COMPUTER NUMERICAL CONTROL OF MACHINE TOOLS

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Chapter 18:
Computer Aided Manufacturing

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Objectives of Chapter 18

- Understand **Computer Aided Manufacturing (CAM)** and its strategic role in the production
- Know about how **CAM** and **CNC** are strongly related
- Discuss about **Flexible Manufacturing Systems** and how **CAM** can be integrated
- Meet the variety of **CAM** software
- Learn some basic programming methods in a **CAM** software

Definition

Computer Aided Manufacturing (CAM) can be defined as the use of computer systems to **plan**, **manage** and **control** the **operations of a manufacturing plant** through either direct or indirect computer interface with the plant's production resources

- In other words, the **use of computer system in non-design activities** but in manufacturing process is called **CAM** (Elanchezhian et al. 2007)

Strategic Role of CAM

- The application of CAM in the production offers advantages to a company to **develop capabilities** by combining traditional economies of scale with economies of scope resulting in the **desired flexibility and efficiency**

Definition

Strategic Role of CAM

- Amongst other **benefits** provided by CAM, Post identifies the following (Post 2003):

- **Greater supervision of the production**
- **Fast response to changes in market demand**
- **Greater flexibility**
- **Product variety**
- **Small lot-sizes**
- **Distributed processing capability**
- **Reduced waste**

Theory and Application

History

- The roots of **CAD**/**CAM** trail back to the beginning of civilization, when the engineers of the ancient civilizations such as Egyptians, Greeks and Romans acknowledged the importance of the graphical communication

- Later on, Leonardo Da Vinci developed technics, such as cross-hatching and isometric views

- The invention of computers and xerography made possible the creation of graphics and visualization (Zeid 1991)

- In the early 1950s, shortly after the World War II, the need for complex parts led to the invention of the **Numerical Control** (**NC**) that substituted the requirements for skilled human machine operators (Chang et al. 2006)

Theory and Application

History

- At the same time another invention, namely the *digital computer*, assisted the development of **NC** and provided the means for the creation of **robots**, **computer-aided design** (CAD), **computer-aided manufacturing** (**CAM**) and **flexible manufacturing systems** (**FMS**)

- The utilization of **CAM** software systems began in large automotive and aerospace industries in 1950

- During the late 1950s, **APT** (**Automatically Programmed Tools**) was developed and in 1959, General Motors (GM) began to explore the potential of interactive graphics.

- By the mid-1960s, the term **Computer-Aided Design** (**CAD**) started to appear. GM announced their **DAC-1** system (**Design Aided by Computers**) in 1964

History

- The decade of **1970** can be characterized as the **golden era** of computer drafting and the beginning of ad hoc instrumental design applications (Zeid 1991)

- Among the first **CAD**/**CAM** systems was *UNISURF* that was developed by Pierre Bezier in 1971 for the *Renault* industry and allowed surface modelling for automotive body design and tooling (Bezier 1989)

- In 1979 the **IGES** (**Initial Graphics Exchange Specification**) was initiated and it enabled the exchange of model databases among **CAD**/**CAM** systems

Theory and Application

History

- Other notably standards that were developed in the same period include (Zeid 1991):
  - **GKS. ANSI** and ISO standard that interfaces the application program with support package
  - **PHIGS**, that supports high function workstations and their related CAD/CAM applications
  - **VDI** (Virtual Device Metafile), that describes the functions needed to describe a picture
  - **NAPLPS,** that describes text and graphics in the form of sequences of bytes in ASCII code
- The computers evolved rapidly and today's systems are capable of **planning, scheduling**, **monitoring**, **decision-making** and generally **managing all the aspects of the manufacturing procedure**, even "think" and adapt to changes automatically (Chang et al. 2006)

History

- The **immense international competitio**n that appeared in 1980s and the high demand for industrial products became a worldwide phenomenon, therefore, **manufacturers were forced to adapt to the changes**

- Small batches, reduced inventories, dynamic environment and rapid changes of the environment call for **increased flexibility** and **exploitation** of the state of the art technological achievements

- **CAM** was recognized as a solution to effectively cope with the requirements in the shop-floor level

Theory and Application

- The **CAM** systems act as an interface between **CAD** and **NC** machines

- The complex drawings created by **CAD** tools require **"translation"** in order to produce the coding for the **NC** machines

- Alongside with **CAD**, robotics and **CNC**, **CAM** is exploited by the majority of the production systems nowadays

- Some of the most recent developments in **CAM** systems include ***rapid prototyping***, ***micro-electromechanical systems*** (**MEMs**), ***nanotechnologie****s and* ***artificial intelligence***

"S. Makris, D. Mourtzis, G. Chryssolouris, "Computer Aided Manufacturing (CAM)", CIRP Encyclopedia of Production Engineering, Luc Laperrière and Gunther Reinhart (Eds.), ISBN: 978-3-642-20616-0, DOI: 10.1007/SpringerReference_341106, http://www.springerreference.com/docs/html/chapterdbid/341106.html "

Theory and Application

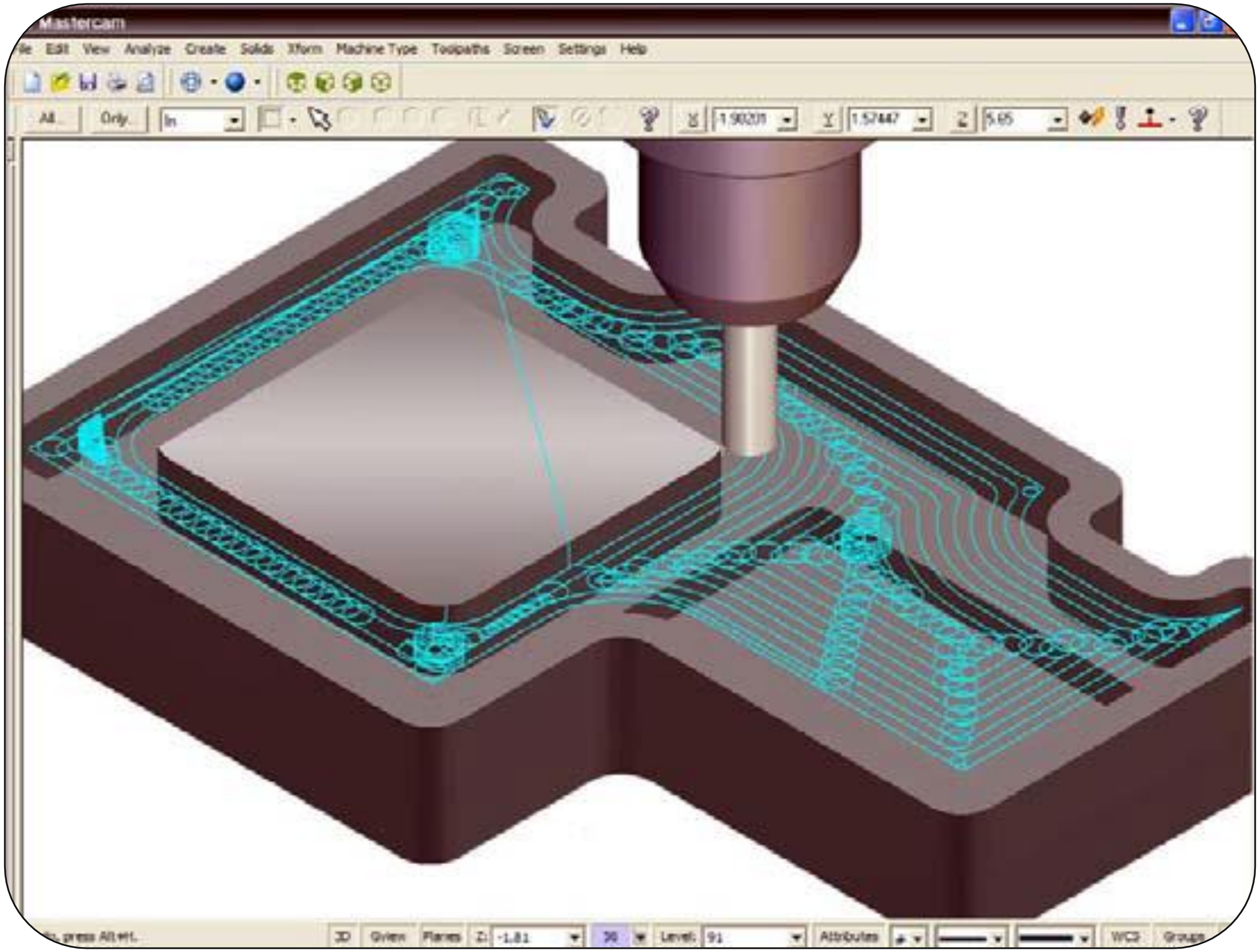


Figure 1: Example of an up-to-date CAM software workspace
(Photo of MasterCAM)

Theory and Application

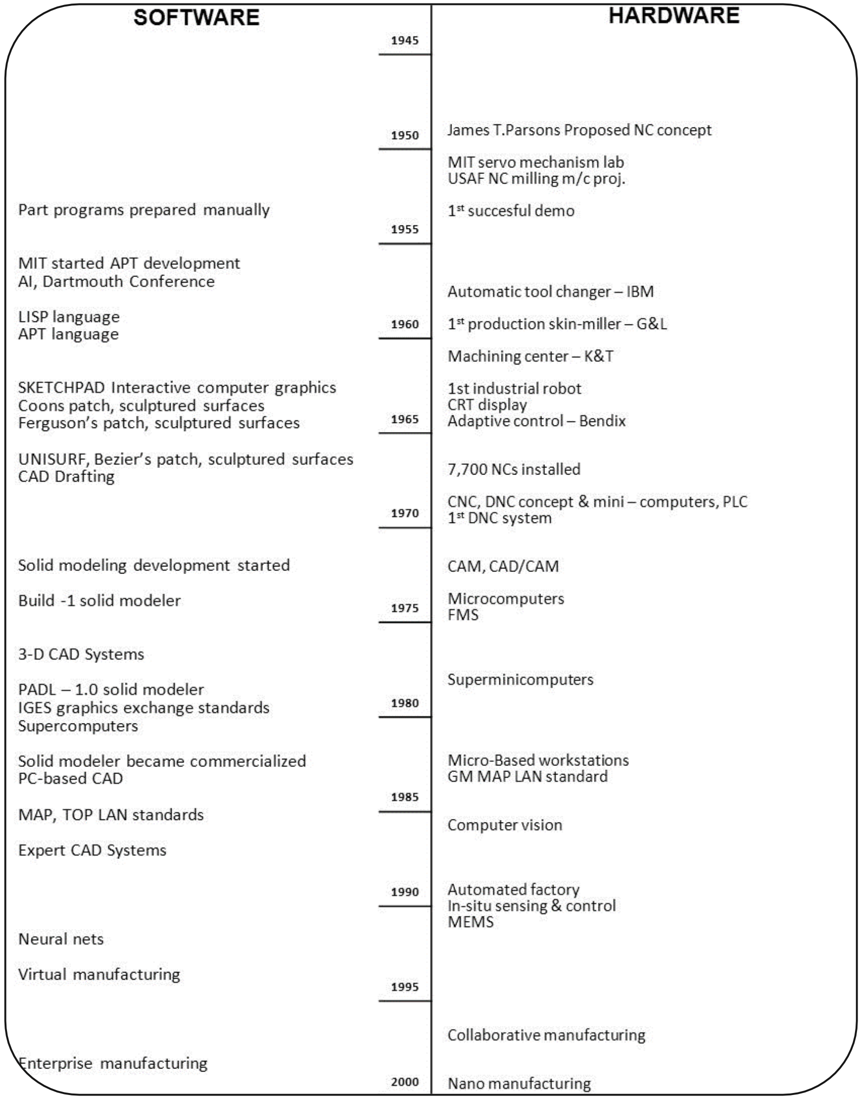
- The evolution of **virtual manufacturing** has led to the creation **of work-cell simulation tools** that are capable of **developing**, **simulating** and **validating** manufacturing processes

- Moreover, off-line programming of multi-device robotic and automated processes (**virtual commissioning**) offer optimization functionalities, from the concept to the implementation phase

- At the 2000s, commercial **CAM** suites provided complete solutions to **Product Lifecycle Management** (**PLM**) in multiple stages of the production, i.e. conceptualization, design (**CAD**), manufacturing (**CAM**) and engineering (**CAE**)

- A great number of **CAD** tools exist today that provide functionalities of **CAM**/**CAE** (Chryssolouris 2005)

Theory and Application



- In Figure 2 the evolution of software and hardware systems related to CAD/CAM is presented (Chang et al. 2006)

Figure 2: Evolution of CAD/CAM and related technologies (Chang et al. 2006)

Application of CAM in the Production

- The utilization of **CAM** enables the **automation** and **computer support** of all the production activities on the **shop floor**, in order to manufacture parts designed with **computer-aided design (CAD)** and analysed with **computer-aided engineering (*CAE*)**

- The equipment on the shop-floor, such as **robots**, **controllers**, **machine tools** and **machining centres** are controlled and operated using **CAM** systems (Post 2003)

- **CAM** technologies comprise **NC machines**, **expert systems**, **machine vision**, **robots**, **lasers** and **FMS** technologies used alongside with **computer hardware**, **databases** and **communication technologies**

- **CAM** systems are tightly connected with ***CAD* systems**

Application of CAM in the Production

- The **CAD** databases must reflect the manufacturing requirements such as tolerances and features
- The *part drawings must be designed having in mind* **CAM** *r*equirements. Moreover, the manufacturing systems nowadays require **high coordination** due to their ***networking* characteristics**
- Synchronization among robots, vision systems, manufacturing cells, material handling systems and other shop floor tasks are challenging tasks that **CAM** addresses
- The role of **CAD**/**CAM** systems in the production can be as the intersection of five sets:
  - design tools
  - manufacturing tools
  - geometric modelling
  - computer graphics concepts and
  - networking concepts (Zeid 1991)

