SAN DIEGO: UNIVERSITY OF CALIFORNIA
LA JOLLA, CALIFORNIA 92037

August 4, 1976

Marcia:

Attached is the information on our 1975-76 NEH grant proposal. I did not xerox the Curriculum Vitae of the four professors involved that were included in the proposal.

For your information I xeroxed 25 copies on your budget #1401.

Please stop by if you would like to go through our files - this might be beneficial.

Ann Ramirez
Ext. 3311
Humanities Office

Attach.

SAN DIEGO: INSTITUTE FOR INFORMATION SYSTEMS

20 January, 1977

PAUL SALTMAN
Vice Chancellor Academic Affairs

SUBJECT: Campuswide Micro-Computer Based Learning Center

This is a proposal for establishment of a campuswide computer based learning center for joint use by courses taught in many departments. The proposal is an outgrowth of our experience in using small stand-alone computers in teaching introductory computer science (AP&IS-61) to large classes, and students in those classes would be one of the main groups to use the new center initially. There are strong reasons to arrange for the same kind of equipment to be used for semi automated testing in mathematics and psychology as a way to reduce present overloaded demands on Teaching Assistants in large courses. The testing approach, and some developed testing materials, have been in use at Irvine for several years with considerable success. For its own reasons, the Irvine group is now seeking to collaborate with us in order to take advantage of the micro computer technology we have been developing. In addition to existing needs for large class instruction by AP&IS, Mathematics and Psychology departments, the same microcomputers now contemplated could be used to satisfy high priority needs for support of upper division courses in Computer Science and Electrical Engineering. In all, we know of courses currently being taught which cover 4000 to 5000 student quarters per year for which the proposed Center would result in a rapid improvement of instructional effectiveness, and a longer term reduction in costs per enrolled student. It is virtually certain that this penetration would increase substantially if the proposed laboratory were available for use in connection with courses in other departments.

The reasons for wanting to combine resources into a campuswide learning center, rather than fostering growth in individual departments, are both economic and pedagogic. The computer based learning center should be operated in close collaboration with the learning media Playback Center that has started to operate this year on a provisional basis, since better use can be made of both kinds of media when used together. The new computer based learning center should be operated under the support and supervision of the campus Computer Center, if that can be accomplished without impacting the instructional objectives. The microcomputers that would form the basis of the new center would be used primarily as stand-alone computing devices connected to a central file storage and message switching microcomputer. At very little extra cost, this interconnection could be extended to make it possible to use any and all of the microcomputers occasionally as remote terminals connected to the B6700 central campus machine. Each microcomputer unit will cost only slightly more than a graphics terminal capable only of communicating with the B6700. The result should allow the campus to allocate its budget for Instructional Uses of Computers in such a way as to reach a nearly optimum balance between the large number of

students needing small scale computational facilities, and the small number for whom large scale facilities are essential.

This memo briefly describes the physical and economic characteristics of the proposed Micro Computer Based Learning Center, and its near term uses in teaching. I have directed the memo to you as the senior campus academic officer, though I would expect detailed policy and staff work will be done by the Campus Computer Policy Committee, the PRC Equipment Task Group, the Chancellor's Committee on Instructional Improvement Projects, and the campus Planning Office, all of whom will receive copies. Chairmen of the three departments immediately concerned, and the Director of OASIS will also be involved. For background, I attach a copy of a prospectus describing in detail the reasons for combining microcomputers with PSI (Keller Plan) methods to improve the effectiveness of instruction while reducing overall costs. The prospectus, with possible editing, will form the basis of an effort we are making jointly with the Irvine group to establish a multicampus Instructional Technology Project with extramural R&D support from a variety of agencies. For budgeting purposes, consideration should be given to initial operation of the proposed Center in 1977-78, since we are already embarked on a process of upgrading the equipment for the AP&IS-61 sequence, and the equipment for that sequence would amount to roughly half of the equipment needed for the campuswide center in the first year of operation.

