FROM MAD TO CAD : AUTOMATIC PRODUCTION OF ACCELERATOR LAYOUTS

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ABSTRACT

When building large installations such as particle accelerators, incorporating many interconnected systems in a confined environment, it is vital to keep track of the space occupation of individual components.
The solution adopted for the LEP project links location data produced by the Methodical Accelerator Design program to the Computer Aided Design system library of components to produce automatically a variety of machine layouts and assemblies in 2D or 3D representation.
The machine assemblies can be either visualized and manipulated interactively on a CAD workstation or plotted on paper.

INTRODUCTION

The decision to install a Computer Aided Design system in the technical divisions at CERN was made in 1981 and a year later, after a detailed technical evaluation, the EUCLID software supplied by MATRA-DATAVISION of France was installed on a Digital Equipment Corporation VAX 780 (1).

Two of the principal reasons for its selection were its 3D solid modelling capabilities and its large potential for user software development.

Today the new version EUCLID-IS (2) runs on more than thirty dedicated work-station connected to two clustered VAX machines, a 8650 and a 6210.

One of the most powerful feature of EUCLID is the existence of a programming interface making it easy for users to develop extensions to the basic software. Extensions fall into two categories, being either additional tools for the interactive user or completely separate batch programs.

Batch programs have a number of advantages. They are well suited to perform pre-defined repetitive tasks based upon user supplied data, they can be executed overnight thereby giving interactive users of CAD the full use of computer resources during day-time, and they do not require the use of hard-sought workstations.

Two EUCLID extensions have been developed to produce the layouts of LEP. LEGO (Layout d'Equipement Généré par Ordinateur) is an interactive as well as batch application used for schematic layouts. ASMAC (ASsembly of MAChine) is a batch-only application producing detailed layouts. They have made it possible to follow closely the evolution of the machine at the design and installation stages with a major saving in manpower.

Two sources of data are exploited to produce layouts :

a) a set of component locations files:
b) the CAD library of models.

THE COMPONENTS LOCATION FILES

The design and installation of a large accelerator is a dynamic process in which data is constantly modified and updated. Computing tools are necessary to deal with the large amounts of data involved. In the case of LEP, the MAD (3) program is used by machine physicists to calculate the beam orbit and to place beam elements, magnets, accelerating cavities, beam instrumentation and vacuum tubes and valves.

The RDBMS ORACLE (4) is used by engineers in charge of cooling, electrical distribution and transport system. Wherever possible, use has been made of the source data to produce up-to-date layouts.

The link between MAD or ORACLE and layouts is established by a set of component location files, one file for each system. The intermediate files are useful for four reasons :

a) the coordinate system of MAD and EUCLID are different.
b) MAD is running on a different computer from CAD.
c) the data extracted from MAD and ORACLE is not sufficient for engineering purposes. Location number and geometric transformation code, taking into account the multiple orientations which a component may have in different part of the machine, have to be added:
d) they make it easy to freeze the layout in a given state.

The civil engineering, monorail and electrical distribution system not being defined in either MAD or ORACLE, their location files are created manually with a text editor.

A summary of LEP systems is given below. Altogether the layout applications deal with 55'000 components of 1'700 different types belonging to 34 systems.

