set standards for AMT equipment are listed.

Appendix C- Case Studies

The case studies are presented in a manner designed to view the strategies, actions and results of these companies so that patterns can be extracted and analyzed. Subject companies are compared and contrasted with competitors, where applicable.

Appendix D- Bibliogrophy

# 3.0 DRIVING AND INHIBITING FORCES

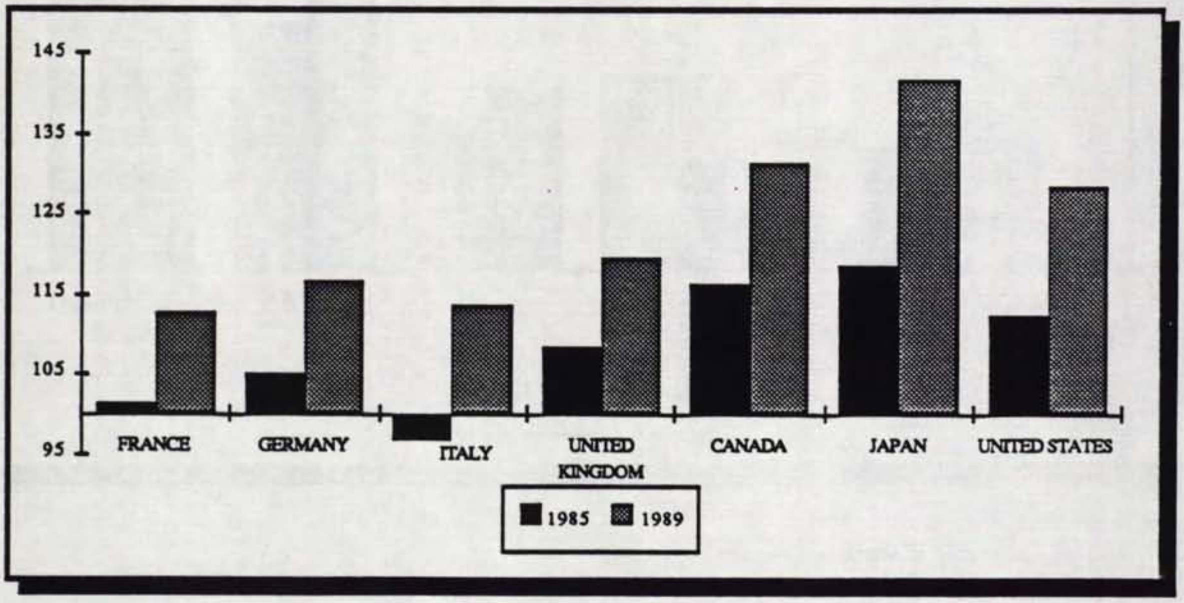
# 3.1 ECONOMIC CONDITIONS

## 3.1.1 ECONOMIC GROWTH PROSPECTS

Worldwide, prospects for growth in the developed nations during the 1990s are positive. There are, however, inhibiting forces in each of the regions that may temper predicted growth: threats of renewed inflation, potential restrictive trade practices, fewer entrants into the workforce, lower worker skill levels and uncertainty regarding energy availability and cost.

Chart 3A shows growth in industrial production for the last ten years in major OECD nations. Japan recorded the largest increase over the decade of the 1980s, with a 42% expansion of industrial production; Canada was second at 32% and the U.S. third at 29%. The four major European countries lagged, with overall growth of industrial production around 15%. It is widely expected that the ramifications of EC92, as well as the opening of the former East Bloc, will serve to stimulate European growth to the level of the U.S. and Japan during the next decade.

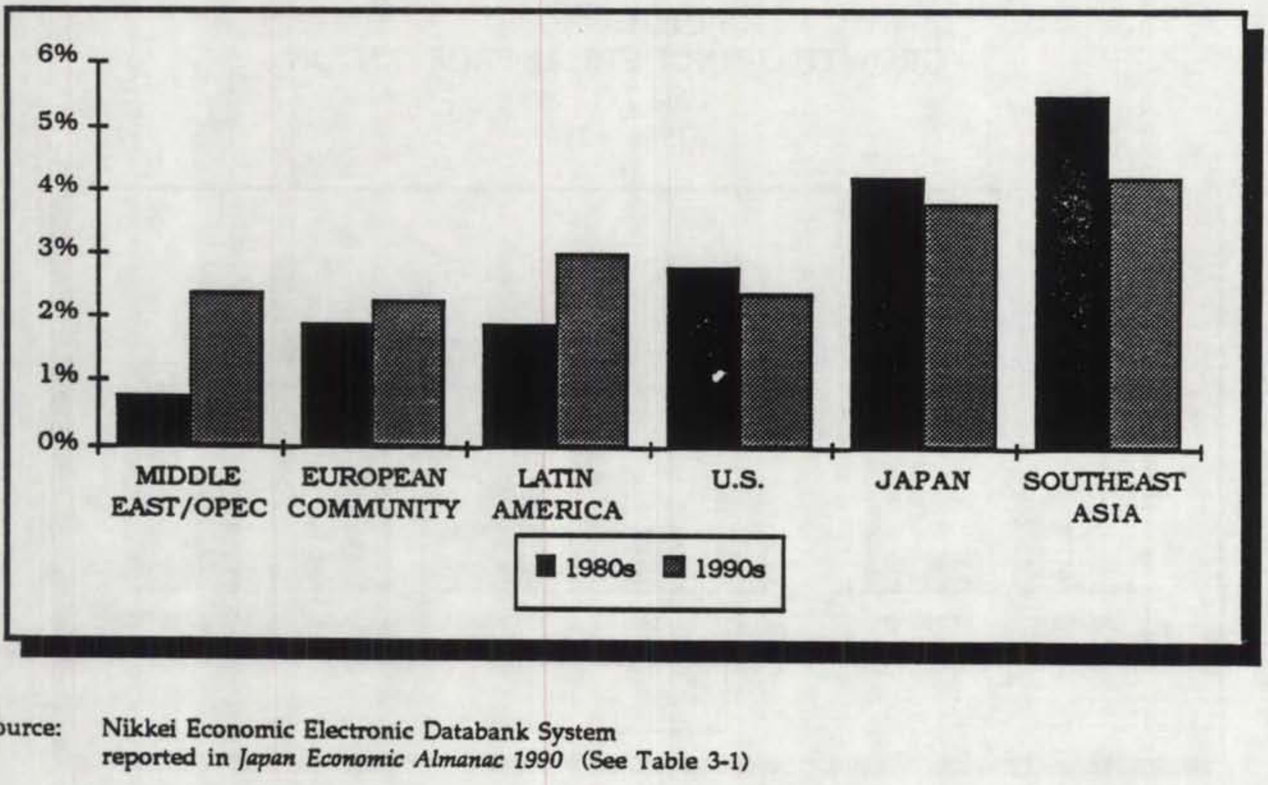
**CHART 3A**
**GROWTH OF INDUSTRIAL PRODUCTION**
**1980 TO 1989**
**(1980 = 100)**




Source: U.S. Department of Commerce

GNP growth forecasts through the year 2000, developed by Nikkei Economic Electronic Databank System (NEEDS), are shown below in Chart 3B and Table 3-1. The only developed region which will show faster growth in the next decade than in the last is Europe — from 1.9% per annum in the 1980s to 2.3% in the 1990s. While U.S. growth will decline in the 1990s, it is still expected to be slightly higher than that of Europe — 2.4% vs 2.3%. Japan's projected growth rate of 3.8% in the 1990s, even though declining from the 1980s, will still be more than 50% higher than in either the U.S. or Europe. Similarly, even though growth in the Southeast Asia countries will drop, they are still expected to grow at a greater than 4% per annum rate, the highest of any of the regions. Overall, NEEDS projects world GNP growth to be the same in the 1990s as in the 1980s, at 2.8%. Canada is not included in the NEEDS data as reported in the Japan Economic Almanac.

**CHART 3B**
**ANNUAL GNP GROWTH**
**1980s VS 1990s**
**SELECTED REGIONS**




Source: Nikkei Economic Electronic Databank System reported in *Japan Economic Almanac 1990* (See Table 3-1)

Inflation is expected to increase in Japan and the U.S. in the 1990s, compared with the 1980s. Nikkei forecasts that the U.S. will have the highest rate in the developed areas, at 4.5% per annum. Europe, on the other hand, is expected to experience a reduction in its wholesale price index, from 5.2% to 3.4%. This would still be higher than for Japan, which is projected at a relatively low 1.6% per annum. Inflation in Southeast Asia is forecasted at 4.6%, only slightly above the U.S. rate and not drastically above that projected for Europe.

## TABLE 3-1
### ANNUAL CHANGES IN GNP AND INFLATION
### 1980s VS 1990s
### SELECTED REGIONS

| | 1980-1990 Estimated | 1990-2000 Projected |
|---|---|---|
| JAPAN | | |
| REAL GNP | 4.20% | 3.80% |
| WHOLESALE PRICE INDEX | (1.10%) | 1.60% |
| UNITED STATES | | |
| REAL GNP | 2.80% | 2.40% |
| WHOLESALE PRICE INDEX | 2.50% | 4.50% |
| EUROPEAN COMMUNITY | | |
| REAL GDP | 1.90% | 2.30% |
| WHOLESALE PRICE INDEX | 5.20% | 3.40% |
| SOUTHEAST ASIA | | |
| REAL GDP | 5.50% | 4.20% |
| WHOLESALE PRICE INDEX | 5.80% | 4.60% |
| LATIN AMERICA | | |
| REAL GDP | 1.90% | 3.00% |
| WHOLESALE PRICE INDEX | 118.00% | 41.00% |
| MIDDLE EAST/OPEC | | |
| REAL GDP | 0.80% | 2.40% |
| WHOLESALE PRICE INDEX | 7.10% | 6.10% |
| WORLD (Aggregate of 8 regions) | | |
| REAL GDP | 2.80% | 2.80% |

Source: Nikkei Economic Electronic Databank System reported in *Japan Economic Almanac 1990*

Note: Gross National Product reported for Japan and the U.S.. Gross Domestic Product reported for the other countries.

The European Community will benefit from two strong growth generators — 1) the thaw in East-West relations resulting in strong demand from Eastern Europe to catch up to the West, and 2) the effect of market integration and lowering of barriers between the EC countries. Although North America and Asia can also expect to benefit from political and economic changes in the old Communist Bloc, the EC will likely get the largest share of the benefits.

Southeast Asia will consolidate and increase its economic clout as it continues to integrate into the world economy. As the economies of the "Four Tigers" (Korea, Taiwan, Singapore, and Hong Kong) mature, they will evidence more balanced economies, i.e., be less export-intensive and driven. GNP for the area is projected to increase from $523 billion in 1990 to $788 billion in 2000. It is expected that Southeast Asia's per capita GDP will overtake Latin America's early in the decade and outpace it through the 1990s.

Japan is expected to continue its long-run growth cycle. Annual real growth rates will fall from the 4.2% level in the 1980s to a still impressive 3.8% in the 1990s. Because its growth will be 50% higher than the rest of the developed world, Japan has the potential to carry even greater weight in international economic affairs. Japanese economic expansion will continue to be led by capital spending, growing at 5%, and personal consumption, growing at 4%. The public sector is also expected to contribute to demand as public spending increases are earmarked for social capital and welfare.

In North America, after a downturn in 1990 and 1991, the decade of the 1990s promises to be a period of economic expansion although not at the robust rates experienced in the 1980s. The overall Canadian economy is expected to expand over the period of 1990s. Projections call for growth to accelerate in 1992 after the period of business slowdown at the beginning of the decade. The OECD is predicting the downturn will continue in 1991 with negative growth while industrial productionin 1992 is projected to expand at the rate of 2.3%.

The U.S. can expect to experience continued growth into the 1990s, after a downturn at the beginning of the decade. The consensus is that the growth rate of the 1990s will lag that of the 1980s, hovering around 2.5%. Growth will be fueled by a higher savings rate from an aging population, higher investment spending, both public and private, and improved productivity.

Over the course of the 1980s, many U.S. manufacturing companies became acutely aware of off-shore competition and responded with intense restructuring. Also, there were a series of rolling recessions, where one industry or section of the country experienced recession while the country as a whole was enjoying the longest period of uninterrupted growth in peacetime. However, the pain produced a much more productive industrial sector. From 1980 to 1987, industrial productivity rose at an annual rate of 3.8%, up from the 1970s rate of 2.3%.

The major stumbling block to the above scenario is uncertainty in the price of oil. If oil is $40 a barrel, then economic growth projections for all regions will be curtailed, Japan most of all.

### 3.1.2 INVESTMENT AND PRODUCTIVITY

Most of the industrial nations made investments in both plant and equipment and research and development during the latter half of the 1980s that will have long-term payoffs. The magnitude and trend of these investments give a good indication of the countries that will continue to expand both production and productivity.

Among the developed countries, Canada lags in terms of commitment of resources to R&D. Unless Canadian manufacturers have an active program of licensing, as was the case with Japan for many years, they would appear to be positioning themselves poorly for the coming decade. In terms of R&D expenditures, Japan, Germany and the U.S. are the major investors, at 2.8%, 2.7% and 2.6% respectively of GNP. While it is not surprising to find the U.S. and Germany among the leaders in R&D, it is revealing that the Japanese are increasingly investing in basic and applied R&D and are not just sourcing their technology from overseas.

Capital investment patterns and R&D expenditures during the 1980s are shown for a number of countries in Table 3-2. Canada's fixed capital formation rate of 20.2% is on a par with that of key European countries and ahead of the U.S.'s rate of 17.7%. However, Canada had a negative rate of growth in fixed capital formation during the 1981-87 period, compared with positive increases in the U.S. and Europe. The dynamics of world competition are such that this trend must be reversed if Canada is to remain competitive.

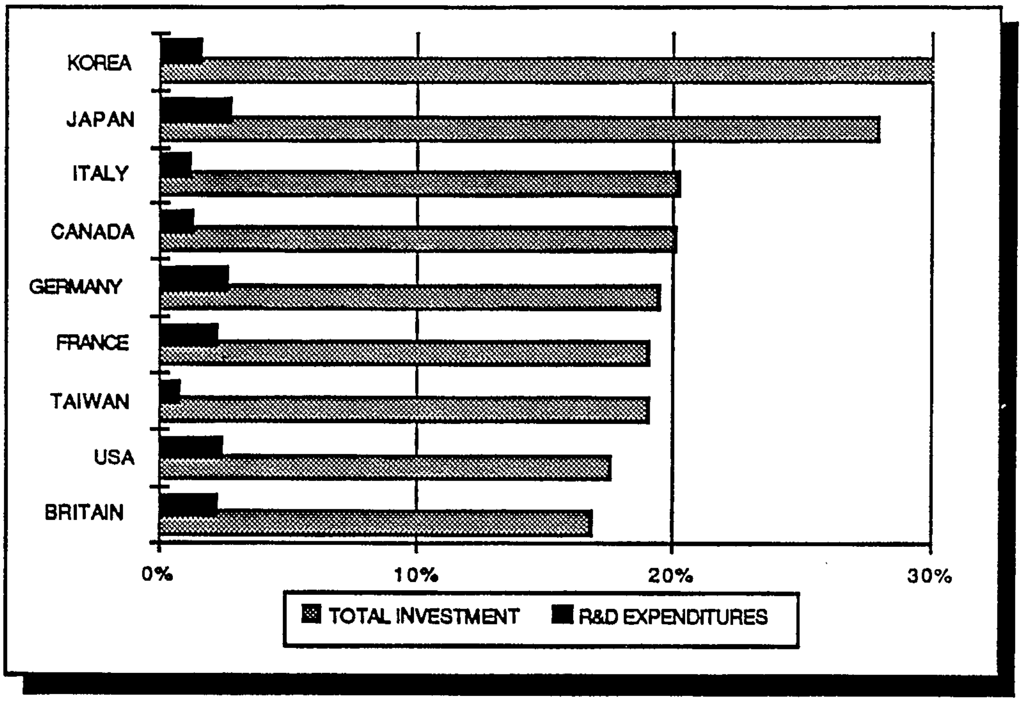
# TABLE 3-2
## CAPITAL INVESTMENTS AND RESEARCH & DEVELOPMENT EXPENDITURES

| | GROSS DOMESTIC INVESTMENT | TREND IN DOMESTIC INVESTMENT | TOTAL EXPENDITURE ON R&D |
|---|---|---|---|
| | Gross fixed capital formation as a % of GDP, 1985-1987 average | Annual compound real % change of gross capital formation, 1981-1987 | As a % of total GDP, 1986 |
| **EUROPE** | | | |
| AUSTRIA | 22.5% | 0.5% | 1.32% |
| BELGIUM/LUX | 15.7% | (0.3%) | 1.61% |
| DENMARK | 19.3% | 6.3% | 1.24% |
| FINLAND | 23.5% | 2.6% | 1.68% |
| FRANCE | 19.2% | (0.3%) | 2.30% |
| GERMANY | 19.5% | 0.3% | 2.71% |
| GREECE | 18.3% | (3.1%) | 0.33% |
| IRELAND | 18.5% | (7.0%) | 0.91% |
| ITALY | 20.3% | (.4%) | 1.30% |
| NETHERLANDS | 19.8% | 2.0% | 2.21% |
| NORWAY | 26.2% | 1.2% | 1.83% |
| PORTUGAL | 23.1% | (0.4%) | 0.44% |
| SPAIN | 19.6% | 1.9% | 0.57% |
| SWEDEN | 18.7% | 2.6% | 2.94% |
| SWITZERLAND | 24.4% | 3.4% | 2.88% |
| TURKEY | 22.7% | 9.0% | 0.54% |
| UNITED KINGDOM | 16.9% | 3.5% | 2.39% |
| **AMERICAS** | | | |
| BRAZIL | 18.3% | 4.3% | 0.64% |
| CANADA | 20.2% | (.7%) | 1.34% |
| MEXICO | 19.2% | (9.7%) | 0.55% |
| USA | 17.7% | 1.7% | 2.60% |
| **ASIA** | | | |
| AUSTRALIA | 24.3% | 1.2% | 1.27% |
| HONG KONG | 22.5% | 0.9% | na |
| INDIA | 20.7% | 6.1% | 0.79% |
| INDONESIA | 21.4% | 3.0% | 0.26% |
| JAPAN | 28.1% | 2.3% | 2.78% |
| KOREA | 30.3% | 11.5% | 1.76% |
| MALAYSIA | 26.4% | (4.4%) | na |
| NEW ZEALAND | 22.9% | (.2%) | 0.97% |
| SINGAPORE | 38.7% | 1.7% | 0.54% |
| TAIWAN | 19.1% | 2.5% | 0.86% |
| THAILAND | 21.4% | 2.0% | 0.33% |

Sources: International Monetary Fund, Washington, D.C.
Organization for Economic Cooperation and Development, Paris
United Nations, Geneva and New York

Chart 3C below shows rates of investment in the 1980s in the key OECD countries, as well as two of the so-called Asian Tigers. Korea and Japan are the clear leaders in investment, at 30% and 28% of GDP. The U.S. and the U.K. lag their key competitors in the critical area of investment. Canada and Italy are in the upper end of the middle rank of investing countries, marginally ahead of both Germany and France.

## CHART 3C
### CAPITAL INVESTMENTS AND R&D EXPENDITURES SELECTED NATIONS (Percent of GDP)




Source: Table 3-2

Note: Capital investment is an average 1985-1987.
R&D expenditures are 1986 figures.

Within Europe, there is a mixed picture of fixed capital formation. France and Italy both have capital formation rates around 20%. However, they have had negative growth in fixed capital formation over the 1981-87 period. In contrast, the U.K. had a very low level of fixed capital formation, but had a very fast growth rate of 3.5%. Germany had a solid fixed capital formation rate of 19.5% and a positive growth rate.

Among the less developed countries in Europe, Greece and Ireland show a poor pattern of both low fixed capital formation and negative compound growth rates. Portugal and Spain are in the upper band of both capital formation and real growth in investment; the latter should be an especially attractive AMT market in the 1990s. Turkey is very dynamic, although starting from a low base.

The Asian countries, with the exception of Taiwan and India, have been investing in gross fixed capital at a rate of more than 20% of GDP. Japan is in a class by itself in the developed world with very high capital formation rates. In 1989, for example, Japan invested more absolute dollars in industrial plant and equipment than did the U.S., even though the U.S. has twice the GNP.

The investment data show the extent to which management is willing to commit dollars to achieve competitive advantage. Equally important, although not quantifiable, is the willingness of firms to invest in the time and effort required to climb a learning curve to implement new methods. A willingness to invest usually means a country's manufacturers are dedicated to competing effectively with a world-class product in selected domestic and exporting industries.

Table 3-3 shows three indicators of a country's propensity to invest in advanced manufacturing technology — 1) the population of industrial robots, 2) the extent of automation in place, and 3) the amount of investment in computer services, in both absolute dollars and as a percent of gross domestic product. The extent of automation in place is indicated on a zero to one hundred scale, based on a survey of 1,937 business executives in 32 countries conducted in April 1989.

With respect to the use of industrial robots, the Japanese are an order of magnitude larger users than their developed country counterparts — 116,000 robots in place in 1986 compared with the next largest user, the U.S., with 25,000 units and the third largest user, Germany, with 12,400 units. Canadian manufacturers appear to lag substantially behind their European, U.S. and Japanese competitors in the use of robots. One must be careful in using these data, however, as they do not distinguish between programmable robots and pick-and-place fixed robots. Nonetheless, it does seem clear that the Japanese are far ahead of their competitors.

# TABLE 3-3
## AUTOMATION INVESTMENT
## SELECTED COUNTRIES

| | Industrial Robots (End 1986) | Automation Rating (1988) | Computer Services User Expenditures (1984) | |
|---|---|---|---|---|
| | Population | How sufficiently and appropriately automation is utilized in main sectors: 0=insufficiently to 100=fully utilized | In millions of US$ | As a % of GDP |
| **EUROPE** | | | | |
| AUSTRIA | 250 | 59.4 | 126 | 0.19% |
| BELGIUM/LUX | 1,050 | 65.0 | 310 | 0.40% |
| DENMARK | 210 | 65.4 | 311 | 0.56% |
| FINLAND | 336 | 65.0 | 243 | 0.48% |
| FRANCE | 5,270 | 60.3 | 1,830 | 0.37% |
| GERMANY | 12,400 | 64.4 | 1,370 | 0.22% |
| GREECE | na | 45.5 | na | na |
| IRELAND | na | 60.8 | 60 | 0.34% |
| ITALY | 5,000 | 56.7 | 906 | 0.26% |
| NETHERLANDS | 630 | 68.4 | 663 | 0.54% |
| NORWAY | na | 59.0 | 261 | 0.47% |
| PORTUGAL | na | 45.3 | 21 | 0.09% |
| SPAIN | 854 | 55.3 | 233 | 0.13% |
| SWEDEN | 2,383 | 75.2 | 386 | 0.39% |
| SWITZERLAND | 382 | 67.1 | 405 | 0.42% |
| TURKEY | na | 40.8 | na | na |
| UNITED KINGDOM | 3,683 | 59.7 | 1,490 | 0.31% |
| **AMERICAS** | | | | |
| BRAZIL | na | 40.0 | na | na |
| CANADA | 1,032 | 62.4 | na | na |
| MEXICO | na | 47.9 | na | na |
| USA | 25,000 | 63.2 | 17,860 | 0.49% |
| **ASIA** | | | | |
| AUSTRALIA | na | 56.7 | na | na |
| HONG KONG | na | 66.7 | na | na |
| INDIA | na | 38.3 | na | na |
| INDONESIA | na | 41.0 | na | na |
| JAPAN | 116,000 | 74.4 | na | na |
| KOREA | na | 49.4 | na | na |
| MALAYSIA | na | 60.0 | na | na |
| NEW ZEALAND | na | 49.2 | na | na |
| SINGAPORE | na | 72.8 | na | na |
| TAIWAN | na | 57.5 | na | na |
| THAILAND | na | 50.6 | na | na |

Sources: Japan Industrial Robot Association
*World Competitiveness Report, 1989*
Quantum Science Corporation

The data on extent of automation in 1988 also show that the Japanese are well ahead of their key competitors. Japan has a rating of 74.4 (on a 0-100 scale). Canadian manufacturers compare well with their U.S. and European counterparts along this subjective dimension, receiving a rating of 62.4, which is at the top end of a 55 to 65 rating for Europe and the U.S.

With respect to computerization, the U.S. is far ahead of its main European competitors in terms of both absolute expenditures and percentage of GNP. Interestingly, the smaller European countries are much more computerized in terms of expenditures as a percentage of GNP than are the big four of Germany, France, Italy and the U.K.

### 3.1.3 DEMOGRAPHICS AND THE LABOUR FORCE

Most of the OECD countries have experienced falling birth rates over the past half-century, resulting in an increased average age of the population and a decrease in the numbers of workers entering the workforce. Table 3-4 shows population levels and growth rates for the OECD countries and several developing countries.

Although all the developed countries are experiencing slow population growth, nowhere is the lack of replacement workers as worrisome as it is in Japan. With the economy growing and full employment, industrial automation has been used in Japan to replace workers. One major goal of Japanese implementors of flexible automation systems has been running a lights-out factory for two shifts a day. The ability to run without a workforce has not had the same urgency or payout in Europe or North America, due to slower economic growth rates and an inward flow of labour in the form of (legal) guest workers in Europe and (illegal) immigrants in the U.S.

Japan is trying a number of strategies to cope with a booming economy and a shortage of workers. Companies are recruiting both women and retired workers; less desirable jobs are going to illegal foreign workers (between 300,000 and 500,000 are estimated to be working in Japan); the country is embracing automation as a solution to the labour shortage. Although Japan faces the most severe shift in the percent of its population over 65, many other developed nations face the same population dynamics. As Europe's growth increases in the 1990s, labour shortages will become more visible. Some of the slack may be taken up by movement of labour from East Europe, although

# TABLE 3-4
## POPULATION SIZE AND GROWTH RATES
## SELECTED COUNTRIES
## 1987

| | Population Size | Population Growth | Youthful Population | Old Age Population |
|---|---|---|---|---|
| | Estimates in millions, mid-1987 | Annual compound percentage change 1981-1987 | Percentage of population under the age of 15 years, 1986 | Percentage of population over the age of 64 years, 1986 |
| EUROPE | | | | |
| AUSTRIA | 7.57 | 0.02 | 17.96 | 14.48 |
| BELGIUM/LUX | 10.29 | 0.11 | 18.57 | 13.89 |
| DENMARK | 5.13 | 0.03 | 18.26 | 15.18 |
| FINLAND | 4.93 | 0.45 | 19.35 | 12.56 |
| FRANCE | 55.63 | 0.44 | 21.04 | 13.06 |
| GERMANY | 61.17 | (0.14) | 14.95 | 14.95 |
| GREECE | 9.99 | 0.44 | 20.77 | 13.52 |
| IRELAND | 3.54 | 0.48 | 29.41 | 10.68 |
| ITALY | 57.33 | 0.24 | 19.01 | 13.06 |
| NETHERLANDS | 14.66 | 0.47 | 19.15 | 12.15 |
| NORWAY | 4.19 | 0.36 | 19.76 | 15.83 |
| PORTUGAL | 10.35 | 0.81 | 23.02 | 11.99 |
| SPAIN | 38.83 | 0.47 | 22.71 | 12.03 |
| SWEDEN | 8.40 | 0.16 | 18.06 | 17.37 |
| SWITZERLAND | 6.54 | 0.28 | 17.45 | 14.12 |
| TURKEY | 51.35 | 2.09 | 37.70 | na |
| UNITED KINGDOM | 56.89 | 0.16 | 19.05 | 15.29 |
| AMERICAS | | | | |
| BRAZIL | 141.45 | 2.22 | 36.16 | 4.38 |
| CANADA | 25.65 | 0.88 | 21.46 | 10.58 |
| MEXICO | 81.16 | 2.19 | 41.58 | 3.54 |
| USA | 243.77 | 0.97 | 21.94 | 11.80 |
| ASIA | | | | |
| AUSTRALIA | 16.25 | 1.43 | 23.38 | 10.24 |
| HONG KONG | 5.61 | 1.34 | 23.56 | 7.76 |
| INDIA | 781.37 | 2.09 | 36.34 | 4.36 |
| INDONESIA | 170.18 | 2.16 | 38.10 | 3.56 |
| JAPAN | 122.09 | 0.62 | 21.28 | 10.28 |
| KOREA | 42.08 | 1.40 | 30.96 | 4.08 |
| MALAYSIA | 16.53 | 2.65 | 37.38 | 3.82 |
| NEW ZEALAND | 3.28 | 0.78 | 23.76 | 10.48 |
| SINGAPORE | 2.61 | 1.13 | 24.16 | 5.28 |
| TAIWAN | 19.54 | 1.41 | 29.15 | 5.30 |
| THAILAND | 53.61 | 1.95 | 35.48 | 3.74 |

Source: International Monetary Fund, Washington
International Labor Statistics, Geneva

this does not appear too likely. In Britain, which had high rates of unemployment through the 1980s as it restructured its industrial base, unemployment in the growing Southeast has shrunk considerably and companies are faced with major labour shortages; at the same time there is large unemployment in the north. Within the EC, the issue of free movement of people starting in 1992 has yet to be resolved.

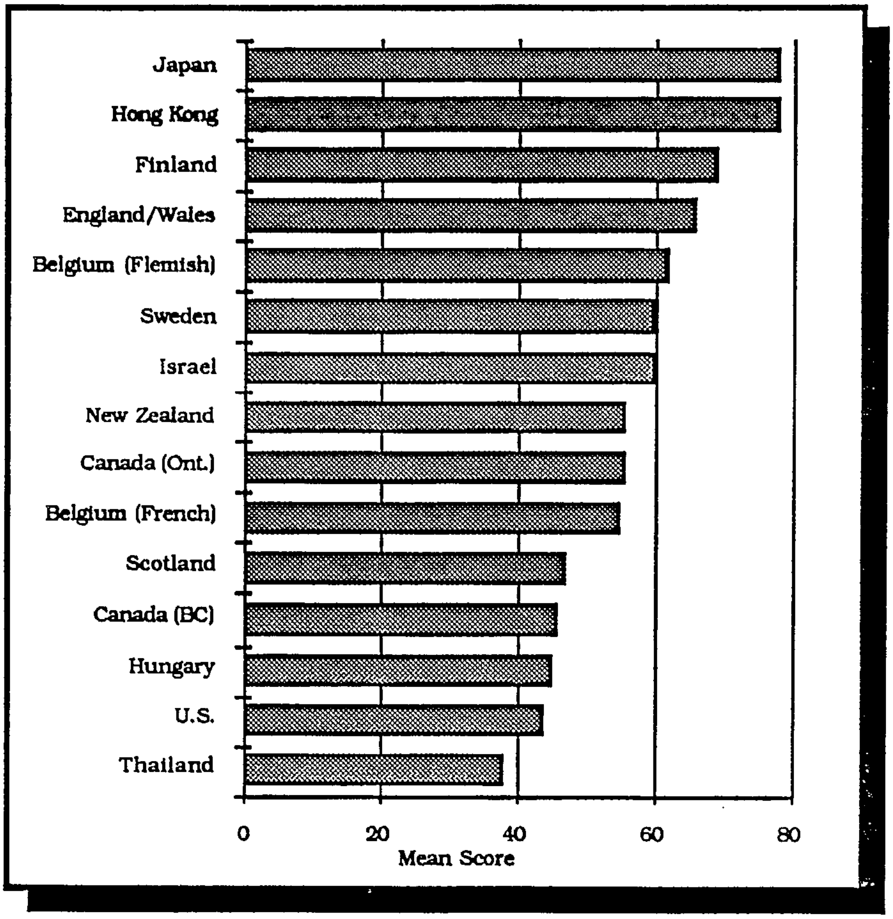
The major developed nations of Europe, faced with declining growth of the entering workforce and increased economic growth in the 1990s, will have to make some key decisions on strategy — encouraging guest workers and immigration; increasing worker productivity by substituting capital for labour; increasing the knowledge and skill level of the existing workforce; or some combination of these activities.

With respect to the workforce and automation, there is clear evidence that labour must be more educated, motivated and empowered in the automated factory than in the traditional workplace. A nation's educational policy and practices must reflect this new reality. Equally, management must be prepared to deal with a different mode of worker relations, as well as take responsibility for more sophisticated worker training and upgrading.

Both Japan and Germany appear to have a competitive edge with respect to the skill levels of their workforces. The Japanese educational system and continuing on-site education combine to develop factory workers who can run, maintain and troubleshoot automation equipment. The German educational system includes a three year technical apprenticeship, which significantly upgrades the skill level and professionalism of their workforce.

In both Canada and the U.S., employers are faced with high school graduates who are deficient in mathematic skills, which are basic to understanding and working with automation equipment. (See Chart 3D below.) This is a major public policy issue for both countries. As well, management in both countries will have to devote considerably more management time and capital resources to the issues of workforce upgrading and empowerment.

## CHART 3D
### TWELFTH GRADE ACHIEVEMENT SCORES IN ADVANCED ALGEBRA 1981-1982




Source: "The Underachieving Curriculum: Assessing U.S. School Mathematics From an International Perspective" appearing in *Making Things Better: Competing in Manufacturing*

The level and growth of productivity is a key indicator of country competitiveness. Table 3-5 lists several productivity measures for the OECD countries and eight developing countries. Although Canada has had a slow-down in its growth of capital formation, has a relatively low rate of R&D expenditures and has apparently less well educated workers, it still ranked quite high in 1985 with respect to employee productivity. There is cause for concern, however, in the trends. While Canada is still experiencing a real growth in productivity, its rate does not match those of Germany, Italy, Japan and the U.K. It is still running at a better rate than the U.S., its main trading partner.

# TABLE 3-5
## WORKER PRODUCTIVITY
## MID-1980s

| | Output Per Employee | Employee Productivity Trends | Employee Productivity |
|---|---|---|---|
| | GDP per employee, in US$, 1987 | Annual compound percentage change of real GDP per employee, 1979-1987 | Manufacturing value added per manufacturing worker, in US$, 1985 |
| EUROPE | | | |
| AUSTRIA | 35,655 | 0.46% | 20,041 |
| BELGIUM/LUX | 38,433 | 1.85% | 22,906 |
| DENMARK | 38,055 | 1.06% | 18,880 |
| FINLAND | 36,519 | 1.34% | 21,901 |
| FRANCE | 41,272 | 2.02% | 25,638 |
| GERMANY | 43,938 | 1.49% | 23,812 |
| GREECE | 13,115 | 0.07% | 8,027 |
| IRELAND | 27,057 | 2.38% | 3,437 |
| ITALY | 36,125 | 4.00% | 19,717 |
| NETHERLANDS | 40,596 | (0.23%) | 28,126 |
| NORWAY | 38,880 | 1.14% | 22,813 |
| PORTUGAL | 8,363 | 0.59% | na |
| SPAIN | 25,338 | 3.47% | 18,592 |
| SWEDEN | 36,674 | 1.09% | 21,568 |
| SWITZERLAND | 53,144 | 0.42% | 41,649 |
| TURKEY | 4,311 | 5.65% | 10,576 |
| UNITED KINGDOM | 26,795 | 1.77% | 18,191 |
| AMERICAS | | | |
| CANADA | 34,939 | 1.51% | 29,713 |
| USA | 39,882 | 0.66% | 38,478 |
| BRAZIL | 5,881 | (1.27%) | 7,403 |
| MEXICO | 4,611 | (3.23%) | na |
| ASIA | | | |
| AUSTRALIA | 27,397 | 0.68% | 27,700 |
| JAPAN | 40,339 | 2.86% | 27,195 |
| NEW ZEALAND | 22,838 | (0.71%) | 18,994 |
| HONG KONG | 17,203 | 4.49% | 7,335 |
| INDIA | 840 | 4.09% | 5,757 |
| INDONESIA | 1,019 | 1.85% | 1,975 |
| KOREA | 7,418 | 4.79% | 6,982 |
| MALAYSIA | 5,475 | 0.36% | na |
| SINGAPORE | 16,678 | 5.81% | 14,673 |
| TAIWAN | 11,798 | 4.46% | na |
| THAILAND | 1,766 | 2.08% | 6,078 |

Sources: International Monetary Fund, Washington
Organization for Economic Cooperation and Development, Paris
International Labor Statistics, Geneva

Within Europe, Germany and France have considerably higher worker productivity than do either Italy or the U.K. Switzerland has the highest productivity of the countries reported.

Although absolute levels of manufacturing productivity are quite low in the Four Tigers, their growth rates are extremely high and underlay the expected growth in their economies.

### 3.1.4 TRADE AND INVESTMENT ISSUES

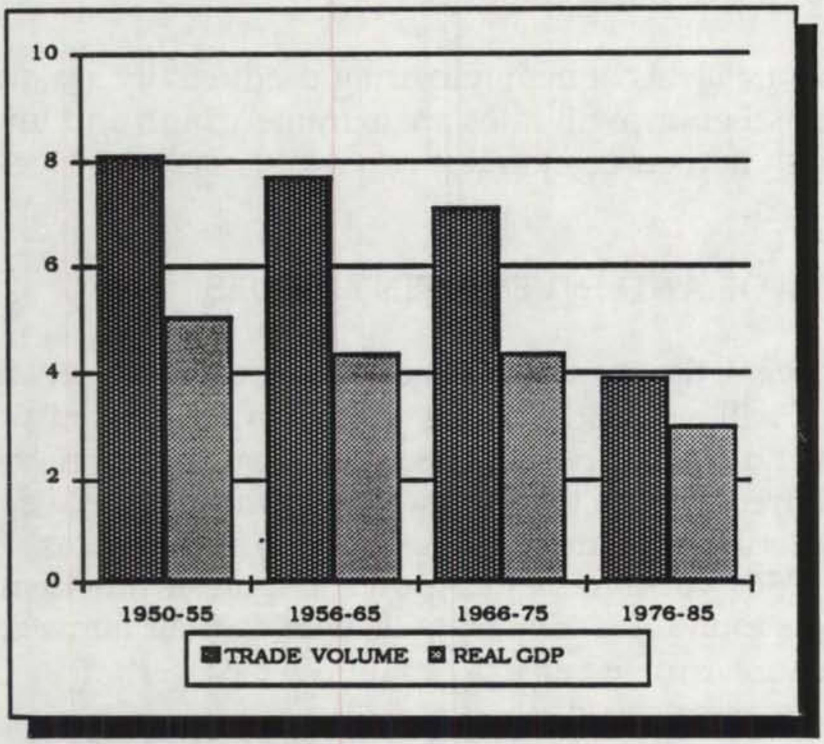
To many observers, the dominant concern over the next decade with regard to trade will be whether there will be an accelerated shift toward protectionism and trading blocs. This is a major issue, as there is little doubt that the free-world's GNP growth over the last three decades owes much to the international interchange of goods and services. For every decade since 1955, world trade has grown at a faster rate than has GDP as strong suppliers found lucrative markets outside their home countries; however, the gap narrowed sharply in the 1976-85 period.

World exports were nearly $3 trillion in 1989, of which approximately three-fourths were accounted for by the industrialized countries. A substantial portion of international trade occurs within regions. For example, over 50% of EC trade is intra-region. The comparable figure for North America is approximately 33% and for Asia/Pacific approximately 40%.

Developments in the following areas will have considerable impact on the trade and investment patterns of AMT suppliers and users:

- Uruguay round of GATT negotiations
- Development of a North American free trade zone
- Europe 1992 — the integrated market
- Japanese trade and investment policies.

## CHART 3E
### WORLD TRADE AND OUTPUT
### ANNUAL AVERAGE % CHANGE




Source: *The Economist*, September 22, 1990

### 3.1.4.1 GATT Negotiations and Free Trade

The current round of trade talks under GATT auspices, started in 1986 in Uruguay, ended in disarray in December 1990. The GATT framework has served the world well in breaking down trade barriers and serving as a forum to adjudicate trade disputes. There is now considerable concern as to whether GATT will be a viable vehicle for the 1990s, especially in the areas of farm policies, trade in services, and intellectual property rights.

In recent years, there has been a marked tendency for key trading countries to approach trade policy on a bilateral basis, focusing on specific products and trading partners. The U.S., which has historically been the developed country most committed to multilateral free trade, has become increasingly aggressive in its trade policy, as seen in the development of bilateral agreements to stanch a flood of imports. Additionally, the U.S. has recently moved to targeting national trade and investment policy issues. The most noticeable recent example of this approach is the Structural Impediments Initiative (SII) talks between the U.S. and Japan.

The issue on which the Uruguay GATT round foundered was the U.S.-led insistence on an agreement which would significantly change the EC's farm policy. The major agricultural exporting countries, including Canada, were demanding that the EC lower its barriers to non-EC farm products and cut its export subsidy programs, positions which the EC strongly opposed and eventually rejected. At this point, all negotiations within the Uruguay round have come to a halt. There does not appear to be a clear route out of the impasse. Many observers are concerned that the world could see a trend toward highly protectionist trading blocs.

#### 3.1.4.2 Trade and Investment: A Continuum

There is a range of vehicles used by corporations to penetrate foreign markets — exports, technology licensing, joint ventures/strategic alliances, and direct investment. Each has its own costs and benefits, at any one point in time, to both the countries and the companies involved.

Companies tend to look first toward exports as a way to leverage their product and technology capabilities, i.e., expanding geographically. For small and medium-sized companies, unless they are possessed of highly differentiated and demanded products or technology, a substantial effort is required to identify and open new market areas. At times there are tariff barriers, at other times, the need to hurdle non-tariff barriers such as government or industry standards and testing (which can be and have been quite effective in keeping out foreign entrants) and at other times, the usual business problems of ensuring the product has the appropriate features, good distribution and solid service in the targeted country.

Trade barriers are often imposed by governments in industries that are employment, defense, or infant industry sensitive. In some cases, governments force quotas on supplying countries, for example, the Japanese voluntary export restraint on cars sold into the U.S.

Companies often do an end-run around trade barriers by establishing production operations in the former export market. Usually, there is pressure on the direct investor to have substantial value added, i.e., not be just an assembler of low tariff components. The Japanese automotive manufacturers are a good example in recent years of direct investment as a means of maintaining and increasing market share via local manufacture. This direct investment approach is fairly well established in the North American market and is now starting to take place in the EC as the Japanese have established a U.K. beachhead.

The economic policy case for and against direct investment is complicated and has any number of emotional overtones. In the 1960s, Jean Jacques Servan-Schreiber wrote a best seller predicting the demise of European companies at the hands of their much stronger U.S. competitors. Canada, faced with the dominating power of the U.S., imposed stringent controls on direct foreign investment during the Trudeau years. The U.S. has recently reacted very strongly on an emotional level to highly visible Japanese acquisitions of American icons, for example, Rockefeller Center. The Japanese, not surprisingly, tend to be among the world's leaders in bureaucratically keeping out foreign direct investors. For the most part, the North American and European markets are open to direct investment. Only the Japanese market in the industrial world still retains a mercantilist approach to international business flows.

TABLE 3-6
GLOBAL STOCK OF FOREIGN DIRECT INVESTMENT

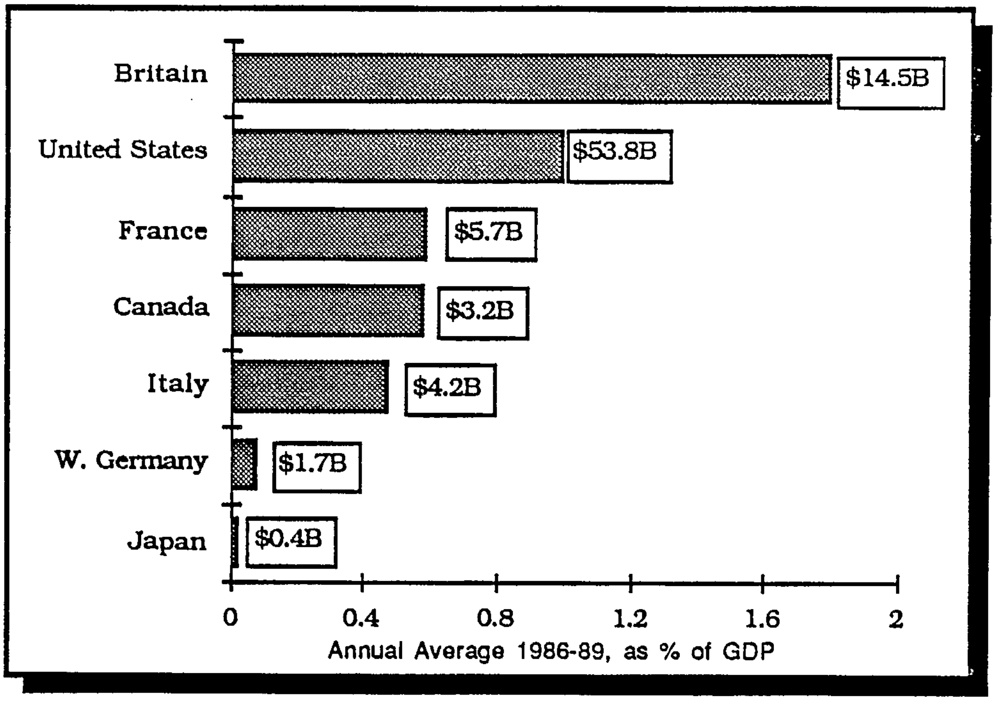
| | 1986 | | 1987 | |
|---|---|---|---|---|
| | $B | % | $B | % |
| United States | $259.6 | 34.0% | $308.8 | 32.1% |
| United Kingdom | 135.9 | 17.8 | 177.8 | 18.5 |
| West Germany | 74.9 | 9.8 | 100.0 | 10.3 |
| Netherlands | 57.3 | 7.5 | 78.8 | 8.2 |
| Japan | 58.1 | 7.6 | 77.0 | 8.0 |
| Canada | 39.6 | 5.2 | 46.1 | 4.8 |
| Sub-Total | 625.4 | 81.9 | 788.5 | 81.9 |
| Other | 138.2 | 18.1 | 174.3 | 18.1 |
| TOTAL | $763.6 | | $962.8 | |

Source: 1989 JETRO White Paper on World Direct Investments, Japan External Trade Organisation

As of the end of 1988, the total stock of foreign direct investment (FDI) was over $1 trillion. The U.S. and the U.K. are the major players with respect to direct investment, both as holders of foreign non-financial assets and as the recipients of direct investment. Table 3-6 shows the stock value of FDI held by the major investing countries in 1986 and 1987. The six major investing countries account for over 80% of the total, with the U.S. alone holding about one-third of the total. The U.S. share has dropped appreciably since 1980, when it held nearly half (46%) of global FDI.

Chart 3F shows the extent to which the U.S. and U.K. are the primary targets of direct investment; France, Canada and Italy are secondary recipients; Germany and Japan receive very little direct investment. The distribution of FDI holdings in the U.S. and the U.K. is shown in Table 3-7.

**CHART 3F**
**INFLOWS OF FOREIGN DIRECT INVESTMENT**




Source: *The Economist*, September 22, 1990

**TABLE 3-7**
**DISTRIBUTION OF DIRECT INVESTMENT SOURCES**
**U.S. AND U.K.**

| | U.S. - 1989[1] | U.K. - 1988[2] |
|---|---|---|
| United States | - | 40% |
| United Kingdom | 30% | - |
| Netherlands | 15 | 18 |
| Switzerland | 5 | 9 |
| Canada | 8 | 5 |
| France | 4 | 5 |
| West Germany | 7 | 3 |
| Japan | 17 | 4 |

Source: [1] Survey of Current Business, U.S. Department of Commerce, August 1990
[2] *The Economist*, September 22, 1990

When foreign firms in an industry with a close network of suppliers, such as automotive, enter a foreign market via direct investment, they tend to bring their trusted suppliers with them. As well, they impose their standards and working policies on indigenous suppliers. To use the automotive industry as an example again, Canadian suppliers to the industry will almost certainly need to adjust their manufacturing quality, cost structure and responsiveness if they wish to be suppliers to the Japanese firms which are taking market share from American firms.

In recent years, there has been considerable renewed interest in the use of joint ventures and/or strategic alliances as vehicles for gaining access to broader product lines, tapping into foreign technology and/or entering foreign markets. These vehicles are generally used by firms which have capital or human resource constraints. They are occasionally utilized as a way to overcome local biases toward domestic suppliers. Recently, large multinationals have attempted to use strategic alliances as an alternative approach to cross-licensing.

These forms of international activity are not new, although some of the terminology and rationale may sound new. History suggests that these approaches to the international marketplace should be carefully thought through, as the staying power of these arrangements is suspect. First, the two parties are not always clear, or candid with each other, about their respective strategic objectives and timetable. Second, strategic objectives and commitments can and do change over time. Third, quite often there are significant differences in organizational and national cultures which make long-term harmony problematic. Fourth, when the two parties are of unequal size and power, the smaller partner may end up at a long-term disadvantage and may lose key differentiating technology. A great deal of caution is required.

#### 3.1.4.3 Trading Blocs

NORTH AMERICA

The U.S. economy is the largest single market and is a target for many foreign suppliers. For Canada, the U.S. market dominates import and export patterns, with some three-fourths of Canadian exports destined for the U.S. and some two-thirds of its imports originating south of the border. Approximately one-fourth of U.S. exports are destined for Canada and one-sixth of U.S. imports are of Canadian origin. Somewhat over one-fourth of two-way trade is in the automotive industry.

The U.S. and Canada have completed interim steps and a free trade regime exists between the countries. Additionally, the U.S. and Mexico have initiated discussions with a view toward establishing a free trade agreement. Canada has been asked to be a part of the process.

It is too early to tell whether the FTA is positive or negative for Canadian business. Examples of each can easily be found. The run-up in value of the Canadian dollar relative to the U.S. dollar, as the FTA came into effect, has probably distorted short-run trade effects. As a result of the FTA, Canadian companies are now faced with a more competitive environment. On the other hand, they now have greatly expanded marketing opportunities, if they can take advantage of them.

A North American free trade area of Canada, the U.S. and Mexico would present a highly challenging environment to Canadian manufacturers. An agreement with Mexico would provide opportunities for low-cost sourcing policies which could make Canadian companies very cost competitive in world markets. There would also be an expanded market for consumer, natural resource, and industrial goods. On the other hand, Mexico's low labour costs, combined with the management and marketing skills of U.S. and international competitors, will make for strong competition in Canada's home market.

As the Uruguay round deteriorated into a stand-off, the U.S. became more vocal over the potential of a North and South America trade bloc. How far the Latin American countries would be prepared to go in this direction is not clear. In any case, the Latin American market is certainly no substitute for the European market.

Whether the U.S. and Canada might be prepared to develop a Pacific rim trading strategy is also of considerable interest.

EC 1992

As Europe is poised for the next steps in integrating its economies, there is concern on the part of its present and potential trading partners that it will turn inward. This concern was originally triggered by events in the East Bloc over the past year, as observers wondered whether Europe would be preoccupied with integrating its two parts. The recent impasse over farm policy only serves to heighten these concerns.

In late 1989, at the Rhodes summit, the EC council declared that "the internal market will not close in on itself. EC92 will be a partner and not a 'Fortress Europe'. The internal market will be a decisive factor contributing to greater liberalization in international trade on the basis of GATT principles of reciprocal and mutually advantageous arrangements."

The EC is the world's biggest exporter, accounting for 20% of world trade, as against 15% for the U.S. and 9% for Japan. In terms of importance to the economy, (non-intra EC) exports account for over 10% of EC GNP, compared with 5.5% for the U.S. and 8.3% for Japan. The Community is, in its own eyes, committed to "free and open international trade."

The EC is, like all economic entities, protectionist in politically sensitive sectors. As is now abundantly clear, agriculture is one of those sectors, one in which the EC is probably more protectionist and export subsidizing than

North America. The EC has also been rigorous in restricting Japanese access to its markets; this has been especially true in France and Italy with respect to automobiles. There does not appear, however, to be any compelling evidence that Europe will become even more protectionist, especially with regard to industrial products, as the EC comes to full fruition.

In some key respects, the EC should be an easier market to penetrate if it reaches its goals for 1992. Product standards will be harmonized in the sense that as long as a product satisfies the standards of any one importing EC country, it will have unrestricted access throughout the Community. In another major move, subsidiaries of foreign firms will have equal access to public procurement and contracts, provided that there is 50% value added within the EC.

There are a number of difficult issues to be resolved, such as harmonization of tax policies and free movement of people across borders. These are important issues to the countries concerned, but perhaps not so critical to the would-be exporter or direct investor.

## 3.1.5 CAPITAL ISSUES

The availability, terms, and cost of capital are key determinants in the growth of the AMT market. They affect the relative competitive advantage of AMT suppliers from the key originating regions of North America, Europe, and Asia. As well, they have considerable impact on the willingness of firms to invest in plant and equipment.

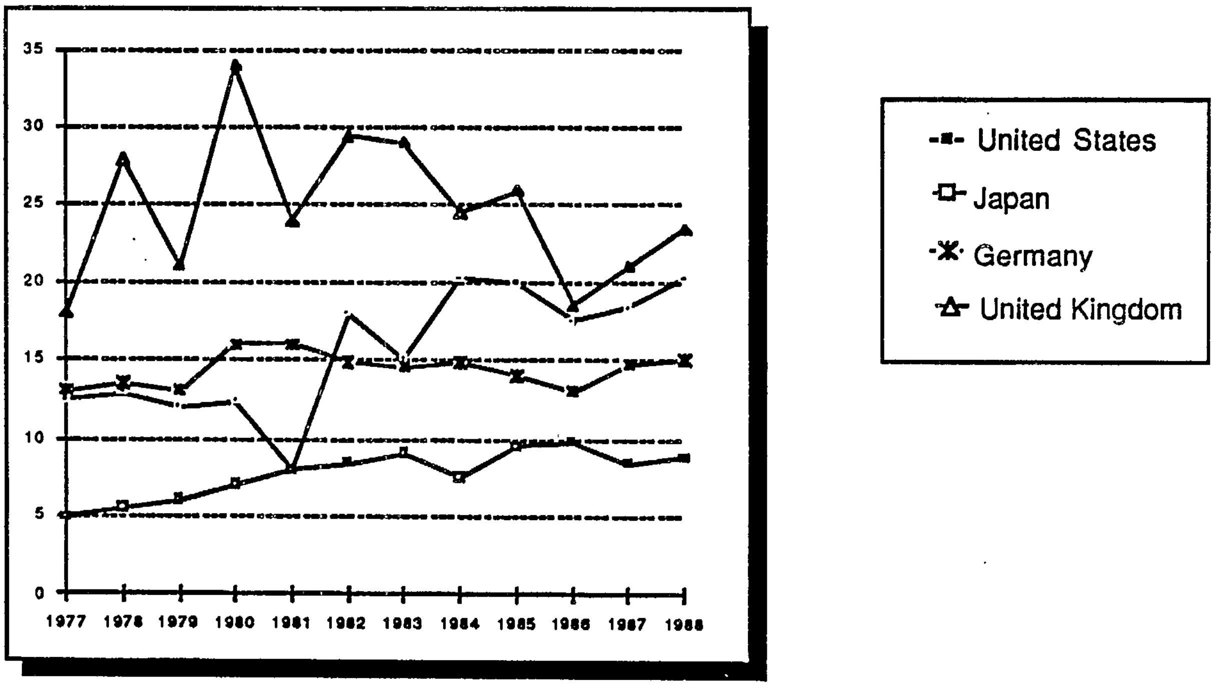
### 3.1.5.1 Relative Capital Costs

In looking at the key issue of capital availability and cost, it is first necessary to highlight the difference between cost of funds and cost of capital. The cost of capital includes not only the debt and equity cost of funds but also the impact of tax policy. It also takes into account the leverage with which companies work, which is generally a function of the patience quotient of the capital provided (either debt or equity).

There appears to be, over time, a substantial difference in capital costs between Japan and Germany on the one hand, and the U.S. and the U.K. on the other. (Data are less readily available for other key OECD countries such as Canada, France, and Italy.) The difference between the two sets of countries seems to be the result of two variables — 1) fiscal policies which encourage investment in the manufacturing sector and 2) the willingness of debt and equity investors to take the longer view, i.e., patient capital.

Charts 3G, 3H, and 3I show the cost of capital in each of four countries for the period 1977-1988 for three different investment situations — R&D with a ten year payout, equipment and machinery with a 20 year life, and factories with a 40 year life.

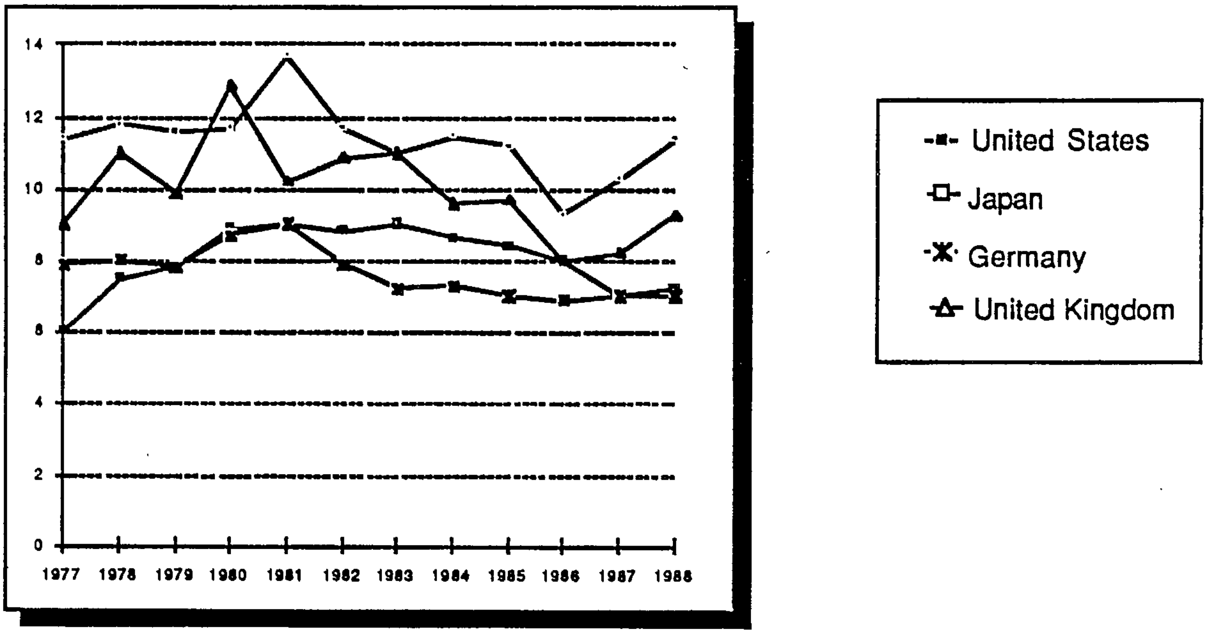
**CHART 3G**
**COMPARATIVE CAPITAL COSTS:**
**R&D, 10 YEAR PAYOFF**




Source: *Federal Reserve Bank of New York Quarterly Review*, Summer 1989, appearing in *Making Things Better: Competing in Manufacturing*

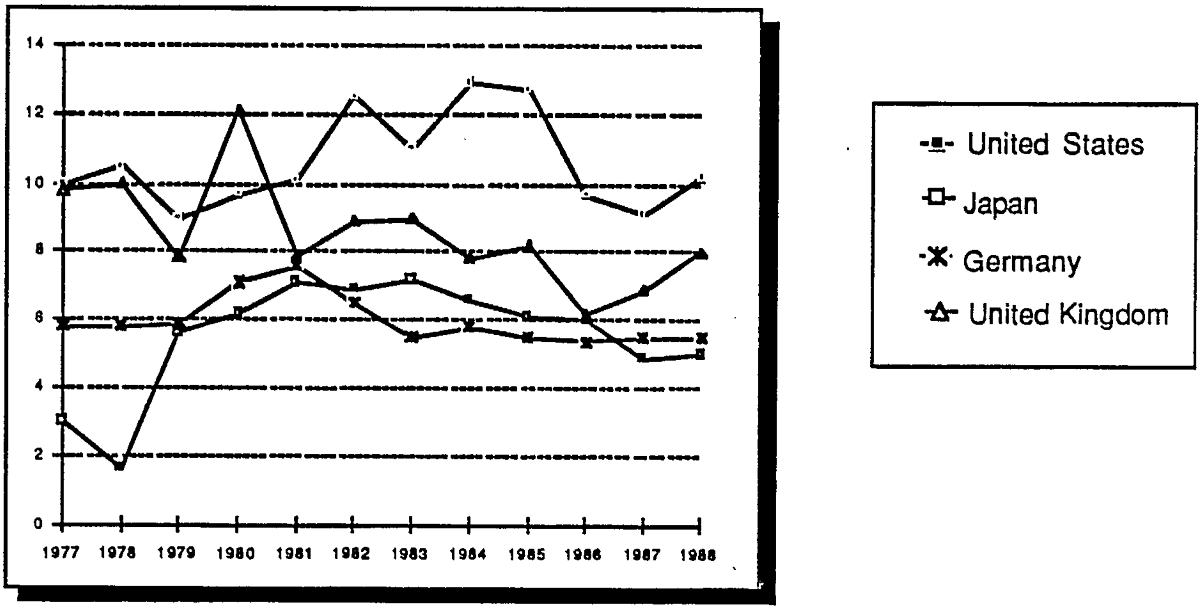
The U.S. cost of capital relative to Japan, over the 1977-88 period, for example, was 3.4 percentage points higher for machinery and equipment investments, 4.9 percentage points higher for a 40-year factory investment, and a full 8 points higher for a 10-year R&D investment. It is also worth noting that both the U.S. and U.K. have highly volatile costs of capital relative to both Germany and Japan, further exacerbating a tendency toward short investment time horizons.

## CHART 3H
### COMPARATIVE CAPITAL COSTS: EQUIPMENT AND MACHINERY, 20 YEAR LIFE




Source: *Federal Reserve Bank of New York Quarterly Review*, Summer 1989, appearing in *Making Things Better: Competing in Manufacturing*

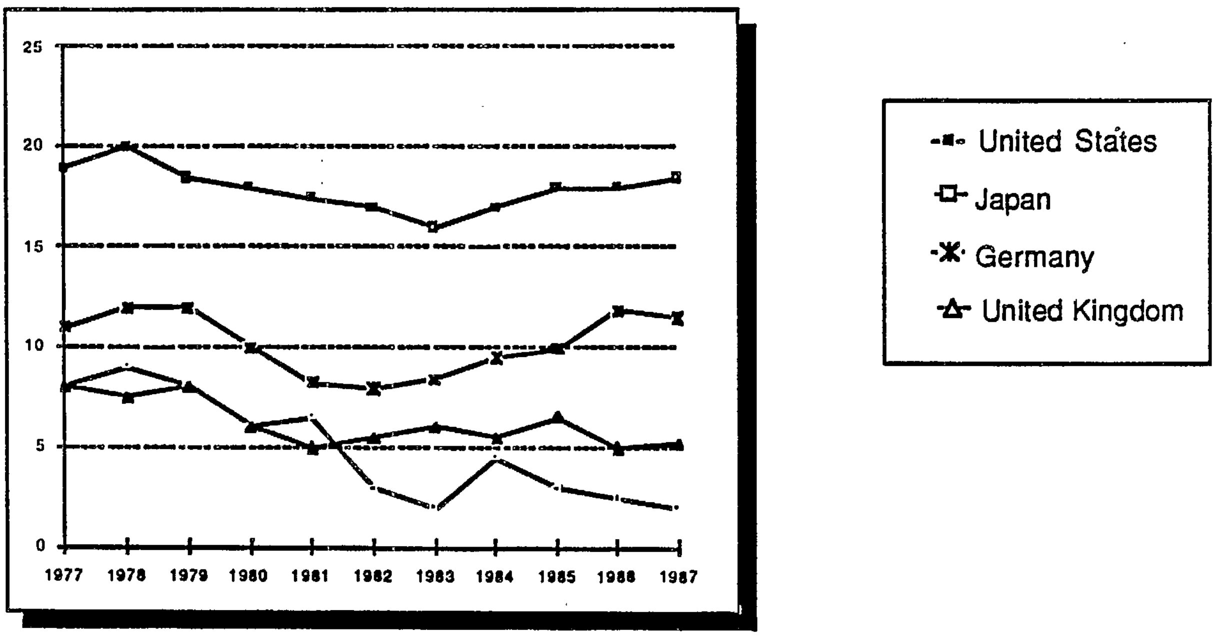
## CHART 3I
### COMPARATIVE CAPITAL COSTS: FACTORY, 40 YEAR LIFE




Source: *Federal Reserve Bank of New York Quarterly Review*, Summer 1989, appearing in *Making Things Better: Competing in Manufacturing*

Savings rates are also considerably different among the four countries (See Chart 3J). Most observers are familiar with Japan's 15% to 20% ratio of net savings to GDP. Germany's rate is much lower at around 10% over the last four years; the U.K. has fluctuated at around 5% over the decade of the 1980s. Starting in 1982, the U.S. savings rate has been almost non-existent at around 2.5%.

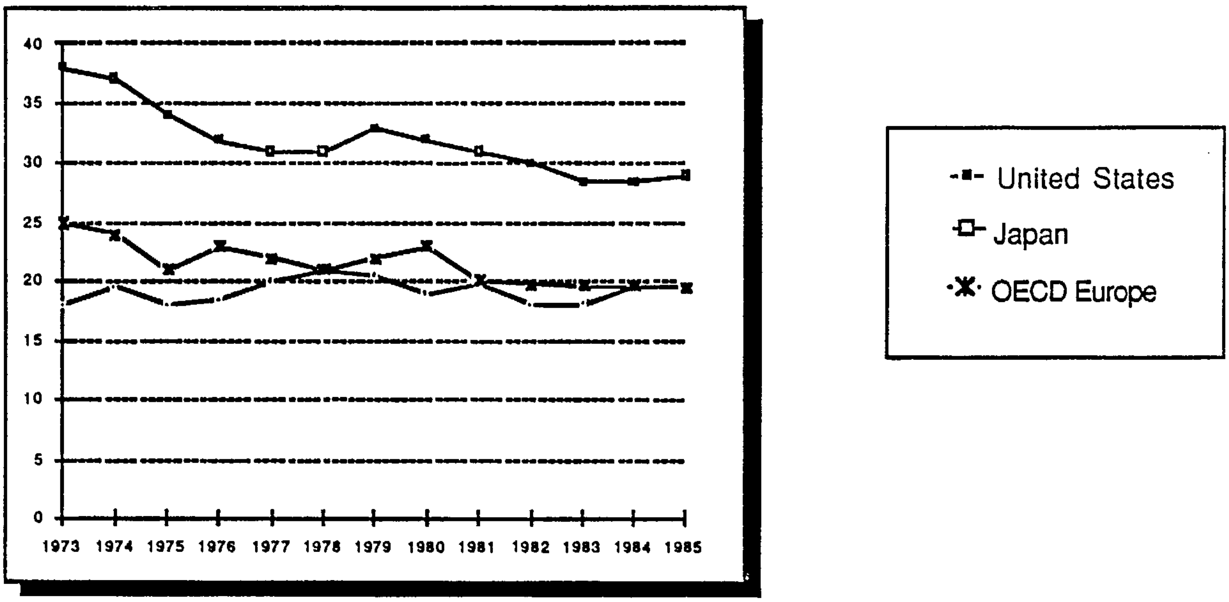
**CHART 3J**
**NET SAVINGS**
**(% of Gross Domestic Product)**




Source: Historical Statistics 1960-87 (Paris, France: 1989), appearing in *Making Things Better: Competing in Manufacturing*

Interestingly, capital formation as a percentage of GDP was approximately the same in Europe as in the U.S. for the period 1981 to 1985. Over the last ten years, the Japanese rate has been approximately 50% higher than for Europe and the U.S. (See Chart 3K).

**CHART 3K**
**CAPITAL FORMATION IN OECD EUROPE, JAPAN AND THE UNITED STATES**
**(% of Gross Domestic Product)**




Source: NATIONAL ACCOUNTS 1960-1984 (Paris, France: 1986), appearing in *Making Things Better: Competing in Manufacturing*

These capital availability and cost differences are great indeed and have significant impact on the investment horizons of entrepreneurs and managers. Clearly, capital markets are not transparently linked given differences of the magnitudes shown above. Of the major international players, the New York and London markets have been leaders in openness while Tokyo has been tightly controlled. Frankfurt has not been a major international player, even though it has not been controlled to the extent of Tokyo.

It is worth discussing briefly the apparent reasons for the lower cost of capital in Japan and Germany relative to Canada, the U.S. and the U.K. First, the Japanese and German economies have been more export driven and *dirigiste* than the U.S. and U.K. have been. That is to say, the former governments have been more likely to provide fiscal incentives to capital investment, quite often for specific industry development and/or export purposes. Furthermore, these policies have a consistency over time, which is not typical in the U.S, for example. Managers can take a longer view in Japan and Germany.

Second, the sources of German and, especially, Japanese capital have a long-term mentality which permits, if not encourages, major strategic and manufacturing investments which will pay out only over a long time period. The riskiness of German and Japanese investment is thereby reduced to the extent that they have lower liquidity and interest rate risk. For example, in 1985, 40% of Japanese corporate borrowing had a maturity of more than one year, compared with only 19% in the U.S.

