

Francis BERNARD
Technical Manager
Dassault Systemes
Suresnes, France

Abstract

Today, about 500 persons of the Avions Marcel Dassault-Breguet Aviation (AMD-BA) make regular use of CAD/CAM on approximately a hundred graphics displays. All the major engineering design and manufacturing disciplines make use of this computer-controlled system whether for definition of shapes, structural strength, kinematic analysis of mobile elements, aerodynamic calculations, machining of parts and tooling or robotics. CATIA is a general application tool which was developed by AMD-BA in order to cover most of those different application fields with the same data base. The different aspects of CATIA such as hardware, software and main functions are described. The CATIA main functions will be illustrated through some examples.

I. Introduction

The implementation of a totally computerized system in the AMD-BA design offices and workshops coincided with the introduction in the 1960's of the first powerful computers likely to process large linear equation systems and the use of the 5-axis numerical control machine-tools.

The computer resources have considerably advanced the development of theoretical aerodynamics and structural stress analysis. The numerical control machine-tools have been used to machine the main components of an aircraft.

Ever since then, the entirely computerized aircraft design and manufacturing process has been gradually achieved. By using a single data base which is available to all users at the same time, all the tedious and conventional transcription operations leading to incoherent and unaccurate results and waste of time were removed.

The implementation of increasingly powerful computers has been gradually introduced in order to replace the batch processings being only justified for long and complex computation runs by interactive programs which are easily managed by all users.

Most of the software systems now in use have been developed by the AVIONS MARCEL DASSAULT-BREGUET AVIATION company - in particular programs related to theoretical aerodynamics, stress analysis or bill of material - among which the most important one is CATIA *, a Computer-Graphics Aided Three-dimensional Interactive Application System.

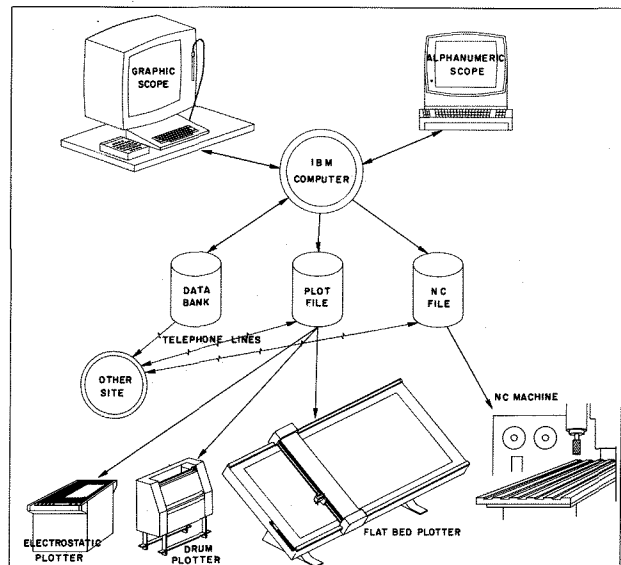
At Dassault, the CAD/CAM system has become a * daily reality for more than 500 workers. The CADAM program is mainly used to handle bidimensional entities while CATIA handles tridimensional entities at the highest level. The data processing system is fully integrated within the industrial process by means of a very simple dialogue expressed at all levels through computer language which needs no specific data processing specialization.

DASSAULT SYSTEMES, a subsidiary of the AMD-BA company, is developing and marketing the CATIA software while IBM is in charge of selling it throughout the world.

CATIA can be defined by both the hardware adopted the selection of which determines the field of applications and the utilization mode as well as its structure and main functions.

II. Hardware

Seven factories located in different sites have a computerized center equipped with hardware adapted to the use of CATIA.



* a Registered Trademark of DASSAULT SYSTEMES

* a Registered Trademark of CADAN INC.

The computers in the different sites are linked by a telephone network used to establish relationships between disk-files.

Thus, the different shapes of the drawing of an aircraft developed in the Engineering Department are instantaneously transmitted to the production units. The size of these computers depends on the local needs. They are not only used for design and manufacturing of parts as they can generate scientific calculations or management processes. Consequently, these computers offer a much more wider range of technical possibilities than all other computer-controlled turnkey systems.

