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# **CAD/CAM SYSTEMS FOR SMALL AND MEDIUM SCALE ENGINEERING INDUSTRIES IN SELECTED ESCAP DEVELOPING COUNTRIES**

Report of a workshop organized by UNIDO and ESCAP  
in co-operation with TECHNOMET ASIA,  
Singapore, 9-20 May 1988

**Working Papers in Industrial Planning  
No.1**

**INDUSTRIAL PLANNING BRANCH  
INDUSTRIAL INSTITUTIONS AND SERVICES DIVISION**

05

**WORKING PAPERS IN INDUSTRIAL PLANNING**

The papers presented in this series have been produced by the UNIDO secretariat or by outside experts in the course of the technical co-operation activities carried out by the Industrial Planning Branch. The series contains selected papers that are believed to be of interest to a wider audience. They are often of an exploratory and tentative nature, presenting issues for discussion, and do not necessarily reflect the official views of UNIDO.

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## Preface

At the recommendation of the 9th Session of the ESCAP Committee on Industry, Human Settlements and Technology held in Bangkok from 10 to 16 September 1985, UNIDO's Sectoral Studies Branch and the ESCAP/UNIDO Division of Industry, Human Settlements and Technology organized a Technical Working Group (TWG) on production and use of machine tools in the engineering industry of ESCAP developing countries (UC/RAS/86/020). The TWG, which was held in Singapore, 17 to 21 November 1986, and was hosted by TECHNINET ASIA, was a direct follow-up of the UNIDO/ESCAP project on "Review and Appraisal of Industrial Progress at the Regional Level".

The participants in the TWG formulated concrete conclusions and recommendations at regional and national levels which are included in the final report of the meeting issued by the Sectoral Studies Branch as Sectoral Working Paper Series No. 55 (UNIDO/PPD.17). Specific joint work with UNIDO was also suggested, inter alia, the organization of a workshop on CAD/CAM systems for Asian developing countries in the form of information, training, personnel, hardware and software. To follow-up this recommendation, UNIDO jointly with ESCAP and TECHNINET ASIA, organized a Workshop on CAD/CAM Systems for Small and Medium Scale Engineering Industries in selected ESCAP developing countries (XP/RAS/88/005).

The present document contains the proceedings of the workshop, which was held in Singapore from 9 to 20 May 1988.

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## 1. ORGANIZATION OF THE WORKSHOP

### 1.1 Introduction

The Workshop on CAD/CAM Systems for Small and Medium Scale Engineering Industries in Selected ESCAP Developing Countries, was convened at Singapore from 9 to 20 May 1988. It was attended by national experts from Bangladesh, People's Republic of China, Republic of Korea, India, Indonesia, Malaysia, Philippines, Singapore, Sri Lanka and Thailand. National experts of UNIDO capital goods project of Colombia (DP/COL/87/023) and Venezuela (DP/VEN/86/001) also attended the Workshop. International experts from Belgium and the United States, and a resource person from Singapore acted as consultants to UNIDO in the Workshop. As observers and special guests, the following institutions also attended the Workshop and made available their facilities for training purposes: Brown Boveri Government Training Centre, German-Singapore Institute, National University of Singapore, Singapore Polytechnic and Microfits and Methods Pte Ltd.

As a non-governmental organization of the Asian region, TECHNINET ASIA hosted the Workshop and provided the necessary secretarial support and assistance. The list of participants is attached as annex I.

At the recommendation of the 9th Session of the ESCAP Committee on Industry, Human Settlements and Technology held in Bangkok from 10 to 16 September 1985, UNIDO's Sectoral Studies Branch and the ESCAP/UNIDO Division of Industry, Human Settlements and Technology organized a Technical Working Group (TWG) on Production and Use of Machine Tools in the Engineering Industry of ESCAP Developing Countries (UC/RAS/86/020). The TWG, which was held in Singapore from 17 to 21 November 1986 and was hosted by TECHNINET ASIA, was a direct follow-up of the UNIDO/ESCAP project on "Review and Appraisal of Industrial Progress at the Regional Level".

The participants in the TWG formulated concrete conclusions and recommendations at regional and national levels which are included in the final report of the meeting issued as UNIDO document PPD.17 (Sectoral Studies Series No.55). Specific joint work for UNIDO and ESCAP was also suggested, inter alia, the organization of a workshop on CAD/CAM Systems for Asian developing countries.

### 1.2 Opening session

Dr. Leon V. Chico, Executive Director, TECHNINET ASIA, welcomed the participants, resource persons and observers who attended the Workshop. He appreciated the UNIDO and ESCAP officials for their continued interest in collaborating with TECHNINET ASIA in SME development programmes. He briefly described on TECHNINET's long time involvement in technical assistances programmes over this region, especially in its 11 member countries (ESCAP region). He emphasized the needs for technology development of SMEs to make it more competitive and maintain sustained growth. UNIDO/ESCAP Workshop on CAD/CAM System for SME Engineering Industries is very timely and any further assistance extended towards this end will be of great help for the developing countries. He advised the participants to take advantage of their active participation in this Workshop. He wished the success of this Workshop and hoped that the participants would be able to formulate specific programmes on CAD/CAM system development involving their respective institution.

The representative of the Industrial Planning Branch, Department of Industrial Operations of UNIDO addressed the participants on behalf of UNIDO and ESCAP. He expressed the appreciation of UNIDO and ESCAP to TECHNINET ASIA for hosting this meeting, and the other Singaporean institutions for having made available their facilities for practical training on their premises.

As an organization committed to promote and accelerate industrial development in developing countries, the representative of UNIDO expressed that UNIDO is keenly interested in industrial automation and technological innovation in the capital goods sector, which is of strategic importance to developing countries. This Workshop has been designed, therefore, to familiarize participants from Asian developing countries with the technologies associated with CAD/CAM systems and more specifically to identify their technical assistance needs in this area.

### 1.3 Election of officers

The participants elected Mr. R. Nagendran, Director, HMT International, Bangalore, India, as Chairman and General Co-ordinator of the Workshop.

### 1.4 Agenda and programme

The participants adopted the programme of the Workshop as attached in annex II.

### 1.5 Documents

The list of documents distributed in the Workshop is attached as annex III.

### 1.6 Adoption of the report

The report of the Workshop was adopted by the participants to the Workshop on 20 May 1988.

## 2. DEVELOPMENTS OF THE WORKSHOP

### 2.1 Presentation of issues

The decade of the 80s presents a considerable challenge to the industry of developing countries especially in the form of increased competition from home and abroad, inflation, soaring cost of labour, and increased material and plant machinery cost. Many enterprises in the newly industrializing countries have met these challenges by employing computer-aided technologies which resulted in increased productivity. In the industrialized countries the application of computer systems in the engineering industries is widespread both for design and manufacture of components.

With the advent of the new technology associated with CAD/CAM, the performance of the small and medium engineering industries in many developing countries (especially newly industrializing countries) has been remarkably enhanced since the early 1980s. In the developing countries, small- and medium-scale enterprises (SMEs) have become aware of their technological deficiencies in turning out competitive products with respect to product design, cost and delivery dates.

The traditional advantage of cheaper labour in the developing countries has greatly lost its significance in face of the greater flexibility of modern production systems using computer-aided facilities.<sup>1/</sup> This new technology directly contributes to significant cost reduction and faster production in all types of engineering industries. SMEs in developing countries now are realizing the necessity of upgrading their production techniques by employing better production methods. This will require the blending of new technologies with the existing set-up in order to improve efficiency and reduce production cost. Thus, entrepreneurs will have to face the question: What new approaches should the engineering industries adopt?

Apart from the basic requirements for operating an efficient engineering industry through proper man-machine-materials balance, the application of computer-aided facilities in the design and manufacturing line can also tremendously boost the production capability. Although this would require a sizeable initial investment, it would be offset within a relatively short time as compared with investment in traditional production hardware.

The terms CAD/CAM are applied in three different but interrelated contexts.<sup>2/</sup>

#### (a) Computer-aided design (CAD)

A CAD system is a system which incorporates one or more computers for carrying out some of the calculations and actions involved in the design process (CECIMO Working Party on Standardization).

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<sup>1/</sup> See UNIDO, Capital goods industry in developing countries: a second world wide study, Sectoral Studies Series No. 15, Volume I, UNIDO/IS.530, 1985; and UNIDO, Final Report of the UNIDO/ESCAP Technical Working Group on Production and Use of Machine Tools in the Engineering Industry of ESCAP Developing Countries, Singapore, 17-21 November 1986, Sectoral Working Paper Series No. 55, PPD.17, 1986.

<sup>2/</sup> See Economic Commission for Europe, Recent Trends in Flexible Manufacturing, Geneva, New York, 1986, p.18. CECIMO is the European Committee for Co-operation of the Machine Tools Industries.



(b) Computer-aided manufacturing (CAM)

A CAM system is a system which incorporates one or more computers for carrying out some of the tasks involved in the organization, scheduling and control of the operations involved in the manufacture of the product. Where machining is involved, a CAM system will usually involve CNC machine tools and means for producing part programmes for them and it may also involve a central computer for scheduling, planning and control of the operation of the system. It may involve a Direct Numerical Control (DNC) system using either the central computer or a separate computer control of stores, orders, etc. (CEGIMO Working Party on Standardization).

(c) CAD/CAM system

A CAD/CAM system is a system in which computers are used to carry out some of the tasks involved in designing and manufacturing a product. In particular, computers are often used to produce part programmes for the CNC machines in the system directly from the design data (CEGIMO Working Party on Standardization).

The main objective of the UNIDO/ESCAP/TECHNET ASIA Workshop on CAD/CAM Systems for Small- and Medium-scale Enterprises in the Engineering Industries in ESCAP Developing Countries, was to provide a forum for consideration of the specific problems faced by the engineering industry in the introduction of new information technologies by means of CAD and CAM systems.