In both the German and Japanese banking systems, banks are permitted to hold equity investments. These holdings lock in the relationship between bank and client, leading to a less adversarial and transactional relationship than in the U.S. or Canada. Equally important, in both Japan and Germany, corporate and institutional investors have historically been willing to forego dividends in favor of growth-producing retained earnings.

The net effect of differences in capital costs (and mind-set) between Japan and North America is substantial. It has been estimated that an American manager looking at a six-year investment may prudently invest only $0.37 to achieve a $1.00 return, whereas a Japanese manager looking at the same investment could invest $0.66 for the same return. The Japanese will win every time.

Capital investment has been the engine of Japanese growth for the last thirty years. During the last expansion period (Q4 1986 - Q1 1990) capital spending accounted for a staggering 55% of real GNP growth. These patterns may be under pressure in the coming years as two key drivers are reversing themselves. First, the Tokyo stockmarket has dropped 40% of its value over the last year. If a real estate collapse of this magnitude occurs, and there is no doubt that the real estate market is vastly inflated, the stock market will fall even further. Second, the Japanese banks are under increasing capital adequacy and profitability pressures. As a result, corporate bank borrowing costs have doubled in the last 18 months.

### 3.1.5.2 Will There Be a Capital Shortage?

As we head into the last decade of the century, there are concerns about a capital shortage and weakened banks in the next few years. The last two decades were marked by excesses of the opposite nature. The 1970s saw a massive flow of revenue into the OPEC countries which was recycled, with disastrous results, into the developing world. The latter half of the 1980s was marked by a borrowing binge in the U.S. — both Government (funded at the margin by foreign investors) and private sector (funded in a number of cases via high cost junk bonds) — which is now causing great pain.

At the start of the 1990s, the concern is likely to be one of access to capital.

### 3.1.5.3 The Japanese Investor

It is probably not too much of an exaggeration to state that Japanese banks, insurance companies and pension funds were willing passive investors on many a deal in the latter half of the 1980s. For example, nearly half of the US$500B internationally syndicated offerings were absorbed by Japanese investors. Japanese banks were the key purchasers in the U.S. real estate syndicated asset sales market. The role of the Japanese investor as the taker of debt was, until very recently, more or less assumed. Japanese banks and industry were, after all, awash in liquidity.

However, as their stock market has plunged, the large Japanese banks have experienced a major squeeze on their capital bases, especially as they must now meet the same Bank for International Settlements (BIS) capital standards as their North American and European competitors. The Japanese banks can no longer easily add thinly priced assets to their portfolio. Additionally, recent debacles in U.S. real estate, leveraged transactions and junk bond markets have had their impact on Japanese investors' mentality. Finally, a potential crash in the Japanese real estate market has only increased the caution of Japanese investors.

The picture seems clear for the next few years. Japanese investors will not be there, either in quantity or at a low price, to fund the public sector deficits and private capital needs of the U.S. and Canada. Indeed, the

Japanese banks are now finding that they are having to pay a premium to borrow on the London interbank market.

### 3.1.5.4 Europe

Events in Europe will also have their impact on international capital flows over at least the first half of the decade of the 1990s. Germany, the major generator of capital in Europe, has in the last year turned its vision toward rebuilding the Eastern region of the new Germany. About $70B annually over the next few years (4% of West Germany's GNP) is estimated as the capital investment required to rebuild East Germany. As well, Germany can be expected to be economically active in the rebuilding of the old East Bloc, as well as the USSR.

Recently, European banks have started pulling back from the U.S. market. The trend is particularly noticeable with the medium-sized banks; German banks, most clearly, are under pressure to limit their North American activity. It is worth noting that the very large European banks are also retrenching. Lloyds Bank has decided to concentrate on the U.K., as well as its strong Latin American position. Deutsche Bank's priority is to be a leading European bank.

As EC92 becomes a reality, the regional focus of the medium and large-sized European banks will most likely become even more pronounced. Of course, the size and dynamics of the North American financial market are such that a total pull-out is not in the cards.

### 3.1.5.5 North America

North America is a net borrower of capital, owing to the budget deficits of both Canada and the U.S., as well as low domestic savings rates. In Canada, particularly, this has meant high interest rates as the Government has been forced to keep its capital markets attractive to outside investors. The problem is less acute in the U.S., but still problematic.

In the U.S., the well-publicized collapse (and cost to the taxpayers) of the

Savings and Loan Institutions (S&Ls), the sinking of the real estate market, the shattering of the junk bond market, and the potential (and actual) problems of heavily leveraged companies have all combined to place great stress on the country's financial institutions. In the short run, there is little question that banks are focused on portfolio and credit quality. The result is reduced lending at higher cost, probably for the next few years.

The Canadian banks, because of their large retail networks are in generally stronger condition than their U.S. counterparts. Nonetheless, portfolio quality appears to be a major issue. While there may be no explicit policy squeeze on corporate and small business lending, most lending officers for the large Canadian banks almost certainly are sensitive to the increased scrutiny being imposed by their internal bank credit committees.

It is also worth noting in the context of this study that, for the most part, Canadian banks are conservative lenders. With some exceptions, there is an in-born reluctance on the part of many traditional bankers to do cash flow lending; Canadian bankers want hard assets as collateral. Unfortunately, software developers and system integrators are long on people assets and short on physical assets. In an upswing, this may not be too much of a problem for those seeking financing from banks; in a downturn, this mind-set poses major capital access problems.

## 3.2 TECHNOLOGICAL FORCES AND TRENDS

### 3.2.1 EMERGING TECHNOLOGIES

The next generation of AMT equipment will be shaped in part by research and development that is currently underway. The AMT applied over the next decade will also include technologies that have previously been developed but have not yet been broadly applied to manufacturing. By the year 2000, AMT in use will result in faster and more accurate manufacturing equipment with increased performance capabilities and flexibility.

The group of emerging technologies expected to impact advanced manufacturing equipment in the next decade includes:

- Artificial intelligence
- High-performance computing
- Advanced semiconductor devices
- Optoelectronics
- Advanced materials including superconductors
- Digital imaging
- High-density data storage

Several of these technologies are interdependent in their development. For example, artificial intelligence techniques and high-density data storage will play a role in the development and implementation of digital imaging technology.

Each of the technologies listed above has potential far-reaching effects extending to many applications within and beyond manufacturing.

These key technologies as well as specific applications thereof, i.e., sensors and flexible computer integrated manufacturing (CIM), are the subject of Table 3-8. It indicates how the U.S. is doing in research and development

(R&D) and in product introduction in these technologies relative to Japan and the European Community. Note that even in those instances where the U.S. has an advantage or is holding its own in R&D, it is losing ground relative to product introduction, especially compared to Japan.

## TABLE 3-8
### RELATIVE STANDING IN EMERGING TECHNOLOGIES U.S. VERSUS JAPAN AND EUROPEAN COMMUNITY

| | U.S. vs. JAPAN | | U.S. vs. EC | |
|---|---|---|---|---|
| | R&D | Product Introduction | R&D | Product Introduction |
| Advanced Materials | o ↓ | - ↓ | + ↔ | o ↔ |
| Advanced Semiconductor Devices | o ↔ | - ↓ | + ↔ | o ↔ |
| Artificial Intelligence | + ↔ | + ↔ | + ↑ | + ↔ |
| Digital Imaging Technology | o ↓ | - ↓ | o ↓ | - ↓ |
| Flexible Computer-Integrated Manufacturing | + ↔ | o ↔ | + ↓ | - ↓ |
| High-Density Data Storage | o ↔ | - ↓ | + ↔ | o ↔ |
| High-Performance Computing | + ↔ | + ↓ | + ↑ | + ↑ |
| Optoelectronics | o ↔ | - ↓ | o ↔ | + ↔ |
| Sensors | + ↓ | o ↔ | + ↔ | o ↔ |
| Superconductors | o ↓ | o ↓ | o ↔ | o ↔ |

Current Status:
+ = U.S. Ahead
o - U.S. Even
- = U.S. Behind

Trend:
↑ = U.S. Gaining
↔ = U.S. Holding
↓ = U.S. Losing

(as compared to Japan/EC)

Source: *Emerging Technologies: A Survey of Technical and Economic Opportunities,* U.S. Department of Commerce (1990)

### 3.2.1.1 Artificial Intelligence (AI)

Artificial intelligence is a set of techniques used to emulate human performance in areas such as decision-making, natural language processing, vision and robotics.

AI-based approaches that have emerged include:

- Knowledge-based systems (also called expert systems)
- Fuzzy logic
- Neural networks

Knowledge-based systems capture human knowledge in the form of symbols or rules to create a system that reacts to situations as would an expert. Knowledge-based systems are best applied to problems that require precise calculations and are well understood and non-dynamic.

Fuzzy logic is an AI technique based on the concept of fuzzy sets, rather than strict, precise modeling methods. Degrees of membership in sets (as opposed to strict true/false membership) are used in making decisions. Systems based on fuzzy logic are capable of optimizing system objectives by monitoring performance and then applying rules. The system may treat certain rules as more important than others or disregard some rules entirely during the optimization process. The output of fuzzy systems is smooth and continuous. Therefore, fuzzy logic is a good approach to control of continuously variable systems.

Neural networks are based on biological or mathematical models that loosely imitate the way the brain functions. A neural net is a dynamic, self-adapting system that can modify its response to external forces by employing previous experience. A neural network consists of a number of interconnected processing elements functioning in parallel. Information in a neural network is stored in a distributed fashion throughout the network. Therefore, a neural network does not have a "memory". Rather, information is stored as patterns and weights of connections between processing elements. The information is "evoked" from the system rather than retrieved. A neural network requires no programming. It is usually trained to perform a particular task by exposing it to examples that demonstrate the typical input it will receive and the expected output.

Systems based on artificial intelligence are currently performing in a range of manufacturing applications. Many of these uses can be classified as follows:

- Product design
- Equipment diagnostics
- Resource planning and scheduling
- Process monitoring and control
- System configuration
- Simulation
- Quality control
- Software development (CASE tools)

### 3.2.1.2 High Performance Computing

A traditional computer commonly utilizes a single processor that tackles problems in a serial manner, executing one step at a time in a specific order. Major bottlenecks arise in serial architectures making them too slow for solving many computational or data-intensive problems.

Computers based on high speed architectures, such as vector processors, multiple processors, or advanced materials and components, are solving some of the problems inherent in traditional computers.

Current supercomputers are capable of operating at speeds up to a few GFLOPS (billion floating point operations per second). The target for the next generation of high performance computers is a teraflop (a trillion floating point operations per second). Supercomputers achieving these speeds will be based on massively parallel processing.

A vector-based supercomputer consists of one or a few specially designed powerful and expensive processors with fast logic. However, a massively parallel supercomputer achieves its high performance by using a very large number (up to 64,000) of low-cost, relatively low-power processors that operate in parallel. In parallel processing, large problems are broken down into pieces that can be executed by separate processors.

The primary advantages of massively parallel computers are the ability to handle heavy compilation and computational loads without degradation in response time and to do this at relatively low cost compared to competing technologies.

Massively parallel computers are currently used in research and development environments. This class of computer is sometimes used in conjunction with artificial intelligence. As massively parallel technology matures, the range of applications will broaden to include:

- Simulation and modeling (product design, seismic simulation, computational fluid dynamics)
- Image processing (robotics, vision, computer graphics)
- Signal processing
- Database management

#### 3.2.1.3 Advanced Semiconductor Devices

Several improvements in advanced semiconductor devices are underway including improved chip materials, fabrication techniques and advanced components and devices. These innovations are in the areas of:

- Materials (e.g., compound semiconductors such as gallium arsenide [GaAs])
- Chip density (e.g., ultra-large-scale integration [ULSI], 256 megabit DRAM memory chips)
- Fabrication processes (e.g., X-ray lithography)

Advances in these areas will result in semiconductor components with improved speed, higher operating frequencies, reduced size, higher density, multiple functions, lower cost and better heat dissipation. For example, within the next five years desktop supercomputers based on GaAs processors with speeds over 250 MHz are expected to arrive on the market. This is about ten times faster than today's typical 386-based computer.

Innovative chip architectures are also important trends. These include:

- Reduced instruction set computing (RISC) chips
- Application-specific integrated circuits (ASIC) chips

RISC removes many of the built-in instructions from a computer processor. Complex instruction set computing (CISC) incorporates several hundred instructions. RISC chips are typically limited to only 70 instructions, which yields a high speed device at relatively low cost. RISC architecture is expected to dominate the future technical workstation market.

ASICs are now appearing on the market. What was previously accomplished with a mother board and several daughter boards is now possible to achieve in a single chip. Chips that emulate a PLC and chips designed for imaging and sound uses have been announced based on ASIC designs.

### 3.2.1.4 Optoelectronics

Optoelectronics involves the use of light to transmit, process and store information. Areas of development in optoelectronics include:

- Integrated optical circuitry
- Optical fibers
- Optical computing
- Solid state lasers

- Optical sensors

Among improvements expected to result from these developments are:

- Better information handling capacity and signal quality
- Reduced sensitivity to interference
- Increased processing speeds and data storage capacity

Optical computing, while holding great promise in advancing high performance computing, is still at least a decade away from implementation. Other developments in optoelectronics have already made important contributions to advanced manufacturing equipment. Many of these innovations have been in the area of sensors, vision and communications. Among these contributions are fiber optic sensors and cables, and laser sensors.

### 3.2.1.5 Advanced Materials

Advanced materials under development with potential to impact advanced manufacturing technology include:

- Structural and functional ceramics
- Ceramic/metal composites
- Intermetallic and lightweight alloys
- Diamond thin films
- Surface modified materials
- Superconductors

This group of advanced materials is expected to yield improvements in material performance characteristics and special functional attributes. Some of the characteristics of composite materials, are their light weight, corrosion resistance, high-strength and rigidity. High temperature and special service applications are likely to benefit from many of the developments in advanced materials.

The development of high-temperature ceramic and advanced low-temperature superconductors will impact electronics, electrical transmission, motors, computers and controls.

### 3.2.1.6 Digital Imaging

The major areas of development in digital imaging technology include:

- High definition systems, such as high definition television (HDTV)
- Large displays
- Data compression
- Image processing

Digital imaging is capable of storing, displaying, processing, analyzing and transmitting images. The technology may be used to enhance an image so that it can be seen better by the human eye. In conjunction with X-ray, ultraviolet or infrared techniques, digital imaging systems are capable of seeing in parts of the spectrum that humans cannot see. This method differs from machine vision, which attempts to emulate human vision.

Advances in digital imaging are expected to lead to improvements in:

- Digital cameras
- High-volume information storage and retrieval
- High-speed computing (including parallel processing)
- High-resolution video display

Digital imaging systems have several potentially important uses in the factory, including:

- Industrial inspection and monitoring
- Process control
- Product assembly
- Document handling

### 3.2.1.7 High-Density Storage

Technological developments in high-density storage are centered around high-density magnetic storage (including perpendicular recording) and magneto-optical storage. Among innovations under development are magnetic disks based on thin-layer technology that will reduce access time and increase information density. New magneto-optical disks have the advantages of very high information densities, reduced danger of contact with storage media, and lower cleanliness requirements.

Developments in high-density storage devices will impact all classes of computers used in manufacturing. The current trend in computational tasks in manufacturing is toward the storing and processing of vast amounts of data. Many of these applications are constrained by current computer system capabilities in storing large amounts of information.

## 3.2.2 FORCES AFFECTING TECHNOLOGY DEVELOPMENT

Factors that affect technology development include:

- Who is supporting research and development
- Who is performing research and development
- How technology is being diffused

Federal governments and private industry are the primary sources of funding for technology research and development.

Research and development activities are being carried out worldwide in universities, government labs, and private industry. Many of the projects are being tackled by collaborative efforts between these organisations.

Attempts at technology diffusion have taken several forms. Among the vehicles used are federal and state subsidized technology centres, university centres, and educational and training initiatives in private industry.

### 3.2.2.1 North America

CANADA

Canada has established a range of programs for supporting basic research and development and dissemination of technology to the AMT supplier and user. Major government bodies that administer these programs include the National Research Council (NRC), Natural Sciences and Engineering Research Council of Canada (NSERC) and Industry, Science and Technology Canada (ISTC).

The goal of the NRC is to coordinate and promote scientific and industrial research. This organisation is active in assisting Canadian companies to enhance technical skills and develop competitive products, obtain technical information (via NRC's Canada Institute for Scientific and Technical Information, CISTI), and perform industrial research. A major source of R&D in Canada, the NRC conducts research with potential for broad and long-term impact. Areas of research relative to manufacturing technology include industrial automation, computer technology, advanced materials and processes and standards. Services of the NRC include assistance in customized R&D, collaborative research projects with several industry participants, and co-funded projects with single partners. Programs are conducted at several scientific and engineering laboratories located throughout Canada.

NSERC is a research granting agency that supports advanced university R&D activities in the natural sciences and engineering. This organisation is committed to the development of capabilities in advanced manufacturing systems through its Strategic Grants Program. Through this program, university-based research is supported in areas that include enhanced system designs, knowledge-based CAD systems, CIM systems, advanced sensor technology, and improved processes and materials.

Most of the government-financed basic research in Canada is performed at universities. Private industry is not typically involved in these efforts. In 1986, the Canadian government initiated an effort to support corporate-university cooperation including university-based research and development of human resources.

Aside from federal programs, provincial programs for technology development and retraining and skills development have been established.

At the university level, studies suggest that Canadian university R&D has fallen in recent years.

UNITED STATES

The U.S. maintains a dual approach to advanced technology development: one strategy for defense and another for industry. Lack of a strong industrial policy and the emphasis on defense policy has had profound effects on manufacturing technology in the U.S. Government organisations in the U.S. have traditionally been key supporters of technology research and development. Government supported R&D primarily has centered around strategic defense applications. For instance, the National Aeronautic and Space Administration (NASA) has earmarked $1.88 billion to the development of robotic technology. This project is intended to enhance robotic capabilities for space exploration but should have significant spillover effects.

The transfer of this technology to private industry has been of secondary importance in much of government supported R&D. Federal agencies, e.g., the Department of Defense (DOD), have had little success in technology diffusion to the manufacturing sector. In fact, only about 2% of the federal R&D budget is earmarked for manufacturing.

Over 70% of U.S. R&D is performed in private industry. Consortia supported by government funding are uncommon.

In the U.S., universities have become key elements in technology advancement. Since 1984, the National Science Foundation has been instrumental in establishing engineering research centres at 21 colleges and universities. Many U.S. companies have formed joint development arrangements with universities.

Efforts to solve the training problem in the U.S. include the establishment of technology centres at universities and colleges. Over 50 community colleges have been experimenting with programs designed to assist small and medium-size manufacturers in implementing new manufacturing technologies. Plans include creation of prototype automated factory systems that can be used to train students and their future employers.

Educational partnerships between universities and suppliers are on the increase. These partnerships generally involve grants to the university of hardware, software, consulting and technical support. In return, the schools in these alliances work together to enhance their CIM curricula and give students and manufacturing personnel hands-on training.

#### 3.2.2.2 Japan

Japan's approach to R&D and manufacturing technology significantly differs from that in other parts of the world. Japan maintains a single national industrial policy directed by the government. One aspect of this policy involves the integration of industry and academia. For example, professors often maintain lifelong relationships with their students. Japan is also unique in that it need not direct any R&D spending to military or aerospace related projects. The primary focus of Japanese R&D is consumer applications.

Japan's Ministry of International Trade and Industry (MITI) supports technologies that are important to Japanese industries. Many programs supported by MITI bring together companies in cooperative R&D efforts. In his book *The Competitive Advantage of Nations,* Michael Porter points out that closer inspection of Japan's R&D initiative suggests that companies participating in these collaborative projects do so for defensive reasons. These reasons include maintaining good relations with MITI, preserving corporate images, and ensuring access to any gains competitors derive from the collaboration. Porter contends that it is unlikely that participating Japanese companies will assign their most talented minds to these projects; rather the real value in these cooperative projects is in highlighting the importance of emerging technologies and stimulating proprietary research.

To remain competitive, Japan recognizes the need to shift its focus from technology adaptation to innovation. In 1990, the Japanese Joint Committee on International Research proposed a $1 billion ten-year joint research program for the development of an intelligent manufacturing system (IMS). Funding for the IMS program would come from Japan, Europe, and North America each of which would contribute 1/3 the total funding. This proposal is being viewed by some as a Trojan horse. Prime targets of Japan's R&D efforts include sensors, software, and system integration. This project could do much to further Japan's technological goals in these areas.

Japanese government support of small and medium-sized manufacturing firms is pervasive. National programs for small and medium-sized enterprises include both financial and technical assistance. In the 1980s, Japan paid special attention to programs dedicated to helping small business adopt high-tech equipment such as computerized machinery and robots. Specific government programs are in place for helping startups. In addition, MITI has opened its research laboratories to small, innovative companies.

National testing and research centres play an important role in technology diffusion in Japan. Local technology and demonstration centres supplement the national centres.

Cooperative networks that are based on horizontal links between firms is another vehicle for technology diffusion used in Japan.

#### 3.2.2.3 Europe

Members of the EC are currently addressing a wide spectrum of R&D issues ranging from basic research to prototype products. The primary focus is on civilian (non-military) applications. A major goal of EC membership governments is full EC-wide coordination by 1992. The Single European Act defines the overall objectives of EC actions in this area as "to strengthen the scientific and technological basis of European industry and to encourage it to become more competitive..." To achieve these goals, the EC established the Framework Programme. Research funding of the Framework Programme amounts to over a billion dollars. Much of this amount is matched by industrial participants.

In conjunction with the EC Commission, nineteen European countries collaborate with industry on application-focused R&D under the organisation European Research Coordination Agency (EUREKA).

It is estimated that less than half of all R&D in the EC is carried out by private industry. However, the initiating of joint research projects is on the rise; consortia are important within EC government R&D funding.

Horizontal networking between small companies is used in Europe. Italy, for example has formed the Third Italy, a network of small technologically sophisticated textile and metalworking firms.

Several U.K. universities are considered worldwide leaders in technology development. Technology utilization, however, has not consistently followed development.

### 3.2.3 TECHNOLOGY TRANSFER

Obtaining the benefit of technological developments from around the world is a complex management task. Technology development and diffusion patterns differ among the major industrialized nations. These differences relate to who pays the bill, who does the research, the mechanisms by which innovations are diffused and how well technology is used in industry.

In Japan, a nationwide government program of financial and technical assistance helps small manufacturers implement new manufacturing technologies. Smaller firms also benefit from the technical help available to them from the major companies that are their customers. In addition to these domestic sources of information, for many years Japanese engineers have been sent to work with their counterparts in the West to absorb as much technological knowledge and experience as possible.

While the Japanese government takes the initiative in some areas of R&D, it looks to private industry for financial support. This support often comes in the form of a cross-company group assigned to work on a project. Of the total R&D conducted in Japan, only about 20% is funded by the government.

The Japanese and Germans have demonstrated great proficiency in managing technological improvements in small steps. U.S. companies have been able to take fundamentally new ideas and build entire industries from them, but have not been proficient at absorbing and putting into practice incremental changes in products and manufacturing processes. The U.S. has begun the commercialization of many products. The Japanese have then overtaken the U.S. through a series of incremental improvements in products and the processes that manufacture them.

As a nation, the United States spends more on R&D as a percent of GNP than Japan, but much of it goes to defense. Major breakthroughs have been achieved from U.S. defense spending. However, most transfer activities designed to move defense technology into the private sector have been woefully unsuccessful.

These patterns extend to application of AMT products. Robots, invented in the U.S, are far more widely applied in Japan. In CNC machines, another American development, Germany leads the way in application and Japan, in spite of a late start, has caught up to the U.S. and is currently applying the controls at a faster rate. Personnel training programs in both Germany and Japan are a facilitating factor in the CNC adoption rate. Technical assistance provided to small Japanese firms is also a factor, evidenced by the fact that plants with under 50 employees in Japan are adding CNC at the same rate as larger plants. As this occurs, American producers of robots and CNCs are disappearing while Japanese and European companies move into world leadership positions.

The technology transfer programs that appear to be producing incremental improvement and long-term advantage for Japan and Germany are person to person exchanges, scientists working with scientists, machinists with machinists, gaining insight and knowledge and the benefit of mutual experience. Technology transfer in the U.S. is often implemented in classrooms or on video tape, and not on a one-on-one or peer-to-peer basis. This contrast may explain the differences in results.

A major challenge for all companies is gaining access to and understanding of technology movements in the key regions of North America, Europe and Japan. A company can no longer remain competitive with a narrow technology focus. Key people must be involved in the technology scanning and assessment function. Sources to be managed aggressively are: foreign language journals, industry trade fairs, linkages with non-domestic suppliers, international standards committees and cross-licensing agreements.

### 3.2.4 STANDARDS

The establishment and adoption of international standards by national standards organisations and government bodies will play a vital role in promoting international free-trade concepts and domestic commerce.

Lack of standards is likely the greatest technological barrier faced by AMT suppliers and users. Current trends resulting in growing concern over standards include:

- The need for manufacturing systems with far greater integration capabilities
- The emerging global market

European companies have long had to deal with the problem of networks that cross international boundaries. For two decades, Europe has had standards organisations working to complement efforts in international standards development. The EC92 project has accelerated the adoption of standards by the EC. A concern to non-European vendors has been that European standards may keep them out of the European market. This, however, is unlikely, since many of the International Standards Organization (ISO) and IEC standards likely to be adopted are derived from U.S. and Japanese products.

Even though several standards will likely gain international approval in the next decade, the implementation process may be slow. The EC has issued a directive for Open Systems Interconnection (OSI) compliance of computers costing over 100,000 ECUs. The OSI communications standard, which promises to facilitate integration of multivendor systems, is an example of the implementation problem. For several years, vendors have pledged their support to this standard, but their installed base of proprietary systems has slowed the move toward compliance.

The adoption of hard metric standards is expected to impact both manufacturing equipment and end products. Hard metrics are based on metric dimensions that are rounded to the required number of decimal places as opposed to soft metrics which are derived from dimensions expressed (for example) in inches, rounded to the required number of decimal places, and then converted to the metric system. By 1992, the ISO plans to base all its standards on hard metrics. In the U.S., all government agencies will have in place a plan to implement hard metric standards by 1992. By the year 2000, hard metric standards are expected to be in widespread international use.

For a listing of worldwide standards organisations, see Appendix B.

### 3.2.5 IMPACT OF TECHNOLOGY ON AMT PRODUCTS

Over the next decade, several emerging technologies are expected to contribute to reshaping AMT equipment. Projected as most important among these are artificial intelligence (AI), optoelectronic sensors, and high performance computing.

The use of AI techniques such as fuzzy logic and expert systems will greatly enhance the functionality and cost-effectiveness of traditional control systems, including PLCs, CNCs and DNCs. Knowledge-based decision-making and adaptive control are among the important capabilities that AI technology will contribute to AMT equipment.

Industry needs faster, more accurate sensing, and optoelectronics appears to be the technology that can provide the solution. Optoelectronic sensors will be applied in uses from metal cutting and forming to process monitoring and control. Capabilities of test and inspection systems will be greatly enhanced by new optoelectronic sensors. More importantly, improvements in sensing devices, coupled with AI, are expected to increase the capabilities of AMT systems to monitor, analyze and dynamically control physical parameters in the manufacturing process. In this way, new sensing technology will yield quality product that will not require inspection.

Several technological developments relative to high performance computing are expected to impact the next generation of AMT equipment. These include advances in digital imaging, high density storage, semiconductor devices, and computer architectures. As a result of R&D in these areas, all classes of computer-based AMT equipment will become faster and more powerful over the next decade. However, a key factor in reaping the benefits from new computing technologies is standards. Compatibility and connectability have become chief priorities of the user. Standards are a prerequisite to achieving these goals. The development and adoption of standards ( e.g, for CAD data, robot programming languages, communications, sensor interfaces) will play a critical role in utilizing the full potential of the advances in high performance computing expected during the next ten years. These standards will enable computing and communications to become a "utility" that is readily available to users of AMT equipment at multiple locations, much like electric power or telephone service.

The above key technologies are among several forces that will be instrumental in creating the next generation of automated systems. New designs, engineering methods, software techniques and advanced materials are expected to play a key role in this process as well.

The following subsections detail advances expected in selected components and classes of AMT equipment.

#### 3.2.5.1 Design Automation

The ability to store information in an organized fashion for later analysis and retrieval is a vital function in manufacturing. New relational database and high-density storage technologies have great potential in making more information available to those who need it.

Expert systems technologies are expected to have an important impact on several areas of design automation. For example, many CAD and CAE systems are currently employed for modeling of part geometry. However, these designs must undergo further alteration for use in manufacturing.

Rule-based systems are expected to play a role in improving this procedure. These new techniques will create improved links to manufacturing data, moving manufacturing information up into the design phase. With this information, design engineers will be able to create product and part designs that conform to the requirements of the manufacturing process, eliminating costly redesign.

The integration of lasers with computers has already given rise to faster and more efficient prototyping methods. The technique, called desktop manufacturing or rapid prototyping, enables prototyping of plastic part models to be done in just a few hours.

### 3.2.5.2 Materials and Parts Handling Systems

Material handling systems are expected to benefit from developments in areas including optoelectronic sensors and communications, artificial intelligence and advanced materials. The next generation of equipment will be integrated with:

- More sophisticated shuttle equipment that is capable of transporting materials and products faster and with less impact on the load; improvements in structures for large loads will result in lighter, stronger and possibly less expensive equipment
- Drive packages that are more tightly controlled, enabling higher throughput and closer tolerances
- Optical technologies that will enable easier determination of absolute position of equipment in aisles and will provide new communications techniques replacing bus bars between the on-board and off-board computers
- Artificial intelligence that will improve on-board monitoring and diagnostic systems, provide better self-correction of errors and easier maintenance. Expert systems will also be employed in developing the control software for material handling systems

### 3.2.5.3 Robotic Systems

Over the next decade, advances expected in robotic systems include:

- Increased capabilities in integration of robots with other production and material handling equipment
- Improved machine vision and sensing capabilities
- Increased use of new computing technologies, including artificial intelligence and massively parallel processing
- Connectivity to more related factory floor systems
- Increased capabilities to program off-line
- Micro robots and systems
- The use of lightweight composites
- Improved structural geometry

Integration of robots with other equipment on the plant floor has already begun to some extent. Currently, robots are interfaced to devices such as workpiece manipulators, shuttles and transfers.

Better ability to sense and control force will extend the use of robots to grinding, polishing and buffing operations. Two or more robots working under coordinated control will be used in automation cells; one robot will perform part load/unload, while a second performs part work such as drilling or cutting.

Robot technology will also be interfaced with AGVs and SGVs for use in hazardous areas and applications requiring high-precision pick-and-place operations.

Vision and acoustic sensing methods will improve the ability of robots to "see, hear and feel" rather than simply to control position. Researchers are developing three-dimensional vision systems expected to arrive on the market in the mid-1990s. Research in vision for welding robots has yielded a through-the-torch imaging technique that will allow arc welding for even extremely specialized uses to be performed by adaptive robots.

In conjunction with new vision and sensing technologies, AI techniques will assist robotic systems in processing sensory input and decision-making. For example, expert systems can monitor the quality of a weld by interpreting the sound emitted from the welding process. The benefits of these technologies will include improvements in product quality, equipment safety, maintenance and troubleshooting. The use of new computing methods such as massively parallel processing and artificial intelligence will significantly increase the number of axes that can be coordinated in the robotic system.

Advances in sensing and computing technologies will also enhance the ability of robots to determine orientation and distance of objects. Inspection systems is an area that will particularly benefit from these developments.

Greater connectivity of robots to other plant floor systems will be accomplished through the development of open architectures, common controllers, I/O interfaces, and compatible programming languages. Robot programming is an area where important improvements are expected during the next decade, including common programming languages, more efficient off-line programming, and new programmer interfaces. Greater capabilities in off-line programming will enable generation of programs directly from CAD systems. Natural language-based menu-driven programming techniques and built-in routines for common applications will make the task of programming easier for the user.

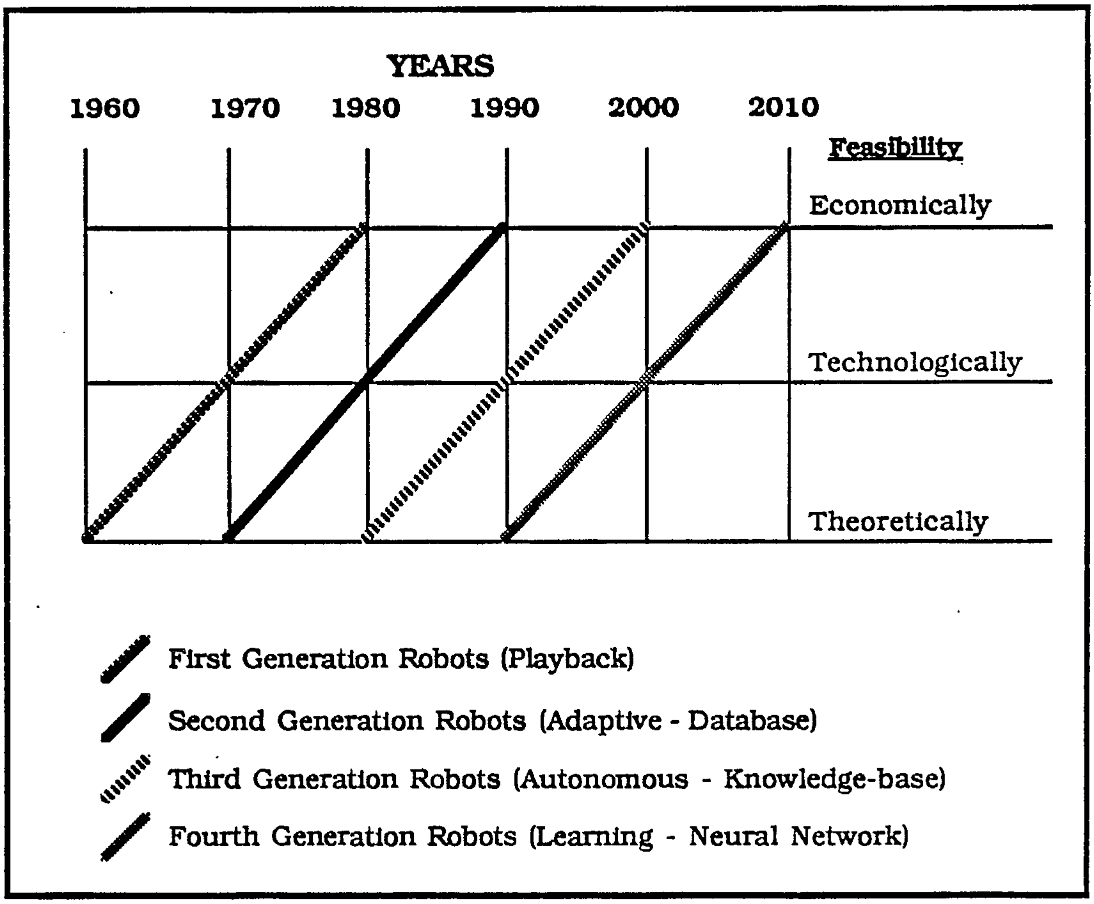
The use of common controllers and the development of more powerful chips will contribute to making robotic systems smaller.

The development of lightweight composites will yield improvements in robots and their end effectors. These new materials will be utilized to meet the demand for strong end-of-arm tools capable of greater flexibility and quick changeover.

Today's robots commonly have single arms. However, precise control often requires multiple legged or armed mechanical structures with coordinated motion. This capability allows the interaction of two or more similar or dissimilar arms. It is expected that generic mechanical systems of this type will evolve during the next decade.

The evolution of robotic products from first generation to fourth generation devices is outlined in Figure 3A.

**FIGURE 3A**
**EVOLUTION OF ROBOTS**
**IMPACT OF ARTIFICIAL INTELLIGENCE**




Source: "Robotics" by Zafar Taqvi Ph.D., presented at ISA 90, New Orleans, October 1990

The first generation of robots were playback devices based on internal sensing and servo technologies and capable of one-dimensional position control of the end effector. Today's second generation robots have the additional capabilities of adaptation and accommodation. Sensor functions have progressed from capabilities such as point location to more sophisticated tasks that include sensing of one or two-dimensional, structured environments. Current products are able to perform dynamic position control of end effectors.

Over the next decade, autonomous mobile robots capable of inference and problem solving will become a reality. These third generation robots will have the ability to perform three-dimensional sensing and movement. The technology for third generation robots exists today; however, robots with these capabilities will not become economically feasible until the year 2000. Fourth generation robots are currently in the theoretical stage of development. These advanced robots will likely be neural network-based devices that are capable of learning and dynamic, coordinated end effector control. Fourth generation robots are expected to be commercially available by the year 2010.

### 3.2.5.4 Plastic Forming Equipment

Improvements expected in blow molding equipment in the next decade centre around mechanical design innovations and more sophisticated controls. Among the anticipated improvements are:

- Twin screw extruders for custom blending materials as part of the blow molding process
- Split accumulator heads that permit quick and easy access for cleaning and maintenance
- Rectangular head tooling that enables closer control of material distribution in blow molding of flat rectangular parts
- Head tooling designs that offer faster changeover
- Better barrel and feed throat design resulting in easier segmental feeding of additives for reinforcement and property enhancement

- Higher machine clamp ratings

- Increased sophistication in controls

  - Automatic compensation for changes in process variables
  - Automatic proportional control of air blow system
  - Integration of flow and pressure with machine sequence control

### 3.2.5.5 Machine Vision

The next generation of machine vision systems is expected to be enhanced by:

- Massively parallel processor architectures

- Artificial intelligence techniques

- Advanced laser light sources

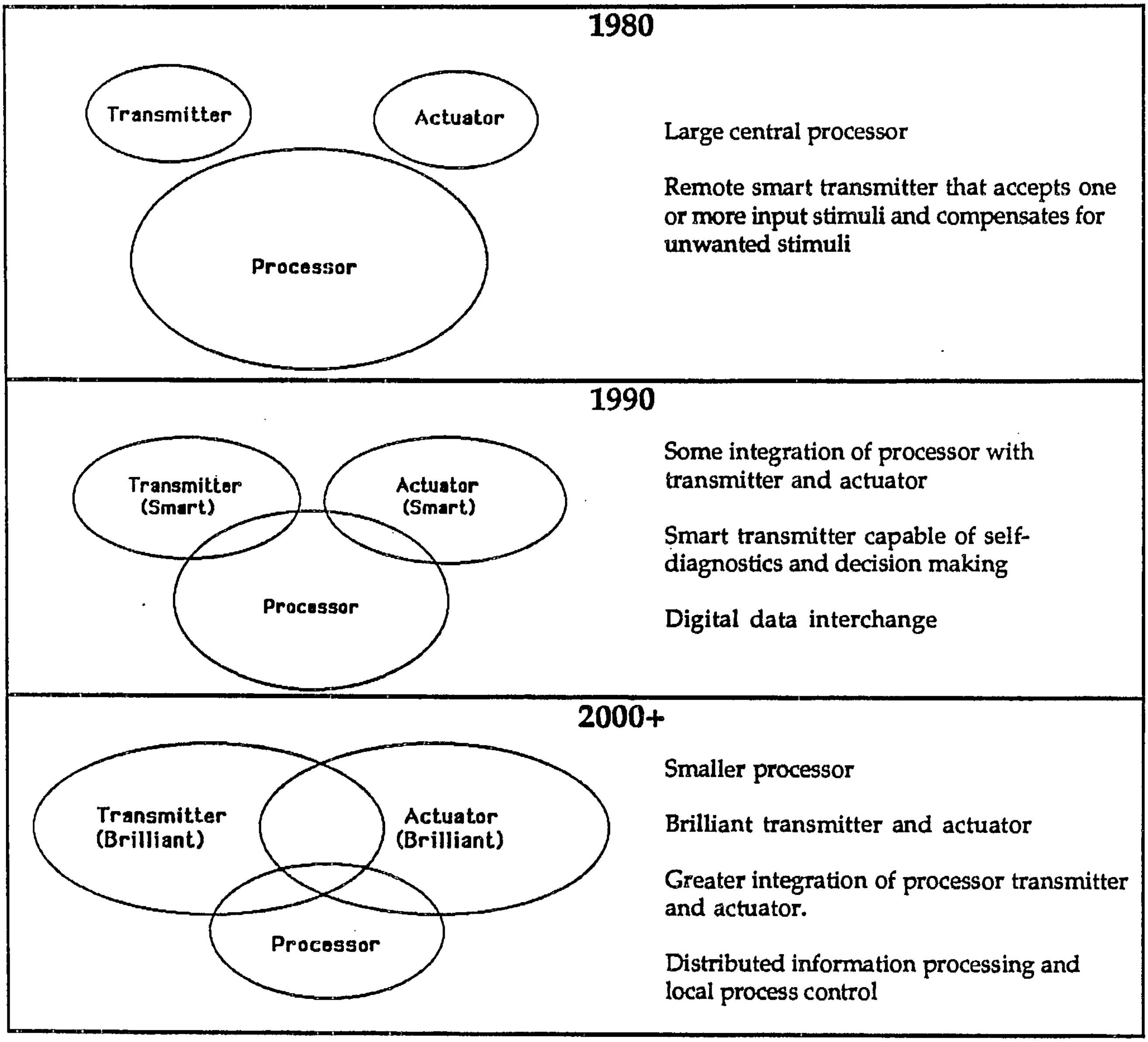
- Higher resolution through new sensor technologies

- Conformance to new industry standards

### 3.2.5.6 Sensors

Figure 3B illustrates the progress made in sensor technology over the last ten years and projects what sensors will become in the future. In the next decade, intelligent transmitters and actuators will be integrated into sensors along with processors. Transmitters, formerly all analog implementations, will likely become all digital beyond the year 2000.

**FIGURE 3B**
**SENSOR TECHNOLOGY DEVELOPMENT**




Source: Honeywell/Solid State Electronics Division

Laser acoustic techniques involve the use of laser light to measure sound and vibration. This area of investigation may yield important devices for non-destructive testing of components and noise analysis of mechanical equipment.

In terms of sensor fabrication, new materials, products and techniques under development will result in important advances in machine intelligence and robotics:

- Solid state sensors for gas, image and touch sensing
- Micromechanical sensors
- Improved fiber optic sensors
- Piezoelectric sensors for determining deformation
- Multisensors capable of simultaneous measurement of multiple parameters
- Biosensors
- Sensory compensation techniques

### 3.2.5.7 Production Control Software

The next generation of production control software is expected to feature:

- Expert systems that will provide decision support as well as enhancing other software functions
- Shop-floor information systems that will link intelligent devices and provide real-time product and process status as well as historical data
- Improved graphics capabilities
- More memory storage

- Easier integration of production control systems into the overall CIM architecture.

- Use of relational databases

Advances in the factory data collection systems over the next decade are likely to include:

- Increased speed

- More memory storage

- Faster data transfer rates

- Improved RF capabilities (increase in the distance over which RF can operate; increase in the number of terminals that may be networked; reduction in power consumption)

- Use of higher density bar code symbologies

## 3.3 COMPETITIVE ENVIRONMENT

### 3.3.1 TRENDS TOWARD GLOBALIZATION

Over the last twenty years, academics and business people have seen that global marketing, product and manufacturing strategies have the potential to provide significant competitive advantage. On the marketing side, in the last few years the argument has been made that there is a reasonably homogeneous world market in which economies of scale can be gained via global brand establishment and product development. Coca-Cola and McDonald's have been offered as prime examples of a global product. Increasingly, however, managers are rediscovering that a global marketing strategy involves considerable adaptation to local/regional requirements. There are very few examples of truly global products. Major international companies have found, though, that the establishment of a brand name which connotes quality, value, and innovation provides an extremely valuable umbrella under which a range of product initiatives can be launched; Sony is an excellent example.

Global strategies are distinguished from multinational, international and national strategies on four dimensions:

- Vision - global vision is evident when a company seeks opportunities around the world and is not content to operate in a single nation or region

- Scanning Horizon - information is constantly sought and the entire world is scanned for opportunity and threats

- Geographic Scope - the markets a global company targets are not necessarily global. The global company concentrates its resources in the markets in which it can best compete

- Geocentric Orientation - a sensitivity to the unique features of individual markets and an appreciation for their similarities and differences

One area in which North American companies have been lax is in the scanning of global markets for product design and technology trends. First, such a scan is an important early warning system of potential competitive activity in the firm's main markets. Second, market pressures and cost elements vary across the globe. For example, European and Japanese product design engineers have had to be far more concerned about raw material costs and energy costs than have American designers. As a result, Mitsubishi was an early leader in small transformers; and European control manufacturers developed smaller motor-control units geared to narrow usage applications. Very few manufacturers can afford any longer to ignore international design trends and international competitors.

Global manufacturing strategies can take advantage of differing costs and capabilities around the world. They also offer the opportunity to develop specialized plants to service global (or regional) markets. Phillips Electric, for example, has plants in each European country as a consequence of prior decisions to get behind tariff walls. The company has been very slow to rationalize its operations and finds itself under extreme price pressure from American and Japanese competitors which are operating European-wide plants.

Historically, one of the strongest incentives to manufacture in foreign locations has been import restraints in targeted export markets. For example, after the U.S. negotiated export quotas with the Japanese automakers, Japanese producers invested in greenfield production facilities in North America. Since 1985, all of the major Japanese auto manufacturers have located plants in their prime export market. Combined production from Japanese plants in North America will be 2.4 million cars in the mid-1990s. Having seen the success of a North American production initiative, Japanese auto makers are now trying the same strategy in Europe, locating plants in Britain and Spain to serve the EC market.

### 3.3.2 IMPACT OF INCREASINGLY DEMANDING BUYERS

Whereas the marketing game in the 1960-1980 period was one of mass marketing and price, the marketing battles in the 1990s will be fought in the arena of more precisely-defined market segmentation and product adaptation, high total-quality levels, and superior service. In the developed world, increased levels of consumer income have enabled customers to be more selective and demanding in their needs. Similarly, industrial buyers, being under price, quality, and service pressures from their management, are growing more sophisticated.

Buyer expectations are a moving target, especially with the information explosion being experienced in the developed world. Customers quickly become blasé about technological leaps and quality improvements. As product quality and variety improve, industrial customers demand a whole new realm of product criteria. Due to evolving complex technologies, customers need more help to integrate new products or processes. Consequently, many industrial purchasing wish lists today are demanding more service bundled into the product offering.

As buyers get more demanding, manufacturers are turning to rapidly evolving design and manufacturing automation to shorten product design cycles. Time-to-market has been shortened for many product categories from automobiles to industrial tools. This has helped manufacturers to enhance their products' reputations by incorporating new features as soon as possible, often within months of development.

## 3.3.3 OUTLOOK FOR DISCRETE MANUFACTURING INDUSTRIES

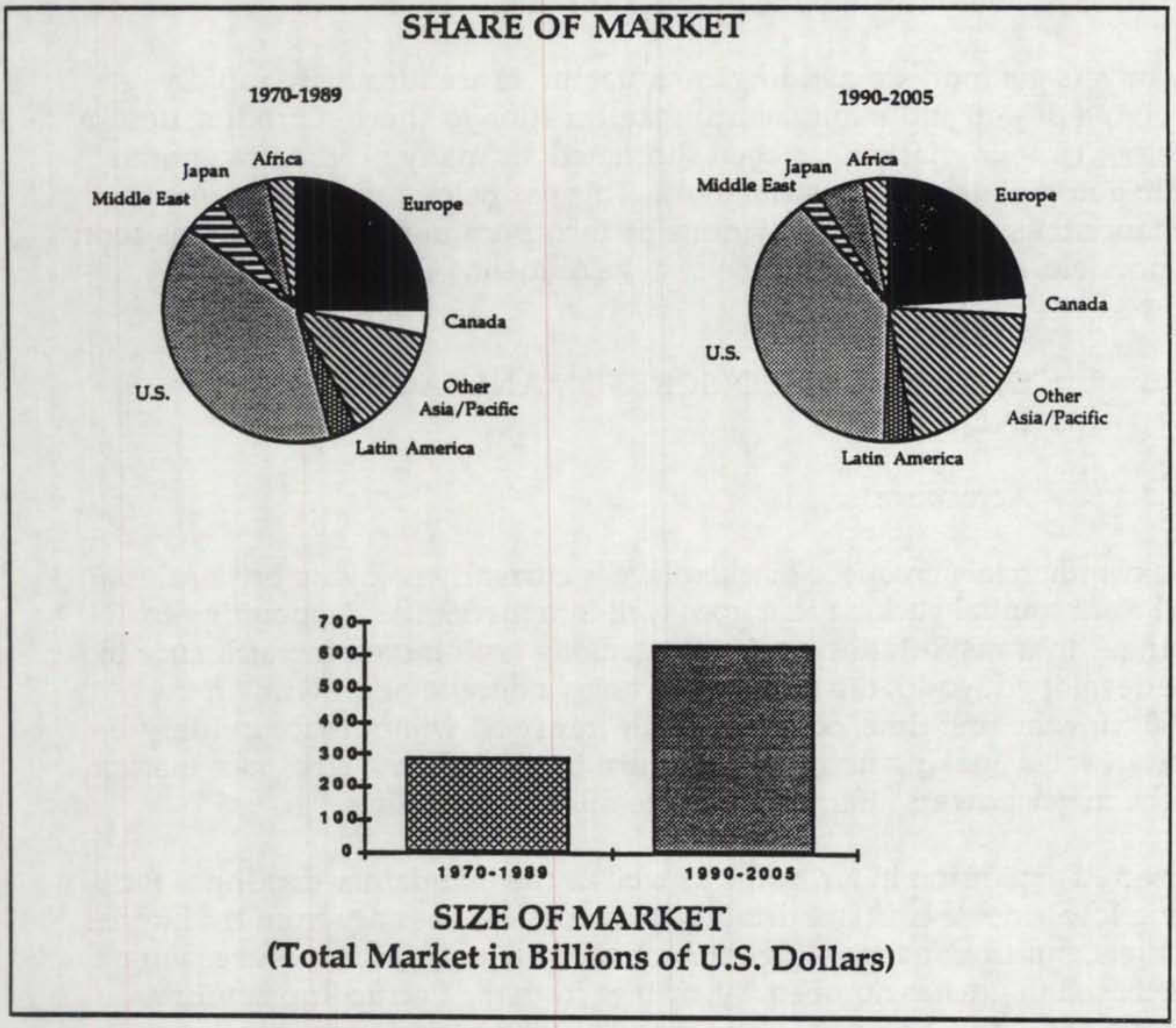
### 3.3.3.1 Aerospace

The commercial aerospace marketplace is currently enjoying brisk sales and a substantial backlog that goes well into the 1990s. Responding to changes in transportation preferences, along with increasing affluence in the developed world, the industry foresees a decade of growth. In the 1990s, for the first time, commercial air transport will outpace military aircraft sales, making up for a downturn in the military aerospace market as the major powers attempt to reduce military spending.

Expected expansion in air traffic as well as the mandatory deadlines for using lower noise craft are driving aircraft sales, not only from traditional markets, but from burgeoning economies as well. New planes are being purchased in greater numbers by airlines from the Pacific Rim countries, Europe and Latin America. Over the 1970-1989 period, total purchases of commercial airplanes were $287 billion (in 1990 dollars); for the 1990-2005 period, the estimate is for purchases to total $626 billion (see Chart 3L).

Along with increased production of aircraft, there are also indications that the 1990s will be a period of expansion of airports, air traffic-control facilities and other infrastructure that will smooth the flow of increased traffic in the skies.

**CHART 3L**
**AIRLINE PURCHASES OF COMMERCIAL AIRCRAFT**
**BY GEOGRAPHIC AREA**
**CHANGES OVER THE 1970-2005 PERIOD**




Source: *Aviation Week and Space Technology*, March 19, 1990

Competition in the commercial aircraft industry has been heightened with the success of Airbus Industries, a joint European consortium currently subsidized by the sponsoring governments. Having an additional competitor has prodded the major suppliers to improve their products and customer awareness. Even with an additional major player in the market, the large producers have had some problems supplying demand, creating opportunities for smaller players with niche products.

Another growth area in the aerospace market is commercial satellite launches. The commercial market is forecast to total between $37 billion and $45 billion during the decade of the 1990s. More than 200 telecommunications, earth observation/meteorological, and scientific satellite launches are expected. During the next decade, primary satellites are expected to increase in weight from their present 2.8 metric tons to 3.4 metric tons. While the average size will be increasing, a small craft market will also develop for lower-cost telecommunications, scientific, and other missions.

Although the primary suppliers are mainly multinational corporations, many subcontractors are smaller, more locally-oriented businesses. Smaller companies that subcontract aerospace work will also benefit from the capacity constraints of the major aerospace suppliers by taking on the modification and repair work that the airlines are commissioning in order to improve their aircraft maintenance programs. Airlines find themselves using aircraft longer to meet soaring passenger demand and to compensate for a shortfall of new aircraft. A spate of accidents over the last several years has called attention to the problems of maintaining older aircraft.

### 3.3.3.2 Transportation Equipment

No other major industry has experienced the competitive challenges to which the automakers have responded during the last decade. In North America in 1980, domestic producers had a dominant market share of over 70% of the market. The same is true today, but that share now includes the substantial sales volume of Japanese automobiles that are now produced in North America. The U.S. Big Three (General Motors, Ford and

Chrysler) now control only half of the market, while Japanese nameplate cars have a 30% share.

Over the past decade, led by the challenge of the Japanese, the auto industry has become truly global. It is no longer meaningful to characterize a producer by national origin; Japanese automakers produce in Asia for the home market, in North America for the North American market, and in Britain for the European market. When they run into capacity constraints in Japan, Japanese automakers can import North American "Japanese" cars back to the home country to meet demand. General Motors produces large cars in North America, small cars in Mexico, and imports captive Korean vehicles for its Geo line. In the automobile industry, joint ventures are common, and such exotic business arrangements as cross-equity ownership of assembly and parts production facilities, parts outsourcing across multiple national borders, and cross distribution and technology licensing agreements, are becoming more widely used. The end result of the challenge and experimenting of the last decade is increased competition among suppliers and higher product quality.

Over the next decade, the number of automobiles sold is not expected to increase by more than 4-5% over the volume of the 1980s, unless the Eastern Europeans and Russians, with their pent-up demand for personal transportation, acquire sufficient disposable income to be purchasers. The European market is expected to be highly competitive as the myriad of tariffs and restrictions on the import of automobiles is removed within the EC.

Having mastered the competitive environment in North America and Asia, Japanese automakers have set their sights on an integrated Europe. However, the Europeans are setting up roadblocks to Japanese entry into the united European market, hoping to prevent the same dislocations that the North American industry experienced in the 1980s. The European automakers, especially Fiat and Peugeot, are counting on the imposition of temporary quotas on Japanese auto imports to allow them to stabilize their market share. The European auto industry may find quotas a two-edged sword. When voluntary quotas on unit shipments to North America were accepted by the Japanese automakers in the early 1980s, the response was to ship more expensive models in order to maintain the same revenues. The Japanese gained market share in the compact and standard sized cars and actually improved their profit margins.

In order to compete successfully with the production and quality-oriented Japanese, North American producers invested heavily in advanced manufacturing technologies during the 1980s. European automakers have also invested substantially in automation equipment. In Europe, the automotive industry is the prime customer of the most advanced manufacturing technology seen in discrete parts manufacturing.

The Japanese entered the North American market with subcompact cars; and during the 1980s, subcompacts were the fastest growing segment of the auto market. Now Japanese manufacturers have moved upmarket, introducing luxury cars to rival the German imports. If market preferences turn again to the small, energy efficient cars, both North American and Japanese producers could be vulnerable to automakers in developing countries where many of the smaller cars are currently produced. Production costs are low in the developing countries and the subcompact technology is especially easy to transfer from country to country. Small cars for North America and Asia are currently being produced in Mexico, Brazil, South Korea, and Thailand.

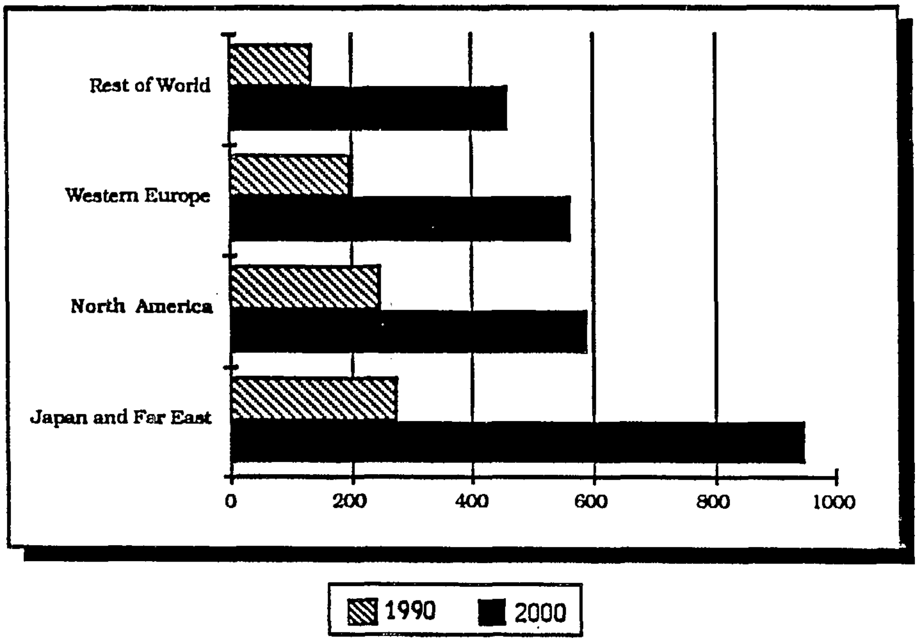
The other major transportation category is railway equipment, including both locomotives and railcars (passenger and freight). The brightest areas in the rail-equipment market are the growing demand for high-speed equipment and urban transit systems. As high-speed networks expand and new technology is put in place, demand for new and updated equipment will continue to grow.

Investments to modernize railway equipment production facilities are crucial, because of severe competition in the industry. Suppliers have been investing to improve productivity, most notably in computer-aided design, high-performance computers, robots (especially for cutting, welding and painting), and numerically-controlled machine tools.

#### 3.3.3.3 Electronic Products (Including Computers)

During the 1990s, electronics and other high technology industries will become increasingly important drivers of national economies and the global economy . Over the last decade, the electronics industry has grown to the point that it now produces more goods and employs more people than any other U.S. industry. It has taken over from the automobile industry as the primary mover of economic activity. The same realignment is expected to take place in Asia and Europe during the 1990s.

**CHART 3M**
**THE WORLDWIDE ELECTRONICS MARKET**
**1990-2000**
**(In Billions of U.S. Dollars)**




| | 1990 | 1992 | 1994 | 1996 | 1998 | 2000 |
|---|---|---|---|---|---|---|
| Japan and Far East | 275 | 367 | 504 | 609 | 760 | 949 |
| North America | 249 | 311 | 350 | 423 | 528 | 590 |
| Western Europe | 198 | 256 | 322 | 372 | 464 | 564 |
| Rest of World | 138 | 178 | 224 | 288 | 359 | 462 |
| TOTAL | 860 | 1,112 | 1,399 | 1,692 | 2,110 | 2,565 |

Source: Electronic Outlook Corporation
appearing in *Electronic Business*, Dec. 11, 1989

Growth from this sector is expected to exceed 11% annually. This is a slowdown from growth in the 1980s, but will take the worldwide electronics industry from $860 billion in 1990 to an estimated $2.5 trillion at the turn of the century. Along with rapid growth will come considerable competition for domination of the different segments of the electronics market. It is expected that the United States will cede further market share in a number of products to both Europe and the Far East. In 1990, Japan and the Far East controlled 32% of the global market; by 2000 their share is expected to grow to 37%, while the North American share shrinks from 29% to 23% and Western Europe nearly maintains its position, moving from a 23% share to 22%. The vastly expanded size of the market means that it will be growing in all regions. Participants are not fighting over a static market. With such a dynamic market, "other" countries will be able to take advantage of their cheap labour or home market to expand their share by the year 2000 to 18% of the world market, from 16% in 1990. This share would include the nations of Eastern Europe and the Soviet Union as they try to become competitive in this vital marketplace.

Capital spending by the electronics industry is expected to start slowly, but increase rapidly as the decade progresses. The overall economic slowdown at the start of the decade will put a damper on investment until corporate profitability rebounds. Investments will then be made in both time and labour-saving equipment. More than half the capital investment from this industry is expected to be in high-technology equipment.

Most of the major participants in this industry are international companies. The more successful of them are in the process of becoming truly global in both manufacturing and marketing. Decisions are being made on global criteria rather than on national criteria, and research and development facilities are being placed where the best research is taking place, not necessarily in the home market. Manufacturing plants are being placed to take advantage of market opportunities, labour skills, and costs and trade related factors.

### 3.3.3.4 Electrical Equipment

Compared to the electronics sector, the electrical equipment industry has experienced few major technological changes over the last decade. The major advance is the development of amorphous metal for use in the production of energy-saving cores for electrical distribution transformers. The new glass-like metallic material has unusual magnetic properties and no grain orientation, resulting in a reduction of transformer-core electrical losses by 40% to 70%.

The electrical equipment industry experienced slow growth in the 1980s, as a result of a concentrated effort to reduce energy expenditures after the oil dislocations of the 1970s. Restructuring in North America has resulted in reduced capacity and lowered costs. Many European producers have yet to rationalize overcapacity in their industry, and the resulting inefficiencies are keeping profits low.

Internationally, several major suppliers formed joint ventures in order to take advantage of partners' distribution systems and products to fill gaps in their own product lines. Along with joint ventures, the most significant competitive response to the slowing of the market has been the merger of two of the major players into the global manufacturer Asea Brown Boveri (ABB). The strategy is to obtain the scale to handle the global needs of industries served.

Low-cost production is a significant competitive advantage in this industry. Much of the production of electrical equipment, such as motors, has moved to areas where lower wages prevail, or where manufacturing is very efficient.

#### 3.3.3.5 Machinery

One of the major demand drivers for the machinery industry will be the impending labour shortage. It now appears that North America will have a severe shortage of skilled labour by 1995. Industry is faced with three choices to offset this shortage: import labour, export the work, or invest in automation.

When faced with this same dilemma in the 1980s, both the Japanese and more recently, the West Germans, made the decision to automate. This response to the aging of their workforce has had several results. These investments are offsetting labour shortages and reducing labour costs. In addition, investment has afforded the manufacturers in both countries a technological advantage over competitors who have not invested in advanced manufacturing technology. Manufacturing industries in both Japan and West Germany have realized a quality, productivity, and cost advantage over their North American and other European competitors because of their response to the aging worker population. Japanese manufacturers are still investing heavily in up-to-date machine tools and automation, and their rates of capital investment are expected to remain high.

Companies in the machinery industry realize that they must respond to this challenge, and investment in new manufacturing technology is expected to grow through the next decade. Machine tool sales are expected to expand at a real annual rate of 3%. Sales of robotics, given an accelerating market in Europe, will expand at an even greater rate, estimated at 8%.

Another trend that will positively affect machinery purchases is the use of new materials. New and exotic metals, composites, plastics and other materials will require new cutting and forming technologies.

Over the past decade the machine tool market has seen considerable competitive rearrangement. By 1990, the Japanese dominated the low end of the market of standard automated machine tools, and the Europeans, particularly the West Germans, dominated the high end of specialized sophisticated machines. North America, an international force at the beginning of the 1980s, held less than a quarter of the world market at the end of the decade. In other types of machinery, for example packaging and plastics forming, North America with its sophisticated consumer market for the output of this equipment, continued to dominate the international market. Even in these segments, though, international competition has increased, and the specialized European suppliers will get a shot in the arm from the Europe 1992 initiative. More competition rather than less will characterize the next decade in the machinery industry. Competition has increased the automation of the machine tool users. It will most likely have the same effect on the users of other industrial machinery.

### 3.3.3.6 Other Discrete Manufacturing

LUMBER AND WOOD PRODUCTS

Remodeling and renovation have been a major market in the past decade, as the value of real estate has grown sharply in North America and in Japan. Entering the 1990s, both housing starts and renovations are down in North America and the market appears to be entering a slower growth trend. In all the developed regions, there will be fewer people setting up households. In North America there is additional concern with potential government actions to protect the environment. Actions could limit access to the public forests for harvesting, and/or compel manufacturers to provide a less hazardous workplace.

With the market growing more slowly, many sectors of the industry have begun to restructure. Marginal facilities have been closed, and productivity has been raised in some of the remaining ones with more modern equipment. Manufacturers are most concerned with lowering costs and increasing yields; there is little incentive to invest in new capacity, but suppliers are interested in upgrading existing capacity to improve current operations. More suppliers are becoming interested in developing new and stronger foreign markets and improving their competitiveness.

There is an international trend toward encouraging trade in more finished wood products and reducing the export of logs. This will increase availability of millwork products from countries with lower production costs, primarily Indonesia and Mexico. The North American producers expect competition to increase for the markets of the developed world, especially the expanding Japanese market for housing repair and remodeling.

Another significant trend is the substitution of oriented strand board (OSB/waferboard) for softwood plywood. Capacity for this product is increasing rapidly in North America, and by 1995 production capacity is expected to be one-third larger than at the beginning of the decade. This lower-cost product can utilize relatively abundant smaller trees that are unsuited for plywood. This product is already being used in all the regions of the developed world, but its demand will surge when the expected certification for use in residential construction is finalized in Japan.

## RUBBER AND PLASTIC PRODUCTS

The plastics industry should experience another decade of growth in the 1990s. Demand in North America is expected to grow by 4% annually through the early years of the decade. Growth will be fueled by developments of new alloys, blends, additives and composites that will encourage new applications and allow plastic products to substitute for traditional materials such as metal and wood.

The plastics industry is extremely fragmented. This industry has historically been able to support niche and regional suppliers, although international trade has grown rapidly through the last decade. Demand for plastics products is increasing most notably from motor vehicle, construction, consumer goods, packaging and electrical and electronics sectors.

The industry is starting to experience a reaction to its success in providing disposable products. Pressure is increasing to provide a solution for recycling the material so that its disposal does not overwhelm municipalities' waste disposal and sewer facilities.

Rubber is expected to grow at about half the rate of plastics products. Most of the rubber used goes into tires and auto parts, consequently the industry's prospects are tied to the automobile industry. The tire industry has restructured significantly during the last decade, with capacity reduced and the remaining facilities upgraded. In 1989, the worldwide tire market exceeded $40 billion. The market is completely internationalized and the significant capital required to achieve necessary production scales means that only a few well-funded companies can compete in the market. Over 80% of the world market is held by eight suppliers. Goodyear and Michelin are the market leaders, each with over 16% market share.

## FABRICATED METALS

The worldwide market for fabricated metal components is highly price competitive. Because of this, foreign exchange rates will continue to have a major impact on the industry in any particular country.

The industry is characterized by a large number of small firms, making large-scale investments in automation, because of a lack of resources, impossible for most companies. However, several major international mergers and acquisitions have occurred recently. As well, joint ventures between North American and Japanese manufacturers have been formed to serve Japanese auto plants.

Much of the industry suffers from international overcapacity, with resultant severe price competition. Capital investment is concentrated in productivity improvments, rather than in capacity building. Investment has been growing slowly through the last decade. The consensus is that the output of metal fabricators will decline in real value over the next decade as many customers turn to plastics and composite materials for their components. Investment in automation and productivity improvement programs is expected to grow slowly, at a rate slightly less than the overall growth in GNP.

## APPAREL AND OTHER TEXTILE PRODUCTS

Despite substantial investment and research in automation, labour remains a substantial cost factor in the textile products industry. Because of this, developing countries have become the major suppliers of apparel products to the developed world. Historically, firms in this fragmented industry have tended to be small and mobile, with little incentive and few funds to make investment in advanced manufacturing technology.

During the 1990s, the structure of the apparel industry will change to include larger, globally-oriented companies that can integrate vertically to control quality and time-to-market. This transformation has begun. The industry is starting to increase productivity with capital investments and restructuring. One of the key factors has been the move to a quick response mode tying the factory to the sales floor, bringing a just-in-time philosophy to the apparel industry. Larger merchandisers are linking producers, suppliers and retailers electronically. The benefits of the networked information system are lower inventory requirements, fewer markdowns of unwanted goods, shorter reorder cycle time, reduced stock-outs, and less paperwork. The system also strengthens relationships through the supply chain and will ultimately force out those merchandisers that cannot compete on the basis of the more advanced systems.

Along with communication-systems advances and state-of-the-art inventory control systems, apparel makers are starting to see some results of R&D expenditures in automating apparel manufacturing. The U.S. Department of Commerce reports: "Automation is providing consistency in cutting and stitching, thereby reducing the number of skilled operators needed. Furthermore, automated machines can be operated in multiple shifts without a reduction in quality, and pattern changes can be made instantly and accurately. New technology such as computer-numeric-controlled machines and quick-change attachments have dramatically reduced the production-cycle time."

It is difficult for a developed nation to maintain a competitive advantage in apparel manufacture in the world market. Technology transfer is becoming more widespread and developing nations are investing in new plants and equipment. Nevertheless, the dexterity of the human hand will remain important for some time to come in some operations, even after most of the manufacture is automated.

