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J. Millaud, F. Goulding, P. Salz, and K. Shimada

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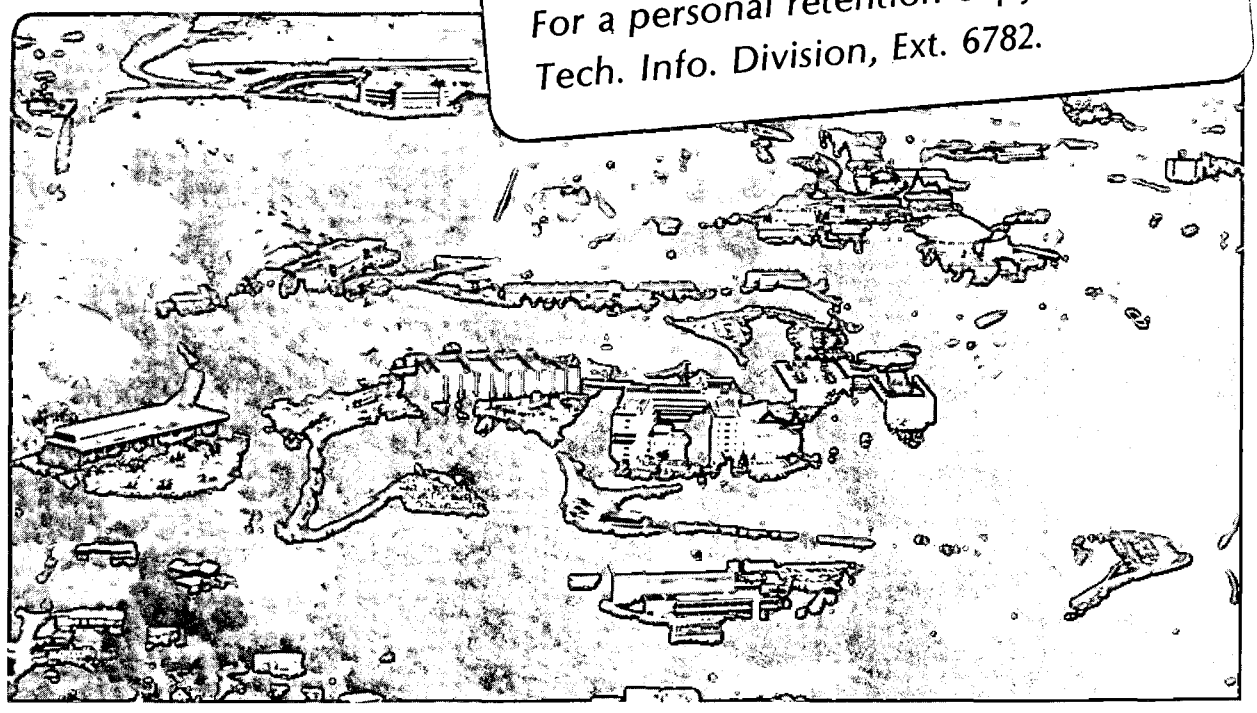

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SUMMARY

A two workstation Computer Aided Drafting system has been in operation since September 1982 at the Lawrence Berkeley Laboratory, Department of Instrument Science and Engineering.

Improvements made to the original hardware and software configuration are described. Benefits from this installation are reported and future developments are outlined.

BACKGROUND

The Department of Instrument Science and Engineering has close to 100 employees divided almost evenly between technicians and scientists working on a broad range of electronic engineering research, development and support activities. Three permanent drafters carry out most of the drafting load, the rest being performed directly by electronic technicians. None of these drafters had any computer experience before the introduction of Computer Aided Drafting in the Department.

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REQUIREMENTS OF THE SYSTEM

- Printed circuit board design.
- Schematics (including parts list and connections list if the board is to be wrapped).
- Data presentation for: publications, report, lectures, and poster sessions.
- Light mechanical drafting.

Figure 1 is a block diagram of the complete CAD system.

In 1980 F. Goulding designed a software package geared towards schematic drafting. This software, running on an HP9845, provided parts listing and systematic filing capability. It also provided us with the first experience on a computer with such capabilities to help us select the next system.