These processors are IBM computers, the 4331 being the smallest one and the 3081, the most powerful one.

The 3250 IBM graphic terminals and the 3278 IBM alphanumeric displays are the interface between man and machine. The graphic terminals are mainly characterized by the fact that they are constantly refreshed which is not the case for storage tubes. As a result, the image is constantly modified which simplifies the dialogue. There are about a hundred graphics stations in the seven factories.

On each site, one or more drafting machines are available according to the local technical needs. These are either unexpensive and relatively fast drum-plotters or electrostatic plotters. Their operating principle makes them operate extremely fast : for instance, they can draw a very complex aircraft component in just a few minutes. In workshops, large flat-bed plotters can draw large components, at scale 1, with high-precision.

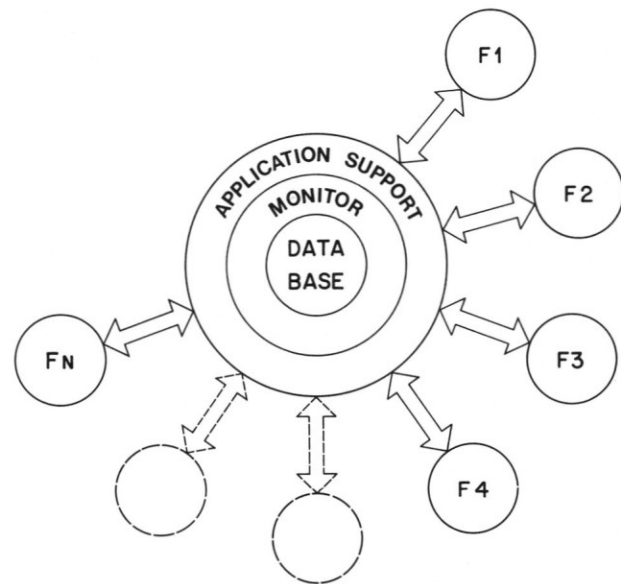


III. Software

The CATIA software includes 250,000 statements (comments excluded) which are written in Fortran (2,500 routines, 80 % of the source) and in Assembler (600 routines, 20 % of the source).

The structure of CATIA is designed to insure and allow for technical growth and flexibility while taking into account the large size of the system, the many people (30) simultaneously working on it and the expected future hardware improvements.

This structure includes three logical units : the monitor, the application support and the interactive application.



III.1 - Monitor

The monitor, which works closely with the IBM operating system and hardware, is written in assembler language and is intended to guarantee the independence of the applications with respect to the hardware.

It handles four main functions :

a) Program control, including :

Automatic restart of the program in case of an abnormal termination of the system, check-point of the user's job at regular intervals, time sharing among several graphic displays and loading the application programs into memory.

b) Dialogue management, including :

All user interactions (from the alphanumeric keyboard or the light pen) and responses from the application programs.

c) Access to the data base

The on-line data base is simultaneously shared by several (interactive or "batch") users and by several computers if the hardware configuration is so designed.

d) Statistics and accounting, including :

Direct access storage of the activity of each scope (number of interactions, operation time, computation time), response time and other accounting information.

(A "batch" program prints out daily summary plots which enable easy system and computer control).

III.2 - Application support

This support consists of all the main dialogue or management routines which are necessary to manipulate elements in 2D or 3D space. It is practically independent of both the hardware and the application modules and operates by means of four functions with specific associated software:

a) Management of stored data

The elements (points, lines, surfaces, volumes, etc ..) may be grouped into sets in order to subject them to common processing operations. Each element is associated with an identifier, a mathematical representation and a graphic representation (which may be modified by the user).

b) Manipulation of the image

The user can generate one to four images (or views) on the screen and manipulate them independently (change of scale, rotation, translation, etc ..). The user can also modify the characteristics of each vector displayed on the screen by changing its intensity level (1,2,3 ...7), its line type (solid, dotted or dot dash lines) and its state (steady, blinking).

c) Management of the disk-file data base

The user can create, erase, read or write all or part of the data base and assemble all or part of several groups into one. The user can also automatically transmit any planar subset from the CATIA data base to the CADAM 2D data base or, inversely, read the bidimensional data generated by CDAM.

d) Dialogue assistance

This software standardizes the dialogue and management between the user and the applications.