## 3.4 MANUFACTURING MANAGEMENT ISSUES

### 3.4.1 FORCES DRIVING MANUFACTURING IMPROVEMENT

#### 3.4.1.1 Global Competition

No longer is it good enough to be a more efficient manufacturer than the other local suppliers. World-class suppliers are invading the attractive markets around the globe. And "world-class" is no longer a nebulous claim; it is an explicit goal of many companies, with progress measured along specific parameters.

Companies successful in global competition are those where global competitiveness is a conscious goal and a key strategic element. These companies develop the capability to meet or beat the best manufacturers anywhere in the world and use that capability to take advantage of the most attractive market opportunities. In the process, they position themselves extremely well to stave off foreign competition in their home market.

The desire to buy "local", whether by individuals or business organisations, is not so strong that customers are indifferent to real benefits offered by foreign suppliers. These can include the full range of advantages such as lower prices, faster delivery, higher quality, improved service or greater selection. With the exception of some markets such as Japan and Germany, few buyers are loyal to home based manufacturers to the extent that they are willing to pay more and wait longer for a product that isn't quite what they wanted.

#### 3.4.1.2 Time-Based Competition

In local and regional markets as well as global, new products are being introduced faster than ever before. Customers are demanding quicker and more consistent delivery of a greater variety of products, and getting it. Manufacturers acting with speed in response to customer needs are taking market share away from slower moving competitors.

Time-to-market with new products is becoming a key competitive factor. Shorter development times mean fresher products with up-to-date technology. A good example is automobiles; it is estimated that the age of automobile designs of Japanese companies averages three years while the average designs of North American auto makers are at least five years old. Consequently, Japanese automobiles have the benefit of two more years of technological innovation. This is a major advantage when the alternatives are being examined by a knowledgeable potential car buyer, especially when the innovations are available at no additional cost.

McKinsey & Co., a management consultant firm, has developed a model which shows that high-tech products developed on budget but appearing on the market six-months late will earn 33% less profit over five years relative to an on-time, on-budget performance. On-time development that runs 50% over budget will result in only a 4% loss of profits over the same period. This presents a powerful argument for getting the new product to market on-time even at a hefty premium in design cost.

Once product design cycles are shortened, another competitive advantage can be realized through increased frequency of new product introduction. Introducing new features individually as they become practical, without waiting for a batch of features has several positive effects: the products are always newer than those of the competition, less time is required to create each new design because there are fewer innovations being included, and the incremental upgrades add up over the years to represent a significant technological advantage that may be viewed as insurmountable by competitors, causing them to retreat from the market.

Another aspect of time as a competitive weapon is the period between getting the order and delivering the product. Reducing the time it takes to fill the customer's requirement is being used to advantage by many companies. This requires more than just reducing manufacturing cycle time as manufacturing often takes less than half of the total time between order placement and delivery to the customer.

#### 3.4.1.3 Competing with Quality

When products are recognized for outstanding quality, it is possible to attract greater price premiums than is imagined by most manufacturers. Consumers' greater concern for quality and willingness to pay a substantial premium for it are driving manufacturers to strive for higher goals.

Manufacturing companies, too, will pay more for better overall quality and performance. In a 1986 survey of 407 manufacturing plants conducted by Automation Marketing Strategies, machine-tool buyers reported that price was not the major determinant in their selection process. In half the cases examined, the product purchased was more expensive than the second choice. In one out of seven situations, buyers paid at least a 15% premium to get the preferred machine.

Manufacturers are not only striving to win customers with higher product quality, but are also attempting to treat the customer relationship with more care in general. This includes the service, support, and paperwork aspects of the interface with the customer.

#### 3.4.1.4 Inventory and Cost Reductions

The inventory and cost reductions that have been reported through the use of just-in-time (JIT) production techniques have caught the attention of manufacturing managers worldwide. The potential benefits of cutting away the lion's share of inventory investment while reducing direct manufacturing costs are driving managers to apply these principles.

#### 3.4.1.5 Top Management-The Essential Driver

The commitment to attain world-class stature must come from the top. It requires a change in operating goals as well as practices. The basis of competitiveness has changed and, for most companies, what is at stake is survival. Those that take reasonable, well-managed risks toward the world-class goal are likely to survive and succeed. Companies, small and large, must simplify their designs, eliminate waste in their operations, reduce the delivery cycle, embrace total quality as a way of life, and use the advanced technologies at their disposal or they will vanish.

World-class manufacturing and global strategy are not concepts for large companies only. In fact, small and medium-sized companies are subject to the same threats and opportunities as are large companies. A global perspective is required to stay abreast of market, technology or competitive developments worldwide, even if there are no immediate plans to export and there is no immediate threat from imports. World-class manufacturing will serve to increase profit and return on assets while protecting markets and expanding horizons.

There is no status quo. The manufacturing business is undergoing essential change, in terms of who the competitors are as well as the technological basis of competition. Those who refuse to move into the future will likely be driven out of business, perhaps by a competitor from halfway around the world. Unless top management understands and communicates this reality, the company will not be able to effect the required changes.

Studies of manufacturers indicate that the gap between the adopters of AMT and non-adopters keeps widening. Non-adopters continue to find excuses as to why AMT is not for them. Adopters, on the other hand, keep moving forward in spite of occasional problems. The message is clear; the toughest decision is the decision to get started.

## 3.4.2 FORCES INHIBITING MANUFACTURING IMPROVEMENT

### 3.4.2.1 Management Awareness and Commitment

There is a lack of understanding and appreciation among top management of manufacturing companies in North America as to effective use of advanced manufacturing technology (AMT) — what it takes to achieve world-class status, and the risks inherent in not meeting that standard.

Based on the data at hand, North American managers typically are either not using AMT or not using it well. In most companies, top management does not understand manufacturing's potential to be a key competitive force. This is a major barrier to undertaking programs to achieve world-class manufacturing status.

Most top managers are far more concerned with product obsolescence than with process obsolescence. Yet, the beneficial effects of up-to-date manufacturing capability are frequently more lasting than product superiority. Product advantage tends to be a game of leap-frog among competitors while process advantage continuously increases the gap between the leader and the followers over time. Process superiority favorably affects costs, quality, delivery, variety and time-to-market with the next new product, generally making the manufacturer with the most advanced process the most effective product innovator as well.

The use of advanced technologies such as computer controls and robotics has taken place more slowly than was expected. Top managers are often afraid to invest in advanced manufacturing technology because they believe that they will be putting the entire company at risk. This view, however, is wrong in two ways. First, not moving ahead with advanced manufacturing techniques will shut the company down more surely, although it may take longer. Second, it is not necessary to "bet the company" in order to start down the path of manufacturing modernization.

Another negative factor is that some companies take a "portfolio management" approach to their businesses. Viewing business units as unrelated investments, that may at any time be sold, doesn't generate the long-term commitment required to make serious investments in manufacturing competitiveness. Core technical competencies, not the least of which are manufacturing process technologies, must be protected for long-term survival and enhanced for long-term success.

#### 3.4.2.2 Capital Requirements and Justification

Experienced users judge capital justification to be the most significant obstacle to the implementation of advanced manufacturing systems based on CIM (computer-integrated manufacturing). One reason is that other capital projects competing for the same funds may be forecasted for better returns. It is difficult to determine the savings that will be generated by the investment in manufacturing with the kind of predictability required by corporate accountants and financial managers. Most manufacturing improvement programs have little to do with saving direct labour; labour saving is a key factor in the indirect areas, where it is much more difficult to relate directly to the investment. Few investment evaluation formulae have mechanisms that consider competitiveness. Many arbitrarily assign zero as the value of savings that cannot be accurately predicted. Proponents of this approach apparently would prefer to be precisely wrong rather than approximately correct.

The time factor in manufacturing investment can also be an obstacle. Most production managers in plants that don't invest in advanced technologies indicate that the short-run payback is not sufficient to justify the investment. By the capital investment rules used by some companies, major manufacturing technology investments can never be made because they will not pay back fast enough to qualify. This approach can make it impossible to stay competitive, eventually resulting in closing the business.

Most top executives have little difficulty with the need to invest toward developing up-to-date products and with a level of uncertainty regarding the return on that type of investment. They have not, however, been able to apply similar standards to process development, which is also fundamental to maintaining competitiveness in the long run.

### 3.4.2.3 Shortage of Skilled Workers

Many North American manufacturers complain that they are unable to apply advanced technologies due to a shortage of skilled personnel needed to operate the equipment. Some companies decide not to invest in training employees because once they get people trained, somebody else hires them away at a higher rate of pay. This leads to stagnation as a company cannot advance beyond the capabilities of its workforce. Management must recognize that there are two costs to upgrading employees - the cost of training, and the higher pay rate which they then merit.

Employee education and training practices in North America differ from those in parts of Europe or Asia. In Japan and Germany, more of the industrial workforce is college educated and more training is given to all the workers. In Germany and Sweden, formal apprenticeship programs are provided to prepare young people to enter the workplace with skills that are immediately useful. After entering the workforce, new hires are often given months of training to help them apply those skills effectively.

In North America, there is much less emphasis on the knowledge base of the production worker. For example, in most plants using programmable machine controls, there are no training classes to give employees the skills to program the equipment. Relatively few companies in the small and medium-size range provide anything more than a week of training before putting a manufacturing worker on the line, and, in many cases, employees are expected to be productive on day one.

Basic skill-level deficiencies of recent high school graduates is another problem for managers of North American manufacturing companies. U.S. and Canadian students score much lower in standardized tests than their counterparts in other industrial countries. As a result, some companies have found it necessary to teach fundamental English and math skills to their employees to make them "trainable" in the skills of the workplace.

### 3.4.2.4 Technological Complexity

Most manufacturing companies do not have the technical capability to tie together the several disciplines required to install comprehensive manufacturing systems. Such systems may include production machinery, material handling devices (e.g., robots, AGVs), communications systems that allow all the elements to talk together, and computers or other sophisticated control equipment to direct the system.

The overall complexity of this entire package of technologies can be a major source of concern for the using company, especially if the entire system isn't available from a single source. Manufacturers don't want to be in the position of having to deal with several vendors, all pointing fingers at one another, when the system doesn't function.

### 3.4.2.5 Lack of Volume

Lack of large lot sizes is often given as the reason for not applying AMT.

Flexibility, not high-volume, is the primary objective of programmable automation. High-volume production is not required to reap the benefits available from AMT. In fact, flexible-manufacturing cells and systems provide little or no benefit over traditional systems when used to address high-volume requirements.

However, the flexibility message has apparently not been effectively communicated to actual and potential users of AMT. Most companies that have not adopted computerized manufacturing methods offer the reason that batch sizes are too small to make computerization cost-effective. Even worse, in companies where computerized equipment has been implemented, it is often applied to volume requirements as opposed to providing a cost-effective means of producing a variety of products. Such applications offer marginal benefit over traditional methods, leading to negative impressions of AMT.

Computerized manufacturing, as well as other advanced-manufacturing methods, are increasing manufacturing flexibility by providing for quick changeover from one product to another. Using these techniques, greater product variety is possible without the significant cost penalties associated with short run production using traditional manufacturing methods.

In short, lack of large lot sizes is a reason <u>for</u> applying AMT.

## 3.4.3 ADVANCED MANUFACTURING MANAGEMENT TRENDS

### 3.4.3.1 Concurrent Engineering

When design engineering and manufacturing people work together on new designs, major bottlenecks are broken and several levels of approval can be eliminated. This practice, called concurrent engineering, also speeds new designs to market. Concurrent engineering produces designs with fewer parts and better overall manufacturability, thereby reducing manufacturing costs and throughput time while increasing product quality. Where applied, concurrent engineering has been so successful that it seems destined to be applied universally.

Prior to the use of concurrent engineering, the manufacturing organisation actually had little effect on the cost of the products it produced. By the time the product had been designed and the design tested, 90% of the manufacturing costs had been locked in.

An additional problem in the traditional design and manufacturing relationship has been a general lack of mutual appreciation and, sometimes, respect. Concurrent engineering puts these people on the same team and gets them thinking about the product under development in terms of manufacturability as well as functionality.

With concurrent engineering, elapsed time to manufacture is reduced because tasks that used to occur serially now happen in parallel, and they tend to get done right the first time because the product is well-understood by manufacturing people from the beginning. This approach also enhances the effectiveness of design automation and computer-aided manufacturing technologies.

Concurrent engineering is actually a throwback to the way American manufacturers operated before World War II, which was copied effectively by the Japanese. Engineers designed products and lived with them in manufacturing as well. There was no handoff from one engineering department to another as there was only one engineering department.

The trend toward large departments, specializing in design engineering, manufacturing engineering, maintainability design, reliability analysis, and production planning is being reversed. Small teams are being formed from the various disciplines to take responsibility for a product; one effect is the elimination of numerous management approvals. Suppliers are part of the team as well because manufacturability is as important for purchased components as it is for items built in-house.

Eastman Kodak is restructuring into cross-functional teams and making decisions without multiple layers of management approval slowing down the process. General Electric's appliance division and Motorola's radio-telephone plant are also cutting large chunks of management hierarchy out of the design loop. Cincinnati Milacron's injection molding equipment plant, using a concurrent engineering approach called "Wolfpack," developed a new machine to ambitious cost and performance goals in record time. Milacron recently announced that the Wolfpack approach will be used on all products.

#### 3.4.3.2 Total Quality Management

The concept of quality has expanded in all directions. Product quality that was once considered "acceptable," based on comparisons with local competition and what customers would put up with, is now totally unacceptable as companies strive for the lofty goals characterized by such phrases as "Zero Defects" and "Six-Sigma Quality" (99.9997% defect free).

Advanced technology in the form of automated equipment is being applied to hold tighter tolerances and obtain more repeatable performance than is possible with manual equipment.

Suppliers must measure up to the same standards if they are to continue to do business with a world-class quality company.

Quality programs are now viewed in a far broader scope than product quality alone. Total quality management means getting everything right the first time. This includes order entry, invoicing, service, housekeeping and maintenance, as well as the product.

Quality is getting top-management attention in companies striving for world-class status. Experience with the application of total quality management has not only proved the once-controversial claim that quality is free, it has proved that quality pays dividends. Companies that don't achieve both the breadth and depth of quality now being pursued by world leaders will have difficulty surviving in the 1990s. What is now considered to be outstanding performance will likely become the norm of world-class competitors by the year 2000. It will be difficult, if not impossible, for those who don't meet increasingly demanding quality criteria to stake out any worthwhile market.

#### 3.4.3.3 Just-In-Time

Japanese manufacturers pioneered a set of manufacturing precepts that result in substantial reductions in inventory, floor space, and product cost. Much of the improvement in the most effective manufacturing organisations has been through the application of low-cost techniques of just-in-time (JIT) production. These are necessary first steps in manufacturing process improvement. Only after the production process is running smoothly and waste has been attacked does it make sense to apply advanced technologies such as computers or other automatic controls.

Key elements of JIT include:

- The elimination of waste

- Building quality in as opposed to inspecting and then rejecting production that doesn't measure up
- Making only what's needed with no stockpiles between production operations.
- The ability to make quick changes from one product to another with minimal set-up time
- Grouping equipment into cells for the manufacture of a family of products, thus allowing production to flow, one unit at a time, from operation to operation
- Applying the principle of pulling parts through the production cycle based on next step requirements, rather than pushing them through based on prior step production
- Bringing supplier goods to receiving docks only as they are needed

Applied properly, JIT is a business approach that orients the entire company toward final customer demand.

Inventory and cost benefits for companies that implement internal and vendor JIT programs make the returns well worth the effort. Inventories are often reduced by as much as 80%. Floor space can typically be reduced by 50%. Generally, approximately 30% is cut from the cost of purchased parts and materials over a two-year period.

#### 3.4.3.4 Flexible Manufacturing

Variety can be an effective, competitive weapon. However, in traditional manufacturing systems, producing a wide variety of products can drive up costs. Flexible systems using manufacturing cells can provide a solution to this dilemma within a wide range of volume-variety trade-offs. Managing the variety factor is a strategic issue requiring management attention as part of overall business and manufacturing strategy.

Flexible manufacturing can help equalize the cost factors between small and large manufacturers. The goal of flexible manufacturing is efficient production of lots of one unit. Establishing a system that can build one unit as effectively as it can build one thousand may be viewed as a concession to variety over volume but, by applying manufacturing principles such as cellular manufacturing and the other facets of JIT, effectiveness is enhanced for a broad mix of lot sizes.

Manufacturing cells are at the heart of the flexible manufacturing strategy. Cells are formed by grouping together machinery and equipment used to produce a family of parts or products. This allows for a flow of units, one at a time, from operation to operation. Quick changeover of tooling and/or part programs from one product to another is essential to making cellular manufacturing cost-effective and timely.

Prior to using the cell concept, parts were generally produced in batches that were wheeled on carts from one machine to another, often in separate departments, to have the various required operations performed on them. Grouping the equipment together eliminates the movement of material and the massive amounts of in-process inventory that prevailed under the traditional system.

### 3.4.3.5 Statistical Process Control

One means of implementing the JIT precept of building quality into the product is statistical process control (SPC). It is important to distinguish clearly between SPC and statistical quality control (SQC). As traditionally implemented, SQC looks at defects and analyzes them by cause. SPC attempts to eliminate defects by taking measurements while production is in process. These measurements allow operators or automatic control systems to adjust the machine or process before defective parts are produced. SPC recognizes that the process must be in control in order to produce quality products. One difference between SPC and SQC is that, while SQC looks at defects to determine what might be done to reduce rejections next time, SPC looks at variations taking place within specification limits to make sure that no defects occur this time.

Effective application of SPC requires an in-depth understanding of the process. The process must have the essential capability to produce the product within the specified limits. If the requirement is tighter than the process can be controlled, no amount of SPC will help.

Making employees responsible for the process they operate is an integral element of SPC. Using SPC and having the ability to control the process allows employees to take an "ownership" attitude toward the process they operate and the parts they produce.

#### 3.4.3.6 Employee Empowerment

Through providing the tools for workers to accept ownership of the processes and machines they operate and by giving teams of employees decision-making authority, better products have been developed faster, delivery cycle times have been reduced, and quality enhanced. The Japanese call it "harnessing the wisdom of the anthill" and it has produced remarkable results in several companies in North America as well as in Japan. Employees of key suppliers are involved too, because their expertise is required to address all the salient factors.

The concurrent engineering examples show what can happen when employees are given authority in the design process. The principle of giving employees decision-making power goes beyond product development, however. In General Electric's circuit breaker plant, one of the obstacles to reduced cycle time was overcome by getting decisions made on the plant floor. *Fortune* magazine described the situation in its February 13, 1989 edition. "The solution was to get rid of all line supervisors and quality inspectors, reducing the organisational layers between worker and plant manager from three to one. Everything those middle managers used to handle — vacation scheduling, quality, work rules — became the responsibility of the 129 workers on the floor, who are divided into teams of 15 to 20. . . . The more responsibility GE gave the workers, the faster problems got solved and decisions made."

Empowering employees is not a fad or short-term program; it represents an essential change in companies' relationships with employees. Many manufacturing executives hold that employment must be guaranteed to get real cooperation of the people. Simply giving lip service to employee empowerment won't work nor will putting in a mechanism for employee input (e.g., quality circles), unless that input is respected and applied.

### 3.4.3.7 Customer/Supplier Relationships

World-class manufacturers work closely with customers and suppliers. Since 60% to 70% of the cost of most manufactured products is in purchased materials and parts, close relationships with major suppliers may be the most important factor in reducing product cost. The importance of vendor participation is based on more than the cost factor, however. Inventories cannot be managed effectively unless suppliers are willing to meet the customer's flexibility and JIT requirements. Product innovation is often dependent on a vendor's ability to use new materials or production techniques.

Customers in this arrangement will want to dig into the books of their suppliers. The president of one American company, now working successfully as a supplier to a Japanese manufacturer, was reluctant at first to give his customer all the requested information. "They want to know things we don't even tell our mothers," was his reaction.

It isn't practical to work this closely with several suppliers for the same materials or parts. Tight cooperation to reduce costs and increase the profits of both companies is the goal, rather than one side getting an advantage to the detriment of the other. Competitive bidding is eliminated as a factor. The relationship had better be a good one because it is likely to be a long one.

### 3.4.3.8 Managing Technology Implementation

Much of the improvement that has been accomplished in the most effective manufacturing organisations has been through the application of low-cost techniques such as just-in-time production, mistake-proof assembly aids that reduce or eliminate costly inspection steps, and generally eliminating waste wherever it is found in the plant or office. These are necessary first steps in manufacturing process improvement.

Only when the production process is running smoothly and waste has been attacked does it make sense to apply advanced technologies such as computers or other automatic controls. In fact, the automation horror stories that strike fear into the hearts of reluctant managers are generally those situations where automation was attempted as a cure for poor fundamental production techniques. In the early days of office automation, "garbage-in, garbage-out" was the phrase used to describe the results of attempting to computerize chaos. In the manufacturing arena, the results are potentially worse; automation, applied to a chaotic production process, can make scrap much faster than manual systems.

A key factor in preparing for automation is "design for manufacturing." This is a natural outcome of the concurrent engineering approach, but that tends to deal only with new designs. Existing designs must also be addressed. There are many examples of manufacturers reducing part counts by greater than 50% when that becomes a major design objective. When automating assembly, the number of part types to be dealt with is a significant factor in the complexity and effectiveness of the application.

Substantial part-count reductions are not unusual because the original designers were not motivated to minimize part types used in the product or across the product line. They may not have been fully aware of the effects in manufacturing of using, for example, five similar but different types of screws as opposed to one. If aware, the designers may have been driven by other forces. A division manager in a major U.S. machine tool company said he was astonished and dismayed when he asked his designers to cut 30% out of the part count on each of the products the division manufactured. "They told me that would be easy. So I asked: 'If it's so easy, why hasn't it been done before?' They told me that we never gave them time to do it right, just to get it done."

Some of the manufacturing concepts that are thought of as part of an automation program can be implemented quite effectively on a manual basis, either as a first step in the automation process or as an ultimate solution. Cellular manufacturing does not necessarily require a computer to control the operations of the cell nor an automated material handling system to move parts from one cell resource to another. Many cells are in operation without automation and many more that are now automated began as manual cells.

SPC is another concept that operates quite effectively in a non-automated mode. Operators take measurements and plot results to see how their machine or process may be drifting. This provides them and management with a much better understanding of how that particular productive resource works and what repeatability can be expected of it. It will also provide valuable information for specifying the new equipment when it is time to apply AMT to that function.

Taking AMT in steps is generally a good plan when upgrading existing facilities. Implementing these production practices prior to investing in AMT equipment can help to prepare for planned automation and computerization. As a part of the step installation of AMT, grouping equipment into cells, implementing SPC on a manual basis, establishing close working relationships with key suppliers, and giving employees more decision-making power, are positive steps that can be taken early in the game. They will help smooth the eventual transition to advanced technologies.

Although total system solutions are what most manufacturers require in the implementation of advanced manufacturing technology in their plants, it is not always easy to find a willing and capable supplier to take on that task. Over the last several years a class of companies called system integrators has evolved to fill this gap. System integration covers a wide range of services that includes activities from the concept development stage of a manufacturing process to the final installation and maintenance of the system. Management may have to rely on qualified integrators to handle systems where the technical complexity is beyond the competence of the user company and the AMT equipment suppliers.

### 3.4.3.9 Managing Changing Relationships

Management of manufacturing companies is changing and not only in terms of the technologies being applied. Significant changes are also taking place in the way management works with customers, suppliers, employees, and shareholders. Alliance partners and system integrators represent classes of relationships entirely new to many companies.

A deeper understanding of customer needs and usage patterns in a total product-service sense is key to linking the factory with the market place. Value is an amalgam of product configured to needs, physical quality, delivery speed and reliability, service, and price.

Supplier partnership means involving suppliers in product and process development, cost management, schedule setting and inventory control. It implies long-term commitment, coordinated improvement programs and the sharing of benefits.

Employee empowerment may entail guaranteeing employment, allowing employees to set their own schedules, and giving them authority in team structures to make important production decisions. Empowered employees are encouraged and expected to take an "ownership" interest in the process that they operate.

Directors, shareholders, and lenders need to commit to businesses and core competencies for the long haul. CEOs who are able to manage these relationships will win the opportunity to strive for world-class status.

Strategic alliances can be useful for entering new markets and learning new technologies. Management must be sure the goals are realistic, the relationship is manageable, and that core competencies are not compromised.

System integrators have emerged to provide a service to manufacturing companies in need of a total-system supplier. Most manufacturing companies cannot tie together the several technical disciplines required to implement a complex automated manufacturing system. Manufacturers investing in these systems may have to rely on an integrator as the one supplier to take responsibility for the total system. Managing activities that are beyond the internal technical competence of the company is a difficult task requiring a combination of trust in the supplier and effective cost and schedule controls.

Managing these new and changing relationships may be among the most difficult steps for traditional managers striving for world-class status. Guaranteeing employment, partnering with suppliers, opening the books to customers, and giving employees authority to make key decisions are foreign concepts to many executives who have ascended through the ranks of manufacturing companies over the past thirty years. For many, the old ways will not be easily or confidently put aside.

# 4.0 AMT MARKET FORECASTS

Note: Except where indicated, the data sources for all Tables and Charts in Section 4 are Automation Marketing Strategies, Inc. and CIMdata, Inc. Data for 1985 actual purchases and 1990 estimates are from CIMdata; forecasts for 1995 and 2000 purchases were developed by AMS.

All figures are reported in millions of U.S. dollars.

Purchase data are based on end-user expenditures, not supplier sales. The figures are the total costs associated with the acquisition of the product or service.

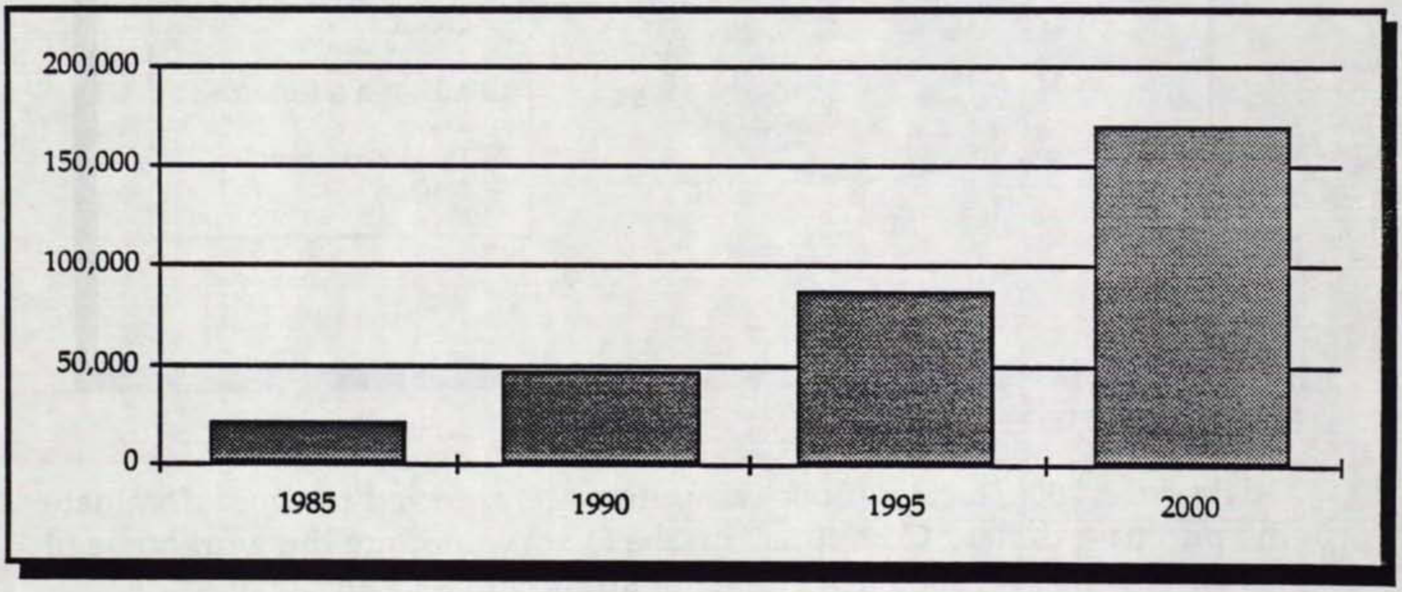
Columns may not sum to total due to rounding.

The column heading CAGR refers to Compound Annual Growth Rate.

## 4.1 MARKET BY PRODUCT/SERVICE CLASS

Worldwide, purchases of AMT products are growing rapidly. Advanced manufacturing technology is one of the most dynamic areas of industrial investment in all regions of the world. From purchases of just over $20 billion (US) in 1985, the market is expected to expand to over $170 billion by the turn of the century. In the year 2000, total purchases of advanced manufacturing technology products and services are forecast to be eight and a half times their 1985 level, having expanded at a compound annual rate of 15% over the last decade of the Twentieth century. From 1985 to 1990, purchases of AMT products and services are estimated to have grown at 18% annually. Although slowing somewhat, the growth rate is forecast to remain in double digits through the 1990s.

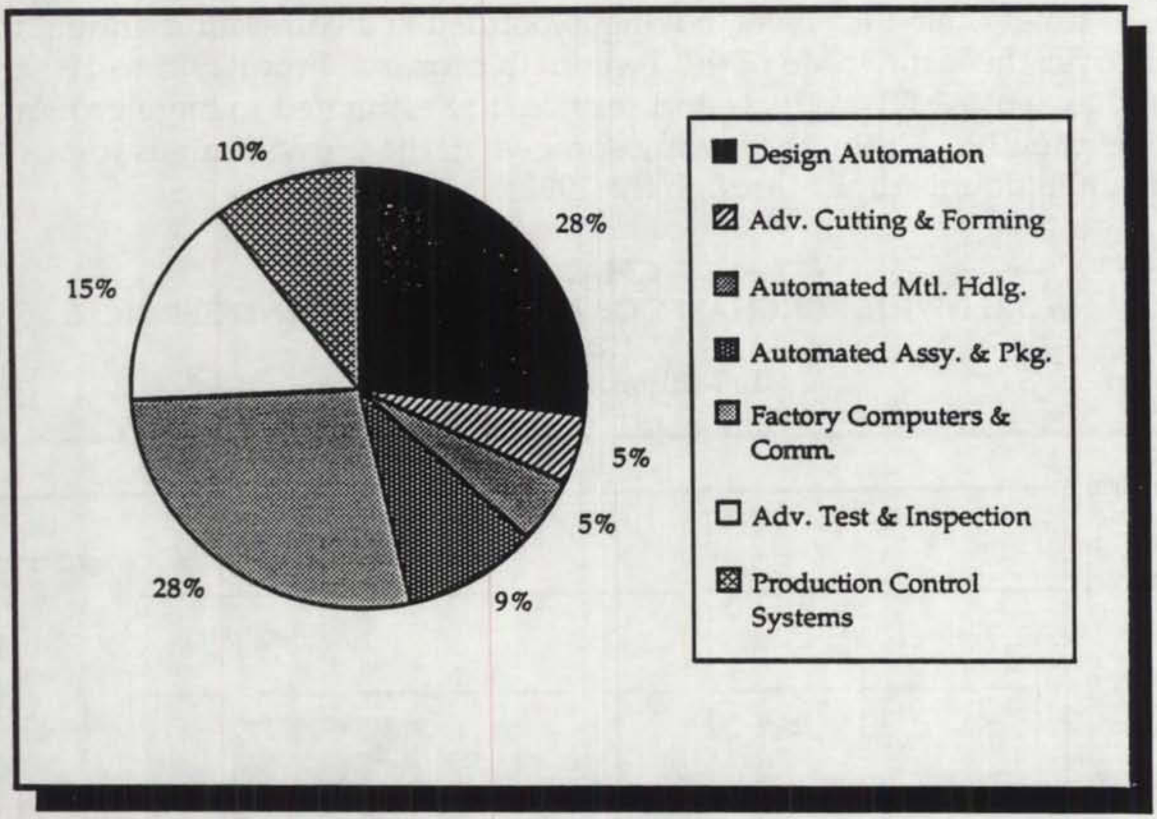
**CHART 4A**
**WORLDWIDE PURCHASES OF AMT PRODUCTS AND SERVICES**
**1985-2000**
**(In Millions of U.S. Dollars)**




Source: Table 4-1

In 1985, the largest product category was factory-floor computers. By 1990, these computers shared that status with design-automation products. The 25% annual expansion of design automation is expected to slow during the next decade to a rate less than half its late 1980s growth. It is expected that this class of equipment will hold about a 28% share of the total purchase dollar in 1990 falling to approximately 21% in the year 2000.

### CHART 4B
### WORLDWIDE PURCHASES OF AMT PRODUCTS AND SERVICES BY PRODUCT CATEGORY
### 1990



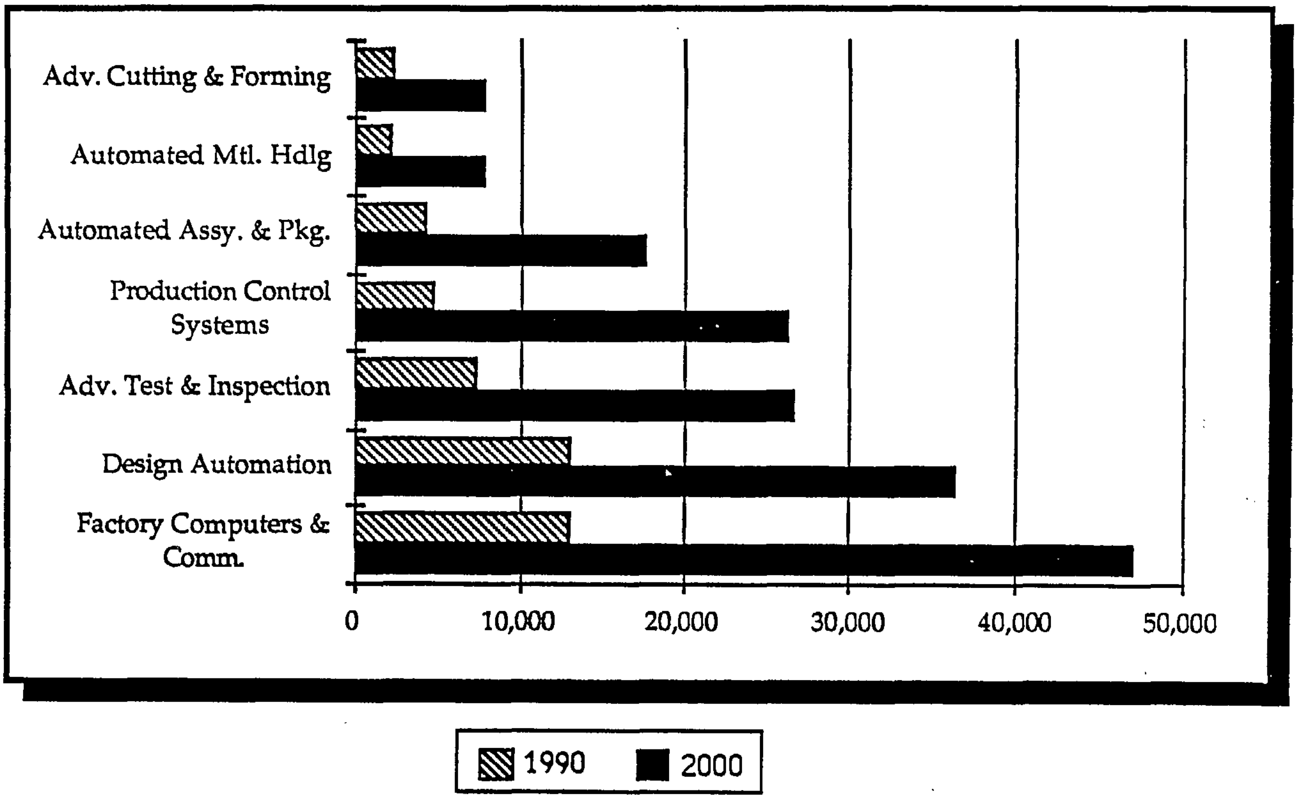

Source: Table 4-1

By the year 2000, factory-floor computers are expected to again dominate the purchase dollar. Computers on the factory floor are the workhorse of the AMT industry, used in a variety of applications by all the user industries, and expected to be equally popular worldwide.

Over the decade of the 1990s, production-control systems are forecast to be the fastest growing product category. Purchases are estimated to grow from $5 billion in 1990 to $26 billion in 2000. This product class is expected to be much more widely used as the production control systems benefit from advances in software sophistication and hardware capability over the next decade.

Automated assembly and packaging systems are forecast to maintain their 15% annual increase over the next decade. At that rate, by the turn of the century, this product class will account for 10% of the overall AMT purchases. Over the 1990s, automated assembly and packaging systems are expected to expand from purchases of $4 billion in 1990 to $18 billion in the year 2000.

### CHART 4C
### WORLDWIDE PURCHASES OF AMT PRODUCTS AND SERVICES BY PRODUCT CATEGORY
**1990 & 2000**
**(In Millions of U.S. Dollars)**




Source: Table 4-1

Purchases of all these products are being driven by a combination of factors, most notably the emphasis on manufacturing quality and the shortage of skilled labour in much of the developed world.

Design automation purchases grew rapidly over the 1980s. The forecast for the next decade is for slowing, but nevertheless healthy, growth. From a 25% annual growth rate over the 1985-1990 period, design automation purchases are expected to expand at an 11% annual rate over the 1990s. This growth rate should take worldwide purchases of these products from $13 billion to $36 billion over the decade.

**TABLE 4-1**
**WORLDWIDE PURCHASES OF AMT PRODUCTS AND SERVICES BY PRODUCT CLASS**
**1985-2000**
**(In Millions of U.S. Dollars)**

| | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Design Automation | $4,343 | $13,069 | 24.6% | $21,372 | 10.3% | $36,406 | 11.2% |
| Advanced Cutting & Forming | 1,284 | 2,358 | 12.9% | 4,141 | 11.9% | 7,963 | 14.0% |
| Automated Materials & Parts Handling | 1,427 | 2,336 | 10.4% | 4,200 | 12.4% | 8,067 | 13.9% |
| Automated Assembly & Packaging Systems | 1,812 | 4,406 | 19.4% | 7,895 | 12.4% | 17,767 | 17.6% |
| Factory Floor Computers & Communications Links | 5,775 | 13,161 | 17.9% | 24,360 | 13.1% | 47,171 | 14.1% |
| Advanced Test & Inspection Systems | 3,757 | 7,528 | 14.9% | 14,106 | 13.4% | 26,685 | 13.6% |
| Production Control Systems | 2,531 | 4,903 | 14.1% | 11,667 | 18.9% | 26,303 | 17.7% |
| **TOTAL** | $20,930 | $47,760 | 17.9% | $87,742 | 12.9% | $170,362 | 14.2% |

Purchases of advanced test and inspection systems are expected to enjoy a 13% annual growth rate for the next decade. Even so, the product category should fall from 18% of the total AMT market in 1985 to 16% in 2000. Even with the concern for product quality, purchases of these systems are not expected to grow as rapidly as the overall market as more manufacturers move toward placing greater resources into controlling process quality and fewer into controlling product.

Increased automation of the manufacturing process is expected to serve to expand purchases of automated materials and parts handling while the concern with inventory control should tend to keep growth rates slightly lower than overall AMT growth. Advanced cutting and forming equipment should continue to experience healthy growth with purchases expanding at a compound annual rate of 13% through the decade. The forecast calls for higher growth rates during the second five year period from 1995-2000. By the year 2000 purchases of this equipment are expected to total $8 billion.

## 4.2 1990 MARKET BY END USER INDUSTRY

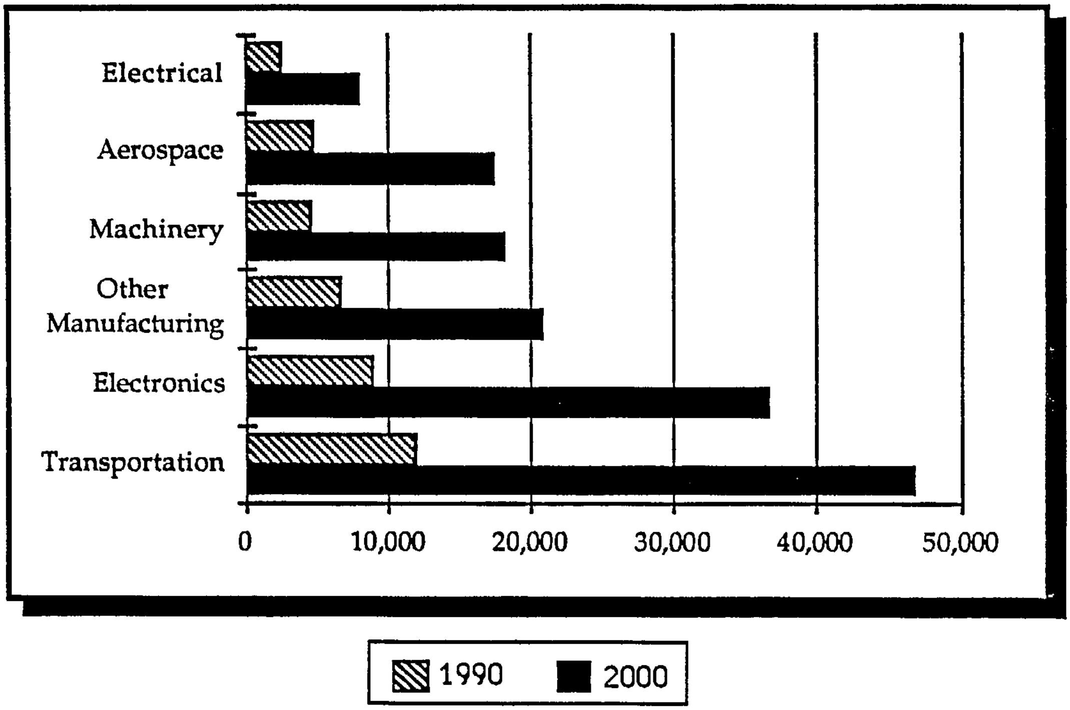
After growing at a compound annual rate of 18% over the five year period from 1985 to 1990, the discrete industries worldwide are projected to continue to invest aggressively in advanced manufacturing technology products and services. As the purchase levels rise, however, the growth rates for the next decade should be somewhat lower than the past period. The overall discrete industries are forecast to expand their purchases of AMT products and services by a total of 250% over the next decade. This is expected to take purchases of AMT by these users from an estimated $40 billion in 1990 to a forecast $149 billion in the year 2000.

The discrete industries are the major users of these advanced manufacturing technology products and services. However, some of these products and services are also used in process industries. The discrete industries share of the purchases, estimated at 84% in 1990, is expected to expand to an estimated 87% by 2000. Table 4-2 outlines the breakdown of purchases by discrete and process end-user industries.

**TABLE 4-2**
**WORLDWIDE MARKET FOR AMT PRODUCTS AND SERVICES**
**BY END USER INDUSTRY**
**1985-2000**
**(In Millions of U.S. Dollars)**

| | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Aerospace | $2,421 | $4,936 | 15.3% | $9,284 | 13.5% | $17,612 | 13.7% |
| Transportation | 5,158 | 12,087 | 18.6% | 23,511 | 14.2% | 46,924 | 14.8% |
| Electronics | 3,922 | 9,018 | 18.1% | 17,873 | 14.7% | 36,737 | 15.5% |
| Electrical | 1,065 | 2,698 | 20.4% | 4,413 | 10.3% | 8,093 | 12.9% |
| Machinery | 2,057 | 4,740 | 18.2% | 9,074 | 13.9% | 18,356 | 15.1% |
| Other Manufacturing | 3,045 | 6,860 | 17.6% | 10,732 | 9.4% | 20,986 | 14.4% |
| Discrete Manufacturing | 17,668 | 40,339 | 18.0% | 74,887 | 13.2% | 148,708 | 14.7% |
| Process Industries | 3,262 | 7,421 | 17.9% | 12,855 | 11.6% | 21,654 | 11.0% |
| **TOTAL** | $20,930 | $47,760 | 17.9% | $87,742 | 12.9% | $170,362 | 14.2% |

## CHART 4D
## WORLDWIDE MARKET FOR AMT PRODUCTS AND SERVICES BY DISCRETE MANUFACTURING INDUSTRY
### 1990-2000
### (In Millions of U.S. Dollars)

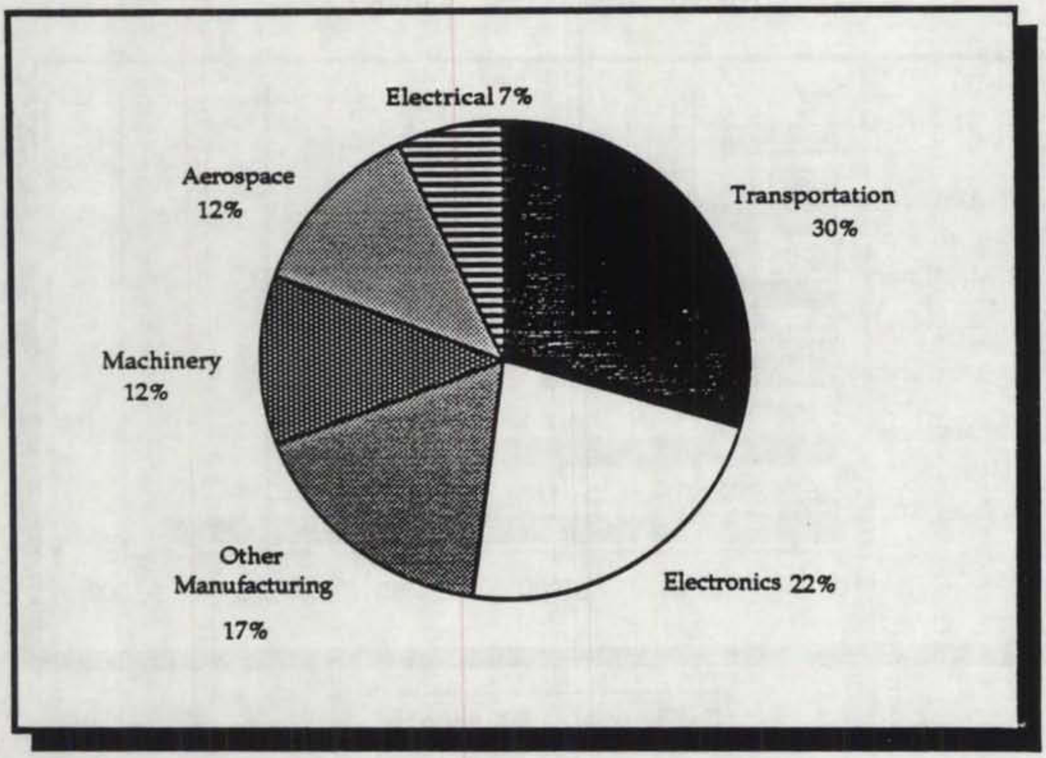



Source: Table 4-2

The major user industry has been, and is forecast to continue to be, transportation equipment. Accounting for $5 billion in overall purchases in 1985, purchases by this sector grew by almost 20% to an estimated $12 billion in 1990. Over the next decade, purchases by transportation industry end users are forecast to expand an average of 15% annually to $47 billion worldwide by the year 2000.

The electronics industry is forecast to experience the highest expansion rate of purchases of AMT products and services over the 1990s. For the decade as a whole, the industry is estimated to expand purchases by 15%. Purchases in the 1990-95 period are expected to expand at just under 15%, with purchases in the second half of the decade growing at 15.5%. As the industry enjoys robust expansion in its own sales rates, it is expected to invest in automation to facilitate this growth. Purchases by the electronics industry are expected to expand from $9 billion in 1990 to $37 billion in 2000.

CHART 4E
WORLDWIDE MARKET FOR AMT PRODUCTS AND SERVICES
BY DISCRETE MANUFACTURING INDUSTRIES
1990 AS A % OF TOTAL




Source: Table 4-2

Both aerospace and machinery industry purchases of AMT have been growing rapidly, and are expected to continue to do so through the decade of the 1990s. The only industry forecast to experience significantly lower growth in AMT purchases in the 1990s as opposed to the 1980s is the electrical industry. The industry is no longer expanding purchases from a small base and is somewhat burdened by underutilized capacity. The other manufacturing segment, after falling off in the early part of the decade, is expected to rebound to higher growth levels in the second half of the 1990s. Discrete industries are expected to expand purchases of AMT products and services more rapidly in the latter half of the decade as they absorb investments in advanced manufacturing technology purchased in the 1980s and as several major national economies recover from the slow-down expected early in the decade.

## 4.2.1 AEROSPACE

The bulk of the investment dollars from the aerospace industry in AMT has been, and should continue to be in factory floor computers and communications links. The industry made significant purchases of design automation equipment in the 1980s. Although purchases should continue strong, the high growth rates are not expected to continue in the 1990s. The most rapidly expanding product categories are forecast to be automated assembly and production control systems. Overall, the forecast for aerospace is for a 13.5% growth rate expanding the overall purchase level from $5 billion in 1990 to $18 billion in the year 2000.

**TABLE 4-3**
**PURCHASES OF AMT PRODUCTS AND SERVICES BY THE AEROSPACE INDUSTRY**
**1985-2000**
**(In Millions of U.S. Dollars)**

| AEROSPACE | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Design Automation | $322 | $828 | 20.8% | $1,391 | 10.9% | $2,222 | 9.8% |
| Advanced Cutting & Forming | 210 | 327 | 9.3% | 612 | 13.3% | 1,138 | 13.2% |
| Automated Materials & Parts Handling | 285 | 411 | 7.6% | 777 | 13.6% | 1,431 | 13.0% |
| Automated Assembly & Packaging Systems | 227 | 596 | 21.3% | 1,126 | 13.6% | 2,757 | 19.6% |
| Factory Floor Computers & Communications Links | 769 | 1,648 | 16.5% | 3,287 | 14.8% | 6,217 | 13.6% |
| Advanced Test & Inspection Systems | 398 | 737 | 13.1% | 1,241 | 11.0% | 2,122 | 11.3% |
| Production Control Systems | 210 | 388 | 13.0% | 848 | 16.9% | 1,724 | 15.2% |
| TOTAL | $2,421 | $4,936 | 15.3% | $9,284 | 13.5% | $17,612 | 13.7% |

## 4.2.2 TRANSPORTATION

Overall purchases from the transportation industry are forecast to grow from $12 billion in 1990 to almost $50 billion at the turn of the century. By 2000 design automation products and services are expected to be eclipsed by factory floor computers and communications links as the largest product category. Design automation purchases, which grew at 23% over the end of the 1980s are expected to expand at much lower rates through the 1990s. Still, by the year 2000, design automation purchases by the transportation industry worldwide are forecast to total over $10 billion.

Factory floor computer and communication links purchases should continue their robust growth through the next decade. Purchases are forecast to grow from an estimated 1990 level of $3 billion to $15 billion in the year 2000.

**TABLE 4-4**
**PURCHASES OF AMT PRODUCTS AND SERVICES BY THE TRANSPORTATION INDUSTRY**
**1985-2000**
**(In Millions of U.S. Dollars)**

| TRANSPORTATION | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Design Automation | $1,372 | $3,922 | 23.4% | $6,496 | 10.6% | $10,124 | 9.3% |
| Advanced Cutting & Forming | 368 | 614 | 10.8% | 1,147 | 13.3% | 2,206 | 14.0% |
| Automated Materials & Parts Handling | 499 | 771 | 9.1% | 1,470 | 13.8% | 2,809 | 13.8% |
| Automated Assembly & Packaging Systems | 398 | 1,183 | 24.3% | 2,249 | 13.7% | 6,365 | 23.1% |
| Factory Floor Computers & Communications Links | 1,426 | 3,154 | 17.2% | 7,236 | 18.1% | 15,170 | 16.0% |
| Advanced Test & Inspection Systems | 864 | 1,948 | 17.7% | 3,640 | 13.3% | 7,231 | 14.7% |
| Production Control Systems | 231 | 496 | 16.5% | 1,272 | 20.7% | 3,020 | 18.9% |
| TOTAL | $5,158 | $12,087 | 18.6% | $23,511 | 14.2% | $46,924 | 14.8% |

## 4.2.3 ELECTRONICS

Purchases of AMT products and services by the electronics industry should by driven by the expansion that the industry is expected to experience with its own product sales growth Overall AMT purchases are expected to expand from $9 billion in 1990 to $37 billion in the year 2000. The largest component of the year 2000 purchases is predicted to be advanced test and inspection systems, followed closely by purchases of design automation products. this represents a change from the beginning of the decade when the purchase estimates show design automation products slightly outstripping the test and inspection systems. The fastest growing product category over the decade is forecast to be the production control systems.

**TABLE 4-5**
**PURCHASES OF AMT PRODUCTS AND SERVICES BY THE ELECTRONICS INDUSTRY**
**1985-2000**
**(In Millions of U.S. Dollars)**

| ELECTRONICS | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Design Automation | $769 | $2,643 | 28.0% | $4,500 | 11.2% | $9,153 | 15.3% |
| Advanced Cutting Forming | 276 | 600 | 16.8% | 1,040 | 11.6% | 2,033 | 14.3% |
| Automated Materials & Parts Handling | 57 | 128 | 17.6% | 252 | 14.4% | 593 | 18.7% |
| Automated Assembly & Packaging Systems | 563 | 1,363 | 19.3% | 2,355 | 11.6% | 4,718 | 14.9% |
| Factory Floor Computers & Communications Links | 188 | 548 | 23.9% | 1,135 | 15.7% | 2,684 | 18.8% |
| Advanced Test & Inspection Systems | 1,480 | 2,507 | 11.1% | 5,410 | 16.6% | 10,073 | 13.2% |
| Production Control Systems | 589 | 1,230 | 15.9% | 3,180 | 20.9% | 7,484 | 18.7% |
| TOTAL | $3,922 | $9,018 | 18.1% | $17,873 | 14.7% | $36,737 | 15.5% |

## 4.2.4 ELECTRICAL

Purchases of AMT products and services by the electrical industry over the second half of the 1980s represented the largest growth rate among the discrete industry end-users. This is not expected to continue in the next decade. The overall growth rate is forecast to fall to 10% in the first half of the 1990s, rising to 13% in the second half. The product category with the largest overall growth rate expected in the last decade of the century is production control systems, expanding from $3 billion in 1990 to $8 billion by the year 2000.

The largest category has been design automation. Design automation is predicted to take the largest share of AMT purchase dollars from the electrical industry. The annual purchases are forecast to expand from 1990s $1.3 billion to $3.3 billion in the year 2000. The next largest product expenditures are predicted to go to advanced test and inspection systems.

Expenditures for this product category are expected to grow to $2.9 billion from a level of $1 billion in 1990.

**TABLE 4-6**
**PURCHASES OF AMT PRODUCTS AND SERVICES BY THE ELECTRICAL INDUSTRY**
**1985-2000**
**(In Millions of U.S. Dollars)**

| ELECTRICAL | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Design Automation | $414 | $1,297 | 25.6% | $1,954 | 8.5% | $3,272 | 10.9% |
| Advanced Cutting & Forming | 11 | 29 | 22.2% | 50 | 11.7% | 117 | 18.7% |
| Automated Materials & Parts Handling | 14 | 36 | 20.3% | 63 | 11.9% | 151 | 19.1% |
| Automated Assembly & Packaging Systems | 8 | 18 | 17.0% | 33 | 13.5% | 78 | 18.5% |
| Factory Floor Computers & Communications Links | 87 | 198 | 17.8% | 373 | 13.6% | 833 | 17.4% |
| Advanced Test & Inspection Systems | 468 | 991 | 16.2% | 1,622 | 10.4% | 2,920 | 12.5% |
| Production Control Systems | 63 | 129 | 15.5% | 318 | 19.7% | 723 | 17.8% |
| TOTAL | $1,065 | $2,698 | 20.4% | $4,413 | 10.3% | $8,093 | 12.9% |

## 4.2.5 MACHINERY

The machinery industry has more than doubled its purchases of AMT products and services over the second half of the 1980s. Although moderating somewhat, purchases are expected to continue to grow rapidly over the next decade to $18.4 billion by the year 2000. The major product area has been, and should continue to be, factory floor computers and communications links. Purchases of products and services in this product class are forecast to expand from $1.4 billion in 1990 to $5.9 billion in the year 2000.

Over the decade of the 1990s the fastest growing purchase category is predicted to be automated assembly and packaging systems. Growing from $80 million in 1990, purchases from this product category are estimated to expand to $600 million by the year 2000.

**TABLE 4-7**
**PURCHASES OF AMT PRODUCTS AND SERVICES**
**BY THE MACHINERY INDUSTRY**
**1985-2000**
**(In Millions of U.S. Dollars)**

| MACHINERY | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Design Automation | $294 | $988 | 27.5% | $1,367 | 6.7% | $2,086 | 8.8% |
| Advanced Cutting & Forming | 137 | 251 | 12.9% | 497 | 14.6% | 1,027 | 15.6% |
| Automated Materials & Parts Handling | 186 | 315 | 11.2% | 630 | 14.8% | 1,292 | 15.4% |
| Automated Assembly & Packaging Systems | 27 | 84 | 25.6% | 192 | 18.1% | 606 | 25.9% |
| Factory Floor Computers & Communications Links | 619 | 1,383 | 17.4% | 2,880 | 15.8% | 5,907 | 15.5% |
| Advanced Test & Inspection Systems | 353 | 770 | 16.9% | 1,283 | 10.7% | 2,374 | 13.1% |
| Production Control Systems | 442 | 950 | 16.5% | 2,226 | 18.6% | 5,065 | 17.9% |
| TOTAL | $2,057 | $4,740 | 18.2% | $9,074 | 13.9% | $18,356 | 15.1% |

## 4.2.6 OTHER MANUFACTURING

The major industries in the other manufacturing sector are fabricated metal, plastic products, apparel, and wood products. Use of AMT products and services by these industries has grown rapidly over the second half of the 1980 as these industries have coped with the forces of competition and other pressures on their margins. The forecast is for investment in AMT to taper off somewhat in the early period of the decade, and then pick up in the second half.

**TABLE 4-8**
**PURCHASES OF AMT PRODUCTS AND SERVICES BY OTHER MANUFACTURING INDUSTRIES**
**1985-2000**
**(In Millions of U.S. Dollars)**

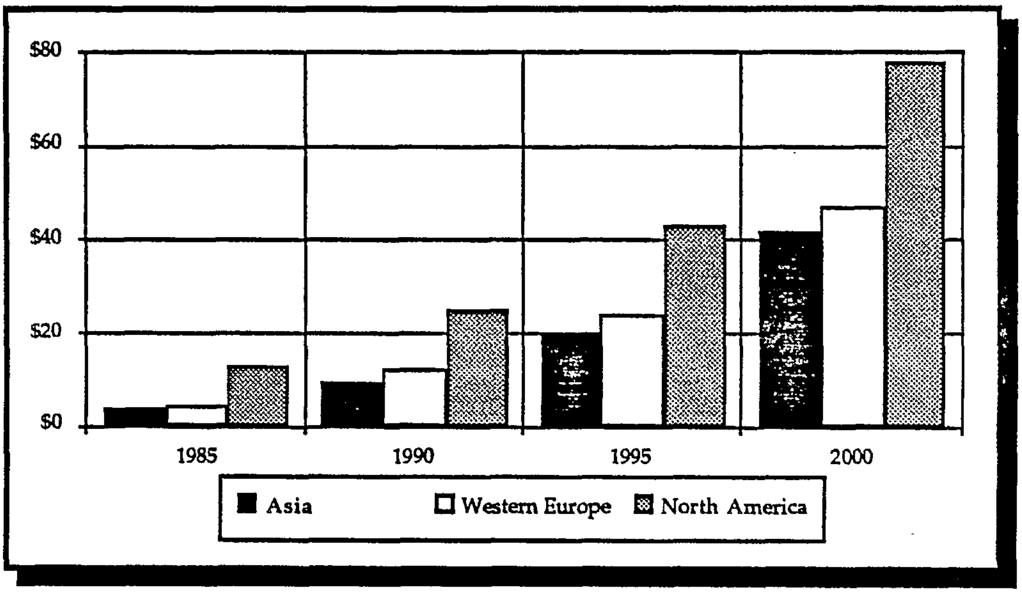
| OTHER MANUFACTURING | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Design Automation | $114 | $461 | 32.2% | $722 | 9.4% | $1,415 | 14.4% |
| Advanced Cutting & Forming | 284 | 538 | 13.6% | 795 | 8.1% | 1,453 | 12.8% |
| Automated Materials & Parts Handling | 385 | 675 | 11.9% | 1,008 | 8.3% | 1,827 | 12.6% |
| Automated Assembly & Packaging Systems | 412 | 734 | 12.2% | 878 | 3.6% | 1,819 | 15.7% |
| Factory Floor Computers & Communications Links | 1,085 | 2,754 | 20.5% | 3,659 | 5.8% | 6,342 | 11.6% |
| Advanced Test & Inspection Systems | 197 | 576 | 24.0% | 914 | 9.7% | 1,980 | 16.7% |
| Production Control Systems | 568 | 1,122 | 14.6% | 2,756 | 19.7% | 6,149 | 17.4% |
| TOTAL | $3,045 | $6,860 | 17.6% | $10,732 | 9.4% | $20,986 | 14.4% |

Design automation expenditures, as is the case with most of the discrete industries, are expected to fall from the very high growth levels to a more moderate growth in the next decade. Factory floor computers and communications links should remain the largest product category of purchases, with production control systems expected to gain rapidly by the end of the decade.

## 4.3 MARKET BY GEOGRAPHIC REGION

North America is projected to remain the largest market for AMT products and services over the decade of the 1990s. However, both Europe and Asia are expected to experience higher growth in AMT investments. By the year 2000 the AMT market in North America is expected to total $78 billion, with European purchases at $47 billion and Asian purchases totalling $42 billion. Over the decade, Asia is expected to expand at a slightly greater rate than Europe, with both outspending the growth in North American.

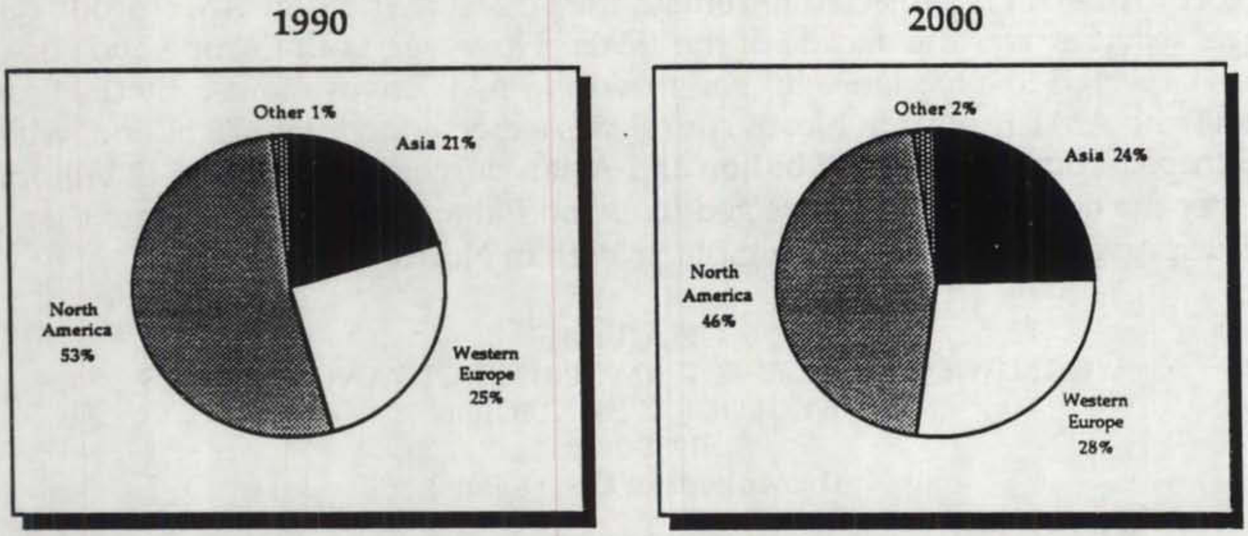
**CHART 4F**
**WORLDWIDE MARKET FOR AMT PRODUCTS AND SERVICES**
**BY GEOGRAPHIC REGION**
**1985-2000**
**(In Millions of U.S. Dollars)**




Source: Table 4-9

The share of the total market that each major region represents is expected to change over the decade of the 1990s. Chart 4G below graphically represents the changes in share. In 1990, North America represented 53% of the worldwide AMT market, Europe 25%, and Asia 20%. The forecast indicates that, by the year 2000, North America will still be the largest market, but is expected to have shrunk to 46%. Both Europe and Asia are expected to expand their investment in AMT at a greater rate than North America, and are expected to command greater shares of the total purchases; Asia 25% and Europe 28%.

## CHART 4G
## SHARE OF TOTAL AMT PURCHASES BY REGION
### 1990 and 2000




Source: Table 4-9

The market for AMT products and services is forecast to expand most rapidly in the "other" areas of the world, but this market segment is still expected to be a minute part of the total market. As the lesser developed countries start to upgrade their manufacturing capabilities, investment in AMT is projected to expand rapidly to bring their capacity up to the technology level of competitors in the developed world.

## TABLE 4-9
## WORLDWIDE MARKET FOR AMT PRODUCTS AND SERVICES BY GEOGRAPHIC REGION
### 1985-2000
### (In Millions of U.S. Dollars)

| | 1985 Actual | 1990 Estimated | CAGR | 1995 Forecast | CAGR | 2000 Forecast | CAGR |
|---|---|---|---|---|---|---|---|
| North America | $12,559 | $25,276 | 15.0% | $43,309 | 11.4% | $77,804 | 12.4% |
| Western Europe | 4,426 | 12,064 | 22.2% | 23,772 | 14.5% | 47,196 | 14.7% |
| Asia | 3,717 | 9,727 | 21.2% | 19,183 | 14.5% | 41,779 | 16.8% |
| Other | 230 | 689 | 24.6% | 1,480 | 16.5% | 3,582 | 19.3% |
| TOTAL | $20,930 | $47,760 | 17.9% | $87,742 | 12.9% | $170,362 | 14.2% |

Within the four regions of the world, the growth rates will vary by country. Each national market has a slightly different set of motivators and varying resources that can be committed to investment in advanced manufacturing technologies. In Europe, for example, the largest market has been Germany; with the growth of the economy and the integration of East and West Germany, investment in AMT is expected to continue to expand at the highest rate on the continent, over 15% compounded annually.

In North America, Canada is expected to increase purchases of advanced manufacturing technologies products/services from an estimated $1.7 billion to a forecast $5.5 billion by the year 2000. This represents an annual growth rate over 12%, while the U.S. investment ratio will grow at just under 12%, falling off from the 1985-1990 increase of 15%. The largest growth rates in the Asian AMT market are forecast for the other regions. India, China, Singapore, Hong Kong, and Thailand are expected to expand at a rate greater than 17%.

Table 4-10 lists the further breakdown of forecast purchases by countries within the regions.