The Workshop enabled a number of experts from selected Asian developing countries to improve their knowledge of:

(a) Design creativity through the use of computer graphics and better design development through optimization and scientific analysis;

(b) Possibilities for improved production performance and reduction of scrap materials through the minimization of fabrication error;

(c) Possibilities of improving the quality of parts and manufacturing productivity through numerical control and automated testing as well as through rationalized production planning;

(d) The needs for CAD/CAM in the engineering industries of the participating countries concerned, and technical assistance possibilities from UNIDO.

The Workshop was divided into five modules:

Module 1 (2 days: 9-10 May)

This provided the participants with an appreciation of CAD/CAM technologies and their integration into the production environment. Major topics covered were CAD/CAM terminologies, applications, benefits, potentials, systems available for installations, selection and evaluation, justification of system installation and training of personnel.

Module 2 (3 days: 11-13 May)

This provided the participants with a basic experience in the application of CAD/CAM systems for design and drawing of mechanical parts and tools. Topics included hardware briefing, familiarization with the commands, graphics generation and information management.

Module 3 (2 days: 16 and 18 May)

This was a practical orientation programme on the use of CAD/CAM systems for integration into production machines (NC/CNC). Demonstrations were made on the machine point to point routing, machine tool paths and files processing.

Module 4 (1 day: 19 May, factory visits)

This programme brought the participants to actual users' premises in the engineering industries. They appreciated the general capability of CAD/CAM applications in the manufacturing process and assessed their versatility in product design and production.

Module 5 (1 day: 20 May)

Submission and approval of the final report of the Workshop.

The issues under discussion were presented to the participants considering the following syllabus:

Module 1: Prof. Erik L.J. Bohez (9 and 10 May 1988)

(1) Introduction to CAD/CAM (2 hours)

- Historic development of CAD/CAM;
- Impact of CAD/CAM technology on developing countries;
- World trend of CAD/CAM applications.

(2) Detailed hardware configuration (3 hours)

- Standalone and host-based systems;
- Small, medium and large systems;
- Input devices;
- Output devices;
- Display techniques.

(3) Software available to the different industrial sectors (3 hours)

- Electronics: PCB (VLSI, IC, circuit simulation, etc.);
- Mechanical: geometric modelling, mechanism modelling, NC, etc.;
- Civil: finite element analysis, steel and concrete detailing, structure analysis, etc.;
- Chemical: piping design, plant design, process simulation, etc.;
- Architecture: mapping, surveying, building design, etc.

(4) Benefits of CAD/CAM systems (2 hours)

- Intangible benefits;
- Tangible benefits;
- Economic analysis and return on investment.

Module 2: Prof. Andrew Nee (11, 12 and 13 May 1988)

(1) Selection and evaluation of CAD/CAM systems (2 hours)

- Micros, minis and mainframe based workstations;
- Selection criteria and procedures.

(2) Installation of CAD/CAM (1 hour)

- Physical requirements;
- Time frame.

(3) Advanced topics on CAD/CAM (6 hours)

- Solid modelling;
- Robotic applications;
- Computer-aided process planning;
- Computer-integrated manufacturing.

(4) CAD/CAM software development (6 hour)

- Parametric techniques;
- Case studies on metal stamping
  - material utilization
  - jigs and fixtures design
  - sheet metal development
  - process planning.

(5) Hands on practice using HP ME10 mechanical drafting and design software at NUS CAE/CAD/CAM Centre (4 hours)

- Hardware briefing;
- Familiarization with commands;
- Construction of an engineering drawing.

Module 3: Mr. Stephen H. Liang (16 and 18 May 1988)

(1) Overview of CAD to CAM to NC process (1 hour)

- CAD requirements:
  - Graphics display
  - Computer
  - Input device
  - Plotter
- Software:
  - 2D CAD
  - 3D CAD
  - Surfaces
  - Solids
  - Finite element analysis
  - IGES.

- **CAM requirements:**
  - **NC/DNC/CNC machines**
    - **Controller**
    - **Machine tool with servo controllers**
  - **Types of NC machines:**
    - **Milling**
    - **Drilling**
    - **Boring**
    - **Turning (lathe)**
    - **Grinding**
    - **Sawing**
    - **Electrodynamic machining (EDM)**
    - **Pressworking**
    - **Welding**
    - **Inspection (CMM)**
    - **Tube bending**
    - **Flame cutting**
    - **Plasma arc cutting**
    - **Laser beam processes**
  - **Graphics machining**
  - **Post processors**
  - **Tape punch/magnetic media/communications.**
  
- **Advantages of CAD/CAM vs NC/CNC/DNC only:**
  - **Long process to generate NC tape**
  - **High possibility of error**
  - **Requires well trained programmer**
  - **No visual verification**
  - **Easy to change existing programmes**
  - **Reduction in programming time**
  - **No redundant entry of geometry data.**
  
- **When to use CAD/CAM:**
  - **Well equipped with NC/CNC/DNC equipment**
  - **When production is of job shop or batch type:**
    - **Low to medium quantity production**
    - **Customized products that are altered often**
    - **Good example is the tool and die industry**
  - **Short lead times are critical to securing orders**
  - **When your customer base uses CAD to design**
  - **Contoured surfaces are required by customers**
  - **Skilled machinests are difficult to get or are very expensive.**

(2) **NC/CNC/DNC**

- **NC (1 hour):**
  - **Definition**
  - **History**
  - **Basic components:**
    - **NC programmes**
    - **Controller - MCU (machine control unit)**
    - **Machine tool.**

- NC programming (3 hours):
  - Breakdown of typical NC commands
  - Breakdown of example programme
  - Programme generation methods:
    - Manual input
    - Computer assisted
    - CAD/CAM with graphics.
  
- Post-processing to machine format (1 hour):
  - APT language:
    - What is it?
    - Role as standard
    - Other standards/options
  - Machine language:
    - Difference from APT
    - Place in CAM system
    - Typical commands.
  
- Download to NC/CNC machine (1/2 hour):
  - NC tape:
    - Tape punch
    - Tape reader
    - Tape format
  - Diskettes
  - DNC.
  
- Computer numeric control (1/2 hour):
  - Definition
  - Advantages over NC.
  
- Distributed numerical control (1/2 hour):
  - Definition
  - Advantages
  - Communication methods
  - Error checking
  - Networking standards.
  
- Adaptive control (1/2 hour):
  - Definition
  - Advantages
  - Sensors.
  
- (3) Graphic machining (3 hours):
  - Milling (2-5 axis):
    - Pocketing
    - Profiling
    - Point to point
    - Roughing
    - Contouring.
  
  - Lathe

- Sheet metal operations:
  - Flat pattern generation
    - Automatic unfolding of part into flat pattern. This assumes that certain information was entered by the designer or the manufacturing engineer
    - This compensates for bend angle, bend radius, material properties and sheet thickness
  - Nesting of parts:
    - Maximize material usage
    - Optimize tool path
  - Punch press programme generation:
    - Laser, water jet, flame and plasma cut path generation
    - NC controlled punch presses:
      - Support of varied punch tools:
        - Round
        - Rectangular
        - Rounded rectangle
        - Corner
        - Special user defined shapes
      - Nibbling of patterns:
        - Linear stepping
        - Circular and spline stepping
        - Area removal: round and rectangular
        - Notching
        - Repositioning of material
    - Warns of overloading conditions based on press tonnage and specific operation.
- Government role in promoting CAD/CAM:
  - Basic requirements:
    - Human
    - Financial
    - Support structure
  - Possible actions to promote and guide CAD/CAM usage
  - Look at what Singapore is doing.
- Demonstration (1/2 day):
  - Design of a part - hands on
  - Graphic part machining - hands on
  - Graphic machining on a complex surface - demonstration
  - NC tape punching - demonstration
  - Download - demonstration
  - Machining of complex part - demonstration

The UNIDO Reference Guide to CAD/CAM systems for use in the capital goods industry of developing countries furnished to the participants as main background, also contains the materials and papers provided by the above mentioned international experts to the Workshop.

## 2.2 Summary of presentations<sup>3/</sup>

### 2.2.1 Overview of CAD/CAM

CAD/CAM means Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM). Basically, it describes a set of tools built around a digital computer to enhance the performance of certain design and production functions. That set of tools include both software and hardware.

In the past, design and manufacturing have been seen as two distinct functions. The designer would be in his world and create the design. Then the designer would put it down on paper in the form of a mechanical drawing. The drawing would then be given to manufacturing to build.

With the advent of CAD, the step of the draftsman was first made easier. Similar to what the word processor has done for the secretary, the CAD system had given the same type of capability to the draftsman. There was no longer the need for drafting tables and erasers. Engineering changes became much easier as the draftsman did not have to re-draw the design from scratch. That CAD is today referred to as Computer Aided Drafting System.

In today's work environment, CAD (Computer Aided Design) encompasses tools to help the designer, not just the draftsman. These tools assist the designer visualize his design better. They also assist him in analysing the relative strengths and weaknesses of his design. The analysis tools provide the designer with information on stress-strain analysis, dynamic response of mechanisms and heat transfer.

As the CAD system evolved, the information stored in the computer contained a complete description of the product to be built. Computer aided manufacturing systems began to become available to take advantage of this new sources of design information. Before, the manufacturer would look at the drawings and then create all the process information necessary to manufacture the parts. This was done manually as the drawings had to be read by a skilled manufacturing engineer. CAD/CAM assists the manufacturing engineering to generate the process information that used to be done by hand.