III.3 - Interactive application

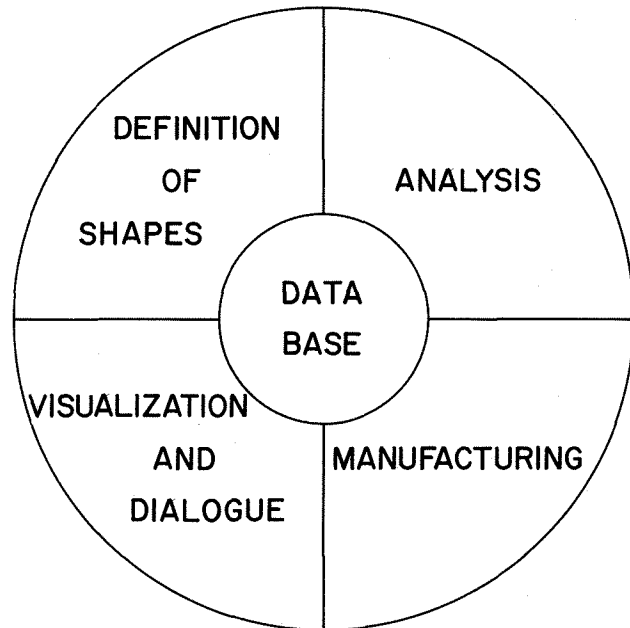
Each application (F1, F2, F3, ..., Fn) is associated with a different key on the function keyboard and a program stored in the program library. Selecting a function causes the transfer of the associated program into memory, the establishment of the connections with the data common to all functions and the sequencing of the requested applications.

IV. CATIA main functions

A computer aided design and manufacturing system manages data stored under the name of "model" into different computer storages, such as disks or magnetic tapes. The model includes data of different nature : mathematical, topological or alphanumerical data.

As a general rule, the mathematical data represent geometrical shapes. The topological data define the various types of relationships between the elements of the model. The alphanumerical data define the elements by their attributes.

This model can be created, modified, analyzed and produced by using the four main following functions, namely : dialogue and visualization, definition of shapes, analysis and manufacturing.



IV.1 - Dialogue and visualization

This function corresponds to the language interface between man and machine. This language is indispensable for operating the three other functions.

The dialogue is designed to reduce both the training period (a few days) and the user's documentation as well as the number of steps for each application.

At all times, basic interactions such as selection of a menu item, selection of an element, use of the function or alphanumeric keyboard are prompted by the program. For each interaction, there is a corresponding type of processing which is clearly indicated beforehand and the result automatically displayed through a modification of the image.

The user can work in 2D mode by selecting a plane and the dialogue is simplified, although the generated data base is still three-dimensional.

The graphic representation of an entity may be modified. This option is of great help for manipulating surfaces and volumes.

The graphic image can be also manipulated in one to four views at all times.

Each element is identified by its image and a character string : as a result, the selection during the dialogue can be done either via the light pen or the alphanumeric keyboard.

One particular key makes it possible to cancel the last operation performed.

IV.2 - Definition of shapes

The user creates and manipulates all the geometric elements in a plane or in space : points (by intersection, projection, etc .), lines (by intersection, projection, through two points, etc.), planes (by equation, passing through points, lines or curves, normal to a line, etc .), text of various sizes and orientations, reference axis (related to another reference axis), linear transformations such as translation, rotation, symmetry, scaling, etc .

Further details are given below on curves, surfaces, faces and volumes.

a) Curves

A curve may be the intersection of a plane with a surface, the intersection of two surfaces, an isoparametric curve, an apparent contour, etc . It results from a computation based on complex elements (curves, surfaces) previously created.

Some curves are defined by their type, such as circles or conics.

A curve may also be defined as an interpolation function of an ordered list of points. Some points have an associated tangential direction, and, if needed, a curvature. The operator may select two types of curves, which are :

- the spline ; which is computed by using the finite element method and defined by 5th degree polynomials in the interval between two consecutive points. It is the smoothest interpolation function and ensures the continuity of the curvatures and even their derivatives.
- the polynomial arc ; which is computed by using the least squares method and defined by a single polynomial with a degree ranging from one to fifteen. It is better suited to rapid design based on approximate points.