1. Cost Arguments Favoring Micro Computers

The primary uses of the micro computers in the proposed Learning Center would be problem solving, and automated support of large PSI (Keller Plan, self-paced) courses. Both applications require interactive computing facilities providing graphics display screens. Our reasons for specifying micro computers, rather than larger timeshared machines, are mainly economic. With a timeshared machine, one uses an interactive terminal for connection to a large computer (or a large minicomputer) in which virtually all of the computation takes place. With the micro computers, most of the computation takes place directly in the device used as a terminal, and only a small investment is needed in communications and centrally located data storage. The instructional computing needs of the vast majority of the students at UCSD (at least 95 percent), and all of those in the courses we have in mind, can be handled using the modest computing power of a suitable microcomputer.

In the proposed Learning Center environment, each microcomputer costing about $4500 will be used approximately 2500 hours per year. Assuming a five year period for amortization, plus a reasonable allowance for maintenance, the effective hourly cost is about $0.40. The cost to use the B6700 services is about $5.00 per hour, plus disk storage charges, plus the cost to amortize and maintain the terminal, even when graphics is not an essential factor as it is here. A graphics terminal suitable for the instructional applications we have in mind costs about

the same as one of the complete microcomputers. Present or contemplated Instructional Uses of Computers (IUC) budgets for UCSD are not nearly large enough to pay for the volume of B6700 computing needed for the instructional applications we propose. Just for AP&IS-61 problem solving at present enrollment levels, the need is about 45,000 interactive hours per year, or about $225K for B6700 services plus the cost for terminals. Eighteen microcomputers will serve the same need at an acquisition cost of about $81K, most of which can be obtained from the planned sale of the set of PDP11 minicomputers now on hand for AP&IS-61. The addition of Interactive Computer Based Testing for Mathematics, Psychology, and for the AP&IS-61 sequence will raise the demand to about 100,000 interactive hours per year covering roughly 5000 student course quarters. This would require a total of about 40 microcomputers costing $180K, plus one central file/message handler costing about $15K.

2. Instruction Strategies

The strategies for using computers for support of instruction are described more fully in the prospectus on the California Instructional Technology Project. A copy is attached to the original of this memo, and copies will be supplied to anyone who requests them. The two strategies most directly related to large class instruction at UCSD are summarized in this section. Uses of the same set of microcomputers to support upper division teaching in Computer Science and Electrical Engineering will also be described. This section also describes the use of computer graphics for instruction. Teaching science or engineering topics with a computer lacking graphics is like lecturing on the same subjects without access to a blackboard or any other visual aid.

2.1 Problem Solving

The main reason we teach AP&IS-61, and the main reason for the enrollment of 400 to 500 students each quarter, is the need to teach virtually all students to be minimally literate in solving problems in an organized way. Teaching them to write computer programs is a secondary objective, though very important. We introduce programming skills through use of the language PASCAL, which was designed for teaching modern ideas of "structured programming". PASCAL is now becoming widely enough used that many students will have no need to learn any other programming language. Those who do need to learn another language will often be required by employers to articulate their problem solutions using a language fundamentally identical to PASCAL, and then to translate to FORTRAN, COBOL, or BASIC. We expect that most students who use the microcomputers in the proposed Learning Center will use PASCAL for problem solving. However, BASIC, COBOL and FORTRAN (and probably APL) will also be available for those who want them.

Since AP&IS-61 now reaches roughly 75 percent of the student population at UCSD, and since computer problem solving is a mainstay of most science and engineering disciplines, one can expect that readily available interactive computing facilities will generate an increased demand in future years. Students in AP&IS-61 each require an average of about 3 hours of interaction with the computer each week. Since one microcomputer can be used about 75 hours per week, before intolerable crowding sets in, about 20 microcomputers are needed to serve an enrollment of 500 students. There is no way to estimate how many additional machines may be needed in future years to serve students in other courses in which instructors may desire to have students work out problems using interactive computation. Problem solving use of the proposed Learning Center by students other than those specifically covered by this memo should be monitored and used by the campus for planning future expenditures of the Instructional Uses of Computers (IUC) fund.

