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Initial CAD Investigations for NET

Final Report June 1, 1985

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INITIAL CAD INVESTIGATIONS FOR NET

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Abstract

This report summarizes the work done under contract no. 164/84-7/FU-D-/NET between the Commission of the European Communities and KfK during the period from June 1, 1984, through May 31, 1985. The following topics are covered in this report

- o initial modelling of NET version NET2A,
- o CAD system extension for remote handling studies,
- o analysis of the CAD information structure,
- o work related to the transfer of CAD information between KfK and the NET team.

ERSTE CAD-UNTERSUCHUNGEN FÜR NET

Abschlußbericht zum 1. Juni 1985

Zusammenfassung

Es wird über die Arbeit unter dem Vertrag Nr. 164/84-7/FU-D-/NET zwischen der Kommission der Europäischen Gemeinschaft und KfK im Zeitraum vom 1. Juni 1984 bis 31. Mai 1985 berichtet. Folgende Einzelpunkte werden erfaßt:

- o Erste Modellierungen der NET-Version NET2A,
- o CAD-System-Erweiterung für Montagestudien,
- o Analyse der Informationsstrukturen im CAD-Bereich,
- o Arbeiten im Hinblick auf den Austausch von CAD-Information zwischen KfK und dem NET-Team.

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1.0 INTRODUCTION

This is the final report for the NET contract no. 164/84-7/FU-D-/NET between the Commission of the European Communities and Kernforschungszentrum Karlsruhe.

1.1 Objective

The objective of the contract is an initial investigation of the application of CAD techniques to the NET design, in particular with respect to establishment of the NET geometric data base and to remote handling.

1.2 Description of the work-plan

It is anticipated that CAD systems will play an important role in the design of NET. It is intended that CAD systems will act as the main geometric data base for NET. The facilities provided by CAD systems in three-dimensional modelling will act as a basis for the development of techniques to study system integration and remote handling. NET has obtained a CAD system and is presently developing expertise in its use. The work to be performed by KfK will allow an immediate application of CAD to NET and assist the NET team in developing and using its own system.

The work will include:

1. Initial modelling of preliminary NET design versions and identification of systems integration and remote handling problems, using the KfK CAD systems. The data will be provided to NET as the NET CAD system develops.

2. Modelling of handling equipment and operations and development of appropriate CAD techniques for definition of the remote maintenance approach. It is envisaged that this will replace item (1) after about the first six months.

3. Acting as consultants to the NET team in the structuring of the NET data base and associated management system.

4. Study of CAD data exchange requirements for NET, both between different associated laboratories and with industry. It will be assumed that the organizations will have CAD systems supplied by different vendors. Data exchange standards (such as IGES) will be critically investigated and, if necessary an alternative NET standard should be proposed.

2.0 MODELLING

2.1 Introduction

Fusion reactors are distinguished from most other large technical plants by the complexity of their three-dimensional geometry. Due to physics requirements, most components have a rather irregular shape and cost implications require these components to be tightly packed. This situation calls for computer aids in the design of fusion machines and remote handling equipment and procedures to a much greater extent than for more conventional products. Therefore, CAD support will be needed for

- design and design representation of fusion and remote handling machines,
- system integration,
- planning of assembly, disassembly, and maintenance procedures.

To start with the work on these general tasks the following subtasks were separated:

- modelling of selected, typical components, and their assembly,
- control of measures and clearances,
- collision detection,
- movement studies,
- accessibility studies,
- simulation of TV system positioning.

The following tools are available at KfK for solving these tasks:

- REGENT-GIPSY, a graphics programming language developed at KfK, and
- Applicon-BRAVO!, a commercially available interactive CAD system.

2.2 Work performed

For the initial investigations design data of two fusion machines were used as a reference:

- o the JET articulated boom as a typical example of a remote handling manipulator, and
- o the NET2A design.

Related work was done based on design data of ASDEX-UPGRADE and TASKA.

2.2.1 Approach

Geometric modelling is generally based on a specification: a **textual description** of design goals and design restrictions. In most cases, a set of **geometric reference data** exists. Such geometric reference data has to be included as the first constituent into a CAD data base. It can then be used directly for modelling the machine components. This reference data should be kept separated from the models which are built from it. A well defined reference geometry is an essential basis for the modelling work and, therefore, should be an integral part of the data base and not only be present in the minds of the designers or on paper outside the system. An example for this kind of geometric reference data work is the data describing the shape of the TF-coils and the PF-coils, and the basic outline of the main components like the blanket and the divertors. Such data is most suitably represented as two-dimensional and properly dimensioned curves defining critical or limiting areas of a component. The definition of this reference data, for the TF-coils, e.g., should include not only a set of points on the boundary of the D-shape, but also the method to be used in the CAD system to interpolate between these points.

Prior to discussing the special CAD tasks, a short summary of the various **modelling techniques** used in the work will be given.

- o two-dimensional modelling: usable for real time simulation;

- o three-dimensional wire-frame: usable for interactive modelling and analysis of complex structures, relatively fast build-up of pictures;
- o three-dimensional solid (volumetric) with the following presentation methods:

  - wireframe,
  - hidden line removal, or
  - shaded and colored.

  Solid modelling may be implemented in an approximate way (facetted models) or with a precise treatment of geometry. On the CAD system at KfK (Applicon-BRAVO!), both methods of modelling are used: The facetted model is used for interactive work; the precision model requires a batch job.

2.2.2 Control of measures and clearances

In a very complex geometry like a fusion machine with a torus as the basic element of construction the control of measures and clearances in various areas of the machine is impossible using the standard drawing technique. The construction of a real mock-up is too inaccurate or too expensive and time consuming. The CAD system can compute exact clearance values on the basis of the three-dimensional model stored in the data base. Errors in modelling due to the complexity of arrangements in space can be detected very soon. The high precision of the CAD calculations is extremely helpful in such tightly and complicated packed arrangements like a fusion machine.

2.2.3 Movement studies

The main problem in performing movement studies is to find a usable solution for the description of the machine's kinematics. This is no particular problem in a normal programming environment for the task, like for example with GIPSY, the KfK solids modelling programming language. This solution was used for the production of movies showing the limiter insertion with the JET-boom [1]. In contrast, most CAD systems do not provide adequate support for the modelling of the machine's kinematics. There are three possible answers to this problem:

- to write programs for the restricted movement of the machine parts using command procedures (e.g. with Applicon IAGL) or a special programming language with CAD data base access (e.g. Applicon AGL),
- to use a special commercially available kinematics package (like ADAMS) based on the CAD data base, or
- to produce a three-dimensional wire-frame model on special computer graphics equipment like the Evans and Sutherland PS300 series workstations.

In order to investigate the command procedure technique for solving this task, the movement of the JET articulated boom was described with IAGL. This pragmatic approach solved the special problem, but also indicated that a more general solution for this problem should be found. Therefore, requirements for a **kinematic subsystem** was implemented as an extension to the basic CAD system using the facilities of the CAD system for this purpose. This kinematic subsystem is described in more detail in "The kinematic subsystem". The third approach (the use of special computer graphics equipment) would require the installation of this hardware and the development (or purchase) of an interface between the CAD system used for modelling and the graphics system.

For the JET articulated boom, movement studies were made using snapshots of critical positions and animation techniques (movies).

2.2.4 Collision detection and accessibility

Four methods of collision detection and accessibility studies were investigated:

1. Visual inspection of wire-frame models. This is fast, but often confusing and misleading because of the excessive number of lines in a view. Therefore, various aids in view enhancement were applied by
   - introducing color for special objects,
   - generating views along problem dependent directions,
   - changing the visibility of objects or parts of objects, and
   - clipping before or behind a plane of interest normal to the line of sight.

Most of these aids were implemented as special command procedures to make easy use of the system's capabilities.

2. Retrieval of measures of critical clearances from the CAD database.
3. Visual inspection based on solid models, using hidden-line and shaded object representations: This method was found useful, but slow.
4. Crash detection based on intersection analysis of the solid objects.

In principle, the best method of collision detection is based on precision type solid models and the computation of intersections. In practice, the usability of this technique depends on the turn-around time. The solution is not satisfactory in the Applicon system. Therefore, it can be used only in conjunction with other techniques which involve the workstation operator's intelligence and three-dimensional imagination capabilities to locate and detect potential or real collisions.

2.2.5 Simulation of TV-system positioning

To support the remote handling operator effectively the position of the TV cameras for the scene presentation is of great importance. Because the possibilities of TV positioning and moving in the tightly environment are restricted, it is important to simulate the viewing possibilities. A computer graphics generated movie showing the boom movement in the torus as seen through the in vessel inspection system was produced. The result of this simulation indicates that this viewing possibility is inadequate if it has to be used as the only or main source of information by the operator of the boom. Hence, KfK is investigating the possibilities of providing the remote handling operator with a computer graphics display of the situation based on a CAD model.

2.2.6 Response time in CAD modelling

Sometimes the response time will become a considerable problem in CAD modelling. This depends on the actions which are required, the complexity of the model, and, last not least, on the number of tasks which are run simultaneously on the CAD computer. Our experiences with Applicon Bravo! (including the Solids Modeller) may be summarized as follows.

If only wire-frame models are processed (basical geometrical data, for instance), almost all operations are finished within seconds or faster. The response time of the system appears to be quite appropriate in this case.

With respect to solid models, one has to differentiate between various situations. The creation of a solid feature entity, for example, takes roughly half a minute. The construction of a solid part by Boolean operations, on the other hand, may last one minute or fifteen minutes, depending mainly on the complexity of the model and on the number of features involved into the operation. But any movement of a solid part within an assembly of solids is performed very quickly. With the BSIM system, for instance, which is described in the chapter "The kinematic subsystem", twelve movements of a blanket module along predefined paths take about three minutes, if each movement step is initiated by manual command input, and about half the time, if the sequence of steps is run by automatic procedure calls. Both values include the time required for the interpretation of IAGL procedures and for opening another movement path.

In the previous examples, the model was always shown on the screen by wire-frame representation. If the specified representation mode demands for shaded or hidden-line removed pictures, the movements themselves are performed as fast as mentioned above, but the screen is updated only by wire-frame drawings. A full screen updating according to the specifications (by a DRAW command) then takes at least one minute for the relatively simple assembly shown in Figure 19 on page 33 and for the same screen layout. With more complex models, the response time may increase up to about five minutes.

Again another situation arises with the creation of precise models, with either representation mode. As this can only be done by a batch run, the response time is of minor importance. The CPU times required for such a run depend considerably on the complexity of the models and - in the case of shaded pictures - on the required resolution (i.e., the number of pixels). Therefore CPU times between ten minutes and twenty hours have been found. Correspondingly, the turn-around times vary between just one hour and more than one day.

Finally, it should be noted that the interactive response times will increase more or less when the CAD computer is simultaneously used by several users. Particularly those activities which require intense CPU work (e.g., Boolean construction operations) will be delayed by a factor of up to two or three.

2.3 Results obtained

The tokamak structure of NET version 2A has been modelled, on the basis of the drawings which had been provided by the JCR Ispra. The "micro-structure" of some large components (which is not yet defined in detail) has not been resolved; rather these components have been modelled as solids to the level of detail that is relevant with respect to global remote handling operations. For example, the blanket modules contain a lot of pipes, tubes, etc., depending on the actual blanket concept. These blanket internals have not been modelled; instead, the models of the blanket modules are built to represent the envelope of all this structure.

Identical parts which are found repeatedly within the tokamak have been modelled only once. The assembly of the tokamak is then completed by copying these parts and by moving the copies to the proper position.

These operations are facilitated by using a single coordinate system for modelling all components. Thus adding an original part to an assembly yields in putting this part immediately to its correct location.

While the final models are three-dimensional solids the modelling work for each part started with a planar wire-frame model representing its poloidal contour. These wire-frame models were used to generate the solid primitives, applying the suitable system-defined operations like REVOLUTION or EXTRUSION. In principal, another plane wire-frame model, built in a toroidal plane, could be used to define the angular extension or the depth of the solid parts; actually, however, this information was introduced directly by numerical input during construction of the solid parts. Some predefined "boxes" (a special kind of features) were placed in such a way that the application of the Boolean operator SUBTRACT resulted in the desired part shape.

The following figures give an impression of the results of modelling. Examples of movement studies which have been applied to these models, are described in more detail in "The kinematic subsystem" on page 19.

In Figure 1 on page 12, one sector of the vacuum vessel is shown (central angle 22.5 degrees). The toroidal vessel part is combined with the divertor access port which is connected to the main vacuum duct. At the top, the vessel has another opening which is required as an access port for mounting and dismounting the blanket modules.

Some of the internals of the vacuum vessel are presented in the following figures. First, Figure 2 on page 13 shows one type (out of three) of divertor modules. In mounting such a module, it has first to be shifted through the access port; then, it has to be moved aside in order to clear the space for mounting the opposite and, finally, the central divertor module.

Figure 3 on page 14 shows the four blanket modules which form one blanket sector. Their relative placement corresponds to how they have to be mounted into the vessel. The body of each module is joint to the envelope of the corresponding connection lines which have to be led out of the vessel through the upper access ports. (The connection lines are represented by the blocks protruding from the top of the blanket modules.) This enforces a sharp concentration of the connection lines to a small part of the blanket circumference. We could not investigate, however, whether there is sufficient space available for the tubes.

Figure 4 on page 15 shows other views of the same assembly of blanket modules, together with the key plug which has to close the gaps between the top ends of the blankets as well as the gaps between the blankets and the vessel. In this picture, the key plug has been lifted from its operational placement in order to emphasize the depth of its structure.

In Figure 5 on page 16, the four blanket modules from Figure 3 on page 14 are mounted into a vessel sector (Figure 1 on page 12). The toroidal boundaries of the blankets do not coincide with those of the vessel sector because of the space constraints for the access port which the blankets have to pass during mounting or replacement operations.

Figure 6 on page 17 summarizes the modelling work for NET2A. Besides all PF-coils, on the right-hand side of the figure three sectors of the vessel and of the blanket are presented, together with the adjacent TF-coils. On the left-hand side, the vessel sectors and the TF-coils are omitted, and two sectors of the blanket, the divertors and the key plugs may be seen in the same position as they must be mounted inside (or atop of) the vacuum vessel.

Figure 7 on page 18 shows two poloidal sections of the NET2A torus. This drawing has been generated using the planar wire-frame models which served for input of the basic geometry. On the left-hand side, the section plane is the center plane of a vessel sector (the contour of the TF-coil being rotated into this plane), whereas on the right-hand side the section plane coincides with the angular boundary of the vessel sector (or with the central plane of the TF-coil). The line between the inboard and outboard blankets represents the separatrix of the plasma. Just for illustration, some dimensions have been included into the drawing.

2.4 Recommendations

- CAD should be introduced in the NET community as soon as possible to prevent data input from drawings as done in the present stage. We found out, that, especially in modelling complex machines, a design description by drawings is not as complete as needed for CAD modelling and a great deal of information has to be communicated verbally.

- The designers and draftsmen who work with the CAD system should be done supported by a computer specialist, starting with one CAD specialist for four designers initially, and one for seven later when more experience has been gained. The specialist is responsible for the introduction, the training, the daily support, and for tuning and enhancing the software which is specially related to the project. Special attention should be given to the procedure of introducing CAD: The main difficulty is to map

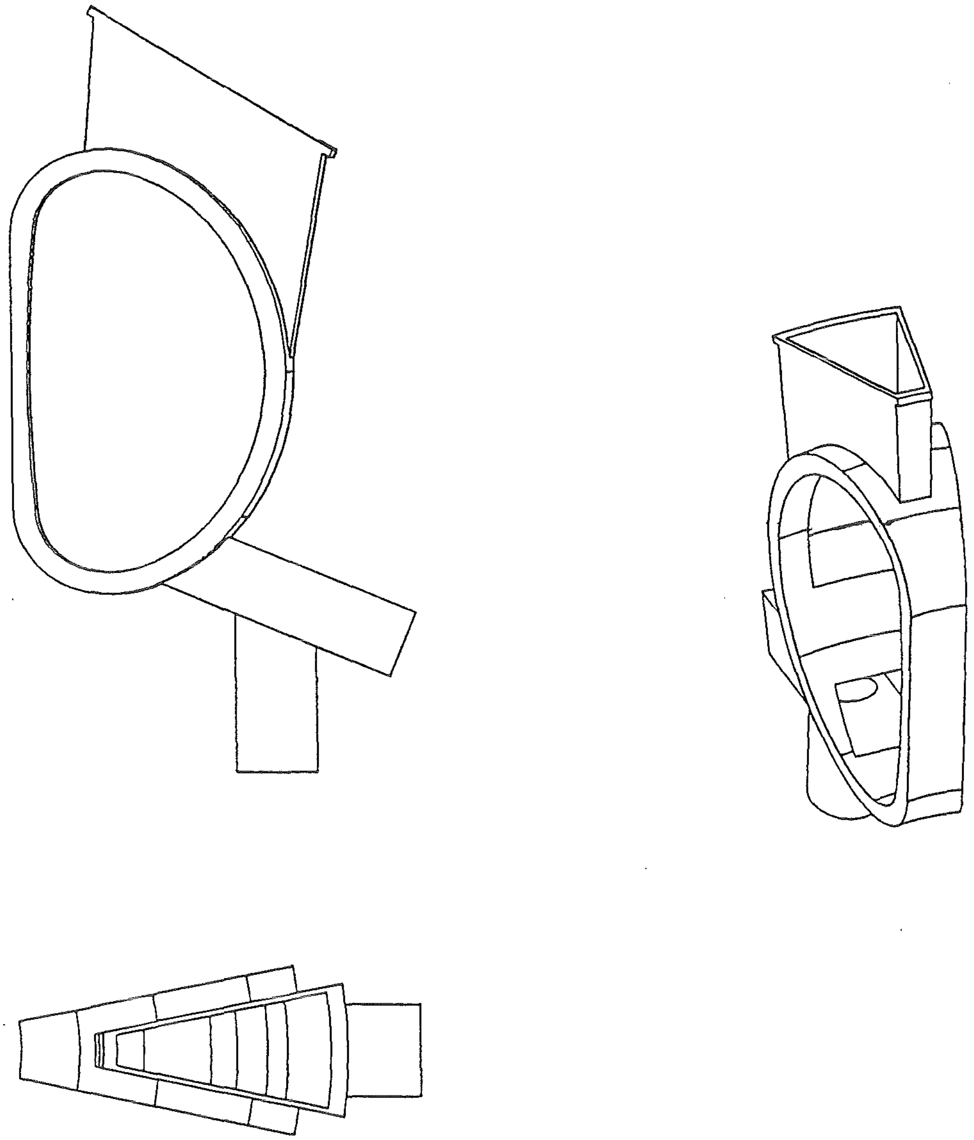


Figure 1. Sector of the vacuum vessel: The solid model of the vessel sector is constructed from several constituents

the process of "drafting" into the elementary steps offered by the CAD system.

- Naming (and naming conventions) of the various parts of the model is a very important process of planning the work, in a way unknown in conventional design. This is because the model is much more atomized in CAD work

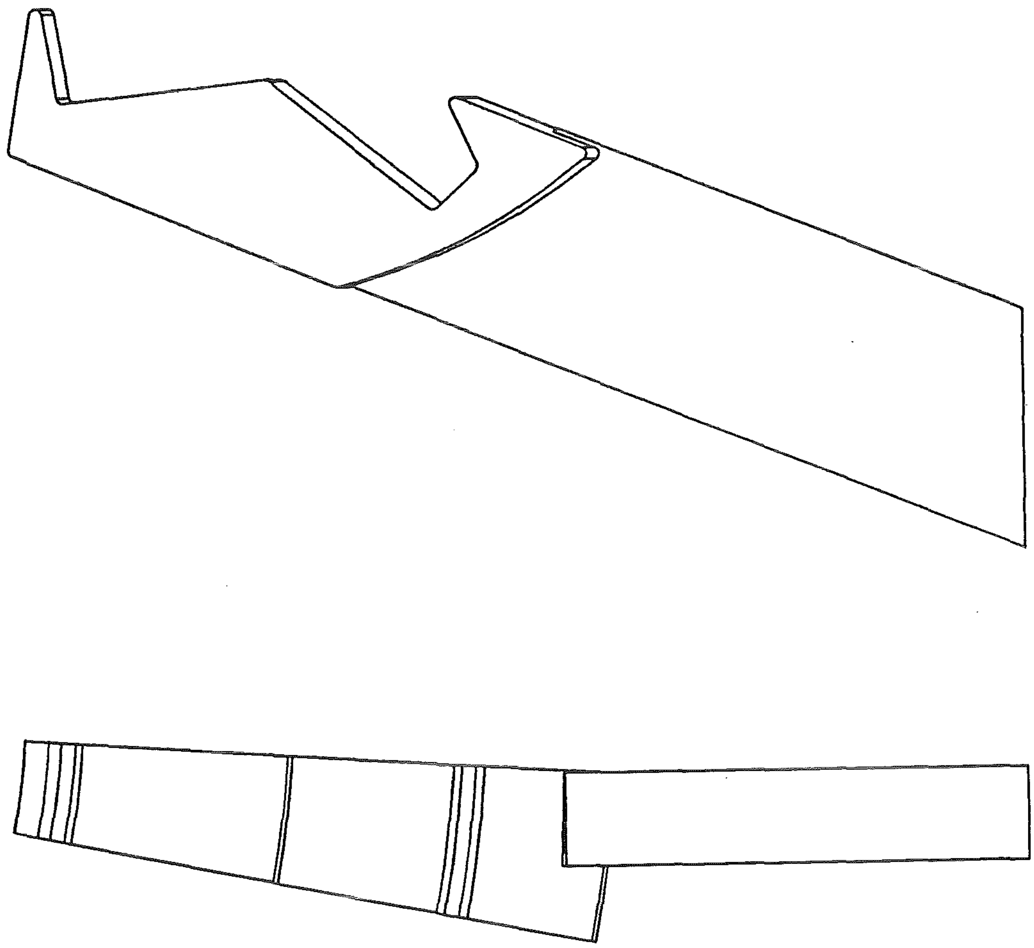


Figure 2. Divertor module: The whole divertor sector consists of three similar parts.

and the parts are referenced explicitly by names instead of attaching a drawing to the drawing board and pointing at it.

