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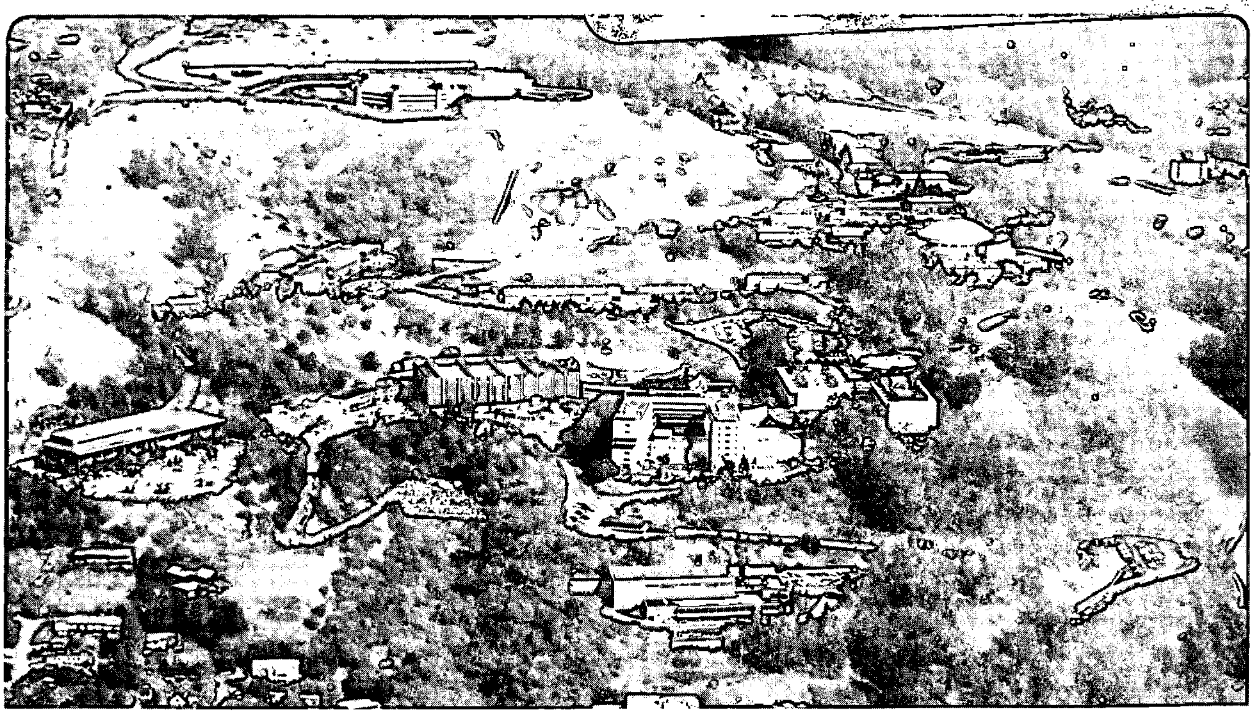

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CIM IN THE RESEARCH ENVIRONMENT *

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The title of this paper raises an issue which must be answered before proceeding : what is a research environment? Lawrence Berkeley Laboratory is a multiprogram national laboratory managed by the University of California for the U.S. Department of Energy. The Lab's role is to serve the nation's scientific and educational communities through energy related research carried out in it's unique facilities. LBL's role forms a four part mission : to perform leading multidisciplinary research in general and energy sciences ; to develop and operate unique national experimental facilities ; to educate and train future generations of scientists and engineers ; and to foster productive relationships between research programs and industry.

Current research programs encompass all the natural sciences, as well as engineering , mathematics , and computer sciences. Basic studies of the atom , as well as research on new treatments for cancer patients, and the development of new materials , and new energy sources are just some of types of reaserch going on at LBL.

Simply put the primary goal at LBL is to increase man's knowledge not produce a manufactured product. Manufacturing at LBL is first , last , and always a supporting role for whatever research projects are in progress. The Lab is actually a relatively small site manufacturing-wise with a very wide variety of sometimes quite exotic work. Combining the type of work done with a limited budget means that the laboratory is unable to commit to a BIG SYSTEM (ONE ANSWER) approach. LBL's approach to CIM has been , until recently , one of continual "fire fights" without ever actually instituting or formulating a long term integrated plan for bringing CIM to the Lab. This stems in part from the fact that CAM was in place at the Lab for a considerable time before CAD appeared.