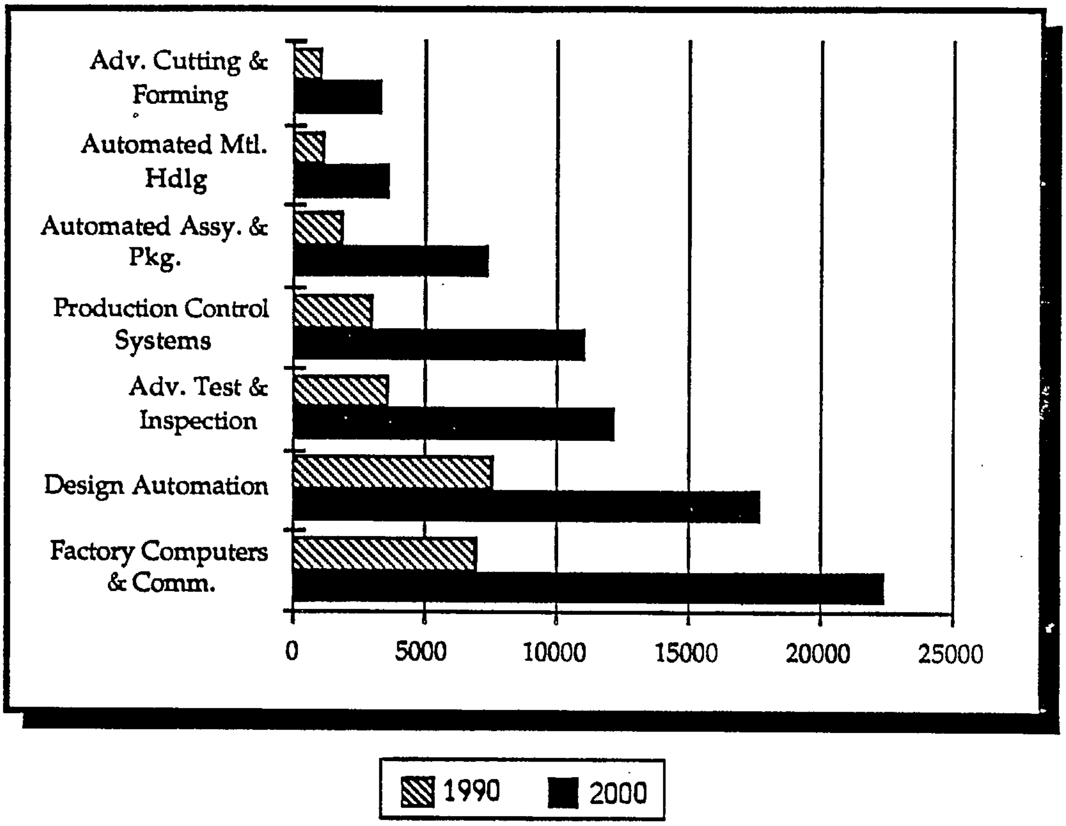
**TABLE 4-10**
**WORLDWIDE MARKET FOR AMT PRODUCTS AND SERVICES BY COUNTRY**
**1985-2000**
**(In Millions of U.S. Dollars)**

| | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|
| **North America** | $12,559 | $25,276 | $43,309 | $77,804 |
| Canada | 974 | 1,707 | 3,022 | 5,518 |
| U.S. | 11,585 | 23,569 | 40,287 | 72,286 |
| **Europe** | 4,426 | 12,064 | 23,772 | 47,196 |
| Germany | 1,625 | 5,110 | 10,820 | 21,709 |
| France | 1,062 | 2,578 | 4,748 | 9,439 |
| U.K. | 558 | 1,384 | 2,600 | 5,192 |
| Italy | 476 | 1,064 | 1,717 | 3,304 |
| Scandinavia | 535 | 1,391 | 2,898 | 5,664 |
| Other | 170 | 537 | 989 | 1,888 |
| **Asia** | 3,717 | 9,727 | 19,183 | 41,779 |
| Japan | 3,382 | 7,717 | 14,771 | 32,170 |
| Korea/Taiwan | 149 | 1,010 | 2,110 | 4,596 |
| Other | 186 | 1,000 | 2,302 | 5,013 |
| **Other** | 230 | 689 | 1,480 | 3,582 |
| South America | 80 | 289 | 592 | 1,433 |
| Mexico | 58 | 221 | 503 | 1,218 |
| All Other | 92 | 179 | 385 | 931 |

## 4.3.1 NORTH AMERICA

North American manufacturers are expected to allocate their dollars for AMT purchases differently in the 1990s than they did in the latter half of the 1980s. The biggest change forecast is in the growth rates of the design automation product group. This product category grew at over 20% during the late 1980s, in the next decade it is expected to expand at rates

**CHART 4H**
**PURCHASES OF AMT PRODUCTS AND SERVICES BY NORTH AMERICAN END-USERS 1990 AND 2000**
**(In Millions of U.S. Dollars)**




Source: Table 4-11

less than half the earlier growth rate. From being the largest product category in 1990, design automation is predicted to drop back to second in purchase totals by the end of the century. The largest category for North

American end-users in the year 2000 is expected to be factory floor computers and communications links.

The fastest growing category is expected to be the automated assembly and packaging systems, expanding at an overall rate of 15% over the decade. This expansion would take purchases of automated assembly and packaging to $7.5 billion from $1.9 billion at the beginning of the decade.

**TABLE 4-11**
**PURCHASES OF AMT PRODUCTS AND SERVICES BY NORTH AMERICAN END-USERS**
**1985-2000**
**(In Millions of U.S. Dollars)**

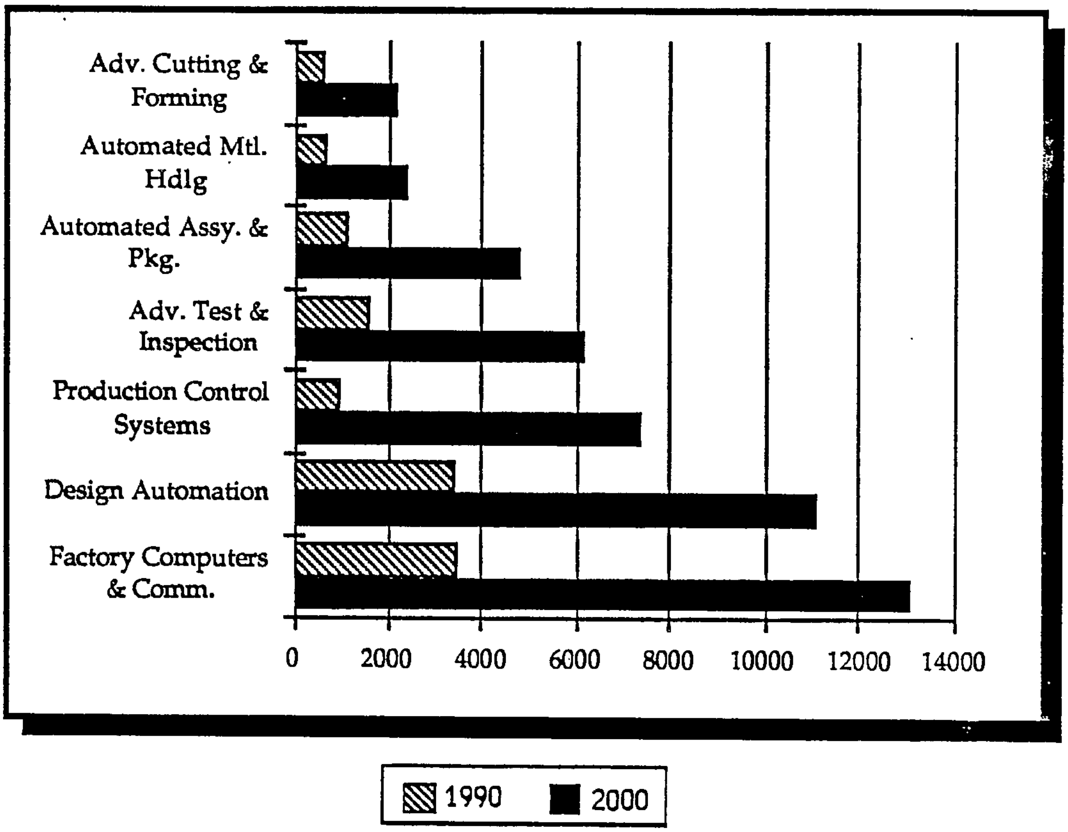
| NORTH AMERICA | 1985 Actual | 1990 Estimated | CAGR | 1995 Forecast | CAGR | 2000 Forecast | CAGR |
|---|---|---|---|---|---|---|---|
| Design Automation | $2,780 | $7,659 | 22.5% | $11,594 | 8.6% | $17,699 | 8.8% |
| Advanced Cutting & Forming | 643 | 1,033 | 9.9% | 1,803 | 11.8% | 3,267 | 12.6% |
| Automated Materials & Parts Handling | 750 | 1,094 | 7.8% | 1,950 | 12.3% | 3,640 | 13.3% |
| Automated Assembly & Packaging Systems | 867 | 1,878 | 16.7% | 3,388 | 12.5% | 7,466 | 17.1% |
| Factory Floor Computers & Communications Links | 3,480 | 7,058 | 15.2% | 12,563 | 12.2% | 22,476 | 12.3% |
| Advanced Test & Inspection Systems | 1,965 | 3,557 | 12.6% | 6,712 | 13.5% | 12,236 | 12.8% |
| Production Control Systems | 2,074 | 2,997 | 7.6% | 5,300 | 12.1% | 11,021 | 15.8% |
| TOTAL | $12,559 | $25,276 | 15.0% | $43,309 | 11.4% | $77,804 | 12.4% |

## 4.3.2 WESTERN EUROPE

The expenditures for AMT products and services by Western European manufacturers is forecast to almost quadruple over the decade of the 1990s. From estimated 1990 expenditures of $12 billion, the investment in AMT is predicted to grow to $47 billion by the year 2000.

In 1990, Europeans were investing most heavily in two product categories, design automation and factory floor computers, each with a 29% share of the total AMT expenditures. In 2000, they are predicted to invest $13 billion in factory floor computers, 28% of total expenditures, and $11 billion in design automation, representing 23% of the total.

**CHART 4I**
**PURCHASES OF AMT PRODUCTS AND SERVICES BY WESTERN EUROPEAN END-USERS**
**1990 AND 2000**
**(In Millions of U.S. Dollars)**




Source: Table 4-12

The most rapidly growing product category is expected to be production control systems, predicted to expand from investment of $1 billion in 1990 to $7 billion in 2000, an estimated annual expansion of 22%.

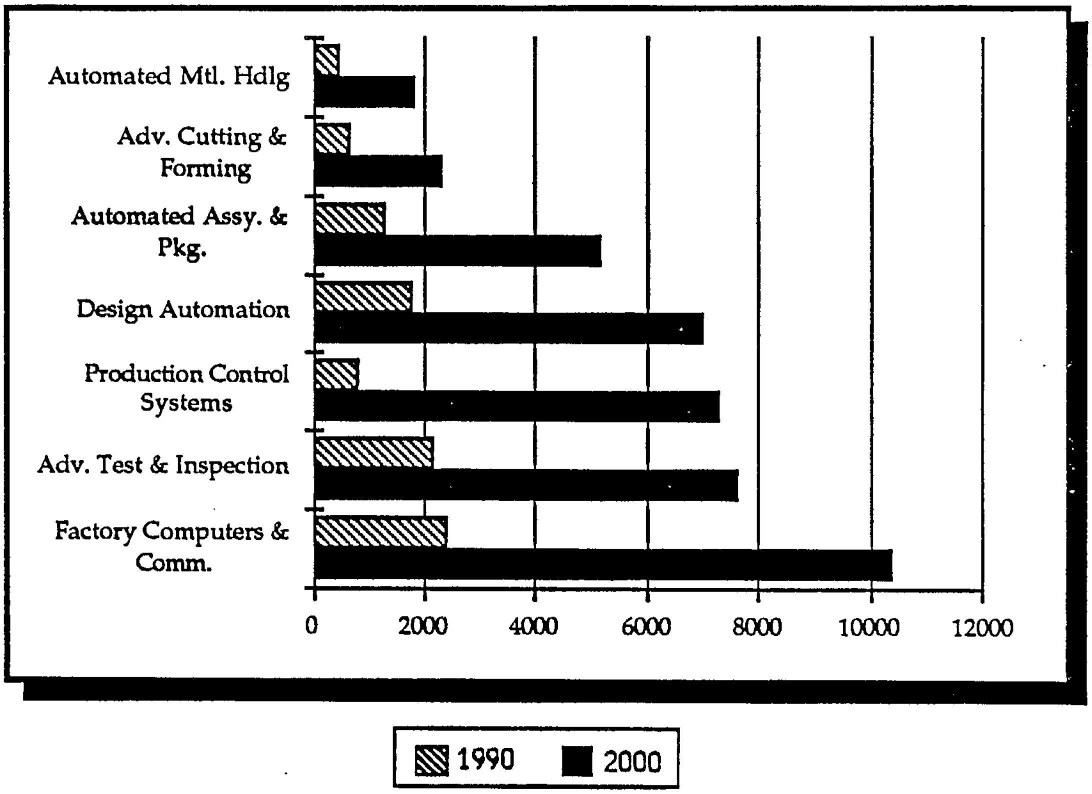
### TABLE 4-12
### PURCHASES OF AMT PRODUCTS AND SERVICES BY WESTERN EUROPEAN END-USERS 1985-2000
### (In Millions of U.S. Dollars)

| WESTERN EUROPE | 1985 Actual | 1990 Estimated | CAGR | 1995 Forecast | CAGR | 2000 Forecast | CAGR |
|---|---|---|---|---|---|---|---|
| Design Automation | $1,066 | $3,451 | 26.5% | $6,183 | 12.4% | 11,083 | 12.4% |
| Advanced Cutting & Forming | 301 | 613 | 15.3% | 1,144 | 13.3% | 2,220 | 14.2% |
| Automated Materials & Parts Handling | 390 | 694 | 12.2% | 1,289 | 13.2% | 2,431 | 13.5% |
| Automated Assembly & Packaging Systems | 408 | 1,176 | 23.6% | 2,144 | 12.8% | 4,824 | 17.6% |
| Factory Floor Computers & Communications Links | 1,312 | 3,463 | 21.4% | 6,578 | 13.7% | 13,099 | 14.8% |
| Advanced Test & Inspection Systems | 678 | 1,633 | 19.2% | 3,156 | 14.1% | 6,174 | 14.4% |
| Production Control Systems | 271 | 1,034 | 30.7% | 3,277 | 25.9% | 7,365 | 17.6% |
| TOTAL | $4,426 | $12,064 | 22.2% | $23,772 | 14.5% | $47,196 | 14.7% |

## 4.3.3 ASIA

Asian manufacturers are expected to continue to invest in advanced manufacturing technologies in the coming decade. Overall purchases are forecast to increase from $10 billion in 1990 to $42 billion by the year 2000.

**CHART 4J**
**PURCHASES OF AMT PRODUCTS AND SERVICES BY ASIAN END-USERS 1990 AND 2000**
**(In Millions of U.S. Dollars)**




Source: Table 4-13

The most rapidly growing product category is expected to be production control systems, expanding at an estimated 25% annually over the decade. this growth should take purchases of production control systems from $800 million in 1990 to $7 billion in the year 2000.

Factory floor computers were estimated to be the largest product category in 1990, and is forecast to remain in that position at the end of the decade in Asia. By the year 2000, purchases of factory floor computers are predicted to total over $10 billion.

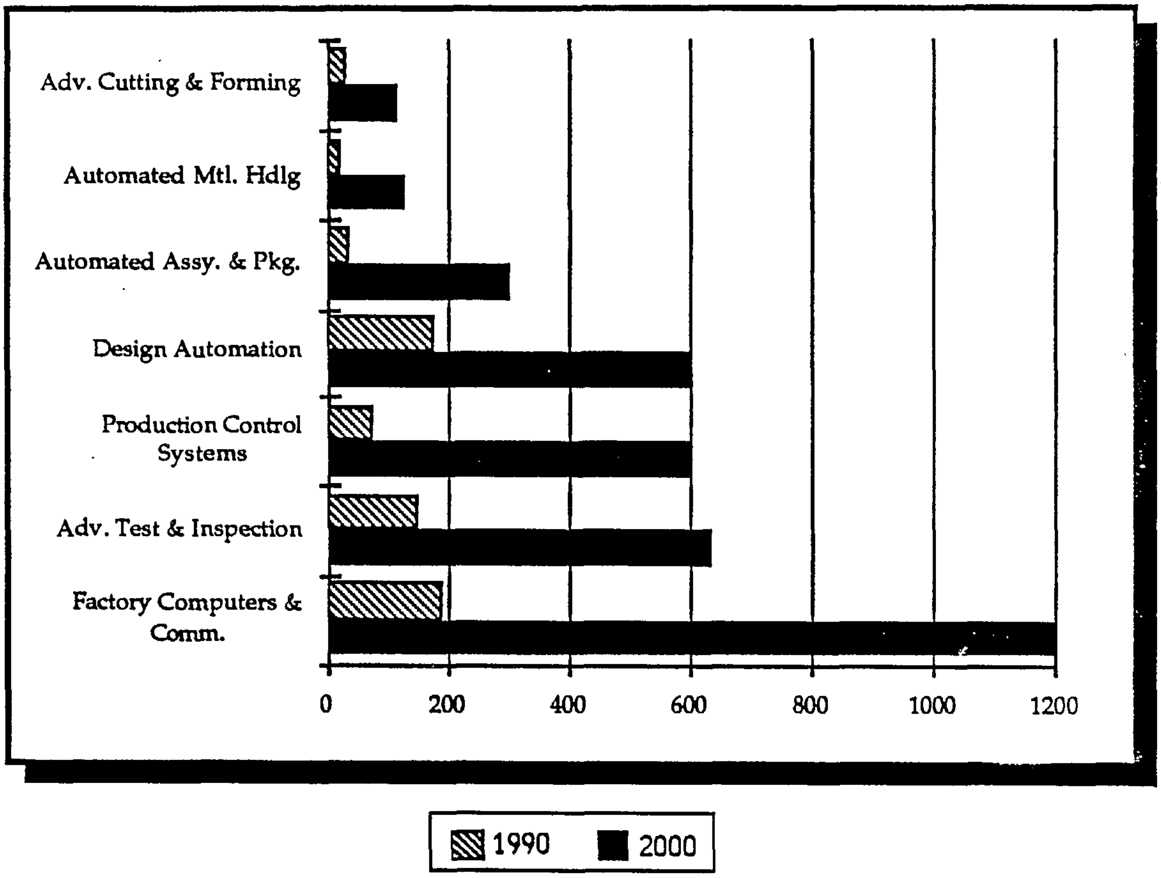
TABLE 4-13
PURCHASES OF AMT PRODUCTS AND SERVICES
BY ASIAN END-USERS
1985-2000
(In Millions of U.S. Dollars)

| ASIA | 1985 Actual | 1990 Estimated | CAGR | 1995 Forecast | CAGR | 2000 Forecast | CAGR |
|---|---|---|---|---|---|---|---|
| Design Automation | $448 | $1,780 | 31.8% | $3,290 | 13.1% | $7,025 | 16.4% |
| Advanced Cutting & Forming | 321 | 679 | 16.2% | 1,135 | 10.8% | 2,360 | 15.8% |
| Automated Materials & Parts Handling | 279 | 525 | 13.5% | 915 | 11.7% | 1,868 | 15.3% |
| Automated Assembly & Packaging Systems | 531 | 1,314 | 19.8% | 2,292 | 11.8% | 5,176 | 17.7% |
| Factory Floor Computers & Communications Links | 922 | 2,446 | 21.5% | 4,757 | 14.2% | 10,397 | 16.9% |
| Advanced Test & Inspection Systems | 1,057 | 2,187 | 15.7% | 3,954 | 12.6% | 7,641 | 14.1% |
| Production Control Systems | 159 | 796 | 38.0% | 2,838 | 29.0% | 7,312 | 20.8% |
| TOTAL | $3,717 | $9,727 | 21.2% | $19,183 | 14.5% | $41,779 | 16.8% |

## 4.3.4 OTHER AREAS OF THE WORLD

The other areas of the world are expected to expand rapidly from estimated 1990 purchases of $700 million to $3.6 billion at the turn of the century. The purchases, however, are expected to remain a very small portion of the world market for AMT products and services.

**CHART 4K**
**PURCHASES OF AMT PRODUCTS AND SERVICES BY END-USERS IN OTHER AREAS OF THE WORLD**
**1990 AND 2000**
**(In Millions of U.S. Dollars)**




Source: Table 4-14

The most rapidly growing product category, and by far the largest, is forecast to be factory floor computers and communications links. Communications links are expected to be especially valuable over the next decade to link these markets with those in the developed world. These countries are expected to experience high growth in demand for design automation products. In fact, all the product categories should experience robust expansion in these markets.

## TABLE 4-14
## PURCHASES OF AMT PRODUCTS AND SERVICES BY END-USERS IN OTHER AREAS OF THE WORLD 1985-2000
### (In Millions of U.S. Dollars)

| OTHER | 1985 Actual | 1990 Estimated | CAGR | 1995 Forecast | CAGR | 2000 Forecast | CAGR |
|---|---|---|---|---|---|---|---|
| Design Automation | $49 | $178 | 29.7% | $305 | 11.4% | $600 | 14.5% |
| Advanced Cutting & Forming | 19 | 32 | 11.0% | 59 | 12.7% | 117 | 14.7% |
| Automated Materials & Parts Handling | 8 | 24 | 23.5% | 47 | 14.7% | 128 | 22.3% |
| Automated Assembly & Packaging Systems | 6 | 37 | 43.4% | 71 | 13.6% | 301 | 33.6% |
| Factory Floor Computers & Communications Links | 63 | 191 | 25.0% | 462 | 19.3% | 1,198 | 21.0% |
| Advanced Test & Inspection Systems | 57 | 150 | 21.2% | 284 | 13.6% | 633 | 17.4% |
| Production Control Systems | 27 | 76 | 22.8% | 252 | 27.1% | 605 | 19.1% |
| TOTAL | $230 | $689 | 24.6% | $1,480 | 16.5% | $3,582 | 19.3% |

# 5.0 THE CANADIAN PERSPECTIVE

## 5.1 INVESTMENT IN AMT

### 5.1.1 AMT MARKET IN CANADA

During the five years from 1985 to 1990, Canadian manufacturers made substantial investments in advanced manufacturing technology. Over the five-year period, investments in AMT have risen 12% annually. Expenditures have grown from just under $1 billion (U.S.) in mid-decade to an estimated $1.7 billion at the end of the decade. This is a 75% overall increase in annual purchases. For the overall Canadian AMT market during the 1990s, slight increases in the compound annual growth rate are projected in each five year period. Total purchases of AMT products and services are detailed in Table 5-1 below.

**TABLE 5-1**
**CANADIAN PURCHASES OF AMT PRODUCTS & SERVICES**
**1985 AND 1990**
**(In Millions of U.S. Dollars)**

| | 1985 | 1990 | CAGR* | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Design Automation | $224 | $483 | 16.6% | $809 | 10.9% | $1,255 | 9.2% |
| Advanced Cutting & Forming | 59 | 81 | 6.6% | 126 | 9.2% | 232 | 13.0% |
| Automated Materials & Parts Handling | 73 | 92 | 4.7% | 136 | 8.1% | 258 | 13.7% |
| Automated Assembly & Packaging Systems | 67 | 124 | 13.0% | 236 | 13.7% | 529 | 17.5% |
| Factory Floor Computers & Communications Links | 305 | 543 | 12.2% | 937 | 11.5% | 1,594 | 11.2% |
| Advanced Test & Inspection Systems | 115 | 205 | 12.3% | 423 | 15.6% | 868 | 15.5% |
| Production Control Systems | 132 | 179 | 6.4% | 370 | 15.6% | 782 | 16.1% |
| TOTAL | $974 | $1,707 | 11.9% | $3,022 | 12.1% | $5,518 | 12.8% |
| % of North American Market | 7.8% | 6.8% | | 7.0% | | 7.1% | |

Source: CIMdata, Inc. and Automation Marketing Strategies, Inc.

* Compound Annual Growth Rate

#### 5.1.1.1 Product Class Purchases

The largest product segment is factory floor computers and communications links. This one product class accounted for almost a third of product sales in 1985 and continues to dominate sales in 1990. Expanding at about the same rate as the overall AMT market in Canada, this product class has maintained its proportion of the market through 1990.

Design Automation, the fastest growing product segment of the 1980s, is expected to slow to a compound annual growth rate of approximately 10% from 1990 to 2000. The fastest growing product areas through the 1990s are expected to be Advanced Test and Inspection and Production Control Systems, each growing at over 15% per year throughout the decade. Automated Assembly & Packaging Systems is projected as the fastest growing product segment in the second half of the 1990s. Advanced Cutting & Forming and Automated Materials & Parts Handling, two of the slower growth product classes during the 1985 through 1990 period, are forecast to grow at increasing rates through the year 2000.

#### 5.1.1.2 Industry Purchases

The largest purchaser of AMT products and services, over the 1985 to 1990 period, was the transportation equipment industry. This one industry accounted for almost half the Canadian purchases in 1985 (see Table 5-2). This fell substantially as a percent of the total by 1990. In 1990, it is estimated that transportation was responsible for about one-third of the total expenditures devoted to AMT. As transportation industry AMT purchases increased at an annual rate of less than 4% from 1985 to 1990, other industries were increasing their purchases at a much faster rate.

The most substantial growth rates among the discrete industries purchasing advanced manufacturing technologies during the latter half of the 1980s have been in the aerospace sector. Sales of AMT products and services to this sector grew at an annual rate of nearly 30%.

Except for the transportation equipment sector, the discrete industries have been increasing their purchases by double digit rates, ranging from 25% in the electrical industry and 20% in electronics and machinery to 13% growth in the 'other manufacturing' sector which includes wood products, apparel, metal fabrication and rubber and plastics.

## TABLE 5-2
## CANADIAN MARKET FOR AMT PRODUCTS AND SERVICES BY END USER INDUSTRY 1985-1990 (In Millions of U.S. Dollars)

| | 1985 | 1990 | CAGR* | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Aerospace | $68 | $249 | 29.6% | $719 | 23.6% | $1,858 | 20.9% |
| Transportation | 483 | 582 | 3.8% | 832 | 7.5% | 1,144 | 6.6% |
| Electronics | 93 | 227 | 19.7% | 472 | 15.7% | 900 | 13.8% |
| Electrical | 29 | 88 | 24.8% | 144 | 10.2% | 255 | 12.1% |
| Machinery | 58 | 143 | 19.6% | 242 | 11.1% | 427 | 12.0% |
| Other Discrete | 107 | 194 | 12.6% | 278 | 7.5% | 455 | 10.3% |
| Process | 136 | 224 | 10.5% | 335 | 8.4% | 479 | 7.4% |
| TOTAL | $974 | $1,707 | 11.9% | $3,022 | 12.1% | $5,518 | 12.8% |

Source: CIMdata, Inc. and Automation Marketing Strategies, Inc.

* Compound Annual Growth Rate

Aerospace is expected to continue to be the fastest growing AMT investor, with annual growth rates declining but remaining above 20% throughout the 1990s. AMT investment growth by the electronics segment is projected at over 15% per year through 1995, falling to about 14% in the latter half of the decade. The transportation equipment sector, where the major dollars have been spent, is expected to rebound somewhat from the slow growth of the late 1980s, hovering around 7% annual growth through the 1990s. Still, transportation equipment is expected to be the slowest growth AMT investor among discrete industries through the 1990s. By decade's end, Aerospace is expected to exceed transportation in AMT investment.

## 5.1.2 COMPARISONS WITH OTHER NATIONS

Canada's investment in AMT products and services presents a mixed pattern. In 1985, Canadian investment in these products was larger than that for any European country except Germany and, marginally, France (see Table 5-3). These countries are roughly at the same level of development as Canada, thus providing a useful comparative picture. Compared with the U.S. and Japan, of course, Canada is a relatively small AMT market. This investment pattern almost certainly underpins the high level of manufacturing productivity enjoyed by Canada in the mid-1980s relative to most of Europe and, indeed, even to Japan.

**TABLE 5-3**
**AMT PURCHASES BY SELECTED COUNTRY**
**1985 AND 1990**
**(In Millions of U.S. Dollars)**

| | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Canada | $974 | $1,707 | 11.9% | $3,022 | 12.1% | $5,518 | 12.8% |
| United States | $11,585 | $23,569 | 15.3% | $40,287 | 11.3% | $72,286 | 12.4% |
| Japan | $3,382 | $7,717 | 17.9% | $14,771 | 13.9% | $32,170 | 16.8% |
| Germany | $1,625 | $5,110 | 25.8% | $10,820 | 16.2% | $21,709 | 14.9% |
| France | $1,062 | $2,578 | 19.4% | $4,748 | 13.0% | $9,439 | 14.7% |
| United Kingdom | $558 | $1,384 | 19.9% | $2,600 | 13.4% | $5,192 | 14.8% |
| Italy | $476 | $1,064 | 17.5% | $1,717 | 10.0% | $3,304 | 14.0% |
| Scandinavia | $535 | $1,391 | 21.1% | $2,898 | 15.8% | $5,664 | 14.3% |

Source: CIMdata, Inc.. and Automation Marketing Strategies, Inc.

Canadian users of AMT have been increasing their purchases at a much lower rate than any of the other major regions of the world (see Table 5-4). Within the North American market, Canada's growth rate wa 11.9% and while of the U.S. was 15.3%. The difference is greatest when comparing Canada with Europe and Asia, where growth rates were in the low 20% range, almost twice Canada's. This difference in growth rates is worrisome, suggesting that Canadian manufacturers will lose their competitive edge in the decade of the 1990s.

## TABLE 5-4
## COMPOUND ANNUAL GROWTH OF AMT PURCHASES
## 1985-1990
## BY REGION

| | CANADA | U.S. | EUROPE | ASIA | REST OF WORLD |
|---|---|---|---|---|---|
| Design Automation | 16.6% | 22.9% | 26.5% | 31.8% | 29.7% |
| Adv. Cutting & Forming | 6.6% | 10.3% | 15.3% | 16.2% | 10.4% |
| Automated Matl. Handlg. | 4.7% | 8.2% | 12.2% | 13.5% | 23.5% |
| Automated Assy. & Pkg. | 13.0% | 17.0% | 23.6% | 19.8% | 43.4% |
| Factory Computers & Comm. | 12.2% | 15.4% | 21.4% | 21.6% | 26.9% |
| Adv. Test & Inspection | 12.3% | 12.6% | 19.2% | 15.7% | 21.2% |
| Production Control Systems | 6.3% | 7.7% | 30.7% | 38.0% | 22.8% |
| **OVERALL** | 11.9% | 15.3% | 22.2% | 21.2% | 25.0% |

Source: CIMdata, Inc.

All the individual product classes show the same trend as the overall AMT category. Canada has not increased its investments in any product area faster than its competitors. In some it was falling behind more quickly. Especially notable is the disparity in investment in Advanced Cutting and Forming where Canada has increased expenditures at 40% the rate of Europe and Asia and two-thirds the rate of the U.S. Canada also has lagged greatly in terms of growth in the use of Design Automation products.

Europe, offers, perhaps, the most instructive comparison. In 1985, Canada could be viewed as a relatively aggressive AMT investor. By 1990 the investment patterns had shifted substantially; only Italy significantly lagged Canadian purchases. The compound growth rates tell the story. As the major European countries increased their purchases of AMT at rates close to or over 20%, Canada's AMT expenditures expanded at 12%.

Although the growth rates for Japan and the major European countries are projected to decrease during the 1990s from the lofty levels of the 1980s, they are generally greater than the growth projected for Canada. Canada's AMT market growth is forecast to be only marginally greater during the 1990s than that of the U.S., where absolute levels of investment are ten times larger. If this scenario plays out as projected, Canada will continue to lose ground to competitive nations through the year 2000.

The trends are also disturbing when AMT purchases are viewed on a per capita basis (see Table 5-5). Given that the major OECD countries are at roughly the same level of development with equivalent economic structures, parity in investment per capita levels might be expected over time.

**TABLE 5-5**
**AMT DOLLAR INVESTMENT PER CAPITA**
**(Canada = 100)**

| | 1985 | 1990 |
|---|---|---|
| Canada | 100 | 100 |
| U.S. | 125 | 147 |
| Japan | 73 | 97 |
| Europe | | |
| Germany | 70 | 128 |
| France | 51 | 70 |
| Italy | 22 | 30 |
| Scandinavia | 102 | 124 |
| U.K. | 26 | 36 |

Source: CIMdata, Inc.
International Monetary Fund

On a per capita basis, the Canadian manufacturing sector has lost significant relative position compared to Germany, the U.S. and Scandinavia. The U.S. position is particularly worrisome, given the Free Trade Agreement (FTA). France is coming closer to parity with Canada on a per capita AMT investment basis, while the U.K. and Italy are still substantially below the Canadian investment rate.

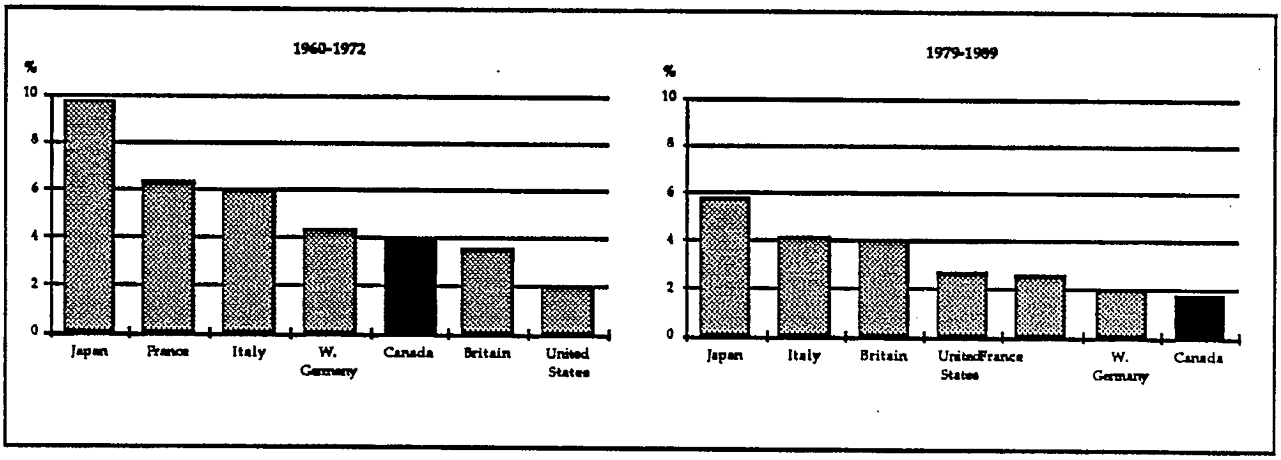
Interestingly, on a per capita basis, the Japanese economy was investing in AMT products in 1990 at the same rate as the Canadian. These data should be taken with caution, however. In the latter half of the 1980s, Japanese manufacturing investment has exploded relative to Europe and the U.S. It would appear that much of this investment has been by those companies operating in the global, as opposed to domestic, economy.

## 5.2 MANUFACTURING PRODUCTIVITY

Canada's relative world position as a leader in manufacturing productivity is at stake. Chart 5A shows a sharp decline in Canada's rate of productivity growth in the past ten years as compared to the growth rate from 1960 to 1972. The distressing factor is that Canada's productivity growth has become the slowest among the seven major industrialized nations.

The OECD data as displayed in Chart 5B shows Canada second among major industrialized nations in value added per manufacturing worker in 1985. Also shown is the relatively higher growth in worker productivity being experienced by Japan and other nations. Although AMT investment is not the only force driving productivity improvement, it is certainly a fact that effective application of AMT enhances productivity. Therefore, Canada's relative slow-down in AMT investment would be expected to result in lagging productivity growth rates such as those shown in Chart 5A. The comparatively higher rates of investment by competitive nations accounts in part for their more rapid productivity growth as depicted in Chart 5B.

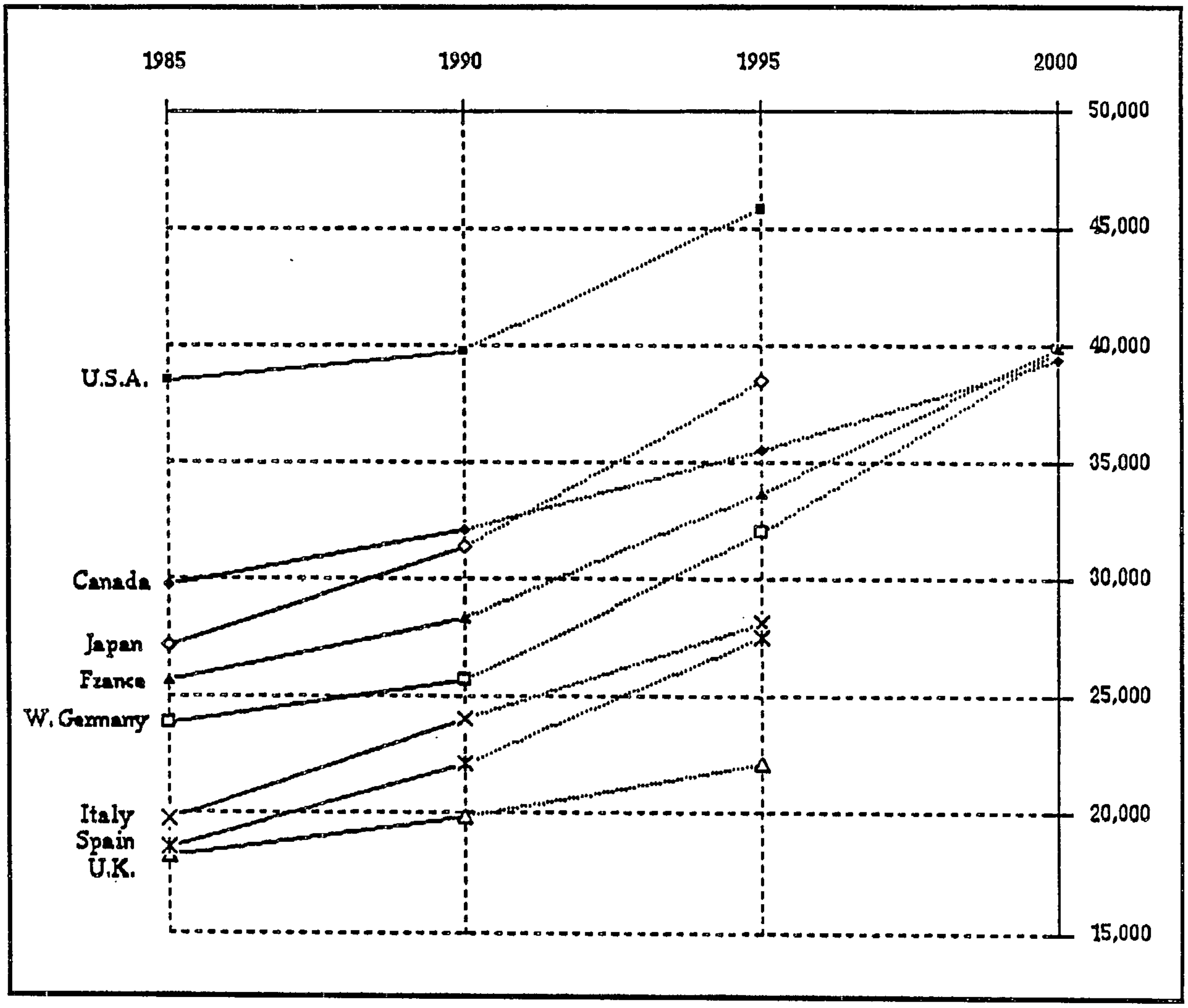
### CHART 5A
MANUFACTURING PRODUCTIVITY
ANNUAL AVERAGE RATE INCREASE




Source: *The Economist*, November 24, 1990 p.19

Chart 5B shows value added per manufacturing employee in 1985 plus preliminary estimates of 1990 results along with a projection for all countries in 1995 and selected countries in the year 2000. Note that Japan may already have overtaken Canada. France and West Germany could pass Canada by the year 2000. Canada's investment in AMT during the 1990s will have a significant impact on its relative position in worker productivity by the year 2000.

## CHART 5B
### INTERNATIONAL MANUFACTURING PRODUCTIVITY TRENDS 1985 AND 1990




Source: OECD and Automation Marketing Strategies, Inc. analysis.
Note: Manufacturing value added per manufacturing employee in U.S. $.

Labour costs in Canada are high. Productivity must, therefore, also be high for manufacturers to be competitive internationally. Productivity relies, in part, on the intelligent application of AMT. The actual rate at which productivity in Canada improves relative to the other countries shown in Chart 5B will be a major determinant of its economic status in the year 2000.

The FTA essentially creates direct competition with U.S. companies. An expansion of FTA, bringing Mexico into the arrangement, would add a low labour-cost country to the pact. Mexico is not included in Chart 5B. Its productivity per worker at about $5,000U.S. is far lower than that of any nation shown. It is also below the levels of the Asian Tigers. Unlike those developing Asian nations, Mexico's productivity is estimated to have declined in the past half-decade. However, productivity is undoubtedly higher in both the export oriented and advanced manufacturing sectors of the Mexican economy than in the country in general.

Canada's competitiveness, overseas and in North America, is dependent on maintaining high relative productivity to offset high costs of labour. That relative productivity position, in turn, is dependent on the use of advanced manufacturing techniques and technologies.

## 5.3 STRATEGIC ISSUES FOR USERS OF AMT

### 5.3.1 MANUFACTURING DYNAMICS OF THE 1990s

The data presented in Tables 5-1 through 5-4 show clearly that Canadian manufacturers have invested substantially in AMT. However, their investment growth rate considerably lags that of their U.S., European and Asian competitors. The absolute dollars of AMT investment are reassuring, however, the trends are disturbing. Canadian manufacturers may find themselves in a considerable competitive struggle during the 1990s. Appendix C contains a number of case studies of Canadian and U.S. companies. The cases explore how these selected companies are dealing with the competitive environment.

Manufacturing competitiveness is now, and will continue to be, a key element in corporate success and survival. The principal elements that must be addressed prior to implementation of AMT are:

- Just-in-time production
- Flexible manufacturing
- Total quality management
- Concurrent engineering
- Employee empowerment

The latter two elements relate to management practices and policies. While they appear at first glance to be "soft", they are in fact critical to the successful implementation of AMT. Much of what is being accomplished in the AMT area is at heart a revolution in managerial thinking about the manufacturing process and its linkages to design engineering and the marketplace.

The data on AMT purchases suggest that Canadian manufacturers are not sufficiently aware of their changing relative position in the world marketplace. Top management are either not yet fully convinced of the up-side potential of AMT and/or are not yet sufficiently fearful of the down-side risks they are running. Given the inherently conservative nature of many Canadian businessmen, this may not be too surprising.

### 5.3.2 NORTH AMERICA AS A HOME MARKET

One of the major concerns frequently expressed in Canada with respect to the use of AMT products and services is the lack of a large home market either: 1) to make AMT investment profitable by manufacturers or 2) to provide a base for suppliers of AMT. Conventional wisdom holds that a small home market limits the extent of home-grown R&D, and reduces the perceived and/or actual payback of AMT investments especially if these investments are lumpy, i.e., they come in the form of large, discrete projects in a discontinuous manner. A small domestic market generally will support only a few world-class industrial sectors. Supplier expertise, which is based on a close working knowledge of specific industry applications, thus tends to be focused on only a few industrial sectors.

However, Canadian manufacturers no longer should be viewing the domestic market as the home market. The FTA, geographic proximity, and culture/language similarities of the U.S. market should enable aggressive companies to realistically expand their core market horizons. The companies studied (see case studies in Appendix C) which have invested in AMT have, without exception, viewed the North American market as their home market.

Of particular note, with the exception of two companies which are foreign subsidiaries set up to service North America, all the user companies studied have expanded outside the North American market. They have become global in scope.

### 5.3.3 FACTORS DRIVING CANADIAN PURCHASES OF AMT

Canadian manufacturers are going through a competitive wringer as are U.S. companies. These competitive pressures will continue as the two economies are drawn closer together via the FTA. As well, aggressive Canadian manufacturers will invest in AMT in order to grow and to facilitate their penetration of the U.S. market.

The driving force behind the AMT investments studied in this project was multi-dimensional. For those manufacturers in the automotive supply business, customer demands were strong and over-riding. Either parts suppliers became world-class and responsive or they would lose their market. This is particularly the case for those selling to demanding Japanese producers. (See the case studies, especially F&P Manufacturing Inc., in Appendix C)

In several cases, AMT investments were made in order to achieve significantly higher levels of quality. Without these investments, key customers would have gone elsewhere. Shortened cycle time was a driving factor in the case of two other manufacturers studied. Dramatic reductions in cycle time were experienced, with substantial sales and marketing impact. (See especially Otto Bock Orthopedic Industry of Canada, Ltd. and Atlas Roll-lite in Appendix C)

It is very important to note that cost reduction per se was a key driving force in only one of the cases studied (See The Pas Lumber Company, Ltd. in Appendix C). This is a critical issue, since most conventional capital budgeting decisions are heavily weighted toward manufacturing cost analyses. The initial gains from AMT investments will be seen in areas which are not readily and conventionally translated into ROI, e.g., customer satisfaction levels, price realisation, retention of customers, and gaining new customers via total quality and production flexibility.

Although not always quantifiable, the experience of manufacturers making strategic AMT investments is that they can have their cake and eat it too. That is, lower costs and higher value added are inevitable concomitants of upgrading total quality, shortening cycle time, and increasing factory flexibility.

### 5.3.4 AMT DECISION MAKING

In all the cases studied, the AMT decision was a top-down commitment. This is consistent with the literature in the field, which clearly shows that a change in management orientation is an absolute necessity if strategic AMT change is to occur. Cost justification was not the most important driving force uncovered. Strategic business and marketing issues drove the AMT decision in the majority of cases.

## 5.3.5 IMPLEMENTING AMT PROJECTS

It takes more than technology alone to implement AMT successfully. The most successful implementations have been accompanied by the application of manufacturing management philosophies and techniques such as those embodied under the general headings of concurrent engineering, total quality management (TQM) and just-in-time (JIT).

A prerequisite to implementing AMT is an effective manufacturing system. Factory automation is not a cure for ineffective manufacturing practices any more than office automation is a panacea for inefficient administrative procedures. The principles of JIT, TQM and concurrent engineering should be applied first.

People programs have played a major part in the successful implementation of AMT and, by the same token, lack of appropriate people involvement has often been a characteristic of those projects that didn't fare so well.

The following are some examples of what can happen when people aren't consulted on AMT implementation:

- At The Pas, management was fully involved and the operators were trained but no indoctrination or training was given to the supervisors. This resulted in early problems in getting the system operating at the desired level of throughput, until the problem was addressed.

- At Gennum, the initial MRP II system was put in place without employee involvement. Management said, "Here it is. It's good for you." The program failed because it was not universally applicable and because some areas of the company did not buy into the system. Gennum expects greater success with its new MRP II system for which all departments' needs were considered in the system design.

That is not to say that management needs to get employee permission before it can implement AMT. Gaining cooperation is critically important, however.

Some of the most aggressive companies in the application of AMT are also, not coincidentally, the most active in training and upgrading of personnel. F&P, Linamar and Husky are excellent examples of companies that are dedicated to using modern equipment to gain competitive advantage, and doing everything possible to help their people use the equipment. Providing real opportunity for advancement is a key element of the human resources program at F&P. Offering significant experience to young engineers is a hallmark of the Husky policy.

AMT doesn't mean the use of unproven technology. Manufacturers are understandably wary of being a proving ground for new and potentially unreliable systems. AMT being employed at Husky and at Linamar consists largely of CNC machine tools, a technology that has been around for several years but is generally underutilized. Although CNC is a well established technology, its use is a differentiating factor because few manufacturers have implemented it on a widescale basis.

North American manufacturers frequently start applying AMT at the beginning of the manufacturing cycle, i.e., product design. For example, both Sun Ice and Otto Bock employed CAD/CAM systems early on. In the Otto Bock case, the objective was a sharp reduction in cycle time, and the application of CAD and CAM techniques achieved the goal. In the Sun Ice example, the CAD/CAM system was simply regarded as the logical first step in the integrated automation and control system planned for all parts of the manufacturing cycle.

Japanese companies are not as likely to start with design automation. They are more likely to take an eclectic approach, tackling first those issues which are causing problems. F&P, for example, implemented several AMT projects prior to addressing design automation. It is not necessary to start at the beginning of the cycle. What is necessary is to be able to integrate the early projects with those undertaken later, and that takes some planning. Most important, according to experienced implementers, is to start. It is vital not to allow planning to take the place of action. Sun Ice's management sums up the company's philosophy this way: "How do you learn unless you dive in? You're never going to cover all the angles and have everything under control if you do something new. The price of learning something new is doing it, making mistakes and learning from your mistakes. If you have to wait for it to be perfect, you're never going to do it."

### 5.3.6 RESULTS OF AMT INVESTMENTS

A significant indicator of user satisfaction with AMT projects is that those that have gone forward with AMT programs continue to invest. Manufacturers are obviously getting the expected results from their investments in AMT. Studies done by Automation Marketing Strategies, Inc. in the U.S. have confirmed that AMT adopters are active and continuing investors, while non-adopters tend not even to get started.

Atlas Door and Otto Bock achieved the significant reductions in cycle time that they sought via AMT investment. With that advantage, Atlas was able to establish a market leadership position from a starting point of zero. Otto Bock's effort speeds relief to seriously disabled people, as well as being good for business.

Those servicing the automotive industry (Linamar and F&P) recognize that world-class quality and delivery turnaround are the minimum basic requirements of doing business with the Japanese car makers and, increasingly, with the Americans. They also appreciate the fact that expecting more from the employees is not the solution. The answer is AMT, properly applied along with appropriate management techniques.

Sun Ice is operating an apparel company where many would say it can't be done, and succeeding. AMT is an essential factor in that success. Without AMT, Sun Ice couldn't manufacture cost-competitively in Calgary. Even the company's upscale product image wouldn't support the prices that would be necessary, had not automation been implemented.

The automation implemented by The Pas may well have kept that company in business during difficult times. In addition to keeping costs down, the new equipment has enhanced product quality and provided for quick and easy dimensional changeover, making multi-size shipping orders more feasible.

At Gennum, the combination of AMT and new management techniques has resulted in a positive impact on cost, quality, and cycle time. Cost reduction was a by-product of a program targeted toward reducing turnaround time and improving product quality.

Husky, which is viewed as an example in both the user and supplier categories, has doubled its sales over the past four years while increasing employee count by only 50%. This is largely the result of using state-of-the-art manufacturing equipment.

Although some of the AMT implementations have had their problems, the companies (e.g., Sun Ice and Gennum) experiencing those problems push on with AMT projects. They recognized from the outset that there would be problems. Experiencing those setbacks has not kept them from moving ahead because they are also reaping the benefits of other AMT implementations.

### 5.3.7 EXPORTS

The Canadian manufacturing companies profiled are supplying export markets. All of them are exporting heavily to the U.S. For most, the U.S. is not just their major export market, but where they sell the bulk of their products. Even F&P manufacturing, the Japanese-owned automotive parts company that was built adjacent to the Canadian Honda plant, ships 80% of its output to Honda's Marysville, Ohio plant. The well-known Sun Ice line of Canadian sports apparel, is becoming more popular in the States, and The Pas is shipping significant amounts of its dimensional lumber products to points below the border.

Except for the two foreign-owned companies (Otto Bock and F&P) that have been established specifically to serve the North American market, the Canadian manufacturers are also exporting outside of North America. In every case, those exports are a growing proportion of sales. Gennum, with its significant world market share position in hearing aid circuits, is a very active exporter. More surprising is the fact that Canadian sportswear and dimensional lumber are being purchased in Japan, and Canadian auto parts are being sold to car manufacturers in Europe.

The manufacturing companies studied for this report illustrate the export trends. Canadian manufacturers are including the U.S. as part of their primary market and are increasingly exporting their products to overseas locations.

## 5.4 AMT SUPPLIER ISSUES

### 5.4.1 CANADIAN AMT EXPERIENCE AND COMPETENCE

Based on the case studies, Canadian AMT suppliers can compete very well in the world market, not just in Canada. For the companies profiled, the majority of sales are made in the U.S. Indeed, in several cases, the U.S. market was where initial sales were made. Several suppliers are even able to compete effectively in the Japanese market.

It is noteworthy that in all cases a market need was identified by entrepreneurs in Canada. For the most part, the identified market opportunities were North American or global, not just Canadian, and AMT suppliers are not constrained by a purely domestic viewpoint. It must also be emphasized that proximity to the U.S. market was critical in identifying these opportunities. These suppliers took advantage of their experience with both Canadian and U.S. users. Canadians should be able to leverage their North American position with multinational or global companies to identify market opportunities outside North America.

The principal opportunities for small to medium-sized Canadian companies as AMT suppliers lie in the software and system integration areas of the business. Problems of scale are less daunting in the software end of the AMT business than on the computer hardware side. Large, up-front capital investments are not required. Several of the successful AMT suppliers studied are phasing hardware out and concentrating exclusively on the software side of the business.

Economic linkages can as easily run North-South as East-West. One of the forest product AMT suppliers, SOFTAC, has found that its optimizing hardware/software has a natural market in the U.S., which is only now beginning the widespread automation of log output optimisation. One system integrator in Toronto, Westhead Systems, defines its market as being within a 500 mile radius of its headquarters. Thus, the U.S. Midwest is within its defined market area, while western Canada is not.

The U.S. market is still a large and attractive "home" market for Canadian companies, especially as the FTA becomes an irreversible fact. From all indications, there will be little or no slackening in the commitment of American manufacturers to improve their manufacturing and total quality competitiveness. As an example of the latter, within three years of its inception, the Malcolm Baldrige National Quality award has achieved a very high profile. In 1990, the Department of Commerce received 175,000 requests for the Baldrige criteria and application worksheets.

At least half of the AMT market is in computer hardware, software and integration/application services. The U.S. continues to be a world leader in these areas. Canadian AMT suppliers are in an attractive position to tap into technology, establish strategic relationships, and be tempered by aggressive competitors. Given Michael Porter's argument that highly competitive and demanding home markets are a necessary condition for becoming a world-class supplier, Canadian AMT producers are in a favourable position if they include the U.S. market as an integral part of their business strategy.

### 5.4.2 CANADA'S IMAGE AS AN AMT SUPPLIER

A number of published studies suggest that Canada's image as a high-tech supplier is not very high and may even be slipping. World trade data also indicate that Canada's position as a supplier of high-tech products is deteriorating. However, one study suggests that definitional issues may substantially distort the data and that Canada's position is not as dire as it appears.[1] The Canadian AMT supplier companies that are subjects of the case studies, indexed in Appendix C, are recognized as technology leaders.

It is crucial not to mix two types of high-tech. One grouping is the highly visible telecommunications, computer, and semiconductor industries. With a few exceptions, Canadian companies have not been able to compete successfully as independents in these areas. Neither, it should be noted, have a number of European and U.S. suppliers.

All high-tech products are not necessarily affected by the same set of dynamics. For many the business is not one of mass markets, heavy and risky product development investment, major plant and equipment investment, global market places, and sheer scale of operations. High-tech AMT product businesses can be regional in scope, can be focused tightly on an industry or application, and can be amenable to small and

[1] See Conklin and St. Hilaire, *Canadian High-Tech in a New World Economy: A Case Study of Information Technology.* (The Institute for Research in Public Policy, 1988), Chapter 6.

medium-sized companies. In the software segment of the AMT business, people and behavioural relationships are critical to success, making it possible for smaller companies to prosper. In this milieu, Canada can be a highly competitive sourcing point.

Several suppliers felt they had more credibility in the U.S. than in Canada. Others commented that outside North America, they actually had an advantage against U.S. firms. Canadians are less politically exposed and culturally are less confrontational and more cooperative than are Americans. Canadians are also more team oriented than are Americans. In our view, image is not a barrier to Canadian AMT suppliers. In fact, there is anecdotal evidence to suggest that the reverse may be true.

Although we did not observe it in our case studies, Canadian AMT suppliers may be in a good position to leverage the Asian linkage of recent entrepreneurial immigrants.

### 5.4.3 STRATEGIC ALLIANCES, PARTNERSHIPS, GROUPINGS

A recent study by Ernst & Young on Canada's competitiveness in technology companies concluded that strategic alliances were critical to Canadian viability[2]. While this may well be true in the telecommunications and computer sectors, we do not believe that these groupings are a necessary condition to AMT success for small and medium-sized companies in other industry sectors.

It is almost certainly true that entrance into the Japanese market is dependent on either a close distributor relationship or a partnership with a complementary supplier with strong market presence. The companies studied which were successful in penetrating the Japanese market all had developed and cultivated key local "partners". In industrial markets in any country, distributor relationships are often critical to success. Japan is perhaps more demanding in this regard, as it is particularly difficult for a non-Japanese company to operate exclusively with its own salesforce.

Two of the companies in our sample have developed important business partnership links in Japan. For hardware companies, it appears that a

[2] *Canada's Technology Industries in the 1990s*, (Ernst & Young, 1990).

joint equity relationship with a Japanese counterpart is necessary for success. Outside of Japan, we did not find that strategic alliances, partnerships, joint ventures, etc. were a necessary condition for success. In fact, it is increasingly possible, and desirable, for small and medium-sized AMT suppliers to be hardware independent, permitting them to choose among a variety of open-systems suppliers.

While strategic relationships may be valuable to expand a product line, gain access to technology, or penetrate a new market, our conclusion is that they are not a necessary condition, except in Japan.

### 5.4.4 ACCESS TO TECHNOLOGY

It is true that Canada is not, with some exceptions, a world-class R&D centre. Canada invests a very low percentage of its GNP in R&D. This is not necessarily a competitive disadvantage in many AMT businesses. For example, and as noted previously, Canadian software suppliers and system integrators can take advantage of the strong and accelerating trend toward generic, powerful hardware. Most of the small and medium-sized companies which are the focus of this study, cannot afford the R&D investment required to maintain their own proprietary hardware. Fortunately, they no longer need to do so to be competitive.

In one case studied, a hardware supplier (SOFTAC) was able to package and apply software to "off-the-shelf" components. The key element in this situation was a significant knowledge of the process application. In another case, a hardware supplier (Husky) is world-class in defined segments of its total market, based on Canadian developed technology. However, the firm is not large enough to expand into other, related product-market segments, and therefore became involved with a Japanese partnership to expand its product line and distribution power.

To the extent that Canadian AMT suppliers are software focused, the key to success will be industry and/or application function expertise. In some cases this expertise has been and will continue to be initially developed in Canada, based on Canadian industry requirements. In other cases, expertise cuts across borders, as in the automotive sector where Canada and the U.S. are closely linked. Finally, some entrepreneurs have seen opportunities in the U.S., either as support functions to U.S.-based hardware, or as suppliers to U.S. manufacturers.

Canadian AMT suppliers that are prepared to look south should experience few barriers to gaining technology or industry/application expertise. Within strong Canadian home industries, such as forest products, energy and chemicals, there is sufficient world competition to ensure that meeting Canadian requirements will keep AMT suppliers current with, if not ahead of, their competitors.

A key factor in maintaining access to information relative to the adoption of technology, is participation in international standards organisations. This is true for Canada as a country as well as for individual companies. Standards and open systems are becoming a competitive force. Computer users are no longer content to accept what they are offered from a single supplier, and want to be able to select equipment for its suitability to the application, whoever the supplier. Computer companies that have been slow to recognize this trend are currently suffering the consequences of sharply reduced sales. Membership in standards organisations is an effective way to keep track of what is likely to happen in official standard-setting circles. Additionally, contact with other members provides powerful insights into foreign market user trends and needs.

### 5.4.5 ACCESS TO CAPITAL

Access to capital is a problem for Canadian companies. However, among the AMT suppliers studied, access to capital was not a major barrier to growth. This is not to say, of course, that capital requirements are inconsequential. There are small companies that believe they could move faster in product development if they had more money. There are other companies that have sold up to half their equity to larger foreign companies. In these cases, however, the motivation involved access to a broader product line or distribution channels as well as raising capital.

## 5.5 CANADIAN ADVANTAGES

### 5.5.1 LARGE NORTH AMERICAN MARKET

Canada has a major open market at its doorstep and successful Canadian companies, both users and suppliers of AMT, consider the United States as part of their home market. This has been a critical factor in the success of several of the companies studied. In fact, some Canadian AMT suppliers found a market in the U.S. in advance of selling their products or services in Canada.

Of the AMT supplier companies studied for this project, most considered the United States to be the primary market for their products or services. This includes hardware suppliers such as Husky and SAMI as well as software companies such as Taylor, PROMIS, and Dynapro.

In the business of system integration, distance can be a negative factor and North America is a large area to cover. Westhead Industries attempted to stretch across the United States with its products and services. When it discovered that the products required more technical support than was originally expected, retrenchment followed. By contrast, ITP Boston has been able to operate effectively on the West Coast as well as in Europe from its East Coast U.S. base. The reason for this difference is the size of the projects. There are often one hundred or more people assigned to the large aerospace and automotive projects in which ITP Boston is involved. Canadian system integrators can be effective in the U.S. as well as Canada, even on relatively small projects, by establishing themselves in application niches that cross the border. This can often be done without over stretching the management resources because the application niches tend to lie close to the border. For example a Canadian integrator can specialize in automation applications in Ontario and Michigan or in wood products in British Columbia and Washington.

Canadian manufacturers can take advantage of organisations located in the U.S., but serving Canada as well, which disseminate information on manufacturing technologies and their application. Two of these are National Center for Manufacturing Sciences (NCMS) and Automation Forum.

## 5.5.2 REPUTATION FOR QUALITY AND ADVANCED TECHNOLOGY

Canadian manufacturers of such diverse products as sportswear, lumber, integrated circuits, injection molding machines, and automotive parts as well as AMT suppliers are competitive on a global basis. In each case the companies studied are recognized outside of Canada as quality suppliers. The quality image of the Canadian companies studied is favourable.

Canadian AMT hardware and software suppliers such as Husky and Taylor are developing products in cooperation with world-class Japanese suppliers. These arrangements are indicative of the Canadian companies' capabilities in specific technology and application areas. PROMIS has supplied systems to global high-tech companies including IBM, Siemens, Motorola, Fujitsu, Bosch, and McDonnell Douglas, another indication of global appreciation of Canadian AMT expertise.

## 5.5.3 ENTREPRENEURIAL SPIRIT IN CANADA

Although Canadian businessmen are often characterized as conservative, there are several examples in the case studies indicating that Canadians and immigrants to Canada have the vision, technological prowess, and entrepreneurial spirit to start new businesses.

With the exception of the two foreign-owned companies, the Canadian case study subjects, AMT users and suppliers alike, represent examples of entrepreneurship. Whether they started from scratch or spun off from a larger entity, the founders undertook to begin and build an independent business enterprise in spite of the personal sacrifice and risk often involved in such ventures.

## 5.5.4 THE CANADIAN LABOUR FORCE

The case studies show that Canada has been recognized for its skilled and cooperative labour force. F&P Manufacturing, the Japanese-owned automotive supplier, located its plant in Canada as opposed to the U.S. for that reason, even though 80% of the plant's output is shipped to the States. As teamwork becomes an increasingly important aspect of industrial production, the tendency of Canadians to work together cooperatively will likely become recognized in plant location decisions.

The companies studied have found that engineers graduating from Canadian universities are well prepared to begin contributing fairly quickly, given the proper training. Husky uses cooperative students from University of Waterloo to advantage, while others hire only experienced engineers that can come up to speed more rapidly.

Of the companies studied, those that are most satisfied with their labour force are those that provide extensive internal training opportunities for their employees, e.g., Husky and F&P.

### 5.5.5 NATURAL RESOURCES

The abundant natural resources with which Canada is blessed are the basis of much Canadian industry. Canada's extensive natural resources contribute to its ability to be world-class as an AMT producer as well. As illustrated in the SOFTAC and The Pas cases, the wood products industry tends to foster the development of companies supplying equipment and demands world-class performance from its suppliers.

### 5.5.6 CULTURAL COMPATIBILITY IN WORLD MARKETS

There is evidence that Canadians are viewed in overseas markets as easier to work with and less aggressive than Americans. Canadians are judged as more patient, cooperative and team-oriented than Americans.

## 5.6 DISADVANTAGES OF CANADIAN COMPANIES

Based on the successes of the Canadian companies examined in the case studies, there appear to be no serious disadvantages to manufacturing in Canada or to being an AMT supplier from a Canadian base. That is not to say that there are no problems; there are positive and negative factors in every economic and competitive environment. The subject companies have overcome the negative factors while leveraging the positive to gain overall advantage from their Canadian base of operations.

### 5.6.1 SMALL CANADIAN MARKET

Disadvantages related to a small home market disappear when the home market is defined as the whole of North America. The inclusion of the United States as part of the home market provides access not only to a large consumption area but to technology as well. The computer industry and semiconductor industry in the U.S. are as geographically accessible to the major industrial centres in Canada as they are to many sections of the U.S.

### 5.6.2 LACK OF A HIGH-TECH IMAGE

It is probably true that Canada is not a leader in basic R&D in the AMT area, especially as it relates to hardware. However, the companies studied for this report have been able to establish themselves as leaders around the world in the application of technology. This has been particularly true for those companies focused on software products

Even though Canada is not a major R&D country, several small and medium-sized manufacturers studied have carved out technology-based positions in diverse fields such as semiconductors, robotics and injection-molding machines. Canadian AMT suppliers are also sought after as development partners by major Japanese companies. Canadian AMT suppliers are serving the AMT needs of global high-tech manufacturers.

### 5.6.3 HIGH COST OF CAPITAL

The cost of debt capital in Canada is high. Venture capital has been difficult in all markets for several years and, at this time, it is even less attainable due to uncertainties in the financial markets.

Partially offsetting the difficulties in raising private-sector funds is the fact that several Canadian companies studied have received financial assistance from federal and provincial Government programs. Many of these programs, however, are being downsized or terminated.

### 5.6.4 HIGH COST OF LABOUR

Labour costs are extremely high in Canada. Fortunately, in spite of current trends, Canada's labour force is one of the most productive in the world. Since, in most manufacturing plants the cost of direct labour is less than 10% of total costs, the labour cost factor is not as critical as it may seem. Generally, however, Canadian companies do not attempt to compete in product areas where a low labour-cost factor is a requirement.

Sun Ice is competing in the apparel business, generally a labour cost-sensitive industry, using AMT to keep the labour content at a minimum and to ensure a very high-quality product. F&P Manufacturing, the Japanese-owned automotive stamping plant, also keeps labour content down through the use of AMT. In F&P's manufacturing improvement programs, cost reduction is not a stated goal. It is, however, an inevitable result. Linamar is able to be competitive in serving automotive companies in the U.S. as well as in Europe. Husky, operating from its base in Bolton, Ontario, is competitive internationally.

### 5.6.5 LACK OF APPRECIATION FOR WORLD-CLASS MANUFACTURING

The most critical barrier to more effective Canadian participation in world markets appears to be management's lack of understanding of the changing nature of competition in the manufacturing industries. Canadian companies, in general, have not begun to recognize the opportunities open to those manufacturers that achieve world-class status and are recognized for world-class quality products and service. Neither, apparently, have most Canadian manufacturers begun to understand the threat posed by world-class competitors with a global presence.

This lack of appreciation represents a barrier in two ways. First, manufacturers not using the techniques and technologies required to achieve the world-class goal will not succeed outside of Canada and will eventually lose their domestic markets to those who supply customers the best value in terms of quality, variety, delivery, and price. Second, Canadian AMT suppliers will have a reduced Canadian home market, although, as noted, this is frequently offset by the proximity of the U.S. market.

## 5.7 CANADIAN ADVANTAGE IN THE YEAR 2000

Canada's relative advantage in the year 2000 will rely on the actions taken by industry and government over the decade of the 1990s. The success of the program will initially be measured in technological and competitive terms but the eventual effects will be economic and political.

Unless Canadian manufacturing companies actively strive for and attain manufacturing excellence, they will find it difficult to survive in 2000. The basis of competitiveness has already begun to change and by 2000 the current goals will be standard procedure. Six sigma quality and customer responsive products and service will be norms for those manufacturers that survive the inevitable shake-out.

Canadian industry must continue to move ahead in its application of AMT and Canadian AMT suppliers need continuously to advance the state of these technologies. The Canadian labour force's standing as one of the most productive in the world is at stake. Canada's high cost of labour will be intolerable if productivity isn't maintained well above those countries with lower labour costs.

Economic and political repercussions will be significant if Canada loses more of its industrial base. Rising unemployment and reduced standard of living are two inevitable results of an eroding industrial base.

The Canadian Government can provide stimuli for advances by the manufacturing community. Although economic stimuli may eventually be effective, the most pressing need is building management awareness. Manufacturers need to understand the opportunities and threats inherent in the changes taking place in the world competitive environment. Management must be alert to the steps that can be taken to harvest the opportunities, fend off the threats, and avoid the possible pitfalls. This lack of awareness is currently judged to be the most significant barrier to the use of AMT and, ultimately, to a stronger competitive position for Canadian manufacturers and AMT suppliers in world markets.

# 6.0 STRATEGIES FOR AMT USERS

## 6.1 SUMMARY OF KEY STRATEGIC ISSUES

- World-class manufacturers from around the globe are competing for the North American market
- Competition is based on overall perceived value: a multifaceted concept including quality, variety, delivery, price, and reputation for service
- The competitive environment of the 1990s presents global opportunities for world-class manufacturers
- World-class competitors from around the globe threaten Canadian manufacturers' markets in Canada as well as elsewhere
- Canadian manufacturers are losing ground to other industrial nations in terms of productivity and, therefore, the ability to compete
- Because of the FTA, losing ground to U.S. companies represents a serious immediate threat in Canada as well as a loss of opportunity to take advantage of membership participation in the world's largest single country market
- The application of AMT is one factor in enhancing productivity and achieving world-class manufacturing status

## 6.2 RECOMMENDATIONS FOR POTENTIAL AMT USERS

❶ Define the Home Market to Include all of North America

For those companies that do not already view the U.S. as part of their home market, it is important to expand their horizons. The Canadian market is reasonably diverse. The U.S. market, however, provides a broader range of customers, technologies, and competitors. As well, it is a larger overall market that can more effectively be segmented into profitable specialized niches.

With the FTA, there are few barriers to trade between Canada and the U.S., and markets are physically accessible from both sides of the border. If Canadian companies don't take advantage of their status as a partner in the world's largest market, they will experience only the negative effects of the FTA as they lose large portions of their domestic market to aggressive U.S. competitors.

❷ Adopt a Global Perspective

Canadian manufacturers may or may not develop a strategy to operate globally. Their scanning horizons must, however, be global. North America is the most lucrative market in the world and global suppliers are constantly focused on it. Canadian companies are subject to competition from world-class manufacturers from anywhere in the world. Global scanning is needed to stay abreast of technical, managerial, competitive, and economic developments that could represent opportunities or threats.

Areas in which Canadian manufacturers should be particularly sensitive to global or regional trends are product technology, standards, and manufacturing management practices. These areas will be critical inputs into competitive business and marketing strategies in the 1990s.

❸ Analyze the Competitive Environment

Determining who the competitors are and are likely to be on a worldwide basis is a necessary step. This includes understanding competitor's product lines, manufacturing methods, marketing strategies, distribution channels, pricing policies, and territorial strengths, as well as growth patterns and goals.