CAM systems utilize the data placed into the CAD data base by the designer. The manufacturing engineer uses the CAD data base as a starting point for generating the programmes used by his machine tools. This saves the manufacturing engineer from a very time consuming and tedious task of recreating the design from a paper drawing. The manufacturing engineer will graphically machine the CAD part. By it meant that he will define the cutter paths on screen using the CAD geometry as a guideline. On the screen he will be able to see how the tool will be moved over the part. Changes to the tool path can be done easily on screen.

After he creates all the cutting actions necessary on the screen, the engineer can then add information such as feed rate, tool speeds, etc. to the cutter path. This information is then post processed into a machine language format which is understood by the machine tool that is to do the work. Each vendor of machine tools are likely to have their own programming language. Thus there will need to be a post-processor software for each type of machine tool.

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<sup>3/</sup> This section is based on a paper prepared by Mr. Stephen Liang as consultant to UNIDO.

The programmes are then loaded onto the NC machines and tested. Loading the programmes into the machines can be performed in one of three ways: by paper tape, by diskette or via a communications wire. Tests are usually run on a wood block or other practice material. Any changes to be made are done at the graphical level, or for easy changes, it can be done at the programme level.

This is the fundamental idea behind CAD/CAM. Various industries and companies using different levels of CAD/CAM technology. In industrialized countries, almost all shops have some NC machinery and a good percentage utilize CAD/CAM. In the newly industrialized nations (NICs) most shops are equipped with NC equipment, but have yet to implement any CAD/CAM technology. The exception to this are the multinational corporations in the NIC's. Some medium sized local industries have started to invest in CAD/CAM recently. In the lesser developed countries, most small and medium enterprises do not have NC technology and certainly no CAD/CAM.

(a) Review of CAD

The basic requirements of a CAD system are as follows: computer, graphics display, input device, plotter and CAD software. In addition, CAE software, hardcopy units, alphanumeric terminals, printers and communication networks can be options to the system.

Computers can range from microcomputers to workstations to minicomputers to mainframes. What computer is used, depends on the CAD/CAM software used, and the amount of work to be done.

Graphic displays range from monochrome monitors to 19" diagonal, 1024 by 1024 pixel intelligent terminals. The choice of displays depends on the complexity of the design, the computer used and the CAD software.

Input devices are the means for conveying the design information from the designer to the computer. Input devices usually consist of an alphanumeric keyboard along with some pointing devices. The pointing devices include: mice, tablets, digitizers, thumb wheels, joysticks and light pens. The choice of which device to use depends on the preferences of the designer and the software.

Plotters come in 2 basic types: pen and electrostatic. Pen plotters use mechanical drives to move a pen over the paper. Electrostatic plotters use an electronic imaging process, similar to copiers, to transfer the image to paper. The choice of plotters depends on the complexity of work and the amount of plots necessary. Generally speaking, pen plotters are much less expensive than electrostatic plotters, but much slower.

CAD software is used to enter the design into a computer database. This database is the foundation of any CAD/CAM system. The CAD software can represent the design by using: 2-dimensions, 3-dimension wireframes, surfaces, or solids. The choice of how the design is represented greatly affects how it is handled in manufacturing.

In today's environment, the most preferred mode for representing design is 3-dimensional with surfaces defined. In the future, we expect that solids will dominate. However much will depend on both hardware and software developments.



(b) Review of CAM

The most critical requirement for application of CAM is the presence of NC machines in the factory. NC machines are machines that can read information from a media (tape, diskette, disk, network) and perform a set of tasks without human intervention. These machines typically have a controller which direct the machines activities. There are numerous types of NC machinery: milling, turning, drilling, boring, grinding, sawing, electrodynamic machining (EDM), pressworking, welding, inspection, tube bending, flame cutting, laser cutting, plasma arc cutting, water jet cutting, component insertion and photoplotters. These are the more common NC machines, there are many other types of NC machines. In some cases, some of these machines are combined into one machine and referred to as a machining center.

NC machines require a part programmes to operate. The part programme contains information on how fast the machines moves, which way to move, how much to move, etc. These programmes were generated by hand, a very tedious task. Moreover, only simple programmes could be generated. Complex shapes could not be handled, except by most skilled of programmers. In the case of contoured surfaces, such as an airplane wing, they could not be handled at all.

To further use the computer in assisting manufacturing, part programme generation was made easier through the development of an NC programming language called APT. APT, or automatically programmed tools, language provided an English like interface for part programming. This meant an easier and faster method of generating NC part programmes. APT was developed at MIT in the 1950's. Its main focus was to develop a mean to programme countered parts, but it is widely used today to handle all types of parts. There are several other part programming languages available today.

Part programming languages, such as APT, made NC programming easier, but it is still required a lot of programming time. The advent of graphics in a computing environment provided an easier means for entering the tooling design and generating the subsequent part programme. The programmer could use CAD capabilities to enter the tooling design and then use the graphics to generate the cutter paths. The programmer could verify the cutter path on screen and make adjustments as necessary. Information about machine feeds, speeds, and other parameters could be added at the same time. This meant a much easier programming job.

At present, for small and medium tooling shops, the design information must be entered into their CAD system as read from drawings. For the large companies which encompass design and manufacturing, the designer give the CAD design to the manufacturing group. The manufacturing group uses the design and adds tooling information, thus eliminating the redundant task of entering the design again (saves paper too). The manufacturing people can then graphically machine the part, process the data, and generate the NC part programme.

The part programme is then either punched on paper tape, loaded on diskette, or communicated by wire to the machine tool. The media used depends on the type of controller used on the machine. Material is then clamped on the machine, the machine is positioned to a home, and the programme started. Usually a test is run to determine that the programme is correct. Errors are corrected. For minor errors, the NC programme is corrected directly. For more serious errors, the graphic machining is reviewed to determine and correct the source of the error.

In many companies, the ease of going from design to finished part has dramatically reduced the new product cycle. CAM plays two roles in this. It allows the designer to quickly see what he has designed, thus changes can be implemented rapidly. Secondly, the manufacturer has reduced his total work load as he does not have to spend as much time preparing process data.

### 2.2.2 Overview of numerical control

#### (a) Introduction

Numerical control, or NC, is a technology which involves controlling a machine through a series of codes. The codes are given to the machine in the sequence that they are to be performed. The machine reads each code and performs the action that the code specifies. All the codes put together instruct the machine to carry out a particular task.

As an example, one can look at the application of NC to a milling machine. The machine would read the code and then perform a series of actions. Such actions would include starting the milling head rotating, turning on the coolant, moving the head relative to the work piece, adjusting the spindle speed, and adjusting the feed rate. After completing the series of commands, the milling machine will have completed the cutting of the part.

#### (b) NC machine tools: The MCU

A NC machine tool consists of 2 basic parts: the machine tool itself and a machine control unit (MCU). The MCU reads the part programme and directs the machine tool to take the actions requested. The typical MCU consists of the following elements: paper tape reader, data buffer, signal output channels to the machine tool, feedback channels from the machine tool and sequence controls to coordinate the actions of the MCU. In almost all modern NC machines, a microcomputer is used as the controller unit.

The tape reader is the eye of the MCU. It is through the tape reader that the programme is passed to the MCU. In most machines installed today, paper tape is used as the method for conveying the programme to the MCU. The paper tape is a long strip of paper, or mylar, which has holes punched in it. These holes punched in the tape are a code. The standard NC tape is usually 25 mm wide with 8 tracks, or channels. Each channel is a location along the width of the tape which a hole can be punched. The standard tape can have a maximum of 8 holes along its width. Depending on which hole of the 8 are punched, letters of the English alphabet can be decoded. The decoding is based on the ASCII (American Standard Code for Information Exchange) Code. The MCU reads one row at a time and inputs the information into its data buffer.

The data buffer acts as a temporary storage of a block of the programme. Each block consists of several characters, enough to describe one action the machine is to take. The block is stored in the buffer, one character at a time until all the blocks are in the buffer. Then the machine acts on the command represented by this block of the programme.

To act on the command, the MCU sends out signals to the output channels. These signals go to servomotors, relays, solenoids and other control mechanisms in the machine tool. Feedback from the machine tool is sent to the MCU through the input signal channels. This is to make certain that the commands have been executed properly. Feedback includes the position of the work piece relative to the tool, coolant flow, tool speed, etc.

The sequence controller has the job of managing all these activities. It initiates the reading of the tape, captures the data in the buffer, sends out the signals, monitors the feedback, and gets the next command from the tape. In addition to this control function, most MCU's have a separate control panel to allow for human interfacing and control. The sequence controller monitors this control panel to see if the operator has some special requests, and it also posts information to the control panel so that the operator is kept aware of critical machine parameters. The control panel may also prompt the human operator to take some actions such as changing tools or loading and unloading the machine.

(c) NC machine tools: the machine

NC machine tools differ from conventional tools in that servomotors are used to position and move the work piece relative to the tool, and that many switches are replaced by solenoids and relays. The machine is also fitted with many electronic sensing devices to determine position, speed, fluid flow, etc. Depending on the specific machines features, other sensing devices may also be employed.

On conventional machine tools, the operator controls the actions of the machine and his senses are the feedback that determines his next step. For the NC machine, the sensors inform the controller when the requested action is complete or if an error has occurred. If the action has completed correctly, then the next block of data is read in and performed. If an error occurs, then the type of error is sent to the controller. Depending on the error type, different actions are taken.

(d) NC programming procedure

The process for creating the NC part programme consists of 4 steps:

- Process planning
- Part programming
- Tape preparation
- Programme verification

These are standard steps taken by most shops today. Tape preparation will eventually be phased out as the use of paper tape is not very reliable nor convenient.

(e) Process planning

Process planning is the first and most critical step of preparing the programmes. The concept of process planning is to evaluate the part to be made and then determining what manufacturing steps are required to produce the part. This either requires one very skilled and experienced person who is familiar with all the manufacturing processes available, or a team of people who collectively are able to represent all the process types. From this evaluation, should come a routing sheet which lists in order the work to be done, by which machine or process, and any special features to be aware of.