The curve and its successive curvatures can be displayed on the graphic scope. It has been found by experience that, due to this quantitative representation, the large conventional drafting table can be replaced by a small screen. The operator modifies the constraints as he pleases (points, tangents, curvatures) and immediately obtains a new curvature distribution. Alternatively, if he assigns a tolerance to each point, an automatic smoothing computation defines the optimal curvature.

b) Surfaces

Some surfaces can be defined by their type, such as spheres, cylinders or circular base cones.

As a general rule, surfaces are more complex. They are defined as an interpolation function of a network of points and curves on which transverse tangent and curvature constraints may be imposed. They can be also generated by circles, conics or any curve moving in space, according to given rules. For instance, a fillet is automatically generated as a law of circles tangent to two surfaces.

They are mathematically defined by biparametric polynomial functions with a degree ranging from one to fifteen.

c) Faces

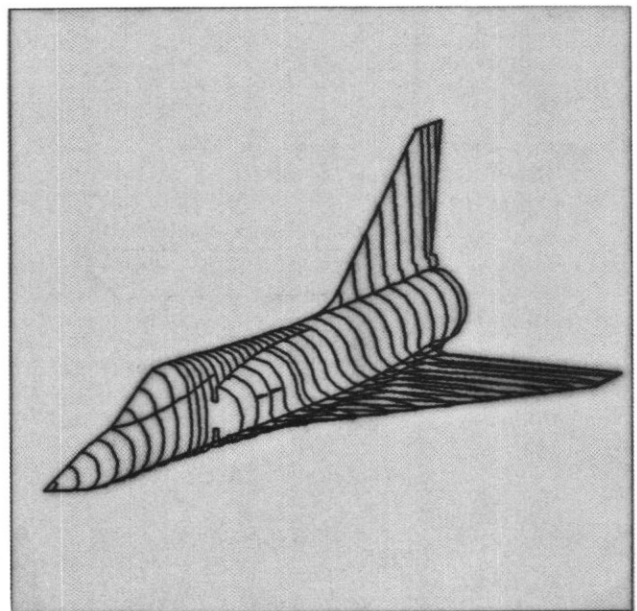
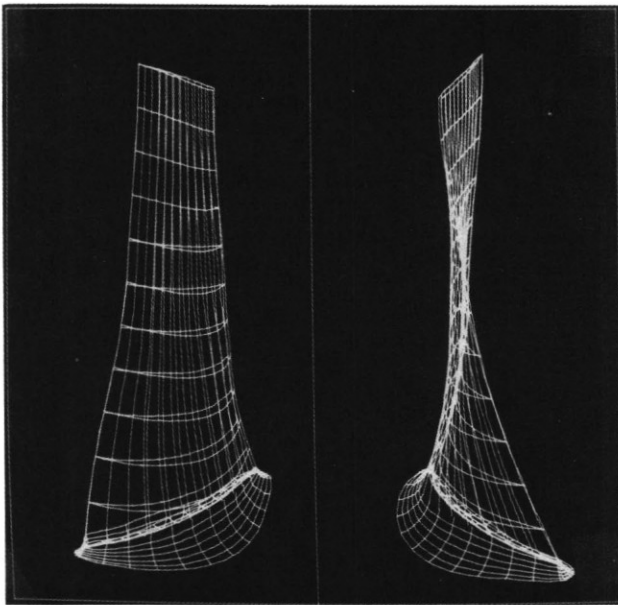
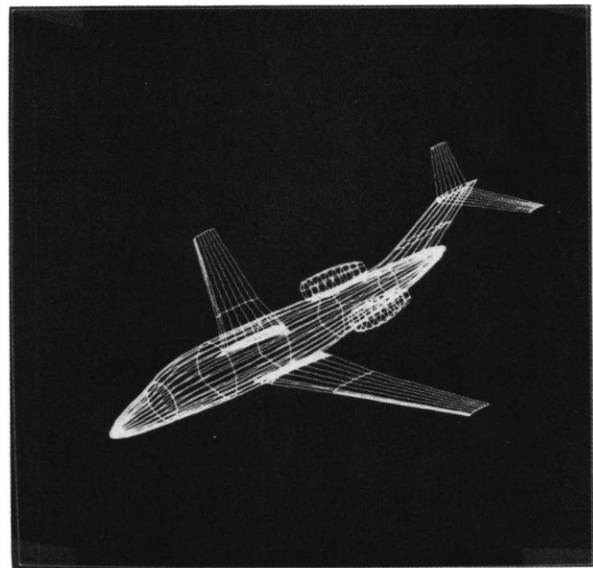
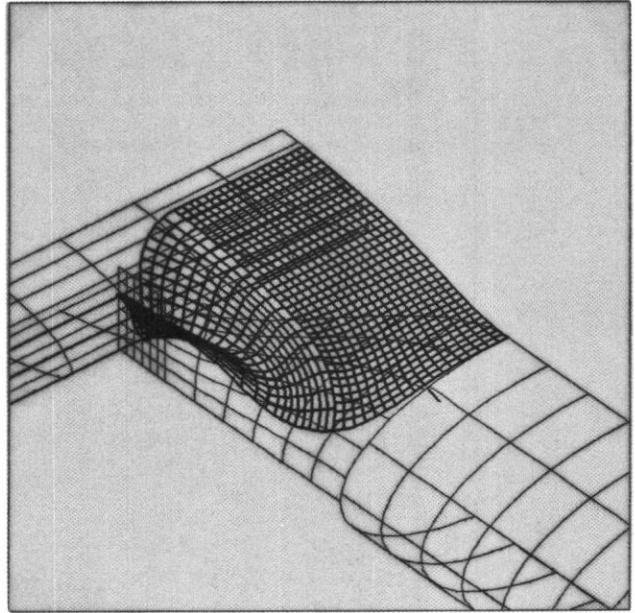
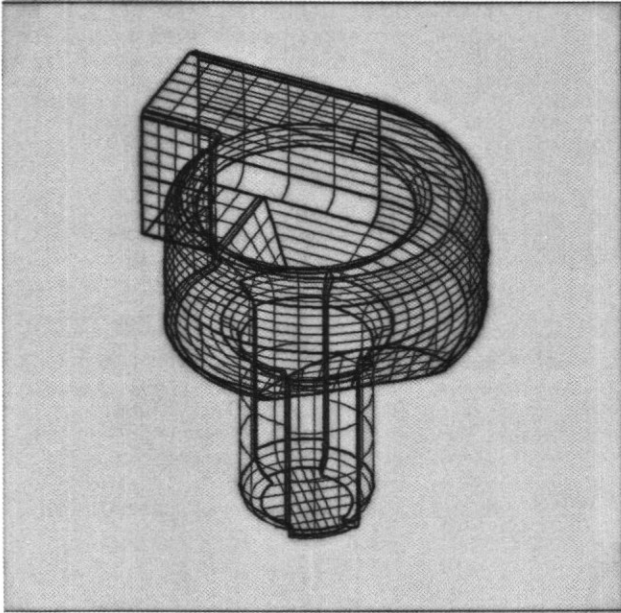
A face is the region of a surface limited by one or more closed contours. It is defined very rapidly regardless of its complexity by the selection of its bounding curves.