❹ Assess Customer Needs and Desires

Understanding what customers expect and what they are getting from their suppliers is imperative to developing a manufacturing strategy including the use of AMT. Manufacturers need to include competitors' customers in this scan as well as their own. A significant level of detail is required. Information to be gathered includes critical factors in evaluating supplier performance, expectations in terms of quality, price, product variety, and delivery, as well as levels of satisfaction with current suppliers, unmet needs, and desires.

❺ Forecast Technology Changes

It is important to look ahead in technological terms. What technologies may supplant what is currently being used in the product? What process technology changes are taking place and what developments in process technology could make a significant difference to you and your competitors? What is the status of experiments that may be going on in product and process technologies? It is imperative to conduct this search on a global basis; the next generation of technology for product or process may come from any where in the world. Technology development must be monitored regularly; often technologies that show great promise dwell for several years in a state of impracticability only to burst into prominence quickly as a result of some related development.

❻ Conduct a Critical Self Evaluation

How does your company stack up against competitors in terms of satisfying critical customer requirements? Are your products as technologically advanced as those of the other suppliers (whether or not they are currently competitors in your market)? How well prepared are you for the next wave of technological product advancements? What is your relative status in terms of process technology? Are you as productive as the best in the world? Are you as customer oriented, as timely, as quality conscious? Does your product mix meet your customer needs? Are your distribution channels serving your customers as completely and conscientiously as you expect? What are your critical core competencies and how do they differ from those of the other suppliers? What are your relative strengths and weaknesses? Where and what are your opportunities, and threats?

❼ Develop Target Market Plan

A marketing strategy focused on specific geographic and industry targets should be developed based on the evaluation of customer needs as well as competitive strengths, weaknesses, opportunities, and threats. The plan must include:

- Market positioning
- Product requirements
- Geographic markets
- Industry/application markets
- Marketing mix
- Pricing policies

The nature of the plan will depend on the status of the company as determined by combination of customer inputs, competitive analyses, and technology forecasts. Opportunities may exist that were unknown. This may stimulate management to draft an aggressive plan. If the program requires external funding, the existence of this level of planning should prove valuable in raising the necessary capital.

At the other end of the scale, the company may suddenly, as a result of the evaluation process, recognize that it is facing a serious threat or is likely to be threatened soon. If the problem has been recognized in time, the company should be able to take action to nullify or dull the effect of the threat.

The marketing plan defines key manufacturing issues including the product variety and volumes to be produced, thus defining manufacturing strategy and the application of AMT.

## ❽ Select and Prepare Distribution Channels

The correct form of distribution is a function of several variables. The variables include the territory to be covered, the technical complexity of the product being sold, the size of the average sale or the annual sales value of the average customer, the technical competence of the customer, the nature of the customer (e.g., end-user vs. reseller), the size of the market in the territory being covered, local buying preferences, the competitive environment, and the relative market position of the supplier company. An analysis of these variables is required to determine the appropriate channel for each situation.

The nature of distribution channel may suggest certain product benefits that can be designed and built into the product. For example, if the distribution channel handles installation, product features that simplify installation may become a positive competitive factor.

Training is a key issue, both in terms of finding a channel with people technically capable of being trained in the product line, and making personnel available for training. Understanding the strengths and weaknesses of the people to be trained may dictate product characteristics that compensate for the weaknesses (e.g., a few, simple dial settings) or work the strengths (e.g., unlimited adjustability).

Distributors or wholesalers are generally effective in selling commodity products, especially component products. Even though technology changes can affect the nature of the products sold, this may not be important to the role of the distributor who is simply acting as a conduit between a knowledgeable manufacturer and a knowledgeable customer. Distributors are expected to continue to fill this role in much the same way in the future as they have in the past. Their main function is location, i.e., making the product available close to where it is needed. Even in a global marketplace, a local source of supply is important.

International trading companies are most effective in large markets with commodity products. Support-intensive products with fast-changing technologies are not effectively moved through this channel. Japanese companies have used trading companies effectively to move their consumer products into North America. This has been a uniquely

Japanese channel and attempts to replicate Japanese trading companies in North America have not borne fruit. The importance of this channel tends to diminish with globalisation. Japanese automakers that once exported large numbers of cars and trucks now build the products within the target market. As globalisation increases the role of trading companies will likely decrease.

Original equipment manufacturers (OEMs) can be viewed both as customers and as distribution channels. Automotive part manufacturers, for example, can reach foreign markets by contracting to produce parts for cars and trucks being sold in those markets. In commodity product areas, OEMs may be reached through other channels such as distributors. The trend toward close relationships between OEMs and their suppliers is expected to intensify as more manufacturers implement JIT principles.

Manufacturers' representatives can be used effectively in small markets where it is not cost effective to install a direct sales force. One advantage of using reps is the relationships they may have with buyers due to the complementary products they sell. These organisations generally have many product lines and have difficulty becoming knowledgeable in more than one or two of them. For this reason they are typically not effective in fast changing technologies. Because they are generally paid on a commission-only basis, they are not easily motivated to work on products that have long sales cycles or that require significant after-sale support. Increased specialisation and rapid technological change tend to work against the use of reps. Canadian companies that need to address broad geographic markets with products that are reasonably stable may be well-advised to use reps to get started.

A direct sales force provides the manufacturing company with a channel over which it has a reasonable measure of control. Technology changes can be dealt with through salesforce training. Training can also be used to teach sales personnel proven approaches to selling the company's products. Employees can be taken out of the field and trained at the company's discretion. This is often a problem when sharing channels such as manufacturers' reps or distributors. The sales focus can be changed either by directive or through changes in incentive-pay structure. Technically qualified direct-sales personnel can provide customers with the application engineering support they may need. The main drawback of a direct salesforce is its cost to the company, especially in the early stages before significant sales volume is achieved. Increases in technical complexity and product specialisation favour the use of direct salesforces where the value of each sale is large enough and the number of customers in a given territory plentiful enough to make direct selling practical. As a rule of thumb, a direct salesperson must generate at least $1 million per year in volume to make the investment worthwhile.

Increasingly, system integrators and other value-added resellers (VARs) are being viewed as a channel for products that can be characterised as system components. In general, these companies are built around applications expertise as opposed to marketing or sales strengths. In some cases integrators do not buy and resell products, they simply perform services for the user to integrate components into a system. Whether they are reselling products or just selling integration services, they have significant influence on customers relative to brand and model selection. Since integrators are being paid by users to help design and implement a system, they are inclined to take the time required to provide application, installation, and other support that the user may require. Integrators and VARs are expected to continue to increase in importance as sales channels through the year 2000 and to enhance their ability as sales organisations.

Marketing alliance partners are generally companies with complementary products that are able to address markets that may not otherwise be reached. In Japan, for example, a partnership with a Japanese company is virtually required to penetrate the market. These arrangements have proliferated over the past several years with mixed results. There is now a larger base of experience from which to learn and that should allow companies to follow the success patterns toward workable arrangements. The continued use of these partnerships is projected as companies, small and large, go global by finding compatible partners in attractive markets.

⑨ Study World-Class Manufacturing

From the CEO down, the company must learn what it takes to be world-class. This process should be going on in parallel with market planning. Top executives must be deeply involved; those who don't get involved don't understand the stakes. Visits to world-class manufacturing plants with similar processes and problems are important to develop ideas and to benefit from the experience of others. World-class manufacturers are generally willing to share their experience. Seeing what others have done helps overcome the fears. Employees should be encouraged and given company time and expense coverage to take advantage of the several means available to learn about AMT applications; these include professional or trade association meetings, conferences and trade shows.

## ⑩ Strive for World-class Manufacturer Status

The final, but never ending, step is to implement a manufacturing program that meets the marketing plan, striving to meet or beat the best manufacturers in the world.

Based on the evaluations of customer needs and competitors' performance, establish benchmarks as to current standing as well as long and short-term goals. Where all competitors fall short of excellent performance, benchmark against a world-class performer in a different field. (Example: Xerox patterned its product delivery system after lessons learned through studying procedures at L.L.Bean). Since the process of achieving world-class status never stops, competitive evaluations, technology scans and customer requirements analyses need to be performed regularly, if not continuously.

The implementation program should operate on three general levels of activity: Management Practices, Human Resources, Application of AMT.

### Management Practices

These include total-quality management, JIT, concurrent engineering, flexible manufacturing, and supplier partnerships. These are not fads or short term initiatives; they are essential changes in the way manufacturers operate their businesses. They are not simply delegated to middle managers to be implemented. Unless top management is committed to the fundamental principles inherent in these practices, a meaningless exercise will be the only result.

Human Resources

The human resource aspects of the program include employee training, continuing education programs, employee empowerment, advancement programs, and regular reports of status toward the world-class goal. It is vital to establish a culture of pride, competitiveness, and continuous improvement. Success in AMT implementation is directly related to the participation, training, and job enrichment opportunities for employees.

Advanced Manufacturing Technologies(AMT)

AMT can be applied once the benefits of the management practices and human resource programs start to take effect. Design for manufacturing is an important preparatory step that can be taken quickly. It also helps both product design and manufacturing personnel to begin to think about the types of AMT that can be used. Getting started is often the hardest part. Make the first project relatively simple. Get it assimilated and then move on to the next one. The success of the first project will be a giant step toward building the all-important pride in accomplishment that helps drive future projects and stimulates employees to strive to meet the goals on the road to world-class status.

## 6.3 CAUTIONARY POINTS FOR PROSPECTIVE AMT USERS

- Don't try to automate what doesn't work well manually
- Don't attempt to apply AMT to an overly complex product design. First, redesign to simplify and standardise components
- Don't apply flexible automation techniques to high-volume requirements
- Don't bite off more than you can chew. Start with relatively simple projects
- Don't deal with more variables than necessary at one time. If a project can be implemented in stages, get stage one working before moving ahead with stage two
- Don't attempt to implement AMT without employee participation and cooperation at all levels and in all affected departments
- Don't skimp on employee training. Make sure everyone gets sufficient training, including operators, supervisors, and maintenance personnel
- Don't wait too long to get started. Chances are that some competitor somewhere already has

# 7.0 STRATEGIES FOR AMT SUPPLIERS

## 7.1 COMPETITIVE ENVIRONMENT AND OPPORTUNITIES

Canadian AMT suppliers are faced with a multi-dimensional matrix of country, product, and industry. Decisions must be made along each of these dimensions with respect to strategic opportunity and risk. For the small and medium-sized companies which are the reference point of this report, it will be very important to achieve the proper business, technology, and market focus.

### 7.1.1 PRODUCT OPPORTUNITIES

Small and medium-sized Canadian AMT suppliers should avoid the computer hardware sector of the business. There is a strong trend toward generic computer hardware platforms. This is a market in which scale with respect to technology, manufacturing, and marketing is critical to success. Industrial users want compatibility and connectability, and are increasingly moving away from hardware with proprietary operating systems. While it may be possible to introduce a new computer platform for AMT, this would be a high-risk move.

Hardware in the product categories of cutting and forming, materials and parts handling, inspection, test, assembly, and packaging, offers selected opportunities. In general, these are among the lowest dollar volume and slowest growing product sectors of the AMT business. Small and medium-sized companies that expect to be competitive in this sector of the AMT market will have to pick out fairly narrow, high value-added product specialties. Such specialty areas are typically based on a combination of product and application technologies. Advanced sensor technologies offer opportunities to establish areas of specialization in each of these product categories. Selective product specialization of this type can often be accomplished without heavy investment in development, and leads to competition on the basis of benefits not price. It is crucial for smaller suppliers to steer clear of commodity products, where price is the major purchase criterion.

Software is a dynamic sector of the AMT market. It is a major component of the largest and fasted growing product categories. Smaller suppliers can succeed in this product area in that entry barriers are low and application expertise is the critical asset in the early stages. The emergence of standardized hardware platforms opens a myriad of opportunities for knowledgeable developers of AMT software. In order to get the maximum leverage from the expertise of the developers, software needs to be a product (as opposed to a service) to the greatest extent possible. Ideally, software products can be shipped anywhere in the world, installed, and run by users, based on instructions in the package. The further the product gets from this ideal, the more people-intensive the business becomes and the less leverage of people assets is realized.

System integration is a people-intensive business. The need for qualified system integrators will continue to grow as more AMT is applied. System integration is generally a regional business. Regional focus is necessary because attempting to execute several projects over a wide geographic area has proven to be extremely risky. Only when projects are large enough to carry their own management load is it practical to effect geographic expansion.

### 7.1.2 GEOGRAPHIC MARKETS

The Canadian market, by itself, is too small to support dynamic AMT suppliers, with the possible exception of those companies focused on Canadian natural resource developers. Concentration on a relatively small home market will almost certainly leave Canadian AMT suppliers vulnerable to the attacks of more internationally focused competitors. Perhaps more importantly, in today's world it is very dangerous to be cut off from the ideas and approaches being tested and used in a variety of national markets.

Viewing North America as the home market expands the industry and application scope of potential Canadian AMT suppliers. It opens wide a range of opportunity. As well, it forces recognition of competitor strengths and offerings, competitors who almost certainly will, in any case, find their way north. At the same time, Canadian entrepreneurs will discover product-service gaps which they can fill in the U.S. market. It is more practical in many cases to go north-south than to go east-west. A market radius of 500 miles, for example, is more likely to encompass the U.S. and Canada, than Canada alone.

The fastest growing AMT markets are in Europe and Asia. With respect to Europe, the largest market is Germany. However, this is a very difficult market for non-Germans to crack. For technology-based products, German firms tend to buy from national suppliers. There are strong historical linkages between German suppliers and their customers.

The other major European AMT markets -- France, Italy, U.K. -- are also growing at a rapid rate. These markets, especially the U.K. market, are relatively open to non-national suppliers. Among the less-developed European markets, Spain is the only one of a size and complexity which would merit a targeted sales effort. The Eastern European markets are too embryonic to justify a major strategic effort by small and medium-sized firms.

Within western Europe, a major driving force for AMT purchases will be that of labour availability. Suppliers should be aware of this critical issue in their product design and sales strategies.

Asia can selectively be an attractive market for Canadian AMT suppliers. Japan, which accounted for approximately 80% of Asian AMT purchases in 1990, is penetrable, but only with the aid of Japanese "partners". Of the other Asian markets, Korea and Taiwan offer the greatest potential over the next five to ten years.

### 7.1.3 INDUSTRY FOCUSED OPPORTUNITIES

The transportation/automotive market has been the largest single market for AMT products. It is expected to decline in importance, but will still comprise a major target segment through the 1990s. Canadian AMT suppliers can tap into their North American customers to leverage themselves into the European and Asian markets. It should be noted, however, that this is a highly competitive sector and not easily penetrated. AMT products that relate to design cycle-time reduction and quality improvement will tap into key concerns of this industry.

The electronics industry is expected to surpass the automotive sector as a key driving force in the 1990s. This is, of course, a relatively diverse industrial sector, thereby offering a wide range of selected opportunities.

Market opportunity-targeting in this sector will be very much a function of the background, experience, and interest of AMT suppliers.

The aerospace and machinery sectors are at a third level of attractiveness to AMT suppliers. The aerospace market is potentially attractive to Canadian AMT suppliers as the U.S. is a major factor in this market. The machinery market can be selectively attractive. However, much of the dynamism in this market has shifted away from North American suppliers.

World-class manufacturers can help develop world-class AMT suppliers. Canadian AMT suppliers that focus on the natural resource industries, such as wood products, get the benefits of working in a home market where the AMT users are world-class manufacturers.

## 7.2 IMPLEMENTATION ISSUES

### 7.2.1 NORTH AMERICA AS THE HOME MARKET

AMT suppliers must actively manage North America as their home market. The first step in this process is simply one of mind-set. Canadian suppliers should view natural markets and customers. For some companies, this may involve a market radius of several hundred miles from home base; product or service businesses that require considerable on-site application support tend to fit this mold. For other companies, the primary focus may well be the North American industry, for example, automotive on both sides of the border.

The second step is to develop a market picture of customer needs and demands and competitive positioning which encompasses the broader market area. This may mean developing an expanded market information base. On-site target customer visits by key company personnel are an integral part of this process. There is no substitute for being face-to-face with customers and their operating environment.

Third, Canadian AMT companies should actively manage their contacts within target industries. Specifically, they should be serious participants in standards conferences and bodies, wherever this is possible. Industry association membership is a must. Trade show participation provides a multiple benefits, it shows commitment to the market, opens lines to customers and distribution channels, and provides a window into competitive offerings.

Fourth, sales representation must be developed in key geographic or industry areas.

### 7.2.2 CHANNEL LINKAGES

One of the key success factors once product and market decisions are made is the development of channels to customers. Sales, application and service/support factors must be considered.

One of the channels to be seriously considered is that of a "marketing partnership" with a complementary local vendor. Canadian AMT suppliers should look for firms which have established marketing/sales links with target industries and can provide any needed technical, application and service support. Of course, not all these elements will be readily available and circumstances will dictate deviations from the ideal.

Within Asia, and especially so in Japan, AMT suppliers must develop a "partnership" linkage with a local market participant. Direct sales and service representation will almost certainly be too expensive for small and medium-sized firms. More importantly, these are markets that require local knowledge and contacts.

The following comments apply to any "partnership" or strategic alignment. First, considerable top management time and effort should be devoted to this effort. Linkages should be strategic in nature. This implies congruity of market perceptions and goals. It also requires a reasonable personal fit of key personnel.

Second, the ensuing structure should not isolate the Canadian company from the marketplace. Suppliers of AMT products must actively manage their access to key customers and knowledge of competitive actions if they are to maintain equal leverage with their marketing and service partners. Information is a scarce and valuable resource.

Third, partnerships must be maintained and nurtured. They will change in a variety of ways over time. The history of these relationships is that they are generally not successful, it is primarily because the partners 1) did not choose wisely in the first place with respect to strategic fit and 2) the partners did not manage and nurture the relationship through changing conditions. It is very important to recognize that power shifts occur between partners over time. Canadian AMT suppliers must, therefore, maintain their competitive technological edge and work hard not to be isolated from key target customers and industries.

Within North America, direct sales and service force representation is best. In Europe, this approach is culturally acceptable in the U.K., France, Italy and Spain. Economics may, of course, dictate otherwise. Suppliers should recognize that there are hidden costs involved in field sales offices. Support personnel at headquarters must be available. Management will have to devote field time to manage and support the salesforce. Manufacturers' reps are a lower fixed cost alternative in that they don't get paid until a sale is made and they pay their own expenses, however, home-office support and field management efforts are still required. If the product is technically sophisticated or if application support is required, reps may not be motivated to promote it actively.

A channel strategy involving system integrators and value-added resellers requires the AMT supplier to develop a large number of relationships, as these channels tend to be geographically and application focused.

OEMs with which the AMT supplier has developed close working relationships in Canada and/or the U.S. can be extremely useful as a marketing channel. These relationships generally develop over the space of several projects, as the parties develop mutual respect and credibility.

In some AMT product categories, electrical distributors have proven to be an effective sales channel. A prominent example is programmable logic controllers (PLCs). Software and peripherals for PLCs are also effectively moved through this channel. For this channel to be effective, products must be reasonably well accepted in the market.

### 7.2.3 PRODUCT MIX

Product mix decisions will be critical to success. A key factor to be considered is the trend toward customer desire for generic computer hardware platforms. One area of focus, therefore, should be specific industries and/or applications, with software tied to standard platforms as the driving force.

AMT software suppliers should be very sensitive to the installation, application, and diagnostic elements of their business. These elements are people intensive at the application level. Good people are in short supply and can be the constraining factor. One of the clear needs in the market is a package which includes installation, application and diagnostic training and support aids.

In the cutting and forming, test and inspection, and materials handling areas there is a clear trend toward specialized hardware. Customers are willing to pay a premium for products which are designed for their applications. Canadian suppliers of hardware should be very sensitive to this opportunity. Interestingly, this trend means that they themselves will be markets for design automation and manufacturing equipment which is geared to rapid response to changing customer needs, and the efficient production of small runs.

New sensor technologies permit more sensitive measurement of key production variables. Manufacturers are driving toward more real time feedback and control of product quality through control of the process. Communications linkages are becoming more pervasive. Sensor technology is an area in which application and technical skills are more important than scale of operations making it attractive for small and medium-sized companies.

Successful system integrators are specialists in specific types of AMT applications, continually becoming more expert and adept in their area of specialization. This application focus allows integrators to use the same or similar products and technologies in multiple projects and often fosters favorable discount arrangements with AMT product suppliers.

### 7.2.4 TRAINING AND EDUCATION PROGRAMS

Manufacturers that have implemented AMT projects recognize that there are major training requirements. The Japanese commitment to on-the-job training and up-grading further reinforces the importance of people skills in advanced manufacturing. Suppliers of AMT recognize that there are major training needs in the market.

The reality, however, is that users are not yet willing to pay for the full complement of training that is needed. Suppliers are reluctant to include complete training in a project proposal for fear of being non-competitive. There is clearly a gap between needed and purchased training. New approaches to product and application training are needed. It may be possible to build in computer-assisted training where computer hardware is part of the overall package, and the package can be designed to be interactive with the user. In other cases, video training may be feasible, along the lines of service and product videos used by the automotive companies for their dealer networks.

### 7.2.5 COMMUNICATION LINKAGES

Operating across long geographic lines poses obvious communications problems. In recent years, innovative retailers have developed communications systems linking their retail outlets, sales people, warehouses and suppliers. The result is an extraordinarily responsive system, keyed to market demand.

The communications technology exists for AMT suppliers to institute similar systems. Information, including real-time support services, can now be available globally and can be a strong competitive tool when used aggressively and imaginatively.

## 7.3 STRATEGIC RECOMMENDATIONS

### ❶ Define the Home Market to Include all of North America

As with AMT users, Canadian AMT suppliers must target the U.S. as part of their home market. This will be necessary to achieve a critical mass of sales volume, to toughen their competitive skills, to expand their application base, and to gain an additional window on technical trends.

The first step in this process is top management mind-set. In-depth market and competitor assessments must then be made, and maintained. Canadian AMT suppliers should become North American companies via their actions within targeted industry groups. Finally, sales resources must be committed strategically to targeted segments of the North American market.

### ❷ Adopt a Global Perspective

Canadian AMT suppliers may or may not decide to operate globally, but their scanning horizons must be global. A global technology and market information base must be actively developed and managed. This involves participation in standard-setting bodies as well as active participation in industry associations and international trade fairs.

Professional market information gathering efforts are also required. Canadian suppliers should establish a pattern of contacts and in-depth visits to trend-setting users. As well, periodic market research must be conducted in key markets in order to identify trends in competitive position and customer needs and requirements.

### ❸ Use Regional Roll-out to Achieve Direct Selling in North America

AMT suppliers must be prepared to invest selectively in a direct sales force in the North American market. While partnership arrangements or manufacturer's reps can be tactical substitutes, in the long run a direct sales force targeting key customers and industries will be necessary for sustained competitive growth in several product classes. Otherwise, the supplier becomes virtually a private labeler for the entity controlling the marketing and sales function.

North America is a large continent with many pockets of industrial activity. It will likely not be economically feasible for smaller suppliers to institute a direct sales force in all areas simultaneously. Thus, a regional roll-out (i.e., establishing a direct sales presence in one or two markets at a time, leading to complete geographical coverage over a period of several years) may be the best way to focus limited resources, establish a direct salesforce and penetrate the market. Establishing a direct sales presence in one or two territories may require no more investment than attempting to support reps in all market areas. Once the first wave of direct selling begins returning on the investment, the next wave can be instituted. Achieving total direct sales coverage of major North American markets may take several years. However, roll-out may be the only way for smaller suppliers to achieve the important benefits of direct selling.

❹ Leverage Home Market Customers into Global Accounts

Canadian AMT suppliers can leverage their North American customer base to help reach global markets. This approach can be used in those customer industries which are global, for example, the automotive sector. Valued suppliers can build on their track record with North American customers to identify overseas opportunity with respect to timing and project scope, establish key buyer contacts and introductions and determine important purchase criteria. A strategic effort is needed to identify, understand, track and market these global sales opportunities.

❺ Address The Western European Market Excluding Germany

The several forces driving European countries to invest in AMT make this an attractive market. Within Europe, Canadian companies should concentrate on the U.K., French, Italian and Spanish markets, which are generally open to outsiders. The U.K. market is culturally similar to the Canadian market and very open to outside suppliers. The French market is growing rapidly. Suppliers must, however, show a commitment to the French market with respect to local service and support capability. It is a mistake to support the French market out of the U.K., for example. The Spanish market is large and growing, and it is at the stage where market positions are best established.

Germany is the largest, single country market in Europe, but is generally inhospitable to outside sources of supply, especially with regard to technical products. Germany has made a major commitment to its eastern sector which may divert the resources of world-class German suppliers from serving other established markets within Europe.

Eastern Europe is not yet a viable target for small and medium-sized companies, nor is it likely to be for the next decade.

⑥ Use Reciprocal Partnerships to Penetrate Asian Markets

The Asian markets, especially Japan, are best penetrated via marketing partnerships. To the extent possible, these relationships should be chosen in such a way that they also provide complementary product and technology for sale in the North American market. In addition to the obvious sales revenue impact of this strategy, it will provide a Canadian company with leverage on its partner, i.e., each side is hostage to the good will and best efforts of the other. Canadian companies possess valuable access to the North American market. As well, they may, by temperament and political "neutrality", be more acceptable as a partner than a U.S. firm.

⑦ Focus on Packaged Software Products for Standard Platforms

Standard computer hardware platforms and standard operating systems represent a major opportunity for growth by AMT software suppliers. A single software product can reach several times the number of customers it would have if developed for a proprietary computer.

Software-oriented AMT suppliers that wish to expand outside North America should avoid support intensive applications. They must develop software which is internally complete. Competent applications and systems people are a scarce resource in the AMT industry. Using telecomputing technologies, several packages and many customers can be supported with a small core group of people if the software is designed as packaged products to be installed and maintained by the user.

❽ Offer Specialized Machine Controls Based on Advanced Sensors

New sensor technologies offer opportunities that can be capitalized upon by Canadian AMT suppliers who possess in-depth understanding of machines and processes. Improved sensors and related controls are needed in each of the machinery product categories. Successful product development will rely on the convergence of sensor technology with machine technology. Those suppliers or entrepreneurs that combine those capabilities are in a position to meet current and emerging needs. The goal will be incorporating the sensors to develop machines that achieve zero defects on an inherent quality basis, i.e., make products so reliably that no inspection or test is required.

❾ Build Training Into The Product

A breakthrough is needed with respect to AMT training. Most AMT products include a computer or controller with one or more processors that can be programmed for multiple functions. The opportunity exists, using this processing power, to build the training into the product. To be most effective the training approach should be interactive and allow the trainee to move at his/her own speed.

❿ Develop Telecomputer Product Support Systems

Canadian AMT suppliers should take advantage of telecomputer technology to establish systems linking designers, application engineers, service support staff, sales force, marketing partners and customers around the world. This type of approach has proven to be a powerful competitive tool for those who have implemented it. It can be used to support sales staff, as well as to provide customer application support, maintenance information, and software product upgrades.

# APPENDIX A

# TABLES

Note: Except where indicated, the data sources for all Tables in Appendix A are AMS and CIMdata, Inc. Data for 1985 actual purchases and 1990 estimates are from CIMdata; forecasts for 1995 and 2000 purchases were developed by AMS.
All figures are reported in millions of U.S. dollars.
Purchase data are based on end-user expenditures, not supplier sales. The figures are the total costs associated with the acquisition of the product or service.
Columns may not sum to total due to rounding.
The column heading CAGR refers to Compound Annual Growth Rate.
Summaries of the data included in this appendix appear in the charts and tables presented in Section 4 of this report.
In the section covering worldwide purchases, by end user industry, the total purchases of the discrete industries listed do not necessarily total the worldwide purchases as some purchases are made by process industry end users.

# APPENDIX A

## TABLE OF CONTENTS

## 1.0 DESIGN AUTOMATION

### 1.1 TURNKEY CAD/CAM SYSTEMS

Direct sales to end users. Total value of turnkey CAD/CAM systems sold to manufacturing and process industries. Systems include workstations and terminals, plotters, and application software sold, installed, and supported by a single vendor. CAE systems are not included in this group. CAD/CAM systems are generally used for physical design and layout.

### 1.1.1 MULTITERMINAL SYSTEMS

Direct sales to end users. Total value of multiterminal turnkey CAD/CAM systems sold to manufacturing and process industries. Systems consist of those with two or more workstations or terminals directly connected to a host CPU.

### 1.1.2 STANDALONE/NETWORKED WORKSTATIONS

Direct sales to end users. Total value of standalone/networked turnkey CAD/CAM workstations sold to manufacturing and process industries. Systems consist of networked CAD/CAM workstations.

### 1.2 TURNKEY CAE SYSTEMS

Direct sales to end users. Total value of turnkey CAE systems sold to manufacturing and process industries. Systems include workstations and application software sold, installed, and supported by a single vendor. Excludes CAD/CAM systems. CAE systems are generally used for engineering conceptual design and analysis. This group includes electronic (ECAE) and mechanical (MCAE).

### 1.2.1 HIGH-END CAE WORKSTATIONS

Direct sales to end users. Total value of high-end CAE workstations sold to manufacturing and process industries. High-end workstations are those based on custom or commercial microprocessor-based workstations such as Daisy or Mentor.

### 1.2.2 PC TURNKEY CAE WORKSTATIONS

Direct sales to end users. Total value of (low-end) personal computer based CAE workstations sold to manufacturing and process industries. Includes the PC and application software sold, installed, and supported by a single vendor.

### 1.3 ENGINEERING COMPUTERS

CPU's and peripherals that are used for product development,process development, facilities engineering, and engineering re-lease control are included . This category of hardware does not include applications for basic research and scientific computing. Engineering computers and peripherals are grouped by price representing the approximate 1986 price brackets for micros, minis, superminis, and mainframes. With computer prices decreasing annually some product group average prices will overlap 1986 brackets in later years of the forecast.

### 1.4 GRAPHICS TERMINALS AND WORKSTATIONS

### 1.4.1 GRAPHICS TERMINALS

Direct sales to end users. Graphics terminals are defined as interactive graphics displays with keyboard, cursor control. They require a host CPU. IBM 5080, Adage, Tektronix, and others are counted as terminals.

1.4.2 GRAPHICS WORKSTATIONS

Direct sales to end users. Graphics workstations are defined as interactive graphics displays with keyboard, cursor control, and local CPU (other than GPU). They may operate stand-alone or with host CPU. Apollo, Sun, and VAXstation are classed as workstations. BREAKDOWN OF: 3. TURNKEY CAD/CAM/CAE SYSTEMS-Direct sales to end users

1.5 ENGINEERING SOFTWARE

This segment includes third party application software sold or licensed unbundled for manufacturing and process industry applications. Includes design, analysis, layout, and control software.

1.5.1 MECHANICAL DESIGN

This segment includes the value of application software used in mechanical design and drafting. This includes all third party and application software not bundled in turnkey systems. Includes MCAE, solid modeling, and other mechanical application software.

1.5.2 PC/IC DESIGN

This segment includes the value of application software used in printed circuit board and integrated circuit design. Included are all third party and application software not bundled in turnkey systems. ECAE and other electronic application CAD software are in this group.

1.5.3 GROUP TECHNOLOGY/COMPUTER AIDED PROCESS PLANNING

Software and systems used for classification, coding, and analyses of parts, processes, tooling, and designs by relationships. Also included is software used to generate production process plans based upon similar shapes, features, materials, and sizes as determined by Group Technology techniques.

1.5.4 PDM/PM - PRODUCT DATA MANAGEMENT AND PROGRAM MANAGEMENT

These are software modules to associate and manage product data, and program data entities. They are used in distributed and heterogeneous computing environments. Support to aid the user in installation, tuning and application of the modules is included.

**2.0 ADVANCED CUTTING AND FORMING EQUIPMENT**

2.1 FLEXIBLE MACHINING CELLS & SYSTEMS

2.1.2 FLEXIBLE MACHINING CELLS (FMC)

An arrangement of machines (usually CNC machine tools with automated tool changers) interconnected by an automated materials transport system. The transporter carries materials and/or parts and tools to the machines on pallets or other interface units so that part-machine registration is accurate, rapid and automatic. The FMC has the same basic configuration as the FMS but is typically smaller, with fewer machines and is intended to complete operations on a part rather than an entire product. The computer, monitors, displays, and controls for the machines and the transport system, and machine tool iron are included in the market value.

2.1.2 FLEXIBLE MACHINING SYSTEMS (FMS)

An arrangement of machines (usually CNC machine tools with automated tool changers) interconnected by an automated materials transport system. The transporter carries materials and/or parts and tools to the machines on pallets or other interface units so that part-machine registration is accurate, rapid and automatic. Central computer(s) and control room monitors, displays, and controls for the machines and the transport system, and machine tool iron are included in the market value.

2.2 MACHINE CONTROLS

2.2.1 CNC MACHINE TOOL CONTROLS

This segment includes the value of control system portion of machine tools and equipment used for: turning, boring, shaping/planing, drilling, milling, routing, broaching, threading, filing, sawing, grinding, honing, lapping, finishing, shearing, stamping, cutting, thermal and chemical mass reducing, casting, molding, compacting, depositing, laminating, winding, forging, extruding, drawing, rolling, bending and forming. Machine tool iron is excluded from the value. Each CNC machine tool has its own computer.

2.2.2 DNC MACHINE TOOL CONTROLS

The control of one or more CNC machine tools by supervisory computer(s). Includes the systems for downloading control programs, and for transmitting individual machine status information back to the supervisory computer(s). The supervisory computer may have capabilities for backup control of individual machine tools. Value of iron excluded.

2.3 SEMICONDUCTOR PROCESSING EQUIPMENT

Computer based systems that control the process operations used to fabricate semiconductor products. Examples include crystal growth. epitaxial deposition, wafer oxidation, chemical etching, etc.

**3.0 AUTOMATED MATERIALS AND PARTS HANDLING**

3.1 MATERIAL HANDLING SYSTEMS

This category includes the computer controls portion of systems and equipment used for both material transfer and for storage within the factory/plant environment. Neither the iron in conveyors, nor the buildings in warehouses are included in the value of this category.

3.1 ROBOTIC MATERIAL HANDLING

This segment includes programmable manipulative machines that can perform functions ordinarily ascribed to humans. The segment includes robotic mechanisms, control hardware and software, and all associated peripheral equipment, such as end-effectors and grippers that are used for the movement of parts, tools and assemblies within the factory.

3.2 AUTOMATED GUIDED VEHICLE SYSTEMS

This segment includes unmanned mobile transporters under programmable control that are used to move materials and tooling throughout the factory and warehouse. Included are: towing vehicles, pallet trucks, light load transporters, unit load transporters, and self-loading and unloading vehicles.

3.3 AUTOMATED STORAGE/RETRIEVAL & WAREHOUSING SYSTEMS

3.3.1 AUTOMATED STORAGE/RETRIEVAL SYSTEMS

This segment includes all hardware, software and systems that are applied for mechanical hoists and carriages, and which interface with racks and bins for automatic storage and retrieval of unit loads, pallets, and individual parts. The systems move materials from inventory to operations and back to inventory, frequently for work-in-process inventories.

3.3.2 AUTOMATED WAREHOUSING

These systems are dedicated AS/RS systems that are used not on the factory floor, but in warehouses that may be co-located with the manufacturing facility. The value includes the control system and the associated material handling equipment and structures, but excludes the building unless it is a structural part of the automated system.

4.0 AUTOMATED ASSEMBLE AND PACKAGING MACHINES

This segment includes machinery and equipment controls that are used for consolidating, laminating, welding, thermal, and chemical joining of parts and subassemblies into complete assemblies. The iron is not included in the market value estimates.

4.1 AUTOMATED MECHANICAL ASSEMBLY SYSTEMS

The assembly of mechanical parts into subassemblies and/or complete assemblies by means of programmable equipment. Non-programmable, hard automation is excluded from the market estimates.

4.2 ROBOTIC ASSEMBLY AND FINISHING SYSTEMS

The use of robots to perform assembly and finishing operations, including robotic paint systems. In discrete piece manufacturing this segment includes spot and arc welding, as well as adhesives. In electronics this segment includes component placement and printed board component insertion. Usually these robots include sensory capabilities.

4.3 AUTOMATED ELECTRONIC ASSEMBLY SYSTEMS

The assembly of printed circuit boards, electronic subassemblies, and/or complete assemblies by means of programmable equipment. Non-programmable hard automation is excluded.

4.4 AUTOMATED PACKAGING SYSTEMS

This segment includes both the programmable control systems and the associated hardware that automatically enclose parts and finished goods into containers and support structures for shipment to locations outside of the originating factory, or for warehouse storage.

5.0 FACTORY FLOOR COMPUTERS AND COMMUNICATIONS LINKS

5.1 FACTORY FLOOR COMPUTERS

5.1.1 CELL CONTROL COMPUTERS
This segment includes the value of direct purchases by end users of computers operating as cell controllers. Cell controllers process information and communicate production information with either an operator, a higher level device, or both, and coordinate and supervise at least one other independent production device which handles machine or process inputs/outputs, also locally store and retrieve production information.

5.1.2 AREA/SUPERVISORY CONTROL COMPUTERS
This segment includes the value of direct purchases by end users of computers operating as area or supervisory controllers. These controllers process information and communicate production information with cell controllers and host computers, and coordinate and supervise cell and production devices, also store and retrieve production information. In process industries generally known as supervisory controllers, and may operate directly with process controllers without cell controllers.

5.1.3 OTHER CAM COMPUTERS
This segment includes the value of direct purchases by end users of computers operating for other than cell or area/supervisory control, including general purpose and special purpose computers.

5.1.4 COMPONENTS
This segment includes controller boards, displays, control rooms, and other hardware that is purchased for direct application to CIM systems, but are not purchased as part of a turnkey system.

5.2 FACTORY FLOOR SOFTWARE

5.2.1 NC SOFTWARE AND PROGRAMMING SYSTEMS This segment includes software that is used to control machinery and equipment with numerical control. Included are software for use with NC machine tools, coordinate measuring machines, etc. This segment also includes systems that generate the NC software programs for controlling specific equipment and the conversion of CAE/CAD geometric data into NC control software.

5.2.2 QUALITY ANALYSIS
This segment includes software for analyzing factory floor quality performance parameters, such as scrap and rework, yields, warranty complaints, and employee suggestions for work/methods improvements, such as may be provided by quality circles.

5.2.3 MAINTENANCE MANAGEMENT
Computer software and systems that provide maintenance, repair, and operations (MRO) including bills of maintenance, mean time between failure (MTBF) parts forecasting, use of engineering-defined capacity data, projecting and tracking consumption of maintenance supplies and disposable repairable equipment, and the interfaces with the MRP-II systems.

CUSTOMER ORDER SERVICING This segment includes the value of software for collecting, grouping, analyzing, and entering customer orders into the master schedule and factory order backlog files. Also included is software for providing data for preparing billing invoices by accounts receivable departments.

PHYSICAL DISTRIBUTION This segment includes the value of software for distribution requirements planning, demand allocation, customer service planning and simulation, shipment scheduling, planning and control, interplant transfer planning finished goods inventory control, vehicle scheduling and routing, warehouse management, carrier selection, and transportation modelling.

SHOP FLOOR SOFTWARE This segment includes software for factory data collection, data acquisition, cell and area control, interface and communication enabling, management information and control, shop floor history, robotic, machine vision, and other equipment and operator control software. User purchased software only is included; software developed and used in-house is excluded.

5.3 PROGRAMMABLE CONTROLLERS
Programmable solid state devices that replace mechanical relays for controlling sequential operations, timing, counting, and similar simple control actions. Where the capabilities exist as a function of the PLC, this segment includes more sophisticated tasks such as mathematical computations, data acquisition, and reporting, and process equipment control.

5.4 LOCAL AREA NETWORKS
Communication hardware and software that is used within the factory environment for transmitting data between points. Includes optic as well as electronic computer controlled systems. Also included are LAN components, such as cabling, that are purchased and assembled into systems configurations by the end-users. Examples include networks between CAD/CAE/CAM workstations, network servers and factory equipment communications links.

5.5 INSTALLATION AND INTEGRATION AND OTHER SERVICES
Services provided to end users for the detailed integration design, installation, startup, and debugging of CIM systems. Does not include services that are provided as a part of a bundled system category of these market models.

5.5.1 SYSTEMS INSTALLATION
Nonbundled installation, startup, and debugging of CIM systems in the case where hardware/software, for the most part, originates from one manufacturer/developer. An example of this is a process control system consisting almost entirely of only one originating vendor's equipment. Installation can be from the originating vendor or a separate installation company.

5.5.2 SYSTEMS INTEGRATION
Nonbundled detailed integration design, installation, startup, and debugging of CIM systems in the case where substantial portions of hardware/software originate from more than one company.

5.5.3 CAE/CAD SYSTEM MAINTENANCE Services provided to end users for maintaining CAE/CAD equipment and systems. Includes contract and non-contract services not covered by system warrantee, but excludes installation and training services.

CIM SYSTEM MAINTENANCE Services provided to end users for maintaining CIM equipment and systems. Includes contract and non-contract services not covered by system warrantee, but excludes installation and training services.

COMPUTER MAINTENANCE Services provided to end users for maintaining computer systems. Includes contract and non-contract services not covered by system warrantee, but excludes installation and training services.

5.5.4 COMPUTER AIDED INSTRUCTION Computer systems, both on and off the factory floor that are used for guidance, training and education of CIM activities to personnel who are involved in CIM responsibilities as a working activity.

SYSTEMS TRAINING & OTHER SERVICES All CIM services that are not included in items 5.5.1 through 5.5.4 above are included in this segment, including in-plant training and consulting services.

6.0 ADVANCED TEST AND INSPECTION SYSTEMS

This segment includes computer-based inspection systems for both electronic and mechanical devices and parts, and test systems for real time and batch testing of electronic and mechanical systems/assemblies. Included are estimates for fixturing and peripherals that are directly associated with the inspection and test systems.

6.1 INSPECTION SYSTEMS

6.1.1 INSPECTION-ELECTRONIC DEVICE

Computer controlled equipment that inspects electronic devices, both active and passive. Analytical and statistical data reduction capability are usually included, with documentation of test results by display, hard copy, and electronic storage.

6.1.2 INSPECTION-PRINTED CIRCUIT BOARDS

Computer controlled equipment that inspects PCB's, by mechanical, electrical, and visual means in an automatic, programmable mode. This segment includes bare boards, and boards which have been loaded with electronic devices. In the latter case, diagnostic capabilities are included as a part of the system definition, if part of the equipment.

6.1.3 INSPECTION-MECHANICAL PARTS

Computer controlled equipment that gages, measures and checks for the presence of parts and assemblies with either mechanical contact, or by non-contact detection methods. Included in this segment are computer vision, heat detectors, laser scanners, and other type of sensory inputs. All hardware, software and associated peripherals are included in the value.

6.2 TEST SYSTEMS

6.2.1 TEST-ELECTRONIC SYSTEMS

Computer controlled equipment that inspects and tests assembled electronic and/or electrical equipment. Analytical and diagnostic capabilities are included, as well as all directly associated output documentation peripherals.

6.2.2 TEST-MECHANICAL SYSTEMS

Computer controlled equipment that inspects and tests assembled mechanical systems, such as engines, compressors, carburetors, hydraulic drives, etc. Analytical, diagnostic, and reporting capabilities are included in the market value estimates.

7.0 PRODUCTION CONTROL SYSTEMS

7.1 PRODUCTION AND CONTROL COMPUTERS

This segment includes the computers and peripherals dedicated to production planning and the CIM portion of business systems, as well as the aggregated portions of MIS computers used for these CIM functions.

7.1.1 through 7.1.4 CAM COMPUTERS BY PRICE

CAM computers and peripherals sales by price group representing the approximate 1987 price brackets for micros, minis, superminis, and mainframes. With computer prices decreasing annually some product group average prices will overlap 1987 brackets in later years of the forecast.

7.2 MANUFACTURING AND CONTROL SOFTWARE

This segment includes application software for planning, control, and support of production operations. Included are software for planning and controlling product demand, plant capacity, material resources, production release, inventory management, quality analysis and control, and production support operations, including maintenance, procurement, physical distribution, and customer order servicing. This segment does not include CPU hardware or software that are bundled into a turnkey system.

7.2.1 MRP II SYSTEMS

This segment includes the value of software for all the following MRP II system modules combined. The modules are defined here.

MRP This module includes the value of software for scheduling production operations, final assembly scheduling, and planning for line balancing alternatives, using simulation and product mix evaluation procedures. Also included are the value of software for planning of inventory for materials used in production, including raw materials, work-in-process, tooling, jigs, fixtures, and purchased materials.

RESOURCE REQUIREMENTS PLANNING This module includes the value of software used to determine the needs for resources to meet product delivery schedules. Included is software that is used to perform simulation analyses for various demand schedules and alternatives for meeting them so that optimum utilization, or rapid response to changes can be formulated.

PROCUREMENT This module includes the value of software used for vendor management. Included are modules for determining current costs, lead times, vendor availabilities, and performance histories for delivery of supplies, piece parts, stock, raw materials, and equipment. Also included is the order backlog, delivery schedules and prioritized lists of quotes.

CAPACITY REQUIREMENTS PLANNING This module includes the value of software used for balancing the resources available (human, equipment, processes) with the requirements necessary for meeting the planned product delivery schedules. Included is software that models the shop floor and identifies critical or bottleneck resources, and then uses sets of rules to schedule these so that optimum factory throughput can be obtained.

SHOP FLOOR CONTROL This module includes software for release of orders to the factory, and for tracking the progress of the orders according to feedback of results obtained from factory floor data collection systems. Included is software that tracks the actual hours required by operation, but also labour and scrap rates.

7.2.2 EXPERT SYSTEMS/FACTORY SIMULATION

Software and systems that are knowledge-based programs and/or object-oriented programs which capture factory experience and are used for decision support such as diagnostics and operational advice. This segment also includes software used for defining manufacturing models, analysis of operations, and optimization studies.

7.2.3 FACTORY DATA COLLECTION SYSTEMS

Systems consisting of terminals, communications hardware and software for batch and factory floor data collection. Distinguished from production monitoring systems in that human input is required, and the terminals have display capabilities. Systems that are used to report production operations and assist in analysis and decision making are included.

7.2.4 PRODUCTION MONITORING SYSTEMS

Systems that directly gather data from the factory floor without human intervention. Systems include capabilities to report equipment utilization, downtime, production capacities, data logging, etc. Increasingly being used with programmable controllers to communicate status, actions, and alarm conditions in a real-time mode.

# PURCHASES OF ADVANCED MANUFACTURING TECHNOLOGY PRODUCT & SERVICES WORLDWIDE 1985-2000

## 1.0 DESIGN AUTOMATION

### WORLDWIDE PURCHASES OF DESIGN AUTOMATION SYSTEMS 1985-2000

| | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|
| Turnkey CAD/CAM Systems | $2,466 | $4,884 | $6,886 | $7,496 |
| Turnkey CAE Systems | 369 | 846 | 1,787 | 3,029 |
| Engineering Computers | 633 | 1,777 | 3,989 | 7,017 |
| Graphics Terminals & Workstations | 652 | 4,763 | 6,837 | 15,352 |
| Engineering Software | 224 | 800 | 1,873 | 3,512 |
| TOTAL | $4,343 | $13,069 | $21,372 | $36,406 |

### WORLDWIDE PURCHASES OF TURNKEY CAD/CAM SYSTEMS 1985-2000

| | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|
| Multiterminal CAD/CAM Systems | $2,210 | $1,595 | $595 | $639 |
| Standalone Workstation Systems | 256 | 3,289 | 6,290 | 6,857 |
| TOTAL | $2,466 | $4,884 | $6,886 | $7,496 |

## WORLDWIDE PURCHASES OF TURNKEY CAE SYSTEMS 1985-2000

| | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|
| High End CAE Systems | $285 | $635 | $1,337 | $2,222 |
| PC Based CAE Systems | 83 | 211 | 450 | 806 |
| TOTAL | $369 | $846 | $1,787 | $3,029 |

## WORLDWIDE PURCHASES OF ENGINEERING COMPUTERS 1985-2000

| | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|
| Engineering Computers <US $15K | $140 | $663 | $1,568 | $3,395 |
| Engineering Computers US $15K-150K | 260 | 563 | 1,132 | 1,478 |
| Engineering Computers US $150K-1.75MM | 114 | 271 | 512 | 695 |
| Engineering Computers >US $1.75MM | 119 | 281 | 777 | 1,449 |
| TOTAL | $633 | $1,777 | $3,989 | $7,017 |

## WORLDWIDE PURCHASES OF GRAPHICS TERMINALS AND WORKSTATIONS 1985-2000

| | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|
| Graphics Terminals | $391 | $324 | $143 | $226 |
| Graphics Workstations | 261 | 4,439 | 6,695 | 15,126 |
| TOTAL | $652 | $4,763 | $6,837 | $15,352 |

## WORLDWIDE PURCHASES OF ENGINEERING SOFTWARE 1985-2000

| | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|
| Mechanical Design | $124 | $530 | $1,275 | $2,436 |
| PC/IC Layout | 94 | 220 | 450 | 704 |
| Group Technology/Process Planning | 6 | 10 | 14 | 28 |
| Product/Program Data Management | - | 40 | 134 | 344 |
| TOTAL | $224 | $800 | $1,873 | $3,512 |

# 2.0 ADVANCED CUTTING & FORMING EQUIPMENT

WORLDWIDE PURCHASES OF
ADVANCED CUTTING & FORMING EQUIPMENT
1985-2000

| | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|
| Flexible Machining Cells and Systems | $133 | $420 | $997 | $2,757 |
| Machine Controls | 917 | 1,440 | 2,315 | 3,679 |
| Other Classes of Production Machinery | 234 | 498 | 830 | 1,529 |
| TOTAL | $1,284 | $2,358 | $4,412 | $7,963 |

WORLDWIDE PURCHASES OF
FLEXIBLE MACHINING CELLS AND SYSTEMS
1985-2000

| | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|
| Cells (FMCs) | $69 | $286 | $798 | $2,409 |
| Systems (FMSs) | 64 | 134 | 198 | 348 |
| TOTAL | $133 | $420 | $997 | $2,757 |

## WORLDWIDE PURCHASES OF MACHINE CONTROLS
1985-2000

| | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|
| CNC Controls | $771 | $1,198 | $1,924 | $3,041 |
| DNC Controls | 147 | 242 | 391 | 638 |
| TOTAL | $917 | $1,440 | $2,315 | $3,679 |

## WORLDWIDE PURCHASES OF OTHER CLASSES OF PRODUCTION MACHINERY
1985-2000

| | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|
| Semiconductor Processing Machinery | $234 | $498 | $830 | $1,529 |

## 3.0 AUTOMATED MATERIALS AND PARTS HANDLING

### WORLDWIDE PURCHASES OF AUTOMATED MATERIALS AND PARTS HANDLING 1985-2000

| | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|
| Robotic Material Handling | $114 | $160 | $353 | $825 |
| Automated Guided Vehicle Systems | 184 | 303 | 565 | 1,112 |
| Automated Storage/Retrieval & Warehousing Systems | 1,129 | 1,874 | 3,282 | 6,130 |
| TOTAL | $1,427 | $2,336 | $4,200 | $8,067 |

## 4.0 AUTOMATED ASSEMBLY AND PACKAGING MACHINES

### WORLDWIDE PURCHASES OF AUTOMATED ASSEMBLY AND PACKAGING MACHINES 1985-2000

| | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|
| Automated Mechanical Assembly Systems | $127 | $214 | $403 | $995 |
| Robotic Assembly and Finishing | 678 | 1,553 | 2,890 | 6,805 |
| Automated Electronic Assembly Systems | 800 | 2,135 | 3,671 | 7,729 |
| Automated Packaging Systems | 207 | 504 | 932 | 2,239 |
| TOTAL | $1,812 | $4,406 | $7,895 | $17,767 |

## 5.0 FACTORY FLOOR COMPUTERS & COMMUNICATIONS LINKS

### WORLDWIDE PURCHASES OF FACTORY FLOOR COMPUTERS & COMMUNICATIONS LINKS 1985-2000

| | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|
| Factory Floor Computers | $1,048 | $2,003 | $3,560 | $6,515 |
| Factory Floor Software | 1,140 | 2,248 | 4,472 | 9,552 |
| Programmable Logic Controllers | 535 | 962 | 1,618 | 2,714 |
| Local Area Networks | 53 | 750 | 1,934 | 4,359 |
| Installation, Integration & Other Services | 3,000 | 7,197 | 12,775 | 24,031 |
| TOTAL | $5,775 | $13,161 | $24,360 | $47,171 |

### WORLDWIDE PURCHASES OF FACTORY FLOOR COMPUTERS 1985-2000

| | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|
| Cell Control Computers | $320 | $712 | $1,421 | $2,906 |
| Area/Supervisory Control Computers | 63 | 126 | 253 | 502 |
| Other Factory Computers | 131 | 303 | 858 | 1,811 |
| Components(Other Control Equipment) | 534 | 862 | 1,029 | 1,296 |
| TOTAL | $1,048 | $2,003 | $3,560 | $6,515 |

## WORLDWIDE PURCHASES OF FACTORY FLOOR SOFTWARE 1985-2000

| | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|
| NC Software and Programming Systems | $195 | $325 | $509 | $909 |
| Quality Analysis | 30 | 143 | 537 | 1,229 |
| Customer Order Servicing | 385 | 622 | 961 | 1,478 |
| Shop Floor Software | 40 | 233 | 1,130 | 3,926 |
| Physical Distribution | 463 | 797 | 1,042 | 1,368 |
| Maintenance Management | 27 | 128 | 293 | 642 |
| TOTAL | $1,140 | $2,248 | $4,472 | $9,552 |

## WORLDWIDE PURCHASES OF PROGRAMMABLE LOGIC CONTROLLERS 1985-2000

| | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|
| Programmable Logic Controllers | $535 | $962 | $1,618 | $2,714 |

## WORLDWIDE PURCHASES OF LOCAL AREA NETWORKS 1985-2000

| | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|
| Local Area Networks | $53 | $750 | $1,934 | $4,359 |

## WORLDWIDE PURCHASES OF INSTALLATION, INTEGRATION AND OTHER SERVICES 1985-2000

| | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|
| Systems Installation | $339 | $894 | $1,762 | $3,370 |
| System Integrations | 480 | 1,458 | 3,056 | 6,693 |
| CIM Systems Maintenance | 960 | 1,394 | 2,094 | 2,968 |
| Computer Maintenance | 575 | 1,982 | 3,467 | 6,406 |
| CAD/CAM Maintenance | 600 | 1,325 | 1,977 | 3,251 |
| System Training & Other Services | 46 | 145 | 420 | 1,343 |
| TOTAL | $3,000 | $7,197 | $12,775 | $24,031 |

# 6.0 ADVANCED TEST AND INSPECTION SYSTEMS

WORLDWIDE PURCHASES OF
ADVANCED TEST AND INSPECTION SYSTEMS
1985-2000

| | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|
| Inspection Systems | $3,293 | $6,583 | $12,413 | $23,170 |
| Test Systems | 464 | 945 | 1,693 | 3,515 |
| TOTAL | $3,757 | $7,528 | $14,106 | $26,685 |

WORLDWIDE PURCHASES OF
INSPECTION SYSTEMS
1985-2000

| | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|
| Inspection-Electronic Device | $1,780 | $2,718 | $4,854 | $9,773 |
| Inspection-Printed Circuit Boards | 1,335 | 3,337 | 6,281 | 10,824 |
| Inspection-Mechanical Parts | 178 | 528 | 1,279 | 2,573 |
| TOTAL | $3,293 | $6,583 | $12,413 | $23,170 |

WORLDWIDE PURCHASES OF
TEST SYSTEMS
1985-2000

| | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|
| Test-Electronic Systems | $384 | $739 | $1,215 | $2,481 |
| Test-Mechanical Systems | 80 | 206 | 477 | 1,033 |
| TOTAL | $464 | $945 | $1,693 | $3,515 |

# 7.0 PRODUCTION MANAGEMENT AND CONTROL COMPUTERS & SOFTWARE

WORLDWIDE PURCHASES OF
PRODUCTION MANAGEMENT AND CONTROL
COMPUTERS & SOFTWARE
1985-2000

| | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|
| Production Management and Control Computers | $1,425 | $1,956 | $3,614 | $7,943 |
| Production Management and Control Software | 1,107 | 2,947 | 8,053 | 18,359 |
| TOTAL | $2,531 | $4,903 | $11,667 | $26,303 |

## WORLDWIDE PURCHASES OF PRODUCTION MANAGEMENT AND CONTROL COMPUTERS 1985-2000

| | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|
| Price Range <$15K | $8 | $32 | $93 | $373 |
| Price Range $15K-150K | 225 | 261 | 510 | 1,231 |
| Price Range $150K-1.75M | 676 | 877 | 1,623 | 3,472 |
| Price Range >$1.75M | 516 | 786 | 1,388 | 2,868 |
| TOTAL | $1,425 | $1,956 | $3,614 | $7,943 |

## WORLDWIDE PURCHASES OF PRODUCTION MANAGEMENT AND CONTROL SOFTWARE 1985-2000

| | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|
| MRP II Systems | $583 | $1,370 | $3,004 | $6,042 |
| Expert Systems/Factory Simulation | 14 | 216 | 1,452 | 3,835 |
| Factory Data Collection Systems | 345 | 1,039 | 3,014 | 7,553 |
| Production Monitoring Systems | 165 | 322 | 584 | 929 |
| TOTAL | $1,107 | $2,947 | $8,053 | $18,359 |

## WORLDWIDE PURCHASES OF AMT PRODUCTS & SERVICES BY END USER INDUSTRY 1985-2000

## 1.0 DESIGN AUTOMATION

**PURCHASES OF DESIGN AUTOMATION SYSTEMS BY THE AEROSPACE INDUSTRY 1985-2000**

| AEROSPACE | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Turnkey CAD/CAM Systems | $200 | $352 | 12.0% | $470 | 6.0% | $476 | 0.2% |
| Turnkey CAE Systems | 30 | 65 | 16.3% | 121 | 13.3% | 193 | 9.8% |
| Engineering Computers | 16 | 66 | 33.4% | 157 | 19.0% | 313 | 14.8% |
| Graphics Terminals & Workstations | 53 | 270 | 38.5% | 492 | 12.8% | 1,015 | 15.6% |
| Engineering Software | 23 | 76 | 27.0% | 150 | 14.6% | 225 | 8.5% |
| TOTAL | $322 | $828 | 20.8% | $1,391 | 10.9% | $2,222 | 9.8% |

**PURCHASES OF DESIGN AUTOMATION SYSTEMS BY THE TRANSPORTATION INDUSTRY 1985-2000**

| TRANSPORTATION | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Turnkey CAD/CAM Systems | $824 | $1,403 | 11.2% | $2,235 | 9.8% | $2,420 | 1.6% |
| Turnkey CAE Systems | 129 | 304 | 18.7% | 626 | 15.5% | 1,000 | 9.8% |
| Engineering Computers | 55 | 221 | 31.9% | 611 | 22.6% | 1,284 | 16.0% |
| Graphics Terminals & Workstations | 244 | 1,653 | 46.6% | 2,175 | 5.6% | 4,277 | 14.5% |
| Engineering Software | 94 | 290 | 25.3% | 671 | 18.2% | 1,144 | 11.3% |
| TOTAL | $1,346 | $3,871 | 23.5% | $6,317 | 10.3% | $10,124 | 9.9% |

PURCHASES OF DESIGN AUTOMATION SYSTEMS
BY THE ELECTRONICS INDUSTRY
1985-2000

| ELECTRONICS | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Turnkey CAD/CAM Systems | $444 | $990 | 17.4% | $1,197 | 3.9% | $1,263 | 1.1% |
| Turnkey CAE Systems | 135 | 273 | 15.1% | 608 | 17.4% | 1,063 | 11.8% |
| Engineering Computers | 38 | 193 | 38.4% | 346 | 12.4% | 699 | 15.1% |
| Graphics Terminals & Workstations | 100 | 985 | 58.0% | 1,807 | 12.9% | 4,992 | 22.5% |
| Engineering Software | 51 | 201 | 31.6% | 542 | 21.9% | 1,135 | 15.9% |
| TOTAL | $769 | $2,643 | 28.0% | $4,500 | 11.2% | $9,153 | 15.3% |

PURCHASES OF DESIGN AUTOMATION SYSTEMS
BY THE ELECTRICAL INDUSTRY
1985-2000

| ELECTRICAL | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Turnkey CAD/CAM Systems | $269 | $575 | 16.4% | $703 | 4.1% | $729 | 0.7% |
| Turnkey CAE Systems | 41 | 104 | 20.6% | 204 | 14.3% | 374 | 12.9% |
| Engineering Computers | 18 | 98 | 40.8% | 224 | 17.9% | 528 | 18.7% |
| Graphics Terminals & Workstations | 57 | 404 | 47.9% | 579 | 7.5% | 1,204 | 15.8% |
| Engineering Software | 30 | 115 | 31.1% | 243 | 16.1% | 438 | 12.5% |
| TOTAL | $414 | $1,297 | 25.6% | $1,954 | 8.5% | $3,272 | 10.9% |

PURCHASES OF DESIGN AUTOMATION SYSTEMS
BY THE MACHINERY INDUSTRY
1985-2000

| MACHINERY | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Turnkey CAD/CAM Systems | $179 | $396 | 17.2% | $523 | 5.7% | $584 | 2.2% |
| Turnkey CAE Systems | 28 | 84 | 24.5% | 159 | 13.6% | 292 | 12.9% |
| Engineering Computers | 13 | 70 | 40.8% | 172 | 19.8% | 316 | 13.0% |
| Graphics Terminals & Workstations | 53 | 359 | 46.6% | 358 | -0.1% | 619 | 11.6% |
| Engineering Software | 20 | 79 | 31.0% | 155 | 14.5% | 275 | 12.1% |
| TOTAL | $294 | $988 | 27.5% | $1,367 | 6.7% | $2,086 | 8.8% |

PURCHASES OF DESIGN AUTOMATION SYSTEMS
BY OTHER MANUFACTURING INDUSTRIES
1985-2000

| OTHER MANUFACTURING | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Turnkey CAD/CAM Systems | $73 | $213 | 23.9% | $275 | 5.3% | $361 | 5.6% |
| Turnkey CAE Systems | 11 | 39 | 28.3% | 79 | 15.2% | 170 | 16.6% |
| Engineering Computers | 4 | 30 | 47.6% | 71 | 18.8% | 207 | 23.9% |
| Graphics Terminals & Workstations | 17 | 135 | 51.3% | 204 | 8.6% | 469 | 18.1% |
| Engineering Software | 8 | 43 | 39.4% | 94 | 17.0% | 208 | 17.3% |
| TOTAL | $114 | $461 | 32.2% | $722 | 9.4% | $1,415 | 14.4% |

## 2.0 ADVANCED CUTTING AND FORMING EQUIPMENT

### PURCHASES OF ADVANCED CUTTING & FORMING EQUIPMENT BY THE AEROSPACE INDUSTRY 1985-2000

| AEROSPACE | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Flexible Machining Cells and Systems | $27 | $74 | 22.7% | $184 | 20.0% | $487 | 21.5% |
| Machine Controls - CNC & DNC | 184 | 253 | 6.7% | 428 | 11.1% | 650 | 8.7% |
| Semiconductor Processing | - | - | - | - | - | - | - |
| TOTAL | $210 | $327 | 9.3% | $612 | 13.3% | $1,138 | 13.2% |

### PURCHASES OF ADVANCED CUTTING & FORMING EQUIPMENT BY THE TRANSPORTATION INDUSTRY 1985-2000

| TRANSPORTATION | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Flexible Machining Cells and Systems | $47 | $139 | 24.4% | $349 | 20.3% | $957 | 22.4% |
| Machine Controls - CNC & DNC | 321 | 475 | 8.1% | 799 | 10.9% | 1,249 | 9.4% |
| Semiconductor Processing | - | - | - | - | - | - | - |
| TOTAL | $368 | $614 | 10.8% | $1,147 | 13.3% | $2,206 | 14.0% |

## PURCHASES OF ADVANCED CUTTING & FORMING EQUIPMENT BY THE ELECTRONICS INDUSTRY 1985-2000

| ELECTRONICS | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Flexible Machining Cells and Systems | $5 | $23 | 34.1% | $60 | 20.9% | $202 | 27.6% |
| Machine Controls - CNC & DNC | 37 | 79 | 16.6% | 150 | 13.7% | 303 | 15.0% |
| Semiconductor Processing | 234 | 498 | 16.3% | 830 | 10.8% | 1,529 | 13.0% |
| TOTAL | $276 | $600 | 16.8% | $1,040 | 11.6% | $2,033 | 14.3% |

## PURCHASES OF ADVANCED CUTTING & FORMING EQUIPMENT BY THE ELECTRICAL INDUSTRY 1985-2000

| ELECTRICAL | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Flexible Machining Cells and Systems | $1 | $6 | 37.2% | $15 | 18.3% | $51 | 28.0% |
| Machine Controls - CNC & DNC | 9 | 22 | 19.3% | 35 | 9.4% | 66 | 13.6% |
| Semiconductor Processing | - | - | - | - | - | - | - |
| TOTAL | $11 | $29 | 22.2% | $50 | 11.7% | $117 | 18.7% |

## PURCHASES OF ADVANCED CUTTING & FORMING EQUIPMENT BY THE MACHINERY INDUSTRY 1985-2000

| MACHINERY | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Flexible Machining Cells and Systems | $17 | $57 | 26.8% | $149 | 21.4% | $440 | 24.1% |
| Machine Controls - CNC & DNC | 119 | 194 | 10.3% | 347 | 12.3% | 587 | 11.1% |
| Semiconductor Processing | - | - | - | - | - | - | - |
| TOTAL | $137 | $251 | 12.9% | $497 | 14.6% | $1,027 | 15.6% |

## PURCHASES OF ADVANCED CUTTING & FORMING EQUIPMENT BY OTHER MANUFACTURING INDUSTRIES 1985-2000

| OTHER MANUFACTURING | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Flexible Machining Cells and Systems | $36 | $121 | 27.6% | $239 | 14.5% | $623 | 21.1% |
| Machine Controls - CNC & DNC | 248 | 416 | 10.9% | 555 | 5.9% | 830 | 8.4% |
| Semiconductor Processing | - | - | - | - | - | - | - |
| TOTAL | $284 | $538 | 13.6% | $795 | 8.1% | $1,453 | 12.8% |

# 3.0 AUTOMATED MATERIALS AND PARTS HANDLING

### PURCHASES OF AUTOMATED MATERIALS AND PARTS HANDLING BY THE AEROSPACE INDUSTRY 1985-2000

| AEROSPACE | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Automated Materials and Parts Handling | $285 | $411 | 7.6% | $777 | 13.6% | $1,431 | 13.0% |

### PURCHASES OF AUTOMATED MATERIALS AND PARTS HANDLING BY THE TRANSPORTATION INDUSTRY 1985-2000

| TRANSPORTATION | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Automated Materials and Parts Handling | $499 | $771 | 9.1% | $1,470 | 13.8% | $2,809 | 13.8% |

### PURCHASES OF AUTOMATED MATERIALS AND PARTS HANDLING BY THE ELECTRONICS INDUSTRY 1985-2000

| ELECTRONICS | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Automated Materials and Parts Handling | $563 | $1,363 | 19.3% | $2,355 | 11.6% | $4,718 | 14.9% |

## PURCHASES OF AUTOMATED MATERIALS AND PARTS HANDLING BY THE ELECTRICAL INDUSTRY 1985-2000

| ELECTRICAL | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Automated Materials and Parts Handling | $14 | $36 | 20.3% | $63 | 11.9% | $151 | 19.1% |

## PURCHASES OF AUTOMATED MATERIALS AND PARTS HANDLING BY THE MACHINERY INDUSTRY 1985-2000

| MACHINERY | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Automated Materials and Parts Handling | $186 | $315 | 11.2% | $630 | 14.8% | $1,292 | 15.4% |

## PURCHASES OF AUTOMATED MATERIALS AND PARTS HANDLING BY THE OTHER MANUFACTURING INDUSTRIES 1985-2000

| OTHER MANUFACTURING | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Automated Materials and Parts Handling | $385 | $675 | 11.9% | $1,008 | 8.3% | $1,827 | 12.6% |

## 4.0 AUTOMATED ASSEMBLY AND PACKAGING MACHINES

### PURCHASES OF AUTOMATED ASSEMBLY AND PACKAGING MACHINES BY THE AEROSPACE INDUSTRY 1985-2000

| AEROSPACE | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Automated Mechanical Assembly Systems | $25 | $43 | 11.0% | $85 | 14.6% | $236 | 22.7% |
| Robotic Assembly and Finishing | 81 | 233 | 23.4% | 491 | 16.1% | 1,351 | 22.4% |
| Automated Electronic Assembly Systems | 120 | 320 | 21.7% | 551 | 11.4% | 1,171 | 16.3% |
| Automated Packaging Systems | - | - | - | - | - | - | - |
| TOTAL | $227 | $596 | 21.3% | $1,126 | 13.6% | $2,757 | 19.6% |