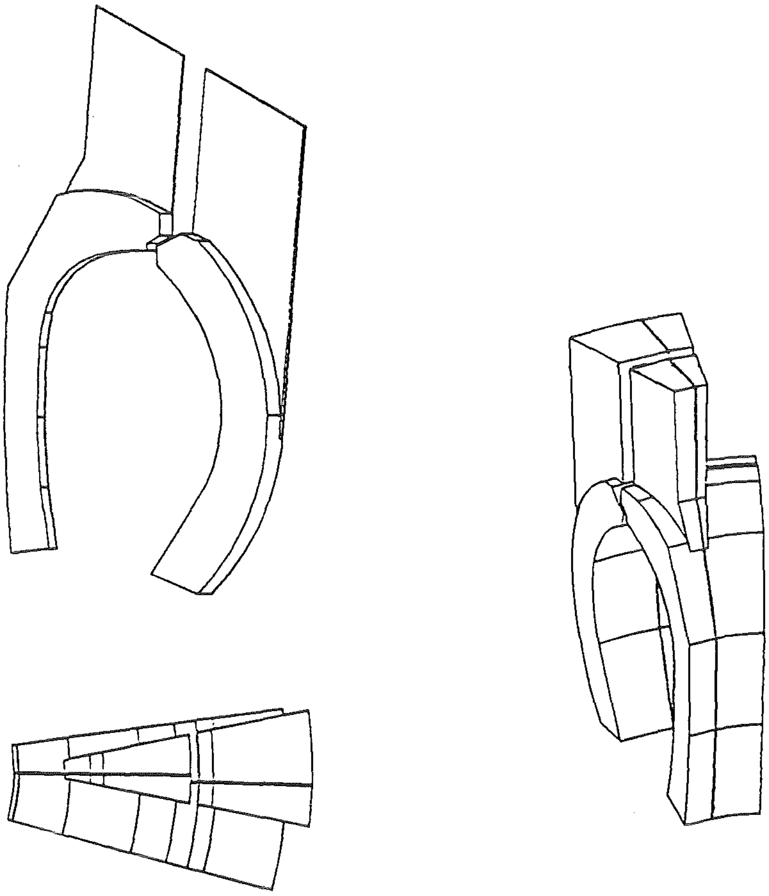


Figure 3. Four blanket modules: These four modules form one blanket sector

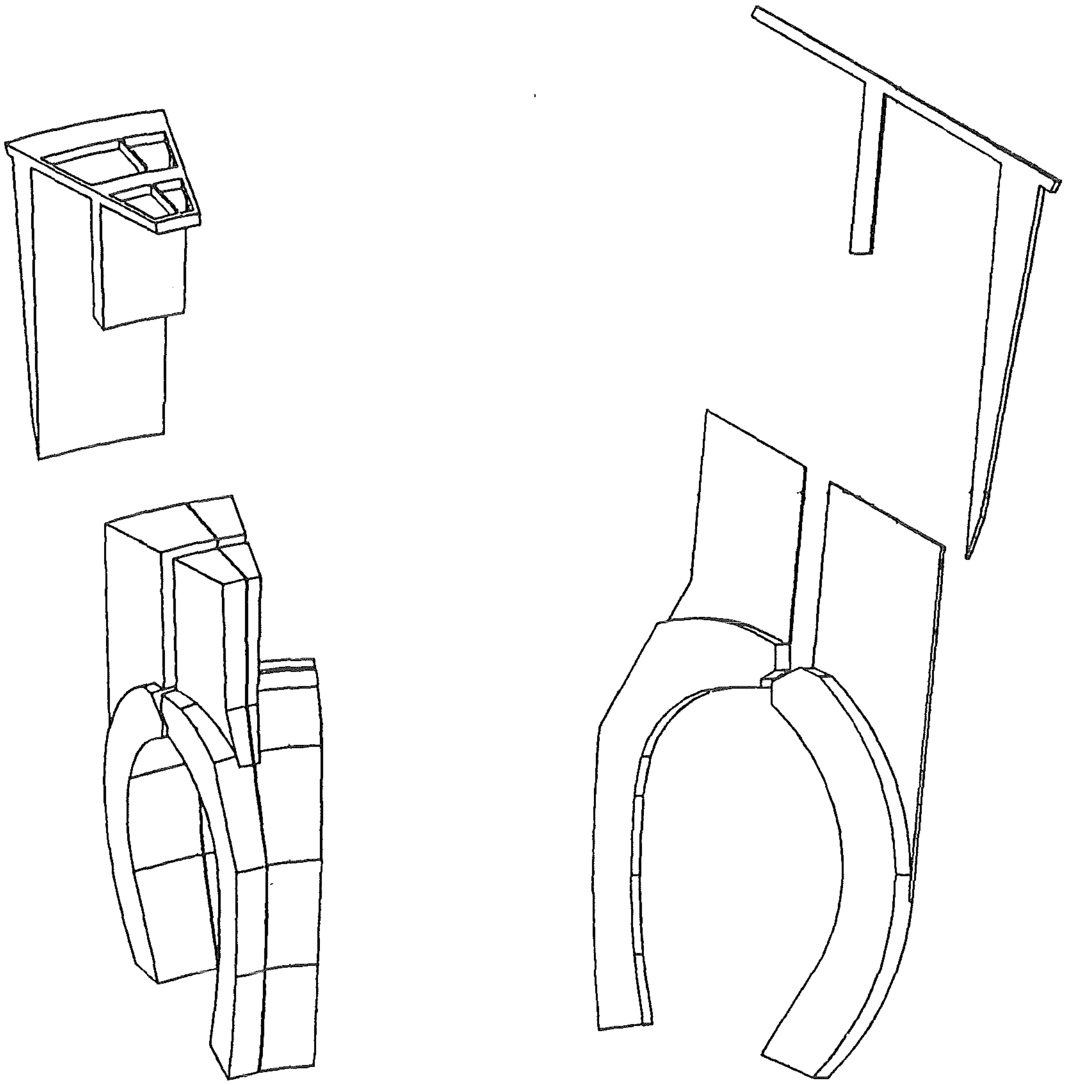


Figure 4. Blanket sector and corresponding key plug: The key plug closes the gaps between the connection lines and the vacuum vessel; in the figure it is lifted from its operational position relative to the blankets.

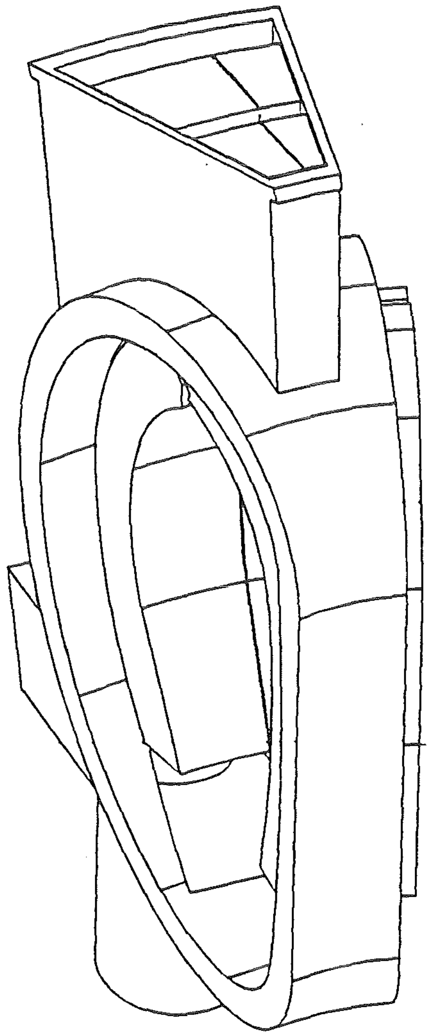


Figure 5. Sector of the vacuum vessel with the blanket modules mounted: The angular sector boundaries of the blanket do not coincide with those of the vessel (which are identical with the mid-planes of the TF-coils)

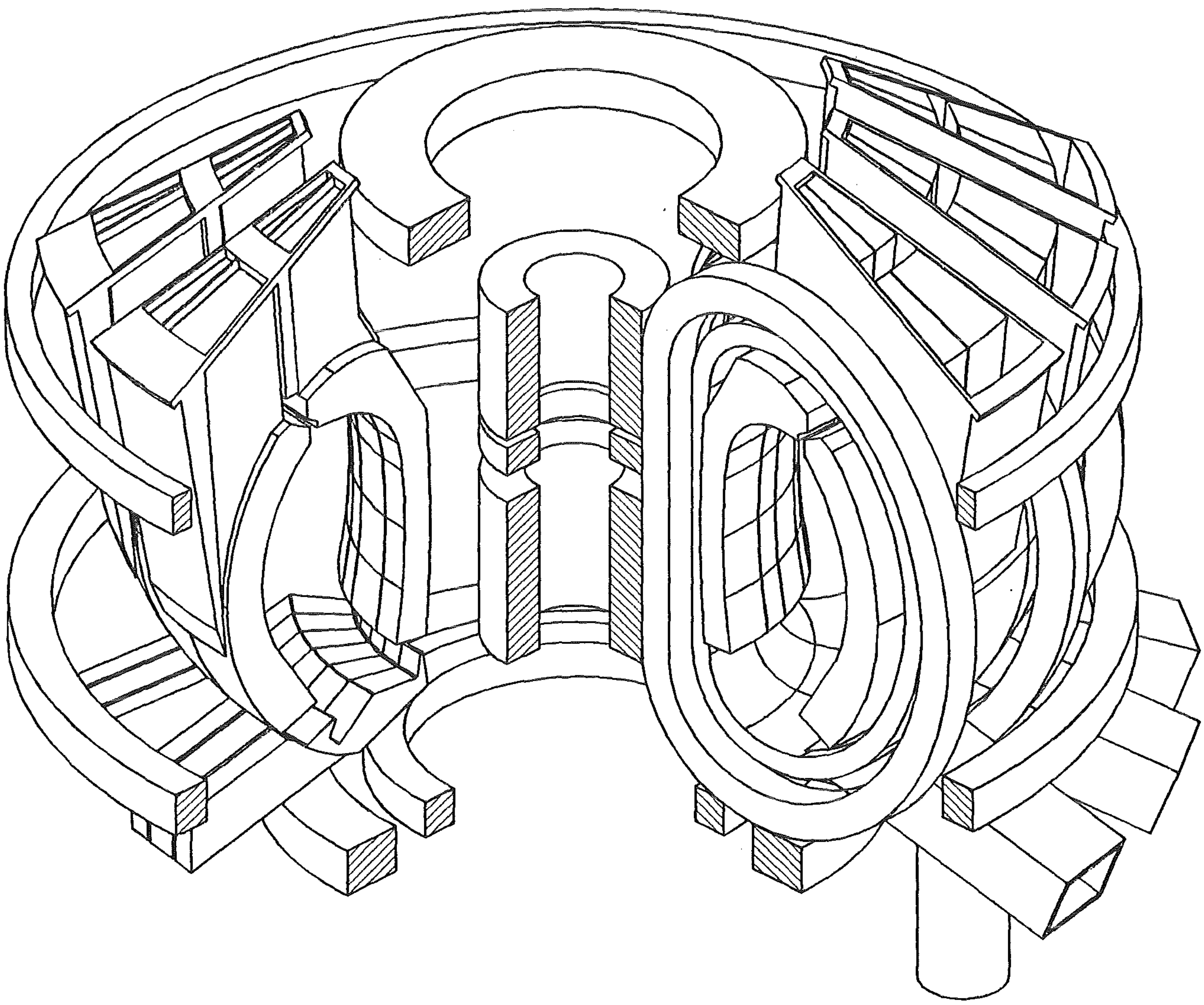


Figure 6. Toroidal assembly of the NET2A components: On the left-hand side, only blankets, divertors, and key plugs are shown, whereas on the right-hand side the blankets are mounted inside the vessel which is surrounded by the TF-coils.

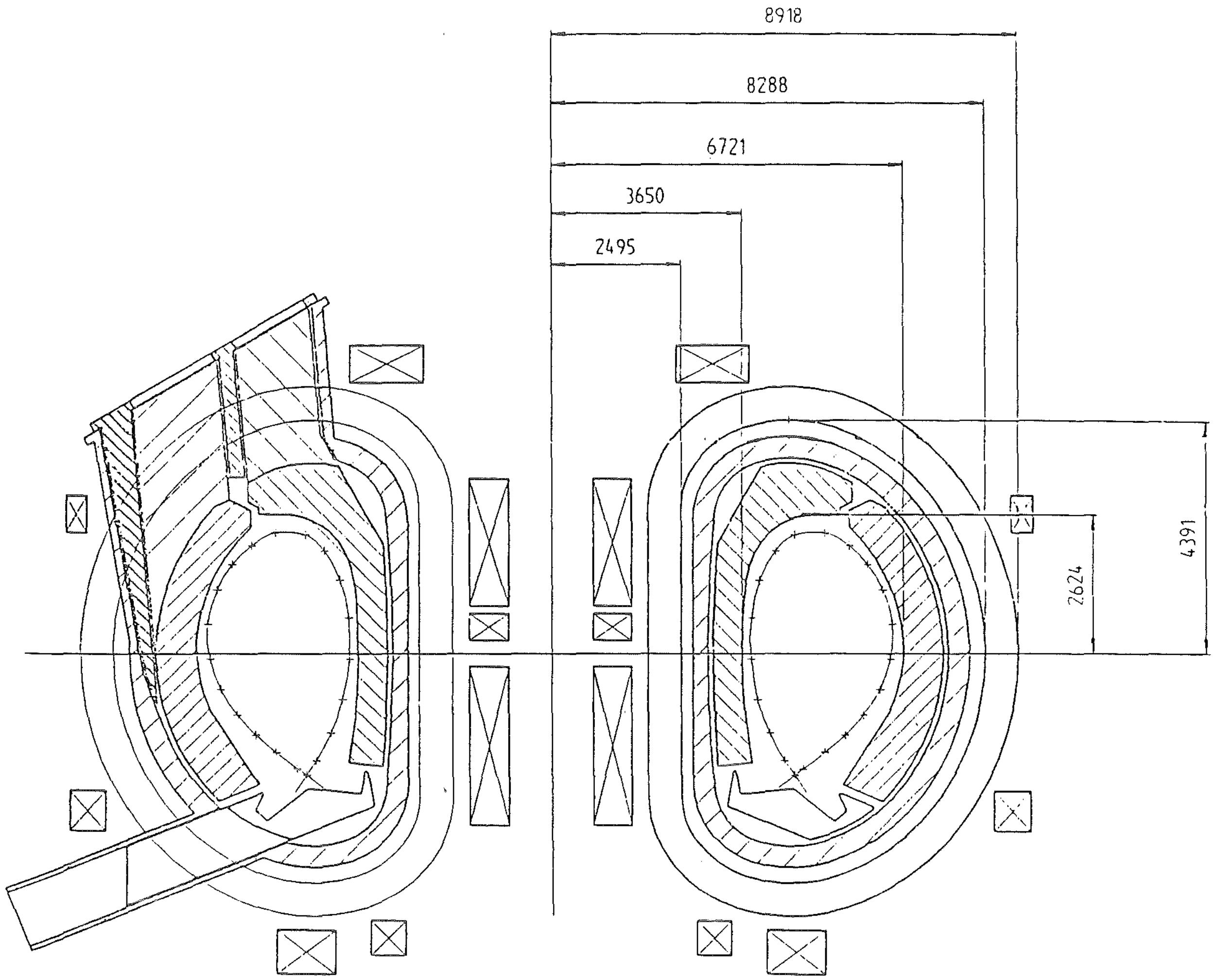


Figure 7. Drawing of the toroidal assembly: On the left-hand side, the section is done along the mid-plane of the access ports, the contours of a TF-coil rotated into this plane. The right-hand side shows a section along the mid-plane of an TF-coil.

3.0 THE KINEMATIC SUBSYSTEM

In order to investigate motion paths for remote handling operations like the exchange of a blanket module a software package was specified and implemented on the Applicon CAD system Bravo!. This was necessary because standard CAD systems while best suited for static modelling do not adequately support the analysis of movements of bodies in space. A subsystem for this class of tasks should support the generation and management of paths and traces of bodies. A simple but typical example is shown in Figure 8 on page 20 through Figure 10 on page 22: The movement of body A between obstacles B and C is described by path T1. The traces in Figure 11 on page 23 show that the movement is free of collisions. The subsystem BSIM (for Bewegungs-SIMulation) was implemented using the Bravo! programming language IAGL and its utilities and, therefore, is fully integrated in the basic CAD system. It allows to work on paths of solid objects, more precisely: it works on paths of Bravo! PARTS in Bravo! ASSEMBLIES (capitalized words indicate technical terms of the Bravo! system). The traces of a path may be stored as Bravo! CURVES in the same ASSEMBLY. For presentation purposes, traces may be dimensioned using the standard Bravo! commands for dimensioning.

3.1 Data types

The kinematic subsystem BSIM adds two new data types: the PATH of an object (a sequence of translations and rotations) and the TRACE (a curve, generated by moving a point along a PATH). TRACES of PATHS are valuable in detecting visually collisions of an object moved on a path with its environment. Figure 12 on page 24 shows, how paths and traces are integrated in the Bravo! database.

A PATH refers the object to be moved and the set of TRACEs generated for this path. Paths are stored in the path library, a special area in the Bravo! database. The actual work on a path is related to the so-called "actual" path. Traces CREATEd for this path are "virtual", but they may be STOREd, that means, they may be converted to Bravo! CURVEs. Transfer of paths between the Bravo! database and a VMS file is done by STORE and RETRIEVE commands.

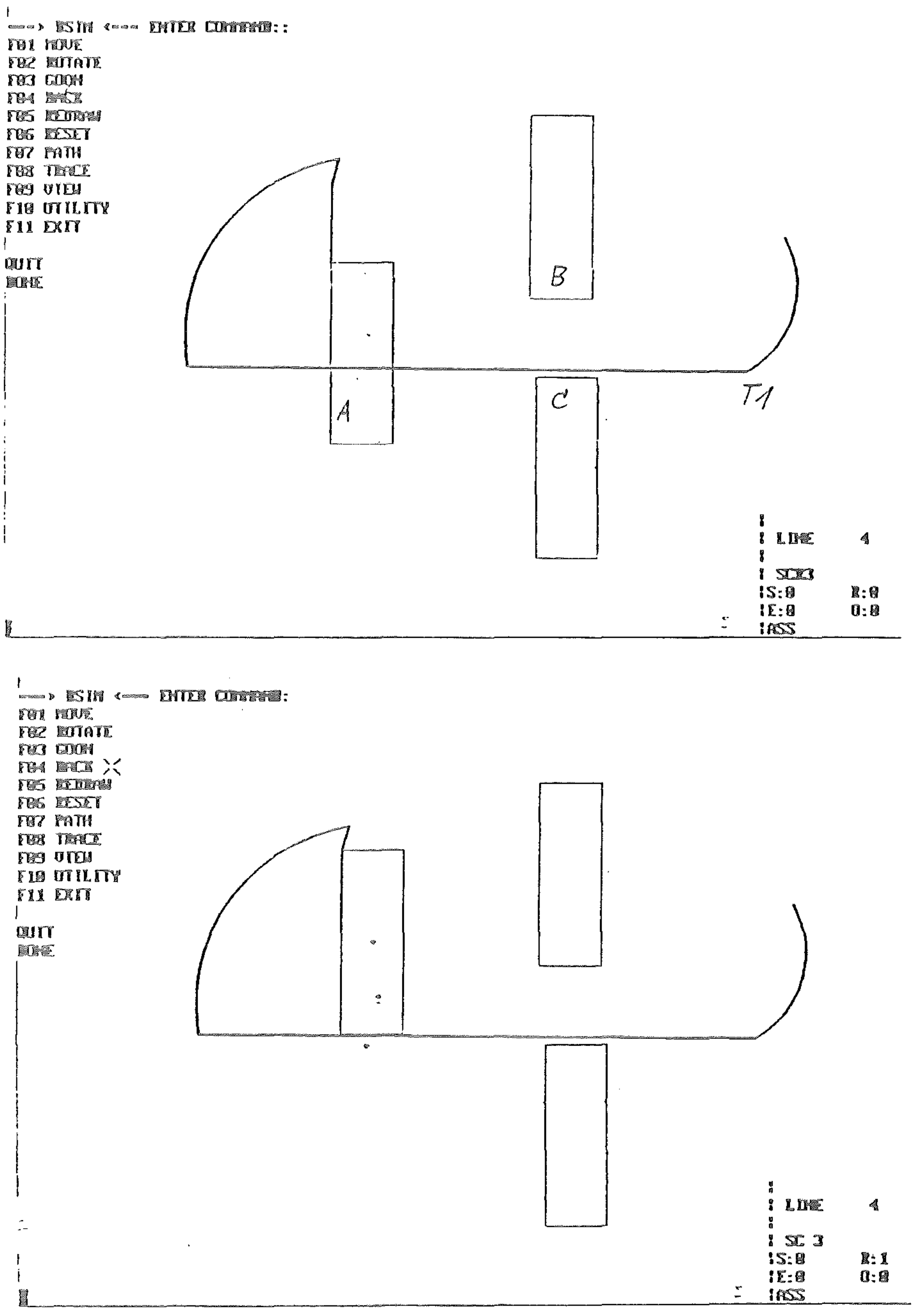


Figure 8. Example of a path: The path T1 describes the movement of body A between obstacles B and C

3.2 Operations

BSIM offers three groups of operations

- management of paths,
- management of traces, and
- utilities.