One common method used is to make a standard routing sheet which list all the processes. Then they can be assigned an order number to control the sequence.

(f) Part programming

Part programming needs to be done for each operation that involves the use of a NC machine tool. For each machine, the following steps must be performed: estimate how the work piece will look like when it enters this step in the process, determine how the part is to be held during machining, determine the coordinate system to be used, determine the parts location on the machine relative to some machine zero, enter the actions that the machine tool is to carry out.

Workholding is necessary to hold the work piece during machining. To design the workholder, the shape of the part entering must be known to some degree. An ideal workholder would have the attributes listed:

- Hold the work piece so that it cannot move or rotate
- Support the work piece so that the part will not deflect, distort or be damaged by the machining
- Provide accurate, reliable positioning of the work piece
- Be simple to operate
- Not interfere with the operation or movement of the machine tool
- Be designed to permit a number of machining operations to be carried out in a number of planes as one setting. This is especially true of modern machining centers
- Provide for easy cleaning and removal of swarf, preferably without human assistance
- Be safe to operate, especially when some pneumatic, hydraulic, magnetic or electrical actuation is involved

Of course, all these features cannot be met usually, but they serve as good guidelines for workholder design. For the part programmer, the workholder will affect the programme in several ways. The programmer must plan his programme to avoid the workholder during cutting and during traverse. He must base the coordinate system for all the positioning relative to where the workholder holds the work piece. The programme may need to be in several segments if the part has to be moved to reach certain areas of the part.

Coordinate system: Once the part is placed on the machining surface, then it will be necessary for the programmer to locate a coordinate system to do his programming. The choice of the coordinate system is based on:

- Ease of locating the origin
- Relation to the machine zero
- Ease of defining the part geometry from the origin in terms of x and y coordinates

It will be necessary to position the machine tool so that it recognizes the location of the origin. All the programmed steps will be in reference to this origin. That means that the origin must be some easy to identify feature in the work piece, a pre-drilled hole or a corner. In the process plan, the programmer needs to remember that the first process must present a clear reference point that all subsequent operations can refer to. This to maintain alignment between operations.

After selection of the coordinate system and its origin, the programmer is ready to move the tool against the work piece. The programmer will need to determine what type of machine he is programming. For certain machines, the machine is capable of defining its origin through operator inputs. This means that the operator can move the tool to a position which was chosen as the origin. This makes programming easier as there is no need to calculate offsets. In part programming, there are three methods for entry of tool path data:

- Manual
- Automatic NC programming language
- CAD/CAM methods

In manual programming, the programmer will use a sheet of paper to log down each move that he determines the machine should make. In this type of programming, the operator must calculate all offsets by hand. He must have a strong background in geometry and trigonometry as he has to calculate the path of the tool around the periphery of the part. The code depends on the type of machine controller used. The codes from one machine to another will be similar, but not identical. The commands are given to the MCU 1 line at a time. The machine will perform that line of code, and then retrieve the next. By properly programming the lines of code, the programmer can produce the desired result.

Manual programming is a very tedious task and can only be used for simple parts. For more complex parts, the likelihood of mistakes becomes great and the programming time so long that it makes manual programming unprofitable. In the case of contoured surfaces, the task is impossible. To handle more complicated work, a programming language call APT (Automatic Programmed Tools) language was developed. This language was written to address the NC part programmer's needs. The language presented in English like interface for the programmer.

Automatic NC programming: In APT, the programmer first describes the part in terms of points, lines, arcs, planes, etc. After the part geometry is done, then the programmer can describe the tool motions in relation to the part geometry. The programmer needs to do no calculations of the exact tool locations as the computer will automatically calculate the exact tool path based on the tool diameter. This saves the programmer from doing a lot of calculations and eliminates much of the mistakes. It also makes possible the programming of much more complex parts.

The drawbacks to APT programming are its computing requirements and the fact that most MCU's are not able to use the APT data directly. To use APT, the programmer must have a post processor that converts the APT statements into machine readable code. The machine readable code is what manual programming uses. That means that a software programmer must write a post processor for each type of machine language that you require to operate the NC machinery in the shop. The good news is that APT is such a popular language that post processors for most machine tools are readily available in the market place.

The second problem with APT has been that it runs only on large costly computers. This is of course changing and should be available on personal computers in a couple years time. In the US, to get around this problem, many companies have developed a business of selling APT programming time to machine

shops. This spreads the capital investment costs of the expensive computer over a large number of companies. Another path that some user have taken is to develop their own APT like language. These languages were written for more specific tasks or smaller computers so that the machine shop could afford to own their own computing resources.

(g) Tape punching

After the part programme is created and in the format acceptable to the MCU, the programme is placed on a paper tape. This is to transfer the program from the programming station to the NC machine tool. The NC tape has been a fixture in the industry for many years, but it has many drawbacks which will lead to its eventual extinction. The following is a list of some of its deficiencies:

- The tapes are large and bulky, especially for large programmes
- The tapes are easily damaged during handling
- Programme loading time is slow
- Correcting or editing the tape is difficult
- Storage of the tapes is space consuming

However they are the predominant method used by NC machines today. This trend is changing towards the use of floppy diskettes as they are an easier format to handle and work with. Another method for transferring data to the machine tool is the use of communications. Both of the methods are explained later.

(h) Programme verification

Programme verification is a vital step that must not be skipped. It is vital to check and make sure that the programme is correct. The machine tool can be very dangerous if used improperly or programmed incorrectly. To verify the programme, the programmer has various tools possible:

- Single step execution, cutting in air
- Dry run, in air
- Graphical simulation
- Pen plot
- First off inspection, test material

Single step execution means to run one step of the programme at a time and waiting to see the machine movement complete before the next block is allowed to be read. Not all machine have this capability. Cutting in air means to not put any material on the machine so that there is not chance of accidents resulting from collision of tool and work piece.

Dry run in air means to run the programme automatically but with no part in place. This run is usually with the feed rate override facilities so that the feed rate from the programme will not take control. This allows the programme to be run at a slow speed for visual inspection. This also give the machinist a chance to stop the machine if he sees any possibility of danger.

There are presently on the market some packages which graphically simulate the tooling programme on the machine. These programmes read in the part programmes and simulates what the machine would do on screen. This is

similar to what CAD/CAM can do, but there is a distinct difference; this type of programme emulates what the machine does, but is not able to generate the programme. Investment in CAD/CAM will obsolete this type of verification.

Another verification method is a pen plot. The part programme is fed into a computer which translates the movements to a pen plotter. By looking at the lines that the programme draws, the programme is verified. This technique is used where a 2 dimensional trace makes sense. Multi-axis programmes could not be verified using this method.

The last verification method is always used, no matter what other verifications are used in addition. This is the first piece to be cut by the programme. In the verification, a part is actually cut using the programme. Depending on the cost of the materials for the work piece, either the real material is used or a cheaper substitute material is used. For the tooling industry, a cheaper material is always used as the tooling material is quite expensive. The cheaper material must exhibit certain characteristics to be used:

- Capable of being machined without tearing
- Must be rigid enough not to deform under cutting forces
- Must be tough enough to be handled
- Should be tolerant of any heat generated from the machining
- Should not be abrasive to the machine tool

Wood, polystyrene, wax, and synthetic plastics have been used as substitute material for first piece testing. When a substitute material is used, the feeds and speeds are not tested, so care must be exercised when doing the actual part. Measurements should be made of the first piece to see if it matches the part specification. Any deviations should be adjusted for. This is why the choice of substitute material is a very important one. In cases where the actual part material is very expensive, a second pass made be made on a harder material, such as aluminum. This is to allow for a more accurate verification of the part programme.

After proper verification, the programme should be put under revision control. This is vital as running the wrong programme on the shop floor can easily be done. Older copies of the programme should be returned to the programming room for storage or disposal. It is a good idea to keep only one old copy on hand in case there is a need to revert to an older design. Machining with the wrong revision has been a bane to the NC industry as putting the wrong programme on can quickly reduce the work piece to scrap.

### 2.2.3 Two common NC terms/types

#### (a) Computer numeric control

Computer numeric control (CNC) differs from traditional NC in that the MCU is a microcomputer instead of an analogue controller. CNC provides several advantages over traditional NC:

- Easily changed to adapt new features
- MCU can be used to control different types of machine tool
- Programme buffers can be larger
- On-line storage of several part programmes

- Storage of quality/status data.
- Cheaper and simpler to design
- Changing the programming language is easily implemented

For these reasons, almost all new NC machinery are CNC in nature.

(b) Distributed numerical control

Distributed NC, or DNC, refers to a situation where there are several machine tools connected to a central computer. In this situation, each machine tool still has its MCU (probably of CNC type). The computer passes the part programme to the MCU via a communications link. The link can be a RS232C wire, LAN, twisted pair, etc. The reason for the use of DNC is 2 fold:

- There is no need to transport material from the programming room to the shop floor
- Good revision control

This is especially useful when a shop has many parts on the floor at once or the programming room is far from the shop floor. This is still a relatively new technology, so its use is limited, but growing. Because in DNC, all the machines are linked to the computer, management has an easy time determining the exact status of the jobs. For this control reason alone, many companies have taken to DNC.

Implementation of DNC will take time as many machine tools are not equipped with the necessary technology to communicate. To address this problem, there have been many devices designed to add on to existing machine tools to perform this function. In purchasing a new machine tool, it would be wise to include communications as a requirement for future growth.