### PURCHASES OF AUTOMATED ASSEMBLY AND PACKAGING MACHINES BY THE TRANSPORTATION INDUSTRY 1985-2000

| TRANSPORTATION | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Automated Mechanical Assembly Systems | $51 | $96 | 13.6% | $174 | 12.6% | $506 | 23.8% |
| Robotic Assembly and Finishing | 325 | 854 | 21.3% | 1,504 | 12.0% | 4,475 | 24.4% |
| Automated Electronic Assembly Systems | 16 | 214 | 67.9% | 540 | 20.4% | 1,298 | 19.2% |
| Automated Packaging Systems | 6 | 19 | 25.6% | 32 | 11.3% | 85 | 21.6% |
| TOTAL | $398 | $1,183 | 24.3% | $2,249 | 13.7% | $6,365 | 23.1% |

PURCHASES OF AUTOMATED ASSEMBLY AND PACKAGING MACHINES
BY THE ELECTRONICS INDUSTRY
1985-2000

| ELECTRONICS | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Automated Mechanical Assembly Systems | $3 | $4 | 11.0% | $8 | 13.5% | $10 | 4.7% |
| Robotic Assembly and Finishing | 41 | 78 | 13.8% | 144 | 13.2% | 205 | 7.3% |
| Automated Electronic Assembly Systems | 520 | 1,281 | 19.8% | 2,203 | 11.4% | 4,503 | 15.4% |
| Automated Packaging Systems | - | - | - | - | - | - | - |
| TOTAL | $563 | $1,363 | 19.3% | $2,355 | 11.6% | $4,718 | 14.9% |

PURCHASES OF AUTOMATED ASSEMBLY AND PACKAGING MACHINES
BY THE ELECTRICAL INDUSTRY
1985-2000

| ELECTRICAL | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Automated Mechanical Assembly Systems | $1 | $2 | 11.0% | $4 | 13.7% | $10 | 19.1% |
| Robotic Assembly and Finishing | 7 | 16 | 18.0% | 29 | 13.4% | 68 | 18.4% |
| Automated Electronic Assembly Systems | - | - | - | - | - | - | - |
| Automated Packaging Systems | - | - | - | - | - | - | - |
| TOTAL | $8 | $18 | 17.0% | $33 | 13.5% | $78 | 18.5% |

PURCHASES OF AUTOMATED ASSEMBLY AND PACKAGING MACHINES
BY THE MACHINERY INDUSTRY
1985-2000

| MACHINERY | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Automated Mechanical Assembly Systems | $6 | $21 | 27.5% | $45 | 16.0% | $129 | 23.5% |
| Robotic Assembly and Finishing | 20 | $62 | 25.0% | 148 | 19.0% | 476 | 26.3% |
| Automated Electronic Assembly Systems | - | - | - | - | - | - | |
| Automated Packaging Systems | - | - | - | - | - | - | |
| TOTAL | $27 | $84 | 25.6% | $192 | 18.1% | $606 | 25.9% |

PURCHASES OF AUTOMATED ASSEMBLY AND PACKAGING MACHINES
BY THE OTHER MANUFACTURING INDUSTRIES
1985-2000

| OTHER MANUFACTURING | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Automated Mechanical Assembly Systems | $41 | $47 | 3.0% | $81 | 11.4% | $176 | 16.8% |
| Robotic Assembly and Finishing | 203 | 311 | 8.8% | 318 | 0.5% | 667 | 16.0% |
| Automated Electronic Assembly Systems | 144 | 320 | 17.3% | 367 | 2.8% | 703 | 13.9% |
| Automated Packaging Systems | 24 | 56 | 18.6% | 112 | 14.7% | 274 | 19.6% |
| TOTAL | $412 | $734 | 12.2% | $878 | 3.6% | $1,819 | 15.7% |

# 5.0 FACTORY FLOOR COMPUTERS & COMMUNICATIONS LINKS

PURCHASES OF FACTORY FLOOR COMPUTERS & COMMUNICATIONS LINKS
BY THE AEROSPACE INDUSTRY
1985-2000

| AEROSPACE | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Factory Floor Computers | $94 | $177 | 13.5% | $377 | 16.3% | $752 | 14.8% |
| Factory Floor Software | 229 | 386 | 11.0% | 779 | 15.1% | 1,514 | 14.2% |
| Programmable Logic Controllers | 3 | 3 | 2.5% | 6 | 13.7% | 9 | 7.1% |
| Local Area Networks | 11 | 132 | 65.9% | 358 | 22.1% | 758 | 16.2% |
| Installation, Integration & Other Services | 432 | 950 | 17.1% | 1,767 | 13.2% | 3,184 | 12.5% |
| TOTAL | $769 | $1,648 | 16.5% | $3,287 | 14.8% | $6,217 | 13.6% |

PURCHASES OF FACTORY FLOOR COMPUTERS & COMMUNICATIONS LINKS
BY THE TRANSPORTATION INDUSTRY
1985-2000

| TRANSPORTATION | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Factory Floor Computers | $165 | $332 | 15.0% | $815 | 19.7% | $1,815 | 17.4% |
| Factory Floor Software | 400 | 723 | 12.6% | 1,684 | 18.4% | 3,653 | 16.8% |
| Programmable Logic Controllers | 87 | 71 | -4.0% | 142 | 15.0% | 197 | 6.7% |
| Local Area Networks | 18 | 248 | 68.2% | 773 | 25.6% | 1,828 | 18.8% |
| Installation, Integration & Other Services | 756 | 1,781 | 18.7% | 3,821 | 16.5% | 7,676 | 15.0% |
| TOTAL | $1,426 | $3,154 | 17.2% | $7,236 | 18.1% | $15,170 | 16.0% |

PURCHASES OF FACTORY FLOOR COMPUTERS & COMMUNICATIONS LINKS
BY THE ELECTRONICS INDUSTRY
1985-2000

| ELECTRONICS | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Factory Floor Computers | $19 | $55 | 24.0% | $122 | 17.2% | $311 | 20.5% |
| Factory Floor Software | 46 | 120 | 21.4% | 253 | 16.0% | 628 | 20.0% |
| Programmable Logic Controllers | 35 | 34 | -0.6% | 71 | 16.2% | 107 | 8.5% |
| Local Area Networks | 2 | 41 | 81.4% | 116 | 23.0% | 314 | 22.0% |
| Installation, Integration & Other Services | 86 | 297 | 28.0% | 573 | 14.1% | 1,325 | 18.2% |
| TOTAL | $188 | $548 | 23.9% | $1,135 | 15.7% | $2,684 | 18.8% |

PURCHASES OF FACTORY FLOOR COMPUTERS & COMMUNICATIONS LINKS
BY THE ELECTRICAL INDUSTRY
1985-2000

| ELECTRICAL | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Factory Floor Computers | $5 | $15 | 26.9% | $36 | 18.1% | $98 | 22.5% |
| Factory Floor Software | 11 | 34 | 24.1% | 68 | 15.2% | 179 | 21.2% |
| Programmable Logic Controllers | 49 | 54 | 2.0% | 97 | 12.5% | 137 | 7.2% |
| Local Area Networks | 1 | 12 | 85.5% | 29 | 20.2% | 80 | 22.5% |
| Installation, Integration & Other Services | 22 | 83 | 30.9% | 143 | 11.5% | 338 | 18.7% |
| TOTAL | $87 | $198 | 17.8% | $373 | 13.6% | $833 | 17.4% |

## PURCHASES OF FACTORY FLOOR COMPUTERS & COMMUNICATIONS LINKS BY THE MACHINERY INDUSTRY 1985-2000

| MACHINERY | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Factory Floor Computers | $61 | $136 | 17.3% | $305 | 17.6% | $678 | 17.3% |
| Factory Floor Software | 149 | 296 | 14.8% | 632 | 16.4% | 1,367 | 16.7% |
| Programmable Logic Controllers | 122 | 121 | -0.1% | 220 | 12.7% | 301 | 6.5% |
| Local Area Networks | 7 | 101 | 71.5% | 290 | 23.4% | 684 | 18.7% |
| Installation, Integration & Other Services | 281 | 729 | 21.0% | 1,433 | 14.5% | 2,877 | 15.0% |
| TOTAL | $619 | $1,383 | 17.4% | $2,880 | 15.8% | $5,907 | 15.5% |

## PURCHASES OF FACTORY FLOOR COMPUTERS & COMMUNICATIONS LINKS BY OTHER MANUFACTURING INDUSTRIES 1985-2000

| OTHER MANUFACTURING | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Factory Floor Computers | $127 | $291 | 18.0% | $427 | 8.0% | $791 | 13.1% |
| Factory Floor Software | 309 | 633 | 15.5% | 939 | 8.2% | 1,743 | 13.2% |
| Programmable Logic Controllers | 52 | 54 | 0.6% | 110 | 15.3% | 165 | 8.4% |
| Local Area Networks | 14 | 217 | 72.5% | 367 | 11.1% | 696 | 13.6% |
| Installation, Integration & Other Services | 583 | 1,560 | 21.7% | 1,815 | 3.1% | 2,947 | 10.2% |
| TOTAL | $1,085 | $2,754 | 20.5% | $3,659 | 5.8% | $6,342 | 11.6% |

Purchases by End-User Industry (Continued)

# 6.0 ADVANCED TEST AND INSPECTION SYSTEMS

## PURCHASES OF ADVANCED TEST AND INSPECTION SYSTEMS BY THE AEROSPACE INDUSTRY 1985-2000

| AEROSPACE | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Inspection Systems | $344 | $635 | 13.0% | $1,064 | 10.9% | $1,778 | 10.8% |
| Test Systems | 54 | 102 | 13.6% | 177 | 11.6% | 344 | 14.2% |
| TOTAL | $398 | $737 | 13.1% | $1,241 | 11.0% | $2,122 | 11.3% |

## PURCHASES OF ADVANCED TEST AND INSPECTION SYSTEMS BY THE TRANSPORTATION INDUSTRY 1985-2000

| TRANSPORTATION | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Inspection Systems | $751 | $1,694 | 17.7% | $3,162 | 13.3% | $6,175 | 14.3% |
| Test Systems | 113 | 253 | 17.6% | 478 | 13.5% | 1,056 | 17.2% |
| TOTAL | $864 | $1,948 | 17.7% | $3,640 | 13.3% | $7,231 | 14.7% |

## PURCHASES OF ADVANCED TEST AND INSPECTION SYSTEMS BY THE ELECTRONICS INDUSTRY 1985-2000

| ELECTRONICS | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Inspection Systems | $1,315 | $2,227 | 11.1% | $4,855 | 16.9% | $8,964 | 13.0% |
| Test Systems | 164 | 280 | 11.2% | 556 | 14.7% | 1,109 | 14.8% |
| TOTAL | $1,480 | $2,507 | 11.1% | $5,410 | 16.6% | $10,073 | 13.2% |

## PURCHASES OF ADVANCED TEST AND INSPECTION SYSTEMS BY THE ELECTRICAL INDUSTRY 1985-2000

| ELECTRICAL | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Inspection Systems | $416 | $881 | 16.2% | $1,456 | 10.6% | $2,600 | 12.3% |
| Test Systems | 52 | 110 | 16.2% | 166 | 8.6% | 320 | 14.1% |
| TOTAL | $468 | $991 | 16.2% | $1,622 | 10.4% | $2,920 | 12.5% |

## PURCHASES OF ADVANCED TEST AND INSPECTION SYSTEMS BY THE MACHINERY INDUSTRY 1985-2000

| MACHINERY | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Inspection Systems | $308 | $670 | 16.8% | $1,112 | 10.7% | $2,017 | 12.7% |
| Test Systems | 45 | $101 | 17.3% | 171 | 11.1% | 357 | 15.9% |
| TOTAL | $353 | $770 | 16.9% | $1,283 | 10.7% | $2,374 | 13.1% |

## PURCHASES OF ADVANCED TEST AND INSPECTION SYSTEMS BY THE OTHER MANUFACTURING INDUSTRIES 1985-2000

| OTHER MANUFACTURING | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Inspection Systems | $161 | $477 | 24.2% | $768 | 10.0% | $1,653 | 16.6% |
| Test Systems | 36 | 99 | 22.8% | 146 | 8.0% | 328 | 17.6% |
| TOTAL | $197 | $576 | 24.0% | $914 | 9.7% | $1,980 | 16.7% |

## 7.0 PRODUCTION CONTROL SYSTEMS

### PURCHASES OF PRODUCTION MANAGEMENT AND CONTROL COMPUTERS & SOFTWARE BY THE AEROSPACE INDUSTRY 1985-2000

| AEROSPACE | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Production Management & Control Computers | $100 | $123 | 4.3% | $208 | 11.1% | $414 | 14.8% |
| Production Management & Control Software | 111 | 265 | 19.1% | 640 | 19.4% | 1,310 | 15.2% |
| TOTAL | $210 | $388 | 13.0% | $848 | 16.9% | $1,724 | 15.2% |

### PURCHASES OF PRODUCTION MANAGEMENT AND CONTROL COMPUTERS & SOFTWARE BY THE TRANSPORTATION INDUSTRY 1985-2000

| TRANSPORTATION | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Production Management & Control Computers | $110 | $157 | 7.5% | $312 | 14.7% | $726 | 18.4% |
| Production Management & Control Software | 122 | 339 | 22.7% | 960 | 23.3% | 2,294 | 18.9% |
| TOTAL | $231 | $496 | 16.5% | $1,272 | 20.7% | $3,020 | 18.9% |

## PURCHASES OF PRODUCTION MANAGEMENT AND CONTROL COMPUTERS & SOFTWARE BY THE ELECTRONICS INDUSTRY 1985-2000

| ELECTRONICS | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Production Management & Control Computers | $279 | $390 | 6.9% | $781 | 14.9% | $1,798 | 18.2% |
| Production Management & Control Software | 310 | 840 | 22.1% | 2,399 | 23.5% | 5,685 | 18.7% |
| TOTAL | $589 | $1,230 | 15.9% | $3,180 | 20.9% | $7,484 | 18.7% |

## PURCHASES OF PRODUCTION MANAGEMENT AND CONTROL COMPUTERS & SOFTWARE BY THE ELECTRICAL INDUSTRY 1985-2000

| ELECTRICAL | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Production Management & Control Computers | $30 | $41 | 6.5% | $78 | 13.7% | $174 | 17.3% |
| Production Management & Control Software | 33 | 88 | 21.6% | 240 | 22.3% | 549 | 17.8% |
| TOTAL | $63 | $129 | 15.5% | $318 | 19.7% | $723 | 17.8% |

## PURCHASES OF PRODUCTION MANAGEMENT AND CONTROL COMPUTERS & SOFTWARE BY THE MACHINERY INDUSTRY 1985-2000

| MACHINERY | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Production Management & Control Computers | $209 | $301 | 7.5% | $546 | 12.6% | $1,216 | 17.4% |
| Production Management & Control Software | 232 | 648 | 22.8% | 1,680 | 21.1% | 3,848 | 17.9% |
| TOTAL | $442 | $950 | 16.5% | $2,226 | 18.6% | $5,065 | 17.9% |

## PURCHASES OF PRODUCTION MANAGEMENT AND CONTROL COMPUTERS & SOFTWARE BY THE OTHER MANUFACTURING INDUSTRIES 1985-2000

| OTHER MANUFACTURING | 1985 | 1990 | CAGR | 1995 | CAGR | 2000 | CAGR |
|---|---|---|---|---|---|---|---|
| Production Management & Control Computers | $269 | $356 | 5.7% | $677 | 13.7% | $1,478 | 16.9% |
| Production Management & Control Software | 299 | 766 | 20.7% | 2,080 | 22.3% | 4,671 | 17.4% |
| TOTAL | $568 | $1,122 | 14.6% | $2,756 | 19.7% | $6,149 | 17.4% |

# WORLDWIDE PURCHASES OF AMT PRODUCTS & SERVICES BY GEOGRAPHIC REGION 1985-2000

## 1.0 DESIGN AUTOMATION

### PURCHASES OF DESIGN AUTOMATION SYSTEMS BY NORTH AMERICAN END-USERS 1985-2000

| NORTH AMERICA | 1985 Actual | 1990 Estimated | CAGR | 1995 Forecast | CAGR | 2000 Forecast | CAGR |
|---|---|---|---|---|---|---|---|
| Turnkey CAD/CAM Systems | $1,424 | $2,549 | 12.3% | $3,148 | 4.3% | $3,104 | -0.3% |
| Turnkey CAE Systems | 285 | 438 | 9.0% | 873 | 14.8% | 1,189 | 6.4% |
| Engineering Computers | 423 | 923 | 16.9% | 1,900 | 15.5% | 2,898 | 8.8% |
| Graphics Terminals & Workstations | 479 | 3,278 | 46.9% | 4,617 | 7.0% | 8,779 | 13.7% |
| Engineering Software | 170 | 471 | 22.7% | 1,056 | 17.5% | 1,730 | 10.4% |
| TOTAL | $2,780 | $7,659 | 22.4% | $11,594 | 8.6% | $17,699 | 8.8% |

### PURCHASES OF DESIGN AUTOMATION SYSTEMS BY EUROPEAN END-USERS 1985-2000

| EUROPE | 1985 Actual | 1990 Estimated | CAGR | 1995 Forecast | CAGR | 2000 Forecast | CAGR |
|---|---|---|---|---|---|---|---|
| Turnkey CAD/CAM Systems | $732 | $1,661 | 17.8% | $2,599 | 9.4% | $3,161 | 4.0% |
| Turnkey CAE Systems | 54 | 231 | 33.5% | 536 | 18.4% | 1,096 | 15.4% |
| Engineering Computers | 124 | 555 | 34.9% | 1,369 | 19.8% | 3,031 | 17.2% |
| Graphics Terminals & Workstations | 112 | 763 | 46.8% | 1,111 | 7.8% | 2,584 | 18.4% |
| Engineering Software | 44 | 241 | 40.7% | 569 | 18.7% | 1,211 | 16.3% |
| TOTAL | $1,066 | $3,451 | 26.5% | $6,183 | 12.4% | $11,083 | 12.4% |

## PURCHASES OF DESIGN AUTOMATION SYSTEMS BY ASIAN END-USERS 1985-2000

| ASIA | 1985 Actual | 1990 Estimated | CAGR | 1995 Forecast | CAGR | 2000 Forecast | CAGR |
|---|---|---|---|---|---|---|---|
| Turnkey CAD/CAM Systems | $281 | $605 | 16.6% | $1,046 | 11.6% | $1,098 | 1.0% |
| Turnkey CAE Systems | 26 | 161 | 44.2% | 340 | 16.1% | 657 | 14.1% |
| Engineering Computers | 76 | 269 | 28.9% | 641 | 18.9% | 929 | 7.7% |
| Graphics Terminals & Workstations | 55 | 665 | 64.8% | 1,040 | 9.4% | 3,856 | 30.0% |
| Engineering Software | 10 | 80 | 51.3% | 223 | 22.6% | 485 | 16.8% |
| TOTAL | $448 | $1,780 | 31.8% | $3,290 | 13.1% | $7,025 | 16.4% |

## PURCHASES OF DESIGN AUTOMATION SYSTEMS BY END-USERS IN OTHER AREAS OF THE WORLD 1985-2000

| OTHER | 1985 Actual | 1990 Estimated | CAGR | 1995 Forecast | CAGR | 2000 Forecast | CAGR |
|---|---|---|---|---|---|---|---|
| Turnkey CAD/CAM Systems | $23 | $68 | 24.3% | $93 | 6.3% | $134 | 7.6% |
| Turnkey CAE Systems | 4 | 16 | 34.9% | 39 | 18.7% | 87 | 17.5% |
| Engineering Computers | 10 | 29 | 23.3% | 80 | 22.4% | 159 | 14.9% |
| Graphics Terminals & Workstations | 6 | 51 | 50.9% | 69 | 6.6% | 133 | 13.9% |
| Engineering Software | 5 | 14 | 21.5% | 25 | 12.0% | 87 | 28.4% |
| TOTAL | $49 | $178 | 29.7% | $305 | 11.4% | $600 | 14.5% |

## 2.0 ADVANCED CUTTING AND FORMING EQUIPMENT

### PURCHASES OF ADVANCED CUTTING & FORMING EQUIPMENT BY NORTH AMERICAN END-USERS 1985-2000

| NORTH AMERICA | 1985 Actual | 1990 Estimated | CAGR | 1995 Forecast | CAGR | 2000 Forecast | CAGR |
|---|---|---|---|---|---|---|---|
| Flexible Machining Cells & Systems | $53 | $189 | 29.0% | $448 | 18.9% | $1,313 | 24.0% |
| CNC Controls | 370 | 527 | 7.3% | 847 | 9.9% | 1,260 | 8.3% |
| DNC Controls | 85 | 131 | 9.0% | 203 | 9.2% | 308 | 8.7% |
| Semiconductor Manufacturing Equipment | 135 | 186 | 6.7% | 305 | 10.3% | 385 | 4.8% |
| TOTAL | $643 | $1,032 | 9.9% | $1,803 | 11.8% | $3,266 | 12.6% |

### PURCHASES OF ADVANCED CUTTING & FORMING EQUIPMENT BY EUROPEAN END-USERS 1985-2000

| EUROPE | 1985 Actual | 1990 Estimated | CAGR | 1995 Forecast | CAGR | 2000 Forecast | CAGR |
|---|---|---|---|---|---|---|---|
| Flexible Machining Cells & Systems | $47 | $134 | 23.3% | $329 | 19.7% | $837 | 20.5% |
| CNC Controls | 193 | 323 | 10.9% | 539 | 10.7% | 854 | 9.7% |
| DNC Controls | 29 | 56 | 13.7% | 94 | 11.0% | 159 | 11.1% |
| Semiconductor Manufacturing Equipment | 33 | 100 | 24.9% | 183 | 12.9% | 370 | 15.2% |
| TOTAL | $302 | $613 | 15.2% | $1,144 | 13.3% | $2,220 | 14.2% |

## PURCHASES OF ADVANCED CUTTING & FORMING EQUIPMENT BY ASIAN END-USERS 1985-2000

| ASIA | 1985 Actual | 1990 Estimated | CAGR | 1995 Forecast | CAGR | 2000 Forecast | CAGR |
|---|---|---|---|---|---|---|---|
| Flexible Machining Cells & Systems | $33 | $96 | 23.8% | $217 | 17.7% | $600 | 22.5% |
| CNC Controls | 193 | 323 | 10.9% | 500 | 9.1% | 865 | 11.6% |
| DNC Controls | 29 | 51 | 11.7% | 86 | 11.1% | 157 | 12.9% |
| Semiconductor Manufacturing Equipment | 66 | 209 | 26.1% | 332 | 9.7% | 737 | 17.3% |
| TOTAL | $321 | $679 | 16.2% | $1,135 | 10.8% | $2,360 | 15.8% |

## PURCHASES OF ADVANCED CUTTING & FORMING EQUIPMENT BY END-USERS IN OTHER AREAS OF THE WORLD 1985-2000

| OTHER | 1985 Actual | 1990 Estimated | CAGR | 1995 Forecast | CAGR | 2000 Forecast | CAGR |
|---|---|---|---|---|---|---|---|
| Flexible Machining Cells & Systems | - | $1 | 33.2% | $2 | 18.9% | $6 | 26.2% |
| CNC Controls | $15 | 24 | 9.2% | 38 | 9.9% | 60 | 9.5% |
| DNC Controls | 3 | 5 | 10.6% | 8 | 10.0% | 13 | 10.1% |
| Semiconductor Manufacturing Equipment | 1 | 3 | 31.3% | 11 | 30.9% | 38 | 28.3% |
| TOTAL | $19 | $33 | 11.0% | $59 | 12.7% | $117 | 14.7% |

# 3.0 AUTOMATED MATERIALS AND PARTS HANDLING

## PURCHASES OF AUTOMATED MATERIALS AND PARTS HANDLING BY NORTH AMERICAN END-USERS 1985-2000

| NORTH AMERICA | 1985 Actual | 1990 Estimated | CAGR | 1995 Forecast | CAGR | 2000 Forecast | CAGR |
|---|---|---|---|---|---|---|---|
| Robotic Material Handling | $43 | $58 | 6.0% | $134 | 18.4% | $325 | 19.3% |
| Automated Guided Vehicle Systems | 92 | 148 | 10.0% | 283 | 13.8% | 567 | 14.9% |
| Automated Storage/ Retrieval Systems | 615 | 888 | 7.6% | 1,533 | 11.5% | 2,748 | 12.4% |
| TOTAL | $750 | $1,094 | 7.8% | $1,950 | 12.3% | $3,640 | 13.3% |

## PURCHASES OF AUTOMATED MATERIALS AND PARTS HANDLING BY EUROPEAN END-USERS 1985-2000

| EUROPE | 1985 Actual | 1990 Estimated | CAGR | 1995 Forecast | CAGR | 2000 Forecast | CAGR |
|---|---|---|---|---|---|---|---|
| Robotic Material Handling | $25 | $40 | 9.8% | $95 | 19.0% | $229 | 19.1% |
| Automated Guided Vehicle Systems | 55 | 94 | 11.2% | 181 | 14.0% | 345 | 13.8% |
| Automated Storage/ Retrieval Systems | 310 | 560 | 12.6% | 1,013 | 12.6% | 1,857 | 12.9% |
| TOTAL | $390 | $694 | 12.2% | $1,289 | 13.2% | $2,431 | 13.5% |

## PURCHASES OF AUTOMATED MATERIALS AND PARTS HANDLING BY ASIAN END-USERS 1985-2000

| ASIA | 1985 Actual | 1990 Estimated | CAGR | 1995 Forecast | CAGR | 2000 Forecast | CAGR |
|---|---|---|---|---|---|---|---|
| Robotic Material Handling | $46 | $61 | 5.9% | $120 | 14.6% | $254 | 16.1% |
| Automated Guided Vehicle Systems | 37 | 57 | 9.3% | 96 | 10.8% | 188 | 14.4% |
| Automated Storage/ Retrieval Systems | 197 | 407 | 15.7% | 699 | 11.4% | 1,426 | 15.3% |
| TOTAL | $279 | $525 | 13.5% | $915 | 11.7% | $1,868 | 15.3% |

## PURCHASES OF AUTOMATED MATERIALS AND PARTS HANDLING BY END-USERS IN OTHER AREAS OF THE WORLD 1985-2000

| OTHER | 1985 Actual | 1990 Estimated | CAGR | 1995 Forecast | CAGR | 2000 Forecast | CAGR |
|---|---|---|---|---|---|---|---|
| Robotic Material Handling | - | $2 | 36.8% | $4 | 17.2% | $18 | 39.0% |
| Automated Guided Vehicle Systems | - | 3 | | 6 | 13.3% | 11 | 15.0% |
| Automated Storage/ Retrieval Systems | 8 | 19 | 19.2% | 38 | 14.7% | 98 | 21.2% |
| TOTAL | $8 | $24 | 23.5% | $47 | 14.7% | $128 | 22.3% |

# 4.0 AUTOMATED ASSEMBLY AND PACKAGING MACHINES

## PURCHASES OF AUTOMATED ASSEMBLY AND PACKAGING MACHINES BY NORTH AMERICAN END-USERS 1985-2000

| NORTH AMERICA | 1985 Actual | 1990 Estimated | CAGR | 1995 Forecast | CAGR | 2000 Forecast | CAGR |
|---|---|---|---|---|---|---|---|
| Automated Mechanical Assembly Systems | $68 | $122 | 12.4% | $230 | 13.5% | $591 | 20.8% |
| Robotic Assembly & Finishing | 339 | 580 | 11.3% | 1,052 | 12.7% | 2,207 | 16.0% |
| Automated Electronic Assembly Systems | 355 | 919 | 21.0% | 1,582 | 11.5% | 3,368 | 16.3% |
| Automated Packaging Systems | 105 | 257 | 19.6% | 524 | 15.3% | 1,300 | 19.9% |
| TOTAL | $867 | $1,878 | 16.7% | $3,388 | 12.5% | $7,466 | 17.1% |

## PURCHASES OF AUTOMATED ASSEMBLY AND PACKAGING MACHINES BY EUROPEAN END-USERS 1985-2000

| EUROPE | 1985 Actual | 1990 Estimated | CAGR | 1995 Forecast | CAGR | 2000 Forecast | CAGR |
|---|---|---|---|---|---|---|---|
| Automated Mechanical Assembly Systems | $32 | $47 | 8.2% | $89 | 13.5% | $185 | 15.8% |
| Robotic Assembly & Finishing | 136 | 466 | 28.0% | 896 | 14.0% | 2,315 | 20.9% |
| Automated Electronic Assembly Systems | 176 | 513 | 23.8% | 918 | 12.4% | 1,856 | 15.1% |
| Automated Packaging Systems | 64 | 151 | 18.7% | 242 | 9.9% | 468 | 14.1% |
| TOTAL | $408 | $1,176 | 23.6% | $2,144 | 12.8% | $4,824 | 17.6% |

PURCHASES OF AUTOMATED ASSEMBLY AND PACKAGING MACHINES
BY ASIAN END-USERS
1985-2000

| ASIA | 1985 Actual | 1990 Estimated | CAGR | 1995 Forecast | CAGR | 2000 Forecast | CAGR |
|---|---|---|---|---|---|---|---|
| Automated Mechanical Assembly Systems | $27 | $43 | 9.9% | $81 | 13.5% | $200 | 20.0% |
| Robotic Assembly & Finishing | 203 | 497 | 19.6% | 925 | 13.2% | 2,236 | 19.3% |
| Automated Electronic Assembly Systems | 264 | 683 | 21.0% | 1,138 | 10.7% | 2,399 | 16.1% |
| Automated Packaging Systems | 37 | 91 | 19.5% | 149 | 10.4% | 340 | 17.9% |
| TOTAL | $531 | $1,314 | 19.8% | $2,292 | 11.8% | $5,176 | 17.7% |

PURCHASES OF AUTOMATED ASSEMBLY AND PACKAGING MACHINES
BY END-USERS IN OTHER AREAS OF THE WORLD
1985-2000

| OTHER | 1985 Actual | 1990 Estimated | CAGR | 1995 Forecast | CAGR | 2000 Forecast | CAGR |
|---|---|---|---|---|---|---|---|
| Automated Mechanical Assembly Systems | $1 | $2 | 29.8% | $4 | 13.5% | $19 | 36.9% |
| Robotic Assembly & Finishing | - | 10 | | 17 | 11.0% | 47 | 22.7% |
| Automated Electronic Assembly Systems | 5 | 20 | 32.3% | 33 | 10.3% | 105 | 26.0% |
| Automated Packaging Systems | 1 | 5 | 54.1% | 17 | 27.6% | 130 | 50.6% |
| TOTAL | $6 | $37 | 43.4% | $71 | 13.6% | $301 | 33.6% |

# 5.0 FACTORY FLOOR COMPUTERS & COMMUNICATIONS LINKS

PURCHASES OF FACTORY FLOOR COMPUTERS & COMMUNICATIONS LINKS
BY NORTH AMERICAN END-USERS
1985-2000

| NORTH AMERICA | 1985 Actual | 1990 Estimated | CAGR | 1995 Forecast | CAGR | 2000 Forecast | CAGR |
|---|---|---|---|---|---|---|---|
| Factory Floor Computers | $563 | $909 | 10.0% | $1,578 | 11.7% | $2,482 | 9.5% |
| Factory Floor Software | 733 | 1,243 | 11.1% | 2,228 | 12.4% | 4,092 | 12.9% |
| Programmable Logic Controllers | 401 | 721 | 12.5% | 1,214 | 11.0% | 2,057 | 11.1% |
| Local Area Network | 39 | 428 | 61.1% | 1,160 | 22.1% | 2,329 | 15.0% |
| Installation & Integration & Other Services | 1,743 | 3,757 | 16.6% | 6,383 | 11.2% | 11,516 | 12.5% |
| TOTAL | $3,480 | $7,058 | 15.2% | $12,563 | 12.2% | $22,476 | 12.3% |

PURCHASES OF FACTORY FLOOR COMPUTERS & COMMUNICATIONS LINKS
BY EUROPEAN END-USERS
1985-2000

| EUROPE | 1985 Actual | 1990 Estimated | CAGR | 1995 Forecast | CAGR | 2000 Forecast | CAGR |
|---|---|---|---|---|---|---|---|
| Factory Floor Computers | $310 | $694 | 17.5% | $1,208 | 11.7% | $2,277 | 13.5% |
| Factory Floor Software | 239 | 572 | 19.1% | 1,236 | 16.7% | 2,771 | 17.5% |
| Programmable Logic Controllers | 64 | 125 | 14.3% | 210 | 11.0% | 345 | 10.4% |
| Local Area Network | 8 | 189 | 90.1% | 442 | 18.6% | 1,179 | 21.7% |
| Installation & Integration & Other Services | 691 | 1,884 | 22.2% | 3,481 | 13.1% | 6,527 | 13.4% |
| TOTAL | $1,312 | $3,463 | 21.4% | $6,578 | 13.7% | $13,099 | 14.8% |

## PURCHASES OF FACTORY FLOOR COMPUTERS & COMMUNICATIONS LINKS BY ASIAN END-USERS 1985-2000

| ASIA | 1985 Actual | 1990 Estimated | CAGR | 1995 Forecast | CAGR | 2000 Forecast | CAGR |
|---|---|---|---|---|---|---|---|
| Factory Floor Computers | $167 | $375 | 17.5% | $712 | 13.7% | $1,606 | 17.6% |
| Factory Floor Software | 162 | 408 | 20.2% | 898 | 17.1% | 2,262 | 20.3% |
| Programmable Logic Controllers | 64 | 106 | 10.6% | 178 | 10.9% | 286 | 10.0% |
| Local Area Network | 6 | 126 | 83.9% | 306 | 19.4% | 790 | 20.9% |
| Installation & Integration & Other Services | 522 | 1,430 | 22.3% | 2,662 | 13.2% | 5,452 | 15.4% |
| TOTAL | $922 | $2,446 | 21.5% | $4,757 | 14.2% | $10,397 | 16.9% |

## PURCHASES OF FACTORY FLOOR COMPUTERS & COMMUNICATIONS LINKS BY END-USERS IN OTHER AREAS OF THE WORLD 1985-2000

| OTHER | 1985 Actual | 1990 Estimated | CAGR | 1995 Forecast | CAGR | 2000 Forecast | CAGR |
|---|---|---|---|---|---|---|---|
| Factory Floor Computers | $8 | $25 | 25.6% | $61 | 19.9% | $150 | 19.7% |
| Factory Floor Software | 6 | 30 | 40.6% | 110 | 29.3% | 426 | 31.1% |
| Programmable Logic Controllers | 5 | 3 | -13.7% | 16 | 44.6% | 25 | 9.5% |
| Local Area Network | - | 7 | | 25 | 28.8% | 61 | 19.9% |
| Installation & Integration & Other Services | 43 | 126 | 23.9% | 250 | 14.6% | 535 | 16.5% |
| TOTAL | $62 | $191 | 25.2% | $462 | 19.3% | $1,198 | 21.0% |

# 6.0 ADVANCED TEST AND INSPECTION SYSTEMS

PURCHASES OF ADVANCED TEST AND INSPECTION SYSTEMS
BY NORTH AMERICAN END-USERS
1985-2000

| NORTH AMERICA | 1985 Actual | 1990 Estimated | CAGR | 1995 Forecast | CAGR | 2000 Forecast | CAGR |
|---|---|---|---|---|---|---|---|
| Inspection Systems | $1,710 | $3,088 | 12.5% | $5,868 | 13.7% | $10,501 | 12.3% |
| Test Systems | 255 | 469 | 13.0% | 844 | 12.4% | 1,735 | 15.5% |
| TOTAL | $1,965 | $3,557 | 12.6% | $6,712 | 13.5% | $12,236 | 12.8% |

PURCHASES OF ADVANCED TEST AND INSPECTION SYSTEMS
BY EUROPEAN END-USERS
1985-2000

| EUROPE | 1985 Actual | 1990 Estimated | CAGR | 1995 Forecast | CAGR | 2000 Forecast | CAGR |
|---|---|---|---|---|---|---|---|
| Inspection Systems | $595 | $1,413 | 18.9% | $2,731 | 14.1% | $5,226 | 13.9% |
| Test Systems | 82 | 220 | 21.8% | 425 | 14.1% | 948 | 17.4% |
| TOTAL | $678 | $1,633 | 19.2% | $3,156 | 14.1% | $6,174 | 14.4% |

## PURCHASES OF ADVANCED TEST AND INSPECTION SYSTEMS BY ASIAN END-USERS 1985-2000

| ASIA | 1985 Actual | 1990 Estimated | CAGR | 1995 Forecast | CAGR | 2000 Forecast | CAGR |
|---|---|---|---|---|---|---|---|
| Inspection Systems | $935 | $1,947 | 15.8% | $3,557 | 12.8% | $6,886 | 14.1% |
| Test Systems | 122 | 239 | 14.3% | 397 | 10.6% | 755 | 13.7% |
| TOTAL | $1,057 | $2,187 | 15.7% | $3,954 | 12.6% | $7,641 | 14.1% |

## PURCHASES OF ADVANCED TEST AND INSPECTION SYSTEMS BY END-USERS IN OTHER AREAS OF THE WORLD 1985-2000

| OTHER | 1985 Actual | 1990 Estimated | CAGR | 1995 Forecast | CAGR | 2000 Forecast | CAGR |
|---|---|---|---|---|---|---|---|
| Inspection Systems | $53 | $135 | 20.4% | $257 | 13.8% | $557 | 16.7% |
| Test Systems | 4 | 15 | 29.3% | 27 | 11.5% | 76 | 23.4% |
| TOTAL | $57 | $150 | 21.2% | $284 | 13.6% | $633 | 17.4% |

# 7.0 PRODUCTION CONTROL SYSTEMS

## PURCHASES OF PRODUCTION MANAGEMENT AND CONTROL COMPUTERS & SOFTWARE BY NORTH AMERICAN END-USERS 1985-2000

| NORTH AMERICA | 1985 Actual | 1990 Estimated | CAGR | 1995 Forecast | CAGR | 2000 Forecast | CAGR |
|---|---|---|---|---|---|---|---|
| Production Management & Control Computers | $1,197 | $1,271 | 1.2% | $1,685 | 5.8% | $3,294 | 14.3% |
| Production Management & Control Software | 877 | 1,726 | 14.5% | 3,615 | 15.9% | 7,727 | 16.4% |
| TOTAL | $2,074 | $2,997 | 7.6% | $5,300 | 12.1% | $11,021 | 15.8% |

## PURCHASES OF PRODUCTION MANAGEMENT AND CONTROL COMPUTERS & SOFTWARE BY EUROPEAN END-USERS 1985-2000

| EUROPE | 1985 Actual | 1990 Estimated | CAGR | 1995 Forecast | CAGR | 2000 Forecast | CAGR |
|---|---|---|---|---|---|---|---|
| Production Management & Control Computers | $142 | $355 | 20.1% | $980 | 22.5% | $2,089 | 16.4% |
| Production Management & Control Software | 128 | 679 | 39.5% | 2,297 | 27.6% | 5,276 | 18.1% |
| TOTAL | $271 | 1,034 | 30.7% | $3,277 | 25.9% | $7,365 | 17.6% |

## PURCHASES OF PRODUCTION MANAGEMENT AND CONTROL COMPUTERS & SOFTWARE BY ASIAN END-USERS 1985-2000

| ASIA | 1985 Actual | 1990 Estimated | CAGR | 1995 Forecast | CAGR | 2000 Forecast | CAGR |
|---|---|---|---|---|---|---|---|
| Production Management & Control Computers | $71 | $302 | 33.5% | $877 | 23.8% | $2,430 | 22.6% |
| Production Management & Control Software | 88 | 494 | 41.3% | 1,961 | 31.8% | 4,882 | 20.0% |
| TOTAL | $159 | $796 | 38.0% | $2,838 | 29.0% | $7,312 | 20.8% |

## PURCHASES OF PRODUCTION MANAGEMENT AND CONTROL COMPUTERS & SOFTWARE BY END-USERS IN OTHER AREAS OF THE WORLD 1985-2000

| OTHER | 1985 Actual | 1990 Estimated | CAGR | 1995 Forecast | CAGR | 2000 Forecast | CAGR |
|---|---|---|---|---|---|---|---|
| Production Management & Control Computers | $14 | $28 | 14.5% | $72 | 21.0% | $131 | 12.7% |
| Production Management & Control Software | 13 | 48 | 29.8% | 180 | 30.2% | 474 | 21.3% |
| TOTAL | $27 | $76 | 22.8% | $252 | 27.1% | $605 | 19.1% |

# APPENDIX B

# STANDARDS

## STANDARDS BODIES

| NON-EUROPEAN MEMBERS OF ISO | |
|---|---|
| ANSI | American National Standards Institute |
| JISC | Japanse Industrial Standards Committee |
| SCC | Standards Council of Canada |

| OTHER STANDARDS-MAKING BODIES | |
|---|---|
| ECMA | European Computer Manufacturers Association |
| IEEE | Institute of Electrical and Electronics Engineers (USA) |
| NIST | National Institute of Standards and Technology (USA) |
| EWOS | European Workshop for Open Systems |
| IFIP | International Federation for Information Processing |

| SOME UK PARTICIPANTS IN STANDARDS DEVELOPMENT | |
|---|---|
| FOCUS | UK Committee set up to identify areas of work needed on information technology standards and to promote action |
| BABT | British Approvals Board for Telecommunication |
| NCC | National Computing Centre |
| ITSU | Information Technology Standards Unit |
| BCS | British Computer Society |
| BETA | Business Equipment Trade Association |
| CSA | Computing Services Association |

| SOME U.S. INDUSTRY GROUPS PARTICIPATING IN STANDARDS DEVELOPMENT | |
|---|---|
| CAM-I | Computer-Aided Manufacturing International, Inc., created by a group of industrial, educational and government organizations |
| AVA | Automated Vision Association |
| RIA | Robotic Industry Association |

Source: IEEE Spectrum, June 1990

# EUROPEAN MEMBERSHIP IN STANDARDS ORGANIZATIONS

| | | |
|---|---|---|
| International | **ISO** International Standards Organization | **IEC** International Electrotechnical Commission |
| European | **CEN** Comité Européen de Normalisation | **Cenelec** Comité Européen de Normalisation Electrotechnique |
| Austria | **ON** Österreichisches Normungsinstitut | **OEK** Österreichisches Elektrotechnisches Komitee |
| Belgium | **IBN** Institut Belge de Normalisation | **CEB** Comité Electrotechnique Belge |
| Denmark | **DS** Dansk Standardiseringsrad | **DEK** Dansk Elektroteknisk Komite |
| Finland | **SFS** Suomen Standardisoimisliitto r.y. | **Sesko** Finnish Electrotechnical Standards Association |
| France | **Afnor** Association Française de Normalisation | **UTE** Union Technique de l'Electricité |
| West Germany | **DIN** Deutsches Institut für Normung e.V. | **DKE** Deutsches Elektrotechnische Kommission im DIN und VDE |
| Greece | **ELOT** Hellenic Organization for Standardization | **ELOT** Hellenic Organization for Standardization |
| Iceland | **STRI** Technological Institute of Iceland | **STRI** Technological Institute of Iceland |
| Ireland | **NSAI** National Standards Authority of Ireland | **ETCI** Electro-Technical Council of Ireland |
| Italy | **UNI** Ente Nazionale Italiano di Unificazione | **CEI** Comitato Elettrotecnico Italiano |
| Luxembourg | **ITM** Inspection du Travall et des Mines | **SEE** Service de l'Energie de l'Etat |
| The Netherlands | **NNI** Nederlands Normalisatie-Instituut | **NEC** Nederlands Elektrotechnisch Comité |
| Norway | **NSF** Norges Standardiseringsforbund | **NEK** Norsk Elektroteknisk Komite |
| Portugal | **IPO** Instituto Portugués da Qualidade | **IPO** Instituto Portugués da Qualidade |
| Spain | **Aenor** Asociación Española de Normalización y Certidicación | **AEE** Asociación Electrotécnica y Electrónica Española |
| Sweden | **SIS** Standardiseringskommissionen i Sverige | **SEK** Svenska Elektriska Kommissionen |
| Switzerland | **SNV** Schweizerische Normen-Vereinigung | **CES** Comité Electrotechnique Suisse |
| United Kingdom | **BSI** British Standards Institution | **BSI** British Standards Institution |

Source: IEEE Spectrum, June 1990

# APPENDIX C

# CASE STUDIES

# CASE STUDY SUBJECT COMPANIES

| COMPANY | CATEGORY |
|---|---|
| ATLAS ROLL-LITE<br>Edison, NJ, USA | U |
| CIMLINC INC.<br>Itasca, IL, USA | S |
| DYNAPRO SYSTEMS INC. (DSI)<br>Vancouver, British Columbia, Canada | S |
| EPIC DATA<br>Richmond, British Columbia, Canada | H |
| F&P MANUFACTURING INCORPORATED,<br>Tottenham, Ontario, Canada | U |
| GENNUM CORPORATION<br>Burlington, Ontario, Canada | U |
| HUSKY INJECTION MOLDING SYSTEMS LTD.<br>Bolton, Ontario, Canada | H/U |
| ITP BOSTON, INC.<br>Cambridge, MA, USA | I |
| LINAMAR MACHINE LIMITED<br>Guelph, Ontario, Canada | U |
| MRS TECHNOLOGY, INC.<br>Chelmsford, MA, USA | H |
| OTTO BOCK ORTHOPEDIC INDUSTRY OF CANADA, LTD.<br>Winnipeg, Manitoba, Canada | U |
| PARAMETRIC TECHNOLOGY CORPORATION<br>Waltham, MA, USA | S |
| PROMIS SYSTEMS CORPORATION<br>Toronto, Ontario, Canada | S |
| SENSOR ADAPTIVE MACHINES INCORPORATED (SAMI)<br>Windsor, Ontario, Canada | H |
| SOFTAC SYSTEMS LTD.<br>Port Coquitlam, B.C., Canada | H |
| SUN ICE LIMITED<br>Calgary, Alberta, Canada | U |
| TAYLOR INDUSTRIAL SOFTWARE<br>Edmonton, Alberta, Canada | S |
| THE PAS LUMBER COMPANY, LTD.<br>Prince George, B.C., Canada | U |
| VADEKO INTERNATIONAL CORPORATION<br>Mississauga, Ontario, Canada | H |
| WESTHEAD SYSTEMS LIMITED<br>Rexdale, Ontario, Canada | I |

**S** AMT Software Supplier
**H** AMT Hardware Supplier
**I** System Integrator
**U** User

ATLAS ROLL-LITE
Edison, NJ, and Orlando, FL, USA

BACKGROUND

**The Company**

Atlas Roll-lite is a U.S. manufacturer of overhead doors. The company was recently formed from Atlas Door Corp. and Roll-lite Overhead Doors. Atlas Door, a manufacturer of heavy rolling steel doors, was founded in 1973 by Irving Sherr, Joel Goldschein, and Julius Kapik. Prior to establishing Atlas Door, one of the founders was a manufacturers' representative for an industrial overhead door supplier.

Roll-lite Overhead Doors, a manufacturer of residential and commercial sectional doors and light-weight rolling steel doors was formed in 1974 by Wallace J. Warner and John L. McLane, Jr. as Architectural Specialties Company, Inc., a small installation business.

Atlas Door's manufacturing operations were initially located in Jersey City, NJ. Manufacturing was later relocated to Edison, NJ. By 1986, the company operated plants in Nesbit, Mississippi, La Habra, California and Etobicoke, Ontario, Canada.

Prior to the merge with Atlas Door Corp., Roll-lite Overhead Doors had manufacturing facilities located in Orlando, FL and Chandler, AZ with distribution centers in Morgantown, PA and Anaheim, CA.

**Product Line**

Atlas Door's product line consists of the following:

- Heavy rolling steel doors for uses such as warehouses
- Security grilles for closures in mall, storefront, and parking garage entrances
- Fire shutters for counter openings in kitchen cafeteria pass throughs, check rooms and concession stands

Roll-lite's product line consisted of the following:

- Residential sectional garage doors for home use
- Commercial sectional doors for uses such as warehouses
- Lightweight steel rollup doors for miniwarehouses and public storage buildings

These complementary product lines made these two companies perfectly suited to a merger.

**Size and Strength**

Atlas Roll-lite's worldwide revenues in 1989 totaled approximately $80 (U.S.) million. Sales for the two product lines accounted for about $40 (U.S.) million each. Atlas Roll-lite has approximately 650 employees.

**Competitive Environment**

The estimated sales of the heavy rolling steel door market is about $100 million per year. The average annual growth in this market has been about 5%.

The residential door market is about $1 billion per year. Residential overhead doors are a commodity product. The market for residential doors is very competitive and highly price sensitive.

Heavy rolling steel doors are generally a custom fabricated product. Customers need industrial doors specially made in the width, height and material that suits their application. The market for these made-to-order products is only slightly less price competitive than that for residential doors.

Atlas Roll-lite's market is primarily North America. The company does sell its products in Puerto Rico, Europe, the Middle East and the Far East.

The competitive environment for this class of commercial and residential doors is changing due to mergers and acquisitions that are underway. Other competitors in this market include Overhead Door Corp. (a division of the Dallas Corporation) and Wayne Dalton Corp. While some market participants are national, others compete strongest in the geographic areas where they manufacture.

**Distribution Channels**

Sales channels utilized by Atlas Roll-lite include a national direct salesforce, factory salesforce and a distributor network. The direct salesforce sells to large end-users and contractors. Factory sales offices sell to the same types of customers that distributors serve and therefore, are in direct competition with distributors. Approximately 65% of sales are made via distributors. National direct sales account for about 15% of sales, while the remaining 20% are made through factory offices.

To handle exports, Atlas Roll-lite has one international salesman who uses several overseas contacts to sell the product line.

## COMPETITIVE STRATEGY

As a new company, Atlas Door Corp. had difficulty convincing new distributors to take on its line of overhead doors. The larger, established distributors already carried products from bigger competitors; no incentives existed to lure these distributors into carrying Atlas' products.

Most door manufacturers required about four months to produce a door that was out of stock or customized. Generally, when a door manufacturer received a price and delivery request from a customer, salesman or distributor, it took more than a week to respond. It took even longer to respond if the door was not in stock or not yet engineered or scheduled. Atlas Door Corp. was convinced that a time-based strategy that provides a high quality product to the customer in a shorter time frame than competitors would get the company into the industrial door market and propel it ahead of competitors.

The company realized that by reducing lead times and providing good service, it could command a large share of the market.

Roll-lite Overhead doors shared this strategy and by providing on-time delivery with good service was able to grow into a profitable manufacturer of overhead doors. Dedicated truck runs and very short lead times allowed it to get a foothold in a very large market and expand to today's sales levels.

## STRATEGY IMPLEMENTATION

### Reducing Production Time

Atlas Roll-lite began by building manufacturing plants that were equipped with the extra tooling and machinery required to reduce changeover times. Much of its product is roll formed. While the changeover operations are somewhat automated, load, unload and assembly is still performed manually. In addition, the manufacturing process was organized by product and the fabrication of all product parts coordinated so that they were completed at the same time. This provided only part of the solution, since manufacture of the product accounted for only 2 1/2 weeks of the product delivery cycle.

### Reducing Pre-Production Time

The next step was to decrease the time period at the front end of the system. Atlas Roll-lite began by streamlining the individual parts of this process, including order entry, engineering, pricing, and scheduling. Then the company set about automating the entire process.

### Computerizing the Process

In late 1979, Atlas Door Corp. began the computerization process by purchasing the initial software program. Due to lack of internal expertise, a programmer was hired as a consultant. The programmer soon became a full-time employee. Department heads advised the programmer what was needed for each department; the programmer then wrote the required software. In addition to writing the code, the programmer provided in-house training to personnel ranging from the clerical level up to department heads.

Each department was provided with its own computer terminal. These computer terminals were linked together to a host system. In the beginning, when interdepartmental transfer of information through the computer had not yet been made automatic, each department entered information into their respective directories (subsystems). These subsystems were set up so that they would ultimately be linked together.

At the heart of the host system is a Data General mainframe computer that connects all departments within the company. This computer system links activities from the estimate stage to order entry, generation of production worksheets and engineering drawings, right through indicating that the job has been completed. The mainframe, located in New Jersey, communicates with remote computer subsystems via modem. Information is transferred daily.

### Overcoming Obstacles

During the automation process, the company encountered some difficulties, but none that could not be solved. For example, the programming language being used did not accommodate the engineering calculations that were required. Atlas Roll-lite's programming department was able to solve this problem.

Since the merger, Roll-lite's computer system was combined with Atlas' to utilize the strength of both and produce a superior system that communicates back and forth on a daily basis.

### Maintaining Tight Control

In addition to the above improvements, Atlas Roll-lite maintained tight control over the logistics of filling an order. The company developed a system that tracks all parts being produced or purchased for each order. The system ensures that all components of an order arrive at the shipping dock in time for the initial shipping. The goal is that only complete orders are shipped to a construction site, saving the additional time and expense of shipping omitted parts.

### Integration

Atlas Roll-lite has streamlined its order entry, engineering, manufacturing, and logistics systems so that information and products are moved efficiently throughout the product delivery cycle. Once all departments were linked, the order entry and tracking process became much more efficient. For example, special orders are now engineered in less time because the design and production data for all previous special orders is stored in the system and may be utilized to engineer incoming special orders.

## RESULTS

### System Improvements

Improvements achieved by the new system include the following:

- Over 80% of the company's orders can be priced and scheduled while the customer is still on the telephone

- Greater amounts of data can now be entered more accurately and in less time

- The time to fill an out-of-stock or custom order has been reduced to three to four weeks. This represents about a two-thirds reduction in the industry average product delivery cycle.

- Significant market penetration through establishing an image as the supplier of last resort

### Growth and Profitability

By the time they were ten years old, Atlas Door Corp. had displaced established rolling steel door suppliers for 80% of the distributors in the country and Roll-lite Overhead doors had made significant gains in a much larger sectional door market. A customer-responsive approach had won Atlas the leading position in its market. The leading competitor, the Overhead Door Corporation's Rolling Steel Division, was nudged into second place. In addition to outpacing the competition, Atlas Door Corp. managed to achieve annual growth of 15% a year in a market that was growing at only 5%. The same customer responsiveness had propelled Roll-lite's miniwarehouse division into becoming the major manufacturer in that market, outpacing all the competition with a 15% annual growth rate. Customers rewarded the both companies' responsiveness by paying prices up to 20% higher than the competition's, producing after-tax earnings above industry average.

### Continuous Improvement Required

Maintaining competitive advantage is a continuous process. Most competitors have now caught up to Atlas Roll-lite in the area of quality and delivery. Thus, Atlas Roll-lite has examined alternative ways of distinguishing itself from the competition. The company is currently focusing on exemplary service in providing a complete line of products, while also continuously looking for specialty market niche needs to fill. By maintaining proven strategies of providing top quality products delivered in a timely manner, Atlas Roll-lite believes its competitive advantage will be maintained.

CIMLINC INC.
Itasca, IL, USA

## BACKGROUND

### The Company

CIMLINC was founded in 1981 by John West, current President, and Michael Sterling. Both had previously been involved in numerical control (NC) systems. The two founders saw changes occurring in the market that they expected would lead away from big mainframe computers toward distributed processing environments. They saw an opportunity to approach the market from the computer-aided manufacturing (CAM) side, whereas most other suppliers were addressing from the computer-aided design (CAD) perspective.

The company was originally formed to sell NC software. However, the development of the Sun workstation, under a U.S. Department of Defense grant, led CIMLINC to license the product and to become a hardware manufacturing company. From 1983 to 1987, CIMLINC produced Sun workstations. Another company, Sun Microsystems, Inc., was also licensed to build and sell the workstations. In 1987 CIMLINC decided to exit the hardware business and focus on software.

CIMLINC sales for the year ended September 30, 1990 were $31.5 million. The company's peak sales level, prior to retrenching from the hardware business, was $35 million in 1988. The conversion into a software-only company has been achieved without new capital infusion. In its continuing business area, CIMLINC recorded an increase in sales of 30% in 1990.

### Market Size, Growth and Competition

There are many companies in the business of providing computer-aided engineering (CAE) plus CAD and CAM software. Several supply the computer hardware as well. Some of the larger competitors are IBM, Interdata, Computervision (subsidiary of Prime Computer), Hewlett-Packard, and McDonnell-Douglas. CIMLINC has a small share of the estimated $6.8 billion sold by U.S. vendors in 1990.

The market for CAD/CAM/CAE has grown at an average of approximately 15% over the past three years.

Concurrent engineering is one of the key trends in helping manufacturing companies to operate at a world-class level of performance. Concurrent engineering, in effect, gets engineering and manufacturing working together from the beginning of a new product design so that the product and the process are designed concurrently. Another competitive weapon being recognized is the value of incremental improvements in products, introduced at relatively short intervals, as opposed to large-scale changes introduced with longer time between product releases.

CIMLINC believes that most of its competitors still view design and manufacturing, CAD and CAM, as two separate thought processes and are therefore not equipped to address these trends with up-to-date products that suit the needs of the market.

## COMPETITIVE STRATEGY

### Customer Strategy

The company is focused on medium to large size customers where sales efforts are more likely to generate repeat orders once the initial penetration has been made. CIMLINC also attempts to find innovative customers, those that will participate in driving the product development with real-world input. Another factor in the strategy is differentiation through intensive customer application support.

### Product Strategy

CIMLINC's product strategy is to have the most easily integrated product line in the business. This includes offering the most complete line in terms of covering the entire set of requirements within the design and manufacturing environment.

### Export Strategy

The company recognizes that it must operate globally in order to be a viable contender in any market. The faster-growing export market is an explicit target.

## STRATEGY IMPLEMENTATION

### Product Development

CIMLINC believes that it has put together more pieces of the software CAD/CAM/CAE puzzle than any of its competitors. The company is offering Unix software to run on multiple brands of engineering workstations over local area networks with easy-to-learn graphical interfaces. CIMLINC products have been rewritten and restructured for Unix compatibility. The company believes that its products are truly right for today's market.

CIMLINC's open product structure allows interface with competitive products currently being used by its customers. The company considers the integration factor the key element in dealing with customer requirements such as concurrent engineering and has made that a priority specification of its product development. This includes having the same graphical user interface for all the applications.

One area in which the company has not previously offered a product has been in the conceptual design arena. CIMLINC is currently developing a conceptual design product based on a revolutionary change in the fundamental mathematics on which these systems are built. The company believes that there is a fundamental flaw in the mathematical basis of current conceptual design packages offered by the competition. CIMLINC's new product will represent an essential product change and therefore a fundamentally differentiated product.

**Customer Partnerships**

CIMLINC is working closely with major customers on a partnership basis. This principle is implemented by the customer agreeing to prepay a number of licenses in order to get a level of functionality that is not currently available. By this process, CIMLINC is able to get its customers to participate in and drive the development process.

In addition to providing its customers with products that are designed to integrate well, CIMLINC also performs integration services for its customers. At least 30% of CIMLINC's total revenue is derived from application support. Two factors that drive customers to select CIMLINC for these assignments are the company's willingness to work with other products and the openness of the product line in interfacing to the products of other suppliers.

Another way that CIMLINC works with its customers is to help management establish a vision of where it needs to go with its CAD/CAM/CAE program. Skeptical or recalcitrant management can be a serious obstacle to sales of this type of software. CIMLINC's approach is to get management to view the long-run requirements of engineering and manufacturing and visualize the different software needs entailed in that long-range view. Then, with its highly integratable line, CIMLINC can show management the benefits of a planned approach to an integrated system. Once the vision is established, the advantage versus the application of a series of packages purchased from several vendors, each as a stop-gap measure, is clear. CIMLINC's willingness to accommodate the products currently in place as an integral part of the overall solution is also a significant advantage in these instances.

**Exports**

CIMLINC has established direct sales activities in Germany and the U.K. from which it launches all European sales efforts. In the Far East, it has an arrangement with Fujitsu in Japan. Fujitsu is the Sun Microsystems reseller in Japan. Fujitsu, in turn, uses two distributor organizations that do the actual selling. In Korea, Hyundai is CIMLINC's marketing partner.

## RESULTS

**Financial**

The year ended September 30, 1990 resulted in record high profits for CIMLINC. The conversion from hardware to software-only was accomplished without the aid of any outside equity capital. In fact, due to redemption clauses in the company's contracts with venture capitalists, it was necessary to repay $3 million during the period of business conversion.

**Growth**

Sales of $31.5 million for the 1990 fiscal year represents 30% growth over like business lines in the previous year. The company currently employs approximately 190 people.

**Exports**

In 1990, even though the sales program in the Far East is still in a formative stage, exports represent 40% of total sales revenue.

## DYNAPRO SYSTEMS INC. (DSI)

Vancouver, B. C., Canada

## BACKGROUND

### The Company

DSI designs and manufactures hardware and software products for the industrial control market. These products apply real-time data collection and processing techniques, interactive graphics for user interfaces, and a variety of communications technologies and protocols. The company's strength originally lay in process control. However, DSI products are used in many areas that require control, communications and graphics capabilities.

DSI was founded by three partners in 1976. The company originally performed consulting that included integration of control systems. By the early 1980s, DSI had taken what it had learned as an integrator and used it to develop an operator interface terminal called Grafix.

President and founder Karl Brackhaus sums up DSI's corporate philosophy: "Attitude is everything, a spirit of team-work where all employees are seen as full and equal partners, 'rule' by example, management by wandering around, zero defects, and do it right the first time."

In 1983, DSI formed an agreement with Allen-Bradley (A-B) under which all of DSI's products are sold and supported through A-B.

### Size and Strength

Sales for DSI totaled over $18 million in 1990. The company's R&D spending, amounting to over $2.5 million annually, places it near the top 50 companies in Canada in terms of R&D expenditures.

The terminal line and software yield about equal sales volume for DSI. On a unit basis, the company sells about four times as many terminals as software programs.

DSI maintains a workforce of about 140 people.

### Product Line

DSI's product line consists of operator interface terminals (PanelView) and software. Software packages include Advisor PC and the company's latest software line, ControlView. DSI software runs on a range of hardware including IBM AT-compatible computers and A-B industrial computers and terminals.

The PanelView operator terminal connects to an A-B PLC and functions as a replacement for pushbutton selectors and other control panel hardware. ControlView consists of a set of software products that integrate process control, information management and operator interfaces for personal computer industrial workstations.

Also sold by the company are intelligent motion controllers and industrial communications hardware for linking computers to A-B networks. Originally designed for table positioning in sawmills, the linear motion controller is a module that fits into an A-B programmable logic controller (PLC). Communications products originally grew from a need to connect DSI's terminals to A-B hardware and to other networks.

### Competitive Environment

Use of graphics terminals on the plant floor has just started to take off in the last few years. Driving this trend are the advent of the personal computer and its use in industrial applications.

As the personal computer hardware gets more powerful, it gets easier and easier for competitors to enter the operator interface market; barriers for the new entrants are much lower. The number of competitors has risen significantly over the past few years. At present, there are approximately a dozen competitors. Competition is especially strong for monitoring and control software due to the low entry barrier to the market for software products. Besides A-B, leading competitors in the market for monitoring and control software include U.S. Data and Intellution, both based in the U.S. On the hardware side, DSI competes with Eaton IDT in the market for operator interface terminals.

The worldwide market for operator interface software products is estimated between $50 and $100 million.

## COMPETITIVE STRATEGY

Not long after establishing its consulting business, the three founders of DSI became convinced that color graphics would have a bright future as an operator interface. Therefore, they developed a reasonably-priced operator interface terminal that interfaced with a PLC. This product was sold in Vancouver to Molson Brewery and to fiberboard plants in the U.S. midwest.

Next, DSI began to design products specifically to interface with leading PLC manufacturers that included A-B, Modicon and Texas Instruments. Modicon soon launched its own display system.

With PanelView, DSI targets a fairly low end, high performance machine control. Software products tend to sit a little bit higher in the plant hierarchy. The company considers its two operator interface products as key to its future.

Through relatively high R&D spending, the company strives to remain in the forefront of product development. DSI teams are investigating use of expert systems, and are developing advanced operator interface and industrial display systems. Much of the R&D has been internally funded in the past. Within the last year, DSI has turned to government programs for assistance in R&D financing. The company is seeking or has received help under IRAP, the Microelectronics and System Development Program (MSDP), and AGAR, a provincial program administered by the Ministry of Western Economic Diversification.

Since products are sold and supported through Allen-Bradley, DSI does not often interact directly with the customer. Being insulated from the customer is a problem that DSI is currently trying to solve.

Two priorities in new product development at DSI are the ability of products to be integrated and conformance to upcoming global standards. The company strives to develop new products that will help its own products work together better, and that will facilitate integration of DSI products with other subsystems.

## STRATEGY IMPLEMENTATION

By the early 1980s, Allen-Bradley, a leading North American manufacturer of PLCs and related factory automation products, had decided that it should add an operator interface to its line. Modicon had already launched its own operator interface, catching A-B short. With no operator interface of its own in the works, A-B sought to purchase this technology. Through A-B's salesforce, Dynapro learned that A-B was anxious to find a line of operator interfaces. Dynapro approached A-B and struck a deal.

In 1983, DSI entered into a marketing and sales agreement that coupled A-B's strength as a leading supplier of automation products with DSI's strength as an innovator in the field of graphics display systems. Under the agreement, A-B purchased a 25% equity in DSI and DSI products are sold exclusively through A-B, which now owns a 50% share of the company. A-B plays the role of both customer and sales channel for DSI products. This alliance provides DSI with international distribution of its industrial products while providing A-B with products complementary to its PLCs.

DSI products are structured so that they fit in with A-B's control hierarchy and are developed according to what A-B's salespeople can sell and what customers want to buy. Thus, product development centers around the architecture of A-B's computer equipment and control equipment and the sales approach that A-B's salespeople take.

To reduce the risk inherent in relying on one customer for business, DSI has diversified its products to customers, but has done so within the A-B family. DSI has accomplished this by cultivating relationships with four product development organizations at A-B. These organizations are within two business groups: the Operator Interface Logic Division and the Industrial Control and Communications Group. Since these business groups are like individual companies, they represent two different and distinct "customers."

DSI has an application support group that is working toward more direct contact with the customer. Through the efforts of this group, DSI hopes to better understand and serve the end-user.

## RESULTS

DSI contends that the single biggest thing that differentiates it from its competitors is the Allen-Bradley logo and the Allen-Bradley sales force. DSI has benefited in several ways from the agreement with A-B. The A-B arrangement provides DSI with strategic advantages that include:

- A large and strong distributor network, ensuring a solid basis for future growth
- The advantages of A-B's worldwide reputation for quality and service
- Access to the worldwide market

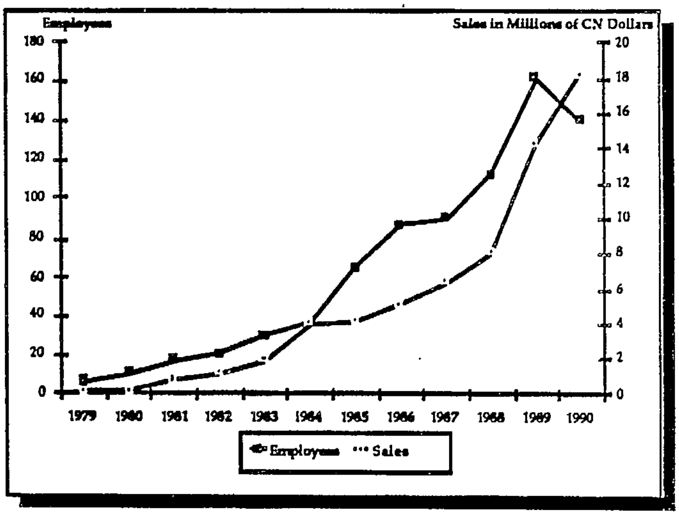
A-B distributors, which number as many as 500 worldwide, not only stock A-B products but also provide local sales and product support services.

As a small company, DSI felt that it lacked the resources to enter the global marketplace, or even the U.S market. The A-B partnership has provided the resources to do this.

In the eleven years of its existence, the company has experienced a dramatic growth in its workforce and in sales. Chart A shows the progression of this growth. In 1976, DSI consisted of its three founding partners; today the company employs 140. These employees include software, hardware and mechanical engineers and technologists as well as manufacturing personnel. In 1990, DSI reduced its workforce to counteract unrealized sales expectations. This was the result of delays in the introduction of a new product that took longer than anticipated to develop.

Rapid growth has necessitated moving to a new location almost every five years. In spring of 1991, DSI will move into a new 92,000 square foot plant and head office on Annacis Island, Delta located near Vancouver.

**CHART A**
**NUMBER OF EMPLOYEES AND SALES**
**1979-1990**




As a result of its relationship with A-B, revenues for DSI have increased dramatically in the past few years. Sales have grown from over $8 million in 1988 to about $14 million in 1989, reaching over $18 million in 1990. About 15% to 20% of this revenue is derived from sales outside of North America.

EPIC DATA
Richmond, B. C., Canada

## BACKGROUND

### The Company

Established in 1975, Epic Data is the brainchild of twin brothers Helmut and Hugo Eppich. Helmut Eppich is the founder of Ebco Industries, Epic Data's parent company. The Eppich brothers needed a computerized system for tracking shop floor information for their manufacturing and fabrication operations at Ebco Industries. Data collection systems on the market at the time did not meet Ebco requirements, so Helmut Eppich became chief architect of his own system. This became the flagship product of Epic Data. The Eppich brothers still maintain a 51% majority equity position in the company.