SYSTEM	DATA SOURCE	NUMBER OF DIFFERENT COMPONENTS	TOTAL NUMBER OF COMPONENTS
BEAM ELEMENTS(MAGNETS AND RF)	MAD	40	120
DIPOLE CONNEXIONS	ORACLE	10	600
COOLED CABLES CONNEXION BOXES	CAD	10	10
BUSBARS MODULES	ORACLE	4	500
BEAM MONITORING	MAD	40	120
ELECTRO. SEPARATORS ACCESSORIES	CAD	80	400
VACUUM VESSELS	MAD	110	6400
DIPOLE VACUUM VESSELS SUPPORTS	Computed from MAD	40	2000
MOBILE PUMPING STATIONS	ORACLE	30	2500
GETTER PUMPS CONNEXIONS	ORACLE	10	2600
ION PUMPS	ORACLE	20	1900
VACCUUM GAUGES	ORACLE	20	700
VACUUM VALVES - MOBILE STATIONS	ORACLE	10	500
ION PUMPS CONNEXION BOXES	ORACLE	50	1900
MOBILE STATIONS CONNEXION BOXES	ORACLE	20	500
VACCUM VESSELS COOLING BELLOWS	ORACLE	1	3600
BAKE-OUT EQUIPMENT	ORACLE	5	160
SURVEY TRIPODS	Computed from MAD	6	780
ACCELERATOR SUPPORTS	Computed from MAD	120	5400
MONORAIL TRACK	CAD	20	20
MONORAIL ACCESSORIES	CAD	10	1700
MAGNET COOLING HOSES	ORACLE	30	110
VACUUM COOLING MANIFOLDS	ORACLE	100	1100
DEMINERALIZED WATER PIPES	CAD	60	90
DEMINERALIZED WATER OUTLETS	ORACLE	110	2500
DEMIN. WATER PIPES SUPPORTS	CAD	90	11300
VACUUM VESSELS COOLING HOSES	ORACLE	180	2200
CABLE TRAYS SUPPORTS	CAD	60	800
ELECTRICAL DISTRIBUTION PANELS	CAD	50	900
SAFETY PANELS	CAD	40	800
TUNNEL LIGHTING	CAD	20	800
CABLE TRAYS	CAD	50	800
CIVIL ENGINEERING	CAD	125	125
STEEL STRUCTURES IN TUNNEL ROOF	CAD	70	70

THE CAD DATABASE

There are two types of EUCLID databases, project databases and standard databases.

The project databases contains all models, assemblies and drawings of machine components designed interactively. The contents of project databases is under the sole responsibility of the designer.

The standard databases contains all models of machine component used for assemblies and layouts. Before a model can become a standard, it has to be approved. It is then transferred from the project to the standard database and documented.

To keep drawings readable and to stay within EUCLID limitations on the complexity of models, up to four level of graphic representation are stored for a component. For example, in schematic layouts, the model is a box whereas in detailed layouts, all geometric details down tc the millimeter level are included.

THE LEGO APPLICATION FOR SCHEMATIC LAYOUTS

LEGO can be used interactively as well as in batch. Interactively, it allows the creation on the screen of the environment in a part of the tunnel when local modification or new implantation of components are studied.

The batch mode is used to produe two types of schematic layouts at scales of 1/250 and 1/50. Input parameters are read from text files prepared with the editor, one file per layout. Each file defines the drawing size and layout, the title block, the LEP systems to include and the part of the machine to draw in units of half-cells (39.5 m in most cases).

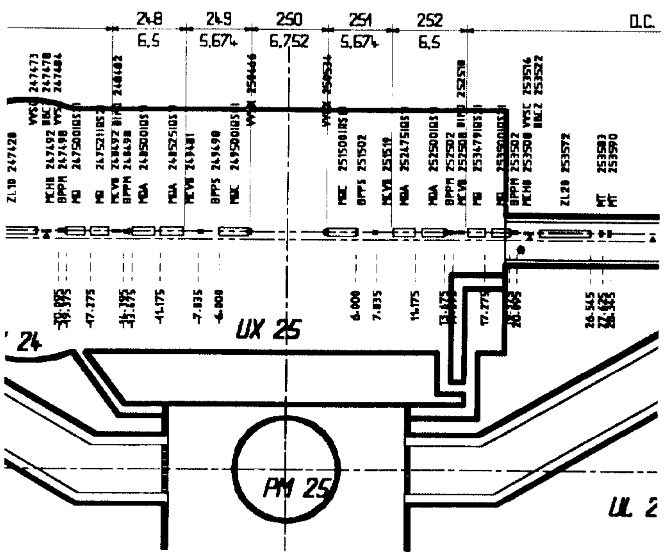

Fig. 1 Parf of a schematic layout - Real scale 1/250

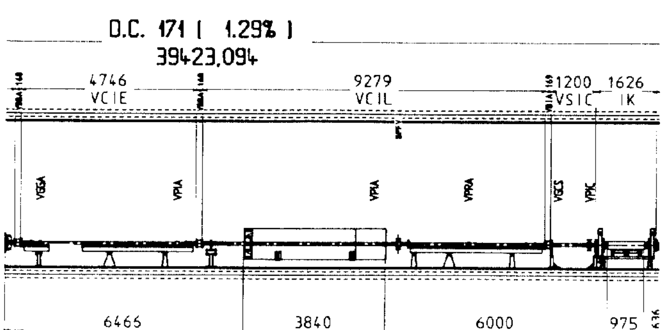

Fig. 2 Part of a schematic layout - Real scale 1/50

THE ASMAC APPLICATION FOR DETAILED LAYOUTS

This application was developed in 1986 to provide the machine installation teams with detailed 3D views of the completely equipped tunnel. It makes use of features not found in earlier versions of EUCLID and therefore differs from LEGO in a number of ways :