2.2.4 Computer aided manufacturing

What is normally referred to as Computer Aided Manufacturing, CAM, tends to be related to what is graphics machining. Actually, CAM encompasses a whole variety of activities, just as manufacturing does. In a more general sense, CAM really relates to the application of computing technology to assist in the manufacturing processes. The computer has been employed in manufacturing in the following areas: materials, purchasing, accounts, quality, machine control, and of course, NC part programme generation. For the time being, the discussion will restrict out to part programming and machine control. But it must be kept in mind that over the long run, to fully realize the benefits of computerization, a Computer Integrated Manufacturing (CIM) environment must evolve. That means all aspects of manufacturing should be computerized and that each function of the manufacturing plant should interlinked in terms of data.

(a) Graphics machining

After a part has been designed on a CAD system, all the information describing the part mathematically has been inputted into a computer database. Graphics machining starts from the point that the CAD design is finished. The key point here is that all the data necessary to describe the part is already entered in the computer. The part programmer will start off at the point that the designer left off. No time is wasted to describe the geometry again as in traditional NC programming methods.



Another advantage results if the designer has used surfaces or solids in his design. Using traditional paper drawings, the programmer would have to guess what the designer intended. Often times this meant that the programmer would need to cut a model to show the designer. They would review the model to see if it was what the designer intended. If it was not satisfactory, then the programmer would have to edit the programme. With surfaces and solids, the designer can define the shape of the product more exactly, leaving less interpretation to the part programmer. This saves a tremendous amount of time and money from the traditional modelling process.

In the process of NC programming under the influence of CAD/CAM, the part programmer will first go through the same first step as he would with traditional NC programming. After a careful review of the part, he will determine the process for producing the part. The review can take place directly on the screen, or more commonly with a plot of the design. Based on this review, the required operations are determined and the proper machine tools are selected for each step.

After determining the needs to be done, the programmer will sit down at a graphics workstation to generate the tool paths. The part will be called up on the screen, where it will be positioned just like the way it will be mounted on the machine tool. The programmer can zoom in and rotate the part on the screen to take advantage of the graphics ability. He can get a detailed understanding of the part and look for any possible trouble spots. Many CAD/CAM systems offer three dimensional displays of the part, so the programmer has a better picture of what needs to be machined than a plotted drawing affords. At this point, the programmer can draw in any clamps or fixtures which would really be on the machine tool. On some CAD/CAM systems, there will be libraries of fixtures and jigs that the programmer can quickly call up to check for interferences. If the system does not have this library, then the user can create his own. This is only necessary if the clamps might get in the way of the machine tool.

After positioning the part, the programmer then can call upon a library of tools that he has previously created or he can create a new tool for use in this situation. Generally speaking, it is to the advantage of the company to create a set of tools which reflect what the company normally has on stock. This has the advantage of reducing inventory and avoiding unnecessary delays due to the non-availability of a particular tool. This library of tools is actually a library of tool descriptions that the CAM software requires to do its work. Information such as tool size, tool number, tool type, gauge length, and tool shape would be in the description.

With the selected tool, the programmer can then start the process of generating the cutting path. This is where the graphics ability of CAD/CAM really pays off. At this point, it will be necessary to differentiate between the various processes in manufacturing the part. Milling, turning and sheet metal work each have their own specific requirements that demands differences in CAM software. Graphics milling is the most complex, but most recognized of CAM.

#### (b) Graphics milling

Milling can be looked at as several possible sub-operations: point-to-point, straight cut, profiling and pocketing. Point-to-point refers to operations where the tool is brought to a particular position, or point,

and then the action required is performed. A good example of this is drilling where the tool is positioned first, then it is lowered to do the actual work. In point-to-point cutting, no cutting is done until the work piece has come to rest. For programming this type of work, the programmer specifies where to drill and then lets the software take over and attend to all the holes. The graphics will display the path of the tools so that any interference problems can be determined. Optimizing the path has been a classic problem for all computer programmers. There is no easy way to find the answer using existing computer technology, so the computer will make a best guess at what the optimal path should be. The programmer can look at the result and then adjust the path as he sees best. Tool changes are handled automatically by the software.

In straight cut machining, the tool is brought against the work piece to make straight line cuts. This is very limited form of machining, but it can be made more powerful when we consider the ability to bring together many of these straight cuts. If we consider a circle, then we can simulate that circle by several straight lines. The more lines the better the approximation. If the tolerances are rather loose, then the straight cut machine can handle the work. Some polishing after milling can smooth out the edges. The problem with this approach for finer tolerance is the size of the program required to do even one circle. Each cut requires a set of coordinates for the machine tool, and a smooth circle may require hundreds of very short straight cuts. For the programmer, he simply tells the CAM system which lines to follow. The computer will then depict the tool path on the screen for verification.

Profile cutting is a function built in to most CAD/CAM systems to ease the programmer's job. The programmer merely needs to identify the geometry that he wishes to cut around. The computer calculates all offsets and automatically generates the tool path with the tool that the programmer has chosen. The programmer can verify and adjust the tool path. Displays usually show the center of the tool as it traverses the path of the cut. At change of direction points, the system usually display the tool in the form of a circle to help the programmer visualize the tool path. Depending on the CAM system, there may also be a dynamic ability to display the tool in motion and to display the tool as a cylinder instead of just a circle. 3D system will allow the programmer to view the tool path and tool position from different angles. The depth of the cut and any possible interference can be determined. In certain CAD/CAM systems, the system is able to process the tool path data to represent how the work piece will look like after passing through this one machining step. These visual tools help the programmer from making mistakes in programming.

The ability to do profiling is a great time saving function. In a few key strokes, the programmer can do what could have taken a few days to do by hand. With CAD/CAM systems that use surfaces or solids, the profiling software is able to generate tool paths to cut countoured surfaces. This would not be possible to do with manual programming. To use the contouring feature, the CAM software would interface to a multi-axis NC/CNC machine tool.

Another commonly found feature in graphics milling is the pocketing routine. Pocketing refers to hollowing out the insides of a work piece. A good CAM system will require the programmer to identify the edges of the

pocket and the bottom. Then the software will calculate the tool path necessary to hollow out the cavity. Depending on the software, it will generate either a zigzag pattern or a circular pattern. On some systems, this user is selectable. Another useful feature in the pocketing software is the handling of islands in the pocket. This means areas in the pocket that are not of the same depth as the pocket in general.

The use of these routines can reduce the part programmer's time drastically. Verification of the tool path is improved as the tool path is visible on screen. The programmer can see the tool travel in: (1) high speed, (2) slow motion, (3) frozen or (4) stepped. These capabilities along with the use of color and magnification allows for easy and accurate verification of the programme. Display of the fixtures, jigs, tool and spindle helps to identify interferences.

(c) Graphics lathe

The graphic lathe software is similar to the milling software. It provides the same types of visual verification. Lather software should support turning, boring, threading, drilling and grooving. Usually routines are written to make threading, rough turning or boring, and grooving a simple question and answer session. For lather operations, 2D CAD systems are generally satisfactory due to the symmetrical nature of the work.

(d) Sheet metal CAD/CAM

For the sheet metal industry, the materials need to look flat before they can begin their work. What this means is that a good look at all the sheet metal pieces reveal that they all result from bending a flat piece of material. In the CAD world, the designer designs the part in three dimensions. This means that he draws the sheet metal part as it would look after the bends are put in.

Under normal operations, the manufacturer receives a plot showing three views of what the part looks like already bent. The manufacturer then interprets the drawings and tries to determine what the original flat piece of sheet metal looked like prior to bending. This leads to misinterpretations and mistakes as some complex parts are very difficult to convert from bent shape to flat shape. To alleviate this problem, CAD/CAM has developed programs which unfold the three dimension, bent part into a two dimensional flat pattern.

Depending on the system, the amount of input from the manufacturer will vary. In a good system, the designer is forced to put in some information at the beginning. This information deals with the location of bend lines and radii. If this information is put in by the designer, then the manufacturer can convert to the flat pattern at a push of the button. If the designer only draws the part, then the manufacturer must determine the bend lines of radii. Of course, the designer knows better where the bends are and the appropriate radii so he should put in the data. But in reality, the designer is rated usually by design time and does not make an effort to put in manufacturing information.

For the manufacturer to convert the three dimensional part to two dimensional, he identifies the surface that remains fixed, then he must pick out the entities to be unfolded to the same plane as the fixed surface. This is much more tedious and time consuming, but is effective in getting the job done.

During the unfolding, the computer calculates for material properties to determine strains that affect what the flat pattern should look like. This allows for a more accurate determination of the dimensions of the flat pattern than if the manufacturer calculated it by hand. In some CAD/CAM systems, after the flat pattern is generated, the system can automatically dimension the flattened part.

Once the flat pattern has been determined, then the process used to create the pattern from a larger sheet of metal depends on the machines available and the quantity to be built. There are two basic types of cutting methods for sheet metal:

- Progressive die
- Profiling

For a large volumes of products, the use of progressive dies is generally more economical. In progressive die technology, there are a series of dies each of which make one cut and or bend. Thus to create a finished part, several dies are required. In making this type of dies, the application of graphic milling is used.

Where volumes are smaller, materials cost higher, or lead times critical, profiling is the optimal choice. In profiling, the flat pattern for the part is placed on a larger sheet of stock material. More patterns are fitted on the sheet to maximize utilization of the stock material. This fitting, or nesting, is done automatically by the CAD system. In a good nesting program, several shapes can be put on the sheet to make even greater utilization of the metal stock.

After nesting, the various profiling tools can be used to cut the metal. These tools are NC punch presses, NC flame cutters, NC laser cutters, NC water jet, and NC plasma cutters. The CAM software will generate the NC part programs to control these types of cutters. The software will optimize the path to minimize the cutting length. This reduces cutting time, thus increasing machine utility. Profiling has receive much attention in CAD/CAM development as its advantages match those of CAD/CAM's.