The earliest version of CAM available at LBL is nothing about which one would brag these days , but working with punched cards was better than nothing (at least most of the time) . Remote terminals linked via hypernet to a CDC 7600 (shared by what seemed like every other person on the hill) were the next big advancement. This allowed batch jobs to be run and the tapes punched in house. Using machinists , turned into mostly self taught APT programmers , always made things exciting since no one really knew what was on a tape until it was test run at the machine. That was not exactly what anyone would call a cost effective use of machine time , especially when only one of each type of part programmed is being made. Then in 1982 LBL management decided that the CDC 7600 was too expensive to maintain and would no longer be able to handle the growing programming needs at LBL, so it was "being retired". At that point the shops had one year to find another way to do its' programming . Thus LBL entered into a search for the world of CIM having never even heard the terms CAD and CAM.

A selection commitee was formed and charged with enumerating a list of the Labs' and in particular the Mechanical Shops' present and future programming needs. The list of needs was quite extensive and heavily emphasized the CAM aspects as well as the need for compatability with the existing LBL computer facility operating systems. The decision was made in 1983 to purchase two Cadlinc workstations for the Mechanical Shops. These workstations would run cimcad 1.0 , gnc , and polysurf in a unix operating environment. These two systems were installed on Jan. 14,1984. The first parts programmed on these two systems were also cut on Jan.14,1984 thus alleviating the commitee's first concern about how long it would take to start being productive.

Because there are approximately only 10 to 15% repeat runs on jobs at LBL the approach to numerical control machining is somewhat different than at most manufacturing concerns. The program is usually not saved on any job which takes less than one hour to program. The decision of whether or not to run parts on N.C. machines is based more on the complexity than on the number of parts which will be made. While this may appear to be ineffective cost-wise (and it definitely is from a manufacturing-for-profit standpoint) it is often the only way of making the part. As frequently as not the parts which are to be produced are , for a variety of reasons , e.g. type of material , length of run , or even lack of prints , just not profitable for any one to manufacture. Because there are so few repeat runs and because the runs themselves are so short , it is crucial , for economic considerations to have correct tapes the first time. This becomes more and more evident as the programming time becomes a more significant part of the total manufacturing time . In order to produce the tapes in a minimum amount of time there is no attempt to put in all the details , eg. speeds,feeds etc., in the tapes . This is most often handled at the machine or in a conference with the engineer, programmer, and machinist. EVERYONE is expected to have some input on most jobs on which they are working. This system works reasonably well for the Lab partly because the individuals running the machines generally design all of their own tooling and also in part because all of the programmers are at least journeyman level machinists. All the candidates for N.C. machinists are selected from this group of experienced machinists based on their machining skills and their "N.C. aptitude" including their skill at fixture design and setups.

Turn around time is often critical as windows of opportunity open and close quickly on many projects and experiments. A great percentage of the jobs have little lead time. The prints and the material reach the shop at the same time so that while the first setup is being made the program is being written. When some one schedules time for his experiment on an accelerator at $5000 an hour and something breaks or is forgotten until the last minute things must move fast. Some times it is amazing at just how fast they move. One case in point is with the ion beams accelerators -- the Bevalac and the 184 inch Synchrocyclotron -- which are being used in experimental trials to develop more effective treatments for certain types of tumors in patients. A beam of ions can be focused and delivered to a tumor without undue damage to the healthy tissue surrounding it. Part of the focusing technique involves masking off the healthy tissue with material that will absorb the over flow or excess beam. These masks are created by X-ray scanning the tumor from four different directions , then digitizing the data and transfering it to a VAX where it is electronically picked up and processed into a usable format for down loading to an available machine tool. The machine tool then proceeds to either mill or drill the grid coordinates of the generated mesh surface. On occasion this kind of work has been done while a police car , with it's lights flashing , waits outside to pick up the finished parts as they came off the machine to deliver them for someone who is waiting on a treatment table following a last minute decision on their method of treatment.

In order to remain economically feasible LBL has just started experimenting with conversationally programmed machines so as not to tie up expensive workstations with simple (but necessary) jobs and also to provide NC capability to all of the machinists in the shops . This is being done because the shops have always tried to have the man who starts a job carry it to completion. In the past this method has been far more efficient than any other when working within the vagaries of research. The exception to this approach has always been if the parts needed NC work, the parts were routed to the NC department for what ever operations and then returned to the machinist who started the job. Conversationally programmed machines have the potential of allowing journeyman machinists with a minimum of NC skills to carry more of their jobs to completion while freeing up more of the expensive numerical control machines which are always at a premium.

At times the entire laboratory finds itself driven or directed by the needs of individual projects. A few of these in particular affected the Lab's approach to integrating computers into the engineering and manufacturing environment. LBL has built two of the world's three active radio frequency quadrupoles designed for the acceleration and focusing of heavy ions and has more in the works. These RFQ's are used in injectors for accelerators which are the tools used by scientists to generate beams of electrically charged particles with which they can probe the structure of the nucleus, study the force of gravity or diagnose and treat cancer. Over five miles of tape was required to produce the first set of radio frequency quadrupole vanes and all of the information had to be transfered from a remote VAX. This file transfer in itself was not a trivial problem because there was no software available for error checking the file transfers on the workstations. All the files had to be transferred repeatedly and then compared to one another for errors. This was the first warning that a means for error free file transfers from remote main frames was going to have to become a reality very soon.