- view arrangements on the drawings are predefined and stored in a library:
- an interactive interface is available for the input of parameters:
- the part of the machine to be assembled and drawn can have any size from millimeters to kilometers:
- a tree structure of the components in each view is built and stored in the database. These assemblies are then calculated in a combinatorial way by recalling the leaves two by two, computing and storing the intermediate results. The final results is then extracted from those partial results.

A structure of any complexity can be calculated this way, the only limitations being the available CPU and disk storage space.

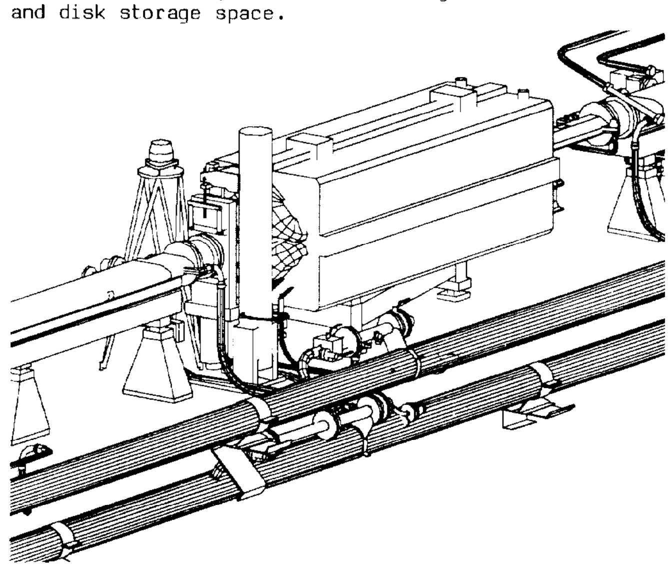

Fig. 3 Part of a detailed layout - Scale 1/10

LAYOUTS PRODUCTION

Producing accurate layouts at the rate imposed by the machine installation teams, i.e. up to 25 schematic and 25 detailed layouts per week, has proved a major challenge for the CAD system and personnel.

Each detailed layout requires over one hour CPU (Vax 8650) to be calculated and plotted whereas 15 minutes are required for schematic layouts. Results have to be stored on disk until the layouts are checked and approved. Two 512 Mbytes disks were reserved for this temporary storage. Plotting high-density drawings can only be carried out on electrostatic plotters which means vector to raster conversion and transmission of large plot files. Managing the production, checking the layouts and making the necessary modifications in the databases has occupied four designers for over a year. The following table lists some of the key production figure.

	LEGO	LEGO	ASMAC
Scale	1/250	1/50	1/10
Number of layouts (A0 size)	24	800	800
Number of components per layout	200	100	500
Computing time (VAX 8650)	5 min.	15 min.	1 hour
Plot file size	0.2 Mb	0.5 Mb	1.5 Mb
Plotting time (including transfer)	3 min.	6 min.	20 min.

STORAGE AND RETRIEVAL OF DRAWINGS

At present CAD engineering drawings are stored in two forms :

- the CAD database representation.
- the computed drawings representation plotted on vellum paper.

Paper is still in use as the common archiving medium for CAD and manual drawings.

In future all drawing images, whether made with CAD or scanned from manual drawings will be stored on a large capacity magnetic storage device such as WORM (Write Once Read Many).

This drawing database, together with the Euclid-Oracle interface (5) under development will make it possible for all end-users such as workshops, maintenance teams and accelerator control-rooms to access engineering data, and drawings at remote locations via a graphic terminal.

CONCLUSIONS

Validating the machine layout with the help of a 3D CAD system has resulted in a smooth installation with few time consuming and costly corrections having to be carried out on site.

The quality, readability and reliability of the CAD layouts is a major improvement over the hand drawn layouts of the past and is achieved with a much reduced work force.