#### (e) CMM interface

Another application gaining popularity in CAD/CAM is the integration of the Coordinate Measuring Machine with the CAD/CAM system. The benefits of this are far reaching, depending on the ability of the CMM used. In the simplest application, the CMM can be used to measure a model and create the CAD database. The NC programs can be generated from this database as described previously. This is an effective means of generating manufacturing data from an artists model.

A second use is in the area of inspection. For manually controlled CMM machines, the interface allows input of CMM measurements into the CAD system for verification against the CAD design database. For automatic, NC controlled CMM machines, the software can generate a NC program to control the CMM machine and automatically inspect the part. Data from the inspection is stored for review and statistical evaluation.

With the CMM piece in place, CAD/CAM completes the phase from design to manufacturing with quality.

(f) Other applications of CAD/CAM

**Robotics:** As robotics are gaining popularity, some CAD/CAM software vendors are producing software to programme robots. These softwares are in their infancy, but the productivity gains seen in CAD/CAM for NC are already seen. These softwares allow the user to generate a robotic workcell on the graphics screen. Then the user can place one of several robots in the cell and program its motions. The resulting programmed motions are seen graphically on screen for verification. Errors in the programme are easily seen and corrected.

**Bill of material generation:** As a normal part of almost all CAD/CAM systems is an ability to generate a bill of materials to be used in manufacturing the part. This means both the material that comprise the part and the tools required to machine the part. Having the ability helps the manufacturer in the job costing and tracking, a critical requirement for profitability.

(g) Future directions in CAM

The field is growing so rapidly that it is difficult to isolate areas where the field is not growing. In the basic areas discussed here, the trend will be to automate the process even more. This means that moves will be made to automate the process planning and workholding. The milling, lathe, flat pattern software will be improved to require even less interaction from the part programmer, or CAD/CAM user.

With the growth of solids, CAM software can be made much more sophisticated. This is because there are less ambiguities in the design process as with wireframe models. Pockets are easily defined in solids, but in wireframe, the user must inform the computer what is a pocket. The next phase of CAD/CAM growth will result from the use of solids in design. But this will hinge on better software and computer hardware to handle the more complex calculations required for solids work.

Artificial intelligence (AI) software techniques will eventually play a major part in CAM as more of the machinists knowledge can be contained in software. Present methods in computing sciences cannot cope with the vast amounts of data and branches that a machinist brings together to make his decisions. But AI techniques are designed to handle these types of decisions. The key will be the ability of the AI programmer to extract the knowledge that the machinist knows and put it down in software. It will only be a matter of time before this happens.

2.2.5 Post processing

For all CAM systems, it is necessary to post process the path data into machine readable format. This is one of the most critical points to consider when evaluating CAD/CAM systems. The post processor are generally of two types: general and machine specific. Both have their advantages and disadvantages, and many systems offer both types to work with.

The general post processor is usually not a post processor in itself, but a simplified method for generating specific post processors. The general post interacts with the part programmer to fill out a list that correlates

machine codes to movements that the general post processor has been programmed to understand. An example is that different machine have different codes for circular interpolation, thus the general post will prompt the user for what the code is for circular interpolation for the specific machine that the programmer is interested in. This has the advantage that the part programmer does not need to know software programming to create new post processor. The disadvantage is that for the general post processor to handle all the different functions on all machines is not possible. Thus for the sake of convenience, certain specialized machine functions may not be accessible. Another area where general post processors have difficulty is in the area of specialized preprogrammed sequences that may come with the machine. This has been overcome by certain CAD/CAM softwares by giving the general post the ability to accept additional routines from the user.

For machine specific post processors, a software programmer will custom write the post processor to be able to utilize all the functions of all the machine tool. The advantage is obvious in terms of performance, but it requires a lot of expertise to write one of these post. This means that it costs a great deal of time and money to have a specific post written.

To properly evaluate which is better for the organization, an analysis must be made to determine how many different types of machine controllers are being used, and if any special routines are used from those controllers. It may be that the general post is satisfactory for 80% to 90% of the machines, but one or two specific posts are required. For general posts, there are also variances between CAD/CAM systems. The reason is that most general post use a group machine languages as a starting point for development, so it tends to work well with these languages.

Post processors have followed several trends in terms of the path from data base to part program. For some systems, the post generates the part program directly from the database. Other systems go to an intermediate step of creating an APT file. Some systems allow you to choose either method. The APT option is there for those companies who have been using the APT technology and already have in house post processors to go from APT to machine language. This means that these houses need only one post to go from database to APT, and they can use the system that they previously set up. Going to APT also allows using post processors from another company should you find that the post processor with your CAD/CAM system is no good.

#### 2.2.6 NC and CAM interface considerations

In the process of selecting the proper CAD/CAM system for a manufacturing operation, a critical consideration will be how well the CAM software matches the NC equipment. Another criteria will be how suitable the software is to type of business the manufacturer is in. Of course, due consideration must be given to future growth.

The first step is to evaluate the equipment in the workshop. The key points to consider are: type of machine, type of controller, programming language, number of tools, number of axis (for milling and EDM machines), and special features. Special features include transfer systems, canned cycles, other exceptional abilities. Based on this type of review, the type of post-processors that will be needed can be identified. The relative strengths and weaknesses of each post-processor can also be judge.

The second consideration is a survey of your business base. If the work is almost all 2 and 1/2 axis, then buying a 5-axis capable CAM system would be over spending. Breakdown the jobs that are done at the shop recently and then go back and see the history of the jobs that have been done. This will help to provide some idea of where the future might lead. To help fix growth paths, conversations with upper management and customers will help determine future requirements.

After the probable future trends are established, then an analysis of probable new NC machine should be made. If the purchase of a 5-axis machining center in the future is foreseen, one should consider a package that has post processors for controlling the 5-axis machine and has the routines in CAM that can make full use of the machine.

Sometimes, companies will make the mistake of ignoring some of their NC machines as they think that the way those machines are used will not require CAM. The most common case of this is with EDM machine. Most tool shops think of EDM as a point to point operation and ignore the NC controller that the manufacturer has provided. With CAM and an interface to these machines, the shop will find that they provide an effective machining tool that can also contour. It may be that making the EDM contour will take up the few jobs that require contoured surfaces, which most shops 2.5 axis machines cannot do. This can result in large savings for a shop.

#### 2.2.7 Initiating use of CAD/CAM

In starting the use of CAD/CAM in any country, there are three areas that must be addressed:

- Human
- Support structure
- Economics

All three are important and necessary for the implementation of CAD/CAM. The first and most critical is when there will be a need to utilize CAD/CAM for the sake of being competitive. This is a very difficult question to answer as there are many factors which affect this answer. The best answer must lie in business trends and government policies/strategies. For a start, a look at the industries to see that level they are using NC technology will determine the viability of CAD/CAM at this time. Surveys of these industries will test if and when NC technology will be utilized on a large scale.

Human development is the single most important factor in establishing CAD/CAM. The place to start must first be in the educational institutions. It is important that CAD/CAM and computer technology be made available at the university and polytechnic level. This need not be sophisticated CAD/CAM system costing large sums of money. Simple personal computer level CAD systems can teach as much about CAD/CAM as much more expensive systems costing many times more. A fundamental failure in some schools presently teaching CAD/CAM is the over concentration on CAD and lack of emphasis on CAM. To truly understand the benefit of CAD, CAM must also be understood.

For CAD/CAM to truly be effective, there must be an effective support structure available to provide service and training to CAD/CAM users. As CAD/CAM is relatively new to the region, there is usually a lack of good support once a system is sold. This lack of support is in hardware support, software support and training. Without this proper support, systems will be used at only a fraction of their total abilities. With this in mind, the purchaser of CAD/CAM system must be carefully detail what is expected of the vendor in the purchase contract. The stability of the vendor must be weighed appropriately.

On the government side, the following activities may help motivate the implementation of CAD/CAM:

- Tax incentives
- Grants to the first few implementations
- Advance the availability of training in schools
- Provide post graduate training for industry
- Provide a consulting service
- Establish some CAD/CAM service bureaus
- Identify and recommend some low cost systems
- Establish the use of CAD/CAM in government and government related business
- Regulate CAD/CAM vendors so that they provide proper support, training and service.

These are only some possibilities for advancing the use of CAD/CAM technology. The key is that given a limited source of funds, a balance must be struck between training assistance and implementation assistance.



### 3. CONCLUSIONS AND RECOMMENDATIONS

#### 3.1 Conclusions

The Workshop concluded that computer-aided design/computer-aided manufacturing are beginning to have a significant impact in the engineering industries of developing countries. Moreover, CAD/CAM is one area of technological change which is being introduced very fast at present, since it helps to improve the competitive position of small- and medium-scale enterprises (SME) through more flexibility in product development.

In fact, the development and diffusion of industrial automation technologies has started a new industrial revolution, the impact of which is already felt but which will become increasingly strong in the years to come. Because of the techno-economic linkages that exist in the world economic system, this will have a profound effect on the industrialization process in all developing countries.

The production process in the manufacturing sector is strongly influenced by the rapid diffusion of highly sophisticated technologies mainly CAD and CAM. These technologies not only tend to save labour, but also provide other substantial benefits to firms implementing them. If this diffusion is faster in industrialized than in developing countries, then the existing technological gap will widen, in which case, the anticipated industrial share of developing countries in industrial production is likely to be even smaller than current perspectives suggest.

Rapid advances in computers and microelectronics are the main driving forces in CAD/CAM. The computer is a tool which is increasingly finding its application in both the production process and its planning. The challenge of the future will be to utilize computer technology in the manufacturing process from the moment of product conception, according to market information to its final delivery to the customer. The success of this concept of industrial automation will depend, to a large extent, on the capability and reliability of the information system which controls and supervises all processes.