Application of CAM in the Production

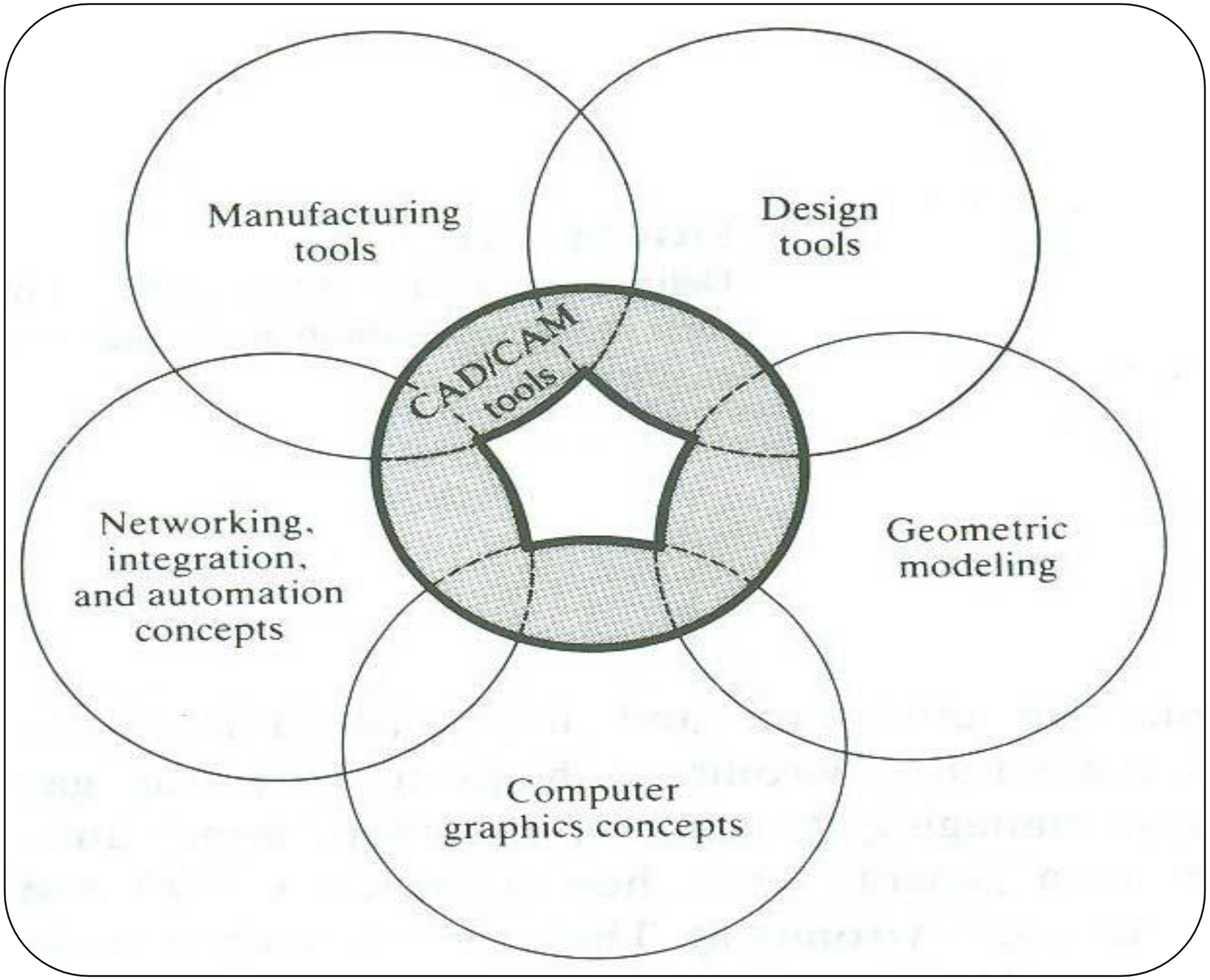


Figure 3: CAD/CAM and their constituents

Application of CAM in the Production

- Apart from the fact that the **CAM** technology has brought a revolution in manufacturing systems by enabling **mass production** and **greater flexibility** (Yeung2003)

- It has also enabled the **direct link between the three-dimensional (3D) *CAD* model and its production**

- The **data exchange** between **CAM**, **CAD** and **CAPP** is a **dynamic procedure** and takes place through various production stages

Application of CAM in the Production

- **Data** is exchanged regarding process routes and machines between function of process route sequence and machine assignments from **CAPP** systems and identified manufacturing process and machines from **CAM** systems

- Moreover, reports regarding setup methods, fixtures and operations sequences between **function of setup planning and fixture selection** in **CAPP** and function of identifying setups, fixtures, getting operation sequences and machined features in **CAM** are transmitted

- Further to that, **information about cutting tools and cutting parameters** between:
  - **Function of operation planning**
  - **Cutting tool selection**
  - **Cutting parameter selection**
  - **Optimization**
  - **Edit and output** in **CAPP** and function of **getting cutting tools** and **cutting parameters** in **CAM** is exchanged

Application of CAM in the Production

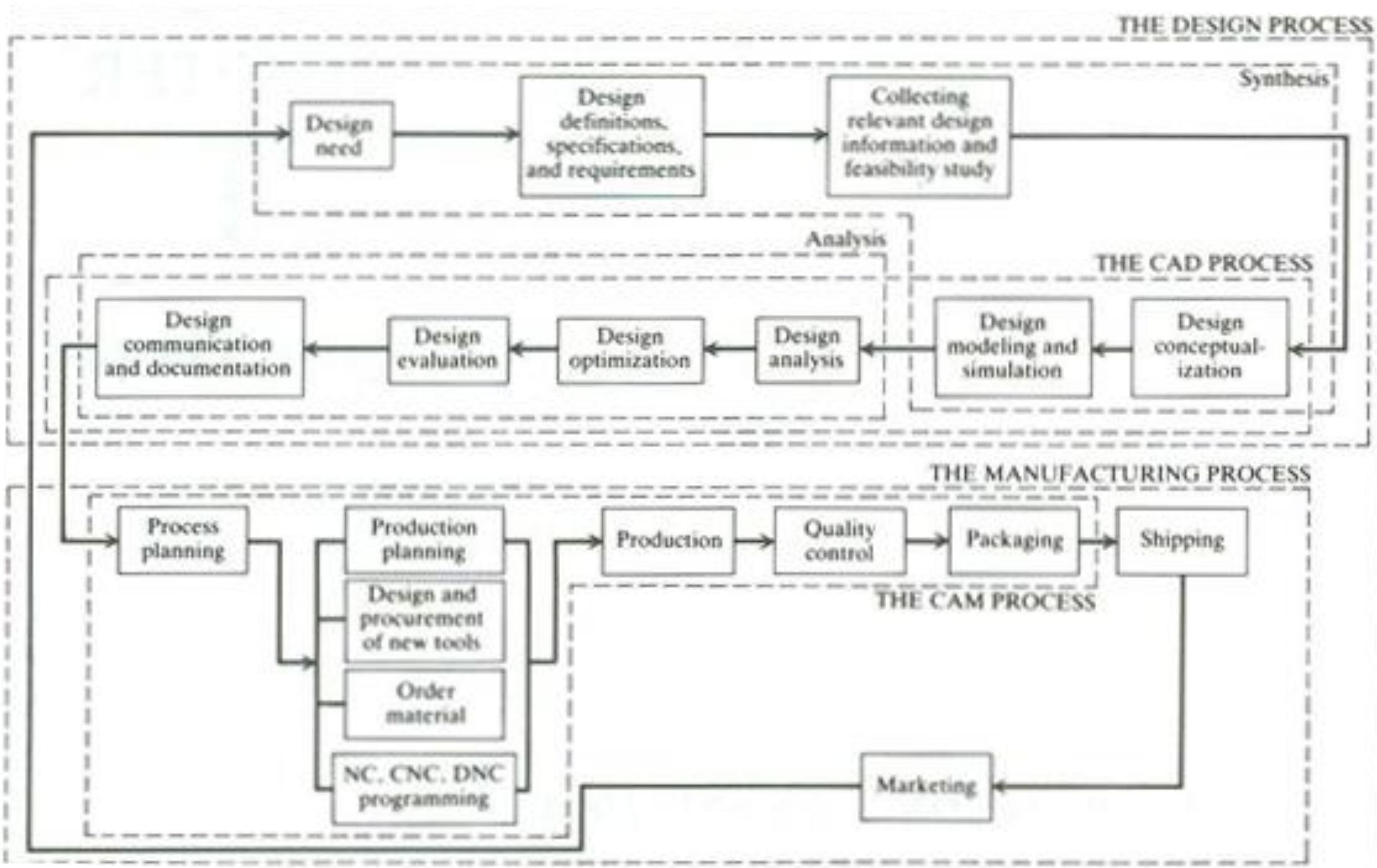


Figure 4: Role of CAM in a typical product lifecycle (Zeid 1991)

Application of CAM in the Production

- Finally, **messages concerning process plan change suggestions** between:
  - **function of operation planning**
  - **cutting tool selection**
  - **cutting parameter selection**
  - **optimization**
  - **edit and output** in **CAPP**
  - function of generating **cutting path**
  - **CNC code** and
  - **simulation** in **CAM** are exchanged

(Ming et al. 2008)

Application of CAM in the Production

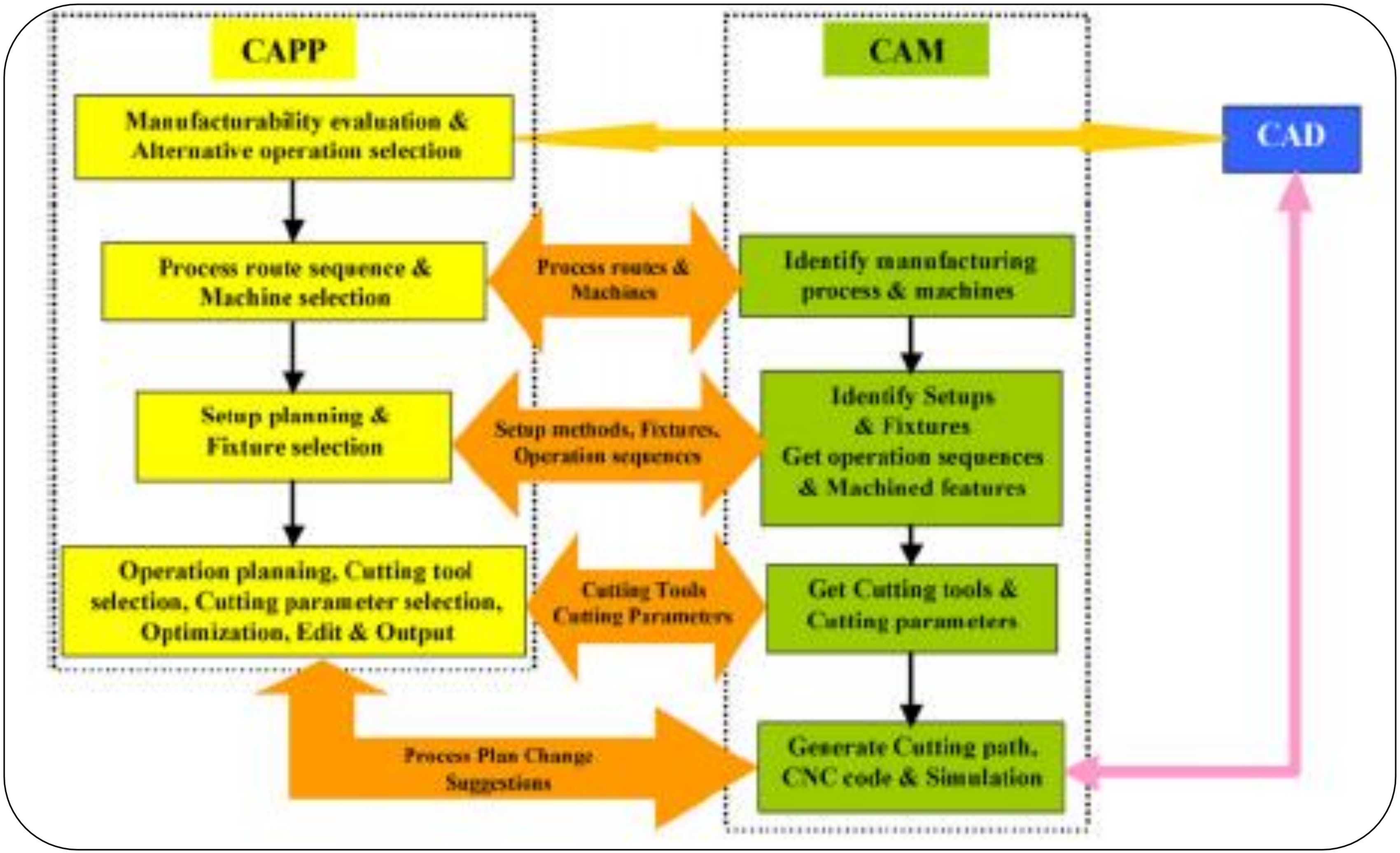


Figure 5:The collaboration between CAM, CAPP and CAD systems (Ming et al.2008)

Application of CAM in the Production

- The data interface between **CAM** and **CAD** is displayed in Figure 6
- The mechanical drawing files from **CAD** applications are required from the **CAM** system in order for a part to be manufactured.
- **CAM** programs represent a **designed part as a wireframe** of two or three dimensions
- The **NC programmer** needs to **define auxiliary geometry** during the programming course and since the **CAM** program do not offer model editing abilities the need is presented for the **CAM** system to be **combined** with a **CAD** system (Seames 2002)
- **Numerical Control** refers to a system that includes **hardware and software and control machine tools** and other production equipment **via numerical input** (Post 2003)
- **NC** is a method of **automatically operating a manufacturing machine** based on a **code of letters**, **numbers**, and **special characters**

Numerical Control (NC) and CAM

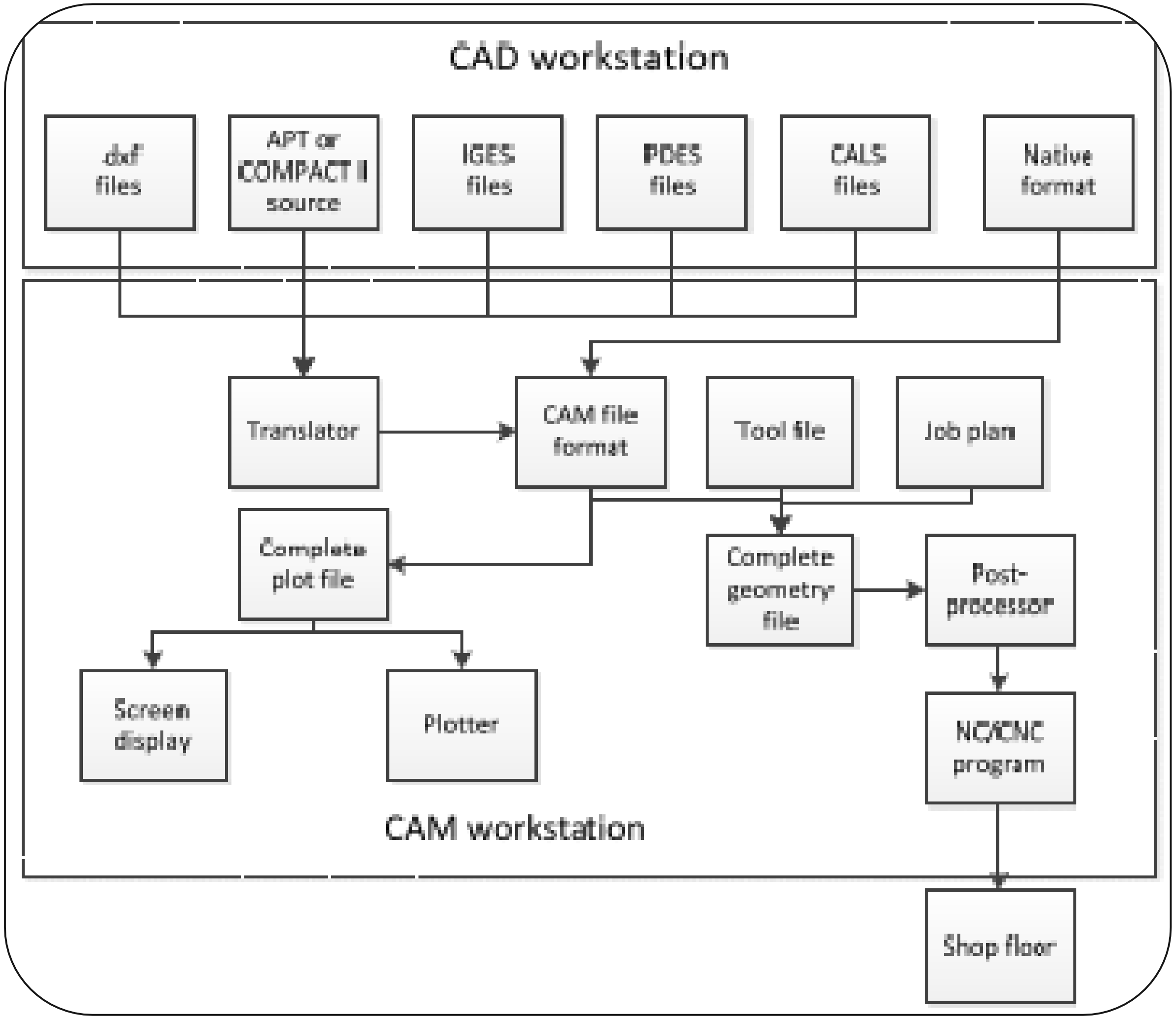


Figure 6: CAD/CAM links and flow of a computer-aided system (Rehg and Kraebber 2005)

Numerical Control (NC) and CAM

Numerical Control Reminders

- **Numerical Control** refers to a **system that includes hardware and software and control machine tools** and **other production equipment via numerical input** (Post 2003)

- **NC** is a **method of automatically operating a manufacturing machine based on a code of letters, numbers, and special characters**

- In 1947, John Parson of the Parsons Group, began experimenting with the idea of using **tree-axis curvature data to control machine tool motion** for the production of aircraft components. The project was funded by the US Air Force

Numerical Control (NC) and CAM

Numerical Control Reminders

- In 1951 MIT (Massachusetts Institute of Technology),USA, assumed the project and the first **NC** machine was developed in 1950s at MIT (Seames 2002)

- The evolution of computers, led to the creation of **Computer Numerical Control** (**CNC**) in the 1970s

- The **difference** in **NC** and **CNC** lies in the **controller technology**

- While, **NC** functions **need to be designed and implemented in hardware circuits**, **CNC** functions can be implemented in **CAM** **software**.