I feel very strongly that graphics capability is essential for teaching AP&IS-61, as a way to reach the large fraction of our students who come to UCSD with no literacy at all for handling high school level mathematics. The technique I plan to use was introduced by Seymour Papert at MIT. It allows the student to work out logical problems which cause the computer to make line drawings on the display screen. The motivational benefit is greatly enhanced if the drawings can be made to move, a point that eliminates the possibility of using the popular graphics terminals made by Tektronix. The programming skills learned by students who are taught by this method are the same as the programming skills learned by students taught by the traditional mathematics oriented methods. Papert has found that the graphics oriented programming often prepares a mathematically illiterate student for susequent successful studies in mathematics.

Of course graphs are very familiar as a way to articulate the mathematical descriptions of all kinds of phenomena in science and engineering. Ten years ago, Glen Culler at Santa Barbara introduced an interactive computing system in which the graphic display of mathematical functions plays a central role. That system is still used extensively at UCSB for instruction, and it has been emulated widely. (?) As an extension of Culler's idea, one can use the computer to simulate certain physical processes, using a program that behaves according to the mathematical description of such a process, and using graphical display showing how a process operates. Alfred Bork and his colleagues at Irvine have been making extensive use of this idea for instruction. I would expect these uses of graphics to become very important at UCSD once the capability of the proposed Learning Center becomes known to faculty in the sciences. In all probability they will be made to know about the facility via their students who have taken AP&IS-61.

2.2 Computer Supported PSI - Automated Quiz Administration

Keller's Personalized System of Instruction (PSI) has been proven very effective, and very popular with students, but it requires a large amount of time from a staff of teaching aides called "proctors". Quite often, limitations in the number of available proctor hours have made it impossible to use PSI successfully. Though experienced undergraduates have been used widely and very successfully as proctors in PSI courses, faculties often refuse to allow them to be used as a substitute for graduate teaching assistants in that role. Where sufficient proctor time is available, as in our AP&IS-61 course, one finds that at least one half hour of proctor time per week is required per enrolled student if a good instructional result is to be achieved. One also observes that a substantial fraction of the proctor's time is taken up in routine activities that would be reasonably easy to automate using computers. The group at Irvine has automated the administration of quizzes for PSI courses in mathematics and physics, and thereby has roughly doubled the teaching effectiveness of their proctors.

In PSI the principal teaching value arises through a strategy in which points of confusion discovered in a quiz or homework problem are corrected immediately in the individual interview between student and proctor. In grading the quizzes, a large part of a proctor's time is taken up in routine checking of correct responses for which little or no additional interaction with the student is required. At Irvine, the PSI quizzes are administered by the computer, with a record of incorrect student reponses being saved for the proctors. A student who does not pass a computerized quiz is required to see a proctor as the next step in the process. This strategy reduces the amount of proctor time spent on routine matters, and allows concentration of the proctor's time on correction of points where students are confused.

When using computers for testing, it is important to find precise ways of stating the expected student response for each question. Methods of programming computers to evaluate unstructured or essay style answers are not yet well understood, and programming time is likely to be very extensive. This problem is what has led to the extensive use of the familiar, and not very effective, multiple choice testing method. The Irvine group has devised an effective variant of multiple choice that comes reasonably close to emulating the strategy that a human proctor uses to discover whether a student understands the subject matter covered by a homework problem or quiz paper. They call the variant "Hidden Multiple Choice", a strategy in which the student is presented with only one potentially correct choice at a time. Each choice must be evaluated independently before the student can proceed to the next choice. Moreover, the order in which the choices for a question are presented is varied randomly from student to student. The result is an arrangement in which the student is virtually forced to understand the subject matter in order to pass, since guessing, memorizing or cheating strategies are non productive.