While mechanization has had the aim of making the material processing system self-contained, industrial automation makes it possible to achieve not only a self-contained but also an integrated information and material processing system. This is because originally the interest was focussed on the process of industrial automation at plant level. The new trends shifted the emphasis towards the domain of engineering, production planning and administrative control.

In order to integrate computers into manufacturing process, new components are required. These components are related not only to the hardware, i.e. oriented integration of computers and machine tools but also to computer software, systems engineering, production and other organizational aspects, and include a true understanding of the manufacturing process which the system is supposed to support.

The hardware component can be seen as:

- Programming logical controllers (PLC's);
- Computer numerically controllers (CNC's);
- Computer robot controllers (CRC's);

- Computers:
  - Microcomputers and personal computers;
  - Mini, super-mini computers (process computers);
  - Mainframes;
- Engineering workstations;
- Data-collection and identification terminals;
- Communication components;
- Test and quality control equipment.

Considering now the systems software, at least the following ones are identified:

- CAB (Computer aided engineering)
- CAD (Computer aided design)
- CAM (Computer aided manufacturing)
- CIM (Computer integrated manufacturing)
- CAP (Computer aided planning)
- CAPP (Computer aided production planning)
- CAT (Computer aided testing)
- CAQ (Computer aided quality assurance)
- CAR (Computer aided robotics)
- CAA (Computer aided assembly)

From the above, it was concluded that industrial automation results in a fundamental change in the production process from machine work to programming and from direct production to, inter alia, repair, maintenance and supervision, which requires highly qualified, specialized and flexible staff.

The most important postulates arising from the presentation of the experts can be formulated as follows:

(a) A technical pre-requisite for successful implementation of CAD/CAM is the automation of the main stages of manufacturing process. Furthermore, it is necessary to undertake a critical review of the product development process and the process technology applied.

(b) CAD/CAM efficiency can only be achieved after an in-depth analysis of all existing data and of their functional relations, with a view to streamlining the network of information and reducing to a minimum the stock of necessary data to be stored in the central data bank.

(c) CAD/CAM systems radically modify the activities linked with production planning. New professions are also created associated with activities related to software, administration and maintenance.

The participants concluded that the incorporation of CAD/CAM in the production process in developing countries may be justified considering the following benefits:

(a) Increased labour productivity in design and production planning as reflected by labour saving, increased labour productivity, increase in production planning capacity;

(b) Cost reduction in technical production planning, reduced time taken in production planning;

(c) Cost reduction in manufacturing (emphasis on cutting of material costs), material saving, reduction of waste;

(d) Attainment of return-on-investment targets, increase of profits;

(e) Reduction of periods of development and preparation for manufacturing and of lead time.

The participants to the Workshop, therefore, concluded that CAD/CAM systems have a large potential to be diffused quite rapidly in developing countries thanks to the very recent and very substantial decrease in cost related to the emergence of personal computer-based CAD/CAM systems. Developing countries may be able to use CAD/CAM for leap-frogging in the field of design since the CAD/CAM software embodies accumulated design and draughting experience. Such experience is currently a scarce resource in most developing countries, which is indicated by their heavy reliance on foreign technical licences.

The value and benefits of CAD/CAM are now well recognized by the metalworking and engineering industries which represent productivity improvements of more than 3:1 with faster and better quality design and more accurate drawings. The question for developing countries is to identify the system which is most suitable for them.

The participants also concluded that this Workshop offered a practical way to familiarize them with the various applications of computer-aided facilities applicable to small- and medium-scale enterprises in the engineering industries. Particular emphasis was given to the application of knowledge concerning known processes, methods, techniques, equipment, modification and approaches to existing operations, affected by the transfer of technical information and provision of industrial advisory services.

### 3.2 Recommendations

Based on the presentation of issues, the presentation of the international experts and the above conclusions, the participants recommended to UNIDO, ESCAP and TECHNUNET:

(1) To organize a second workshop on CAD/CAM systems for Asian developing countries in line with the methodology used in the present Workshop. The main objective of the second workshop should be the training of trainers, in such a way that further national workshops on the benefits and drawbacks on the introduction of CAD/CAM systems can be diffused in the countries, and most specially on software development for industrial automation.

(2) To issue as UNIDO document the Reference Guide on CAD/CAM, which was jointly prepared with TECHNUNET. The Reference Guide should be distributed to a wider spectrum of users at national level, including universities, research institutes, industrial associations and individuals interested in the topics on CAD/CAM. The special participants from Latin America recommended, if possible, to make the translation of this document into Spanish.

(3) Following the recommendations of the UNIDO/UCIMU Seminar on Machine Tools in Selected Developing Countries, held in Milan (Italy) in October 1987, it was also recommended that UNIDO continues the systematic analysis of the impact of industrial automation in the industrial sector of developing countries. The main objective should be to foster the development and growth

of industrial production in developing countries through an adequate and programmed introduction of new information technologies. This requires the formulation of planning and technology policies to create the necessary domestic capacities in the form of human resources and managerial capabilities through, e.g. training and demonstration and other technology centres as vantage points for an industrial automation policy in the industrial sector.

The above mentioned objective should lead to:

(a) Set up a capacity in UNIDO to give direct technical assistance and specialized professional services to enterprises in developing countries, which decide to introduce automation technologies;

(b) Provide decision-makers in enterprises at different levels of the public and private sector with the necessary information for a national automation policy through:

(i) Knowledge of the technological requirements for upgrading the industrial production by means of improving the use of installed capacity and increased productivity;

(ii) Knowledge of the impact of industrial automation on specific branches of the industrial sector with particular emphasis on the implications for management skills, training of human resources and know-how requirements.

(4) UNIDO in collaboration with the Department of International Co-operation, State Commission of Machinery Industry of the People's Republic of China are organizing a study tour for participants from selected developing countries of Asia, Africa and Latin America. The study tour is a follow-up of the recommendations of workshop and seminars organized by UNIDO. The main idea of the study tour in the People's Republic of China will be to visit machine tools producers in different cities of the country, and most specially to organize a high level seminar during the forthcoming Machine Tool Exhibition, to be held in May 1989 in Shanghai.

Taking the opportunity of the study tour in the People's Republic of China, the participants to the Workshop recommended to continue the study tour to other countries of the ESCAP region, as follows: The area of Hong Kong, Singapore, Thailand and India.

The main objective of the continuation of the study tour to these countries is to visit on the spot, facilities and industries directly involved in the production of capital goods in general and machine tools in particular, with special relevance to the introduction of CAD/CAM in the production processes.

(5) Technical assistance requirements on CAD/CAM in line with the main results of the Workshop were elaborated in details and submitted to UNIDO for appropriate action (see annex IV). IT was strongly recommended to UNIDO to keep the participants informed on the outcome of the submission of these proposals, through the official channels.

(6) Participants from Venezuela and Colombia, UNIDO's Capital Goods Projects, were keen to express their gratitude to UNIDO, ESCAP and TECHNUNET for having invited them to the Workshop. Very clear implications arise for Latin America's possibilities of gaining competitive edge in metalworking and other

manufacturing industries, like plastics or electronics. For these reasons, it was proposed to organize a study tour for selected personnel in industry from Andean countries so that the potential advantages of CAE/CAD/CAM technologies can be perceived by those directly concerned with investment and modernization decisions. It was further recommended that the study tour should be based in Singapore where several training, research and service schemes have been developed, in many cases on a co-operation basis with industrialized countries' firms and governments and where the local government has been very actively involved in promoting these technologies.

Annex I

UNIDO/ESCAP/TECHNET Workshop on  
CAD/CAM Systems for Small and Medium Scale Engineering  
Industries in Selected UN ESCAP Developing Countries  
(Singapore, 9-20 May 1988)

A. Participants

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Annex II

**UNIDO/ESCAP/TECHNONET Workshop on  
CAD/CAM Systems for Small and Medium Scale Engineering  
Industries in Selected UN ESCAP Developing Countries  
(Singapore, 9-20 May 1988)**

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**PROGRAMME**

**9 May 1988, Monday**

8.30

Registration: Rose Room, York Hotel

9.00 - 10.00

Opening of Workshop

Welcome Remarks by  
Dr. Leon V. Chico  
Executive Director  
TECHNONET ASIA

Opening remarks by  
Dr. Leonardo Pineda-Serna  
Industrial Development Officer  
Industrial Planning Branch  
United Nations Industrial Development  
Organization (UNIDO)

Introduction of resource persons  
Prof. Erik L.J. Bohez  
Mr. Stephen H. Liang  
Prof. Andrew Nee

Introduction of participants and guests

10.00 - 17.00

Module 1 will provide the participants an appreciation of CAD/CAM technologies and its integration into the production environment. Major topics which will be covered are CAD/CAM terminologies, applications, benefits, potentials, evaluation, justification of system installation and training of personnel. (Prof. Erik L.J. Bohez, Asian Institute of Technology, Bangkok)

**10 May 1988, Tuesday**

9.00 - 17.00

Module 1 as above

11 May 1988, Wednesday  
12 May 1988, Thursday  
13 May 1988, Friday

9.00 - 17.00

Module 2 will provide the participants a basic experience in the application of CAD/CAM systems for design and drawing of mechanical parts and tools. Topics will include hardware briefing, familiarization with the commands, graphics generation and information management.  
(Prof. Andrew Nee, Associate Professor/  
Director, National University of Singapore)

14 May 1988, Saturday

9.00 - 12.30

Field trip

16 May 1988, Monday  
18 May 1988, Wednesday

9.00 - 17.00

Module 3 will be a practical orientation programme in the use of CAD/CAM systems for integration into production machines (NC/CNC). Demonstrations will be made on the machine point to point routine machine tool paths and files processing.  
(Mr. Stephen H. Liang, Data General,  
Singapore)

19 May 1988, Thursday

9.00 - 17.00

Module 4 will bring the participants to actual users' premises in the engineering industries. They will be able to appreciate the general capability of CAD/CAM application in the manufacturing process and assess their versatility in product design and production.  
(Messrs. Bohez, Liang and Nee)

20 May 1988, Friday

9.00

Module 5 refers to the evaluation of the Workshop by the participants and the submission and approval of the final report of the meeting, including present state regarding the CAD/CAM systems in the ESCAP developing countries and the needs for technical assistance from UNIDO.