Norman Cafik, president of Epic Data during the 1980s, was a tool and die maker who progressed to tool and machine designer, process engineer, printer and publisher. He served as a member of Parliament and Cabinet Minister from 1968 to 1979, joining Epic Data in 1979. Cafik now holds the position of Vice Chairman at Epic Data.

Epic Data's current president, Alex Klopfer, is a Hungarian who escaped from his homeland to Australia in 1956. Originally trained as an electrical engineer, Klopfer spent 21 years in sales and marketing at IBM. Klopfer has a background in engineering science and electrical engineering.

Products are marketed worldwide. Epic Data maintains regional sales offices in Canada, the U.K. and throughout the U.S. The company has representatives in several locations including the U.S., Australia, Norway and Korea.

Ebco Industries is comprised of several autonomous business units including Epic Data. Other entities owned by Ebco include heavy fabrication and machine shops, light metal fabrication, tool and die, and metal finishing companies. In addition, the parent company operates an aerospace division and Ebco Technologies, which focuses on applied particle accelerator systems.

Epic Data became publicly held in 1985.

### Product Line

Epic Data is a supplier of data collection terminals, software and related consulting and support services, including systems analysis, design, integration, preparation and training. The company's data collection equipment is primarily employed for time and attendance and maintenance (tracking of time and materials).

Products sold by Epic Data are generally developed in-house.

### Size and Strength

Epic Data reported sales of $31 million in 1988, with net earnings of about $1.1 million. Sales declined to $22 million in 1989, recovering somewhat in 1990 to $26 million. The company suffered a net loss of nearly $6 million in 1989. Declining defense contracts in 1989 contributed to a 30% decrease in sales of factory floor data collection systems. R&D expenditures for Epic Data amounted to $4.4 million in 1989.

The company sold about $6 million in services in 1990. Much of this revenue came from maintenance contracts. Over 90% of Epic Data's revenue is derived from export sales. Most of these export sales go to the U.S.

During the 1980s, Epic became heavily dependent on defense contracts. Norman Cafik, the company's president at that time, had arranged defense contracts through contacts developed while a member of Parliament. Cafik's tenure coincided with the U.S. arms buildup under President Reagan. By 1988, about 58% of Epic Data's revenue came from defense contracts. The company has been working toward reducing its dependence on the defense industry. In 1989, defense contracts accounted for only 25% of revenue, primarily due to trailing off of these contracts. Contracts with large airlines took up some of the slack and were responsible in part for this change in business mix.

In 1990, Epic received a $5 million financing from Discovery Enterprises Inc. This money was applied to the mortgage on the head office and plant, shoring up existing bank credit and funding marketing and development. Due to the tight equity market, the company is relying on self-financing for the time being. This is slowing research and development and expansion in Europe and the Far East.

To return to profitability, Epic has taken several cost-cutting measures. These have been in the form of staff reductions, cutbacks in promotion expenditures and reduction of inventory from $6 million to $2 million.

Ebco Industries has consolidated annual sales of approximately $100 million and employs over 900 people. Epic Data has about 200 employees.

**Competitive Environment**

Intermec, IBM and Epic Data are considered the leading suppliers in the market for data collection systems. Epic Data considers IBM its most formidable competitor. Epic views name recognition and customer-perceived availability of service and support as IBM's primary strategic advantages. Intermec operates at the low end of the market, selling systems for relatively simple uses; Epic Data is not generally in direct competition with Intermec.

In various reports, Epic Data has been assessed as having from 5% to 22% (depending on how the market is defined) of the worldwide market for data collection products. A study by Automation Research Corporation reports that Epic Data held 12.7% of the nearly $250 million 1988 market for bar code terminals. Epic Data is likely in the number two position, holding about a 6% market share behind IBM which has 18% of the worldwide market for data acquisition products.

## COMPETITIVE STRATEGY

**Product/Service Strategy**

Epic Data takes a customer-responsive approach to product development. This strategy includes listening to customer needs and designing products in response to those needs. Customers are demanding systems that are easier to configure and faster to get up and running. In the large, complex systems installed by Epic, this is a particular challenge. Epic's strategy includes:

- Offering the customer a total solution, thereby easing system installation and integration problems
- Providing products that are:
  - Easier to configure and user friendly
  - Flexible
  - Hardware-independent

**Positioning Strategy**

Epic Data has positioned itself as a supplier of complex, high-end data collection systems, primarily for the aerospace and defense industry; however, the company has expanded its focus to include the airline and printing and publishing industries. Most revenue in the data collection industry is derived from projects of $100,000 or less. Epic's contracts are generally for $250,000 or more.

Background and reputation, including prior installations and references from customers, are important selling tools in Epic's industry. The company promotes an image as *the* premier supplier in the data collection industry. Epic Data products are positioned as slightly more expensive, but of the highest quality.

## STRATEGY IMPLEMENTATION

**Products and Services**

**Customer involvement** is strong in new product development. Epic estimates that 75% percent or more of new products have been developed primarily from customers' requests. New products have often resulted from building a product for one customer and then selling it to others.

Also an indication of the company's customer-driven product development is Epic Data's use of market research in developing the next generation of products. This approach was taken for Epic Data's new multipurpose terminal, the MPT. About two years ago, the company's main customers and a few prospects were surveyed relative to what they felt was needed in the ideal terminal. Epic Data discovered that its customers want flexible (multifunctional) terminals that offer superior performance at a reasonable price.

**Hardware improvements** made by Epic include design of less hardware-dependent systems and use of chips with greater functionality. The company is moving away from use of its own proprietary hardware platform toward an Intel-based platform. As such, this supplier is selling a greater proportion of software than 10 years ago, when most of its sales were in controller hardware. Epic Data can now sell its customers a software package that will run on hardware the customer already owns or can purchase elsewhere.

Based on customer demand for faster, more capable products, Epic Data's controllers will utilize a 486 chip within 2 years.

**Integrated functionality** is a capability that the company has built into its latest product, the MPT. This is aimed at providing greater product flexibility. The company has developed an option cartridge that includes several functions. Enhancements or customizations are designed into this option cartridge.

### Positioning

Epic Data has positioned itself as a supplier of complete solutions by offering all the elements required in data collection systems This includes hardware, software and system integration services.

The company maintains its position in the high end of the market by targeting complex and large applications. For example, Epic's systems contain as many as 1500 terminals connected to one controller. The average application for the data collection industry handles about 128 terminals.

### Reduced Dependence on Government Business

Typically, aerospace and defense applications are large and complex, making these segments likely targets for Epic. However, in its plan to reduce dependence on the defense industry, Epic is is shifting its focus to the airline and printing and publishing industries. In 1989, Epic added 41 new customers to its list and accelerated penetration of these new markets.

In addition, the company expects to increase its exports to Europe. Exports outside of North America amounted to about 8% of Epic's business in 1990. In 1991, the company plans to increase this to about 14% of sales.

## RESULTS

### Business Mix

Epic Data is recovering from the staggering loss incurred in 1989. Recovery measures taken by the company in the area of cutting of expenditures and pursuit of non-defense markets are beginning to show positive results. Net losses in 1990 were reduced significantly over losses in 1989. For the first three quarters of 1990 net losses totalled $143 thousand, compared to $2.5 million for the same period in 1989.

Over the past two years, Epic Data has worked to decrease its dependence on the defense industry. Revenue from defense contracts has been reduced slightly from 58% of overall sales in 1988 to 52% in 1990. However, a major turnaround in the company's business mix will require time. The lion's share (perhaps 80%) of the company's sales is still derived from repeat business. Epic is pursuing other markets, including those in Europe. Up until a few months ago, the company maintained one office in England. Offices are being opened in Germany and Switzerland. Other locations are under consideration as well. The company anticipates that this will contribute to bringing in business from new segments.

While Epic is making progress in bringing in new customers, it takes time to realize profits from a new customer base. Studies indicate that long-term customers generate greater profits over time than do new customers. Profits from loyal customers tend to grow each year they remain with a supplier due to increasing sales to the customer and declining operating costs associated with repeat business. On the other hand, acquiring new customers often involves one-time costs for items such as personal sales expenses, advertising and promotion. The combined effect of the reduction of long-term customers in its traditional defense market and the addition of customers in new markets must be overcome before Epic can significantly profit from its new business mix.

### Products

For large and complex applications targeted by Epic Data, sales cycles are relatively long, typically running from 12 to 18 months. One approach to shortening sales cycles is to design products that are faster and easier to configure for the customer's application. Epic is banking on this benefit from recently introduced products that have been designed to be flexible and easier to understand and configure. While it is too early to assess the effect, Epic is hoping to achieve a 6 to 12 month sales cycle.

Epic's products have become less hardware-dependent. The company is now capable of selling its customers only software packages. This move away from low margin, support-intensive hardware products, toward higher margin software is likely to yield enhanced profits.

## F&P MANUFACTURING INCORPORATED
Tottenham, Ontario, Canada

### BACKGROUND

**The Company**

F&P Manufacturing is a component supplier that started a stamping plant recently with the encouragement of Honda of America. It is one of the companies that have followed the Japanese automakers from Japan. F&P is a subsidiary of Fukuda Stamping, a major Japanese stamping producer which has a close supplier relationship with Honda in Japan.

**New Plant**

F&P started operations in Canada with a greenfield plant in Tottenham, Ontario. It selected the site because it was near the Honda Allison facility. The choice was also based on a number of other criteria. F&P chose to place its plant in Canada rather than the United States in order to take advantage of the cost savings of lower utility rates and the benefits of the local labor force. As well, the company wanted to have access to a supply of qualified workers in an environment with a history of good labor relations.

F&P is currently at full capacity, selling all of its production to Honda. Eighty percent of the components it manufactures go to the Honda plant in Marysville, Ohio.

The stamping plant was built at an initial cost of $73 million, of which $43 million was equity. The majority of equity funding was provided by Fukuda Stamping, but Honda of America put up a 35% stake.

**Products**

The company currently produces 25 different parts for Honda, adding to that number every year. Over the past 12 months, five more parts have been taken on. The major components supplied to the automaker are the pedal assembly for the Accord and suspension parts for all Hondas manufactured in North America.

**People**

F&P currently employs 350 people in its Tottenham facility. Of these, 55 are engineers. There are 15 Japanese employees; these are people that the parent has sent over for a 2 to 5 year time period. One of the permanent Japanese employees is the president of F&P.

### COMPETITIVE STRATEGY

**Global Strategy.**

The Canadian facility is an integral part of the Fukuda Press global strategy to have a marketing presence outside of Japan, to build its volume and experience base, and to grow. The parent is expanding its operations in Canada to be better able to supply its best customer, Honda, from a North American manufacturing facility. Currently the R&D and design work is still carried out in Japan, but it is the corporate goal eventually to move both of those functions to the Tottenham plant. The design function, which is both product and process design done concurrently, will be tied in via satellite to the Japanese design group in 1991. R&D will be tied in at a later date.

**Canadian Strategy**

The corporate strategy for F&P in Canada is to perfect its production capabilities working closely with Honda, and then branch out to other customers. It plans to implement a niche strategy, starting with one model from one manufacturer, and grow from there. The company is seeking constant steady growth when it is able to handle the additional work.

Before F&P seeks additional business, it tries to perfect both production techniques and technology required to move to the next step.

**Competitive Standing**

Competition for Honda's business comes from a number of sources. Although there are no local suppliers with the advanced design and production know-how that F&P has in conjunction with its parent, there are several North American suppliers that could take the business from the company if Honda were dissatisfied. The major competition for the business comes from its parent. If F&P cannot supply parts with the same quality and cost that Fukuda can, it will lose the business to its own parent. There are very few North American stamping companies that can do a complete assembly from design to prototype to manufacturing through welding, painting and assembly as a Tier I supplier. But the window of competitive superiority is a temporary one. The company feels that within five years, the North American component manufacturers will have capability to compete on the same basis. F&P has five years to establish relationships with the North American automotive companies on the basis of a more complete manufacturing capability.

## STRATEGY IMPLEMENTATION

### Advanced Manufacturing

In order to provide its customers with the quality that will ensure its own success, F&P has implemented both advanced manufacturing technologies and management techniques. Among the management techniques that it has successfully used are just-in-time manufacturing, total quality control, concurrent engineering, and a human resource strategy that seeks to make all the employees more efficient. The company has also invested in all appropriate automation for the current state of its production requirements and employee knowledge. As well, F&P has continued its investment in equipment as more advanced manufacturing technologies could be successfully utilized.

### Just-In-Time (JIT)

The just-in-time philosophy is an extension of the JIT requirements that the company has to meet for Honda's production requirements. It is a very serious commitment to be so closely tied to a production facility hundreds of miles away across a national border. F&P has never missed a production schedule. Trucks go out daily with deliveries for the Marysville plant. The company is proud that there are only three days between its line and shutting Honda down. The only time that delivery was problematical was last summer when the Detroit-Windsor border was blockaded. Parts were shipped by air freight. Its own commitment to JIT includes developing a five to eight minute die change in its own stamping machines and minimal inventory in its own lines.

### Total Quality Management

Total Quality Management at F&P is ensured with its quality assurance program. For F&P, total quality has two aspects, quality control and quality assurance. The quality control is the same basic inspection that most stamping plants do at the end of the line to see that the customer's specifications are being met. The quality assurance is the philosophy that builds in quality at every step in the process. It is partially a result of the product/process design, and partially from building in employee awareness of quality requirements and the critical role they play in assuring quality. Ultimately, quality control will entirely give way to quality assurance as the employees are all brought through the training program.

### Employee Training

Every new employee is given a three day orientation to become familiar with company procedures, to work on the line for a couple of days, and to have a complete tour of the factory to have a thorough understanding of how everything works and fits together. It is important to F&P that every employee understands how every facet of each part is manufactured.

Employee training is given a lot of attention at F&P, and the company considers the training a long-term investment in its ability to compete. Because of the commitment to long-term employment, F&P prefers to hire recent college engineering graduates and graduates of trade schools for its technical requirements. Both types of employees are on the same training track for the first several years, receiving the same rotations through the departments and the same on-the-job training. On the floor, everyone works together. The associates with trades backgrounds are offered classes to give them the technical education they did not get in a classroom setting at school. Over a multi-year period of after work classes provided by the company, the associates will be able to progress steadily and ultimately become engineers. The production workers are also offered the opportunity to get into the same training program and over time advance into production engineering. For more advanced engineering, completing the academic training and on-the-job rotations is required. The company offers all workers the opportunity to advance.

### Advanced Manufacturing Technologies

The company had made extensive ongoing investments in advanced automation equipment. Half the original investment was devoted to equipment purchases, and F&P has increased that investment every year since. The additional investment has been made to replace manual operations gradually with automation and to increase the production capacity of the facility as more parts are made.

F&P tends to use the same equipment as its parent. When the facility was planned in 1985, the parent's use of automation was much lower than it is today. This is particularly true in the welding operation. When it was set up, manual operations accounted for 70%, today that figure is down below 20%. The operation always used robots for the welding; the robots were developed by the parent for its own use. Material handling has become gradually more automated so that only one manual process is left in the welding area. The department has gone from eight workers in 1986 to four today. People released from the welding operation were needed on the technical side to maintain the new equipment.

One goal of the company is to use local equipment to the greatest extent possible. The new welding robots were sourced locally as was some of the assembly equipment. The company estimates that within 5 to 8 years it will be able to source its dies and molds locally also.

**Continuous Improvement**

In order to analyze whether to automate a process, the company takes a close look at the problems that exist in the process. If there are quality problems, then the automation that would allow tighter tolerances and reduce the human element in the production process would be evaluated. If the automation were needed to increase capacity, perhaps to move from a production of 800 parts to 1200 parts so that an additional car model could be accommodated on the same equipment base, then automation offering greater efficiency would be welcomed.

With the automation that has been added since the plant went on line in 1986, the production has been expanded every year, the quality of the parts has steadily improved, and the work load per employee has been reduced. Without the new equipment the work load on the employee would have increased substantially. In the automobile industry, single components are getting heavier as the number of individual parts decreases. Without the additional automation in material handling, the weight that the employees would be required to maneuver manually would have increased substantially.

The next automation project planned is a design system tied into the parent's CAD/CAM system via satellite. This will allow the Canadian subsidiary to be more independent in design. The long-term objective is to be able to support its North American customers in both R&D and component design, as the parent does for Honda in Japan.

## RESULTS

F&P is one of Honda's favorite suppliers. The company regularly increases the amount of business it does with Honda, and is always at capacity. Honda is not easy to please. One $30 million per year American auto parts company, Variety Stamping of Cleveland, went into bankruptcy trying to make Honda happy, losing existing General Motors contracts in the process. Honda indicates that Variety Stamping lacked the engineering capability and financial depth to handle its workload and meet its standards. According to Honda, Variety couldn't grasp its business philosophy.

The results of the automation that F&P has invested $75 million in over the past 4 years can be seen in its ongoing plans to continue the investment. After the plant is finally at the level of production it wishes to sustain, it still expects to add automation at a value of between 3% and 5% of sales every year. As the company says: "It's part of doing business. It's part of being competitive. It's part of being global. You have to do it."

F&P manufacturers over 550 thousand units a year for Honda of America, worth $100 million. The relationship is steadily growing.

The objectives that F&P was trying to obtain from the automation project were in the area of quality, efficiency and a lighter work load. In setting goals, the management did not consider cost savings to be a primary goal. If the other objectives are met, lower costs follow.

GENNUM CORPORATION
Burlington, Ontario, Canada

## BACKGROUND

### The Company

Gennum Corporation is a manufacturer of linear integrated circuits, primarily used in audio amplifiers. The company is a wholly-owned subsidiary of Linear Technology Inc. (LTI), a Canadian high technology designer and manufacturer of electronic products. Formed from a management buyout from Westinghouse in the late 1970s, LTI became publicly-owned in the early 1980s.

### Size and Strength

LTI had sales of nearly $23.2 million in fiscal 1989. Sales of Gennum products account for most of STI's business. Net income for this period dropped to $2.7 million in 1989 from $3.5 million (on sales of $22.5 million) in 1988. Change in business mix is cited as the basis for the decline in net earnings.

In 1989, most of LTI's business came from the U.S. and Western Europe. U.S. customers accounted for about 43% of LTI's sales in 1989, while almost 40% of sales were made to Western Europe.

Sales made by Gennum to the hearing instrument industry in 1989 were down 12% from 1988. Gennum's sales for fiscal 1990 were down 20% from the previous year. The company's largest geographical market is the U.S.

Gennum maintains a workforce of nearly 200 people. Over one-third of these are scientists, engineers and technologists. All company employees share in profits; over 90% of employees are stockholders of the LTI.

### Product Line

LTI's major product areas are silicon integrated circuits and hybrid circuits. Silicon integrated circuits are produced by Gennum Corp.; hybrid circuits are manufactured by another subsidiary, Anatek Microcircuits Inc. of Vancouver, B.C. Because outside sources of appropriate materials are not available, Gennum also operates its own silicon foundry.

Products manufactured by Gennum fall into three product groups:

- Linear bipolar circuits, or BiFETS, in the form of both chips and packages for low voltage, low current systems such as hearing instruments

- Application-specific integrated circuits (ASICs) for use in products such as high frequency power supplies, video signal switch matrices, and speech recognition systems and custom and semi-custom, user-specific integrated circuits (USICs)

- Integrated circuits for radio frequency (RF) uses including microwave, radar and cellular radio systems

Gennum products are custom designed. These electronic products are engineered with the final product assembly in mind. Gennum's manufacturing engineers provide the customer with all assembly specifications. This service is especially important for new, small integrated circuits, since they are often difficult to assemble into the final product.

### Competitive Environment

The hearing instrument industry experienced a contraction in 1989. For the two years preceding 1989, the industry experienced an above average expansion. The downturn in 1989 is attributed to the saturation of a largely replacement market in the U.S. following the introduction of miniature in-the-canal hearing aids in 1987. Reduction of government subsidies for hearing aid purchases in part of the European market also adversely impacted this market. The industry is showing signs of returning to its historical annual growth of about 6%.

The worldwide market for integrated circuits for hearing instruments is estimated at $23 million. To date, the Japanese have shown little interest in this relatively small market. As the only Canadian supplier of this type of integrated circuits, Gennum has no significant domestic competition. The major competitors include Gennum and Cherry Semiconductor of New Jersey.

Gennum commands a large share of the international market for hearing instruments. Gennum reports that it has between 64% and 70% of the worldwide market and supplies products to every major manufacturer of hearing instruments in the world. Products are sold in several countries including Great Britain, Germany, Denmark, Switzerland, Holland and Japan.

Integrated circuits for the hearing instrument business are high margin products that are subject to little price sensitivity.

## COMPETITIVE STRATEGY

### Advanced Manufacturing

The manufacture of a quality product and on-time delivery are important components of this company's strategy. Reduction of manufacturing cycle time and increased product quality have been key drivers in adopting new management techniques and advanced manufacturing technologies. Maintaining the capability to develop the products needed for a dynamic global market also drives utilization of new technology.

### Serving Customers Large and Small

Hearing instrument customers range from large manufacturers like Siemens and Belltone to small "mom and pop" operations. Gennum makes an effort to help keep smaller customers in business. If the market were dominated by one large customer, Gennum would be subject to the demands of that customer.

### Diversification

To achieve greater sales growth, Gennum plans to diversify into larger markets such as the video broadcast industry for which is now makes switches.

## STRATEGIC IMPLEMENTATION

### Marketing Programs

The company strives to implement its niche strategy through a balanced combination of opportunity identification, product specification and development, and appropriate production technology. Gennum is actively working at further penetration of its primary market as well as diversification into other markets. The company recently began marketing switches for video broadcasting. The switches are intended to be a springboard product for gaining a foothold in the broadcasting industry. In late 1989, Gennum's Tokyo office was upgraded to a branch office. This is expected to facilitate penetration of the potentially large Japanese market for video broadcast products and power controllers.

### Staying in Touch With Technology

To remain current on state-of-the-art technology, Gennum maintains affiliations with the scientific and engineering departments of three Canadian universities. In addition, the company makes substantial investments in R&D and new facilities.

### Design Automation Tools

Computer-aided design and simulation programs are a major component of the product development process. CAD is used to shorten design time and cost and increase reliability. Simulation programs are used to optimize design and check circuit performance.

### Manufacturing Techniques

Gennum utilizes techniques such as JIT, concurrent engineering and quality management. A four-phased approach has been adopted in product design and manufacture. The first phase involves the cooperation of the marketing and design groups. In phase two, design and testing work together to engineer the product. The third phase consists of a collaborative effort that includes production engineering, manufacturing engineering and test. In the final phase, production manufacturing takes over making the final product.

Gennum's use of quality teams has been most successful in the silicon operation, where quality management has been applied to the manufacturing process. Attempts at using this technique to improve areas such as service (e.g., answering phones) or interdepartmental cooperation have been less successful.

### Manufacturing Technology

Several of the activities in the assembly of the company's products are highly operator dependent in terms of quality. Direct operator involvement in these areas has accounted for a large part of product quality problems. Therefore, elimination of the operator, wherever possible, is highly desirable. Gennum has set about automating these key parts of the manufacturing process. The number of human material handlers has been significantly reduced. Since the early 1980s, the company has been automating assembly operations using computer control for activities such as wire bonding. This has been a process of evolution that is still ongoing. Automation of the assembly process is tackled in an incremental manner. Gennum proceeds slowly, gains some success and then moves forward to automate other areas.

Throughout both wafer fabrication and chip assembly operations, statistical process control (SPC) is employed to monitor consistency and quality as products move through each step of manufacturing and assembly.

### MRP II

In 1986, Gennum installed an MRP II system. The system, however, did not function throughout the company and failed to meet the needs of the silicon manufacturing group. A new MRP II system is slated to be finished by December of 1990. The new system, which was purchased at a cost of about $35,000, will operate throughout the company. The Director of Assembly Operations at Gennum has been a key force in adopting the new MRP II system, which is intended to integrate all operations within the company including silicon manufacture, integrated circuit manufacture and customer orders. To assure success of the new system, a team was assembled consisting of a decision-making core group and members representing all operating groups including finance, purchasing, mass production scheduling and marketing. The project manager, V.P. of Finance, and Director of Assembly Operations are the core group.

### Employee Culture

A key means of realizing Gennum's competitive goals over the past four years has been creation of a culture in which people want to succeed. The company has used delegation downward within the company to effect this culture change. Through delegation, Gennum finds that engineers and operators provide valuable input on how to improve quality and cycle times. This approach is evident in the way Gennum is handling some of its AMT projects.

## RESULTS

### Positive Results

Gennum has realized the following benefits from new management concepts and advanced manufacturing technologies:

- Reduced design and product manufacturing times
- Higher product quality
- Reduced manufacturing costs
- Improved ability of employees to work together (e.g., operators and engineers)

JIT manufacturing methods have resulted in shortening of cycle times from 31 days to 8 days. This translates to less work-in-process and a shorter order cycle time (currently 4-6 weeks, down from 12 weeks before JIT).

Increased use of AMT has allowed the company to decrease the number of operators by 20% over the past four years. Greater reliance on more sophisticated equipment rather than skill of the operator has resulted in a corresponding increase in product quality. Displaced operators have been retrained to handle different types of tasks, including overseeing the automated manufacturing process and performing SPC. In essence, they are trained to perform higher level tasks.

Defective products have been reduced from 3,100 parts per million (PPM) four years ago to a current level of about 100 PPM.

### Negative Results

Gennum cited two instances where attempts to implement new management concepts or manufacturing technologies did not meet expectations. First, the initial MRP II system was put in place in a top-down fashion. Management said, "Here it is. It's good for you." The program was not universally applicable and some areas in the company did not buy into the system. Gennum expects greater success with its new MRP II system for which all departments' needs were considered in the system design.

A second project that yielded unsatisfactory results was in the use of quality teams to change the culture within the company. Gennum found that this program was unsuccessful in effecting cultural change.

## HUSKY INJECTION MOLDING SYSTEMS LTD.
Bolton, Ontario, Canada

### BACKGROUND

#### The Company

Husky is a manufacturer of injection molding machines, molds, parts handling and robotics for the injection molding industry. The company had its beginnings in 1953 in a garage where founder Robert Schad built a snowmobile. Schad was unable to market the snowmobile he had built. Therefore, Schad decided to devote his resources (his experience and his little shop in a garage) to the business of making molds. Schad's background is in tool making and engineering.

In response to customer needs for a machine that could operate consistently at thirty shots per minute, Husky began building injection molding machines in 1961.

From the start Husky began to export. The company had begun manufacture of a group of custom machines for a Canadian customer. When the customer cancelled the order, Husky sought a market for the machines. The machines were exhibited at a trade show in the U.S. and were well received.

In 1990, Husky formed an alliance with Komatsu, a Japanese manufacturer. Under the agreement, Komatsu now holds a 26% equity position in Husky; in four years, Komatsu can achieve up to 50% ownership of Husky, with employees holding the other 50%.

Manufacturing facilities are maintained in Bolton, Canada, Boston, MA, Germany and Luxembourg, where Husky has its European headquarters. The company has sales and service offices worldwide. It recently opened a wholly owned subsidiary in Japan to provide local sales and service to Japanese customers.

#### Product Line

Husky supplies both complete systems and system components. In addition to injection molding machines, robots and molds, the company is in the hot runner business which represents a substantial part of its sales ($14 million in 1990).

Types of plastics machinery sold include horizontal injection, unscrewing machines, toggle machines and tandem molding machines.

Husky manufactures injection molding machines with clamp capacities ranging from 160 to 3,650 metric tons. Operator interfaces in the form of industrially hardened personal computers (PCs) are offered as an option.

Robots and product handling equipment sold include top and side-entry robots capable of carrying up to a 180 kg load at speeds up to four m/sec with positioning accuracy within 0.1 mm. They function in applications such as oriented parts removal, pick-and-place, insert loading and stacking.

A consulting program to design complete plants is also offered. Husky has a systems engineering group dedicated to complete plant layout scanners.

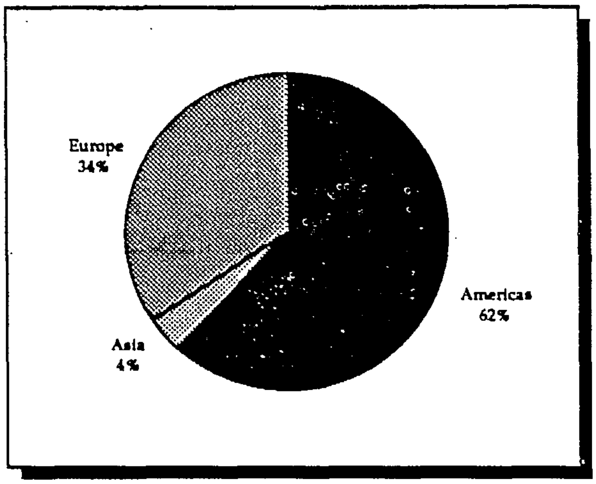
#### Size and Strength

Husky's sales in fiscal 1990 amounted to approximately $202 million. Sales have shown steady growth of over 20% annually throughout the 1980s. The company is currently funding R&D at a level of 5% of sales.

Most of Husky's equipment is exported; exports represent about 90% of sales. Sales in the U.S. account for a large portion of this business, totalling 50% of Husky's sales. Sales of molds represent about half of the company's business.

The company now has about 1,000 employees worldwide with 700 employees in Bolton, Ontario.

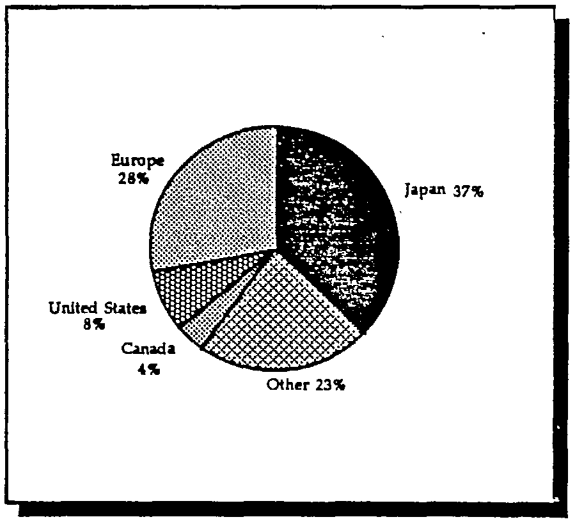
CHART B
HUSKY SALES
BY GEOGRAPHIC REGION 1990




In addition, it supplies hot runners to a large number of moldmakers. Other products sold include standard machines and robots.

Currently the company is strongest in medium size injection molding machines. Smaller size machines will be supplied by Komatsu. In the larger sizes, Husky is just starting to penetrate the market. The company's most formidable competitors are German and Japanese companies. Cincinnati Milacron is Husky's strongest North American based competitor.

CHART C
WORLD PRODUCTION OF
INJECTION MOLDING MACHINES
1988 - U.S. $3.69 BILLION




Source: **Business Trends Analysis, Modern Plastics and Husky Estimates**

### Competitive Environment

There has been a decline in the overall number of market players due to mergers and acquisitions and failures of some smaller players (e.g., Reed and Natco in the U.S.). This has resulted in fewer, but larger, competitors. In addition, the generalists are disappearing; specialists are teaming together to become a more powerful force in competing in the global marketplace.

The 1988 total world market for injection molding machines was estimated at about U.S. $3.7 billion. The market has been growing at a rate of approximately 5%; annual growth is expected to decline to about 2%. In the size ranges sold by Husky, the 1988 market for machines and molds is estimated at U.S. $7.2 billion.

Husky's 1990 overall market share was estimated at 2.5%.

Husky divides its sales of injection molding systems into four major markets:

- Polyethylene teraphthalate (PET)
- Packaging and closures
- Automotive
- Other selected markets

Husky attributes continued product development as the single most important factor to improve global competitiveness.

## COMPETITIVE STRATEGY

### Competitive Goals

Husky's goals are ambitious: to become a leading worldwide supplier of injection molding systems to the plastics industry by the year 2000, with sales of $1 billion and a market share of 15%.

The company plans to extend its image as a top-of-the-line, high quality, specialized systems supplier to all segments of the injection molding market.

**Product Strategy**

Specialization has been one of the keys to the company's success, Husky contends. In the 1960s, Husky built an injection molding machine that was the fastest in the world and targeted a special market. In order to capitalize on this development, the company thought globally. Due to the uniqueness of its product, Husky was able to sell the technology at premium prices all over Europe and even in Japan.

Husky takes a modular approach to machine design. This enables the company to build each machine or system to meet the customer's individual needs.

In conjunction with Komatsu, Husky plans to offer the most extensive product line of the industry. This product strategy includes:

- Modular Machine and Mold Program — Through the establishment of a modular design for all machines and molds, even the most sophisticated special purpose systems can be built from the base up in record time. The resulting product line allows the customer to select the precise performance specifications required for any application. This program should result in substantial savings in manufacturing cost and improved quality. Through performance pricing for the specific application, Husky's product should be within reach of the average processor.
- Strategic Mold Partners — Through alliances with specialized moldmakers, penetration into new systems markets will continue.
- Hot Runners and Robots — Through the sale of hot runners and robots to a wide group of moldmakers and processors, many new accounts will be opened up. In addition, the combination of these programs provides a powerful opening in all markets for machines, molds or the complete systems approach.

**Human Resources**

Training and employee ownership are high priorities in Husky's strategic plan. Husky contends that these are critical to maintaining an entrepreneurial environment and to achieving speed — the speed necessary to satisfy customers with the technology and quality product it needs to compete globally.

Husky's competitive strategy includes attracting and keeping the best employees in the industry by creating an attractive work environment.

**Technology Transfer and R&D**

Husky believes that hands-on collaborative efforts with customers are a key method of technology diffusion, systems development, integration and training.

**Sales Strategy**

Further strengthening of the company's international sales organization will center in the three geographical regions of the world: America, Europe, and Asia.

Staying close to the customer is a key fact of Husky's sales strategy. This implies an intensive service-oriented relationship.

**Long-Range Planning**

By investing in more advanced manufacturing equipment, Husky looks for technological advantage, not fast payback. The goal is to maintain the technological edge for as long as possible with each equipment purchase. In an era where many companies expect a one-year payback, Husky considers a five-year payback period as its goal.

Husky compensates for the high cost of labor by being capital intensive, investing in the specialized technology and thereby, attaining speed in manufacturing new products.

## STRATEGY IMPLEMENTATION

### Changing Environment

The plastics machinery industry, Husky contends, is undergoing severe structural change characterized by consolidation, globalization of markets, high cost of capital and rapid introduction of new technology. To meet these challenges, Husky sees a need for substantial investment in people, facilities, equipment, and research and development. As well, a strengthened organization is required to attain the economies of scale and efficiencies needed to reach the long-term objective.

### Human Resources

Husky has established extensive training programs and relationships with colleges and universities to ensure its employees receive the best possible training. Through cooperative programs with the University of Waterloo, the company is obtaining a number of top graduates each year. Over 60% of the company's labor force is highly skilled. More than 40% have received Husky sponsored training in the past year through either internal or external programs. Training programs include 3 to 4 year apprenticeships for machine operators. The company generally selects only employees with a strong technical background.

Husky utilizes employee empowerment to foster success. A team approach is used for all its major projects. The company finds that this creates a winning spirit and an environment of innovation and vision. The team is assembled without regard to turf, and is based strictly on those who can make the best contribution to the job at hand. Teams may consist of young and less experienced graduate engineers who may even act as captain of a project team. While the less experienced are sometimes given much responsibility, they are surrounded by experienced members that keep the team on track. According to Husky, teaming promotes excellence in performance and accelerates learning in employees.

Employee participation has been encouraged by initiating programs that include stock ownership, profit sharing and an employee counsel.

### International Manufacturing, Sales and Service

Within each geographic region where the economies of scale justify, regional manufacturing will be established. Strategically located area offices offering the industry's most complete product line allow for high density sales and service networks. This in turn gives Husky better local customer support and backup than provided by competitors. A strong position in molds and hot runners keeps Husky in close contact with the customer. This implements the service orientation strategy, casting the Husky salesperson as a critical member of the customer's team.

Husky uses what it calls the "McDonalds approach" in its area offices. The offices are set up much like franchises. When something is needed, the area office can bypass corporate channels, for example, go directly to an independent mold maker to get assistance. This is one example of employee empowerment. Husky is responsive to the differing product requirements in its regional markets. Instead of pushing a standard product line everywhere, Husky develops products that are in demand in its area offices' local markets as defined by its local people.

### Research and Development

R&D is an important component of Husky's competitive strategy. Subject to financing, Husky plans to expand and advance its specialized manufacturing operations and to build a Technology Center to develop automation of the injection molding process in a laboratory environment. These systems will be developed in alliances with processor, resin manufacturers, institutions and suppliers. The Center will also be used as a training ground to ensure that personnel are trained in the use of technologies developed in the Center. This unique approach will further promote Husky's image and provide a showroom for Husky's technology.

### Strategic Alliances

To further its strategic goals, Husky has entered a partnership agreement with Komatsu, a Japanese manufacturer of construction equipment, industrial machinery and small injection molding machines. The two companies have a complementary product line. Komatsu builds injection molding machines between 30 and 160 tons. This size equipment will fill out Husky's line to cover machines from 30 to 3,600 tons.

## RESULTS

Husky's financial turnaround during the past decade gives testimony to the company's ability to develop and implement a long-range competitive strategy. The company's ability to focus on long-term goals is likely the key to Husky's staying power in an industry that has experienced slow growth and consolidation in recent years. Sales for Husky have steadily improved over the last ten years. In an industry that has experienced a 4% to 5% annual growth, Husky sales have been growing at a rate of over 20% per year for the past 10 years.

Husky's commitment to up-to-date equipment and modern manufacturing techniques have enabled it to double its business over the past four years while increasing employee count by about 50% (see charts).

The equity participation of Komatsu is expected to enhance Husky's capital and technology as well as its ability to compete in the Japanese market. Additionally, the Komatsu product line will fill out the range of Husky product offerings.

CHART D
HUSKY SHIPMENTS
1980 - 1995

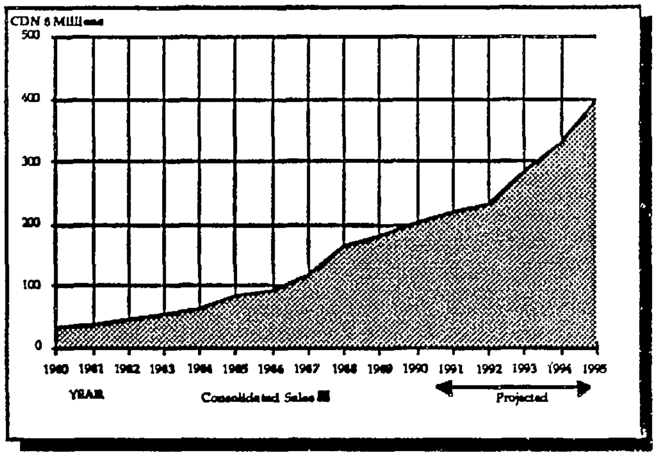
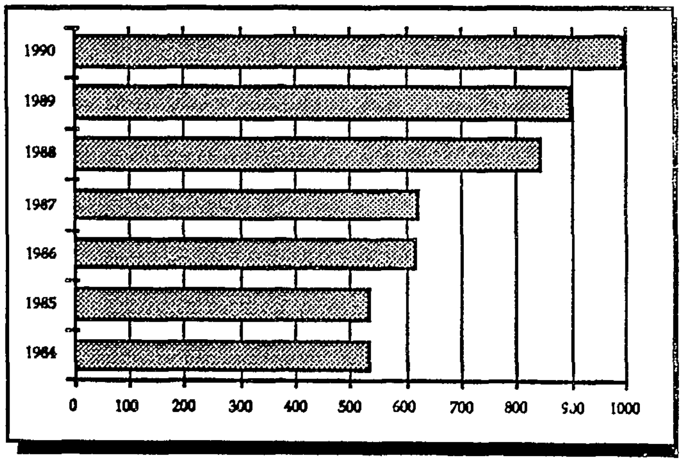



CHART E
HUSKY EMPLOYEES
1984 - 1989



ITP BOSTON, INC.
Cambridge, MA, USA

## BACKGROUND

### The Company

ITP Boston was incorporated in 1980 by a group of engineers from the Charles Stark Draper Laboratory, Inc., formerly the MIT Instrumentation Laboratory. The group had worked together on industrial automation projects for more than 12 years. Sergio Brosio is a founder of ITP Boston and the current chairman of the board.

Draper Laboratories had honed its skills in several basic manufacturing technologies including simulation, sensors and computers. During the 1970s, Draper pursued funding and contracts from industry for automation projects. Most projects handled by the Laboratory were government-sponsored. An exception was a $10 million contract from Fiat of Italy. It included development of tool management systems, warehouse management control systems and flexible manufacturing systems. Through the Fiat connection, ITP landed its first job in 1980. ITP was contracted to assist Comau, a large European machine tool builder that is controlled by Fiat, to produce the first flexible manufacturing system for General Motors Gear and Axle. ITP also worked with Comau on installing 14 framing lines in several GM plants.

Through several years of growth, ITP has remained focused on one business: factory systems integration. The mission of the company is "to provide the portfolio of products and services which serve the best interests of progressive manufacturing companies." The company focuses primarily on discrete and batch manufacturing applications.

In 1984, ITP entered into a joint venture with Allen-Bradley (A-B), forming Decision Software. Decision Software was intended to develop user configurable software for A-B's Unix workstation-based Vista 2000 cell controller. In 1990, Decision Software was integrated with ITP Enterprise Software into a new company, MainStream Software Corp.

ITP Boston presently consists of two organizations: ITP Systems, Inc. and MainStream Software Corporation. ITP Systems is the services organization of ITP's North American operations. ITP Systems includes regional engineering and implementation centers in Boston, MA, Baltimore, MD, Detroit, MI and Seattle, WA. ITP's software products are marketed through MainStream Software Corporation.

ITP Boston markets its products and services worldwide. The Company maintains offices at several locations in the U.S. and has an affiliate, ITP Italiana, in Europe.

### Services

ITP's original office in Cambridge, MA is now the company headquarters and central engineering facility. From this location, ITP is currently implementing or has completed over forty CIM projects. Systems have ranged from complex flexible manufacturing systems to area and plant control software. The engineering staff in Cambridge also developed the reusable software which is now the foundation of many of ITP's real-time control projects.

Capabilities of ITP's Detroit organization include services for industrial control systems that range from design to installation. This includes hydraulic, pneumatic, and electrical design, and development of control logic for PLCs and CNCs, as well as monitoring and diagnostics. In addition, ITP Systems of Detroit supports computer-based control applications in the midwest United States.

ITP Systems of Baltimore, Maryland is an engineering services company that offers process control and automation services to manufacturers in the mid-Atlantic United States. Capabilities of this organization include delivery and support of systems from the design stage through installation.

### Software Products

The company's key software product is the recently introduced MainStream. MainStream is an application integration platform, or application enabler, which ties together PLCs, CNC machines, networks and general purpose computers through a transaction processing-based architecture. MainStream is based on an open system approach that reduces dependence on proprietary hardware and technologies.

### Size and Strength

Sales of the privately held company are estimated at U.S.$100 million in 1990. Most of ITP's sales in the U.S. come from system integration work; the company's primary software product is very new to the market and is just beginning to generate revenue.

Sales in the U.S. account for about one-third of ITP's worldwide revenues. Over three-fourths of ITP's business in Europe comes from Italy. Due to language and cultural barriers , ITP has no current plans to extend its exporting program to include Japan.

The company has over 600 employees worldwide; one-third of these are located in North America.

## COMPETITIVE STRATEGY

### Changing Customer Focus

In its first few years of existence, GM was the source of much of ITP's business. When GM bought Electronic Data Systems, also a system integrator, a large amount of ITP's business was at risk. To protect its revenue base, ITP expanded its capabilities from high volume, flexible manufacturing applications in the automotive industry to include the low volume, high product variety mix environment of aerospace, at the time a booming industry. This move resulted in long-term relationships with General Electric and Pratt & Whitney. The company also found a market in supplying warehouse management and control systems to a variety of clients.

### Application Targets

ITP's current focus is predominantly on plant level systems that are running in real-time (defined by ITP as a one or two second response time). The company is not active in business functions such as time and attendance or order entry. Rather, ITP gets involved in factory scheduling, production monitoring and quality control systems.

### Hardware Strategy

Vendor-independence relative to hardware suppliers is an important element in ITP's competitive strategy. The company believes that maintaining the ability to choose whatever hardware best suits a project is key to serving the broadest range of customers and increasing market penetration.

### Service Strategy

ITP has noted important changes in customer's system integration goals. Automation is no longer being justified by labor reduction. Customers are moving away from high risk, leading edge projects. Today's emphasis is on reducing work-in-process and increasing quality through "tried and true" methods. In response to this shift, ITP takes a complete solutions approach in selling its integration services.

ITP considers its experience to be its most important competitive advantage in the system integration business. It is this experience that ITP markets to its customers. One of the lessons experience has taught ITP is that successful system integration projects are the result of collaborative efforts between vendors and the customer.

### Software Strategy

Throughout the 1980s, ITP has witnessed a trend toward low risk, low cost and fixed price contracts. Customers were increasingly demanding more control over project costs and less risk on their part. In response to this trend, ITP began moving away from custom-developed software solutions toward development of standard, off-the-shelf software programs. Writing custom code from scratch for a customer is time-consuming and expensive.

## STRATEGY IMPLEMENTATION

### Customer Collaboration

ITP uses several techniques to foster customer collaboration. These include early involvement in the conceptual phases of a project, inclusion in all internal and external vendor reviews, decisions and planning sessions, use of team building techniques, effective project management, and communication on all material issues.

### Complete Solution Supplier

ITP has utilized a strategic partnership to achieve its goal of becoming a supplier of complete solutions. In March of 1989, ITP and Coopers & Lybrand (C&L), a leading accounting and consulting firm, announced a strategic alliance to pursue integrated manufacturing business jointly. Under this arrangement, C&L purchased a minority equity stake in ITP, with options for purchase of further equity.

### Modular and Customized Solutions

Over the past 7 years, ITP has evolved into the product business. To reduce the time requirements in its integration projects, in the mid-1980s, ITP developed its own integration tools. These products are based on reusable code in the form of internal modules. ITP's current generation of modular software allows the customer to purchase only what it requires. This reduces cost, risk and time to implement custom software solutions.

## RESULTS

### Alliances and Partnerships

C&L's manufacturing and CIM planning practices offer an important complement to ITP's system implementation capabilities. The partnership provides ITP with greater financial and technical resources to pursue larger projects of greater breadth in a broader customer base. In conjunction with C&L, ITP can offer a high level system integration, a strategic orientation with MIS capabilities along with ITP's manufacturing capabilities.

Additional advantages of ITP's strategic partnerships are a lead stream not generally available to a small company and a perception of financial depth that comes with an alliance with larger and well-known entities like C&L and Allen-Bradley.

Customer partnerships in which systems are developed through a collaborative effort have yielded reusable solutions that with little or no adaptation can be applied to other customers' problems.

### Growth

In 1990, ITP expects about a 60% annual sales growth in its system integration business in an industry that it estimates is growing at about 30%. The company anticipates sustaining a future annual growth rate of 40%. Growth may be tempered by economic factors such as cutbacks in U.S. government spending.

LINAMAR MACHINE LIMITED
Guelph, Ontario, Canada

## BACKGROUND

### The Company

Linamar Machine is a manufacturer of precision components for the automotive, transportation, defense and aerospace industries. The company began as a one-man operation in 1966. Initially, Linamar operated as a job shop that machined small lots of a variety of products. Six years ago, Linamar landed its first major, long-term automotive contract.

Linamar entered the global marketplace in 1989, becoming sole supplier of high precision automotive parts to Steyr-Daimler-Puch of Austria, a manufacturer of 4-wheel drive trains for cars such as Audi, Mercedes Benz, VW and Fiat. The company won this contract away from a plastics and stampings company that was unable to finish the contract. To manufacture the 4-wheel drive trains for Steyr-Daimler-Puch, Linamar has established Quadrad Manufacturing Ltd., a 50-employee business in Canada.

Last year, the company launched itself into a new business, the manufacture of combines. Linamar's subsidiary, Western Combine Corporation is the manufacturer of this new product line.

Although Linamar has recently begun to export, Linamar's products are primarily sold in North America. The company is planning to expand into other European markets. Through contacts of its Hungarian-born president, Linamar is investigating a move into the Hungarian market.

Manufacturers' representatives are Linamar's primary sales channel. The company has established long-term relationships with a handful of reps. A small in-house salesforce is also maintained.

Linamar has 12 manufacturing plants. These relatively small plants are operated as independent subsidiaries.

### Product Line

On the automotive side, Linamar is the sole source for a wide variety of steering, transmission, driveline and suspension components for GM, Ford, and Chrysler. For heavy and medium trucks, the company supplies engine components to Cummins and Detroit Deisel and transmission parts to Allison Transmission.

Aerospace products include turbo-prop engine parts (some in exotic metals) and structural aluminum components. Defense-related work includes suspension systems for heavy military vehicles, mobile missile launch systems and some ordnance components.

### Size and Strength

Sales for 1990 reached a record high of $128.6 million, up 13% from the previous year. Over the past five years, sales growth has been steady with the exception of nearly flat sales in 1989. Net earnings for the five year period have fluctuated, reaching a low of $1.6 million in 1989 and recovering to $3.3 million in fiscal 1990. Increased earnings in 1990 are attributed in part to cost reductions derived from improvements in manufacturing processes.

The company has 1300 employees.

### Competitive Environment

At its inception, Linamar was a job shop that handled relatively small product runs. Low market entry barriers have created a crowded field of competitors for job-shop business. As CNC technology became more affordable, CNC usage became widespread among even small job shops. This led to even fiercer competition. As a result, Linamar has shifted from job shop work to larger projects.

Linamar's customers in the automotive industry demand adherence to strict quality standards. Suppliers are often rated on the basis of factors that include quality, extremely low allowed part defects and timeliness of delivery. Based on its Targets for Excellence Program, GM employs a complex rating system for scoring suppliers. GM evaluates the supplier's management, costs, product quality, delivery and technology capabilities. Chrysler with its Pentastar program and Ford also have rigorous standards for evaluating and rating their suppliers.

Price competition is very intense in the automotive components and assemblies industry. However, high quality and on-time delivery are often uppermost on the car manufacturer's list of criteria in choosing a supplier.

Linamar considers itself the largest manufacturer of its type in Canada. The company has several U.S. competitors.

## COMPETITIVE STRATEGY

Since its founding, Linamar has shifted its attention from job shop work to long-term, high volume, dedicated contract work. Linamar specializes in high volume automotive applications and complete systems for the defense industry.

Linamar's competitive strategy includes:

- Retrenching to core competencies
- Enhancing its image as a leading edge manufacturer

In addition to contributing to its high tech image, the company's strategy relative to advanced manufacturing technology is centered around:

- Improving product quality
- Reducing time-to-market

Linamar's strategy is driven in part by the strict standards required of suppliers by customers in the automotive industry.

## STRATEGY IMPLEMENTATION

### Retrenching to Core Competencies

Several initiatives have been undertaken to refocus the company's business strategies in order to build value for the long-term. Linamar has retrenched into what it knows best: the manufacturing of defense, commercial and automotive assemblies, subassemblies and high precision components with a life span of 10 to 15 years on the market. The company sold its plastics division in 1990 and expanded its core business. Under the Steyr-Daimler-Puch of Austria contract, the company has become involved in a new line of manufacturing for four-wheel drive systems.

### Product Quality and Time-to-Market

Linamar utilizes a focused factory approach to manufacturing. All of the plants operated by the company are relatively small and are dedicated to the manufacture of a single product or a closely related group of products.

Early on, Linamar began the process of automating its manufacturing operations. Over ten years ago, while the company still had only one plant, Linamar began investing in NC and CNC machine tools. At the time, this was relatively advanced technology. Management viewed this move as necessary in remaining competitive. Today, about 75% of the company's machine tools are CNC controlled.

Much of the test and inspection activities at Linamar, particularly on high volume lines, are conducted with automated testing and inspection equipment.

Automation projects at Linamar are generally initiated by the management at individual plants or by the corporate engineering group under the VP of Manufacturing. However, ideas may come from the operator level on up to the President. Most projects are proposed from the foreman level on up. The projects then must be justified to the President and Executive VP who is also the Financial Officer.

Whenever possible, Linamar has purchased its advanced manufacturing products from local sales channels. Fast response is important, especially on JIT manufacturing lines. As insurance against lack of timely assistance from the supplier, Linamar generally relies on internal resources to troubleshoot equipment.

Some of Linamar's special purpose manufacturing equipment is made in-house. Linamar often finds this the fastest and least expensive solution.

**Image as a Leading-Edge Supplier**

By virtue of its early and widespread adoption of CNC technology in its manufacturing operations, Linamar has earned an image as a leading-edge supplier. This is a valuable marketing tool in the business of making high-precision components.

## RESULTS

Linamar demonstrates an important lesson to manufacturers: very selective use of proven advanced manufacturing technologies is an effective approach. As soon as the company recognized the benefits of the new technology to its business, Linamar adopted it and remained with it. The technology is no longer considered new, but Linamar continues to reap its benefits. The company can consistently produce quality parts at a much quicker rate and has greater manufacturing flexibility than with manual equipment.

As a result of its investment in manufacturing technology, Linamar has been able to win contracts over competitors that were either unable or unwilling to make these investments.

Early adoption of CNC equipment has gained Linamar an image as a leading edge manufacturer. This has paid off for the company in garnering business from its target markets. Linamar has developed a reputation for quality and on-time delivery that has won contracts with GM and Ford over competitors with lower bids. The company's capabilities have earned it the role of sole supplier of four-wheel drive trains to Steyr-Daimler-Puch.

In 1990, Linamar was listed by *Canadian Business* as one of the 50 fastest growing companies in Canada. In the last 8 years, the company has progressed from 2 manufacturing plants to 12.

## MRS TECHNOLOGY, INC.
Chelmsford, MA, USA

## BACKGROUND

### The Company

MRS was founded in 1986 as a result of listening to customers. Of the six founders, five had spent some time at GCA Corp. pioneering the wafer stepper for semiconductor production. By 1985, GCA was in trouble, losing market share rapidly to its Japanese rivals, Canon and Nikon. It was in no position to follow up on the repeated customer inquiries for a special machine to be used to make flat panel displays.

What was a challenge to be passed over by GCA had the sound of opportunity to Griffith Resor, the team leader of the group that invented the wafer stepper. Resor put together a team of industry veterans, mostly former colleagues. The six founders included research, manufacturing, marketing and management specialists. They pooled their funds and came up with $350,000. The early equipment, adapted from IC steppers, had several shortcomings. For one, IC steppers could not cost effectively produce patterns for screens larger than two to three inches.

Rather than immediately starting the company, the seed money was used to research every aspect of the industry, the technology and the market. Results were used to pull together a business plan that left little to chance. Having witnessed the departure of the U.S. semiconductor industry to Japan, and the equipment market with it, the six knew where some of the quicksand was.

The fledgling MRS team (the name is based on the founders' initials) went to the venture capitalists with the business plan and raised a total of $10 million from six groups. The plan called for a two to three year development window with $10 million in start-up development costs. Now on its way, MRS had one more key element to put in place, a tie to a Japanese company.

### Product and Technology

MRS Technology inhabits a market niche with only two other companies in the world, both Japanese. MRS supplies a production lithography system designed for the manufacture of color active-matrix liquid crystal displays (AM/LCDs). These machines are similar to the 'steppers' that etch the masks for integrated circuits (ICs). The manufacture of AM/LCDS is very similar to the production of ICs, using a photolithographic process to transfer circuit patterns from a master to a substrate.

Right now the limiting factor to flat screen displays is the cost of production for larger size displays. Until mass production techniques are perfected, the technology is limited to putting small size screens on the market - about 5 or 6" maximum.

MRS is part of the solution for producing AM/LCDS. The company's Panel Printer solves the four major problems with the lithography process:

- It prints a large area (up to 20" diagonal)
- Provides higher resolution
- Gives more throughput
- Ensures greater control

### The Market

Active matrix LCDs are getting a lot of attention lately. They are one of the key technologies for high definition television that many observers expect to be a major breakthrough product in the 1990s. LCD flat panel displays are already widely incorporated in laptop computers. Small color active matrix LCDs have already shown up in miniature TVs and other consumer products made in Japan. The market for AM/LCDS is expected to explode during the next decade reaching $5 billion by the mid-1990s. According to forecasts, they will be found in computer displays, televisions, dashboard displays in automobiles, and in the cockpits of airplanes, along with defense and aerospace uses. In the office, they will show up in the control panels of copy machines and faxes and will be the displays in the new audio-video color computers.

The core technology will be used for more than just displays. As described by Jim McKibben, Director of Marketing for MRS: "What we are doing is building these devices on a substrate and these are really just thin film transistors, TFTs. We call it circuits on glass. There's a whole new era of electronics production that is affected by this. Scanner bars, page at a time FAX's, or a fully integrated office machine where you have your FAX, your computer, your printer, and everything built into one single machine. It's going to miniaturize many of the other types of PC board electronics that can now be reduced to these glass strips. Many applications that are beyond the realm of todays imagining will happen. It's going to take 10-15 years, but it's going to happen."

**Competitive Environment**

One key to surviving in MRS' chosen market niche is to penetrate the Japanese market. Right now, that is the only region that is actively pursuing market introduction of active matrix displays. Although some research is going on in Europe, and to a lesser extent in the U.S., the Japanese suppliers are the only ones close to going into production. For a Japanese company to buy such a crucial product from an American supplier takes a lot of persuading.

When American companies were selling silicon wafer steppers in the 70s, no such technology existed in Japan nor was there a vibrant semiconductor business in Japan. It was relatively easy to sell them equipment to get them into the semiconductor business. They recognized that American equipment gave them a quicker path to semiconductor production. Now, that's reversed. The Japanese own the semiconductor equipment market in Japan. It's no longer possible to point to examples in the United States of somebody getting way ahead by using advanced American equipment.

MRS Technology's Japanese customers are rooting for the Japanese suppliers to catch up. There is a MITI initiative to help drive that catch up process and to put Japanese technology out in front.

Griff Resor illustrates the technology dynamics in the active matrix display market by charting the announcements from research labs and actual product introductions. The lag between development and market introduction has been consistent over the last several years. What has changed drastically is the steady progress toward larger display size. MITI recently announced a goal of a one meter square display by 1996. This has had the effect of shifting the development trend upward. According to Resor, MRS has to be able to lead product development. "We looked at the trend lines associated with this business and where our machine had to be in order to be involved with the customers' programs. ... in 1986, when we designed the machine, all people were doing at that time was 6 to 8 inch research displays. We designed a machine that could take people up to about 25 inches. We wanted people to have about five years of life with the machine, so we really had to challenge ourselves and get to a big machine."

## COMPETITIVE STRATEGY

**Growth Goals**

Managment's long-range goals are to achieve sales of several hundred million dollars and to be the leading supplier in its market niche.

**Market Strategy**

MRS' entire market strategy is based on competing with the Japanese in Japan. The four-pronged approach to penetrating the Japanese market consists of:

- A substantial Japanese presence
- A Japanese corporate partner
- Equity participation from Japan
- A way to support Asian customers from the U.S.

**Product Strategy**

The real secret to penetrating Japan is to give them sufficient incentive to put aside other concerns and buy an off-shore product. MRS believes it has a three year technological lead and that it can maintain a lead of that size.

## STRATEGY IMPLEMENTATION

**Japanese Presence**

Griff Resor, President of MRS capsulizes the strategy: "To be competitive in Japan, you have to be Japanese and you have to be in Tokyo."

The Japanese presence was a given from the start. One of the founders, Massaharu Miki, moved back to Japan to coordinate activities there. He was instrumental in setting up distribution in Japan, and invaluable in determining the penetration strategy. Miki's experience in identifying and qualifying Japanese part and subsystem vendors for GCA served MRS when it was time to recruit a Japanese corporate partner.

Being in Japan is a crucial, but expensive part of the strategy. MRS calculates it costs a million dollars a year to operate its sales and support office in Tokyo. It has made this investment because it is necessary. MRS also set up a demo center in Tokyo and a service center in Kyoto.

**Japanese Corporate Partner**

The competition for the Japanese customer is severe. Nikon and Canon are formidable competitors. Since 80% of the market is in Japan, they have a built-in advantage. They have Keiretsu[1] relationships with a number of the display manufacturers. The display manufacturers are huge and vertically integrated. They use Canon and Nikon equipment for many of their semiconductor lines.

The venture capitalists advised that it would be critical to have a Japanese partner, a manufacturing partner rather than a trading company. The manufacturing partner would have more credibility with the prospective customers and would have more invested in the relationship. A trading company would be seen as taking a flyer in the new technology, not as having a position in its future. After talking to a number of candidates, MRS chose Dainippon Screen to be its corporate partner in Japan.

Dainippon Screen was interested in adding MRS equipment to its own extensive line. With the MRS PanelPrinter™, the Dainippon Screen line of AM/LCD production equipment includes a plasma etcher, washing, drying, resist coating, pre-bake and developing machines along with the largest panel stepper offered in the market (from MRS). The Kyoto based Dainippon Screen has a strong position in Japan, with over $1 billion in sales overall. The company has a strong sales and service network in Japan, supplying about a third of the LCD lithography equipment to the Japanese market.

Dainippon Screen was interested in more than a marketing agreement. It became one of MRS' equity investors at the same time. The relationship is mutually beneficial, giving Dainippon Screen technology leadership in the equipment over its rivals Canon and Nikon. MRS gets the marketing clout it needs to sell in the Japanese market.

**Technical Support**

Dainippon Screen will be in the local market for sales and service but technical support will still have to come from the U.S. This aspect of the strategy was explained by Jim McKibben: "I think we've solved the problem of being a long distance from our customers as far as servicing them. Our machine has a built-in modem, we call it Stepper-Net™. We're able to network via satellite to our machines in Japan. We can call up from our demo lab here in Massachusetts and run a machine that is at our Japanese demo center in Tokyo, our service center in Kyoto, or any one of our customer sites around Japan. We can run diagnostic routines from the U.S. and discover what our problems are with a particular machine anywhere in the world. We can also upload software fixes, bug fixes, and so on without getting a guy on an airplane for 25 hours and discovering we sent the wrong guy with the wrong tool box, only to try again. That iteration could take eight or ten times before we solved a problem. Japanese customers would not stand for it."

"So far, the Japanese are a little reticent to allow us to hook up to their machines and use the full power of this networking solution. We find that it's a much slower process to change the way things are done there. Often times in Japan people are more interested in form than in substance. But this will work in the long-term. It has to. That's the only logical way we can support machinery around the world. It's the only thing that makes sense in the information age - use your information gathering

1 Keiretsu is a collection of firms, one from each of a number of industries, and usually centered on a lead bank which holds equity in as well as loan claims on group members

capabilities so that you don't have to duplicate the group of experts. There are not that many experts worldwide who understand this technology. We can't easily duplicate the group here and move them all around the world, we have to provide another solution. This is a perfectly adequate and, as a matter of fact, an elegant solution. We simply need to get the Japanese used to it."

### Technology Development

MRS is determined to stay on top of the technology to keep its headstart over its Japanese rivals. About 65% of the people in the company are employed in R&D. In August of 1990, MRS was one of six contractors chosen by DARPA to pursue research in high definition television. MRS' role will be to work in large area photo lithography tool development for active matrix displays. These contracts average about $1 million apiece.

## RESULTS

### Sales Growth

The strategy for Japan appears to be working, MRS has sold between 15 and 20 machines, to date, at $1.5 - $2 million apiece. It has proudly announced placing one at the David Sarnoff Center, one at the University of Stuttgard, one at IBM's Thomas J. Watson Research Center. The rest have apparently gone to Japanese companies, but there is no official confirmation of that. The customers do not want to be identified.

MRS shipped its first machine in 1989. It was sent to the Osaka demo center. In November of that year the company successfully solicitated an additional $4 million in venture funding. In 1990 sales have expanded rapidly, and the indications for 1991 are optimistic.

Although the company is not releasing its sales forecasts, Jim McKibben outlined the manufacturing strategy: "We have expanded our factory here tremendously since even 1988. We now have the capability to build between 20-30 machines a year and we have the manufacturing systems in place to take us to 50 machines quite quickly. Part of what we did here is hired in every slot, every key slot anyway, people with the experience to build up to 400 of these machines a year."

### Marketing Presence

One of the tactics that have helped MRS to further its sales efforts are its very successful use of public relations. There is a great deal of interest in HDTV, both among the public and in government. As a leading supplier of equipment to make the displays, the company's founders have made a strong case that the U.S. is ceding the market to Japan without a fight.

Another is its use of distribution channels. In Japan, when Dianippon Screen attends a trade show, the MRS steppers are the star attraction in the booth.

Competing with Japan on its own defined turf certainly adds to the difficulty of executing an export strategy. So far the careful planning and detailed marketing strategy pursued by MRS appear to have served it well. Whether it will take it to dominance of its market is yet to be determined. After introducing its product three years later than Canon, MRS has the technological edge to force Japanese customers at least to consider its machines.

## OTTO BOCK ORTHOPEDIC INDUSTRY OF CANADA, LTD.

Winnipeg, Manitoba, Canada

### BACKGROUND

**The Company**

Otto Bock Orthopedic Industry of Canada, Ltd., is a Winnipeg, Manitoba, based subsidiary of Otto Bock GmbH headquartered in Duderstade, Germany. Otto Bock is a leading worldwide supplier of artificial limbs, crutches, wheelchairs, and other aids for disabled persons.

**The Need**

A modern, motorized wheelchair can mean the difference between freedom and dependence for a disabled person. But a wheelchair can create a problem of its own, especially for users suffering from muscular atrophy or paralysis. Such a severely disabled person cannot move to relieve the pressure of the wheelchair's seat on his or her body, and the unrelieved pressure can create or aggravate body sores. Indeed, the problem of body sores can become so serious as to deny a severely disabled person the relative freedom of a wheelchair.

**Previous Solution**

Wheelchair cushions have been custom designed to relieve the pressure on those portions of a user's anatomy afflicted with body sores. The resultant cushions are extremely helpful to the disabled person. The problem is, however, that the process of designing and manufacturing these custom cushions has generally taken several weeks.

The process typically starts at a medical facility where a therapist sits the wheelchair user on a bean bag in approximately the same position he or she will sit in the wheelchair. The therapist then shapes the bean bag around the user to create a negative impression adjusted to the user's support needs. For example, the therapist may shape the bag to avoid putting pressure on areas of the user's body afflicted with body sores. Once the desired impression has been created in the bag, the next step is to capture this impression for manufacturing purposes.

The therapist spreads plaster over the bean bag, filling in the impression left by the wheelchair user's body. The plaster is then allowed to dry and removed from the bag. The result is a positive plaster impression of a desired seat cushion shape.

The plaster model must then be packed carefully in a box and shipped to Otto Bock, Canada's manufacturing facility in Winnipeg — a process that can take several days depending on the location of the medical facility making the cast.

Once the plaster model is received and unpacked in Winnipeg, it is processed in manufacturing. Molten plastic is then injected around the mold and allowed to harden to create the cushion.

During the total turnaround time of several weeks for this entire process, the disabled person might have to endure a great deal of discomfort.

### AUTOMATION STRATEGY

Otto Bock, Canada decided to develop an automated approach to designing and manufacturing custom wheelchair cushions. The main goal was to effect a sharp reduction in the turnaround time. Based on its experience in the use of three-dimensional modeling tools in the design of artificial limbs, the company was familiar with the capability of advanced design and manufacturing technology and was confident that an automated solution could be developed to shorten the cycle time for custom wheelchair cushions.

### STRATEGY IMPLEMENTATION

**Making the Model**

One key to the shorter turn-around time is a three-dimensional mathematical modeling approach to seat cushion design and manufacturing. With the new system seat cushions are also made by a plastic injection molding process, but the injection mold is created from a three-dimensional digital model of the patient's anatomy rather than a plaster model.

The 3D mathematical modeling approach saves time in several ways. For one, it enables an accurate model of a patient's anatomy to be created much more quickly than with the plaster approach.

With the 3D molding approach, the therapist employs a 3D digitizing system to measure the location of points on the surface of the bean bag and enter them into a computer. The resulting collection of points constitutes a 3D mathematical model that, like the plaster mold, accurately reflects the desired seat cushion shape. Using the digitizing system, a therapist can create the mathematical model in about a half hour. By contrast, the plaster casting approach took about six hours, counting drying time.

The 3D modeling approach saves time in another way. The mathematical model can be shipped to Winnipeg in a matter of minutes via telephone.

**Keeping Costs in Line**

While the 3D modeling approach speeds creation of a seat cushion design shaped to meet a wheelchair user's individual support needs, the approach does have some potential drawbacks. One is the cost of the 3D modeling process. The plaster approach is inexpensive. Making plaster casts requires no specialized equipment and plaster itself is cheap. By contrast, the 3D mathematical modeling approach requires access to a 3D digitizing system. While such systems are available commercially, they tend to be too expensive for most medical institutions — especially for the limited use entailed in customized seat cushion design.