The question of file transfer programs posed some difficult problems; the program had to be as close to universal as possible to communicate with anyone anywhere running on anything, and it had to be capable of transfering both binary and text files. It turned out that LBL as well as the other national laboratories were already using a file transfer program called "kermit" on most of their main frames. Kermit is a public domain program originally developed and presently maintained by Columbia University. The source code for a unix version of this program was secured from Columbia University and modified to run on a Cimlinc workstation. This program plays a key role in the use of CIM at LBL because it is runs on so many machines. These machines, whether they are main frames, workstations, or micros, have to be able to transfer any type of file to one another regardless of the operating systems involved at either end. At the present time any files, binary or ASCII, that are to be sent to manufacturing (Mech. Shops) are first transferred using kermit to a file depot maintained on a VAX 8600. This "depot" is a directory used only to pickup and leave files. The Mech. Shops are then notified either by electronic mail when they login or by phone that there is a file ready to be picked up. Regardless of the computers used the file transfers are done at each individual's convenience and no one is ever allowed access into anyone else's computer.

Another one of the projects being worked on at LBL is the nation's proposed Supercollider which when complete will be the world's largest scientific instrument and the most powerful particle accelerator in existence. It will have a 60 mile circumference with a surface area of up to 11,000 acres and contain approximately 8000-50 ft. long magnetic coils encased in a 10" diameter tube containing liquid helium at 4.3 K. The scale of this project is so immense that any errors will be magnified enormously. The coils required for this project will have to be produced at a rate of ten per day and will have to be better by a factor of ten than the best so far produced in a "one of a kind" situation. Because of the enormous costs involved in shutting down a facility of this size and opening up a section of the 60 mile long tube filled with liquid helium, these magnetic coils must also have an average life span of at least 50 years. This means that an increase of only 1/2% in the coil's reliability is worth millions of dollars. Part of the job at LBL has been in finding out what configurations work best both mechanically and magnetically. Another part of the job has been to determine what kinds of problems private industry will have in manufacturing some of these "sculptured surface" parts on a large scale to the kind of close tolerances necessary and within a relatively short manufacturing time frame.

The lab has come a long way with this type of sculptured surfaces project. At the beginning there were stacks of paper with hundreds of XYZ coordinate points on them and they had to be typed in one at a time. Then came the electronic transfer of data , either taken from a mockup by a technician or derived from a series of formulas on a scientist's computer. This process still involved transferring very large data files.

At the present stage a scientist or an engineer can generally just send to the shops the formulas he or she would be using on his or her own computer. The formulas are then translated and reformatted to run on the Mechanical Shops' work stations. These workstations can then directly produce the desired toolpaths in a machine code format. This has been so successful that it is not unusual to see parts being manufactured for which there presently exists no prints. The workstations in the shops have shown the ability to take over something that has always been the purview of the scientist or engineer and do it more economically. This increased ability has been a large part of the evolutionary process that has lead to the blurring of traditional roles and areas of responsibility. It is now possible to format the data for immediate use as a by product of it's creation on the workstations at the manufacturing site. This is an important feature right now since the manufacturing facilities are somewhat removed physically from the engineering facilities and as yet there is no ether net connection between them (though by mid 87 there will be).

Even though the large amounts of data necessary for creating sculptured surfaces can now be produced at the manufacturing work stations , the problem of getting it out to the machine tools accurately and economically still remains. The problem of insufficient memory at the machines is also becoming a problem. These problems have naturally lead to installing DNC (direct numerical control) which raised the question , of whether such a system would be purchased or built in house. It was decided that the shops would attempt to design and implement their own system. After experimenting with some after market add ons for the machine controllers some measure of success was achieved in down loading files to the machine tool by electronically emulating it's tape reader. It was later decided that what was needed to make the system most effective was to establish full screen editing with global subsiations coupled with the ability to send an edited tape file back to a file manager for storage. The Mechanical Shops are now experimenting with using several Macintosh computers as terminals connected to a workstation that is being used as a file manager. The Macintoshes are very economical and very similiar in operation (point the mouse and click) to the workstations now in use. Mac kermit is the public domain program which is used to down load files from the file manager to the Macintosh. A combination file transfer-editor program written in house is used to modify and transfer the tape files to the machine tools. With the present hookup it is possible to run a single tape file of up to 20 megabytes in size.

At LBL CIM continues to be a growing process and not at all the event that was expected. At the present CIM is still primarily individual pieces that are just starting to grow together. How they continue to grow at the Lab will always be a function of the new directions research continues to take and the demands that it makes upon existing technology.

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