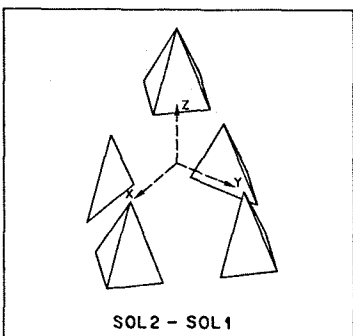
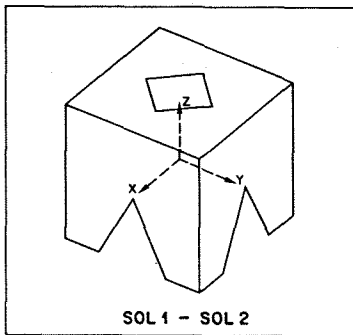
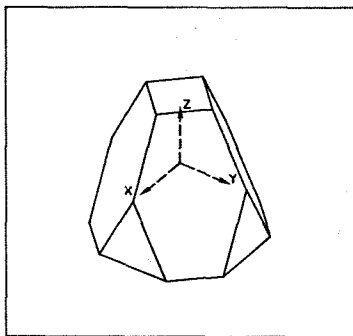
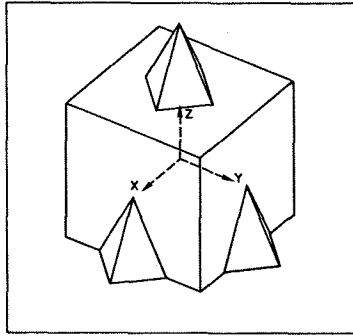
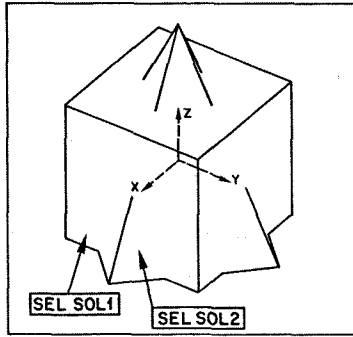
d) Complex volumes