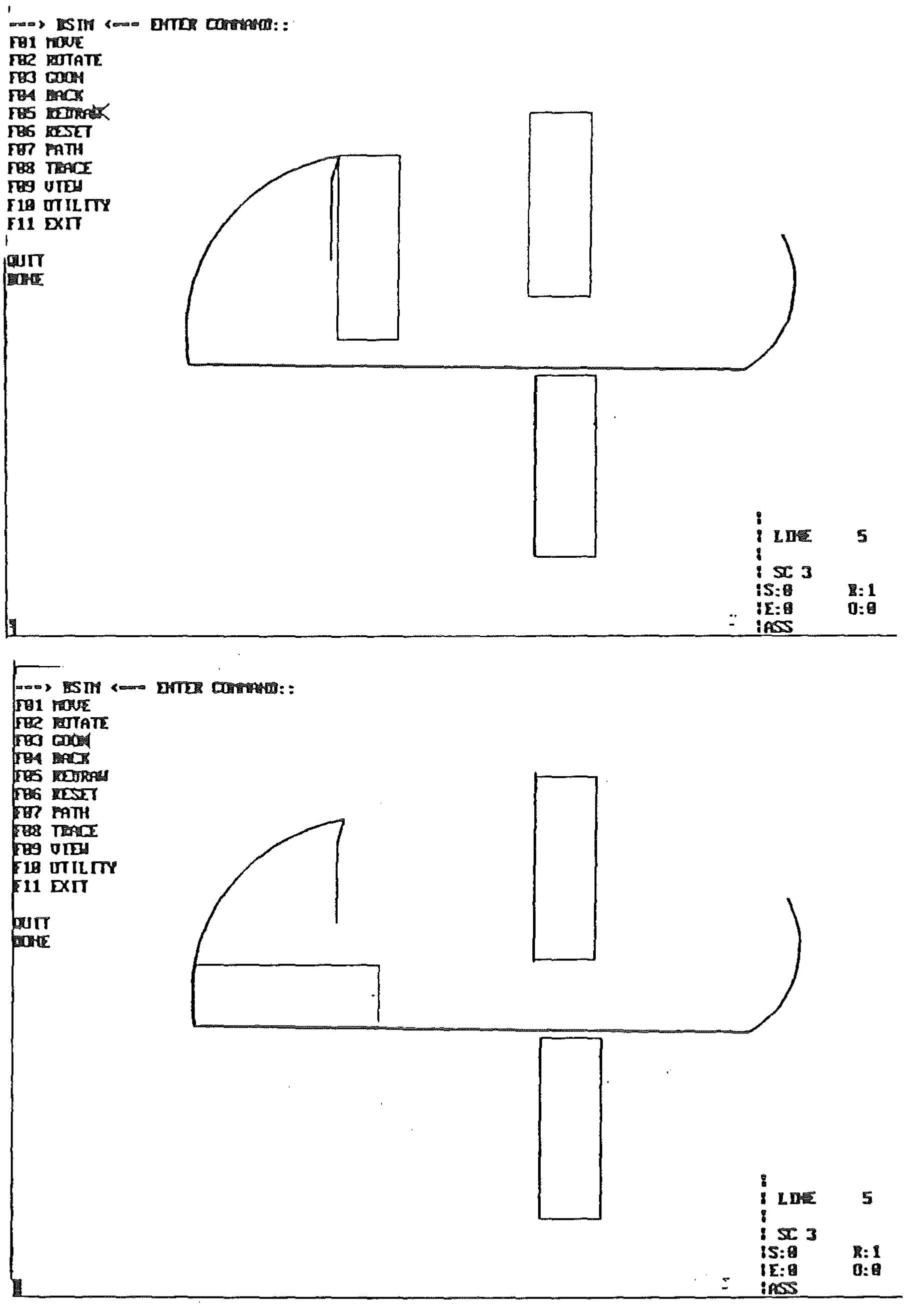


Figure 9. Example of a path: Step 2 and step 3

The operations are activated via command menus, shown in Figure 13 on page 25 through Figure 18 on page 29 and discussed in the following subchapters. Starting the BSIM system means to open a Bravo! ASSEMBLY (the scenario of objects to be worked on, generated with standard Bravo!) and a new or old BSIM PATH. The basic menu, appearing after BSIM initialisation, is shown in Figure 13 on page 25.

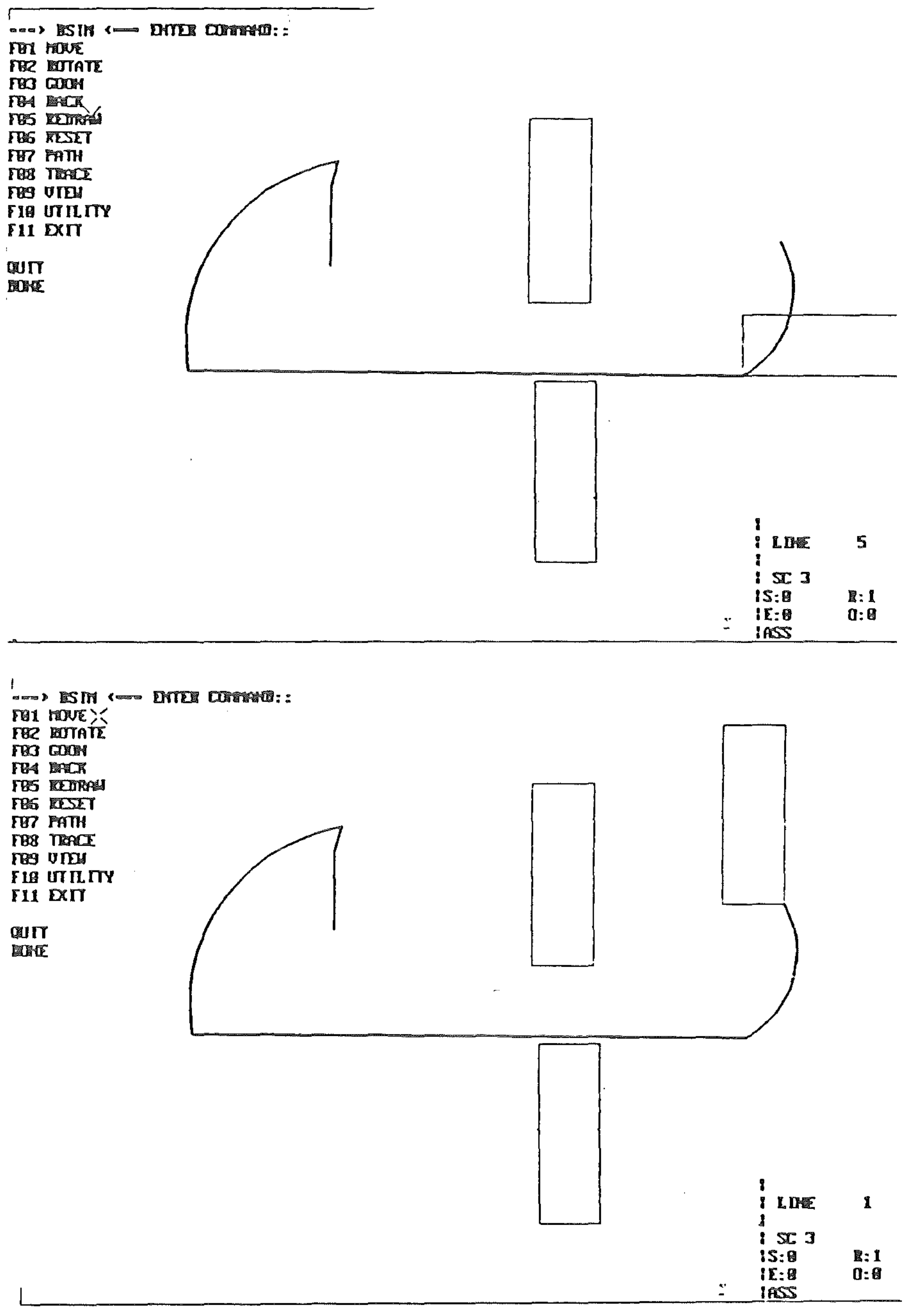
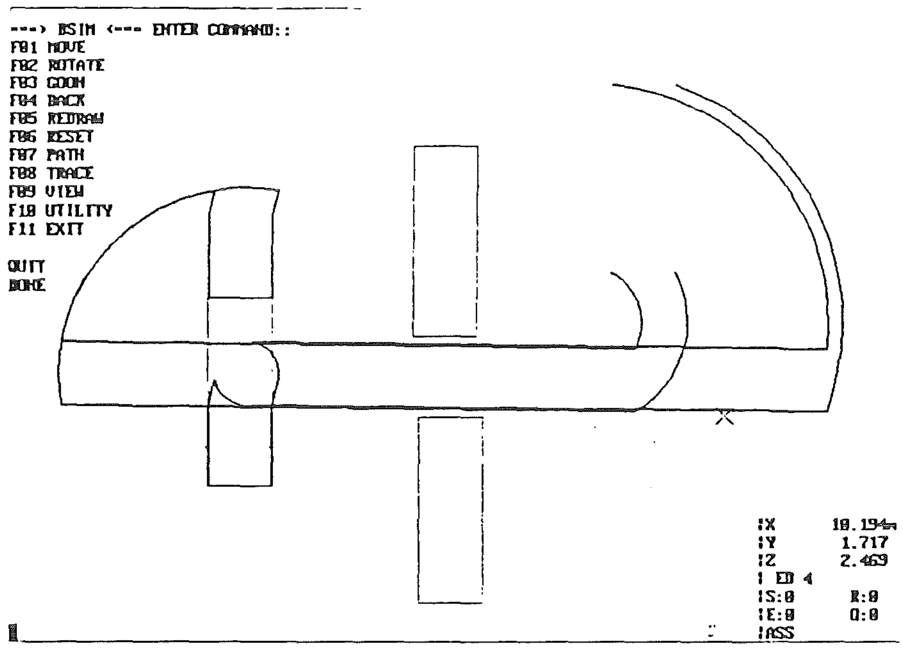


Figure 10. Example of a path: Step 4 and step 5



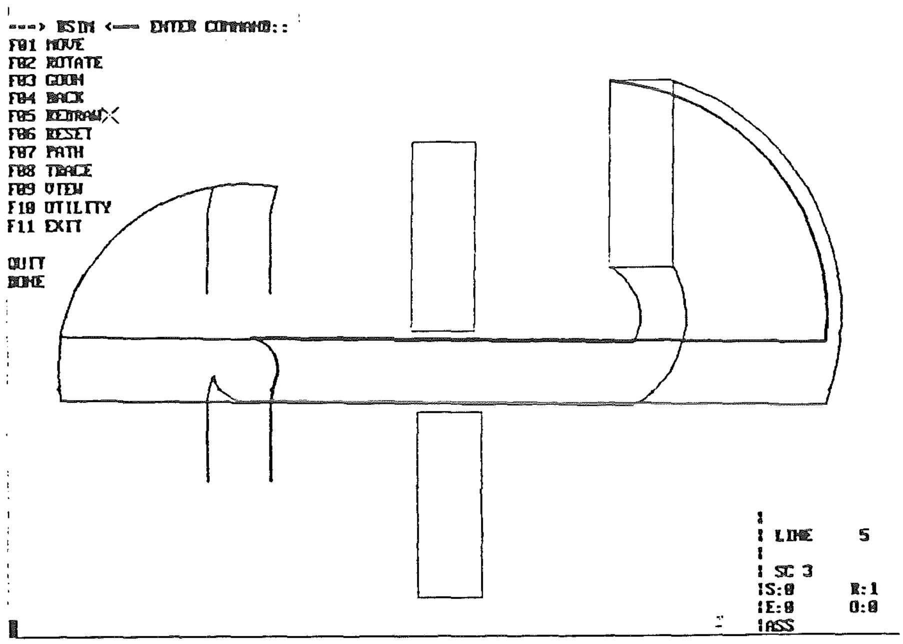


Figure 11. Example of a path with traces: Traces of all four corner points show a collision-free movement

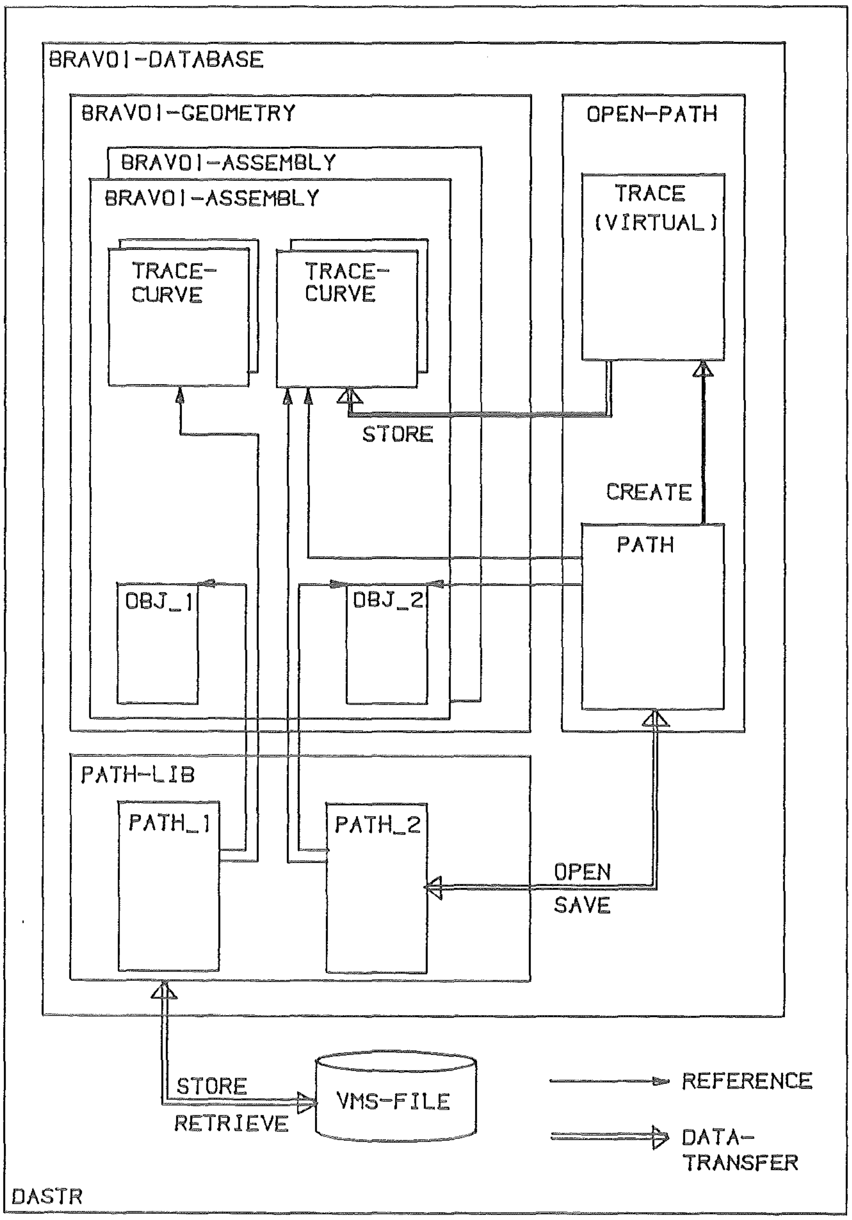


Figure 12. Data structures of BSIM

```
===> BSIM <=== ENTER COMMAND:
 MOVE     move actual object
 ROTATE   rotate actual object
 GOON     go forwards on path
 BACK     go backwards on path
 REDRAW   redraw whole picture
 PATH     manage paths
 TRACE    manage traces
 RESET    reset path object to start
 VIEW     change viewing parms
 UTILITY  print system information
 EXIT     exit from BSIM
```

Figure 13. Basic menu

3.2.1 Working with paths

Working with paths is done using two groups of operations: to create or change paths and to manage paths.

3.2.1.1 Creation and presentation of paths

These operations are available in the basic menu because they are often used. They always refer to the actual path.

MOVE MOVE adds a translation of the path object to the path. The translation is specified by using the standard Bravo! vector processor. If the path object is not positioned at the end of the actual path, then the rest of the path will be deleted (possibility to change a path).

ROTATE rotates the path object around an arbitrary axis by an angle. To specify the axis, the Bravo! LINE processor is used, input of the angle is done using the Bravo! ANGLE processor.

GOON moves the path object on the path one step forwards

BACK moves the path object on the path one step backwards

RESET moves the path object to the begin of the path

REDRAW plots the ASSEMBLY (scene) and existing traces of the path

VIEW activates the Bravo! WINDOW command to change viewing parameters

3.2.1.2 Administration of paths

The selection of the PATH option in the basic menu produces the following menu:

```
ENTER PATH OPTION:
 OPEN      open path
 SAVE      copy path
 INIT      create new path
 IDENT     manage path object
 DELETE    delete path
 LIST      list all paths
 STORE     write paths on VMS file
 RETRIEVE  read paths from VMS file
```

Figure 14. PATH menu

OPEN prepares a path for manipulation:

OPEN_NEW prepares a path for redefinition (maintains the data structure but deletes its content).

OPEN_OLD prepares a path for usage. Traces of this path become visible.

SAVE copies a path into another path.

INIT initiates a new path. The user is prompted for a name, a description, the length (maximum number of steps), and the path object.

IDENT manages path objects by providing the following sub-menu:

```
ENTER OPERATION:
 NEW       identify path object
 SHOW      show actual path object
 END       stop blink of path object
```

Figure 15. IDENT Menu.

IDENT_NEW exchanges the path object.

IDENT_SHOW highlights the actual path object.

IDENT_END stops highlighting of the path object.

DELETE deletes a path.

LIST lists the paths.

STORE writes paths on a VMS file.

RETRIEVE reads paths from a VMS file.

3.2.2 Management of traces

The selection of the TRACE option in the basic menu (Figure 16 on page 28) produces the following menu:

```
ENTER TRACE OPERATION:
 CREATE   create virtual trace
 STORE    store virtual trace as curve
 DELETE   delete stored trace curve
```

Figure 16. TRACE menu

3.2.2.1 Generation of traces

Traces are generated as virtual traces of the actual path. Only the last generated trace exists as data (others may be visible as lines on the screen) and may be transformed into a Bravo! CURVE by the STORE command.

CREATE generates a virtual trace to the actual path, using an arbitrary point, identified by the user.

3.2.2.2 Administration of traces

STORE generates a TRACE CURVE for the virtual trace.

DELETE deletes a TRACE CURVE from the Bravo! database

3.2.3 Utilities

The selection of the UTILITY option in the basic menu produces the following menu:

```
ENTER UTILITY:
 DUMP     dump various system variables
 LENGTH   length of path list
 CHANGE   change length of path list
```

Figure 17. UTILITY menu

DUMP produces a sub-menu (Figure 18 on page 29) for printing of several system parameters

ACT	prints values of actual path positions
PATHLIST	prints path names
PATH	prints path management informations
TRANS	prints path translations
ROT	prints path rotations

LENGTH prints actual length of path list

CHANGE changes length of actual path list

TYPE OF DUMP:

ACT	actual position on path
PATHLIST	print pathlist
TRANS	print transformations
ROT	print rotations

Figure 18. DUMP menu

3.3 Results obtained

The kinematic subsystem has been applied to one sector of the NET2A model. This sector comprised a 22.5 degree cut-out of the vacuum vessel and four blanket modules. All other parts like divertors, coils, or plugs which are not relevant with respect to the insertion or placement of the blankets were omitted in this particular assembly in order to minimize the computing time as well as the computer storage requirements.

The kinematic subsystem has been used to construct removal paths (or insertion paths, if applied backwards) for all four blanket modules. The following features turned out from this work to be advantageous:

- The screen should contain several windows with different views for easy identification ("picking") of objects and for the geometrical construction of movement vectors or axes of rotation.
- One view should be directed along the most significant movement vector which describes the translational movements through the opening of the access port. In this way collisions in the range of the opening may be detected and avoided more easily than without such a view.
- Foreseeable vectors and axes of rotation which have to be used repeatedly, should be predefined and preassigned to appropriate IAGL variables for at least two reasons:
  - Errors in construction of such geometrical objects are less probable if the construction is done separately, and they do not interrupt the work with the subsystem if they do occur.
  - The more or less troublesome task of constructing such objects has to be performed only once.

In order to demonstrate the results of the exercises with BSIM, some examples have been selected and are presented in Figure 19 on page 33 to Figure 25 on page 39. Each of these figures shows two views of a special configuration: the view direction on the left hand side is parallel to the main translational movement through the port, whereas the view direction on the right hand side is normal to the vertical mid-plane of the sector. Three modes of representation have been used:

- Facetted wire-frame representation. The surface of the solid body is approximated by facets, and the edges of these facets have been drawn regardless whether they are visible or hidden. This is the usual representation for interactive work. The left hand side of Figure 19 on page 33 demonstrates the confusing multitude of lines and the difficulty of identifying certain edges.
- Facetted hidden line representation. Only visible edges of the approximative model are shown. This mode of representation, which is much easier to survey, is also available for interactive work, but it takes considerable amount of time, and it cannot be transferred to the plotter. Therefore those figures which make use of this representation are reproduced from workstation hardcopies.

- "Precise" hidden line representation. Such figures use the accurate geometrical description of the solids, but they have to be generated by a batch job consuming much CPU time. The "hidden" lines are shown on the screen in a colour which is different from that of the visible edges. Their visibility (on the screen or in a plot) may be switched off or on. In Figure 25 on page 39 they are omitted in the left view, but plotted in the right view.