In addition to Hidden Multiple Choice, two other types of student responses are relatively easy to implement in computer programs. One is a question requiring the student to give a numerical answer, or an algebraic expression that evaluates to a numerical result. The other asks the student to point to one or more locations on a graph that describes the subject of the test. This technique can be extended by asking the student to add one or more straight lines to a graph by pointing to their end points. Combinations of the three techniques are also easy to program, for example by asking a student to select a location on a graph by pointing, then to evaluate which of several possible graphs corresponds logically to the point selected. Once again, graphics is shown to be an essential part of effective instruction by these methods.

2.3 The Computer as a Data Collection and Evaluation Tool

The Interactive Computer Based Testing approach just described requires the use of a central computer capable of storing substantial amounts of data on the progress being made by individual students. The record keeping otherwise imposes a heavy burden on proctors in PSI courses, and the possibility of record keeping errors is substantial. The centrally located computer is used primarily for handling a "hard" disk drive of moderate size (25 million bytes), and for communicating with the microcomputers used directly by the students. These tasks can easily be handled at the central location by a microcomputer identical in most respects to the microcomputers used by the students.

Once the computer is used as a testing medium, it can also be used as a communication medium through which much of the proctor/student interaction takes place. Computers have already been used enough to support human intercommunication to be sure that they can be effective in this role for the support of PSI courses. Once again graphics is important as a blackboard replacement. The computer medium should be supplemented by voice telephone in some situations. One of the principal benefits of using the computers for communications should be the possibilities thus provided for capturing data on how a class is progressing, and for analyzing that data. This should make it easier to upgrade course materials, easier to check on the performance of individual proctors, easier to obtain feedback from individual students or to locate individual students who need supplementary help, and so on. The communication medium can be used to facilitate cooperative sharing of course materials between geographically separated campuses, and even to teach in a "Distributed Classroom" context in which students and proctors are not necessarily located on the same campus. Details on these points are discussed in the prospectus on the California Instructional Technology Project.

2.4 Instruction on Digital Systems Engineering

Instruction on the design of modern digital electronic systems is badly needed by many students at UCSD. Attempts are being made by the Computer Science group in AP&IS to establish courses in this area. An off campus lecturer has been hired temporarily to teach such a course in the spring of 1977, and efforts are being made toward a more permanent solution in future years. Evidence of the need can be found in the fact that the Physics department is starting a course this year to meet the need of its students to work with digital systems. Campuswide, the need appears to be for a course of at least two quarters duration, with an enrollment of at least 100 students in each quarter. At present, the most serious impediment to the teaching of a serious course in this area seems to be the lack of adequate equipment on which the students can carry out design projects. (This year the off campus lecturer's principal attraction is that he is bringing in his own equipment for the teaching!)

It happens that the microcomputers that now seem most cost effective for the teaching uses already described are also very appropriate as the basis for teaching a serious course in Digital Systems Engineering. The field is rapidly converting to use of microprocessors as a cheaper and more flexible solution to many problems that have previously been handled using specially designed electronic circuits. It is already true that people who spend most of their time designing digital systems, devote more than half of that time in writing and debugging computer programs. Accordingly, the industry has introduced both hardware and software aids intended to increase the designer's productivity, often by orders of magnitude. A "serious" course at UCSD needs to teach students to use these aids, and to demand them wherever they work. The Z80 based microcomputers that we have selected as the cheapest way to serve the problem solving and PSI support needs of the proposed Learning Center, are actually designed as the basis of one of the leading microprocessor development systems now available. Not all of the specialized hardware modules for assistance to equipment designers will be needed in the Learning Center. However, the number of microcomputers so equipped for use in teaching of Digital Systems Engineering could be kept to a minimum if students in DSE courses had access to the same basic machines in the Learning Center for use in program development. On average, students in the DSE courses will need about 10 hours per week of interactive time. An enrollment of 100 would require a total of about 14 microcomputers, at 75 hours per week per machine, with about 5 of these being equipped with the engineering design aids.