Numerical Control (NC) and CAM

Numerical Control Reminders

- The coding of the early **NC** machines and todays **CNC**s is performed using the same standards, namely **G**&**M codes** formalized as the **ISO 6893 standard** (International Standards Organization 1982)

- The codes were **stored in magnetic tapes**, the most common of which were ¼ - inch computer grade cassette tape

- The **Electronics Industries Association** (**EIA**) developed standards for tape format and coding (Seames 2002)

Numerical Control (NC) and CAM

- In order for the machine code to be produced, certain stages are required as shown in Figure 7
- Moreover, to ensure the **interoperability** and the **seamless data exchange** between the different stages of the chain that utilize different commercial tools and technologies, the **STEP** standards have been developed and formalized into
  - **ISO10303** (International Standards Organization 1994) and evolved later to
  - **ISO14649** (International Standards Organization 2003) and
  - **ISO10303-AP238** (International Standards Organization 2004) commonly known as **STEP NC**

Numerical Control (NC) and CAM

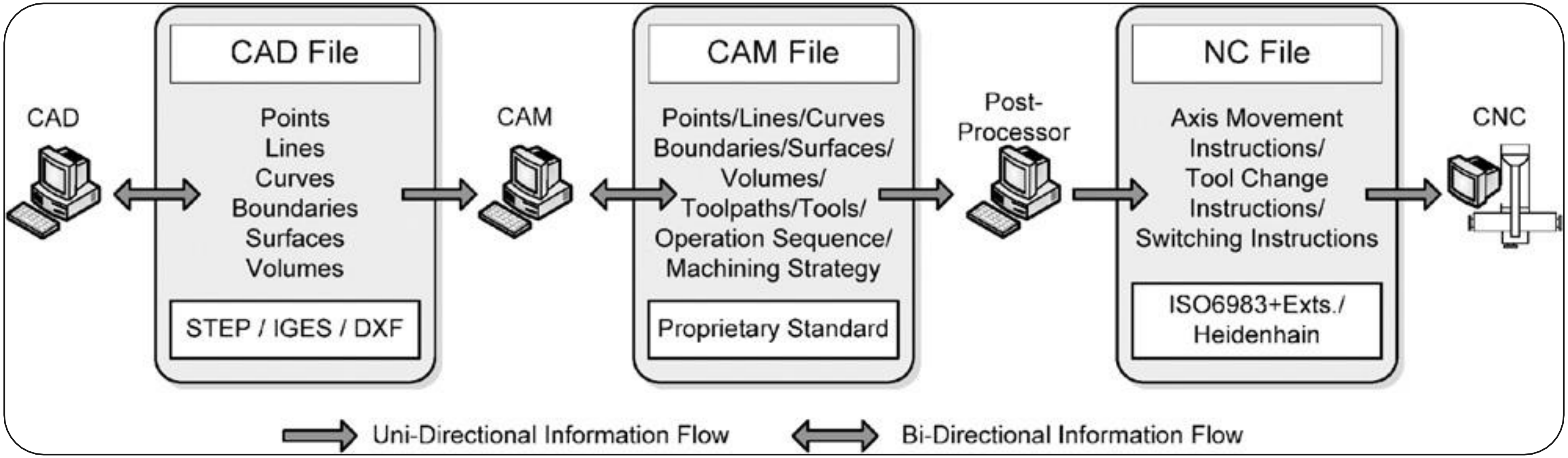


Figure 7: Manufacturing information flow in the state-of-the-art CAD/CAM/CNC chain (Newman et al. 2008)

Numerical Control (NC) and CAM

- The improvements in the computer technology led to the creation of **Direct Numerical Control** (**DNC**)
- **DNC** involves a computer that acts as a partial of full controller to one or more NC machines
- Further to that, improvements in the field led to the creation of **Distributed Numerical Control**, where several CNC machines are linked together inside a network allowing the gathering and storing of upstream and downstream shop-floor information
- In Figure 8 and Figure 9 the differences in the architecture of **Direct** and **Distributed Numerical Control** are presented

Numerical Control (NC) and CAM

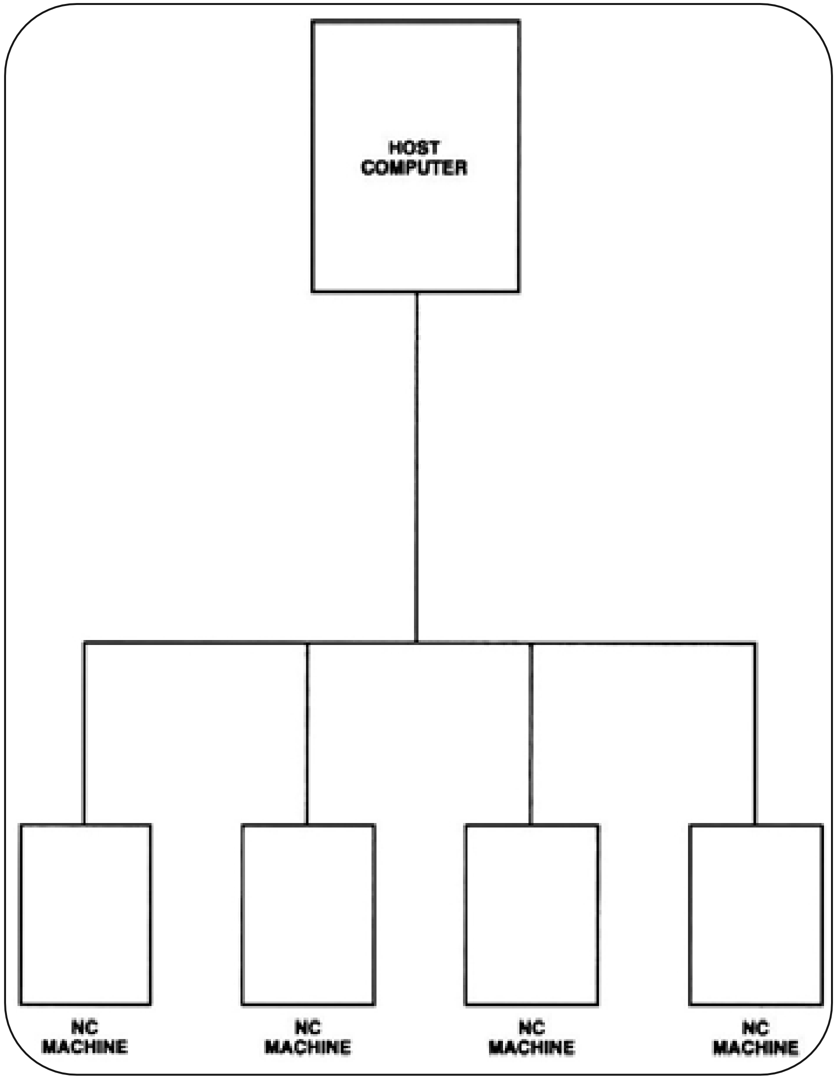


Figure 8: Direct Numerical Control (Seames 2002)

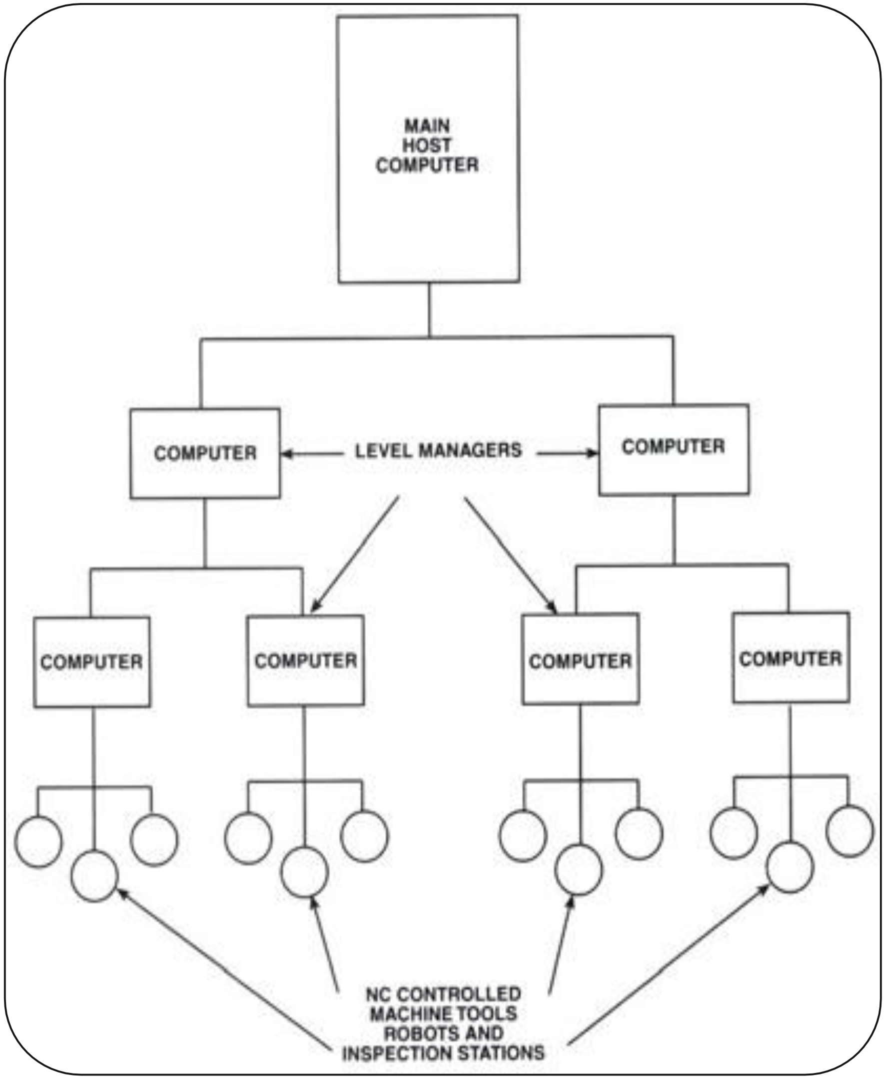


Figure 9:Distributed Numerical Control (Seames 2002)

Flexible Manufacturing Systems (FMS) and CAM

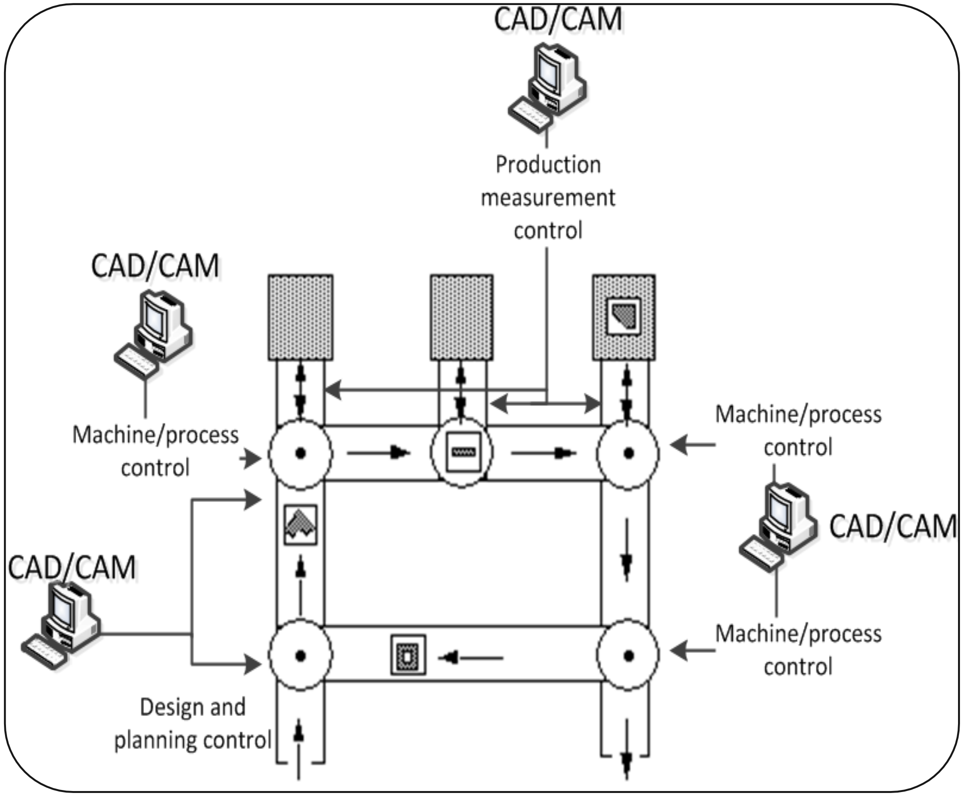
- A **Flexible Manufacturing System** (**FMS**) is a **reprogrammable manufacturing system** capable of producing a **variety of products automatically** (Chryssolouris 2005)

- An **FMS** employs **programmable electronic controls** that, in some cases, can be set up for random parts sequences **without incurring any set-up time between parts**

- Inside **FMSs**, the production components **require adaptability to a variety of product processing requirements** and therefore, CNC turning/machining centers and robotic workstations comprise the majority of equipment in these systems (Chryssolouris 2005)

- **CAM** systems, **NC** and **robotics** offer **reprogramming capabilities** at the machine level with minimum setup time

Flexible Manufacturing Systems (FMS) and CAM



- An **FMS** (Figure 10) comprise the following features:

  - Interchangeable and/or specific machining units
  - Various work pieces within a component range
  - Usually free component selection

Figure 10. FMS with integrated CAD/CAM systems

Flexible Manufacturing Systems (FMS) and CAM

- The main challenge in the installation of a **FMS** lies to the control of the **complex network of equipment** and shop floor activities of such a system

- By utilizing state of the art **CAM** systems, the implementation of **FMS** becomes feasible due to the benefits that **CAM** systems provide

- The deployment of an **FMS** with integrated **CAD**/**CAM** systems offer a variety of benefits such as:
  - improved productivity through higher machine utilization,
  - shorter lead times,
  - more reliable production (self-correcting production and uniform quality),
  - reduced work-in-progress (Koenig 1990)

- Moreover, by integrating **CAPP systems** into **FMS**, the **process plans can be created rapidly and consistently** and total **new processes can be developed** as fast as plans similar to those for existing components (Rehg and Kraebber 2005)

Flexible Manufacturing Systems (FMS) and CAM

- The **benefits** of **FMS** with **CAD**/**CAM** systems can be found in Table 1.