In Figure 19 on page 33, the sector is shown with all four blanket modules in place. The traces, visible in the right view, belong to the path which allows the removal of the smaller outboard blanket module. Figure 20 on page 34 through Figure 25 on page 39 give a sequence of configurations which occur along a path for the removal of the second and broader outboard blanket module. Likewise paths for the removal of the inboard blankets have been constructed.

The figures demonstrate that it is impossible to detect collisions reliably from the approximate facetted models alone. Since the facets remain constant relative to the respective part, a movement of a part may yield the confrontation of incompatible facets of different parts. Figure 24 on page 38 and Figure 25 on page 39, for instance, present almost the same configurations. The blanket module has been moved by one meter along the main translational direction in the latter. Since the left view of both figures is in just this direction, it should be practical identical in both figures. We now concentrate on the rear side (right hand boundary) of the blanket module. In the approximate model of Figure 24 on page 38 it seems to overlap with the wall of the access port. The precise model of Figure 25 on page 39, however, clearly shows that the two boundaries are separated by a small but distinct gap.

On the other hand, even a precise model representation may not satisfy the requirements of collision detection if there are oblique boundaries and very small gaps in between. It is hard to discern from Figure 25 on page 39, for instance, whether the edges at the front side of the module mentioned above are colliding with the side walls of the port or not.

In such situations there are two ways available to solve the problem. The first one is to measure numerically the clearance between the concerned solids. For this aim, one has to use human judgement to select the critical region and to construct - within a three-dimensional view of the precise model - the point within the surface of the first solid which is closest to the second solid. Then the distance can be questioned using standard capabilities of the CAD system. The obvious disadvantages of this solution are due to the necessary judgement and due to the fact that the required point construction may become very laborious.

The second method is to apply the Boolean intersection operator. In order to do this with Bravo!, a new assembly has to be created where all solids are made from only one material, but have the same geometrical data as in the original one. Then the Boolean operator has to be applied to complete the construction tree. The result has to be analysed by a precision analysis, which is a time-consuming batch job. There is no collision if the intersection turns out to be empty. Besides the fact that the batch job takes considerable amounts of time (CPU time as well as turn-around time), this procedure inflates the storage requirements of the database. For these reasons, it was not applied routinely.

It is concluded from the previous considerations that the tools for collision detection in models of assemblies of solids are presently not yet satisfying. Applicon has announced a package which will work with future versions of its Solids Modeller. This package will allow to determine immediately the clearances between parts of an assembly, either precisely in a fast running batch job, or approximately but interactively with the facetted model. As far as known today, this tool might meet the requirements of collision control in the present context.

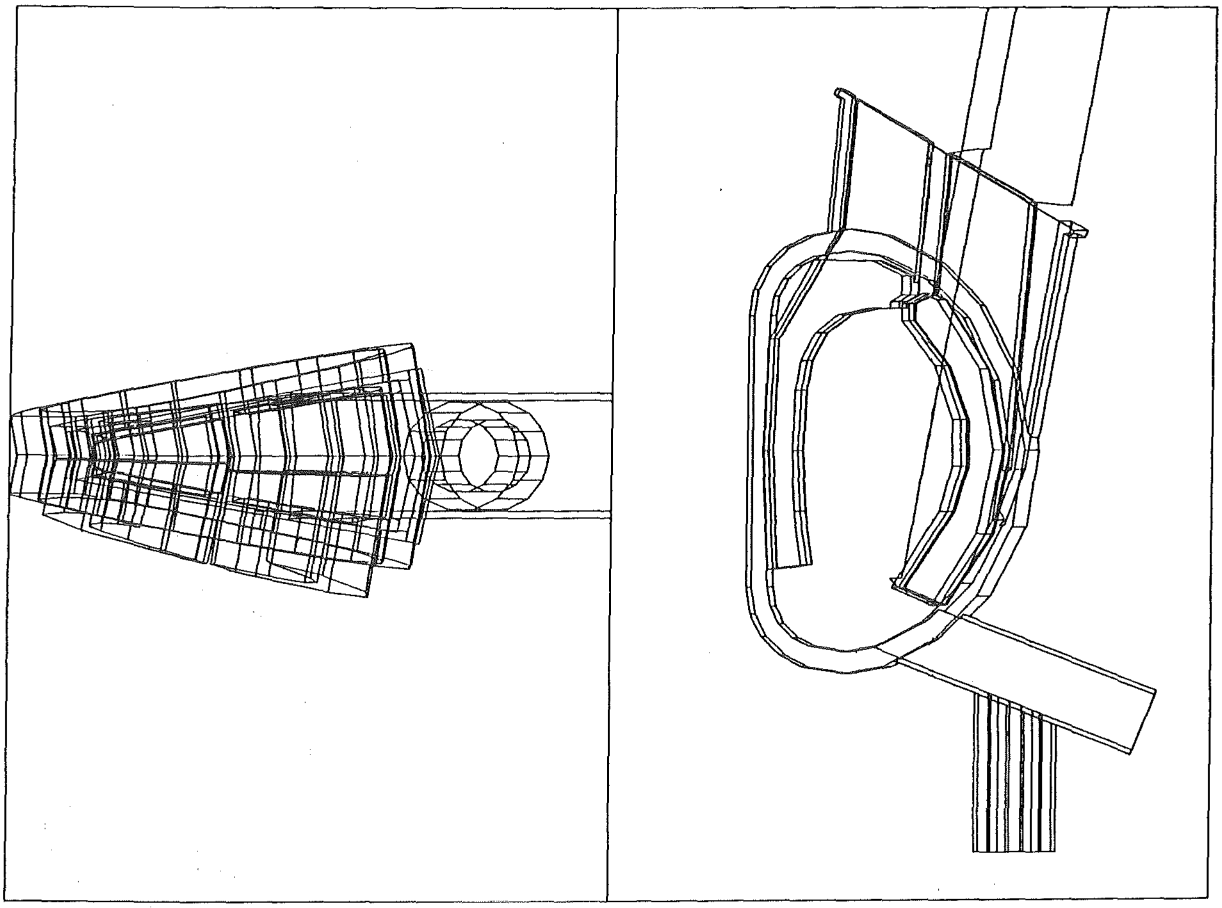


Figure 19. Sector of the vacuum vessel with all blanket modules inserted: Facetted wire-frame representation; left view along main translation vectors; right view normal to the sector mid-plane. The additional curves visible in the right view are traces of the path for the removal of the smaller outboard blanket module (the upper one in the left view).

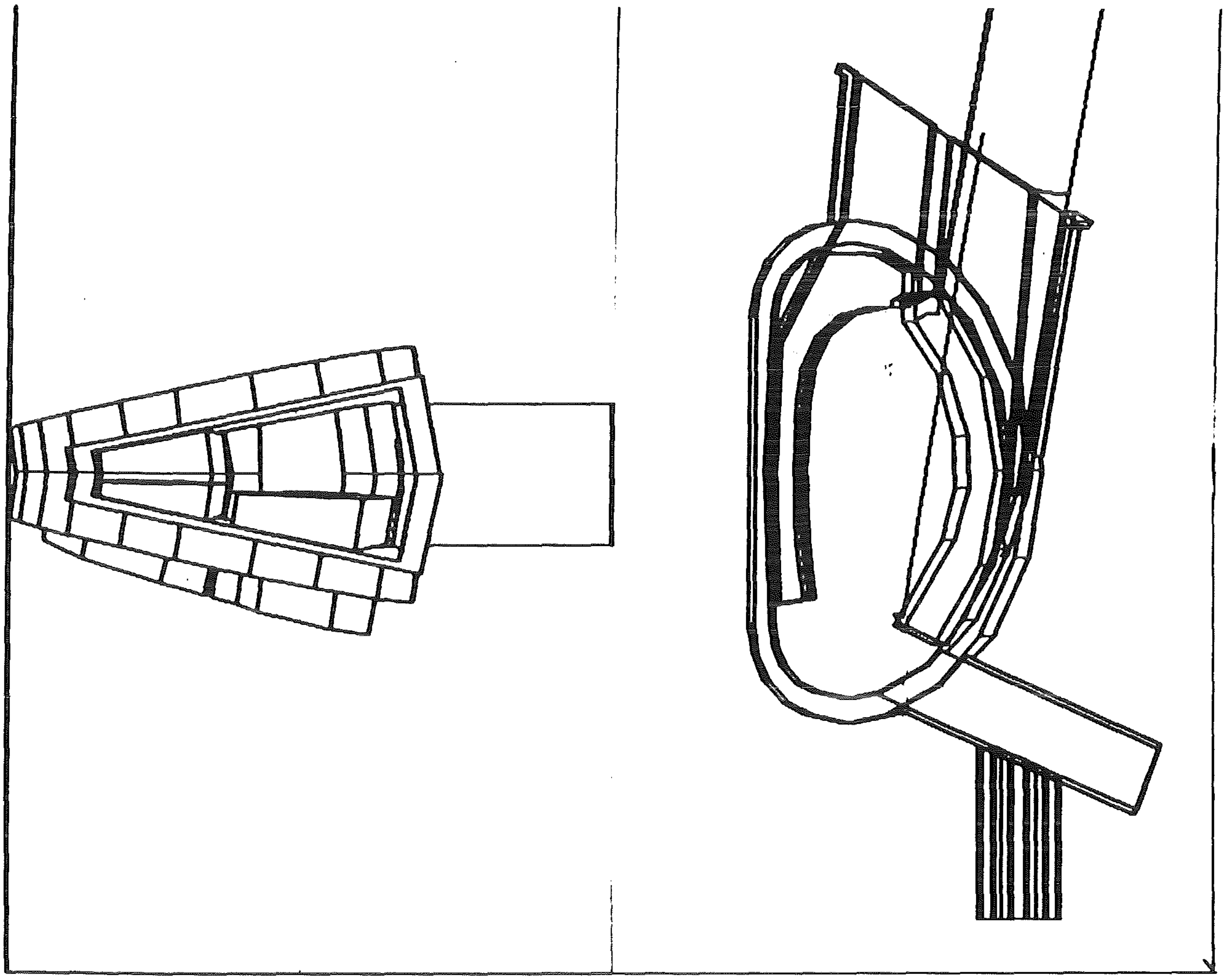


Figure 20. Removal of the broader outboard blanket module: Initial configuration. Views like in Figure 19 on page 33; facetted hidden line representation on the left, facetted wire-frame representation (including traces of the removal path) on the right hand side.

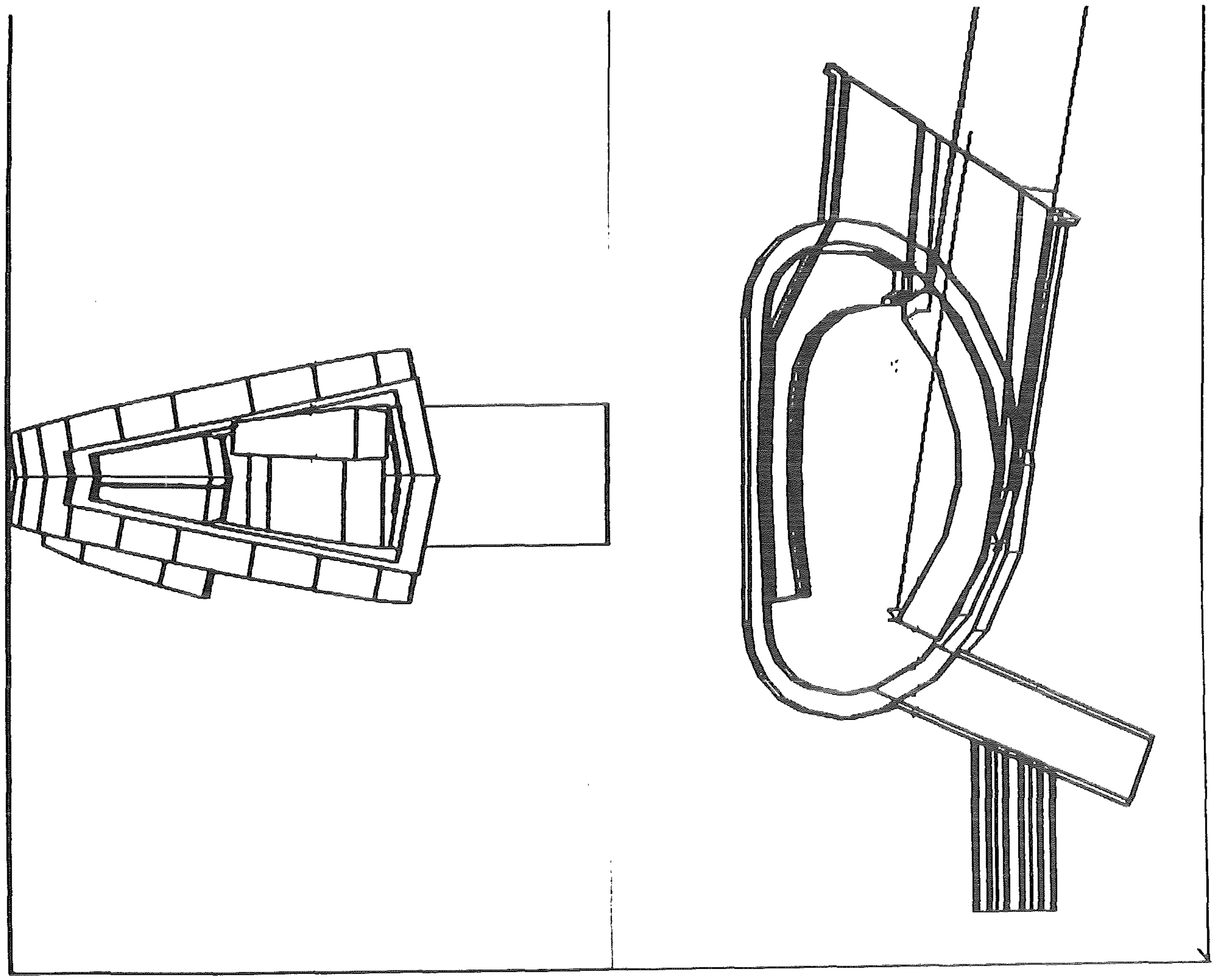


Figure 21. Removal of the broader outboard blanket module: First step: rotation about the central axis of the torus. Views and representations like in Figure 20 on page 34.

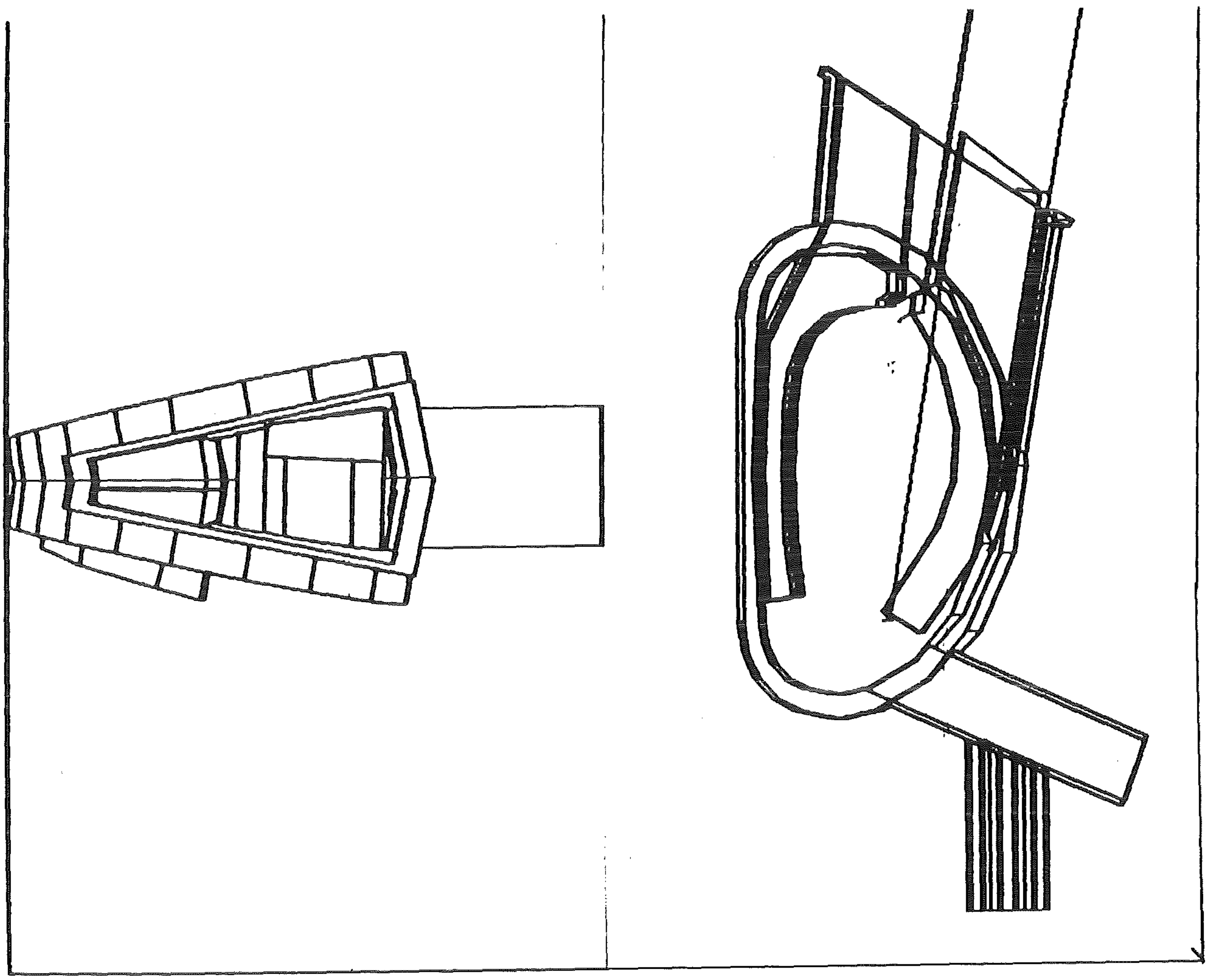


Figure 22. Removal of the broader outboard blanket module: Second step: rotation (tilting) about an horizontal axis normal to the mid-plane of the sector. The outboard face of the upper part is now parallel to the wall of the access port. Views and representations like in Figure 20.

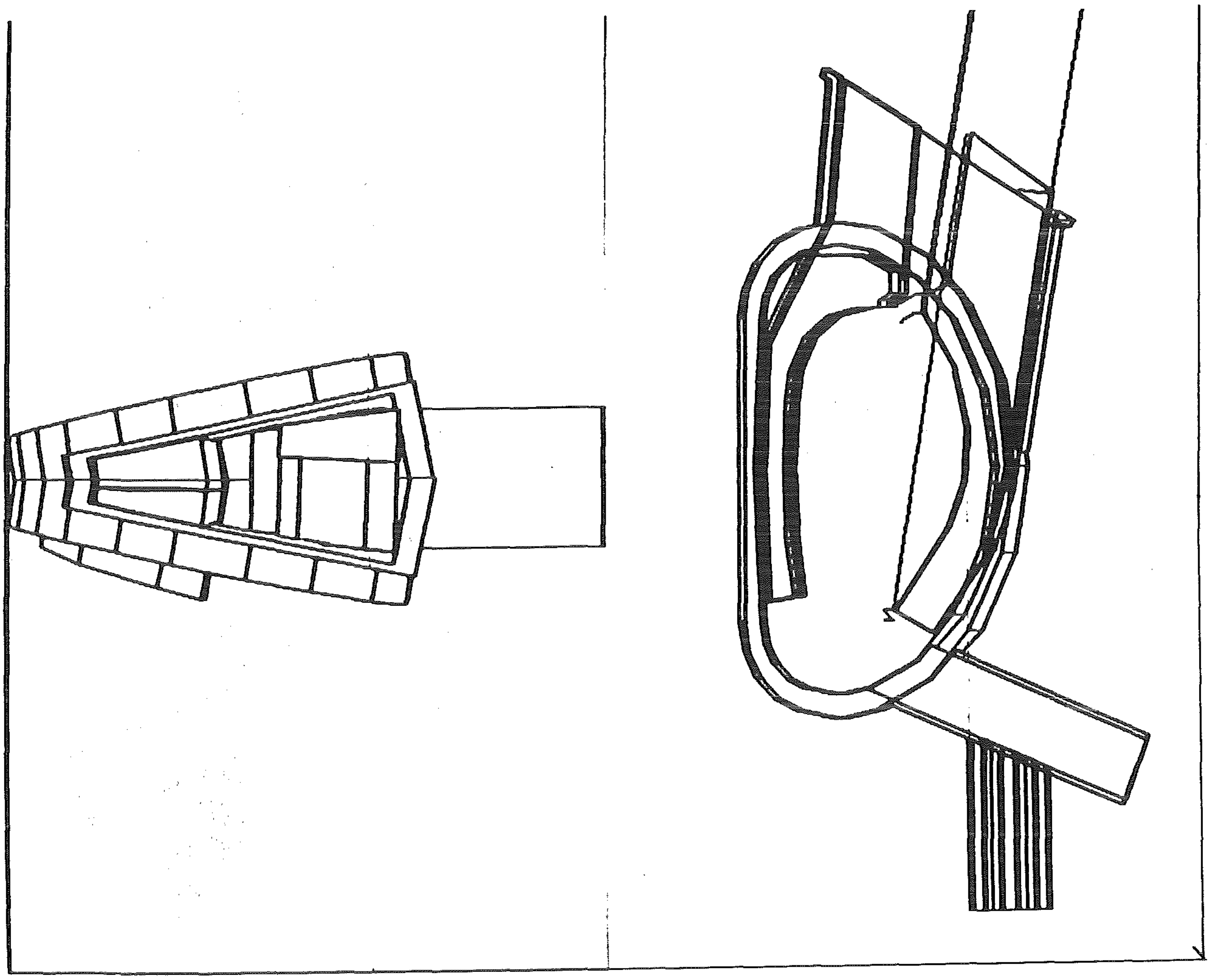


Figure 23. Removal of the broader outboard blanket module: Third step: translation in radial direction. The outboard face of the upper part is now close to the wall of the access port. Views and representations like in Figure 20 on page 34.