The new system was acquired in September, 1982 for a total cost less than $110,000 and has been operational since that time. It has been in operation 16 hours a day since August, 1983 and some of the processing is run automatically during the night.

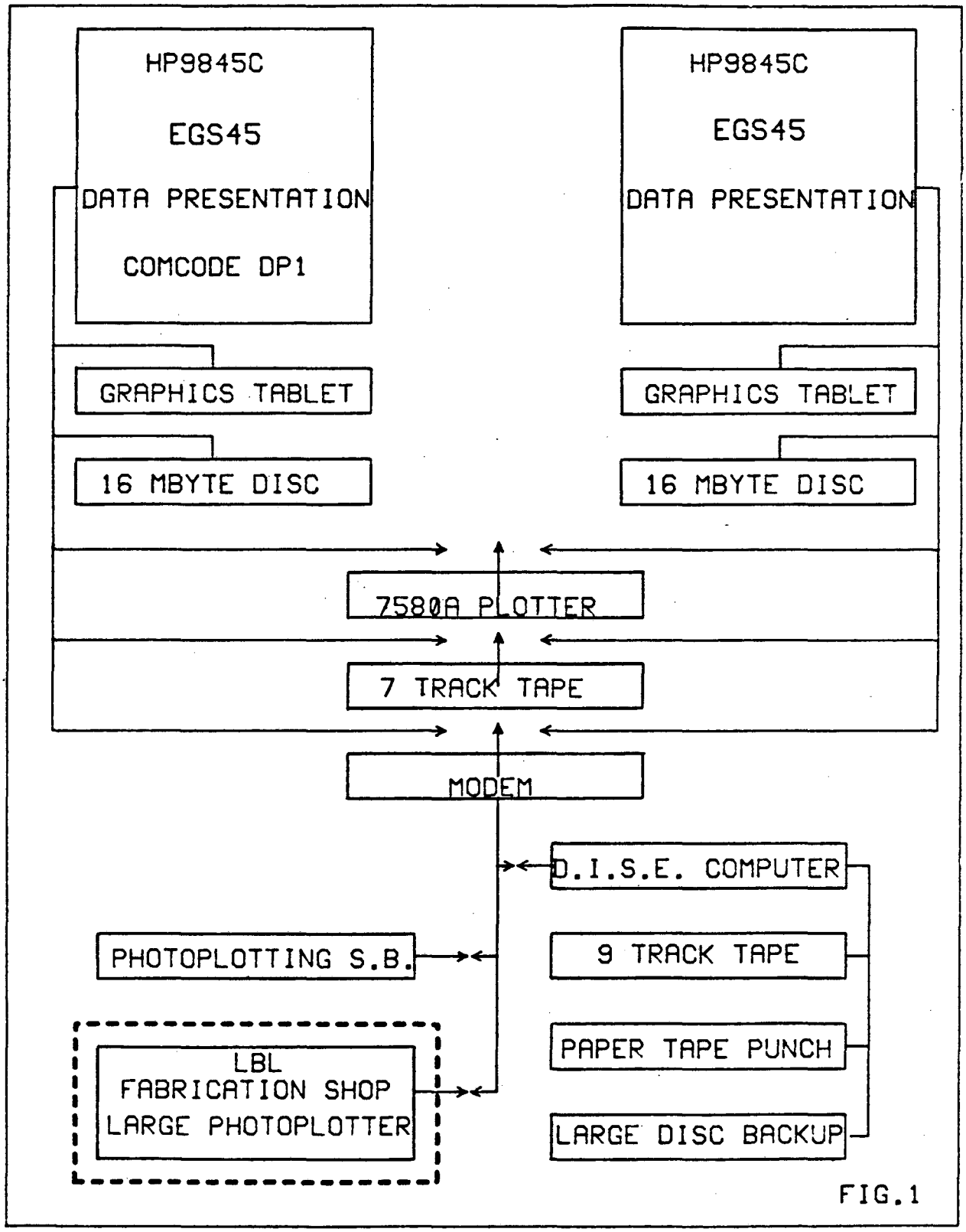
SYSTEM DESCRIPTION

HARDWARE

- Two independent workstations (HP9845C computers) operating under E.G.S. 45 software.
- Two Graphics Input Tablets (HP9111A).
- Two 16 Mbyte disc with back up cartridges (HP7908).
- One HP7580A plotter manually switchable to either machine.