Benefits	**CAD/CAM**		
	Machine/process control	**Production and measurement control**	**Design and planning control**
Operate equipment around the clock	✓		
Minimize direct labour		✓	
Minimize lead time			✓
Reduction of in process inventory		✓	
Reduce tools and fixture requirements		✓	
Obtain high flexibility		✓	

Table 1: Benefits of FMS with integrated CAD/CAM systems (Koenig 1990)

CAM Software

- **CAM** software can be divided into **2D** and **3D applications.** The **2D** means that the **CAM** system imports a **2D drawing file** from a **CAD** system and **calculates a tool path** with all movements taking place on a constant Z-level

- **Several tool paths on different Z-levels** can be combined to **create a 3D result**, which is then called **2.5D machining**

- A **3D CAM system** in contrast imports a full **3D CAD model and calculates tool paths** to create a **3D result**

- A second distinction of **CAM** systems is between simple and **high-end CAM software**

CAM Software

- The **high-end CAM software** targets large enterprises that require **absolute control of the manufacturing parameters** in order to produce an optimum result

- **High-end systems** include functionalities that support **a fourth or for full 5 axis machining**:
  - **constant tool loading features**
  - automatic step-over **calculation**
  - **automatic detection**
  - **removal of rest material**
  - **rendered machining simulations**

- Software vendors are currently developing integrated **CAD**/**CAM** systems, further enhancing the capabilities of today's **CAM** applications

CAM Software Survey

- Table 2 gives a glimpse of the status of **CAM** technology by presenting some of the **most popular CAD/CAM** systems, the **software vendors** and some **notable features** of each one

CAD/CAM suite	Vendor	Features
CAD/CAM v7.0	Cimatron www.cimatron.com	• Solid modelling capabilities range from wire-frame and surfaces to parametric solids • 2 1/2 to 5-axis milling, drilling, turning, punching, and wire EDM tool paths generation
VERICT	GCTech www.cgtech.com	• Multi-axis milling, drilling, and turning • Optimizes NC tool paths automatically • Simulates and optimizes NURBS interpolation
MasterCAM	CNC Software Inc. www.mastercam.com	• Intel-based 2 1/2-axis milling and drilling package • 5-axis positioning and lathe operation handling • Creates CAD geometry and wire EDM
CATIA	Dassault Systemes www.catia.com	• Generative machining and assisted manufacturing that captures manufacturing and process know-how and automates repetitive NC functions • Networking and collaborative design feature
CADDS Version 5	PTC www.ptc.com	• 2 1/2-, 3-, and 5-axis machining

CAM Software Survey

Virtual Gibbs CAM	Gibbs & Associates www.gibbsnc.com	• Quick re-sequencing of operations, tool size modifications, feed and speed changes, and multiple part programming
NX CAM	Siemens http://www.plm.automation.siemens.com	• High Definition 3D technology • PMI Driven Feature Based Machining (Product and Manufacturing Information) • Synchronized point distribution
PowerMILL	Delcam www.delcam.com	• Multi-axis machining • Object linking and embedding for design and modelling
Helix Engineering	MicroCADAM	• Addresses the needs of sheet metal design and fabrication • Flat-wrap and flat-pattern provides methods for unbending or flattening a surface or solid
SurfCAM Version 6.0	Surfware Inc. www.surfware.com	• Machines undercut surfaces in one setup • Parametric design capabilities • Creates optimized tool paths according to user-defined tolerances
Alphacam	Planit http://www.alphacam.com/	• Parallel and Flat Area 3D Machining • Adaptive Feed Rate Support for Z Contour Roughing • Editable Spline/Polyline Tool Paths
Tebis CAM	Tebis http://www.tebis.com/	• 2 1⁄2 axis machining • Creation of collision-safe tool paths for 5-side complete machining • Neutral and control-specific post-processing

Table 2:Commercial CAD/CAM suites

CAM Software Survey

- The solutions provided by the leading **CAD**/**CAM** vendors, offer **high-end features**, like:

  - parametric modelling for solid shapes
  - 2 ½ to 5 axis machining tool path generation
  - networking and collaborative design features
  - post processing capabilities
  - re-sequencing of operations
  - simulation and optimization of NURBS interpolation and
  - generative machining and
  - assisted manufacturing that captures manufacturing and process know-how and automates repetitive NC functions

CAM Software Survey

CAM and related technologies Vendors Market share in 2009

- For 2009, **Dassault Systèmes** was the market leader on the basis of both direct vendor revenues received and end-user payments for CAM software and services
- **Delcam** was the leader in terms of industrial seats shipped
- **Planit Holdings** was the leader on the basis of industrial seats installed
- **Siemens** PLM Software's NX was the leader in industrial seats shipped by brand
- **CNC Software's** Mastercam was the leader in both industrial and educational seats installed by brand name
- **OPEN MIND Technologies** was named as the most rapidly-growing vendor, although their revenue growth rate was only 1.6% (Table 2)

CAM Software Survey

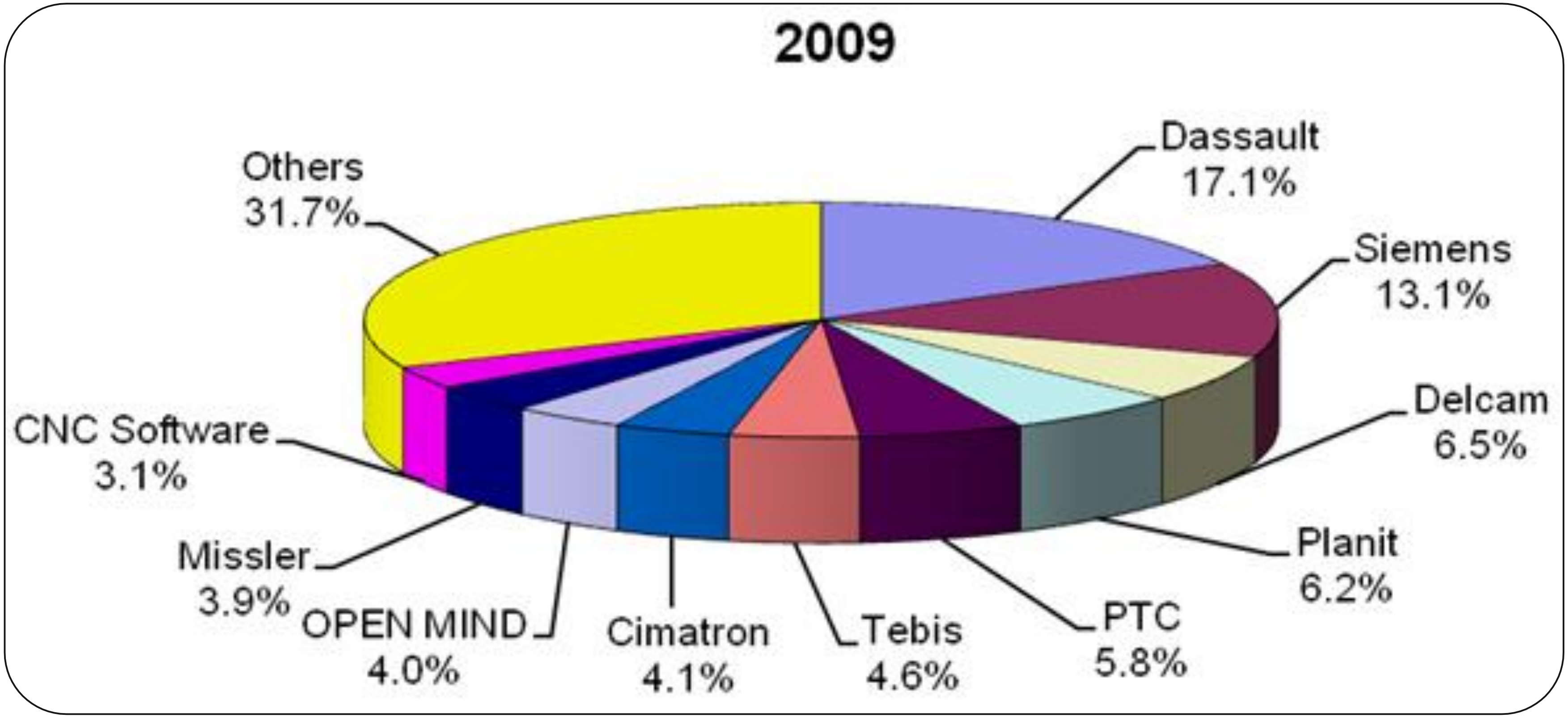


Figure 11: Market share of CAD/CAM software vendors in 2009

Future of CAM Systems

- The manufacturing environment is characterized by **ever changing dynamics** and **evolution**

- The **production procedure** is based more and more on **virtual simulations** and **networking features**, in factory level as well as and global level

- The **need** is presented **for effective coordination**, **collaboration** and **communication** amongst all the aspects of production, **from humans to machines**

- The future **CAM** systems need to **focus on collaborative technics, effective communication and efficient data exchange**

Future of CAM Systems

- Moreover, **Artificial Intelligence** (**AI**) will allow the development of **"thinking" tools** and the exploitation of **AI** in the **CAM** systems will offer **automatic optimization ofNC tool paths** and benefit from knowledge-based systems

- Adding to that, **self-evolving robots** are a fairly new concept and will have positive impact on **CAM** systems

- The development of **self-evolving robots** can bring on **CAM** advantages on more economical approach to robotics

- The **cost of designing and building a robot will be reduced** from millions of dollars to just a few thousand dollars

Future of CAM Systems

- In the future, the use of **these inexpensive robots to assemble parts, clean up spills, and perform many other specific tasks in a factory will become a reality** (Post 2003)

- Moreover , **Virtual commissioning** is a new concept that addresses the complexity of the production systems and the need for short ramp-up time

- In the **Virtual commissioning** approach, **virtual prototypes are used for the commissioning of control software** in **parallel to the manufacture and assembly of the particular production system** (Reinhart and Wunsch 2007)

Future of CAM Systems

- **Virtual commissioning** is **tightly connected** with **CAD**/**CAM** software and the advances in the second impact the first

- Finally, **digital manufacturing** incorporates technologies for the virtual representation of:
  - factories
  - buildings
  - resources
  - machine systems equipment
  - labour staff and their skills, as well as
  - for the closer integration of product ,and
  - process development through modelling and simulation

- **The implementation of digital manufacturing is relying on state of the art CAD/CAM and CAPP systems and their evolution** (Chryssolouris et al 2008)

Future of CAM Systems

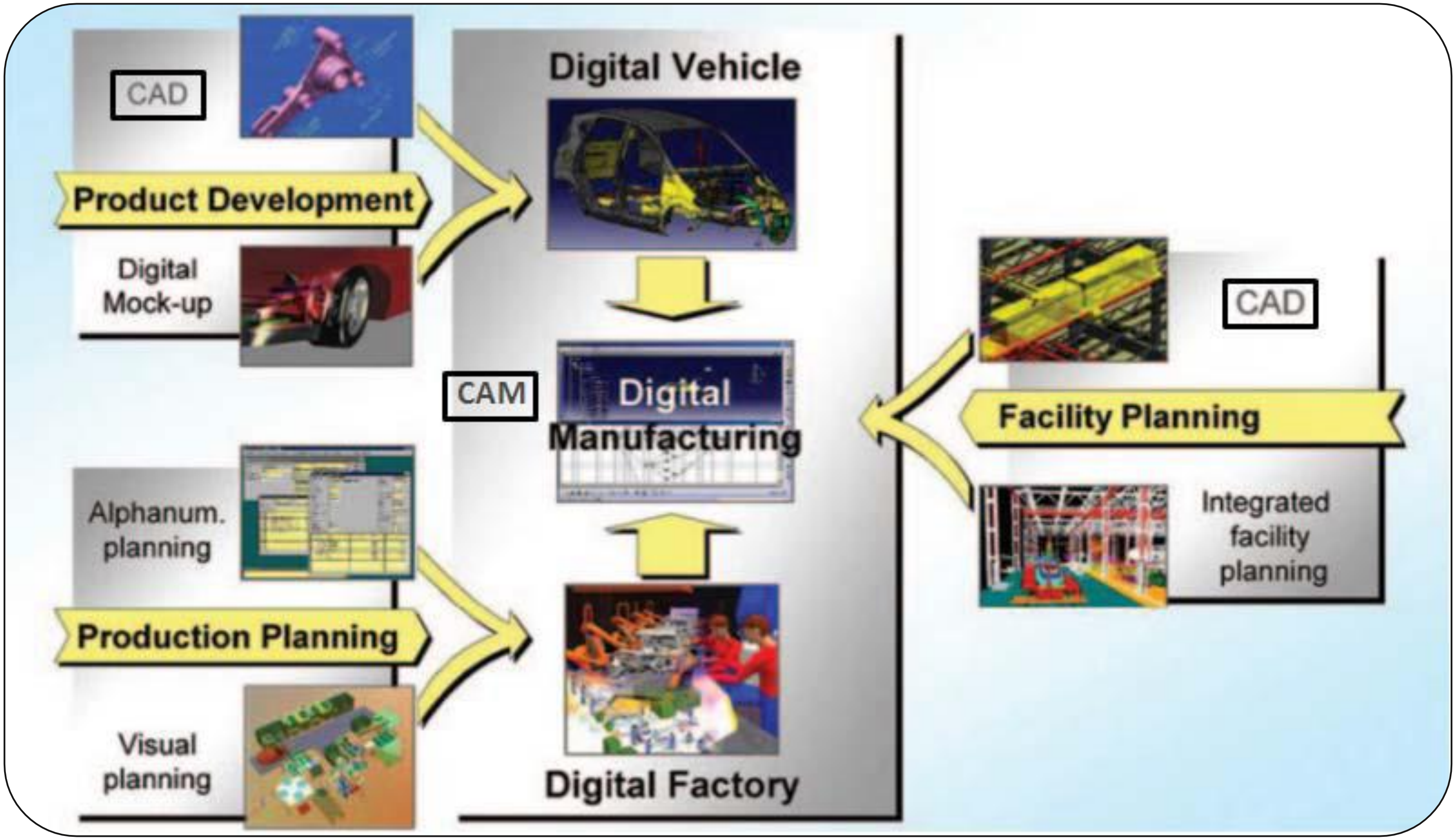
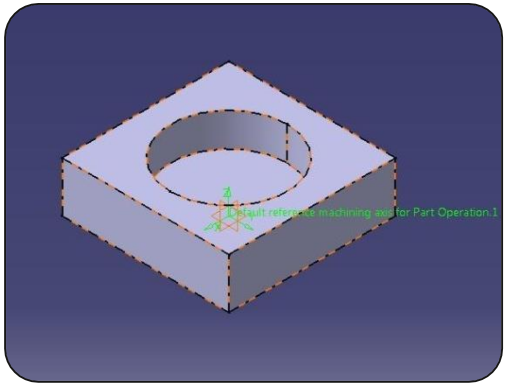
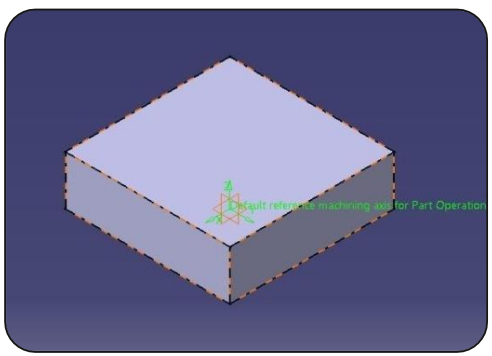