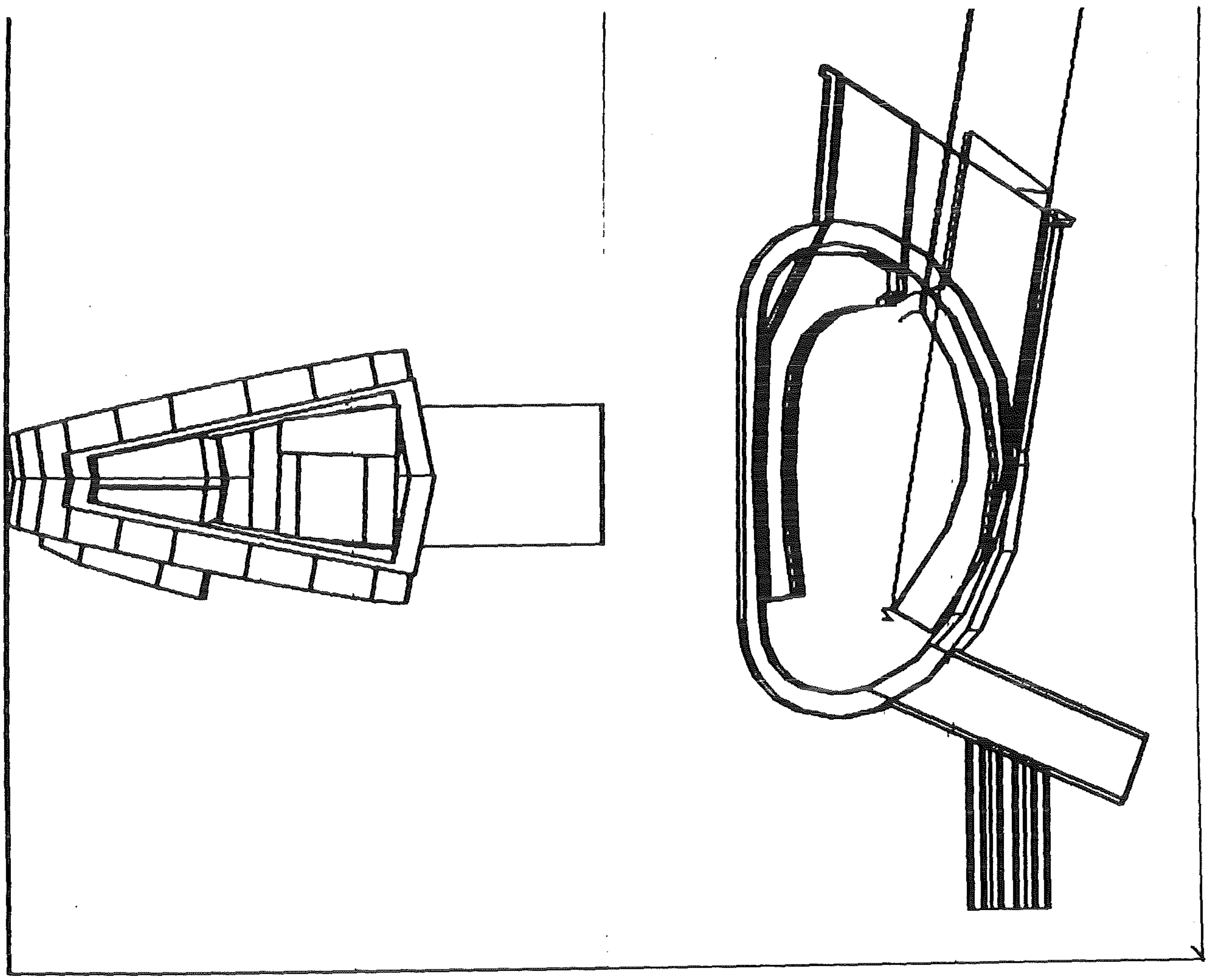


Figure 24. Removal of the broader outboard blanket module: Fourth step: rotation about the central torus axis. The module is almost centered in toroidal direction relative to the port. Views and representations like in Figure 20 on page 34.

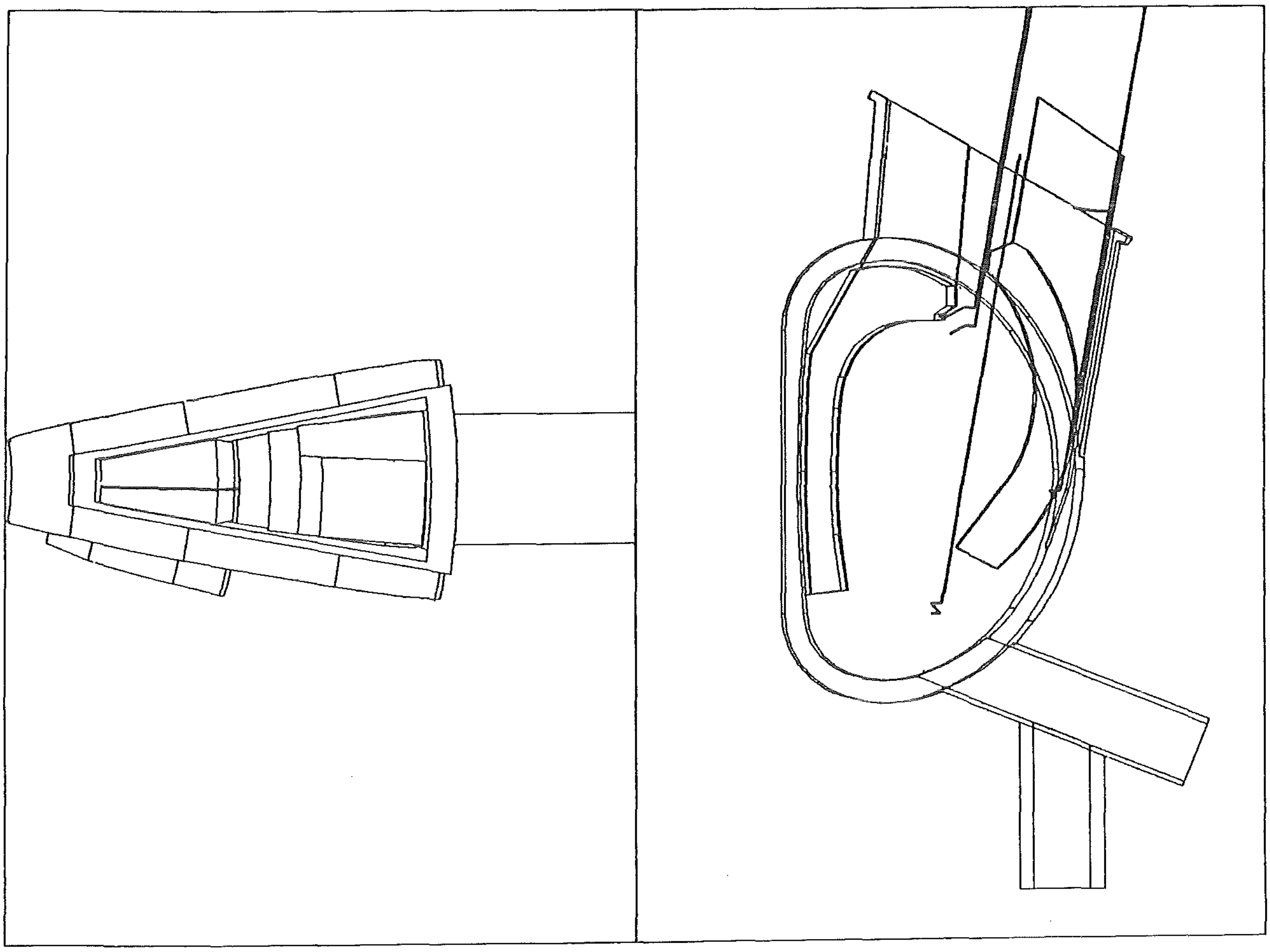


Figure 25. Removal of the broader outboard blanket module: Intermediate step of the final translational movement parallel to the generatrix of the access port. Views like in Figure 20 on page 34, "precise" hidden line representation.

3.4 Recommendations

o The suitability of the implemented set of commands should be further tested in practice, to find out a generally applicable functionality of systems for this purpose.

- Because of the good results obtained with the BSIM extension to Bravo! the possibility of a similar extension of Medusa should be investigated. For this aim, a system like that proposed in the report NET/IN/84-080a should be implemented into the Medusa environment at NET, whenever possible.

- A data format for paths should be defined for data transfer between different CAD systems.

- It should be investigated how paths defined with a CAD system can be used as input for simulation packages like ADAMS for dynamic simulation (including force analysis) and for robotics control of the remote handling equipment. Such investigations are part of KfK's fusion technology project.

4.0 CAD DATA TRANSFER

4.1 Situation

The task of exchanging information between two CAD systems can be split into three problem areas:

1. The transport of files which contain the CAD information in a suitable format from one computer to another; this is called the low level data transfer.
2. The definition (or selection) of a suitable format for this file. Suitable here means that the essential information defining the geometry of the object and possibly attached annotations can be mapped onto the data representations of both participating CAD systems.
3. The provision or (if necessary) the development of pre- and post-processors which correctly convert the information from and to the intermediate file format on one side and the CAD system data base on the other. This is called the high level data transfer.

Suitable solutions for these three problem areas have to be established for a configuration as indicated in Figure 26. At KfK, the Applicon system BRAVO! runs on a VAX-751, in Garching the NET team has access to the MEDUSA CAD system from AGS and to ROMULUS, both running on a VAX-750. As intermediate transfer support, the central computer systems at both sites are available.

4.1.1 Low level data transfer

On the file transfer level , we have to transfer data from a VAX-751 at KfK to a VAX-750 at IPP and vice versa. Between these, the central computer systems at KfK (IBM and Siemens computers) and IPP (IBM and Siemens computers) can serve as transmission points. The solution to be selected must be open to extensions to other partners cooperating with the NET team, in particular to the Joint Research Center at Ispra, to the Culham Laboratory, and eventually to JET, but possibly also to Interatom (where Control Data's Synthavision is used, using the same type of constructive solid geometry modelling as the Applicon system for its exact solid geometry version) and others. Data transfer between the computers can in principle be established by

1. physical transport of magnetic tapes,
2. local area networks (LAN) or special local computer connections,
3. public networks like DATEX-P or DATEX-L,
4. wide area networks with restricted access like EARN and DFN.

MAGNETIC TAPES: Data transfer via magnetic tape is possible over short and long distances. Over a decade of experience in handling large volumes of data on tapes tells us that this is a safe and cheap solution, but too troublesome for routine work. Hence, magnetic tapes as carriers for CAD data can be considered only as a preliminary approach for testing preceding technically more advanced solutions for production. Procedures for reading and writing IGES type tapes have been established (see "Procedures for reading and writing IGES tapes on VAX and IBM").

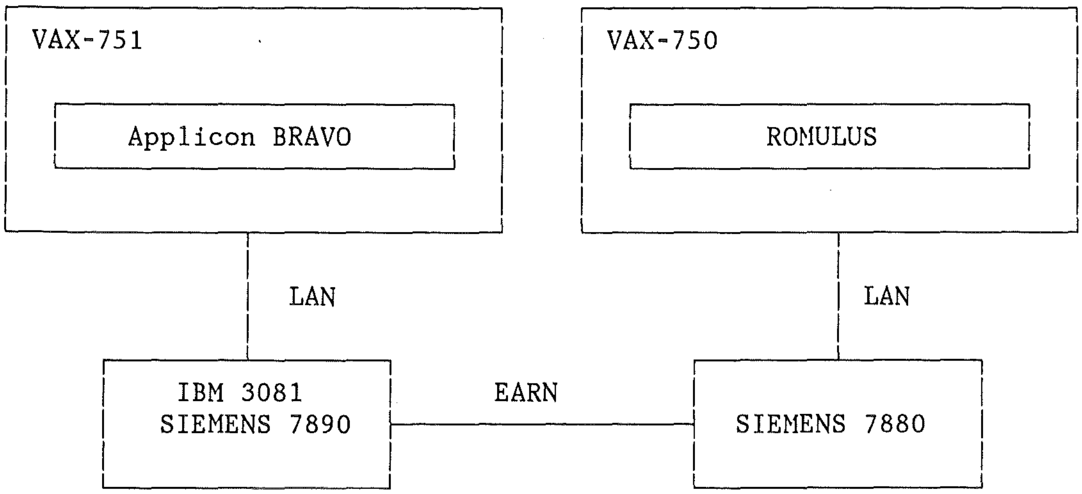


Figure 26. The computer configuration: The CAD systems run on VAX computers both at KfK and at IPP. As intermediate transfer support, the central computer systems at both sites are available.

LAN: A local area network (or an equivalent special purpose coupling of two computers at the same site) is the preferred solution for short range data transfer. High transmission rates (up to millions of bits per second) can be achieved, but rates in the order of 10000 bits per second are more common. At KfK, an Ethernet-type LAN is being planned for coupling the CAD computer to the central computer system; at IPP a similar coupling between the VAX and the IBM has been established.

DATEX-P: This is a public data transfer service offered by the Deutsche Bundespost. DATEX-P (data exchange by packages) is especially well suited and cost-effective for smaller amounts of data to be transferred over long distances. The information is cut into packages of equal length. The communication link is built up for each package separately and deleted afterwards.

DATEX-L: For DATEX-L (L stands for line) a communication link is built up and maintained throughout a whole transaction (a whole terminal session or a complete file transfer). This mode of operation becomes more attractive for routine exchange of large amounts of data unless less expensive means (EARN, DFN) can be made available.

EARN: The EARN (European Academic and Research Network) has been implemented between the main European universities and research centers. The complete listing of computer nodes which are accessible via EARN is given in "List of all nodes accessible from KfK via EARN in May 1985". KfK and IPP are connected to EARN. During the period of this contract, EARN has become fully operational as a reliable tool for exchanging files and messages between the computer centers of IPP and KfK. - In the UK, there are no nodes connected to EARN. It is possible, however, to communicate with computers in the UK via links between EARN and the JANET network. Details of this linkage have not been explored up to now.

DFN: The DFN (Deutsches Forschungsnetz) is presently being developed for providing higher (than file transfer and remote job entry) services to the user. DFN facilities are considered as a possible replacement for EARN once the network becomes available.

4.1.1.1 Procedures for reading and writing IGES tapes on VAX and IBM

This chapter recommends the procedure for reading and writing sequential files as specified by the IGES standard on tape for

1. IBM computers with operating system MVS,
2. VAX computers with operating system VMS.

The following basic characteristics of the tapes were established.

density	: 1600 Bpi
number of tracks	: 9
data coding	: ASCII
label type	: NOLABEL or ANSI - Label
record format	: fixed blocked
logical record length	: 80 bytes
block size	: 800 bytes

4.1.1.1.1 Write tape on IBM with MVS

: The use of the IBM utility IEBGENER is recommended. The following example illustrates the procedure. The job copies the data set 'IGES.DATA' to an ANSI label tape.

```
//  .......    JOB  CARD  .......
//CREATE       EXEC PGM=IEBGENER
//SYSPRINT     DD   SYSOUT=A
//SYSUT1       DD   DSN=IGES.DATA,DISP=SHR
//SYSUT2       DD   UNIT=T1600,VOL=SER=tape_name,LABEL=(1,AL),
//             DCB=(BLKSIZE=800,LRECL=80,RECFM=FB,OPTCD=Q),
//             DSN=IGES.DATA,DISP=(NEW,KEEP)
//SYSIN        DD   DUMMY
```

For a NOLABEL tape the job would read as follows:

```
//  .......     JOB  CARD  .......
//CREATE        EXEC PGM=IEBGENER
//SYSPRINT      DD   SYSOUT=A
//SYSUT1        DD   DSN=IGES.DATA,DISP=SHR
//SYSUT2        DD   UNIT=T1600,VOL=SER=tape_name,LABEL=(1,NL),
//              DCB=(BLKSIZE=800,LRECL=80,RECFM=FB,OPTCD=Q),
//              DISP=(NEW,KEEP)
//SYSIN         DD   DUMMY
```

4.1.1.1.2 Read tape on IBM with MVS

: For reading the use of the IBM utility IEBGENER is recommended. The following job copies an ANSI label tape to data set 'IGESNEW.DATA'.

```
//  .......     JOB  CARD  .......
//READ          EXEC PGM=IEBGENER
//SYSPRINT      DD   SYSOUT=A
//SYSUT1        DD   UNIT=T1600,VOL=SER=tape_name,LABEL=(1,AL),
//              DCB=OPTCD=Q,DSN=IGES.DATA,DISP=(OLD,PASS)
//SYSUT2        DD   DSN=IGESNEW.DATA,DISP=SHR
//SYSIN         DD   DUMMY
```

For a NOLABEL tape the job would read as follows:

```
//  .......     JOB  CARD  .......
//READ          EXEC PGM=IEBGENER
//SYSPRINT      DD   SYSOUT=A
//SYSUT1        DD   UNIT=T1600,VOL=SER=tape_name,LABEL=(1,NL),
//              DCB=(BLKSIZE=800,LRECL=80,RECFM=FB,OPTCD=Q),
//              DISP=(OLD,PASS)
//SYSUT2        DD   DSN=IGESNEW.DATA,DISP=SHR
//SYSIN         DD   DUMMY
```

Remarks:

The use of the DCB parameter OPTCD=Q is essential. This parameter causes the necessary conversion from EBCDIC to ASCII and vice versa to be performed by the operating system.

4.1.1.1.3 Write tape on VAX with VMS

: On the VAX the treatment of such files is slightly more difficult. The reason is the different structuring of data on direct storage devices of the VAX computer. VMS, in order to optimize disk storage, does not handle fixed length records. A number of steps is required to generate such a record format. The following example illustrates this procedure for a normal VMS disk file called IGES.DAT.

1. With the VMS/RMS - Utility ANALYSE a descriptive file of the actual data set is produced:

   ANALYZE/RMS_F/FDL IGES.DAT

   This generated descriptive file has the name IGES.FDL.

2. Now the descriptive file has to be modified such as to fit to a fixed blocked data set. This is done with an interactive editor. The user is guided by the menu of this editor. The following modification of parameters have to be performed:

   EDIT/FDL IGES.FDL

   In Menu MODIFY RECORD :

CARRIAGE CONTROL	changed from	CARRIAGE_RETURN	to NONE
FORMAT	changed from	VARIABLE	to FIXED
SIZE	changed from	0	to 80

   After completion of this modification a new file IGES.FDL has been generated automatically by VMS.

3. Using this file description, the original file IGES.DAT can be converted to the required format by applying the VMS utility CONVERT. In our example, we generate the file IGES.IGE as follows:

```
CONVERT/CREATE/FDL=IGES.FDL/PAD=%X20  IGES.DAT  IGES.IGE
```

File IGES.IGE now contains the same data as IGES.DAT but in a different format.

4. For copying this file to a tape, the utility COPY is used. Prior to copying, the tape has to be mounted via the MOUNT command. The blocksize of 800 bytes and the label type are specified in the MOUNT command.

- write a NOLABEL tape:

```
MOUNT/FOREIGN/BLOCK=800/RECORD=80  tape_unit_name
COPY/LOG  IGES.IGE  tape_unit_name
```

- write an ANSI label tape:

```
INIT  tape_unit_name tape_name
MOUNT/LABEL/BLOCK=800/RECORD=80  tape_unit_name
COPY/LOG  IGES.IGE  tape_unit_name tape_name
```

4.1.1.1.4 READ tape on VAX with VMS

: For reading an IGES type file from tape two possibilities are proposed. The first one uses only VMS facilities while the second one is based on special software.

With the DEC control language DCL the reading procedure is as follows:

```
        MOUNT/REC=80/BLOCK=800/FOREIGN  tape_unit_name
        OPEN/WRITE FILE  file_name
LOOP:
        READ/END_OF_FILE=END  TAPE  DATA
        WRITE  FILE  DATA
        GOTO LOOP
END:
        CLOSE TAPE
        CLOSE FILE
        EXIT
```

The second method is as follows: Special software is used to convert from fixed length data records to variable ones, to insert Carriage Control characters and to generate a standard VMS file. On the VAX computer of KfK, this software has been implemented as an image file with name TAPECOPY.EXE. This file can be made available. The source of this software is not available; neither the author of it nor his company nor the source are known to KfK.

Prior to mounting the tape, some assignments have to be executed:

```
ASSIGN  tape_unit_name     TAPE
ASSIGN  terminal_name      FOR007
MOUNT/FOREIGN  tape_unit_name
```

Now the program is started:

```
RUN TAPECOPY
```

After displaying a short introduction to the use of the program, the program requests the input of some control parameters. For reading of IGES compatible tapes, the required input is "1". The next two questions have to be answered with "N". Then the name of the receiving disk file is requested. After input of the file name TAPECOPY performs the data transfer with the required conversions. After completion, the program asks for any subsequent tasks. "STOP" terminates the program.

4.1.2 High level data transfer

An overview of the present state of the art in this field was given by the workshop on product defining data (PDD) at Braunschweig on October 1st, 1984, during the 14th annual conference of the Gesellschaft für Informatik [2]. The present situation can be summarized as follows:

1. The Initial Graphics Exchange Specification (IGES) [3] has become a practicable basis for CAD data exchange for some types of design data. Pre- and post-processors are offered by most vendors of CAD systems. Tests have shown that most wire-frame information, both two-dimensional and three-dimensional, is transmitted correctly. Also the transmission of dimensioning and other annotations is successful in many cases, though considerable difference of appearance of this information may be encountered on the receiving system. Where IGES processors do not yet comply with the requirements in these areas, one can expect them to meet the standard soon because of the tremendous pressure of the market (e.g., imposed by General Motors requirements).