A volume is the region in space limited by one or more closed boundaries defined by adjoining faces. It is defined by simply selecting bounding faces regardless of its complexity.

All processing operations such as intersection by a line, a curve, a plane, a surface, another volume, a numerical control, etc .. are possible.

This accurate numerical definition is not always operated on just as it is. Sometimes, it is necessary to simplify it by creating a "polyhedral volume".





e) Polyhedral volume

The technological possibilities offered by computers now in use such as memory size, computation speed, graphical image quality, are too limited to support some applications in an interactive environment. It is possible to mitigate the effects of this problem by modifying the description of the objects when an accurate numerical definition is not required. This simplified solutions opens up new important possibilities which are :

- Hidden line removals on a constantly modified image,
- Boolean operations : addition, subtraction, intersections and split of volumes,
- Structural resistance, theoretical aerodynamics computations, etc .

The use of the polyhedral volume has led to a simplified numerical definition of objects. It is deduced from a complex volume by schematizing non planar bounding surfaces in a series of quasi-planar polygonal facets. It can be created directly if it is simply defined (cube, prism, pyramid, sphere, torus, etc .).

IV.3 - Analysis

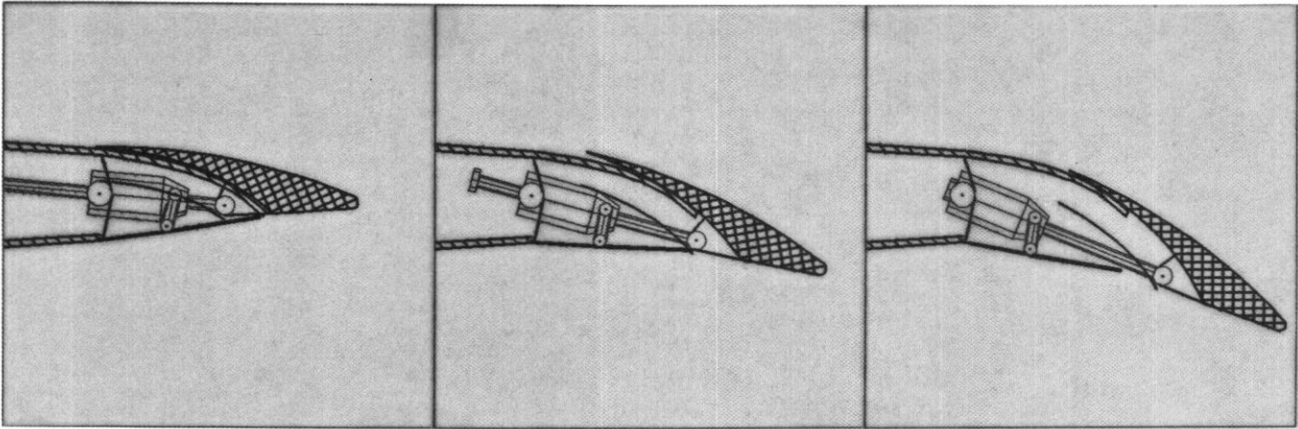
The model is estimated by analysis. The analysis consists in comparing the degree of adaptation of the product to be created with the specifications. The definition of shapes is a function which allows the modification of the model so that a new analysis be more adequate. Thus, the model is fully optimized.