Figure 12: CAD/CAM and Digital Factory

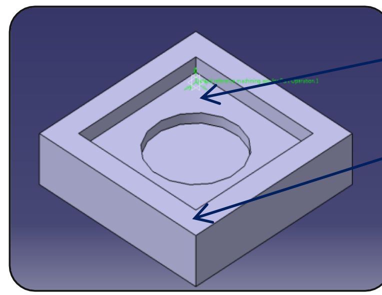
CAD-CAM



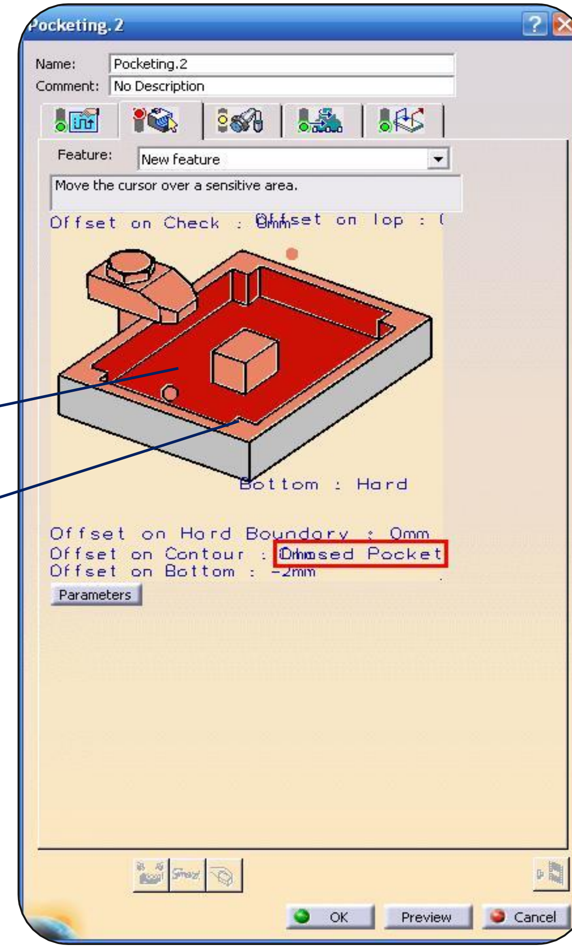
Design Part



Design Stock



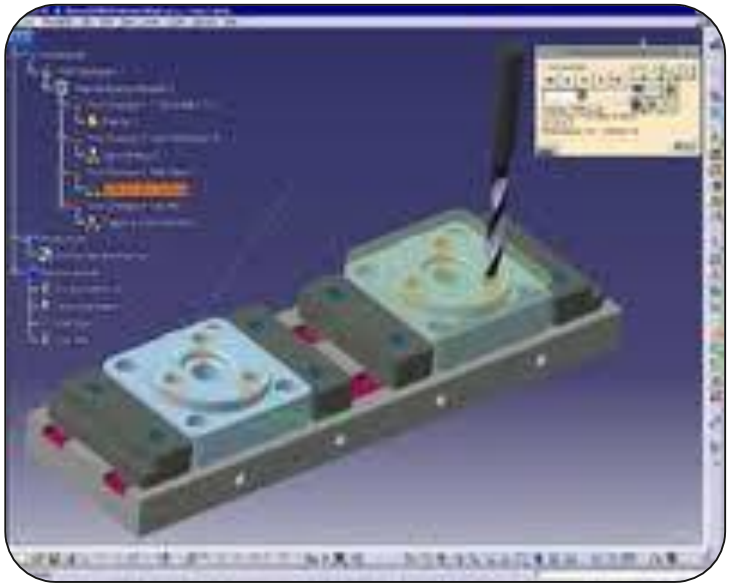
Assembly Part



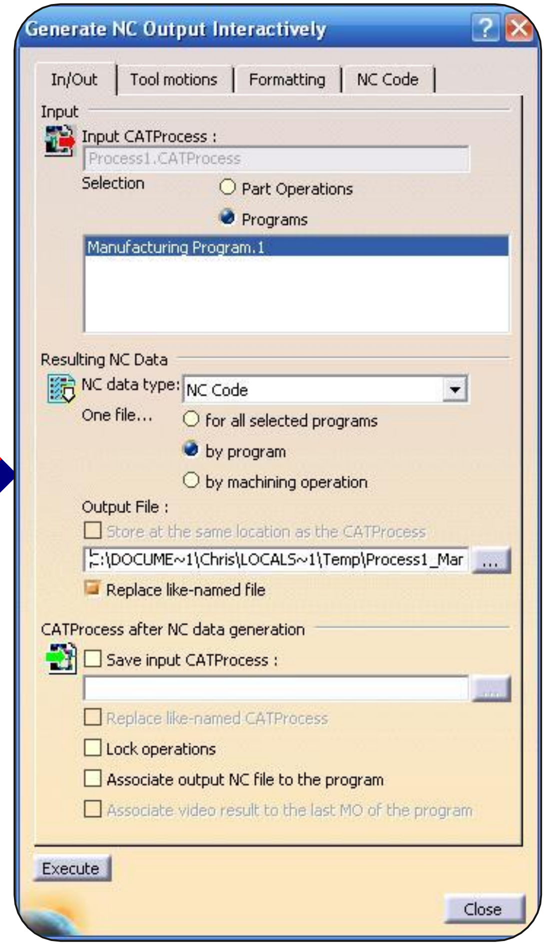
Prismatic machining

Figure 13a:CAD/CAM Process to generate G-Code

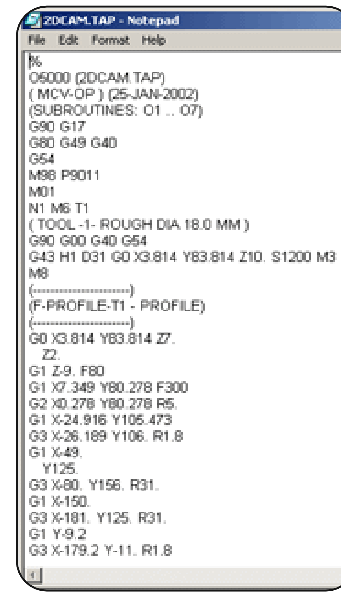
CAD-CAM



Machining simulation



Execute code



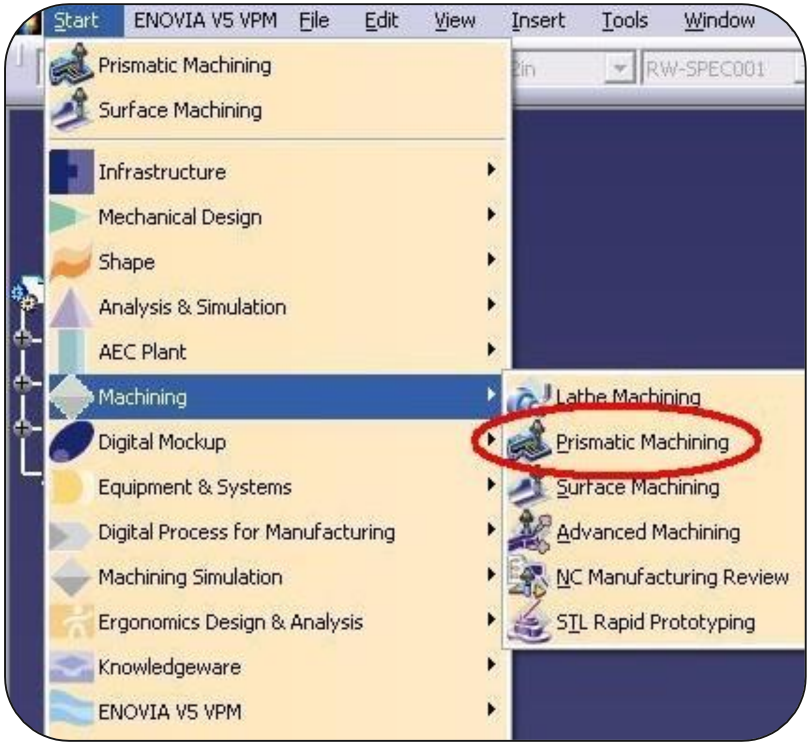
G - code

Figure 13b:CAD/CAM Process to generate G-Code

CATIA-CAM Tutorial

Program Basic Settings

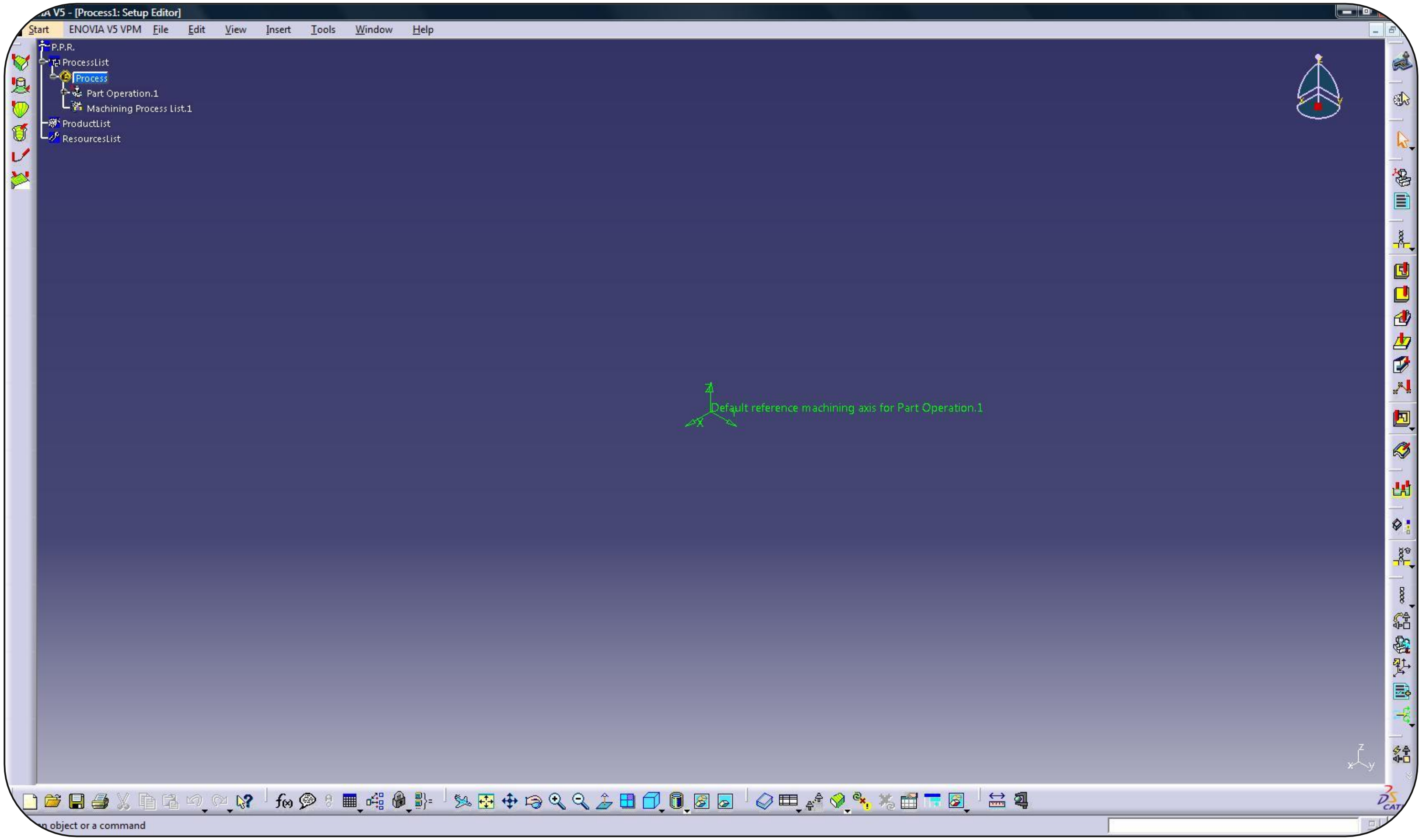
On Catia starting screen we select "**Start**" , "**Machining**" and "**Prismatic Machining**"



NOTE: The design part and the stock must have **been designed and assembled before this step**