2. For surface geometry, IGES has failed to provide an acceptable standard. Alternate standards or standard proposals have been developed in France [4] and in Germany [5].

3. For solids, IGES does not provide any basis. New approaches are necessary and are underway, such as the XBF (experimental boundary file) and the ESP (experimental solid proposal). These activities are organised in the ISO working group ISO-TC184-SC4-WG1 on an international basis, and in the standardization committee DIN-NAM-AA-96.4 (TAP) (Transfer and Archiving of Product Defining Data) in Germany. KfK is actively participating in this work. KfK has launched a project "CAD Interfaces" within the ESPRIT programme of the European community. This project has as one of its major goals the development of standard proposals and of processors for transfer of solid geometry models. As an initial exercise, solid models will be transferred from Applicon's Bravo! to Shape Data's Romulus system.

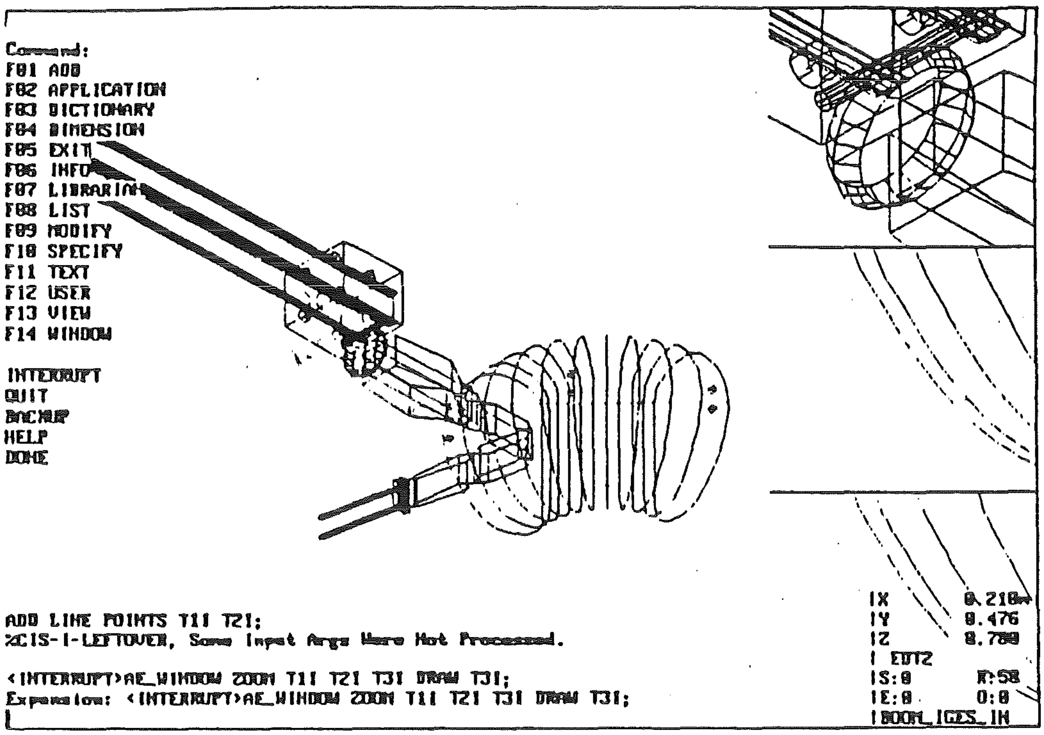


Figure 27. The JET boom after IGES processing: This is the correct result of processing an Applicon CAD model via IGES in a cycle test.

4.2 Approach

The approach selected for communicating CAD information between NET and KfK is characterized as follows:

1. On the low (file transfer) level a combination of several techniques should be used:

   - o At IPP the VAX is connected to the IBM of the computer center via a local connection.
   - o EARN is used for the long distance file transfer between the IBM at Garching and the IBM/Siemens system of KfK.
   - o At KfK a connection between the VAX-751 and the IBM/Siemens computers will be established in the first half of 1985.
   - o As it is difficult to monitor the file transfer through EARN with EARN itself (the user is not notified when data is lost, or when the net-

work breaks down) a DATEX-P connection has been made available to perform all interactive supervisory operations on the IBM at IPP. A DATEX-P connection to the VAX-750 at the IPP is desirable for future routine operations. They same advice applies to a DATEX-P connection of the CAD computer at KfK if data transfer is to be initiated and supervised from the NET team.

2. The high level data transfer is to be based on IGES for the next years.

- IGES processors (pre- and post-processors) will be available for the CAD systems Medusa at IPP and the Applicon system at KfK. However, their performance is still to be tested. One can expect that the transfer of two-dimensional and three-dimensional wire-frame geometry will be successful. Thus, this option can be used for transmitting of basic geometry from the central CAD data base of the NET team to KfK, and for return of design solutions and remote handling paths to NET from KfK.
- The next step will be transfer of fully dimensioned and annotated design drawings in both directions. Here, IGES files offer promising prospects, though some corrections to the transferred information will likely be required.
- In the near future Applicon will offer a 'SURFACE' package, so that at a later stage, the capabilities of the IGES processors of the two systems for transfer of surface geometry are to be tested. If they fail and if the transfer of surface geometries becomes necessary, the development of processors on the basis of the VDAFS interface format may be advised.
- At this time, the transfer of solid models between Medusa and the Applicon system is beyond the state of the art (probably for the next three to four years). KfK is actively working in this field in its ESPRIT project. Even if we assume that an intermediate file format and pre- and post-processors become available, the present data models of the two systems can allow transfer of exact three-dimensional solid models from the Applicon system to Medusa only, not vice-versa. This is because the format used by Medusa is a boundary representation, the

synthavision format used by Applicon is a CSG (constructive solid geometry) representation of the exact solid geometry.

4.3 Results obtained

4.3.1 Low level data transfer

Data transfer via magnetic tapes has worked succesfully. The low level data transfer via computer networks between the CAD computers of NET and KfK has been established and tested. An IGES file was brought from the KfK VAX to the NET VAX via the intermediate main computer centers. Until now two IGES files have been transmitted from the NET VAX to the KfK IBM. Their checking will be performed later when the new Applicon IGES translator will be available.

4.3.2 High level data transfer

A first test of the IGES capabilities of the Applicon system has begun and has been partially completed. The test contains three parts:

CYCLE TEST: In this test three-dimensional three wire-frame models produced at KfK were transformed into the IGES format and used to reconstruct an Applicon CAD data base via the IGES pre- and post-processors of Applicon. The test was successful with respect to the geometrical information. Some minor failures occurred for the dimensioning. A few measures were mirror imaged, a few dimensions were positioned in a different way as compared to the original. One of these examples is shown in Figure 27.

RPK TEST SUITE: 47 tests produced by the institute RPK of the University of Karlsruhe with different CAD systems (2 from Computervision, 1 from Control data, the remainder from other systems) were made available to produce CAD data bases with the Applicon system. 12 of these tests were executed. The result was satisfactory for the geometry, errors occurred in the dimensioning part. Some examples failed with as yet uninterpreted errors.

MODEL EXCHANGE WITH MEDUSA: An IGES tape with one test produced by the Culham Laboratory with a MEDUSA to IGES converter was used to create a CAD data base with the Applicon system. The protocol of the conversion shows that some IGES entities as subfigure definitions, drawing subfigures, instances and views are lost. On the other hand, an error was detected in the global area of the IGES file for a given resolution of zero. The next version of the Applicon IGES postprocessor will be able to convert the lost entities. Also one IGES file with a KfK model was tested with MEDUSA at the Culham Laboratory and at the NET team at Munich. The tests were successful although the model was shifted from the middle of the sheet in the BRAVO! representation to bottom left on the MEDUSA window. That's because MEDUSA's world coordinate system has its origin in the lower left corner of the sheet while Bravo! normally displays the origin in the center of the screen. Most recently, KfK has received an IGES file of a dimensioned NET layout drawing from NET via EARN. The header and the trailer of this file have been inspected visually and were found to be correct. The conversion of the file to an Applicon Bravo! drawing will be performed in the near future, when the Applicon IGES processors will be implemented at KfK.

IGES ANALYSER APPLICATION: The three IGES files produced from the KfK models were given to the RPK institute. RPK has developed an IGES analyser program which checks IGES files for formal correctness. This test has not yet been executed.

4.4 Recommendations

4.4.1 Low level data transfer

For an enhancement of the CAD data exchange the following measures are recommended:

1. The optimum solution would be the integration of the CAD computers into EARN. This is technically feasible. Several of the EARN nodes are implemented on VAX computers.

2. Provision of a DATEX-P attachment to the CAD computers for exchange of data whith organizations which are not attached to EARN (such as the JRC at Ispra or industry).

3. Finally, magnetic tapes can be used. For reading and writing IGES tapes on VAX and IBM computers the necessary procedures have been established.

4.4.2 High level data transfer

1. For transfer of CAD data between CAD systems of the same vendor each CAD system offers the possibility to store data on a sequential file and to read such files. This technique is best suited for this purpose, but it cannot be used for data exchange between different CAD systems.

2. For transfer of design drawings and basic two-dimensional and three-dimensional wire-frame geometry, IGES is the proper solution. It is recommended to continue with testing of this technique for the Medusa-Bravo! exchange as soon as the Applicon IGES processors (which have been ordered) are installed at KfK.

3. For solid model data exchange between unlike CAD systems no solution is available up to now. The situation is not likely to change much before about 1988.

4.5 List of all nodes accessible from KfK via EARN in May 1985

*	DAAFHT1 = D	FHS Aalen, Germany
*	DBNGMD21 = D	GMD Bonn, Germany
*	DBNRHRZ1 = D	RHRZ Uni Bonn, Germany
*	DBNRHRZ2 = D	RHRZ Uni Bonn, Germany
*	DBNUAMA1 = D	Angewandte Mathematik Uni Bonn
*	DBNUOR1 = D	Oekonom. u Operatns Rsrch Bonn
*	DBNVB12 = D	Anorganische Chemie, Uni Bonn
*	DBSNRV0 = D	NRV-Gateway TU Braunschweig
*	DBSTU1 = D	Techn. Uni. Braunschweig
*	DB0HMI41 = D	HMI Berlin, Germany
*	DB0TUI11 = D	TU Informatik, Berlin, Germany
*	DB0TUM11 = D	TU Maschinen, Berlin, Germany
*	DB0TUS11 = D	TU Schiff und Meer, Berlin
*	DB0ZIB21 = D	ZIB Berlin, Germany
*	DCZRZTU0 = D	TU Clausthal, Germany
*	DDADVS1 = D	TH Darmstadt, FB Informatik
*	DDAGMD11 = D	GMD Darmstadt, Germany
*	DDAGSI3 = D	GSI Darmstadt, Germany
*	DDATHD21 = D	TH Darmstadt, Germany
*	DDOHRZ11 = D	Uni Dortmund, Germany
*	DEARN = D	EARN Central Node, Germany
*	DERRZE1 = D	Uni Erlangen, Germany
*	DEOHRZ1A = D	Uni Essen, Germany
*	DEOWTZ1A = D	Uni Klinikum, Essen, Germany
*	DFVLROP1 = D	DFVLR Oberpfaffenhofen Germany
*	DGAIPP1S = D	MPI Plasmaphysik Garching
*	DGOGWD01 = D	GWD Goettingen, Germany
*	DHAFEU11 = D	Fern-Uni Hagen, Germany
*	DHDDKFZ1 = D	DKFZ Heidelberg, Germany
*	DHDEMBL5 = D	EMBL Heidelberg, Germany
*	DHDIBM1 = D	IBM Scientif.Center Heidelberg
*	DHDIHEP1 = D	Hochenergiephysik Heidelberg
*	DHHDESY3 = D	DESY Hamburg, Germany
*	DHNFHS1 = D	FHS Heilbronn, Germany
*	DHVRRZ01 = D	Uni Hannover, Germany
*	DJUKFA11 = D	KFA Juelich - ZAM, Germany
*	DJUKFA21 = D	KFA Juelich - ZAM, Germany
*	DJUKFA51 = D	KFA Juelich - SNQ, Germany
*	DJUKFA53 = D	KFA Juelich - SNQ, Germany
*	DKAFHS1 = D	FHS Karlsruhe, Germany
*	DKAUNI12 = D	Uni Karlsruhe, Informatik 3
*	DKAUNI13 = D	Uni Karlsruhe, Informatik 3
*	DKAUNI14 = D	Uni Karlsruhe, Rechenzentrum
*	DKAUNI48 = D	Uni Karlsruhe, Rechenzentrum
*	DKIUNI0 = D	Uni Kiel, Germany
*	DK0ZA1 = D	Zentralarchiv Koeln, Germany
*	DMAFHT1 = D	FHS Technik, Mannheim
*	DMARUM8 = D	Uni Mannheim, Germany
*	DMSWWU1A = D	Uni Muenster, Germany
*	DMSWWU2B = D	Uni Muenster, Germany

* DMOMPF11 = D MPI psych. Forschung, Muenchen
* DMOMPI11 = D MPI Physik, Muenchen
* DMOTUI1S = D TU Informatik, Muenchen
* DOLUNIO = D Uni Oldenburg, Germany
* DOSUNI = D Uni Osnabrueck, Germany
* DSOFBD11 = D FBD - Schulen, Stuttgart
* DSOIKE51 = D IKE, Uni Stuttgart, Germany
* DSOMPA51 = D MPA, Uni Stuttgart, Germany
* DSORUS1I = D Uni Stuttgart, Germany
* DSORUS51 = D Uni Stuttgart, Germany
* DTUZDV1 = D ZDV Uni Tuebingen, Germany
* DTUZDV2 = D Uni Tuebingen - ZDV BASF
* AKRON = USA University of Akron
* ANLCHM = USA ANL Chemistry Division
* ANLCMT = USA ANL Chemical Technology Div.
* ANLEES = USA ANL Energy & Environ. Systems
* ANLEL = USA ANL Electronics Division
* ANLHEP = USA ANL High Energy Phisics Div.
* ANLIPNS = USA ANL Pulsed Neutron Source
* ANLMCS = USA ANL Math and Computer Science
* ANLMST = USA ANL Materials Science Tech.
* ANLNESC = USA ANL Nat'l Software Center
* ANLOS = USA Argonne National Lab
* ANLPHY = USA ANL Physics Division
* ANLVM = USA Argonne National Lab
* ASUACAD = USA Arizona State University
* ASUCADAM = USA ASU/ECC
* ASUEJS = USA ASU/ECC
* ASUIC = USA Arizona State University
* AUVM = USA American University
* BARILAN = IL Bar Ilan University
* BBADMIN = USA CUNY - Baruch College Admin.
* BBADMIN2 = USA CUNY - Baruch College Admin.
* BB003 = USA CUNY - Baruch College
* BIBLIO31 = CDN Centennial College
* BINGTJW = USA SUNY Binghamton
* BINGVAXA = USA SUNY Binghamton
* BINGVAXB = USA SUNY Binghamton
* BINGVAXC = USA SUNY Binghamton
* BINGVMA = USA SUNY Binghamton
* BINGVMB = USA SUNY Binghamton
* BITNIC = USA BITNET Network Support Center
* BKLYN = USA CUNY - Brooklyn College
* BKLYNMVS = USA CUNY - Brooklyn College
* BMACADM = USA CUNY - Manhattan C.C. Academic
* BM002 = USA CUNY - Manhattan C.C. Admin.
* BNL = USA Brookhaven National Laboratory
* BOSTCIML = USA Boston Univ./CIML
* BOSTONU = USA Boston Univ./ACC
* BROWNCOG = USA Brown Univ. Ctr - Cogn. Sci.
* BROWNCS = USA Brown University CS Department
* BROWNHEP = USA Brown University/HEP
* BROWNVM = USA Brown University Comp. Center
* BUASTA = USA Boston Univ. Astronomy

* BUCASA = USA Boston Univ. Adapt. Sys.
* BUCHMA = USA Boston Univ. Chemistry
* BUCHMB = USA Boston Univ. Chemistry
* BUCHMC = USA Boston Univ. Chemistry
* BUENGA = USA Boston Univ. Engineering
* BUPHYA = USA Boston Univ. Physics
* BX001 = USA CUNY - Bronx Community College
* CALTECH = USA Caltech
* CANADA01 = CDN University of Guelph
* CARLETON = CDN Carleton University
* CATE = CDN Center for Adv. Tech. Educ.
* CBEBDA3C = CH Uni Bern, Switzerland
* CBEBDA3T = CH Uni Bern, Switzerland
* CCNY = USA CUNY - City College of NY
* CDC205 = USA Colorado State University
* CEARN = CH CERN, Geneva, Switzerland
* CENCOL = CDN Centennial College
* CERNADP = CH CERN, Geneva, Switzerland
* CERNVAX = CH CERN, Geneva, Switzerland
* CERNVM = CH CERN, Geneva, Switzerland
* CERNVME = CH CERN, Geneva, Switzerland
* CGEUGE51 = CH Uni Geneva, Switzerland
* CGEUGE52 = CH Uni Geneva, Switzerland
* CITCSSTV = USA Caltech Comp. Support Services
* CITHEX = USA Caltech High Energy Physics
* CLSEPF51 = CH ETH Lausanne, Switzerland
* CLVM = USA Clarkson University
* CLVMS = USA Clarkson University
* CNLASTRO = USA Cornell U./Dept. of Astronomy
* CONU1 = CDN Concordia University
* CORNELL = USA Cornell U. Computer Services
* CORNELLA = USA Cornell U. Computer Services
* CORNELLC = USA Cornell U. Computer Services
* CRNLCS = USA Cornell University CS Dept.
* CRNLGSM = USA Cornell Grad. School of Mgmt.
* CRNLNS = USA Cornell U./Lab of Nuc. Studies
* CRNLTHRY = USA Cornell Univ./Theory Center
* CRVXALFB = CH CERN, Geneva, Switzerland
* CRVXALTP = CH CERN ALEPH TPC
* CRVXDEV = CH CERN OC Developement
* CSU = USA Colorado State University
* CSUOHIO = USA Cleveland State U./Comp Serv
* CUCCVX = USA Columbia University Adm. Dept.
* CUCEVX = USA Columbia U. - Civil Eng.
* CUCHEM = USA Columbia Univ. Chem. Dept.
* CUCHMB = USA Columbia Univ. Chem. Dept.
* CUGSBVAX = USA Columbia Business School
* CUGSBVM = USA Columbia Business School
* CUMC = USA Cornell Univ. Medical College
* CUNYJES3 = USA City University of New York
* CUNYVM = USA City University of New York
* CUNYVMS1 = USA CUNY - Graduate Center
* CUVMA = USA Columbia University (CUCCA)
* CUVMB = USA Columbia University (CUCCA)

* CUVMC = USA Columbia University
* CUVMD = USA Columbia University
* CYBER = CH CERN, Geneva, Switzerland
* CZHETH5A = CH ETH Zuerich, Switzerland
* CZHRZU1A = CH Uni Zuerich, Switzerland
* CZHRZU2B = CH Uni Zuerich, Switzerland
* DKCCRE01 = DK Univ. of Copenhagen, Comp.Ctr.
* DKEARN = DK NEUCC Techn. Univ. of Denmark
* DKUCCC11 = DK Univ. of Copenhagen, Comp.Ctr.
* DUKE = USA Duke University
* DUKEFSB = USA Duke Univ. FSB Computer Center
* EARNET = I IBM SC - Roma
* EBOUB011 = E Uni Barcelona, Spain
* EBOUB012 = E Uni Barcelona, Spain
* EDUCOM = USA EDUCOM, Princeton, N.J.
* EEARN = E IBM Scientific Center Madrid
* EMDUAM11 = E Universidad Autonoma Madrid
* EMDUPM11 = E Universidad Politecnica Madrid
* FARMNTON = USA U. of Maine Farmington
* FNAL = USA Fermilab
* FNALA = USA Fermilab
* FNALBSN = USA Fermilab
* FNALCDF = USA Fermilab
* FNALVM = USA Fermilab
* FNALVX13 = USA Fermilab
* FORSYTHE = USA Stanford University
* FRECP11 = F Ecole Centrale de Paris
* FREMP11 = F Ecole des Mines de Paris
* FRHEC11 = F Ecole Hautes Etudes Commerce
* FRIAP51 = F Inst. of Astrophysics, Paris
* FRMOP11 = F CNUSC, Montpellier
* FRMOP22 = F CNUSC, Montpellier
* FRONI51 = F Observatoire de Nice
* FRORS31 = F CIRCE, France
* FRTOU71 = F CICT Toulouse
* FRULM11 = F Ecole Normale Superieure Paris
* FSU = USA Florida State University
* GEN = CH CERN, Geneva, Switzerland
* GITIBM1 = USA Georgia Tech
* GWUVM = USA George Wash. Univ. Comp. Ctr.
* HAIFAUVM = IL Haifa University
* HAMLET = USA Caltech
* HARVARDA = USA Harvard/HCC
* HARVHEP = USA Harvard/High Energy Physics
* HARVLAW1 = USA Harvard University
* HARVLIT1 = USA Harvard University
* HARVMA1 = USA Harvard University
* HARVSC1 = USA Harvard University
* HARVSC3 = USA Harvard University
* HARVSC4 = USA Harvard University
* HARVSC5 = USA Harvard University
* HARVSC7 = USA Harvard University
* HARVSC8 = USA Harvard University
* HARVUNXA = USA Harvard University