The first method of analysis available is the study of the various graphical representations.

The better analysis of a complex image is facilitated by using a function which allows mathematical analyses (for example : What is the equation of this plane ?), relative analyses (for example : What is the distance between these two points ?) and, above all, logical analyses (for example : On what surface (s) does this curve lie ?).

The other methods of analysis available are computation operations, such as : computations of surfaces, volumes, centers of gravity and inertia, etc. Aerodynamics or structural stress analysis computations are processed by batch programs.

A mechanism is a combination of solids which are related by geometric relationships : the points, curves or surfaces of a solid are in contact with the points, curves or surfaces of another solid and, in some cases, are subject to rolling or slipping constraints.



IV.4 - Manufacturing

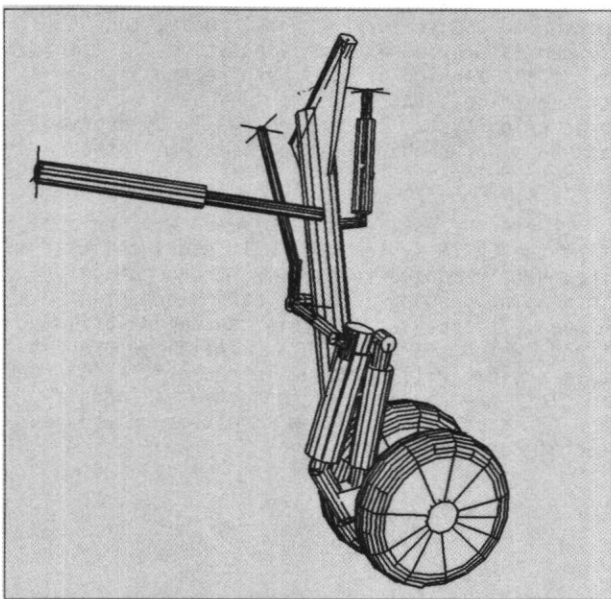
a) Numerical control manufacturing

CATIA is also the preparation tool for the numerical control machining of geometric elements filed in the data base.

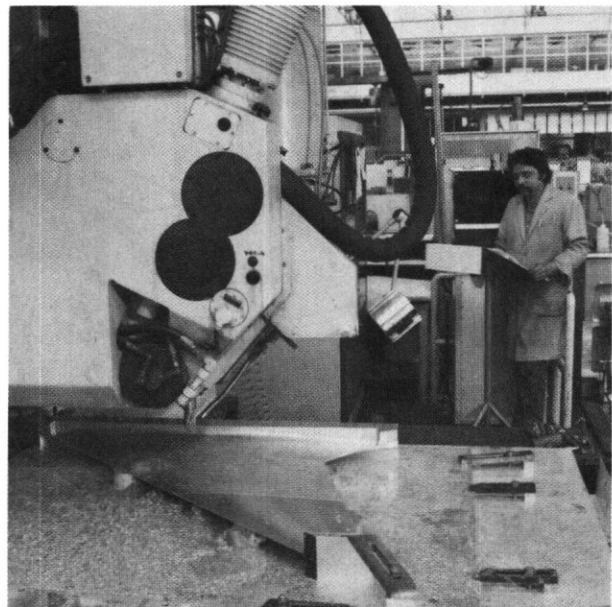
The numerical control (NC) programmer uses the interactive graphic display to describe the path of the cutter or select the geometrical figures which are in contact with the cutter. He can also define the shape of the tool (ball-end, filleted-end, cylindrical end), the type of machining - 3-axis or 5-axis machining - and the technological data requirements.