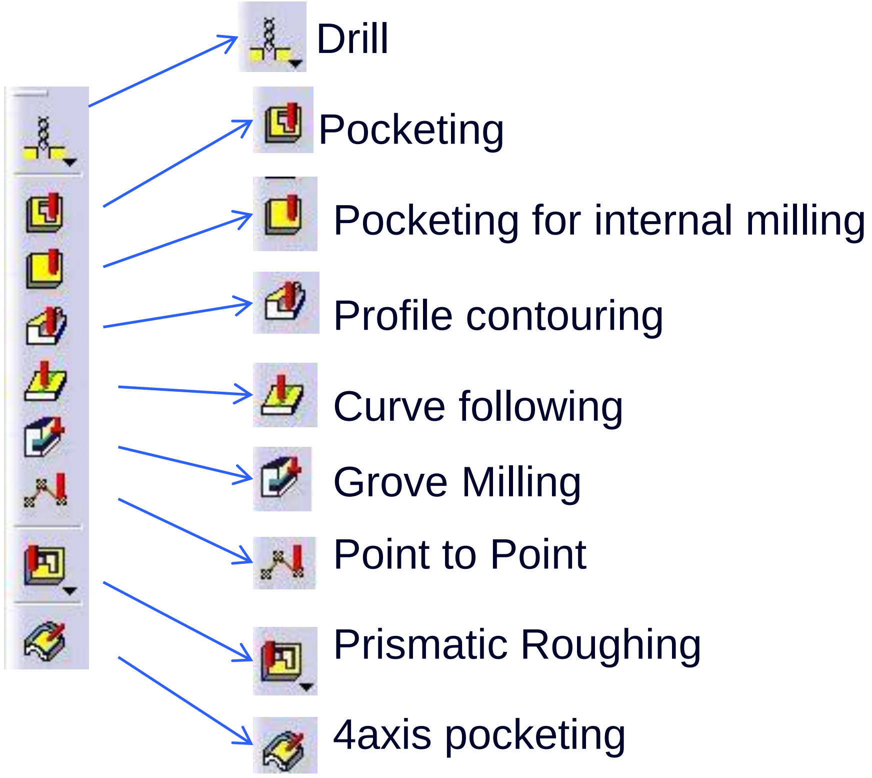
Program Basic Settings

- Starting screen of “Prismatic Machining” Workbench



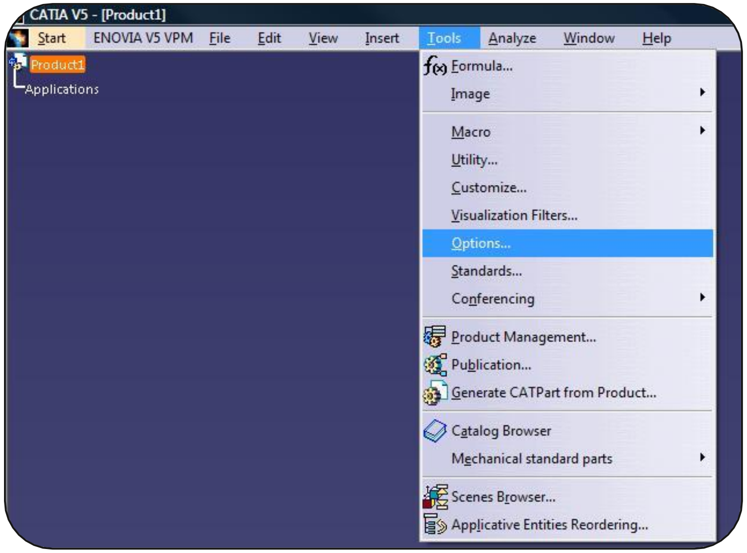
Program Basic Settings

Machine operation menu



Program Basic Settings

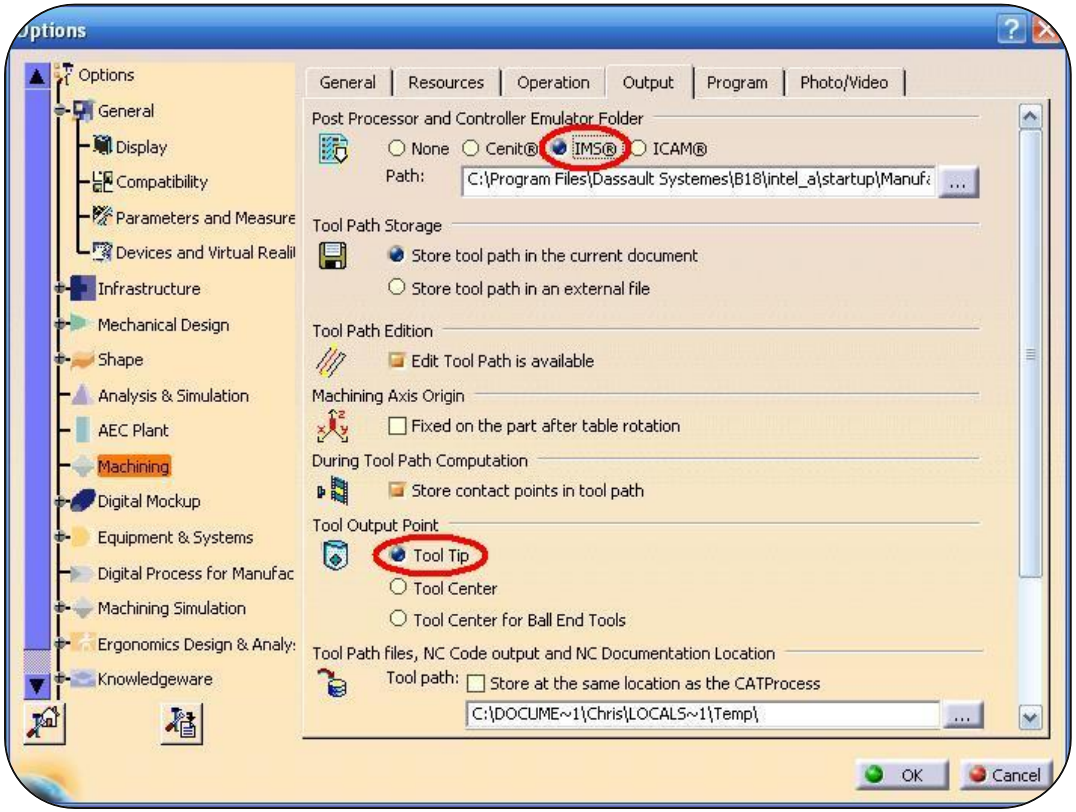
- Firstly we select “**Tools**” then “**Option**”



- On the appearing menu we select from the process tree the “**Machining**” section

Program Basic Settings

- The options we focus on are :"**Post Processor ,Controller Emulation folder**" and "**Tool output point**"



We select:

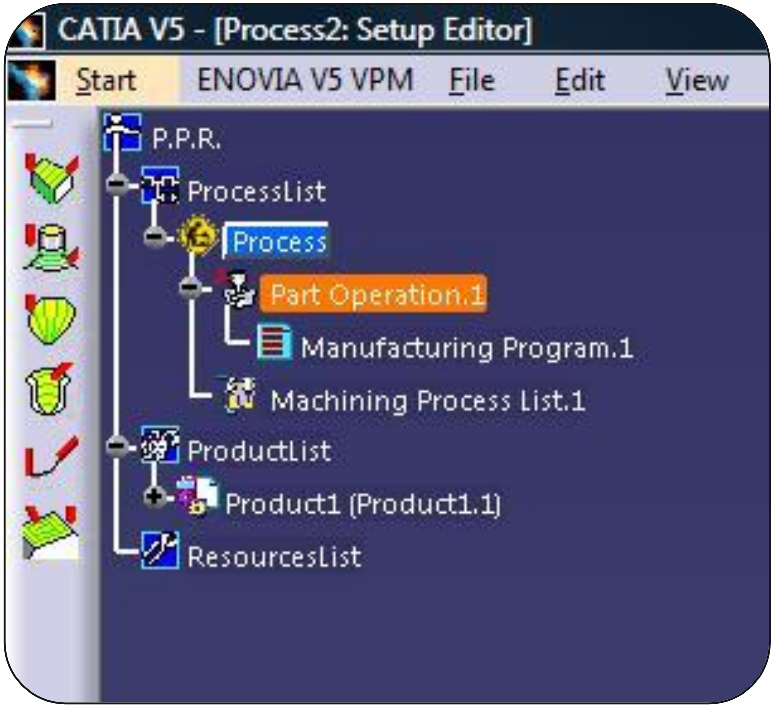
- **IMS**
- **Tool Tip**

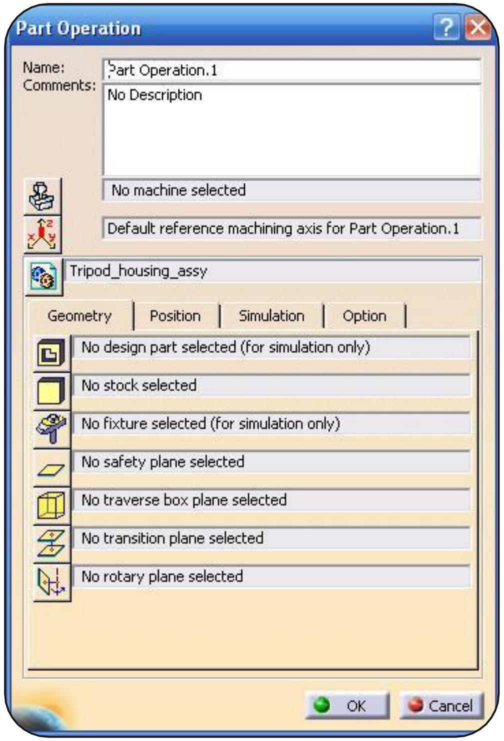
- Since these settings are selected, "OK" to close "option" menu

Program Basic Settings

- Then we have to choose the proper machine,the coordinate system and define the role for every part

- Firstly we select part operation from the process tree and by double-clicking the menu appears



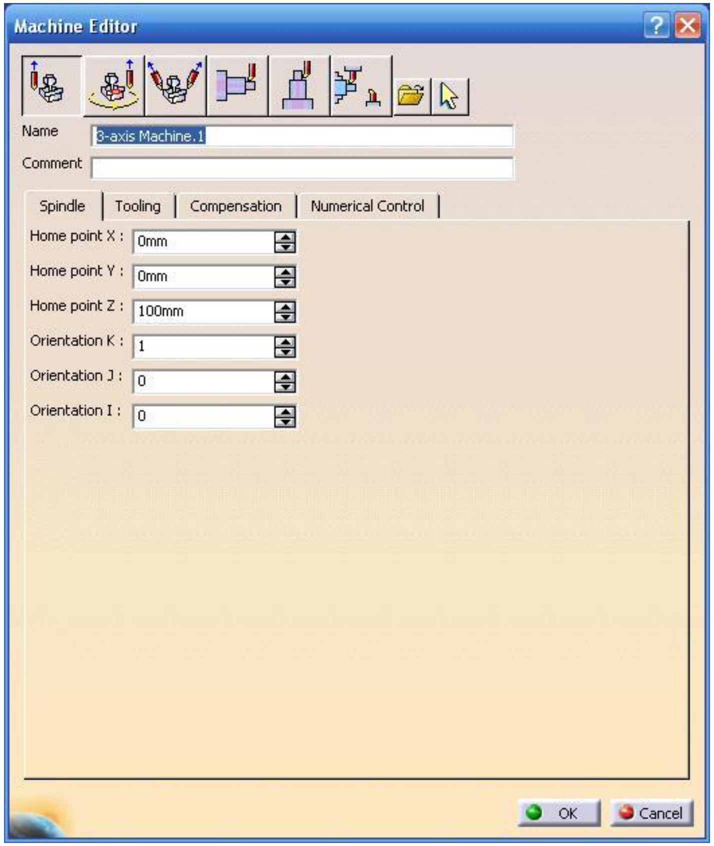


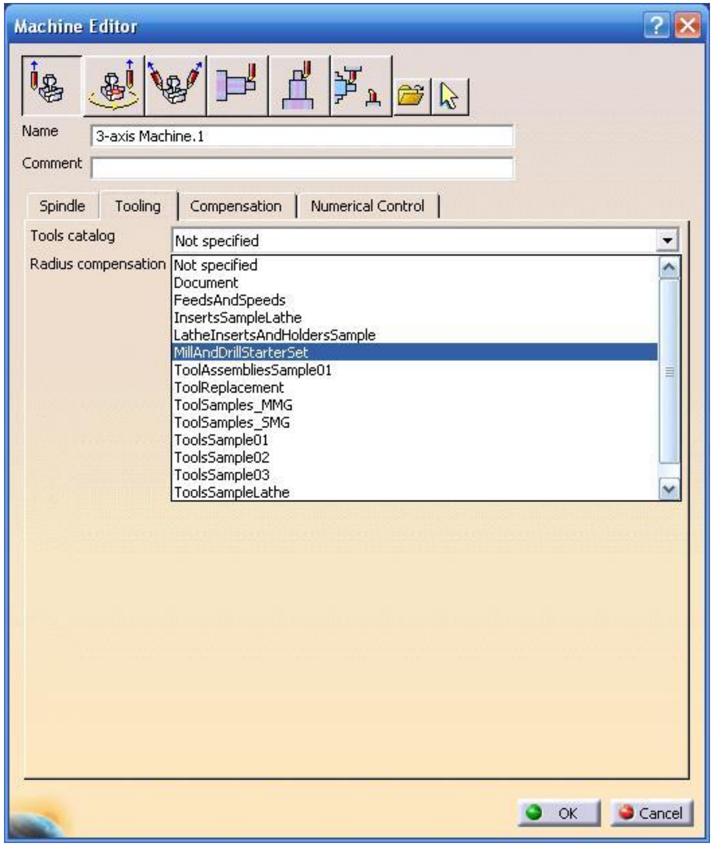
Part Operation menu

Program Basic Settings

- We click on machine tab: 

➢ **Then select 3axis machine** (default choice) and in the tooling tab **MillanddrillStarterSet**



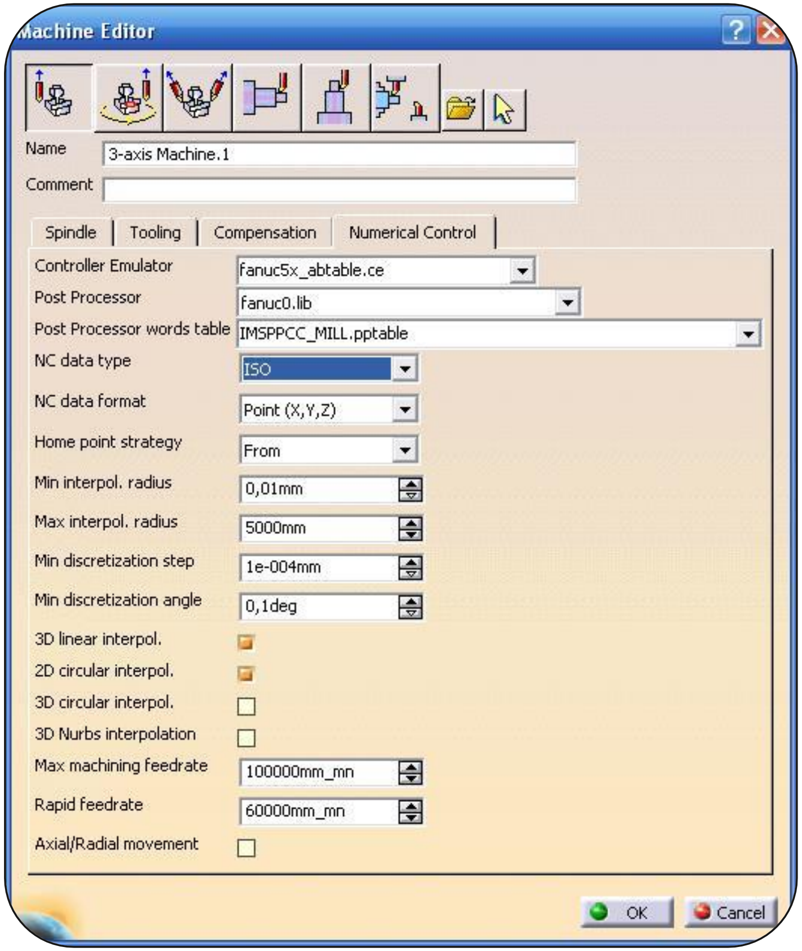


Program Basic Settings

In the Numerical Control tab we select:

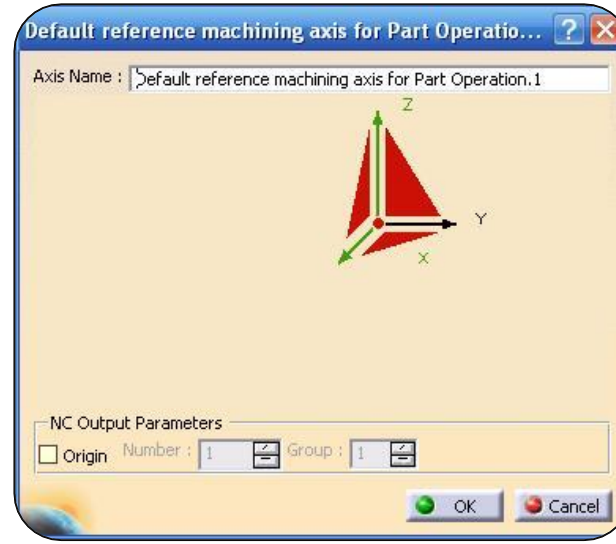
- Controller Emulation: Fanuc5x
- Post Processor: fanuc0.lib
- Post Processor Table:IMSPPCC_Mill.pptable
- NC data type: ISO

We select OK to save changes and return on previous menu

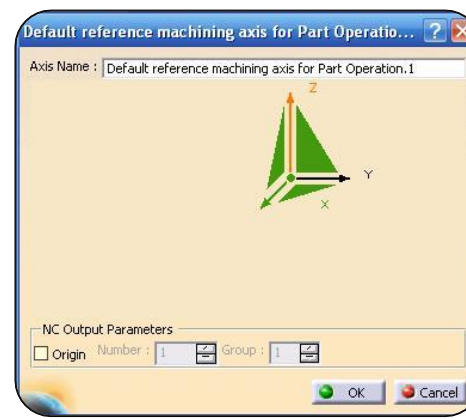


Program Basic Settings

- **We select Reference Machining Axis System:** 



On the appearing window the coordinate system appears on the reference machining axis
By selecting the center point,we define the center point on our design, and by choosing X and Z axis a menu appears to define the directions of these axis depending on the process