* HARVUNXH = USA Harvard University
* HARVUNXT = USA Harvard University
* HARVUNXU = USA Harvard University
* HARVUNXW = USA Harvard University
* HASARA5 = NL SARA Amsterdam, Netherlands
* HBUNOS = IL Hebrew University
* HDETHD2 = NL TH Delft, Netherlands
* HDETHD5 = NL TH Delft, Netherlands
* HEARN = NL Uni Nijmegen, Netherlands
* HEITHE5 = NL TH Eindhoven, Netherlands
* HENTHT5 = NL TH Twente, Enschede, Netherlds
* HGRRUGO = NL Uni Groningen, Netherlands
* HGRRUG5 = NL Uni Groningen, Netherlands
* HLERUL2 = NL Uni Leiden, Netherlands
* HLERUL5 = NL Uni Leiden, Netherlands
* HMARL5 = NL Uni Limburg, Netherlands
* HNYKUN11 = NL Uni Nijmegen, Netherlands
* HNYKUN22 = NL Uni Nijmegen, Netherlands
* HNYKUN51 = NL Uni Nijmegen, Netherlands
* HNYKUN52 = NL Uni Nijmegen, Netherlands
* HNYKUN53 = NL Uni Nijmegen, Netherlands
* HNYKUN54 = NL Uni Nijmegen, Netherlands
* HNYKUN55 = NL Uni Nijmegen, Netherlands
* HNYURC11 = NL Uni Nijmegen, Netherlands
* HROEUR5 = NL Uni Rotterdam, Netherlands
* HTIKHT5 = NL Katholieke Hogeschool Tilburg
* HUJICS = IL Hebrew University
* HUMBER = CDN Humber College
* HUNTER = USA CUNY - Hunter College
* HUTRUUO = NL Uni Utrecht, Netherlands
* HWALHW5 = NL Landbouwhogeschool Wageningen
* IBACSATA = I IBACSATA - Bari
* IBAUNIV = I Bari University
* IBOINFN = I ICINECA - Bologna
* ICINECA = I ICINECA - Bologna
* ICNUCEVM = I Nat'l U. Comp. Ctr - Pisa
* ICNUCEVS = I Nat'l U. Comp. Ctr - Pisa
* ICSATAXA = I CSATA - Bari
* IECMICC = USA Illinois Educ. Consortium
* IFIIDG = I Inst. Doc. Guiridica - Firenze
* IITVAX = USA Illinois. Inst. of Tech.
* IMIBOCCO = I Universita' Bocconi - Milano
* IMISIAM = I Instituto di Fisica Cosmica
* IPACUC = I Universita' di Palermo
* IPIINFN = I INFN - S. Piero a Grado - Pisa
* IPIVAXIN = I INFN - S. Piero a Grado - Pisa
* IRISHMVS = USA Univ. of Notre Dame Comp. Ctr
* IRISHVM = USA Notre Dame PC Lab
* IRLEARN = IRL University College Dublin
* IRMCRA = I Ist. Ricerche Aerospaz. - Roma
* IRMIAS = I Ist. Astro. Spaz. (CNR) - Roma
* IRUCCIBM = IRL University College Cork, Irel.
* IRUCCVAX = IRL University College Cork, Irel.
* ISRAEARN = IL IBM Israel SC - Haifa

* ISUMVS = USA Iowa State University
* ITOIMGC = I Ist. Meteo. Colonnetti- Torino
* JHUNIX = USA Johns Hopkins University
* JHUP = USA Johns Hopkins Univ. HEP
* JHUVM = USA Johns Hopkins University
* JHUVMS = USA Johns Hopkins University
* KB001 = USA CUNY - Kingsborough C.C.
* KSUVM = USA Kansas State University
* LEHMAN = USA CUNY - Lehman College
* LUCCPUA = USA Loyola University
* MAINE = USA U. of Maine
* MCGILLA = CDN McGill University
* MCGILL1 = CDN McGill University
* MCGILL2 = CDN McGill University
* MCMASTER = CDN McMaster University
* MECAN1 = USA U. of Maine Appl. Net
* MITECCF1 = USA MIT - East Campus Comp. Fac.
* MITLNS = USA MIT - Lab. for Nuc. Sci.
* MITVMA = USA MIT - Info. Systems
* MUVMS1 = USA Marshall University
* NCSUADM = USA North Carolina State Univ.
* NCSUCHE = USA North Carolina State U.
* NCSUIE = USA North Carolina State U.
* NCSUMAE = USA NCSU Mech. & Aero. Engr.
* NCSUMAEV = USA NCSU Mech. & Aero. Engr. Dept
* NCSUMTE = USA North Carolina State U.
* NCSUVAX = USA North Carolina State U.
* NCSUVM = USA North Carolina State U.
* NER = USA Florida NE Regional Data Ctr
* NERVM = USA Florida NE Regional Data Ctr
* NEUMVS1 = DK NEUCC Techn. Univ. of Denmark
* NEUVMS = USA NE Univ. Dept. of Physics
* NEUVM1 = DK NEUCC Techn. Univ. of Denmark
* NJECNVM = USA NJ Educ. Comp. Net (NJECN)
* NJECNVS = USA NJ Educ. Comp. Net (NJECN)
* NMSUMVS1 = USA New Mexico State Univ.
* NMSUVM1 = USA New Mexico State Univ.
* NNOMED = USA Louisiana St. U., Med. Ctr.
* NNOMEDV = USA Louisiana St. U., Med. Ctr.
* NSNCC = USA Louisiana St. U., Baton Rouge
* NSNCCVM = USA Louisiana St. U., Baton Rouge
* NTSU = USA North Texas State University
* NYSPI = USA NY Psychiatric Institute
* NY001 = USA CUNY - NYC Technical College
* OACVAX = USA UCLA-OAC
* OHSTVMA = USA Ohio State University / IRCC
* OHSTVMB = USA Ohio State University, CAD/CAM
* PENNDRLN = USA U of Penn/DRL Comp. Facility
* PENNDRLS = USA U of Penn/DRL Comp. Facility
* PENNHEP1 = USA U of Penn/HEP
* PENNLRSM = USA U of Penn/LRSM
* PORTLAND = USA U. of Southern Maine Portland
* PSUARCH = USA Penn State Arch. ComCAD Lab.
* PSUDEC10 = USA Penn State Engin. Computer Lab

* PSUECL = USA Penn State Engin. Computer Lab
* PSUMVS = USA Penn. State University
* PSUPDP1 = USA Pennsylvania State University
* PSUVAXG = USA Pennsylvania State University
* PSUVAXS = USA Pennsylvania State University
* PSUVAX1 = USA Pennsylvania State University
* PSUVM = USA Penn State/Computer Center
* PSUVMS1 = USA Penn State Engin. Computer Lab
* PSU2020 = USA Penn. State Eng. Computer Lab
* PUCC = USA Princeton University/Comp. Ctr
* QB001 = USA CUNY - Queensborough C.C.
* QUCDN = CDN Queens University
* QUCDNCMC = CDN Queens University CMEC
* QUCIS = CDN Queens University
* QUEENS = USA CUNY - Queens College
* RICE = USA Rice University/ICSA
* RICECSVM = USA Rice U. CS Dept.
* RITVAXC = USA Rochester Institute of Tech.
* RITVAXD = USA Rochester Institute of Tech.
* RITVM = USA Rochester Institute of Tech.
* RLG = USA Stanford University/RLG
* ROCKVAX = USA Rockefeller University
* RUTGERS9 = USA Rutgers University - CCIS
* RYERSON = CDN Ryerson Polytechnic
* SBHEP = USA UCSB/HEP VAX
* SFASYS = USA U. of California at SF
* SFBSYS = USA U. of California at SF
* SITVXA = USA Stevens Institute of Tech.
* SITVXB = USA Stevens Institute of Tech.
* SI001 = USA CUNY - College of Staten Isl.
* SJRLVM1 = USA IBM San Jose Research Ctr
* SJRLVM4 = USA IBM San Jose Research Ctr
* SJRLVS1 = USA IBM San Jose Research Ctr
* SJRVM3 = USA IBM San Jose Research Ctr
* SLACASP = USA SLAC ASP Experiment
* SLACCAD = USA SLAC CAD VAX
* SLACCB = USA SLAC Crystal Ball Exp.
* SLACHRS = USA SLAC HRS
* SLACMAC = USA SLAC Magnetic Calorimeter
* SLACMKII = USA SLAC Mark-II Detector
* SLACMK3 = USA SLAC Mark-III Detector Exp.
* SLACNIKH = USA SLAC 2-Gamma Experiment
* SLACPCR = USA SLAC PEP COntrol Room
* SLACSLC = USA SLAC Linear Collider Project
* SLACSLD = USA SLAC SLD Detector
* SLACTBF = USA SLAC Test Beam Facility
* SLACTWGM = USA SLAC Two-Gamma Experiment
* SLACUCD = USA SLAC 2-Gamma Experiment
* SLACUCSD = USA SLAC 2-Gamma Experiment
* SLACVM = USA SLAC
* STANFORD = USA Stanford University
* SUCASE = USA Syracuse University (CASE)
* SUHEP = USA Syracuse University (HEP)
* SUNYABVA = USA SUNY Buffalo

* SUNYABVB = USA SUNY Buffalo
* SUNYABVC = USA SUNY Buffalo
* SUNYBCS = USA SUNY Buffalo
* SUNYBING = USA SUNY Binghamton
* SUVM = USA Syracuse University
* TAMCBA = USA ACC/CBA/Texas A&M University
* TAMMVS1 = USA CSC/Texas A&M University
* TAMVM1 = USA CSC/Texas A&M University
* TAMVM2 = USA CSC/Texas A&M University
* TAMVXCGF = USA Texas A&M Engineering Graphics
* TAMVXEE = USA Texas A&M Univ. EE Dept.
* TAMVXME = USA Texas A&M Univ. ME Dept.
* TAMVXPHY = USA Texas A&M Univ. Physics Dept.
* TAMVXRSC = USA Texas A&M Remote Sensing Cent.
* TAUNIVM = IL Tel Aviv University
* TAUNOS = IL Tel Aviv University
* TAURUS = IL Tel Aviv University
* TECHMVS = IL Technion - Haifa
* TECHNION = IL Technion - Haifa
* TECHSEL = IL Technion - Haifa
* TECHUNIX = IL Technion - Haifa
* TSSNRC00 = CDN NRC, Ottawa
* TTUVM1 = USA UCF/Texas Tech Univ.
* TUCC = USA TUCC
* TUCCVM = USA TUCC
* UCBCMSA = USA U.C. Berkeley Computer Center
* UCBCMSB = USA U.C. Berkeley Computer Center
* UCBJADE = USA U.C. Berkeley Computer Center
* UCBRUBY = USA U.C. Berkeley Computer Center
* UCBUNIXA = USA U.C. Berkeley Computer Center
* UCBUNIXB = USA U.C. Berkeley Computer Center
* UCBUNIXC = USA U.C. Berkeley Computer Center
* UCBUNIXD = USA U.C. Berkeley Computer Center
* UCBUNIXE = USA U.C. Berkeley Computer Center
* UCBUNIXG = USA U.C. Berkeley Computer Center
* UCCCMVS = USA University of Cincinnati
* UCCCVM1 = USA University of Cincinnati
* UCCVMA = USA U.C. Corporate Headquarters
* UCF1VM = USA Univ. of Central Florida
* UCF2VM = USA Univ. of Central Florida
* UCHICAGO = USA UofC Computation Center
* UCHIMVS1 = USA UofC Computation Center
* UCHISTEM = USA UofC Crewe Laboratory
* UCHIVM1 = USA U. of Chicago
* UCLAMVS = USA UCLA-OAC
* UCLAMVSX = USA UCLA-OAC
* UCLASSCF = USA UCLA Social Sciences Facility
* UCLAVM = USA UCLA-OAC
* UCONNMVS = USA University of Connecticut
* UCONNVM = USA University of Connecticut
* UCSBVM = USA U.C. Santa Barbara
* UCSCVM = USA U.C. Santa Cruz
* UCSFCCA = USA U. of California at SF
* UCSFHC = USA U. of Cal.-SF, Hosp. & Clinics

* UDACSVM = USA University of Delaware
* UDCVM = USA Univ. of the Dist. of Columbia
* UFENG = USA UF College of Engineering
* UFFSC = USA UF Faculty Support Center
* UGAIBM1 = USA University of Georgia
* UHRCC = USA UH Research Computer Ctr
* UHUPVM1 = USA U. of Houston
* UIAMVS = USA University of Iowa
* UICACC1 = USA U. of Illinois Admin.
* UICMVS = USA U. of Illinois at Chicago
* UICVM = USA U. of Ill. at Chicago
* UIUCHEPG = USA U of Ill at Urbana/HEP
* UIUCUXC = USA U of Ill at Urbana/CSO
* UIUCVMB = USA U of Ill at Urbana/VLSI
* UIUCVMC = USA U of Ill at Urbana/Engineering
* UIUCVMD = USA U of Ill at Urbana/CSO
* UIUCVME = USA U of Ill at Urbana/CSO
* UMAB = USA U. of Maryland Med. School
* UMASS = USA University of Massachusetts
* UMASSVM = USA Univ. of Mass., Engineering
* UMCINCOM = USA U. of Maryland, CSC
* UMCVMA = USA University of Missouri (UMC)
* UMCVMB = USA University of Missouri (UMC)
* UMDA = USA Univ. of MD, CSC
* UMDB = USA Univ. of MD, CSC
* UMDC = USA Univ. of MD, CSC
* UMDNJPW1 = USA NJ Univ. of Med. & Dentistry
* UMDNJVM1 = USA New Jersey U. of Medicine
* UMDNJVM2 = USA NJ Univ. of Med. & Dentistry
* UMDT = USA Univ. of MD, CSC
* UMDU = USA Univ. of MD, CSC
* UMD2 = USA Univ. of MD, CSC
* UMD7 = USA Univ. of MD, CSC
* UMEE = USA Univ. of MD
* UMES = USA U. of Maryland, UMES
* UMKCVAX1 = USA University of Missouri (UMKC)
* UMKCVAX2 = USA University of Missouri (UMKC)
* UMKCVAX3 = USA University of Missouri (UMKC)
* UMMVSA = USA University of Missouri (UM)
* UMRVMA = USA University of Missouri (UMR)
* UMRVMB = USA University of Missouri (UMR)
* UMRVMC = USA University of Missouri (UMR)
* UMSLVMA = USA University of Missouri (UMSL)
* UMUC = USA U. of Maryland U. College
* UMVMA = USA University of Missouri (UM)
* UNBMVS1 = CDN University of New Brunswick
* UNC = USA Univ. of North Carolina
* UNFVM = USA University of North Florida
* UOFT01 = USA U. of Toledo
* UOFT02 = USA University of Toledo
* UOGOAC1 = CDN University of Guelph OAC
* UOGUELPH = CDN University of Guelph
* UOGVAX2 = CDN University of Guelph
* UORDBV = USA University of Rochester

* UORMVS = USA University of Rochester
* UORVM = USA University of Rochester
* UOTADM01 = CDN University of Ottawa
* UOTTAWA = CDN University of Ottawa
* UOTVMS01 = CDN University of Ottawa
* USCVAXQ = USA U. Of Southern California
* USCVM = USA U. of Southern California
* UTA3081 = USA U. of Texas, Austin
* UTA4341 = USA U. of Texas, Austin
* UTCVM = USA U. of Tennessee, Chattanooga
* UTDALVM1 = USA ACC/Univ. of Texas
* UTELP = USA U. of Texas at El Paso
* UTKVM1 = USA University of Tennessee
* UTKVX1 = USA University of Tennessee
* UTORONTO = CDN University of Toronto
* UTSA4341 = USA U. of Texas, San Antonio
* UTSA4381 = USA U. of Texas, San Antonio
* UWASHVM = USA University of Washington
* UWOCC1 = CDN University of Western Ontario
* VANDVMS1 = USA Vanderbilt University
* VANDVM1 = USA Vanderbilt University
* VASSAR = USA Vassar College
* VCUMVS = USA VCU Computer Center
* VNET = USA Gateway to VNET (IBM)
* VPICS1 = USA Virginia Polytechnic Institute
* VPISDA = USA Virginia Poly Tech (VPI)
* VPIVAX3 = USA Virginia Poly Tech (VPI)
* VPIVAX4 = USA Virginia Poly Tech (VPI)
* VPIVAX5 = USA Virginia Poly Tech (VPI)
* VPIVAX6 = USA Virginia Poly Tech (VPI)
* VPIVM1 = USA Virginia Poly Tech (VPI)
* VPIVM2 = USA Virginia Poly Tech (VPI)
* VPIVM3 = USA Virginia Poly Tech (VPI)
* WATACS = CDN Univ. of Waterloo, ACS
* WATARTS = CDN Univ. of Waterloo, Arts VAX
* WATCSG = CDN Univ. of Waterloo, CSG
* WATDCS = CDN Univ. of Waterloo, DCS
* WATDCSU = CDN Univ. of Waterloo, DCS
* WATMNET = CDN Univ. of Waterloo, MICRONET
* WATMTA = CDN Univ. of Waterloo, MTA
* WATSON = USA Gateway to IBM Research Div.
* WEIZMANN = IL Weizmann Institute of Science
* WESLYN = USA Wesleyan University
* WISCMACC = USA Univ. of Wisc., MACC
* WISCMSE = USA Univ. of Wisc., Eng. Dept.
* WISCPSL = USA Univ. of Wisc., Phys. Sci. Lab
* WISCPSLA = USA Univ. of Wisc., Phys. Sci. Lab
* WISCPSLB = USA Univ. of Wisc., Phys. Sci. Lab
* WISCVM = USA CS Dept. - Univ. Wisc. at Mad.
* WISDOM = IL Weizmann Inst. Dept. of Math.
* WUVMA = USA Washington University
* WUVMD = USA Washington University
* WVNMVS = USA WV Computer Network (WVNET)
* WVNVAXA = USA WV Computer Network (WVNET)

* WVNVAXB = USA WV Computer Network (WVNET)
* WVNVAXD = USA WV Computer Network (WVNET)
* WVNVAXE = USA WV Computer Network (WVNET)
* WVNVM = USA WV Computer Network (WVNET)
* WYOCDC1 = USA University of Wyoming
* WYOCDC2 = USA University of Wyoming
* YALASTRO = USA Yale University Astro. Dept.
* YALEADS = USA Yale University Administrative
* YALECS = USA Yale University CS Department
* YALEHEP = USA Yale University/HEP
* YALEMVS = USA Yale Univ. Computer Center
* YALENSL = USA Yale University/NSL
* YALEVAX5 = USA Yale University Computer Ctr.
* YALEVM = USA Yale Univ. Computer Center
* YALEVMX = USA Yale Univ. Computer Center
* YKTVMH = USA IBM TJ Watson Research Ctr
* YKTVMT = USA IBM TJ Watson Research Ctr
* YKTVMV = USA IBM TJ Watson Research Ctr
* YKTVMX = USA IBM TJ Watson Research Ctr
* YKTVMZ = USA IBM TJ Watson Research Ctr
* YORK = USA CUNY - York College
* YORKVM1 = CDN York University
* YORKVM2 = CDN York University
* YUGEMINI = CDN York University
* YULEO = CDN York University
* YUORION = CDN York University
* YUURSA = CDN York University
* YUVENUS = CDN York University
* YUVULCAN = CDN York University

5.0 INFORMATION MANAGEMENT

The production of more and more data with CAD systems gives automatically rise to the question of how this information can be managed and archived. This question breaks down into two parts:

1. How is the information stored physically?
2. How is the stored information organized?

5.1 Physical storage

The first one of these questions is more easily answered. There are only two practical alternatives: storage on disks and storage on magnetic tapes. Storage on disks is feasible only for the most recent and most frequently used data, and for data that is still being worked on. All other information will have to be stored on tapes in order to avoid excessive costs for online peripheral storage devices. It is common and recommended practice to identify the tapes simply by sequence numbers and to provide for a seperate book-keeping which tells what pieces of information are where on which tape.

5.2 Organization

The task of setting up an information management (storage and retrieval) facility for a new project corresponds to the task of defining the conceptual schema of a data base management system for a new application. The questions to be asked and answered are:

- What are the basic entities of information (the objects) that should be treated as separate items?
- What is a suitable identification scheme for the objects?

- What are the attributes of the objects which have to be understood by the management system itself (e.g., criteria for searches) and not merely by a person after the information was presented?
- What are the relations between the objects?
- How should the objects, their attributes, and their relations be represented in terms of files, formats, keywords?
- Which queries are to be performed?

The answer to these questions requires an intimate knowledge of the information flow in the project organization. Furthermore, the answers will change as the project evolves in time. Here, only some preliminary comments can be expressed. It is recommended that the questions of information management be considered in the project in an integral way, not merely related to CAD information. This task should be specifically assigned to a single person in the project management.

There appear to be significant differences between the information structures in a large development project like NET as compared to a manufacturer of conventional technical products. For NET, a much larger number of design versions on all levels of detailing, including incomplete and inconsistent options have to be anticipated. Design of closely related components will have to proceed in parallel with the need for backfitting when consistency becomes a requirement. Furthermore, the same component may have to be treated under different aspects with the consequently different forms of representation (e.g., external shape for assembly studies, internal design details, models emphasizing electro-magnetic aspects, finite element models, simplified schematics for public relation presentations). In addition to geometry in the form of three-dimensional or two-dimensional representations, textual information, data tables and diagrams will have to be considered as elements which contribute to the whole information base.

For illustration of the proposed abstract CAD data structure please refer to Figure 28.