SOFTWARE

- HP EGS45 Menu Driven
  - General drawing
  - Schematics (including parts list)
  - Printed circuit boards (including photoplotting and N.C. drill)
- HP Data Presentation Package
- COMCODE DPl Mechanical Drafting Package



CAD System Block Diagram

Initially the output device for photoplotter data was an old seven track tape recalled from retirement. It was used as an intermediate media. More recently, data has been sent via a modem either directly to a photoplotting service bureau or to a computer equipped with a nine track tape drive and a paper punch machine.

Our choice of computers operating under several independently selectable software packages (rather than dedicated workstations) is supported by the variety of tasks encountered in our work. In addition, the computers can potentially be used during the night for calculations and data processing.

PRINCIPAL LIMITATIONS OF THE SYSTEM

- Slow plotting speed
- Quite slow data processing (photoplotter data generation)
- No multitasking capability
- No connection list
- No autorouting and clearance checks
- Inadequate filing capability
- Board size limited to 32" x 32"

Some of these limitations have been overcome or will be in the near future.

IMPROVEMENTS MADE

HARDWARE

Addition of a modem connection to either:

Any photoplotting service company.

A computer equipped with the appropriate output device.

In the near future LBL's large photoplotter and printed circuit fabrication shop will be equipped with the transmission equipment to receive our data.

This structure is far less costly than the purchase and maintenance of a nine-track tape drive and a paper-tape punch. In addition, it simplifies the drafters' task by reducing the number of steps required to generate the data.

SOFTWARE

Use of incremental data and elimination of the Gnn codes:

- Reduce the volume of data to be transmitted by an average of 40% and decrease temporary disk occupancy.

- Allows transmission quality check by verifying that the coordinates check sums are equal to zero at the receiving end.

Interface to N.C. drill machines

- To make the N.C. drill codes compatible with LBL's machine.

Design of large boards

Large boards are used commonly in high-energy physics detectors. The 32" x 32" limit of EGS45 was overridden by designing the boards in independent sections. The photoplot data files corresponding to the sections are concatenated into a unique file after due processing. This technique allows us to easily achieve a 1 mil accuracy across the largest photoplotter beds (6' x 8').

Speed Up Processing

Systematic use of the COMMAND FILES module of the system has allowed us to do the processing during the night, thus avoiding any competition with the editing and drawing process. Standardization of the procedures and the pre-editing of a set of commands renders use of the COMMAND FILES very easy for the operators.

RESULTS

TRAINING SUPPORT

It takes no more than a week to familiarize an untrained operator with most of the commands of the Editor. Within a month the operator will reach a speed plateau. Knowledge of the output processing and good house-keeping of the files storage system is acquired more slowly because of infrequent use. Within two months the need for closer support by engineering staff totally disappears. Very limited support is then required for daily operation.

It must be pointed out, however, that engineering support must be available immediately in case of difficulties. An operator finding himself/herself totally helpless in front of a machine will rapidly develop feelings of aggravation and frustration.

Such support is not available from the manufacturers and we had to provide it locally. The person in charge of support is naturally also responsible for improvements and developments. For the first year of operation the level of support, including installation, has been in the order of 3.5 work months. In the future, this level should decrease slightly.

SCHEMATICS AND PRINTED CIRCUIT BOARDS

It is obvious that the extent of benefits when compared to pure manual operation is very much task dependent. Certain chores of manual drafting are totally eliminated (erasing, taping, untaping, etc.) and changes can easily be input. For this first year of operation the estimate is that time savings are in the order of 30% to 50%. This level may well improve with time as:

The number of new library parts to design is decreasing as the library grows to cover most applications. Schematics will always require new parts but their number is relatively small compared to the existing library. This is also true for apertures wheels and command files.

Better design approaches are slowly being put in application. For example drawings and layouts should preferably be built in relatively small modules assembled together in a final stage. This saves on panning time and minimizes memory occupancy. This is very different from practice in manual design and is necessitated by the relatively small area of the drawing displayable on the screen with sufficient accuracy and detail.