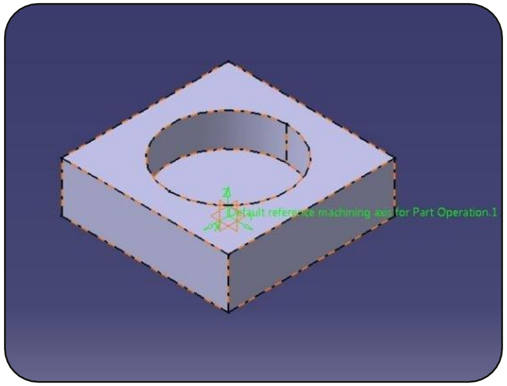


- **The result is that the coordinate system is determined:**

Program Basic Settings

- **We select Design Part:** 

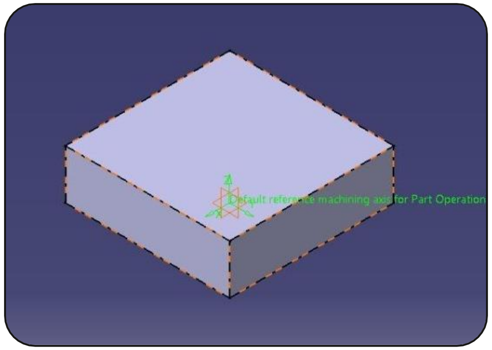
  ➢ Choosing this option we define the design part that is going to be manufactured



Design Part

- **We select Stock:** 

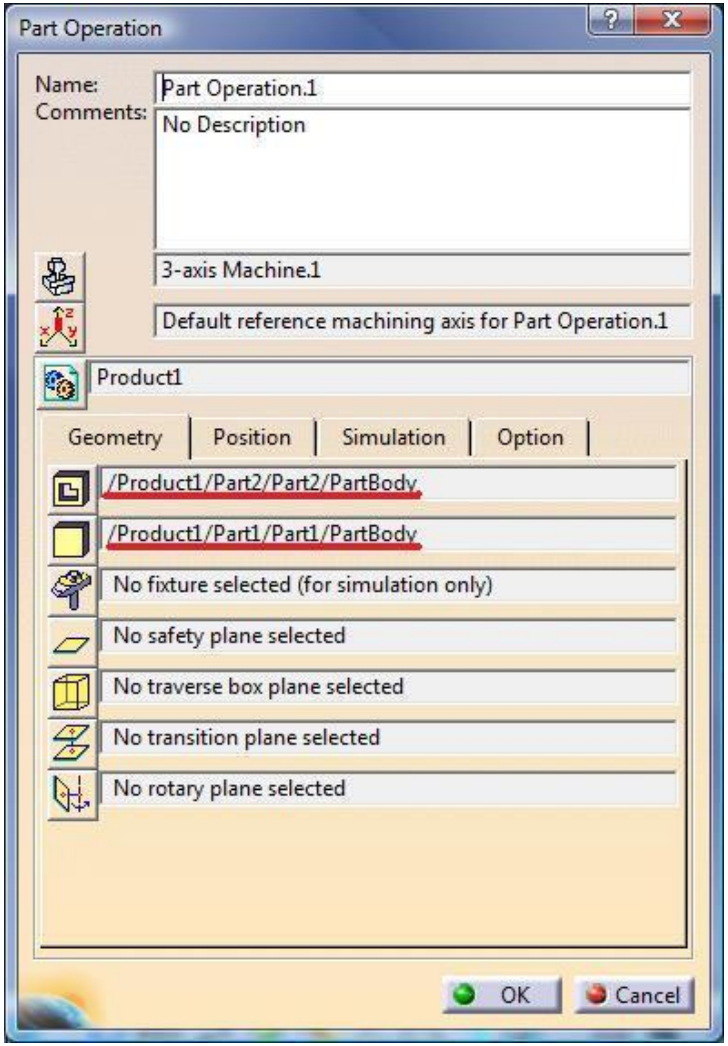
  ➢ Choosing this option we define the stock that we will process



Stock

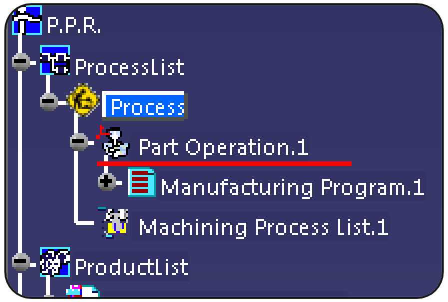
Program Basic Settings

- **The final form of the Part Operation menu** should be like the one of the image
- We click OK and leave menu



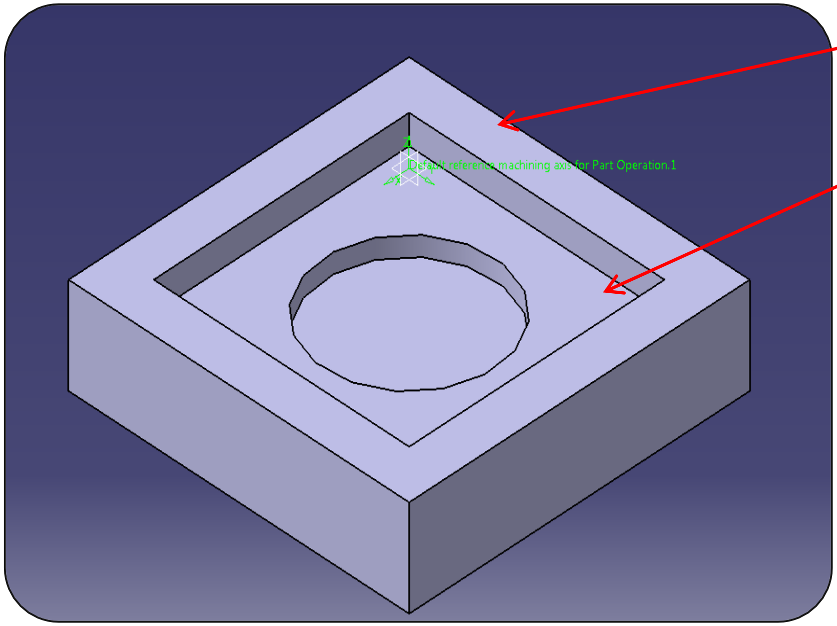
Part Programming

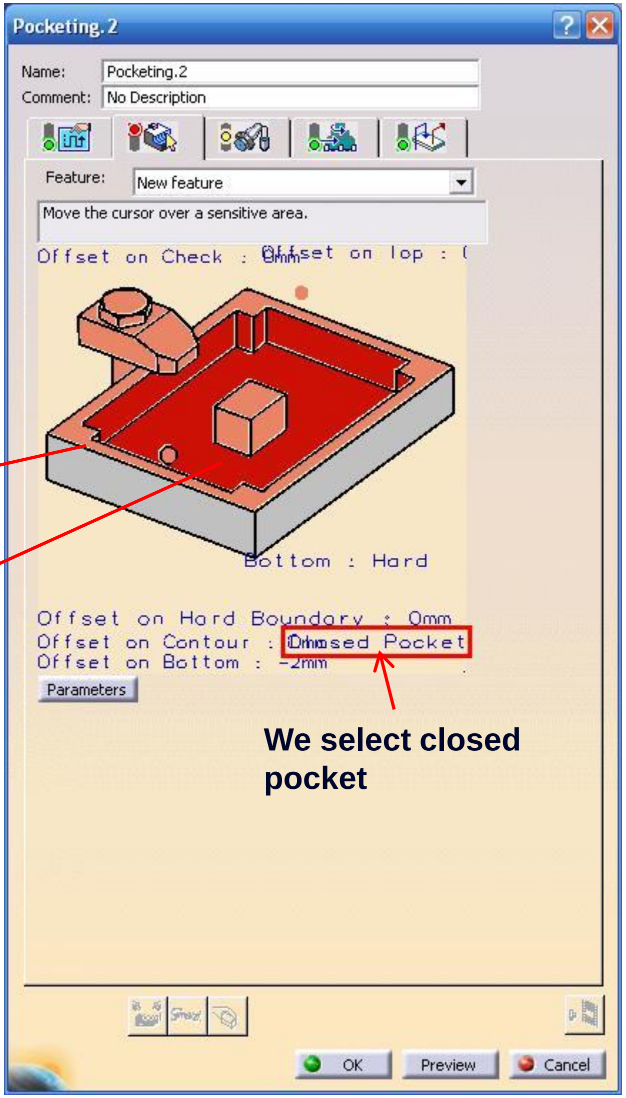
- We select **Manufacturing Program**, from the tree and start adding processes:



We select **Pocketing**

Then the corresponding areas of the part that the arrows indicate:

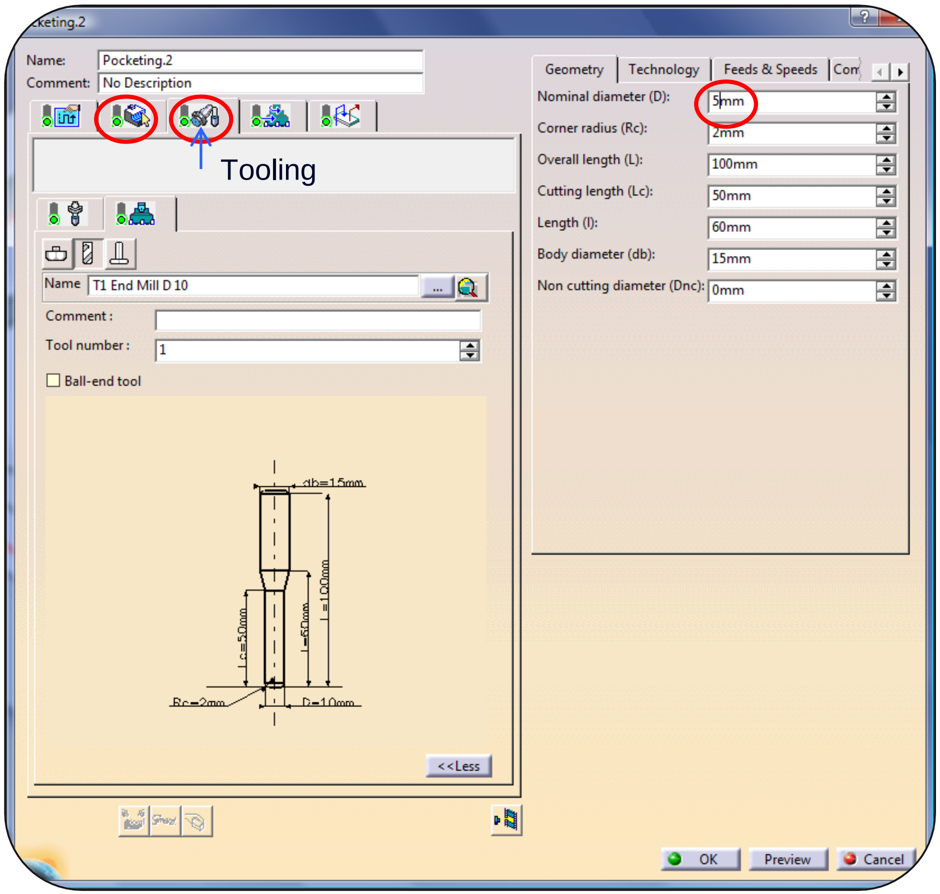




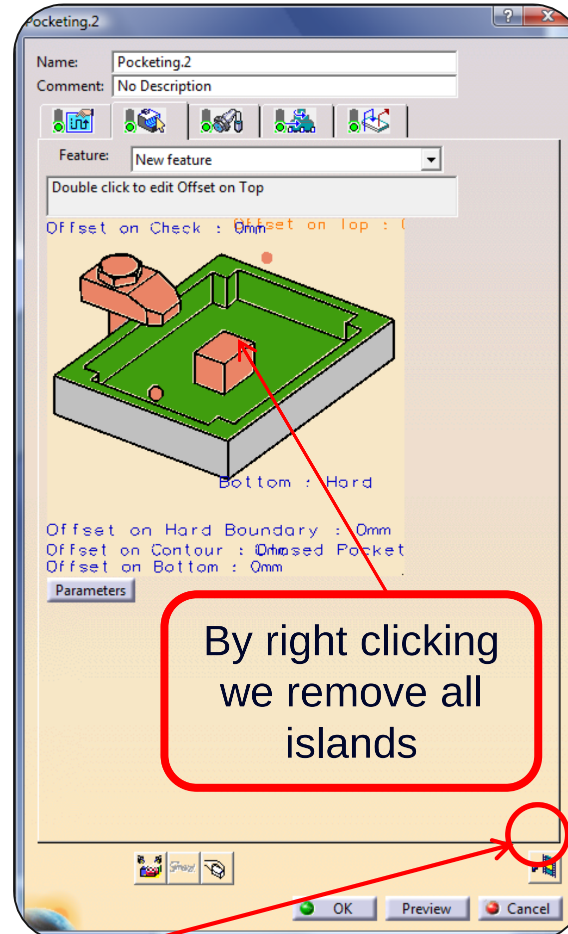
We select closed pocket

Part Programming

- We select the tooling tab, then more and insert cutter's diameter of 5mm then we return to second tab