12.00

Closing session

UNIDO/ESCAP/TECHNONET Workshop on  
CAD/CAM Systems for Small and Medium Scale Engineering  
Industries in Selected UN ESCAP Developing Countries  
(Singapore, 9-20 May 1988)

SCHEDULE OF VISITS

TRANSFER: Bus Regn No - PH 973  
Driver's Name - Albert

12 May 1988, Thursday

8.30 Pick up participants at York Hotel

9.30 - 12.30 National University of Singapore  
Kent Ridge  
Singapore 0511  
Telephone: 772 2212  
Contact: Prof. Andrew Nee  
Director, CAD/CAM Centre

14 May 1988, Saturday

8.30 Pick up participants at York Hotel

9.30 - 12.30 Brown Boveri Government Training Centre  
15 Kallang Junction  
Singapore 1233  
Telephone: 296 7833  
Contact: Mr. Walter Siener, Director

18 May 1988, Wednesday

13.30 Pick up participants at York Hotel

14.30 - 16.30 Singapore Polytechnic  
Engineering Department  
Dover Road  
Singapore 0513  
Telephone: 775 1133  
Contact: Mr. Quah Kok Wah, Head  
Mechanical & Engineering  
Department

19 May 1988, Thursday

9.00 Pick up participants at York Hotel

9.30 - 12.30 Microfits and Methods Pte Ltd.  
Blk 996, #01-05/06  
Bendemeer Road  
Singapore 1233  
Telephone: 291 4357  
Contact: Mr. Goh Bun Hong  
Operations Manager

14.30 - 16.30 German-Singapore Institute  
10 Science Centre Road  
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Singapore 2260  
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Contact: Mr. Dieter Haefner  
Head, CAD/CAM Department

Annex III

Handouts for participants

1. Reference Guide to CAD/CAM Systems for Use in the Capital Goods Industry of Developing Countries
  2. Production and Use of Machine Tools in the Engineering Industry of ESCAP Developing Countries - Final Report of the UNIDO/ESCAP Technical Working Group, Sectoral Working Paper Series No. 55, PPD.17
  3. The Machine Tool Industry in the ASEAN Region: Options and Strategies (Main Issues at Regional Level), Sectoral Working Paper Series No. 49, Volume I, UNIDO/IS.634
  4. The Machine Tool Industry in the ASEAN Region: Options and Strategies (Analysis by Country), Sectoral Working Paper Series NO. 49, Volume II, UNIDO/IS.634/Add.1
  5. Technological Requirements for the Machine Tool Industry in Developing Countries, Sectoral Working Paper Series No. 51, UNIDO/IS.642
  6. Industrial Automation in the Production of Capital Goods - Issues for Developing Countries, Sectoral Working Paper Series No. 61, PPD.44
  7. Selected Aspects of Microelectronics Technology and Applications: Custom and Semi-Custom Integrated Circuits, Technology Trends Series No. 1, UNIDO/IS.631
  8. Selected Aspects of Microelectronics Technology and Applications: Numerically Controlled Machine Tools, Technology Trends Series No. 2, UNIDO/IS.632
  9. Technological Perspectives in the Machine Tool Industry and their Implications for Developing Countries, Development and Transfer of Technology Series No. 19
- + Corrigendum
10. Country Papers - Bangladesh, Indonesia, Republic of Korea, Malaysia, Philippines, Sri Lanka, Thailand, Colombia, India and People's Republic of China

## Annex IV

IDENTIFICATION OF TECHNICAL ASSISTANCE NEEDS ON  
CAD/CAM IN ASIAN DEVELOPING COUNTRIES

COUNTRY	BANGLADESH	CHINA, People's Rep. of	INDIA	INDONESIA	KOREA, Rep. of
NATIONAL COUNTERPART	Bangladesh Small and Cottage Industries Corporation (Under Ministry of Industries)	Beijing Machine Tool Research Institute Ministry of Machine Building Industry, China	Confederation of Engineering Industry	Directorate for Small Scale Industry Department of Industry	Ministry of Commerce & Industries
TITLE OF THE PROJECT	CAD/CAM Demonstration Centre for Small and Medium Engineering Industries	UNIDO/BMTRI Workshop on CAD/CAM for Small and Medium Scale Enterprises	CAD/CAM Training Facility for Engineering Industries	The Design and Manufacturing Assistance in the Field of Electric Components and Electronic (CAD/CAM Training Program)	CAD/CAM Training Center for Small and Medium Industries
IMMEDIATE OBJECTIVE (Only One)	In order to create awareness among the prospective entrepreneurs regarding the benefits of CAD/CAM systems.	Set up a CAD/CAM Workshop which plays an exemplary role of using CAD/CAM technology in small and medium enterprises of developing countries.	Training and application orientation for all Engineering Industries.	To train engineers of Directorate for Small Scale Industry (DJIK), Department of Industry, on CAD/CAM system.	CAD/CAM consulting for Tooling (Mould & Stamping Die)
EXPECTED OUTPUT	Prospective entrepreneurs would gain knowledge & deeper understanding on the possible applications of CAD/CAM system in local small & medium scale engineering enterprises.  Training of technical people on the basic of CAD/CAM technology and their applications.	<ol style="list-style-type: none"> <li>1. A workshop shown a good practice of the usage of CAD/CAM technology and experiences on getting cost effectiveness, productiveness, and productivity.</li> <li>2. Establishing centre for managers and engineers from domestic or abroad.</li> <li>3. As consultant and adviser to CAD/CAM users.</li> </ol>	Indian Engineering Industries established nearly 25 to 30 years back have to be modernized. Familiarization with CAD/CAM will create confidence in the Industry to go in for CAD/CAM machines.	A well trained and knowledgeable DJIK officer in the field of CAD/CAM are expected to be available.	High Productivity.
INPUTS REQUIRED	Financial assistance for setting up microcomputer-based CAD/CAM unit for demonstration with at least 5 workstations.  Training for the technical people to operate and maintain the system.	<ol style="list-style-type: none"> <li>1. CAD/CAM software</li> <li>2. CAD hardware, peripherals</li> <li>3. Training on site and experts team</li> <li>4. Initial fee</li> </ol>	Hardware, software and experts for training	<ol style="list-style-type: none"> <li>1. Experts to help in the planning of training program as well as the establishment of CAD/CAM centre.</li> <li>2. Financial aid for the training program.</li> </ol>	CAD/CAM facilities (10 machines)

## Annex IV (cont'd)

IDENTIFICATION OF TECHNICAL ASSISTANCE NEEDS ON  
CAD/CAM IN ASIAN DEVELOPING COUNTRIES

COUNTRY	MALAYSIA	MALAYSIA	PHILIPPINES	SRI LANKA	THAILAND
NATIONAL COUNTERPART	Standards and Industrial Research Institute of Malaysia (SIRIM)	Majlis Amanah Rakyat (MARA) Vocational Training Division	University of the Philippines Institute for Small-Scale Industries (UP ISSI)	Industrial Development Board of Sri Lanka (IDB)	The Metalworking and Machinery Industries Development Institute (MIDI)
TITLE OF THE PROJECT	CAD/CAM Training Program	CAD/CAM Centre in MARA Vocational Institute	CAD/CAM for Small and Medium Enterprises	Establishment of a CAD/CAM Demonstration Centre	CAD/CAM Demonstration Unit for the Metalworking and Machinery Industries
IMMEDIATE OBJECTIVE (Only One)	To train engineers (Metal Development Centre) of Standards and Industrial Research Institute of Malaysia to gain the knowledge of CAD/CAM system or technology.	To set up a CAD/CAM Centre in one of the MARA Vocational Institutes. This Centre will provide CAD/CAM facilities for the trainees of the relevant trades (machining, tool and die-making etc.)	To educate SME's in the ways of CAD/CAM.	To make the small and medium scale industrialists aware of the benefits of utilizing CAD/CAM system in their industries.	To improve linkage between design and manufacturing units within the MIDI.
EXPECTED OUTPUT	A well trained and knowledgeable SIRIM's officer in the field of CAD/CAM are expected to be available.	Craftsmen who are competent in CAD/CAM to work in the industries.	1. Better products (quality). 2. Increase in productivity	To train a group of engineers, technicians and personnel attached to industry in the field of CAD/CAM system and their utilization. This Centre will be able to provide the consultancy/ advisory services to the industrialists interested in applying CAD/CAM system in this mark places.	A CAD/CAM Unit 1. providing design and computer aided manufacturing technology advisory services. 2. being a model as well as demonstration unit for the industries.
INPUTS REQUIRED	1. Experts to help in the planning of training program as well as the establishment of CAD/CAM Centre. 2. Financial aid for the training program. 3. A well experience expert in the area of CAD/CAM to train the engineers/officers.	1. Computer hardwares and softwares. 2. CNC machines. 3. CAD/CAM training for the teaching staff. 4. Continual advisory support of the latest development in CAD/CAM.	1. CAD/CAM Demonstration Unit. 2. Training for trainers.	1. Equipment necessary for the establishment of CAD/CAM Centre. 2. International experts to carry out studies and prepare a detailed plan of action including training programs.	Technical assistance: o experts - CAD/CAM, tool/die fixture/jig o training - basic, intermediate and advance Equipment: o minor PC based workstation o plotters o main storage o NC tape punch o 3-D Geometry creation software (AUTOCAD, Personal designer) o tool path generator o NC code generator