As a result, Otto Bock developed its own digitizing system, with the goal of minimizing cost. To keep costs down, the Otto Bock system employs a digitizing technique based on sensing the distortions caused in a magnetic field by metallic objects. (The bag chairs used to make the initial impression of a user's anatomy are filled with metal beans.) The magnetic digitizer used by the Otto Bock system consists of a handheld sensing unit linked to a small controller box by a cable.

As another cost-containment feature, the Otto Bock system employs an inexpensive off-the-shelf PC-compatible color graphics system to store seat cushion data captured by the digitizer. The system includes 3D color graphics software that enables a therapist to display and edit the seat cushion data to ensure that it accurately reflects the wheelchair user's support needs. The total cost of the system used by the medical institution is less than $10,000.

**Manufacturing the Cushions**

The 3D modeling approach posed another potential problem, namely creating the mold required for the plastic injection process. With the plastic approach, the plaster seat cushion model could be used, after some surface hardening treatment, directly as an injection mold. The mathematical modeling approach entails a further step, i.e., creating a plastic injection mold from the mathematical model. This step, if not done expeditiously, could offset the time saved by using mathematical modeling instead of plaster casting to derive the customized seat cushion shape.

To assure rapid creation of the plastic mold, Otto Bock planned to use a computer-controlled machine tool to mill customized seat cushion molds out of plaster blocks. But this solution, in turn, creates a problem. Because each seat cushion varies in shape, a machine tool program would have to be created for each seat cushion — a potentially time-consuming process, especially since the seat cushions have complicated surface shapes.

To solve the machine tool program problem, Otto Bock turned to an advanced computer-aided manufacturing (CAM) system. The system automatically generates machine tool programs from digitized 3D surface models of the objects to be machined. In a matter of minutes the CAM system generates customized seat cushion mold programs from the 3D mathematical surface models created by the digitizing systems.

## RESULTS

Custom wheelchair cushion turnaround has been reduced to less than a week from the typical several weeks of cycle time required by the previous procedure. Otto Bock, Canada views this solution as pointing the way to future applications of advanced 3D modeling technology to developing aids for the disabled.

# PARAMETRIC TECHNOLOGY CORPORATION
Waltham, MA, USA

## BACKGROUND

### The Company

Parametric Technology Corporation (PTC) was founded in 1985 by Dr. Samuel Geisberg, formerly of Computervision, to enter the computer-aided design/computer-aided manufacturing/computer-aided engineering (CAD/CAM/CAE) market with radically new products. The company, located in Waltham, MA, U.S.A., began shipping its CAD/CAM/CAE software in 1988.

### Product Concept

CAD/CAM/CAE has revolutionized the way many designers work. Especially in industries such as aircraft and automobiles, designers have long ago traded in their pencils and drawing boards for a computer terminal. Traditional CAD/CAM/CAE software, however, runs on expensive mainframe computers and has some characteristics that make it inflexible when dealing with changes that have effects on different design documents, models, or assemblies. PTC was formed to develop a product line to address some of these deficiencies.

The company's Pro/ENGINEER® product family is based on a unique software architecture that integrates the different stages of mechanical design automation (MDA) and allows changes made in one stage of the design process to be automatically reflected in all other phases of this process. Pro/ENGINEER offers a high-performance solution that enables customers to reduce product time-to-market and manufacturing costs and to improve product quality through easy evaluation of multiple design alternatives. The company's next-generation CAD/CAM/CAE software is revolutionizing the design automation process for manufacturers in aerospace, automotive, consumer products, and electronics industries by allowing design-to-manufacturing teams to work on a product design concurrently and iteratively for the first time.

## COMPETITIVE STRATEGY

### Stated Corporate Strategy

Parametric Technology intends to be the leading provider of mechanical design automation tools by executing a strategy that includes technological leadership, hardware independence, aggressive price/performance, worldwide distribution, and extensive customer support.

### Software Strategy

A key goal in the software development was to establish relationships between the various elements of the system. For example, if a designer makes a change in a part, the system may automatically change a matching part within a set of guidelines it has been given, without any input from the designer. A change in a component is automatically fed into the documentation of the products into which that component is to be assembled.

### Operator Interface Strategy

Traditional CAD/CAM/CAE systems require the designer to work in geometric terms. The strategy here is to provide the operator with engineering terms to work with instead of mathematical terminology. This strategy makes the system adapt to the language of the designer, not vice versa.

### Hardware Platform Strategy

Traditional CAD/CAM/CAE packages run on big computers. Workstations, especially those based on reduced instruction set computing (RISC) principles, have become extremely powerful at relatively low cost. The strategy is to design the system to run on these platforms offering significant value for the investment relative to the systems sold by established competitors.

### Design Time Benefit

Time-to-market is a major competitive factor. A system with the described relational characteristics and ease of use features was expected to be highly attractive to a market looking for tools to implement faster product design cycle time.

One factor that implements the cycle time improvement is that the system supports the principle of concurrent engineering by offering a consistent unified database. This allows several people to work on the design from their own points of view and reflects changes made throughout the system so that the working design is always up to date.

### Sales and Distribution Strategy

Working closely with major customers is a basic strategy. It was recognized that only a small part of the overall market potential could be addressed early in the game. Building close relationships with key customers was considered more important than trying to find lots of potential buyers.

## STRATEGY IMPLEMENTATION

### Product Line

The PTC system, called Pro/ENGINEER, was designed to meet those objectives. A complete product line has been introduced that addresses every phase of the design cycle — from initial conceptual design through detailed product design and analysis and the generation of manufacturing plans and instructions. This modular design permits a user to tailor a Pro/ENGINEER configuration to suit a particular need — whether that be a complete design through manufacturing solution or to enhance an existing CAD/CAM installation.

### Industry Standards

The system supports both the importing and exporting of designs with other systems via an industry standard interface (IGES). It is written to run on all major Unix-based workstations providing a variety of powerful and cost-effective platforms from which users may choose.

### Sales and Distribution

The initial sales thrust has been focused on Fortune 200 companies. PTC is working closely with customers to develop and enhance its products and to deliver precisely what its customers want. Each product release includes hundreds of customer driven enhancements. PTC also updates its products more often than its competitors; whereas traditional suppliers may issue a new release every eighteen months, PTC's cycle is every six months. The company will assign its best application engineers to work with strategic customers for indefinite periods of time to ensure the customer's success with the system.

One advantage of the workstation platform strategy is that the workstation manufacturers become strategic partners virtually automatically. Since PTC is selling software to run on their workstations, those suppliers, Sun Microsystems for example, promote PTC's products.

The company is now turning its attention to establishing and supporting an effective worldwide distribution system. The focus now is to increase sales coverage globally. Although 35% of sales is already accounted for by exports, PTC believes it has just scratched the surface in those markets where there is far less entrenchment by the competition.

## RESULTS

### Competitive Market Advantage

IBM, Intergraph, McDonnell-Douglas, and Computervision (now a subsidiary of Prime Computer) are some of the competitors in the CAD/CAM/CAE field. They are major entities and PTC is still a small company, but PTC's new products give these formidable opponents some real problems. The difference in PTCs line from that of the traditional suppliers is a fundamental element of the design concept; it cannot be added on to existing products. The traditional suppliers cannot simply change their software to incorporate the new features available from PTC. It would be necessary to rebuild the existing packages from the ground up. Not only would this be expensive, more importantly the changes would not be available to the current installed base of users; they would have to scrap what they've done to date in order to get the new system.

IBM, Computervision and the others could introduce products with the new benefits but that would cause them competitive problems and/or support problems.

The introduction of a PTC-like product opens the door for a new supplier, like PTC, to move in on major customers; the major hold a CAD/CAM/CAE supplier has on its customer base is the compatibility factor. Supporting two, essentially different, CAD/CAM/CAE product lines would be an expensive proposition and, since the existing users cannot be abandoned without massive loss of reputation and trust, a new line means two lines.

This complex situation tends to paralyze the intrenched competitors allowing PTC to go after new applications even within the major suppliers' customer base.

### Market Penetration

On a cumulative basis, PTC has sold approximately 2,750 seats of software representing 16,000 software modules, compared with 1989 levels of 1,200 and 6,000, respectively. The customer base grew from 330 to 700 during the same period. Repeat business from existing customers, such as Whirlpool, General Electric, Northern Telecom, Chrysler and Motorola represents 63 percent of total revenues. New customers in 1990 include Matsushita, Aerospatiale and Hughes EDSG.

### Financial Results

PTC's net income from the 1990 fiscal year ended September 30, 1990, increased 252% to $5.6 million, or $0.65 per share, from 1989's income before extraordinary credit of $1.6 million, or $0.22 per share. Revenues for 1990 rose 131% to $25.5 million, compared with fiscal 1989's level of $11.0 million. Pre-tax profitability in 1990 was 34% of sales, up from 21% in 1989.

## PROMIS SYSTEMS CORPORATION
Toronto, Ontario, Canada

### BACKGROUND

#### The Company

PROMIS Systems Corporation (PSC) develops, sells and services its Process Manufacturing Integration System ("PROMIS") through licensing agreements with customers. PROMIS plans, monitors and controls complex manufacturing environments such as semiconductor and pharmaceutical manufacturing facilities.

The company's business can be divided into four kinds of activities:

- Selling standard software products
- Custom modification and custom projects
- Support services
- Consulting

PROMIS started as the manufacturing systems group of I.P. Sharp. The group was originally formed as a project organization addressing various software tasks in manufacturing as well as other areas including air traffic control, water and gas distribution systems and defense work. It first became focused on its present lines of business in 1978 when it was called upon to address a requirement for a coordinated shop floor management system for a U.S. semiconductor manufacturer. The experience gained on that project led the group to negotiate with its customer for rights to sell the technology elsewhere and to seek other customers with similar requirements. It was organized as a subsidiary company in 1985. In 1988, after I.P.Sharp was acquired by Reuters, Douglas Scott, who headed the subsidiary, negotiated a spin-off arrangement and PROMIS became an independent company.

#### Products and Services

The PROMIS Shop Floor Management (SFM) products allow
real-time performance analysis of all manufacturing operations from raw materials inventory to finished goods. PROMIS provides the capability of specifying manufacturing instructions for the entire manufacturing sequence. It permits operators to track the status of work in progress and enables engineering analysis to be conducted using in-process data. It also provides detailed records on the status of production equipment.

PROMIS provides an automation platform, whereby certain production equipment can be controlled directly by the PROMIS software. PROMIS also offers planning and manufacturing support by comparing order backlogs and forecasts against work in progress, supplying complete and uniform standard cost analysis and reporting upon the status of manufacturing and inventory activity.

PROMIS has been used mainly in semiconductor wafer fabrications, integrated circuit assembly and testing, hybrid electronics, printed circuit boards, aerospace parts, medical devices and pharmaceutical manufacturing facilities.

### COMPETITIVE STRATEGY

#### Competitive Environment

One aspect of competition comes from manufacturing resource planning (MRP) products. The MRP system is shift-based or day-based planning, monitoring and controlling. PROMIS controls the operations of a factory on a minute by minute basis by direct instructions to operators or via direct downloading of recipes to the process equipment itself. Although MRP does not perform the same functions as SFM products, it often competes for the same budget dollars. A major obstacle in the company's sales program is the targeted customers' general lack of knowledge of the benefits of SFM and factory automation as opposed to MRP.

Internal development within customer companies is an additional area of competition for PROMIS. In general, however, companies are trending away from attempting to implement this type of system on their own.

PROMIS views Consilium, a California based company, as its primary competitor of similar products. Consilium is somewhat larger than PROMIS and is more aggressive in its marketing and sales program. PROMIS contends that its products are superior to those of Consilium, especially in terms of linkages to the factory floor automation equipment.

#### Product Strategy

With increasing international competition and the squeezing of profit margins, manufacturing companies are focusing more attention on better running of the factory.

One aspect of the ongoing product strategy is to broaden the addressable market by making the software transportable across hardware platforms thereby opening the doors to users of computers other than Digital Equipment Corporation (DEC). Another is to offer additional packages to make the offering even more complete by addressing the requirement for complete product data management systems.

### Market Strategy

The factory is emerging as a key focal point of corporate strategy, and there is a new realization that mastery and control of the production process is required to stay innovative. The market for computer integrated manufacturing (CIM) is growing and will continue to grow throughout the 1990's. PROMIS has positioned itself to exploit this trend.

Although PROMIS has had success in the market, the company intends to become more aggressive in its marketing program in order to take better advantage of this favorable positioning.

There is not sufficient market in Canada in its principal market (semiconductor manufacturing). PROMIS recognizes that it must export.

A Key strategy for PROMIS for the 1990s is the expansion into markets beyond semiconductors and pharmaceuticals, its first two industries of application focus.

## STRATEGY IMPLEMENTATION

### Implementation of Product Strategy

One PROMIS strategy is to address these needs with factory floor software to implement effective management of minute-to-minute activities. PROMIS Shop Floor Management systems have been developed to address these needs in the following ways:

- Manufacturing specifications are managed to ensure repeatability and consistency in the manufacturing process, to reduce the time to market for new products, and to ensure compliance with regulatory authorities
- Work in process and cycle times are reduced to minimize carrying costs and expedite delivery to the customer
- Equipment utilization is increased through better queuing management and earlier detection of equipment problems
- Engineering data collection and analysis, and real-time statistical quality control reduce scrap and improve product quality
- Materials and capacity planning are provided to bring materials to the line just-in-time, to reduce inventories, and to improve manufacturing productivity
- Management reporting and cost accounting provide management with complete, accurate and timely information on the performance of their manufacturing operations, with 100% traceability
- And finally automation, i.e., the direct connection of manufacturing, testing and material movement systems to the factory management system reduces operator-induced errors and guarantees accuracy

Conventional manufacturing systems (such as MRP or process control systems) perform only portions of these functions. What they do is often inadequate and not integrated.

PROMIS software manages the whole factory, and performs all these functions in an integrated and consistent manner. It raises the productivity of indirect labor and middle management where the big payoff is. In many manufacturing environments today direct labor represents no more than 5 of 10% of production costs; indirect labor is generally a much larger component of total operating cost.

PROMIS has 50% of its staff in R&D functions. New product development is a continuous and vital element of the company's operations. Additionally, PROMIS is seeking partnership arrangements with other Canadian companies to conduct product development that is beyond the scope of its internal funding capabilities.

One ongoing area of development is converting existing programs to Unix, thus making them transportable to most common computer brands. Programs were previously written in VMS, the Digital Equipment Corporation (DEC) proprietary operating system. This tended to limit the software to running on DEC equipment.

### Marketing Strategy Implementation

One area in which PROMIS has differentiated itself in the past is in the area of customer service. PROMIS feels that it is superior to its competition and that it is judged as a superior service provider by the market. This will be a continuing focus for the company.

PROMIS sells its products mostly on a direct basis with sales offices at key points around the world. Selling takes place at multiple levels in the customer organizations and a long sales cycle is the norm.

The company has been an exporter since its beginning. It reached the level of $10 million in annual sales prior to selling a system in Canada. It will continue to export to reap the benefits of the rapid growth expected in Europe and Asia. Continued growth in demand for the company's products is also expected to occur in the U.S.

Strategies for entry into other end user industry markets have yet to be implemented.

## RESULTS

PSC had revenues in 1989 in excess of $10 million, and has over 100 employees. The company has nearly 100 installations throughout North America, Europe and S.E. Asia.

The customer base includes:

| | | |
|---|---|---|
| Allied Bendix | IBM | Rockwell International |
| Analog Devices | Kendall McGaw | Samsung |
| AT&T | LSI Logic | Siemens |
| Bosch | McDonnell-Douglas | Taiwan Semi.Mfg. Co. |
| DEC | Medtronic Micro-Rel | Thiokol Corporation |
| Ericsson | Merrell Dow | TI |
| Fujitsu | Motorola | TRW |
| GE | Northern Telecom | Upjohn |
| GEC | NSA | VLSI Technology |
| Gould-AMI | Polaroid | Warner Lambert |
| Hughes | Raytheon | |

In 1989 the company grew at the rate of 30%. Expectations for 1990 are for growth at approximately 15%. The company expects that the reduced rate of growth is temporary, due to uncertainties currently prevailing in industry, and rates of 30% per year or more will be attained in the future.

## SENSOR ADAPTIVE MACHINES INCORPORATED (SAMI)
Windsor, Ontario, Canada

### BACKGROUND

#### The Company

SAMI is a company established in 1989 by its current president Dr. Tim Pryor. The company is a spin-off of Diffracto Ltd., also of Windsor, Ontario. Diffracto's business centers around in-line inspection, gaging and robot guidance applications in the automotive and aerospace industry. Pryor brings his 15 years of experience in these areas at Diffracto to SAMI. Pryor also founded Diffracto and retains 22% ownership of it.

#### Product Line

Product development at SAMI has two thrusts:

- Gaging and inspection equipment for automotive end-users and component suppliers. These systems are intended to assure "zero defects" through on-line inspection and control.
- "Intelligent" machines and their sensor-based controls. This product line consists of machine vision and other sensor-based intelligent machine tools and automatic assembly systems, primarily for the automotive and defense industries.

SAMI is currently marketing second generation inspection and measurement products developed by Diffracto during the 1980s.

The company sells its products as turnkey systems to end-users and as subsystems to original equipment manufacturers (OEMs).

#### Size and Strength

In 1990, revenue of the company was $600,000. Bookings for 1991 total $1.4 million.

SAMI received a conditionally-repayable contribution of $2.4 million under the Microelectornics and Systems Development Program (MSDP) administered by Industry, Science and Technology Canada. This was received from MSDP in 1990.

The company has 10 employees.

#### Competitive Environment

The 1990 U.S. markets for equipment relative to SAMI products are estimated by SAMI as follows:

| | |
|---|---|
| Gages and Inspection Equipment | $500 million |
| Controls for Machine Tools and Robots | $650 million |
| Complete CNC Machine Tool Systems | $8 billion |
| Complete Robotic Assembly Systems for Car and Aircraft Assembly | $500 million |

According to SAMI, its products are unique and currently without competition in the market.

### COMPETITIVE STRATEGY

The business strategy of the company is based on major long-term growth opportunities in the sensor-based adaptive control of productive machinery. The company plans to leverage its strong foundation in advanced quality control instrumentation, particularly its experience in electro-optical machine vision.

#### Market Opportunities

The company has selected areas of endeavor in which competition is relatively weak and demand is potentially high. While these conditions may not be sustainable in the long run, SAMI intends to take advantage of "windows of opportunity" that it expects will last for two to five years in the inspection business and about ten years in the specialized machine tool and related control business.

SAMI believes that there is great potential in the OEM market for its surface inspection products. These products are unique and OEMs do not have similar products with which SAMI's will compete.

#### Financing

In order to realize its product objectives, SAMI needs capital. The company's approach to this involves partnering with larger entities to develop products. The company's sensor-based systems offer the potential for a 5 to 20-fold increase in productivity. SAMI expects that this will attract end-users that will serve as beta sites for its products.

#### Sales Channels

With the exception of gaging products, sales of the company's products will initially be through the partners in the company's major development projects, e.g., General Motors.

## STRATEGY IMPLEMENTATION

### Intelligent Production Machines

The company has already obtained first orders for optically-based in-line inspection systems from domestic and foreign automotive suppliers and manufacturers. In conjunction with General Motors and Hughes Aircraft, SAMI is acting as prime contractor in a $10 million control development project to develop an Intelligent Sensor Adaptive Machine Controller.

SAMI has a Phase One development contract from the Canadian Space Agency Robotics Program for machine vision efforts relative to the Space Station. This is expected to lead to a $1 million follow-on project and a spin-off product for automobile assembly. Hughes and General Motors of Canada are also involved in the space effort.

### Gaging and Inspection Systems for Automotive and Aerospace

SAMI is selectively marketing electro-optical based turnkey inspection solutions based on its experience in high precision measurement. These include products for precision measurement of part dimensions and detection of surface irregularities in parts such as turbine blades.

## RESULTS

This young company has already realized one of its key goals - to find a development partner. If it continues to attract organizations that will bear some of the financial risk, SAMI will likely attain a foothold in its target markets.

SAMI has several strategic advantages working in its favor. These include:

- The company's products are the first on the market
- The partnership with GM is providing both development support and a potentially significant customer
- Trends in machining (e.g., the trend toward dry machining) are likely to favor use of SAMI's products

SOFTAC SYSTEMS LTD.
Port Coquitlam, B.C., Canada

## BACKGROUND

### The Company

Warren Thomlinson President and CEO of SOFTAC Systems formed the company in Vancouver B.C. in the early seventies. The focus on laser technology and lumber scanning systems proved to be scucessful over the following years. The first laser scanner installation in 1987 made SOFTAC the leader in the industry.

Today SOFTAC has grown to employ 52 people making and selling a growing list of high tech products. Sales are in the order of magnitude of $7-$9 million. The company's major product, responsible for about 80% of sales, is a laser measuring system, the Optimizer. SOFTAC edger, trimmer and cant optimizers are now sold throughout North America.

### Competitive Environment

SOFTAC now commands from 25% to 30% of the North American market for lumber mill optimizers. The market is divided among five key players, 3 Canadian and 2 from the U.S. Now that most of the B.C. sawmills have the basic optimizers, the competition for new installations is fierce.

There are a number of new suppliers entering the market; perhaps not to remain, but increasing the level of competition. Most of the major components of the system are available to a knowledgeable entrant. The real barrier is the edger/trimmer optimizer, a sophisticated piece of equipment requiring advanced programming skills and knowledge of the mill operation.

Although the system price is one factor in winning customers, there are other, more important, considerations for the mill operator customer. He is most concerned with having a system that will work, and work consistently. Being able to bring a prospective customer to see a system up and working is the best sales aid. When Mill A wants a new system they'll go look at systems in place at other mills. The supplier has to, first, be able to demonstrate its experience. Then customers will look at the quality of the system, the special features it offers, the opportunities for customization, and most importantly, service capabilities. The company explains: "The customer wants the mill closed for only minimal amounts of time; they don't want it shut down for more than two weeks. The time to full operation, called 'acceptance testing', has to be done fairly quickly, too."

## COMPETITIVE STRATEGY

Over the years, SOFTAC has been as careful about what it doesn't do as about what it does. The strategy was based on a number of considerations;

- To complement, not compete, with the basic business of the mechanical equipment suppliers, so that it could partner projects with them and not be direct competitors;
- To concentrate resources where the company founders felt the greatest value-added to the customer would be over the next decades; and
- To develop in-depth expertise in a narrow field, not be merely competent in a wide variety of engineering disciplines.

### Strategic Marketing Plan

The company has put together a five year plan to focus its efforts and help it to capitalize on the opportunities it sees. The plan consists of three major expansion thrusts: technology, customers, and regions.

The technology initiative is focused on refining a new camera based scanner/systems to stay ahead of the requirements of Softac's forest industry customers in B.C. In addition, the R&D effort will be used to take the core competence of the company, in scanner hardware and the software that controls it, and move into other industries with closely allied products. Finally, product development will include simplifying the current offerings for less sophisticated users, as well as bringing costs down in general.

SOFTAC plans to expand its customer base by moving into other industries with needs similar to the lumber industry. The handling of basic materials, scanning, sorting and optimizing based on orders, market pricing, etc. is a common requirement. The next market for the company will be agriculture. SOFTAC is jointly developing an automatic 'reader' for grain and fertilisers. One of the attractions of this market is that the Canadian suppliers are global leaders in the grain market, with world-class requirements. If the Canadian suppliers can be supported, the company will be able to offer the product internationally.

The final initiative is to expand into new regions. The southern U.S. is an obvious choice since the company has already sold several systems there. SOFTAC will also be targeting the Australia/New Zealand forest industry.

**Product Development and Support Strategy**

The company prides itself on the engineering content of its offering. Although SOFTAC employs only 52 people, it has 2 of them in research and development. This has paid off in two major ways --in the ability of the company to provide customized installations and in the product line. R&D has developed a product line that has some unique features, e.g., the trimmers measure the boards every inch rather than the standard 4-6" increment. The optimizers have been simplified to lines of single laser head with a split beam eliminating the multiple lasers formerly required. Laser heads are warranted for three years.

The product includes a large service component. The company provides help in design, installation and training, as well as on-site visits for regularly scheduled preventive maintenance. Training for the operators, electricians and millwrights is done at a two day course at SOFTAC and a follow-up the next month at the sawmill.

The latest product innovation for the industry is non-contact camera based scanning systems. The new camera systems will include lumber grade scanning for the detection of knots and rot and will work in conjunction with the laser scanner. This grade scanning, when combined with the dimensional laser scanning will greatly increase the profitability of todays high production mills, particularly hardwood mills.

**Promotion Strategy**

Because it is a small company with a niche market, the promotion strategy is primarily personal sales. SOFTAC does some advertising in trade journals and appears at the major trade shows, Wood Expo in Vancouver and the Portland Sawmill Clinic. This year, for the first time, SOFTAC will be exhibiting at a major show in New Orleans. The company explains the strategy of adding a new trade show: "We are looking for opportunities to be in front of the customer, we need to get to know them and have them know us. They need confidence in us, confidence that we know their mill and their system."

**Export Strategy**

Based on the success SOFTAC has had in its home market, it is now expanding into export markets. Most of the mills in B.C. are now equipped with multiple optimizers. Before the home market was saturated, SOFTAC had no motivation to sell in foreign markets; it already was serving the most demanding customers in the world and those most inclined to invest in advanced manufacturing technologies. As the opportunity for mill conversions slowed, the company looked for other opportunities. The table shows the declining increase in capital investment in British Columbia lumber mills.

Capital Investment in B.C. Lumber Mills from 1986 to 1989

| Year | Capital Investment | Change From Prior Year |
|---|---|---|
| 1986 | 165 | - |
| 1987 | 260 | 58% |
| 1988 | 384 | 48% |
| 1989 | 406 | 6% |

Source: *Price Waterhouse, The Forest Industry in British Columbia, 1989*

The first new export product was a smaller, simplified model designed for small mills that had neither the expertise nor the funds to install a standard optimizer system. This product also expanded the product line offered at home, to a market niche that SOFTAC felt was just developing among the smaller private mills facing a raw material shortage and searching for greater productivity. But, it was the opportunity to sell to a wider market in the southern U.S. that made the product introduction feasible.

Because the U.S. producers don't have the same economic pressures as the mills in B.C., they are just starting to implement widescale optimized production. The market opportunity looks very like the B.C. market in 1986 when capital investment started to take off. By 1989, B.C. lumber operators' capital investment had reached 9% of sales.

Four years ago, SOFTAC began to export its systems to the U.S., starting in neighboring Idaho and Washington, and quickly expanding to Texas and Alabama. Because of its in-house engineering expertise, the company was able to modify its basic product to the requirements of the new market.

The company has been selling systems in the southern U.S. for the last four years. When sales in Canada began to show signs of slowing down, SOFTAC began to look for other opportunities. The two most practical appeared to be the southern U.S. and Australia/ New Zealand. The attractiveness of the U.S. market was that it was close and familiar. The southern Pacific market was gearing itself towards optimization and therefore became a prime target for serious market planning.

Having already decided to target the U.S. market, SOFTAC knew that it needed a local presence to sell and service customers. Although product support and installation engineers could come out from Vancouver, it recently added knowledgeable sales engineers in the States.

SOFTAC feels it is critical to have an installation up and running before a serious sales effort can be made. Now, there are several installations in the Carolinas and Alabama that can serve as referral, 'go-see' sites.

To go into the southern Pacific, SOFTAC is acting in concert with Kockums, a major international supplier of the mechanicals — saws, headrigs, edgers and de-barkers, etc. SOFTAC has always worked closely with the suppliers of the mechanicals; in fact it was to be in a position to preserve these relationships that the decision was taken early on to concentrate on the electronics side of the business. As it moves into the Australian and New Zealand markets, Kockums is providing help and introductions to its Canadian partner, SOFTAC. The companies are co-bidders on overseas installations, and have been successful in China, as well as Australia and New Zealand. Now that the market is starting to expand, SOFTAC is ready to exploit it by putting in a technical representation.

The export strategy is expected to bring results quickly. Foreign sales are already 20% of the overall business. The objective is to increase that to one-third over the next five years.

### Leveraging The Core Technology

The expertise that the company has created through its participation in large integrated projects and its ongoing in-house R&D has led to the development of a core competence in scanner technology. SOFTAC has joined its expertise with other overseas companies to enter joint development projects which move it into markets in other industries. The next initiative will be into the grain market with an automated grain 'reader', a scanner that can evaluate grain grades. Other product initiatives include a robotic paint sprayer for lumber marketing and a lumber grade scanner.

## RESULTS

Although a small company, SOFTAC has been quick to exploit opportunities. Because it chose to serve the lumber industry, it developed customer partnerships with the most advanced sawmill operators in the world, those in B.C. Now, it can serve any lumber market. Because it made the decision to remain an engineering focused company, it has developed a technological competence that will allow it to transfer its expertise into other markets with new customer requirements. Every project it has been associated with was basically a one-off. In the process of serving each demanding customer, SOFTAC has developed the expertise to customize for new customers in other industries.

SUN ICE LIMITED
Calgary, Alberta, Canada

## BACKGROUND

### The Company

Sun Ice Limited is Canada's largest outerwear and sportswear manufacturer and has a rapidly growing international presence. Incorporated in 1978, the company specializes in the design, production, marketing and distribution of several collections of outerwear and sportswear with a recreational focus. The company headquarters are located in Calgary, Alberta, Canada, where it operates out of a 150,000 square foot modern production and distribution facility. The U.S. market is served out of the Seattle based Sun Ice U.S.A. office, and the Sun Ice Far East office in Hong Kong provides a base for its Pacific Rim operations. Sun Ice products combine fashion with function, appealing particularly to the growing number of fitness conscious consumers with discriminating taste. Fully two-thirds of Sun Ice products are worn by non-skiers today, accessing the large casual outerwear and sportswear market.

### Founding

Sun Ice was founded 12 years ago in the home of Sylvia and Victor Rempel in Calgary. The timing of the company's beginning turned out to be fortuitous. Sun Ice started as a ski and mountaineering apparel specialist. The brand was established in ski specialty shops. When consumer tastes changed, and true ski jackets were fashionable for general wear, Sun Ice had the cachet of a specialist.

### Background of Founders

The company founders were an unusual pair to start an apparel company. They were neither in an apparel center nor did they have experience in the industry. Sylvia Rempel was a design teacher at a technical high school and Victor was a school principal. But the family had the talent to take the concept for a new ski jacket and make it a $30 million dollar business from a base in Calgary.

### Industry Overview

The apparel industry has been slow to automate partly because it operates on very tight margins, with barriers to both entry and exit very low.

During the last decade, manufacturers have been moving into more vertical integration. Designers have integrated backward to operate their own production and forward to get more involved in retail sales. At Sun Ice the company appraises its distinctive competence as an ability to integrate the skills needed to produce a quality garment with the skill needed to design one that is both functional and fashionable.

### Benefits of Alberta Location

Although Sun Ice has encountered problems designing and manufacturing products in Calgary, the location does offer several distinct advantages. By being in one of the most demanding environments for ski apparel, Sun Ice has developed designs that meet the criteria of the knowledgeable skier in any market. Because the climate and conditions in its home market require more than fashion, the company has concentrated on using the latest materials in breathable waterproof and windbreaking shells, and has thoroughly explored the advances in thermal fill to keep the jackets lightweight and warm. In some other markets, either fashion or function would have been sufficient. In the Canadian Rockies, both are required, along with freedom of movement and comfortable fit.

The company is also in a position to test its new designs thoroughly right at home. Staying close to the customer is no trouble when all your personnel are customers, as well as your neighbors.

## COMPETITIVE STRATEGY

### Strategic Options

Companies have two basic ways of competing in the North American outerwear marketplace. Using the low price, high volume option, margins are limited. The typical strategy is to manufacture in low wage countries. To offer a price appealing to a niche market, it must be identified and targeted. Sun Ice targets an upscale market which is brand quality conscious. The company has been involved in numerous sports related marketing programs and the Sun Ice brand has become well known. Seventy percent of Canadians recognize the Sun Ice name and the quality products it stands for. In the U.S., where less marketing has been done, 10% of the market is familiar with the name.

Competition has intensified for Sun Ice since the Free Trade Agreement passed. The agreement has put a focus on the Canadian market and large U.S. companies are in Canada fighting for share. The domestic competition comes from six smaller companies, and is not worrisome.

**Marketing Strategy**

Sun Ice sells its clothing through a network of agents. The efforts of the agents are augmented through the exposure the company gets at the major trade shows. There are 30 agents in North America covering the 1300 retailers. They service them, work with them, and show them the new collections.

Trade shows are in Montreal, Las Vegas, and Chicago in North America. Along with the trade shows, Sun Ice shows at the rep shows, put on by the regional agencies that run their own shows so their customers don't have to travel. Customers book their orders at the shows. Orders are completed in March for delivery by September-October.

The retailers are specialty sporting goods houses. This type of outlet has evolved in the past decade. The specialty shops appeal to the upscale customers who want the special service they do not get in a department store.

The channels are changing and will continue to do so. Small stores are growing to become multiple stores, and even chains, to economize on marketing and volume buying. There is a market transition from independent one store sites to multiple outlets.

## STRATEGIC IMPLEMENTATION

**The Automation Imperative**

The company made a decision to compete from a Calgary base. To do so it has had to do some things a little differently from some of the competition. Management understood from the beginning that to survive in North America in the garment industry, it would have to automate and it would have to do so as quickly as possible.

Producing a ski jacket takes a different set of solutions than the standard apparel automation. An insulated garment that has three plies and all the color combinations as well as multiple pockets, snaps and zippers is a highly complicated garment which takes an average of 2 hours to sew.

The product line is very complicated. There are many different raw materials and the component products are numerous. Making a whole line requires, on the average, 50 pattern pieces which have to be sized to all the body sizes in children's, men's and ladies'. In the fashion business it is necessary to change style to some degree every season. To make all those pattern pieces for roughly 250 different styles competitively in Canada is impossible if done manually. So it was necessary to automate.

**Introduction of Computer Systems**

The first piece of automation Sun Ice invested in was a design and pattern grading CAD/CAM system. After the CAD/CAM system, the company put in a specialized management information system based on a mid-range IBM computer and a customized software package developed specifically for the apparel industry. Even so, Sun Ice has had to take on specialized personnel to maintain and upgrade its computerized systems. Along with the systems-analyst programmer the company has taken on technicians and engineers to handle the automation equipment.

The management information system tracks the flow of materials through the plant. Bar coded production tickets are on everything. Every jacket has a label, bar coded so it can be read electronically. Information includes style, color, size and suggested retail price. It generates production tickets for all the sewers and generates a pay package. It also generates tickets for the warehouse, prints invoices, and expedites the shipping process. The system ties into an EDI (electronic data interchange) system that links Sun Ice to some of its largest customers. Thus far this is not a large number of customers, but when the specialty stores elect to be electronically linked into a Quick Response type system, Sun Ice is already equipped.

### Unit Production System

One of the more innovative systems that Sun Ice installed is an overhead conveyor system called a Unit Production System. The system cost close to $400,000. This type of material handling system is especially important to a skiwear company because the materials used are so bulky.

The supplier chosen had provided a number of the automated systems Sun Ice had installed over the years. The company was familiar with the supplier and its service. Sun Ice was satisfied with the other equipment, and was reassured that the new system would work well with the management information system. Sun Ice relied on the supplier to install the system and adapt it to its needs.

The Unit Production System has a number of advantages for Sun Ice. It keeps the many pieces of a jacket together in a production packet; it moves the material from one operator to another overhead, out of the way. It is controlled by a central computer that can tell the whereabouts of each work-in-process item, what stage it's at and where it's going to be an hour from now. It gives instant feedback for production control, how much time it takes to do each operation on any type of jacket; and finally, it serves as a quality control device. If a mistake is made, it can be tracked right to the operator that did the sewing.

The system runs off the same programming that the production tickets are using, with the ticket telling the production floor how to process or move the material through the process from one station to another.

### Human Resources

One of the most worrisome aspects of being an apparel manufacturer in a place like Calgary is the lack of trained engineers and operators. Sun Ice has found this to be a continuing problem, so far a problem without a good solution.

The company finds the most productive operators are immigrants. Although they generally haven't sewn in high tech factories, they have some skills and are trained to work with the high tech equipment.

Engineers are more difficult to recruit. The company advertises worldwide for them. Training on the equipment has to be done on the job.

### Quality

Sun Ice ensures its high level of quality by using the most effective weatherproofing and thermal materials and by instilling a quality culture. Management operates on the basis that quality is a must, so nothing goes through without checking. Everything is inspected three times. It's part of everyone's daily function to make sure that the quality is there. The garment can't go out with a flaw. If it has a flaw then it gets rejected and researched to find out why.

### Problems With the Automation

The only major problem the company encountered with the on-going automation effort was early on in the process. It was a costly software bug that cost in both revenues and customer satisfaction. The MRP system was erasing orders as they were entered. At the end of the season, the company discovered that orders for more than half a million dollars had been lost.

Even with the problems, Sun Ice is committed to advanced manufacturing technology. The company believes very strongly in the need to increase productivity in order to compete. Management sums up the company's philosophy this way: "How do you learn unless you dive in? You're never going to cover all the angles and have everything under control if you do something new. The price of learning something new is doing it, making mistakes and learning from your mistakes. If you have to wait for it to be perfect, you're never going to do it."

## RESULTS

It is Sun Ice's commitment to the leading edge in technology that allows it to be competitive in the global apparel industry even though it is headquartered in a very non-traditional city for an apparel company. Although the company has problems finding qualified personnel, has to import all of its raw materials, and is 1,000 miles from a service location for critical automation equipment, it has succeeded. Sun Ice has developed a distinctive product, segmented the market well, and developed a competitive manufacturing strategy. Advanced manufacturing technology has made it possible for Sun Ice to produce the complex garments it designs and to provide consistent quality at an attractive price.

### Financial Results

Sun Ice has expanded rapidly. Over the past 5 years sales have more than tripled, growing to $30 million in fiscal 1990. Sun Ice has been consistently profitable. In the current year net returns were 4% on sales, down slightly from 5% last year.

## TAYLOR INDUSTRIAL SOFTWARE
Edmonton, Alberta, Canada

### BACKGROUND

**The Company**

Taylor Industrial Software is a privately owned, Alberta based company that develops and markets computer software for industrial applications. The company was started in 1979 by Neil Taylor. In 1982 Taylor Industrial Software introduced software to perform automatic documentation of industrial programmable controllers. The company has since grown to a staff of 60 people and annual sales in excess of $5 million in over 30 countries.

**The Products**

Taylor was one of the first companies in the world to offer micro-computer based software to support programmable controllers. Programmable controllers (often called programmable logic controllers or PLCs') are used to control groups of machines or process control equipment in all types of industrial plants. The software performs documentation, programming and loading of ladder logic programs in PLCs.

Several of Taylor's software packages are considered the accepted industry standard for their application. Many major corporations such as Ford, E.I. Dupont and Miller Brewing have standardized on Taylor software for its many plants around the world.

Taylor now offers over 30 separate software products to support users of PLCs and markets a number of other software products developed by other companies. Taylor's customers are in all types of industries including auto manufacturing, forestry, petroleum, food and beverage and other industries requiring plant automation.

### COMPETITIVE STRATEGY

**Strategy for the 80s**

In the early 1980s an opportunity was identified. The tools available for creating and documenting PLC programs were extremely limited. As personal computers became available they provided a potential platform for which software could be developed to perform these tasks in ways that provided significant benefits to PLC users.

Neil Taylor recognized that his background in industrial applications and his ability to write PC programs for developing and documenting PLC programs represented a potential product. Another early recognition was that the Canadian market was not large enough to sustain a company specializing in this range of software products. It was clear that the U.S. market would have to be addressed in order to be successful.

**Strategy for the 90s**

Although the market for PLC support software continues to grow, one source of competition is becoming more significant and is expected to limit growth for other suppliers in the future. This potentially dominating competitive force is the PLC manufacturers themselves. Taylor's products are primarily targeted to support the PLC product lines of Allen-Bradley (A-B), the leading U.S. supplier, and Modicon, another major U.S. supplier. Both A-B and Modicon are currently delivering products competitive with those of Taylor and other PLC support software suppliers . Although the PLC companies have been attempting to offer competitive products in this class for several years, the newest editions are the first to represent effective feature and benefit competition against the products of independent suppliers such as Taylor.

Although Taylor is firmly committed to the long-run support of A-B and Modicon products, the potential limitation on opportunities in these traditional lines represents a new challenge. In order to maintain or enhance the growth curve it has enjoyed over the past several years, Taylor is currently offering and planning new products that benefit from the established reputation of the company and that can be distributed through the same channels to the same customers. The strategy includes similar products in support of other lines of PLCs and other industrial application oriented software products that run on industry standard PCs.

Japanese suppliers are not up to North American standards in terms of software proficiency. This offers Taylor the potential for associating itself with major Japanese PLC lines. By bringing its expertise to these situations, Taylor expects to expand in the Far East where the Japanese lines are dominant and to participate in the growth as Japanese PLCs capture additional portions of North American and European markets.

Other identified areas of opportunity include computer-aided training and finite capacity scheduling.

## STRATEGY IMPLEMENTATION

### Implementation of the 80s Strategy

In 1983 after recognizing the void in PLC programming and documentation software and developing early products to meet that need, Taylor began a marketing and sales effort to capitalize on the opportunity. Recognizing that the U.S. market was important and accessible, that was the immediate target. The company began advertising its products and exhibiting at trade shows in the U.S. resulting in orders from large and small companies.

Several forces contributed to the success of Taylor in these markets. One factor was simply the growth of the PLC as the standard building block of automation. Another was that the products offered by the PLC vendors to address the functions covered by Taylor and other independent software providers were expensive and inflexible. A-B and Modicon were slow to introduce an effective PC implementation. At the same time the PC was becoming more of a ubiquitous programming tool in factories, especially as portable units became smaller and more powerful; this created an increasing demand for a programming and documentation solution that could be run on a PC. Also, Taylor's early entry along with its up-to-date, quality products earned the company a solid reputation, helping it to protect its share as newcomers entered the market.

Exports outside of North America began to grow as large multinational companies began to standardize on Taylor products. This meant that as these companies implemented automation in other regions of the world, the Taylor support products were implemented there as well. Another export force was essentially driven by international distributors that recognized the need for support software as U.S. PLC brands were being applied in their markets. These dealers saw the opportunity and visited U.S. trade shows to find products, such as Taylor's, to fill that requirement.

### Implementation of the 90s Strategy

Taylor is taking a global approach to finding new product offerings and developing partnerships. Taylor is presently involved in contracts or development agreements with a number of major Japanese PLC vendors including Mitsubishi, Toyoda and Yaskawa Electric. Taylor also has a partnership with a company in the U.S. which is developing Computer Based Training (CBT) software for the industrial marketplace. The manufacturing resource scheduler product presently offered by Taylor was developed by Fortune Systems in India.

The opportunity to take advantage of the gap in software sophistication between North America and Japan is not without its obstacles. One is the need to work with Japanese characters on the screen. Taylor personnel are meeting this challenge, however.

As new products are being developed at Taylor, the company is employing modern development techniques, including limited use of some computer-aided software engineering (CASE) tools. New quality control methods are being introduced, as well. Some of these have been derived from the close working relationships with Japanese PLC producers.

## RESULTS

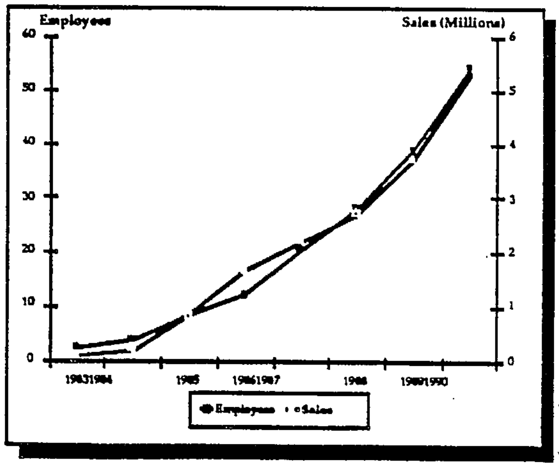
### Sales Growth

Taylor Industrial Software has grown from a one-man engineering consulting practice to sales of over $5 million in 1990. The growth has been funded entirely from within.

### Employment Growth

Employee growth has tracked sales growth closely, as sales have stayed consistently around the level of $100, 000 per employee.

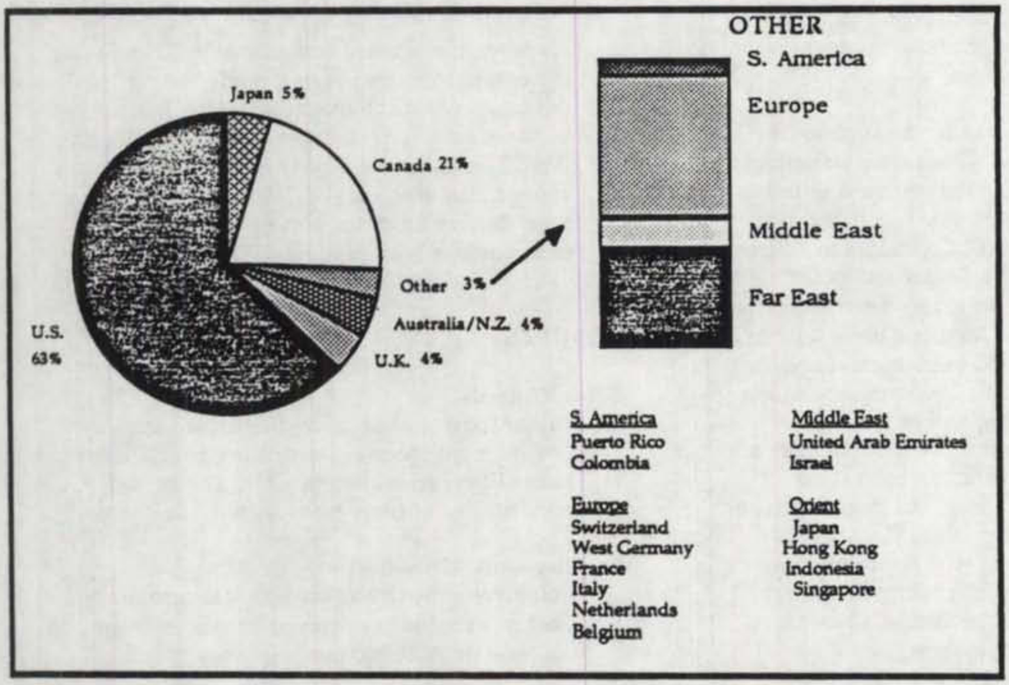
CHART G
SALES AND EMPLOYMENT
1983 THROUGH 1990



**Exports**

The strategy for the 1980s resulted in a broad distribution of sales to various geographic regions. Only 21% of sales is in Canada. The U.S. represents approximately five-eighths of total sales. The balance of the company's sales is spread widely.

**CHART H**
**SALES LOCATIONS**
**YEAR ENDING MARCH 31, 1990**




**Projected Growth**

It is too early to tell whether the strategy for the 90s can sustain the growth achievement of the 80s. The focus on the PLC lines of the Japanese firms can offer penetration into the fastest growing automation markets. That, along with the introduction of early stage products such as finite capacity schedulers and training packages, could make 90s growth even greater than that of the 80s.

THE PAS LUMBER COMPANY, LTD.
Prince George, B.C., Canada

## BACKGROUND

### The Company

The Pas Lumber Company is operating in a global market where, as a small company with only one sawmill and a total of three facilities, it is successfully competing with international corporations more than 100 times its sales size.

Selling its lumber under the Winton trademark, The Pas has been able, over the years, to add value to a commodity product by a combination of better service and a better appearing product. The company has nurtured its relationship with its customers by accommodating them on mixed width shipments, by on-time delivery and by selling only the best looking lumber as top grade. Along with its traditional dedication to serving the customer, The Pas has also made a substantial investment in state-of-the-art automation in its mill. The company credits the $20 million investment it made in advanced automation technology in the middle of the 1980s with allowing it to compete in the difficult economic conditions that have existed since 1987.

### Competitive Environment

The integration of the European market, the Free Trade Agreement and the opening of the Eastern Bloc will result in intensifying competition in the forest products industry. As Price Waterhouse reports: "In particular (these changes) are resulting in increased corporate concentration and a trend to bigger manufacturing plants and competitive pricing." Both mergers and acquisitions are becoming common in the global industry, along with several significant joint ventures in Europe. Price Waterhouse concluded that: "Canadian producers must continue to rationalize operations, seek market niches and build world scale facilities. They must also grow by national and international acquisition in order to remain competitive."

Large, vertically integrated companies are favored to survive in the pulp and paper industry. However, a number of smaller companies are doing nicely in lumber products by holding costs down through state-of-the art facilities, developing defensible market niches or providing extraordinary service to customers.

A number of these smaller companies are in British Columbia, where the sawmill industry is truly world class. The B.C. industry is often cited as the most technologically advanced in the world. Blessed with some of the best timber stock and aggressive industry leadership, the B.C. timber industry exports most of its production to fill the demand for softwood lumber from the U.S., Japan and even Europe.

Canadian lumber producers are very competitive in world markets, Price Waterhouse's Forest Industry Specialist Group points out that Canadian producers are relatively small compared to the largest manufacturers in other countries. In the list of world-wide top 50 forest product suppliers, the largest Canadian corporation is 14th (Noranda Forest). Canada has only six companies in the top 50, whereas the U.S. has 19 and Japan has 8.

## STRATEGIC IMPLEMENTATION

### The Background of the Automation Project

The Pas' Hart sawmill near Bear Lake has been operating since 1972, when it was built to consolidate the British Columbia operations of The Pas' predecessor company, Winton Lumber. Until 1987, The Pas was owned by the Winton family on Minneapolis. The Wintons have been operating lumber companies in both the U.S. and Canada since 1889 - for three generations. Since 1964, the only remaining lumber company owned by the Winton family was The Pas.

### The Decision to Automate

The Pas started looking at upgrading the Hart sawmill in 1982 when the managers decided that a chipper canter had to be replaced. Replacing the chipper canter became a major decision point in the operation of the mill and of the entire company. Because upgrades and additional equipment had to be accommodated in the mill wherever they would best fit without disturbing the existing equipment, replacing the chipper canter with the latest model meant that the mill would have to be reconfigured. There was no surplus space to accommodate new equipment. Over the previous few years, top management had been going to equipment shows and talking to the machine suppliers; the company had wanted to try out the new edger/trimmer optimizing equipment but didn't have room in the mill building to add anything new.

Major changes to the mill would have to be made to replace the old equipment. Top management and the managers on-site looked at the obsolescence as an opportunity to increase the efficiency of the mill. When the company went into the project, the main objective was to improve the operating efficiency of the mill and the utilization of the timber being worked. It knew a more efficient system would increase the recovery of lumber from the same volume of logs being processed shippable lumber and, therefore, improve the profitability without using any more logs.

**The Course of the Project**

The first step taken was to engage the services of a specialized consulting engineering firm. For almost a year, the consulting engineers and the company examined all the issues that they believed would be involved in planning and implementing a major overhaul of the sawmill. The study included extensive use of a computer simulation of the outcome of the investment depending on the probable lumber species to be harvested and their mix. Various scenarios were run to determine the benefits of what, by this time, was going to be a significant investment. The company was deciding on an investment that amounted to almost a third of the value of sales the year before. The automation would also mean that the company's only sawmill would be closed down for at least three months. The simulation software SAWSIM proved to be an efficient way to try out a number of options and to zero in on the best all-around solution. It also proved to be very accurate. Because of the risk, The Pas was looking for a minum 20% rate of return on a discounted cash flow basis on this.

Top management had determined that if they were going to upgrade the mill, it would become the most efficient production facility in the northern interior, an area noted for its high tech orientation. The old equipment was moved out of the mill in August 1984, the floor replaced, and the new equipment moved in. Only one major piece of equipment remained; the Chip-N-Saw, which had been purchased ten years before, was overhauled and then considered efficient enough to go in with the new optimized processors.

**The New Equipment**

The mill now optimizes in every major area. The first decision point when the log enters the sawing operation is equipped with three primary breakdown scanners. As the log is taken down to a cant, it is evaluated by a cant optimizer to ensure the best use of the log. The process was vividly described in the Prince George *Citizen* on August 14, 1985: "A large log comes into the mill, is stripped of its bark and goes to a 'headrig'. Inside a control booth four television screens showing aspects of the equipment and two readouts tell the sawyer information about the log that photocells and a computer produced. Fingers move on a bank of buttons. The log has two opposite sides chipped flat, then bandsaws remove two side boards. Total elapsed time, six seconds. The flattened centre section, called a cant, goes to a machine unique in Canada. It's called a 'cant optimizer'. Again optical scanners and a computer are involved. What they do is look at the cant, then mull over some basic problems. If the piece is just slammed against a bar, clamped in place and cut, a curved piece of wood 16 feet long might produce 176 board feet of lumber... and a lot of chips. But if the piece was moved so it went through at a slight angle, you'd get 200 feet of lumber. That's 12% more lumber from the same piece of wood. And that's exactly what the optimizer does. It angles the cant, chips away everything that isn't needed to make a squared piece with all the lumber possible."

As the lumber continues through the mill, it encounters three edger optimizers and two trimmer optimizers. All these high tech pieces of the system are contributing to maximizing lumber output.

The newest milling equipment is also coupled with the latest in control equipment. Basically, the mill went from a mechanical operation to an electronic one. The scanners control operations of the sawing equipment and PLCs drive the material handling equipment, sorting the logs and directing them into the next process that particular timber should go through depending on the logic of the system.

Along with new production equipment, The Pas has also installed a complete management information system so that keeping track of production and productivity is completely automated.

### Training the Personnel

While the mill was shut down for the changeover, the production workers chosen (by seniority) to stay on were thoroughly trained on the new equipment they would be running. When the automated mill started up in November 1984, the operators were taken through a test run of the new equipment. The extensive training given the operators allowed them to quickly take hold of their new duties. The equipment itself went through the same type of extensive shakedown with the software controlling it.

An absence of trouble with the hardware, software and operators did not mean a stress-free implementation. The problems with the equipment and the software were minimal compared with problems with the supervisors. The only ignored aspect of the project was the direct supervisors. These were men from their late forties up to their early sixties. Men who had been in the industry all their lives, but couldn't make the adjustment to the new operating systems.

### Problems With the Supervisors

As The Pas had spent a lot of time and effort getting the operators up to speed on the equipment, the supervisors had been completely ignored. While the operator only had to worry about one machine, the supervisors were responsible for a whole line with several pieces of automated equipment all working together. They had to keep up the flow. And The Pas had very ambitious objectives for the flow, 450,000 board feet per shift; that means that in some of the operations the lumber is moving past a saw at the rate of 300 or more feet per minute.

Management explains: "It was a full 10 months into operating the new mill that we finally figured out what our real problem was. It was the supervisors. Here the operators had been extensively trained, the electricians and millwrights had their on-the-job training from the vendors, but the supervisors who had the responsibility for a quarter of the whole system had never been trained to handle the new equipment. Once we turned our attention to the first line supervisors, we quickly got up to speed. The solution turned out to be replacing two of the supervisors and training the new men along with the two who stayed on. What really amazes me is that it took us so long to isolate the main problem."

## RESULTS

How did it all work out? There are 74 mills in the northern interior of British Columbia, The Pas' Hart sawmill leads them all in production per man day. It boasts the region's highest lumber recovery rate, i.e., the amount of usable lumber from the available logs. The Lumber Recovery Factor (LRF) increased by 25%.

The Pas's President feels that the automation project was vital to the continued profitable operation of the company's mill. Although returns have been substantially reduced because of recently increased stumpage fees, the mill is still operating at a profit. Without the automation project that would have been impossible with the new economic climate.

### Changes in Marketing Strategy

When the mill went on line the company made several changes in its marketing strategy, capitalizing on its long held reputation for providing a value added product and on its new capability to produce a consistent high quality product from the automated mill. The Pas now supplies only one grade of dimension lumber, the Winton grade. As the company explains, "Its an appearance product...it is a very high line domestic grade for North America and Japan. It's a preferred brand name."

Exports are up now and the new equipment makes it easy to change cutting orders at the sawmill. At the beginning of the decade the Winton brand was practically unknown outside North America. Less than one percent of the shipments went overseas. Now that has changed to a mix of 65% to the U.S., 15% to Japan and about 5% to Europe.

The Pas has made some other adjustments to its marketing strategy based on its expertise with high tech equipment. The company moved into the value added field with the addition of finger joining equipment that combines the less valuable short pieces into longer, premium lengths of lumber up to 40 feet.

The best indication of the company's satisfaction with its commitment to advanced manufacturing technology is its current $12 million investment to build a new automated and upgraded planer mill. The Pas had already been offering a variety of lumber products (siding, panelling, decking and fascia board) from its old planer mill, producing a quality product based on its proficiency in steam conditioning for re-sawn products. The new planer mill in Prince George came on line in November 1990. With the state of the art planer mill, the company will be operating entirely with advanced manufacturing methods, both in production and control equipment and in management techniques.

## VADEKO INTERNATIONAL CORPORATION
Mississauga, Ontario, Canada

### BACKGROUND

**The Company**

Vadeko was founded in 1981 by two engineers from the project team that developed Spar Aerospace's Canadarm for the space shuttle. Graham Whitehead, Vadeko's president, was senior engineer with Spar Aerospace when he wrote the proposal that got Spar its government funding for the remote manipulator on the space shuttle. When Whitehead thought he saw opportunity to expand the large robot technology to several industrial niches, he went to the company with a business plan for large-scale robotics. Spar wasn't interested. The two engineers went out on their own and started Vadeko.

The company was financed by personal funds of the founders. From the first it realized that it would have to find enough business to keep the group together while it developed marketable robotics. For the first few years, products were whatever the company could get a customer to fund. They ranged from a large manipulator used for nuclear materials to a thin-film anti-counterfeit system used by the Bank of Canada on its large denomination bills. Other products included turnkey robotic systems for cleaning, painting, paint removal and inspection. The system have been used on aircraft and railcars.

### COMPETITIVE STRATEGY

In 1986 the company decided to re-think its strategy and look for market niches that would be willing to pay a premium for its engineering expertise. The two major areas markets considered were railcars and aerospace. The aerospace sector was especially appealing, the founders had some experience with the industry from their time with Spar Aerospace. The industry appeared to offer the best market for what they felt they could best supply, large-scale robotics with high engineering content. It was determined that the aerospace market would correctly value the expertise that Vadeko could add, certainly much more than the automotive industry, the major market for industrial robotics at that time.

The first requirement to fulfill its strategy was money. In 1986, Vadeko got its first outside funding. Agra Industries bought 50% of the company. The alliance was essential to Vadeko's expansion, by that time the major U.S. aerospace companies were demanding performance guarantees that a company of Vadeko's size found impossible to give. With Agra, expansion funding was assured. The essential piece was in place for a frontal assault on the major jobs that Vadeko was seeking.

Although Vadeko started to focus on aerospace in 1986, it was some time before the real fruits of that strategy would appear. Sales to aircraft and space vehicle suppliers often have very long sales cycles, with extensive up front expenses for the suppliers. Vadeko continued to supply some of the more profitable products that it had developed earlier.

### STRATEGIC IMPLEMENTATION

Vadeko describes itself as a vertically integrated system integrator. Some of what it uses in an engineered system will be purchased and some of it the company builds. Because nothing it has supplied to date has found another purchaser for an identical system, every application is unique. Vadeko is, however, able to reuse the engineering content frequently. Experience can be leveraged from one application to another.

Experience is what the company competes on most often. In order of importance, customers are concerned with experience with a similar project, price and technology. Support is expected, both at start-up and when the customer runs into trouble later on.

Vadeko has placed an emphasis in reducing risk for its customers by emphasizing its experience with similar projects. One of its most successful promotional activities is to have an open house when a system is up and running in the plant just before shipment to the customer. Many of its systems are very impressive with multistory robots. To capitalize on the interest in the technology and the awe many engineers have for such huge manipulators, Vadeko holds open houses and invites prospective customers to come have a look at the finished product. These low key, festive occasions can reduce concerns with company capabilities and robot technology.

In order to convince customers that it is the low risk choice, Vadeko will specify only name brand components, those that have the highest profile local support in the region of the project. It will use IBM and Digital computers, Allen-Bradley PLCs, etc. These choices reflect in life cycle costs, but they also reduce the perceived risk.

### The Proposal as a Risk Reducing Tool

Another strategy the company uses to reduce risk both for itself and the customer is to prepare very detailed and well planned proposals. By the time the company had prepared its proposal, the analysis and engineering planning have defined the scope of the project in minute detail, and reduced about 85% of the risk. The typical proposal runs about five times as long as the competitive documents, and can be as long as 1000 pages for a complex project. For the NASA project, the proposal alone cost the company $300,000. But the detailed examination of what the project will entail gives both the customer and supplier a feeling of comfort with the overall proposal and the feasibility of the approach.

### Client Involvement in the System

Once a project is underway the company insists on strong client involvement in the design phase of the project. Both plant engineers and maintenance people are included in design meetings. This increases their understanding of the design, reduces questions and increases their stake in the project. The customer's personnel are also invited to Toronto for final assembly and encouraged to participate. When they later work on the equipment, they understand it from the inside out. The software is handled similarly, the customer is in on everything from design to receiving the source code.

Vadeko's philosophy is that the traditional turnkey engineering is not a viable concept, client participation is needed for the system to work.

### On-Time Completion

One of the reasons for Vadeko's success is its commitment to fulfilling the client's schedule and requirements. The company has a culture that enforces on-time completion. The company has been known to detail secretaries out to the plant floor to paint equipment so that a job will be finished on time. With time an increasingly important competitive factor, Vadeko's consistent on-time performance gives it a competitive advantage.

## RESULTS

Vadeko is currently celebrating its largest order to date, a $24 million multi-year contract from NASA for a gantry robot seven stories high to facilitate preparation for shuttle launches.

After stagnating at the $5 million level in sales while the company was repositioning itself in mid-decade, sales have steadily increased. In 1989, revenues were $9 million; in 1990 the company has booked $50 million in new orders including the $24 million NASA robot. The major new orders are all from the aerospace industry.

In 1986 the company booked no orders outside Canada; in 1990 when Vadeko has an estimated 75% market share for large-scale robot projects in North America, 90% of the business is outside of Canada.

Vadeko is also profitable. Historically it has earned an estimated 15% on sales. Its emphasis on planning to reduce risk has served the company well in preventing the unpleasant surprises that impact earnings at many heavily engineering oriented firms. Since taking a $1 million loss in 1984 completing a troubled job, Vadeko had always made money on its projects.

### The Future

The company is looking forward to additional business from NASA and commercial aerospace customers, and a continuing business in the painting and cleaning robot systems it sells to the railcar industry. For future growth, Vadeko is exploring some new niches including nuclear power plants and chemical weapon decommissions.

Within the next few years many of the nuclear plants that were built in the 1960s and 70s will need a lot of work to add productive years to their lives. This dangerous upgrading can most safely be done with the large-scale robot systems that Vadeko specializes in. In the weapons area, governments have stockpiles of chemical and germ agents that have to be disposed of. Robots again are the perfect vehicle for such hazardous duty.

WESTHEAD SYSTEMS LIMITED
Rexdale, Ontario, Canada

## BACKGROUND

### The Company

Westhead Industries was founded in 1980 by Barry Westhead, formerly head of the Canadian-based engineering unit of Fischer & Porter Co. From the outset, Westhead recognized that in order to realize the full benefits of automation, end-users would require engineering services to integrate various products and to customize the applications into a complete, functional system.

In its early years, Westhead Industries provided engineering services and, as it recognized needs, developed hardware and software products, e.g., data acquisition or operator interfaces to standard manufacturing automation equipment such as PLCs. Over the years, as the standard personal computer (PC) emerged as the platform of choice, Westhead Industries discontinued its hardware product development and concentrated on selling software for that platform. The software sold by Westhead includes products developed in-house as well as those developed by other companies.

Westhead's early projects were largely for process industry or utility applications. In 1984, it became involved in the Automotive industry. The initial application was a production line diagnostics application.

The company had been self-financed from its inception through 1985. Venture capital financing was acquired in 1986 to take advantage of growth opportunities. The company's expansion included five offices in the U.S. Sales grew to $7 million by 1988.

Growing pains, however, were severe. The company's products required more engineering support than anticipated which caused the expansion to be unprofitable; the company had spread out beyond the practical reach of its technical support resources. Some of the U.S. offices were closed to confine operations closer to home. In 1988, the focus of the company changed from one of risk and expansion to one of control and profitability. The venture capital investment was also repurchased by the company in 1988.

Westhead sales have fallen back to $4 million but profitability has been restored. The company feels that it is now in a position to grow in a manageable and profitable manner.

In October 1990, Setpoint Canada Limited's Toronto operation was merged with the Westhead engineering group. This combination now operates as a separate business unit, Westhead Systems Limited (WSL). The goal of the merger is a stronger system integration capability including software development capabilities for larger-scale computer systems and critical project management skills.

Westhead Industries continues to sell products for industrial automation as a distributor or licensee. Through the combination with Setpoint Canada, a cell control product has been added that runs on minicomputer platforms.

### Services Provided

The types of application and integration services that Westhead provides are:

- Integration strategies, hardware, applications and data
- Specification and design studies
- Project management
- Hardware and software selection and procurement
- Interconnecting wiring design and drafting
- PLC programming and documentation
- Custom software, applications and integration
- System staging, integration and testing
- Installation and start-up supervision
- Training
- Software and hardware maintenance and life cycle support

## COMPETITIVE STRATEGY

### The Market Need

North American production is under attack. Changes such as globalization, free trade, mergers, acquisitions, environmental issues and consumer behaviour are pressuring competitiveness.

All producers are keenly assessing how to reduce costs and simultaneously to produce consistent and appropriate quality products.

At a more detailed level, there is the need to use automation and control equipment already in place as well as the need to integrate that existing equipment. This can represent a severe problem in that there has been little standardization of communications protocols. Integrating, or simply interfacing, the equipment on hand requires a special capability. In fact, this communications interface requirement is the system integration task most likely to be outside the range of the in-house capability of the user.

### Application Focus

Westhead views itself as a system integrator operating at the level between MRP systems and factory floor control systems. The company is targeting the cell or plant-wide control level of applications activity. It views this level as having needs that are not adequately filled by the information systems integrators at the high end nor by the control system integrators working primarily with PLCs at the low end.

### Product and Service Strategy

Experience gained from projects has contributed to the evolution of a comprehensive system engineering approach to automation systems. The increasing interest in computer integrated manufacturing (CIM) has placed even more emphasis on system integration services as enterprises strive for more efficient business operations by linking management information systems with plant floor control systems.

The Westhead total solution approach combines business and technical services and proven products with a system engineering methodology to implement complex automation systems. It includes a logical series of steps that are followed to ensure successful systems.

The company has a distinct competency in its ability to deal with multiple communications systems that may be in existence in the plants of its customers. This competency is expected to be leverageable as a key factor differentiating Westhead from its many competitors.

The products offered by Westhead Industries are system tools that can be used to implement systems at the cell or plant level. The skills of the people in the Westhead Systems group are well-suited to applying these tools and solving the communications and control problems associated with these applications.

Westhead will not develop new hardware products but will focus its development activities on software for industry standard hardware.

### Geographic Market Strategy

The company is dedicated to confining its operations to a geographic area that it can manage and within which it can provide outstanding service and support to its customers.

### Sales Strategy

A key factor in the company's success with customers has been the ability of Westhead technical personnel to establish close working relationships with technical people in the customer companies. The relationships have resulted in "customer partnership" type arrangements where Westhead is regarded as an important resource by its customer. One result is repeat business, which has been a significant factor in Westhead's success. This relationship-based technical selling approach will remain as a key element in Westhead's sales strategy.

## STRATEGY IMPLEMENTATION

### Product and Service Offerings

The company no longer designs or develops hardware products. It concentrates its efforts on software applications for industry standard hardware platforms using standard operating systems.

With the merger of the Setpoint group, Westhead has enhanced both its product and service capabilities for its target applications. The added personnel are experienced in addressing applications using minicomputers which are often required at the cell or plant level of manufacturing control. The merger has also brought with it a relationship with Allen-Bradley, the North American leader in PLCs, relative to that company's Pyramid Integrator product. Pyramid Integrator combines a VAX minicomputer on a backplane with a PLC to address the cell control market requirement.

Similarly, the PC based products and the expertise in applying PCs to manufacturing control applications addresses other aspects of the market. These factors result in complementary product and service offerings for the target areas of application.

### Geographic Focus

Westhead is focusing its attention on the market opportunities within 500 miles of Toronto. Within this range, the company is confident of its ability to satisfy customer requirements and to maintain profitability. It is also confident that this region offers significant growth opportunity. The company has one remaining U.S. office located in the Detroit area.

## RESULTS

The geographic retrenchment and the move away from developing and supporting proprietary hardware have returned the company to profitability, although at a reduced level of sales.

The merger of Setpoint Canada's products and personnel into the Westhead family has established a formidable set of capabilities with which to address the target market. It is too early to tell if this can be effectively leveraged into profitable growth.

# APPENDIX D

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