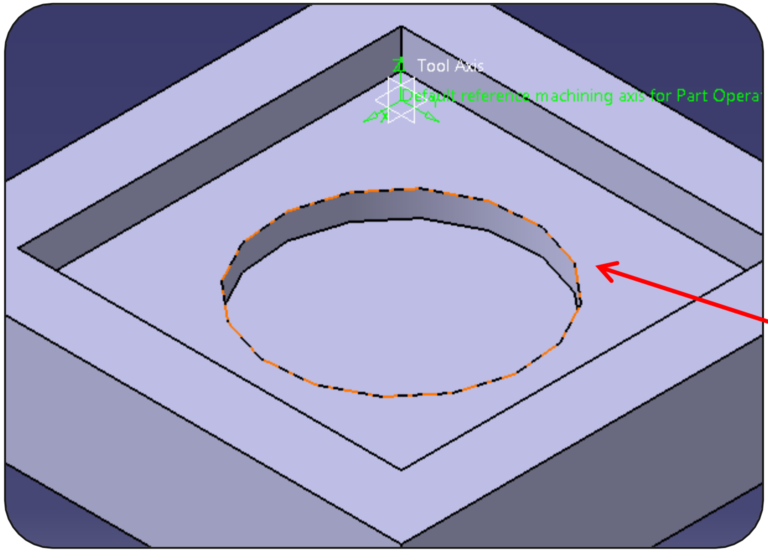
Final form of Pocketing menu

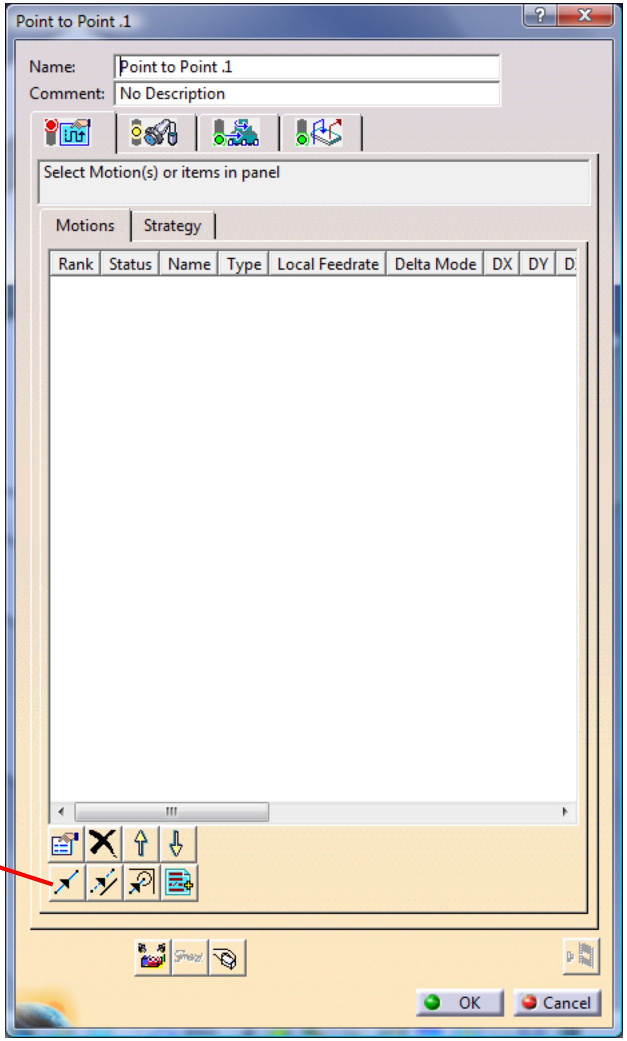


Click **replay** then OK

Part Programming

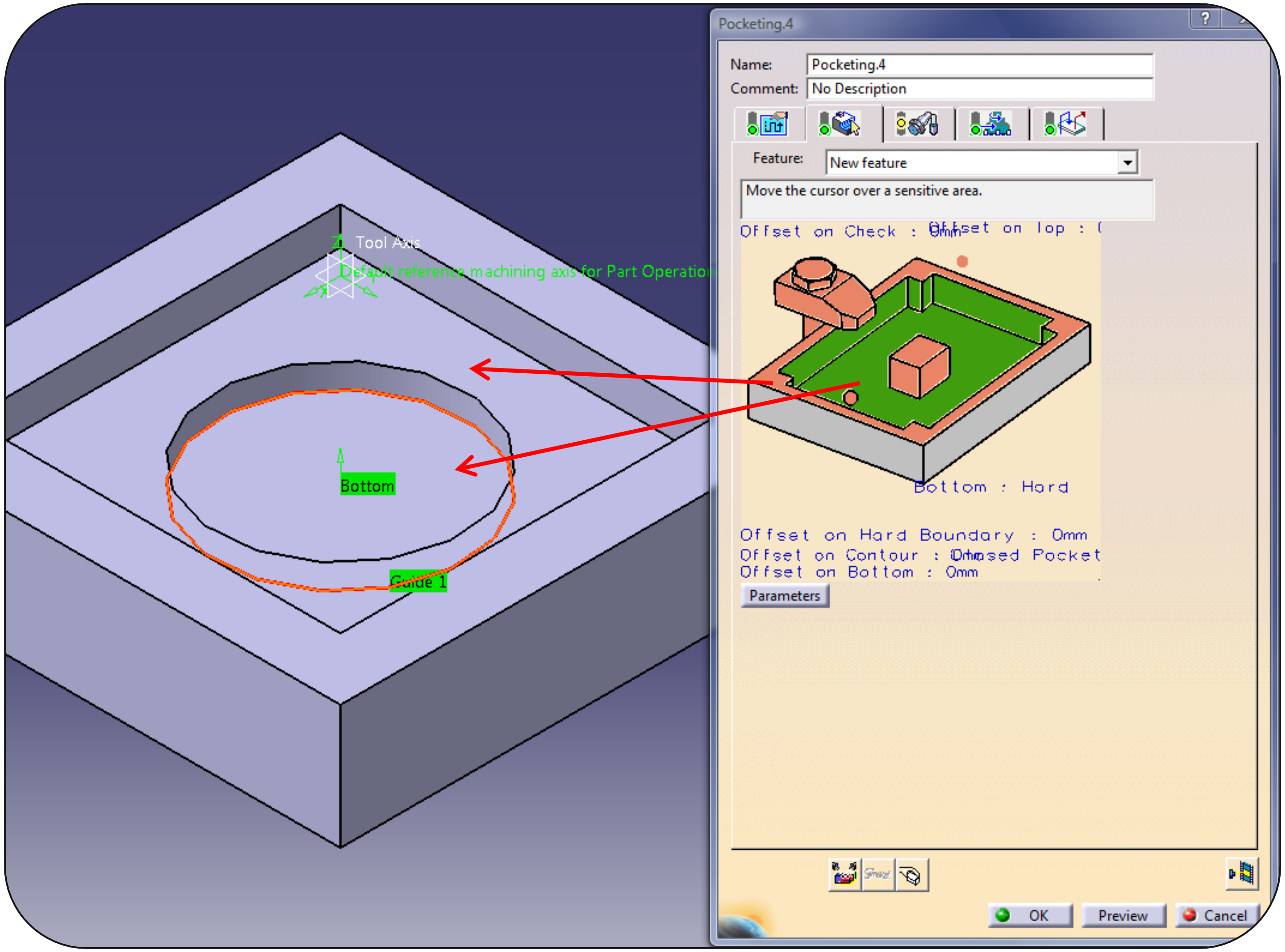
- We select **point-to-point** tab  and the menu appears
- Then we select import new feature and we select the **perimeter**
- Double click on an empty screen area and return to menu
- Then we select **replay**, OK and again OK to close the menu





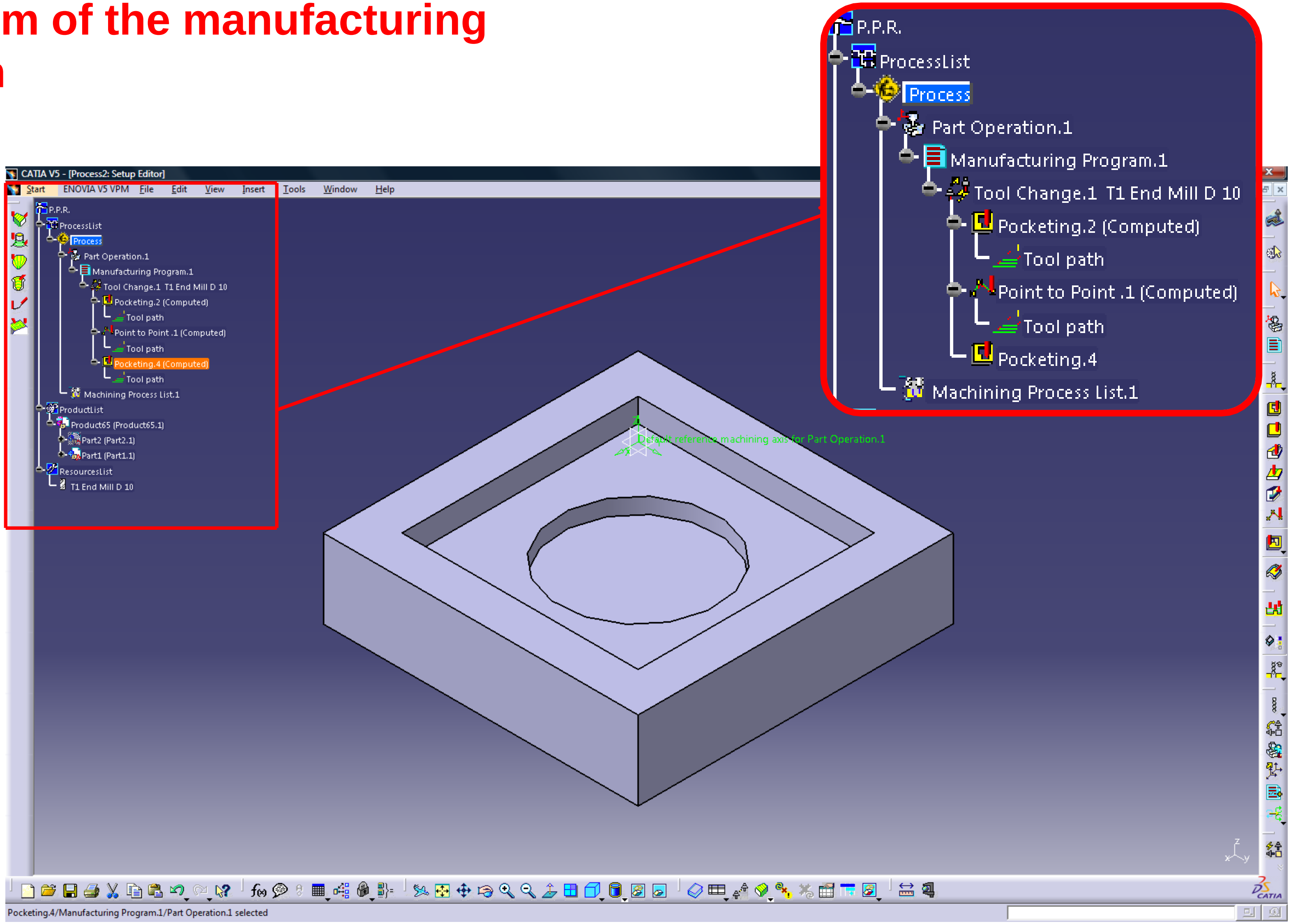
Part Programming

- The process is the same like the previous pocket then we select as the **arrows** indicate:



Program Basic Settings

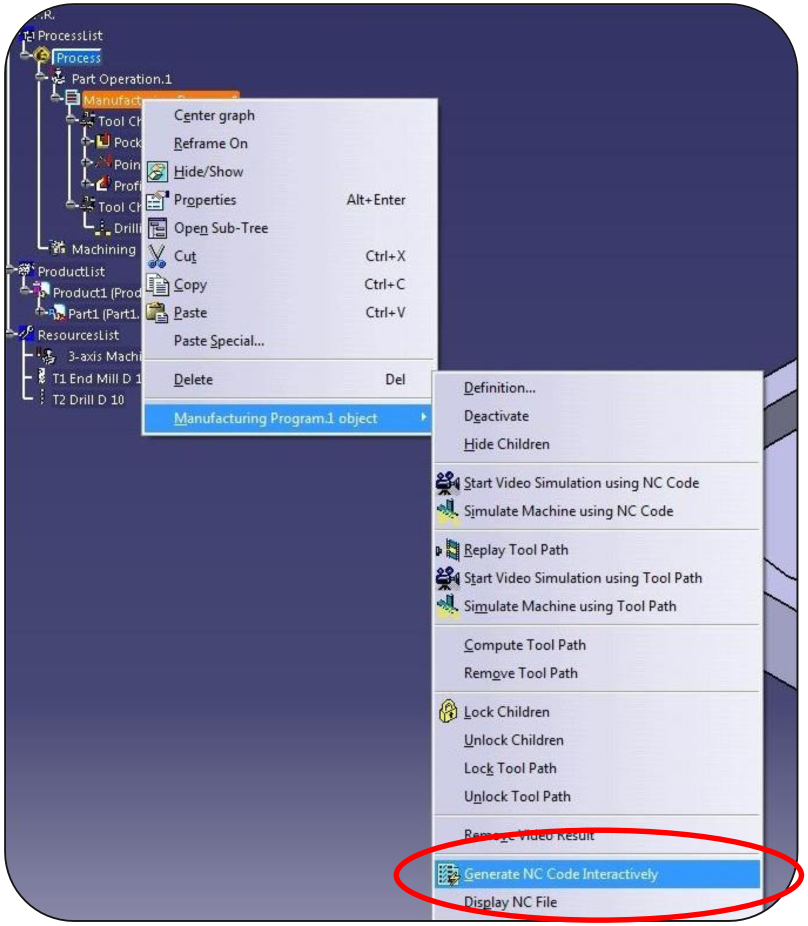
Final form of the manufacturing program



Program Basic Settings

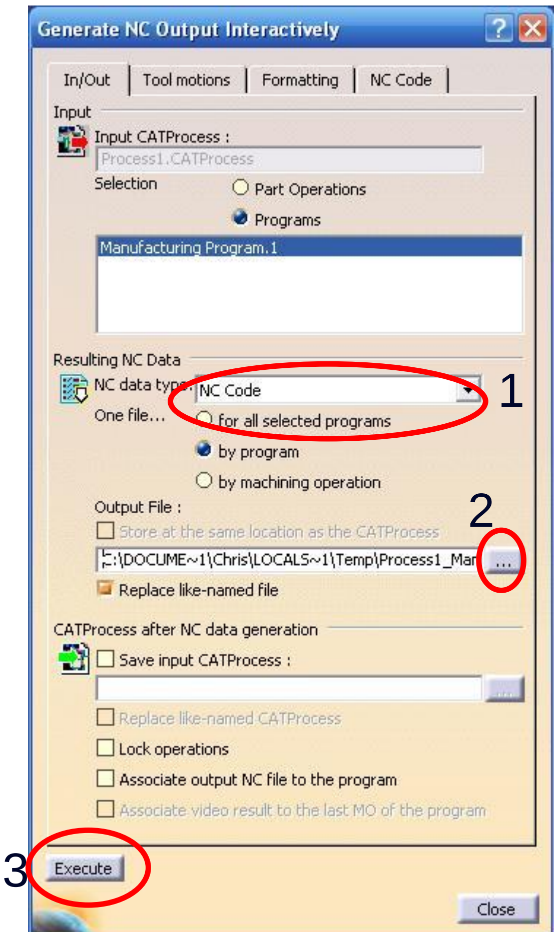
NC Code Output

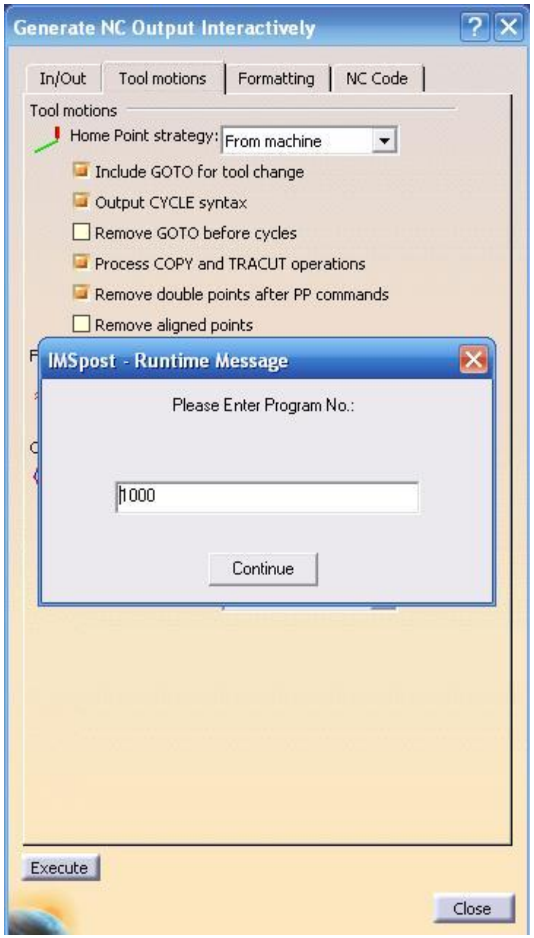
- On the procedure tree, we select **manufacturing program** and by right clicking,we select “**Manufacturing Program.1 object**” then “**Generate NC Code Interactively**”



LAB Program Basic Settings

1. We select NC code then browse
2. Name the folder that G-code files will be saved in
3. Then we click execute, to generate G-code and we are asked for a number to name of the code





Vocabulary Introduced to Chapter 18

- Computer Aided Technologies (CAx)
- Computer Aided Design (CAD)
- Computer Aided Engineering (CAE)
- Computer Integrated Manufacturing (CIM)
- Flexible Manufacturing Systems (FMS)
- Computer Aided Process Planning (CAPP)
- Numerical Control (NC)
- Computer Numerical Control (CNC)

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