Processing of data files will be done only during the night through the systematic usage of command files.

Schematics: Editing is simplified in two ways:

Parts used have pin labelling. This used to be very much time consuming and a source of errors.

Repetitive patterns can be reproduced within a few minutes error free by a step and repeat command.

Parts list processing can be done during the night and is error free.

This inherent capability of limiting the errors to connections and parts referencing is extremely valuable as it decreases the time required to check the drawing as well as the time needed to enter the corrections.

Printed Circuit Boards: The keyword is accuracy:

The 1 mil limit is rarely used, however, for applications such as large detectors, it is almost impossible for manual operation to match the performance of the system. In such cases, time savings by factors of ten or more are possible.

In cases where shapes or patterns results from calculation and cannot be entered manually, it is always possible to create a BASIC file which will be read by the software and transposed into a layout.

For more conventional layouts:

Editing is simplifed by:

The existence of library parts which have components on all layers of the board including the silkscreen.

The availability of many commands allowing copying, step and repeat, rotate any subset of the board--all while keeping the 1 mil accuracy.

The automatic alignment of all layers.

The possibility to turn layers or component types (lines, circles, etc.) on and off.

The standard process allows a maximum of six layers including components and circuit included. However, the process can be easily expanded to accommodate more layers.

Additional savings result from the generation of the drill tape which eliminates the digitization of pad locations. The checkprint plotting is quite a time consuming task; therefore, we generally do this automatically during the night.

DATA PRESENTATION

The Data Presentation Package has been particularly useful for the generation of transparencies and large posters. It provides a choice of fonts and colors which certainly improve the quality of the presentations and would not be available to us without using the system.

ADDITIONAL GAINS

The time savings and quality work associated with the Computer Aided Drafting system have generated enough interest among users in the whole Laboratory to encourage them to have their drafting jobs done on the computers. It frees their electronic technicians from those tasks and allows them to focus on activities more challenging to their skills.

Last but not least is the increase in job satisfaction that has resulted from the use of the CAD for the drafter. In their own words, "they would have a hard time going back to the drawing board".

In summary, the introduction of Computer Aided Drafting has resulted in surprising savings in the first year of operation. The human response (in an environment where engineering support was immediately available when requested) has been extremely good.

FUTURE DEVELOPMENTS AND HOPES

Some of the limiations of the present system have been pointed out earlier in this paper. Some have been overcome within the present frame work:

- Maximum board size.
- Slow processing.

Additional improvements will be available in the coming year:

- Connection list allowing the generation of the codes necessary to drive a wire wrapping machine.
- Aperture wheel generation from the board file.

The present system wil be expanded, in a few months, by a third station (an HP9836CS) operating under EGS200. This additional unit will allow us to face an increase load while maintaining a high level of file compatibility between the different machines. It will provide an increased processing speed and a connection list capability. Furthermore, additional features should be available on EGS200 in the coming years.

Future plans are drawn towards the networking of the present machines and the inclusion in this network of Computer Aided Engineering capabilities.

It is hoped that the next generation of workstations will provide:

- More screen resolution in order to decrease the number of panning operations.

- A multitasking capability to allow editing as a foreground task and plotting or processing as the background task. Editing being an interaction with operators leaves the computer relatively free to take care of additional tasks.

- Simpler ways to interact with the machine. As much as possible the software should be didactic. Operators should be informed not only about their errors but their source(s) and the different options to correct them. The machine should closely monitor and inform the operator but never interfere with his/her choices.

CONCLUSION

Finally, considering that operators spend a non-negligeable part of their lives facing a terminal, there is a need for more research in the ergonomics of workstations. Noise and visual fatigue reduction are primary targets. Speech synthesizers could well bring some relief to the eyes while making good usage of a sense so far abandoned to listening to the sound of cooling fans. At a time when computers are increasing efficiency, it would be paradoxal to loose this advantage by giving little consideration to people.

DISCLAIMER

This report was done with support from the Department of Energy. Any conclusions or opinions expressed in this report represent solely those of the author(s) and not necessarily those of The Regents of the University of California, the Lawrence Berkeley Laboratory or the Department of Energy.

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