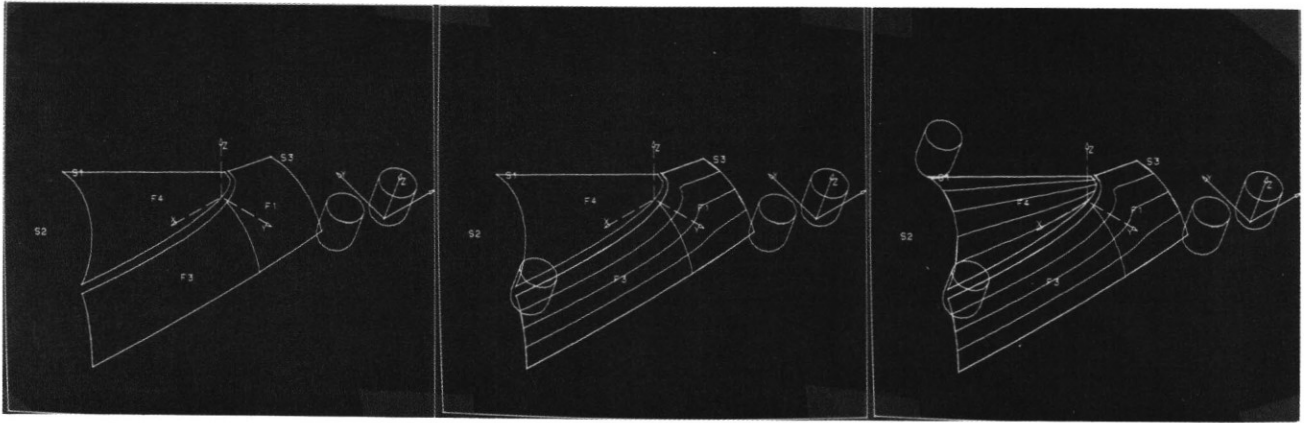
The animation on the display of the cutter motion allows the NC programmer to avoid errors and correct, if necessary, the geometry of the component in order to adapt it better to manufacturing techniques.

This is how wind-tunnel models, integral structural components and most tooling items are produced.



By using the CATIA system, it is possible to define this mechanism and its environment, simulate its movements on the graphic screen and remove the hidden lines in real time, if it is defined by polyhedral volumes, as well as deduce speed and instantaneous rotation centers. The user can modify the geometry of solids and their relationships and, as a result, gradually optimize this mechanism.



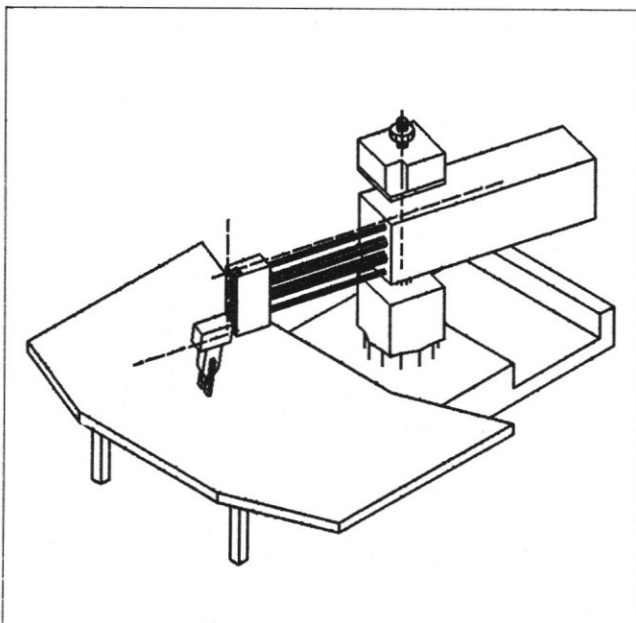


b) Robotics

By using the CATIA system, it is possible to define a robot by its geometry and its various working parameters.

At this stage, the engineer can pilot the robot with optimized movements in space and time : it can move from one point to another or take an object up and down, etc ... The visualization of the robot at work is constantly displayed on the graphics display.

This is how all the robots located in Dassault workshops will be piloted before the end of the coming year.



Conclusion

CATIA represents an enormous investment superior to 150 years/man. Until today, the CATIA system is proving extremely positive. In fact, it is at the service of all. Despite its high level of technology, CATIA is a tridimensional data processing system to be used easily by everybody and does not require any specific data processing training.

Nevertheless, those engineers who are promoting the CATIA system are fully convinced that they hardly manage to discover the constantly increasing possibilities of data processing techniques. It appears that this new technological trend, which started with the CATIA new prospective system, will continue in the future in order to glut the manufacturing branches of industry and to adapt it to the new requirements and new techniques of the future.