2.5 Instruction on Software Design

One of the most fundamental areas of instruction for Computer Science is the field of software design. AP&IS department courses in this field are required at the sophomore, junior and senior levels with a total attendance of over 200 students per quarter. A substantial

fraction of this attendance is from students who are not majors in Computer Science or Computer Engineering. Though the faculty teaching these courses varies regarding the amount of computer use required of the students, these courses as a whole are among the largest consumers of computing resources for instruction at UCSD and throughout the country. The observed average cost per student quarter for the software courses is at least five times the cost for the introductory AP&IS-61 course, and the software courses frequently run out of funds before the end of a quarter.

While some of the work in the software courses is so related to big machines that the B6700 must be used, a large fraction of the homework assignments could just as easily be carried out on the microcomputers that we propose for the Learning Center. In past years, AP&IS has requested funds to equip a classroom with computer terminals so that the computer science students would be able to make interactive use of the Computer Center. Because they will be able to communicate with the B6700, the Learning Center microcomputers will be able to serve a dual purpose, and would satisfy the needs embodied in the earlier AP&IS requests. The average load of about 200 students in software courses each quarter will require roughly 2000 hours per week of interactive time, or the equivalent of about 25 microcomputers. These courses currently consume, for B6700 time, enough funds to buy the 25 microcomputers in roughly 5 academic quarters. The amount being spent by the courses is not really representative of the need, since the students enrolled in these courses have represented a major drain on the unsupervised "Computer Literacy" accounts. In effect, the IUC funds now being spent by these students would buy the needed microcomputers in little more than one academic year, though the microcomputers would last for at least five years and could be used in many courses.

3. Design and Organization of the Learning Center

I stated earlier that the reasons for combining resources into a campuswide learning center are both pedagogic and economic. As you will see, it is difficult to separate the two concepts in this case.

3.1 Quantity Discounts

By combining our buying power in such a way as to acquire a large number of virtually identical units, we will qualify for very substantial discounts. In fact a move by UCSD in this direction is almost certain to trigger cooperative action elsewhere throughout the University, and also in the EDUCOM community. EDUCOM has asked me to run a national seminar on the concept of a "departmental" microcomputer, which is intended for general purpose university uses including instruction and word processing. The Seminar will be held at UCSD on 12 April this year. EDUCOM has been able to arrange for discounts of over 40 percent on some types of computer equipment to be

passed on to member campuses. They intend the same concept to apply to the microcomputer.

3.2 Protection Against Pilferage and Cheating

Stealing or damaging of equipment, and students who cheat, are the two largest operational problems likely to plague the proposed Learning Center. Compared with some campuses, UCSD has been very lucky in avoiding losses of computer terminals due to stealing or destruction. Now that small computers have become a major field for hobbyists, it is certain that the most attractive equipment for instruction will also be very attractive for stealing. As a result, proposals to distribute the microcomputers throughout the campus may not be very practical anymore.

The Irvine group note that recognition of "ringers" who take quizzes for friends is a problem when using the computer to administer quizzes. They also note that the same problem exists in any large lecture course, though we have fewer ways to detect ringers in that situation. The most practical strategy to combat ringers seems to be similar to the strategy used in UCSD's undergraduate library, where a picture identification is surrendered by the student upon entering a controlled area. There is no cheap and secure computerized technique to make a positive identification of a student, and the only practical solution seems to be to use a human gatekeeper. Unless the Learning Laboratory

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3.3 Central Message Switching and File Storage

With most of the needed computing power for the Learning Center located in the microcomputers, the principal need for a central computer is for the support of record keeping and intercommunication. These tasks do not require a large amount of computational power, and one of the microcomputers could readily handle the load. The volume of record keeping, and temporarily stored messages for individuals, will require the use of about 25 million bytes of fast access disk storage. This facility can be backed up with a film video disk unit capable of storing over one Billion characters of reference information. In

concept, the central microcomputer would serve a function similar to that of the "multiplexing" small computer now being used by the computer center for a classroom containing many terminals connected to the B6700. We would use a microcomputer virtually identical to the individual units used for teaching, as this would greatly reduce the problem of writing special software to run on the centrally located machine. Connections for all of the microcomputers to the B6700 could then be provided at little more than the cost of the interconnection line from B6700 to the central microcomputer.

MORE TO COME .....

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