The computer memorisation of the whole LEP machine is a tremendous asset in view of the possible future installations foreseen in the same tunnel.

REFERENCES

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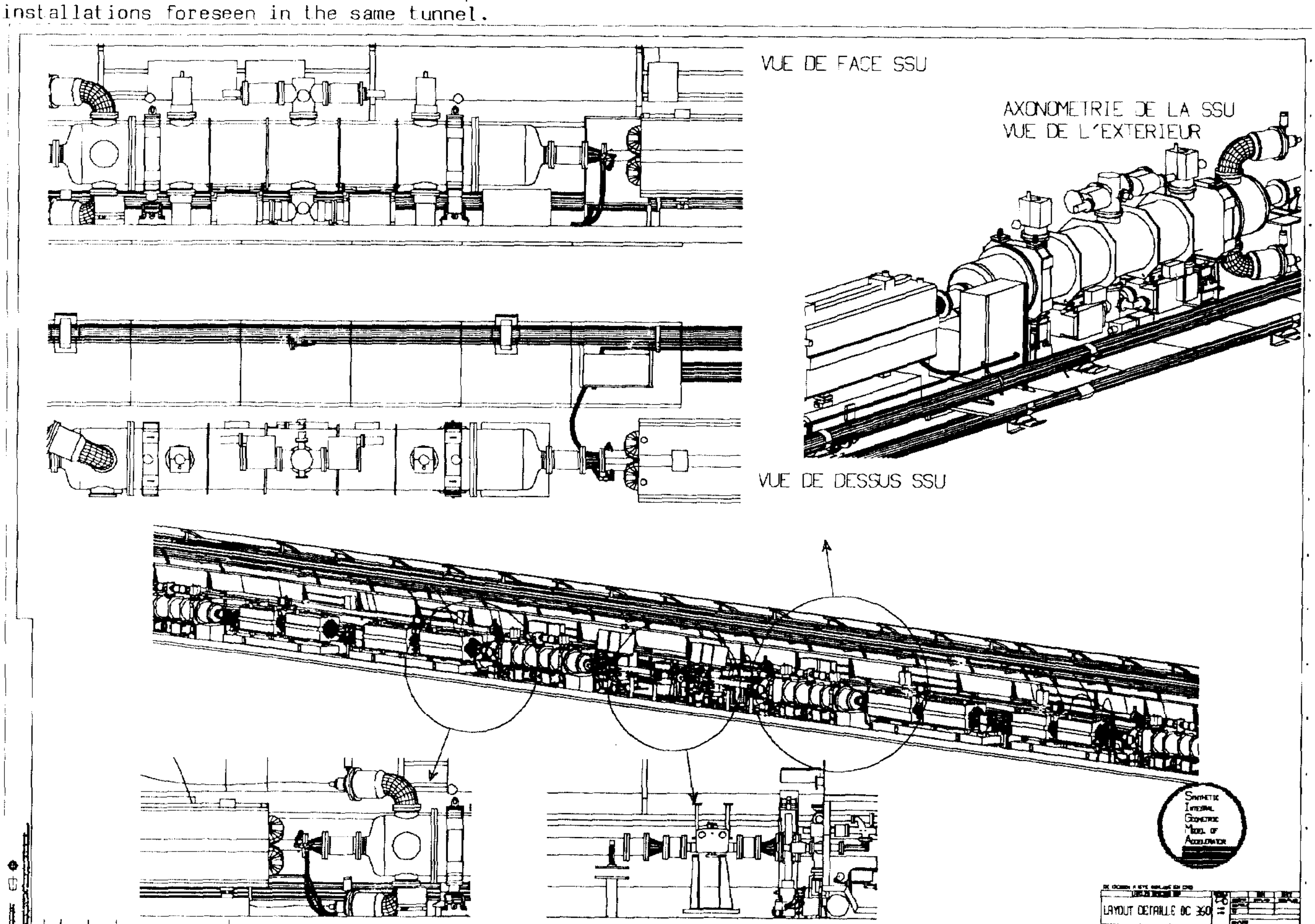

Fig 4 The detailed layout at interaction point 3. The complete LEP detailed layout comprises 800 such drawings - Real scale 1/10 and 1/50