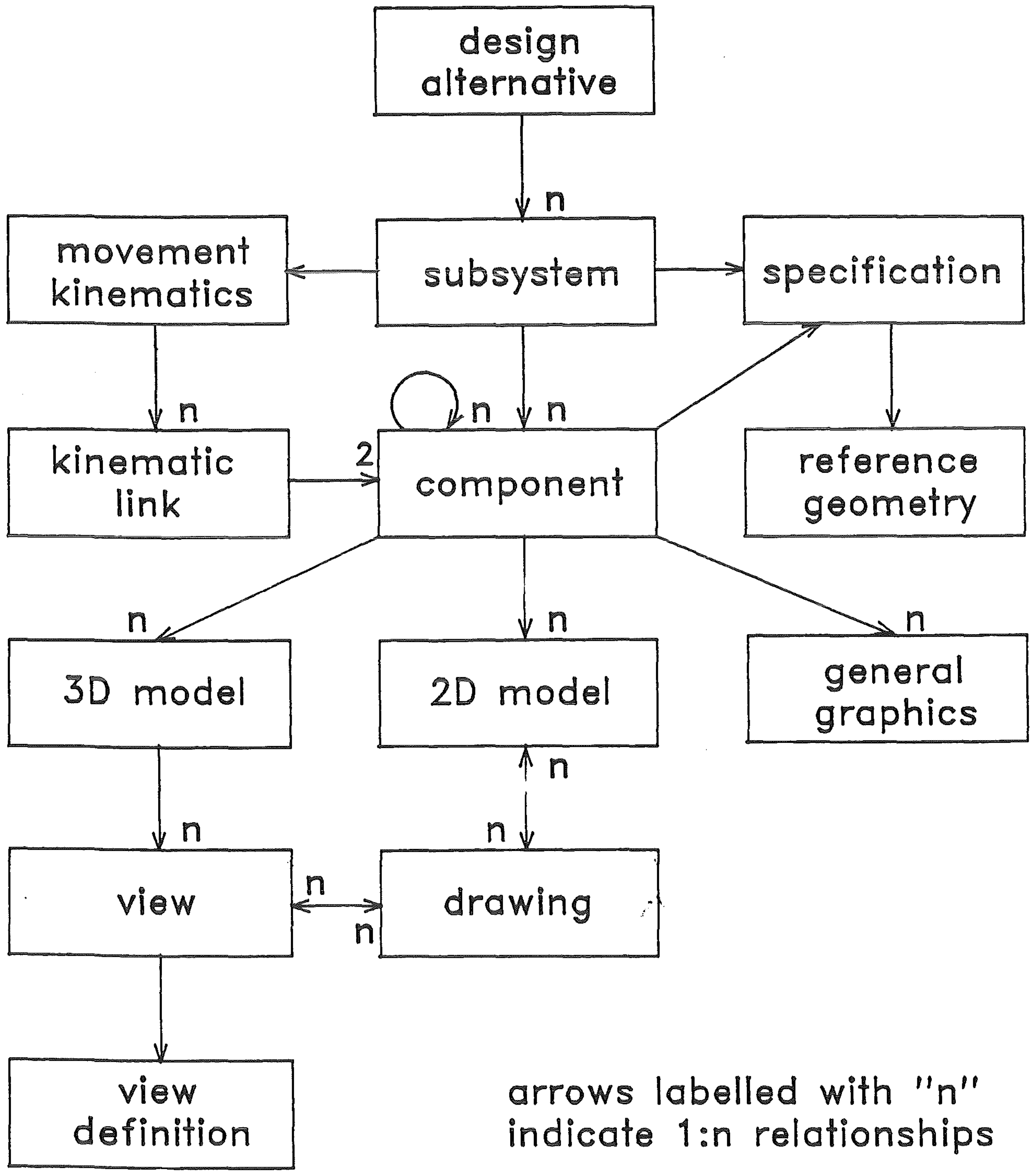


Figure 28. Abstract schema of the CAD data base

5.2.1 Identification scheme

Hierarchical identification (or naming) schemes have their inherent deficiencies because one tree structure can only represent a single organizational aspect. Nevertheless, it is recommended practice to use a hierarchical identification scheme to some extent. For NET, the following gross hierarchy is recommended:

LEVEL 1: DESIGN ALTERNATIVES. Each official design alternative is identified by a name (e.g. NET2A). On this level, information that is valid for all other levels and information that has been produced from several level 2 data bases is allocated, e.g.:

- o reference geometry data for the whole machine;
- o assembly drawings and assembly models containing several major subsystems.

LEVEL 2: MAJOR SUBSYSTEMS. This level is structured according to the NET team organization. Information pertinent to the whole group is allocated on this level:

- o Physics,
- o Tokamak,
- o Technology,
- o Nuclear and Plant,
- o ....

LEVEL 3: COMPONENTS. All information not pertinent to the whole major subsystem is allocated on this level. No further structuring below this level is recommended for the identification scheme. Instead, the relationships between the information items on this level should be expressed in a separate information system (or data base). No naming convention except uniqueness is required on this level.

5.2.2 Data base schema

The following **entity types** are expected to be present in the CAD data base:

- Machine component (represented by all documents referring to the component)
- 3D-model
- 2D-model
- projection
- view definition
- drawing
- specification
- textual description
- graphical description (other than drawing)

Entities are characterized by a set of **attributes**. In this context, a whole text file containing a specification or the geometrical definition of a component produced with a CAD system has to considered merely as an attribute. Note that some attributes may be irrelevant for some entity types.

- initialized on (date)
- being worked on by (person)
- completed on (date)
- approved on (date)
- approved by (person)
- outdated on (date)
- outdated by (person)
- text (arbitrary text file)
- geometry (CAD data in the specific format of a CAD system or in a standard format such as IGES)
- plot file (standard plot format file, e.g., GKS metafile)
- keyword list (keywords from the NET thesaurus)
- status

  The following states refer to the state diagram in Figure 29 on page 72:

  1. existent

2. being worked on
3. approved
4. being used
5. outdated

The following state transitions are allowed between these states:

- start work (existent → being worked on)
- approve (being worked on → approved)
- use (approved → being used)
- modify (approved → being worked on)
- outdate (approved → outdated)
- outdate (being worked on → outdated)
- inform user about outdating (being used → outdated)
- inform user about modification (being used → being worked on)

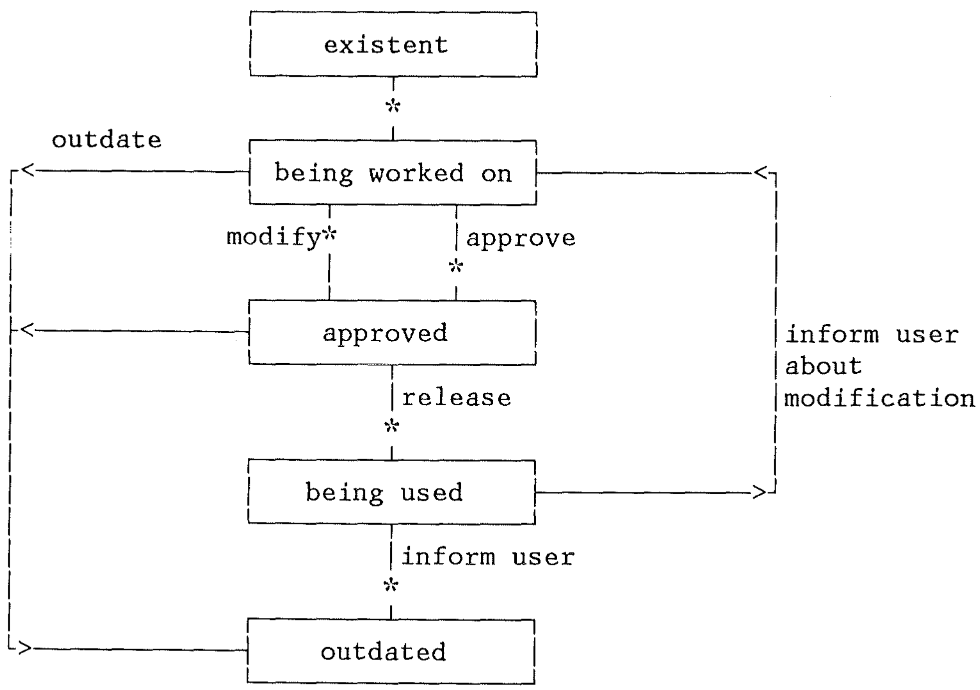


Figure 29. The state diagram of CAD information

The following **relationships** between all entity types should be represented in the data base:

- entity (1 to m) entity: built_from_internal_entity (reference to another entity)
- entity (1 to m) entity: built_from_external_entity (textual reference to an external source of information, e.g., "drawing number ###### from Ispra")
- entity (1 to m) user name: used_for_external_output (textual reference to an external user)

  Note, that there is no need for a used_internally relationship, as this is the inverse of the built_from_internal_entity relationship.

- entity (1 to m) entity:
  has_as_component (reference to another entity)
- component (1 to m) 3D-model: is_represented_by
- component (1 to m) 2D-model: is_represented_by
- component (1 to m) drawing: is_represented_by
- drawing (1 to m) projection: contains_a_plot_of
- drawing (1 to m) 2D-model: contains_a_plot_of
- projection (1 to 1) view definition: uses_projection

5.3 Thesaurus

An essential element of information management systems is the thesaurus. This is a listing of all keywords (often called: descriptors) which are used to characterize a certain entity of information and which may be used for automatic retrieval purposes. The thesaurus may be a sequential alphanumeric listing or may be structured to reflect relationships between descriptors like synonyms or set relations. A thesaurus may evolve naturally from unrestricted assignment of descriptors to entities or may be predefined in a planned manner. The latter approach is recommended. An example of a thesaurus for nuclear applications is given in [6]. This thesaurus was developed at KfK for a reactor safety information system [7, 8].

5.4 Elementary solution

The previous paragraphs have indicated that the CAD information structure in projects like NET is very complex. Neither the NET team nor any of the associated laboratories have an information management system available which is adequate. Hence, the abstract information structure must be mapped onto the available software capabilities. The most primitive solution requires at least a file management system and a text editor. Such a solution may be considered as a predecessor of some more advanced system. "Results obtained" illustrates how a text editor is used at KfK to maintain information about the content of the CAD data base in the Applicon environment.

With this solution, the file management system is used merely to reflect one selected aspect of the information structure. The names of the files are then entered into a text file together with appropriate descriptors and annotations. Descriptors are used for retrieval while the annotations are interpreted only by the person who performs a search. Attributes and relationships are treated as descriptors. If attributes require a value, a suitable syntax has to be defined. For instance, the string "INIT(1984/11/16)" might be used to allow searches for all informations which were created in november 1984.

5.5 Back-up copies

The data base structure discussed in this chapter does not involve back-up copies of the valid information. Security measures against loss or damage of information have to be taken separately and independently of the structuring of information. It is dangerous to mix the aspects of information structures (design versions of the same component) with the copies which are made simply for recovery purposes.

5.6 Results obtained

For the management of CAD information with the Applicon system, the following approach has been taken:

- CAD data related to a particular NET design version is stored in a single data base which is characterized by a name ("NET2A", e.g.) and which "belongs" to a single user in the VMS operating system sense.

- the text editor is used to maintain a list of the names of "cells" (a cell is the elementary data set in the data base upon which a user operates at any given time). Five different types of cells are distinguished:

1. model cells containing elementary geometry to be used for modelling. This basic geometry is either two-dimensional or three-dimensional wire-frame data and includes also the solid model primitives (called features).
2. part cells containing three-dimensional solid models of basic components produced by Boolean operations applied to features;
3. assembly cells containing assemblies of parts;
4. view cells containing three-dimensional wire-frame representations produced from a perspective view of an assembly or a part cell;
5. drawing cells containing the finally edited two-dimensional projection of one or several view cells ready for plotting.

As an example, the list of content of the NET2A data base is reproduced in Figure 30 through Figure 33.

Another important information can be derived immediately from the CAD data base: The Boolean operations which were used to model the parts. Figure 34 shows an example of a listing which can be produced by the CAD system user at any time.

MODELL NAME	FEATURE NAME	BEZEICHNUNG
KBLAA	FKBLAA	BLANKET AUSSEN UNTEN
KBLAI	FBLAI	BLANKET INNEN UNTEN
KBLAO	FBLAO	BLANKET AUSSEN ANSCHLUSS
KBLIO	FBLIO	BLANKET INNEN ANSCHLUSS
KEYPL	FKEYP	KEYPLUG
KPLKA	FPLKA	KEYPLUG AUSSCHNITT OBEN AUSSEN
KPLKI	FPKI	KEYPLUG AUSSCHNITT OBEN INNEN
KPFSP	FKPFSP	POLOID. SPULE
KPFSP	FSP2	POLOID. SPULE
KPFSP	FSP3	POLOID. SPULE
KPFSP	FSP4	POLOID. SPULE
KPFSP	FSP5	POLOID. SPULE
KPFSP	FSP6	POLOID. SPULE
KPFSP	FSP7	POLOID. SPULE
KPFSP	FSP8	POLOID. SPULE
KPLAS		PLASMA
KTFSAA	FTFSA	TOROID. SPULE AUSSEN
KTFSI	FTFSI	TOROID. SPULE INNEN
KVGEA	FKVGEH	VAKUUM GEHAEUSE AUSSEN
KVGEI	FGEHI	VAKUUM GEHAEUSE INNEN
SCHBL	FDIVI	DIVERTOR INNEN
SCHBL	F_DM	DIVERTOR AUSSEN MITTE
SCHBL1	F_DU	DIVERTOR AUSSEN SEITE
TRCHA	TRA	TRICHTER AUSSEN IM S_KVGEH
TRCHI	TRI	TRICHTER INNEN IM S_KVGEH
NZUS		ZUSAMMEN ALLE KONTUREN

Figure 30. Basic geometry and feature cells of data base NET2A

PART NAME	BEZEICHNUNG
S_BLAGR	BLANKET AUSSEN GROSS
S_BLAKL	BLANKET AUSSEN KLEIN
S_BLIGR	BLANKET INNEN GROSS
S_BLIKL	BLANKET INNEN KLEIN
S_DVMI	DIVERTOR MITTE
S_DVOB	DIVERTOR OBEN
S_DVUN	DIVERTOR UNTEN
S_KEYPL	KEYPLUG
S_KPFSP	POLOIDALSPULEN
S_KPSP90	POLOIDALSPULEN MIT AUSSCHNITT 90 GRAD
S_KTFSP	TOROIDALSPULE
S_KVGEH	VAKUUMGEHAEUSE

Figure 31. Part cells of data base NET2A

ASSEMBLY NAME	BEZEICHNUNG
A_ALM90	ZUSAMMENBAU ALLER TEILE BESTEH. AUS 2 ASSEMBL. A_SEKTOR, BUB UND 1 PART S_KPSP90
A_DIV	ZUSAMMENBAU DIVERTOREN (3 TEILE)
A_SEKTOR	ZUSAMMENBAU AUS PARTS: S_KVGEH S_KTFSP S_BLAGR S_BLAKL S_BLIGR S_BLIKL
BUB	ZUSAMMENBAU AUS ASSEMBL. A_DIV UND PARTS: S_KEYPL S_BLAGR S_BLAKL S_BLIGR S_BLIKL
A_BLALL	ZUSAMMENBAU ALLER 4 BLANKETS S_BLAKL S_BLAGR S_BLIKL S_BLIGR
A_SEG	ZUSAMMENBAU ALLER 4 BLANKETS UND GEHAEUSE S_KVGEH S_BLAKL S_BLAGR S_BLIKL SBLIGR

Figure 32. Assembly cells of data base NET2A

VIEW	DRAWING	PLOT	BEZEICHNUNG
V_ZUSH	D_ZUSH	PL3	ZUSAMMENBAU A_ALM90 GEDREHTE ANSICHT
V_NZUS	D_NZUS	PL20	ZUSAMMENBAU ALLER KONTUREN BEMASST
V_ISBL	D_BL	PL13	ALLE 4 BLANKETS GEDREHTE ANSICHT
V_BLAB	D_BL		ALLE 4 BLANKETS BOTTOM
V_BLAF	D_BL		ALLE 4 BLANKETS FRONT
V_BKY	D_BLKY	PL14	ALLE BLANKETS UND KEYPLUG BOTTOM ANSICHT
V_ISKY	D_BLKY		ALLE BLANKETS UND KEYPLUG GEDREHTE ANSICHT
V_DIVB	D_DIV	PL15	DIVERTOR UNTEN BOTTOM
V_DIVF	D_DIV		DIVERTOR UNTEN FRONT
V_GEB	D_GEH	PL18	VAKUUM GEHAEUSE BOTTOM
V_GEF	D_GEH		VAKUUM GEHAEUSE FRONT
V_GEI	D_GEH		VAKUUM GEHAEUSE GEDREHTE ANSICHT
V_BGEH	D_BGEH	PL19	VAKUUM GEHAEUSE UND BLANKETS GEDREHTE ANSICHT

Figure 33. View and drawing cells of data base NET2A

5.7 Recommendations

For practical reasons long terms storage of CAD data will have to be on magnetic tapes. It is recommended to archive CAD data preferably in the IGES format as the evolutions of CAD systems over periods of several years usually lead to incompatibilities.

For book-keeping (information about the CAD data in the CAD system data bases) over periods of years no satisfactory solution appears available.

It is recommended to establish a thesaurus for the NET project as such an ordered list of keywords will likely have a longer lifetime than any rigid organizational systems based, e.g., on a tree structuring of the NET machine components.

It is recommended to use those facilities which are at hand (file management systems, text editors, data base management systems) for book-keeping. Practical use will clarify the specific needs and, hopefully, lead to a specifica-

```
SOLIDS INFO :   TARGET = CURRENT SOLID   ;  DETAIL = INTERMEDIATE

Solid Name : S_KVGEH
Material   : STEEL
Density    :  10.50
Color      : CYAN
Solid Type : PART
Instance Counter   :      3
Evaluation Counter :     10
C_flags            : 0000100000000000
Facet Count        :    156
Facet min      :   2.6207E+02 -1.5351E+02 -7.3816E+02
Facet max      :   1.0183E+03  1.5351E+02  6.7000E+02

No precise mass properties data for this solid
No faceted mass properties data for this solid

This solid contains these instances :
               Part     - S_TRCHA
               Feature  - fkvgeh   Type REV
               Feature  - MESSER   Type BOX
               Feature  - fgehi   Type REV
               Feature  - MESSER   Type BOX
               Part     - S_CYLA
               Part     - S_TRCHI
               Feature  - FSCHUA   Type EXT
               Feature  - FSCHUI   Type EXT
               Feature  - FCYLI   Type CYL
               Total # Assemblies instanced =      0
               Total # Parts instanced      =      3
               Total # Features instanced   =      7
--------------------------------------------------
```

Figure 34. Informative listing about a part cell

tion of a CAD information management system which is suitable for a project of NET dimensions. However, we see no chance to avoid the complete reorganization of the book-keeping scheme during the course of the project (with all undesirable consequences such as loss of information which appeared to be out-dated at the time of reorganization but which turns out to be needed later).

```
Construction Tree Name     : S_KVGEH
Construction Tree Code     :     36
# on the Construction Tree:      10

Instance on Construction Tree     : fkvgeh      - Feature     type REV
            Construct Operator    : Union         , Ukey :   53
Instance on Construction Tree     : MESSER      - Feature     type BOX
            Construct Operator    : Subtract      , Ukey :   55
Instance on Construction Tree     : MESSER      - Feature     type BOX
            Construct Operator    : Subtract      , Ukey :   56
Instance on Construction Tree     : S_TRCHA      - Part
            Construct Operator    : Union         , Ukey :   82
Instance on Construction Tree     : FSCHUA      - Feature     type EXT
            Construct Operator    : Union         , Ukey :   94
Instance on Construction Tree     : S_CYLA      - Part
            Construct Operator    : Union         , Ukey :   92
Instance on Construction Tree     : FSCHUI      - Feature     type EXT
            Construct Operator    : Subtract      , Ukey :   95
Instance on Construction Tree     : FCYLI      - Feature     type CYL
            Construct Operator    : Subtract      , Ukey :   96
Instance on Construction Tree     : S_TRCHI      - Part
            Construct Operator    : Subtract      , Ukey :   97
Instance on Construction Tree     : fgehi      - Feature     type REV
            Construct Operator    : Subtract      , Ukey :   54
```

Figure 35. Continuation of Figure 34.

6.0 SUMMARY

6.1 Achievements

- Based on NET2A data, a section of the torus has been modelled including magnets, blanket modules, shielding, divertor drawer.
- Various techniques for treating remote handling operations with CAD systems have been investigated.
- An extension of the CAD system BRAVO! was developed which now allows the definition, analysis, and dimensioning of paths for remote handling operations using traces of selected points of the moved components for visualization.
- Low level CAD data transfer has been investigated. A particular solution (a combination of the private network EARN and the public network DATEX-P) was selected and successfully tested.
- For high level data transfer of two- and three-dimensional wire-frame geometry the IGES standard format was selected. A wire-frame model of the JET boom produced with the CAD system BRAVO! was successfully processed by the IGES processors of MEDUSA and returned to BRAVO!.
- A preliminary analysis of the abstract information structures for the CAD area in the NET project has been made.

6.2 Recommendations

- The low level data transfer between KfK and the NET team via EARN is recommended for future use. The optimal solution is the integration of the CAD computers as EARN nodes into the EARN network. This would eliminate the need for interactive communication via DATEX-P from a terminal at KfK to the IBM at Garching.
- It is recommended to continue the investigation and implementation of computer network connections to other organizations cooperating with NET, in particular the JRC at Ispra and Culham Laboratories. EARN should be used as far as possible.

- High level data transfer will continue to be based on the IGES standard for years to come. It is recommended to continue testing of the compatibility of the IGES processors of MEDUSA and BRAVO!, in particular, to establish a listing of the IGES entities which can successfully be exchanged between the two systems.
- The abstract CAD data structure will have to be mapped onto the software capabilities available to the NET team. CAD information management over a period of years, even decades, must be considered as an experimental enterprise. It may be necessary to change the organization during the course of the project. It is recommended to use an approach which is less sensitive to such changes than a rigid tree structuring: a characterization of all pieces of information by keywords taken from a structured thesaurus.
- The assignment of a person responsible for the overall NET information flow is recommended.

6.3 Literature

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