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GIS Teaching Facilities: Six Case Studies on the Acquisition and Management of Laboratories (91-21)

Authors
Palladino, Stephen D.
Kemp, Karen K.

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GIS TEACHING FACILITIES:
Six Case Studies on the Acquisition and Management of Laboratories

Edited by

Stephen D. Palladino and Karen K. Kemp

National Center for Geographic Information & Analysis
University of California at Santa Barbara
Santa Barbara, CA 93106-4060

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Simonett Center for Spatial Analysis
University of California
35 10 Phelps Hall
Santa Barbara, CA 93106-4060
Office (805) 893-8224
Fax (805) 893-8617
ncgia@ncgia.ucsb.edu

State University of New York
301 Wilkeson Quad, Box 610023
Buffalo NY 14261-0001
Office (716) 645-2545
Fax (716) 645-5957
ncgia@ubvms.cc.buffalo.edu

University of Maine
348 Boardman Hall
Orono ME 04469-5711
Office (207) 581-2149
Fax (207) 581-2206
ncgia@spatial.maine.edu

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Preface

This compilation of reports describing GIS laboratory facilities for teaching is one in a suite of educational resources developed by the NCGIA. It is unique in that, where the other resources highlight course or laboratory exercise content, this report focuses on the actual physical laboratory. This report is intended to further the objective of the Center's educational initiative: to support and improve GIS education.

Key supporters of this laboratory facilities project were the Association of American Geographers and the National Science Foundation, through its establishment of the NCGIA. We appreciate the help of both of these agencies and the hard work of the authors of the site reports. We would also like to thank the many individuals who gave of their time to discuss their laboratory situations.

Introduction

Many colleges and universities around the world have begun to offer courses in GIS (geographic information systems), but many do not have access to adequate facilities for laboratory sections of these courses. The purpose of this NCGIA technical report is to provide examples of the successful establishment of computer labs for GIS instruction. Since every situation is unique, we have identified six colleges and universities with GIS teaching laboratories which together represent a broad spectrum of experience. Some of the sites have labs that are solely dedicated to GIS instruction. In many cases, however, laboratory resources are divided between GIS teaching, GIS research, and other uses. The sites also reflect a balance between labs operated and used by only one department and labs which are shared by departments.

In order to select the sites for our report, we identified several educational institutions that have instructional GIS laboratory facilities. Over twenty sites were contacted, many of which would have been good examples. We narrowed the field to six to allow for a more in depth view of each site. One person at each site was asked to write a report detailing the process they went through when attempting to set up their lab, the present configuration and operating concerns presented by their labs, and the manner in which the lab is used for GIS teaching. Each individual received a list of topics as a guide to writing, but for the most part the reports reflect personal style and the major concerns presented by each situation.

The following is a list of the individuals at each site with whom the NCGIA worked to compile this report. We greatly appreciate their efforts.

Dr. Richard Scott	Glassboro State College Dept. of Geography and Anthropology Glassboro, New Jersey
Dr. Susan Macey	Southwest Texas State University Dept. of Geography and Planning San Marcos, Texas
Dr. Peter Keller	University of Victoria Dept. of Geography Victoria, British Columbia
Dr. William Smith	Central Washington University Dept. of Anthropology Ellensburg, Washington
Dr. Gregory Elmes	West Virginia University Dept. of Geology & Geography Morgantown, West Virginia
Dr. Richard Wright	San Diego State University Dept. of Geography San Diego, California

This NCGIA technical report has been designed to provide the reader with a wealth of information that stems from experience. Points of similarity with your situation will most likely be found in some or all of the reports. The technical report begins by providing a summary of the situation at each site. This will give you an opportunity to concentrate on the reports which seem most germane to your own needs. Following the introduction are the separate reports from each site. Tables and figures referenced in each narrative are placed immediately after the text. These may include a diagram of the facilities, lists of hardware and software, proposed and final budgets, and other documents provided by the authors. Finishing off this technical report is an appendix of summary tables listing approximate values for a number of significant indicators related to lab use.

The tips found within the reports have the potential of saving valuable time and energy for anyone seeking to create a lab. In order to increase the utility of the reports, each author has concluded with a list of recommendations. We hope you will find the reports not only interesting, but also a valuable aid as you set up a new laboratory or re-evaluate an existing one.

Site descriptions

The following information is provided to give the reader a quick overview of the different situations represented in the six sites. The descriptions include the type of institution, the users and uses of the lab, and the size of the lab. The following can be used as a guide when reading the report. It will help you identify the sites and reports which have the greatest similarity with your own situation.

Glassboro State College

Glassboro State is an undergraduate teaching college in the state of New Jersey. It is a medium size institution of less than 10,000 students. The GIS teaching lab at this site is actually subsumed as part of a Social Science Computer Lab. The lab is, however, used extensively by the Geography and Anthropology Department. The sharing of the lab is necessary in the case of Glassboro due to small size of the Geography and Anthropology Department and due to the fact that as a teaching institution it does not generate the research funding that could support a separate lab.

Besides providing an example of a shared lab, this report also stresses the use of a LAN (Local Area Network) to connect the various computers. Most of the hardware in the lab is purchased from one vendor due to an educational discount and campus-wide service agreement. The report also addresses concerns faced by this type of institution and discusses general operational and configurational issues that arise when establishing a lab.

Southwest Texas State University

In contrast to Glassboro State, Southwest Texas is a fairly large institution of 22,000 students with a very large geography program. The university serves undergraduate and masters students. The department's focus is on teaching and training (e.g. applied geography), rather than research. In this case the lab is solely used by the Department of Geography and Planning. The need for a lab dedicated to one department is easy to understand considering the over 500 majors and masters students in the department.

The report highlights the close working relationship developed with a particular vendor. Both the hardware and software are primarily from this one vendor. This is a brand new lab which is just beginning to receive use. Though this report does not provide a wealth of hindsight on lab operation, it does describe a very current solution.

University of Victoria

This university is located on Vancouver Island in British Columbia, Canada. It is a PhD granting institution with an enrollment of about 14,000. The Geography Department has maintained a strong tradition in resource management research. Cooperation between the university, government, and industry has encouraged the development of GIS research and instruction.

The report focuses on two teaching labs. One lab is the outgrowth of a collaborative effort within the social sciences. It is a graphics lab based on DOS computers that was developed in 1988 to compliment a general use lab for social science. The graphics lab is located in and operated by the Geography Department and is used heavily for GIS teaching purposes. The second lab, just recently completed, is an advanced GIS teaching facility with RISC based machines.

Central Washington University

Central Washington is another university of about 7,000 students which offers both undergraduate and Masters level graduate education. The GIS lab is a multidisciplinary facility. The three directors represent the Anthropology, Geography, and Geology Departments. It had its origins in funded research. Over time it has evolved into an instructional facility as well.

This report discusses the use of the lab for short workshops. An important ingredient to this report is the strong connection of the lab with a single public domain GIS software package. The hardware includes a mix of systems. Also emphasized are the benefits to the lab of public service efforts.

West Virginia University

West Virginia University is the primary PhD granting institution for the state. It has a student body of over 17,000. GIS laboratory instruction takes place in a Department of Geology and Geography facility. This lab serves 60 undergraduate and graduate students each year and has both teaching and research functions.

This report outlines a series of proposals both funded and unfunded that have established and sustained the lab. The use of funded research to keep the lab viable for both teaching and research is discussed. Hardware and software are described in detail.

San Diego State University

This large university of over 30,000 students mainly serves undergraduate and masters students, although some departments, including Geography, have joint PhD programs with the University of California. The department serves over 200 students. This relatively large department provides GIS laboratory instruction in its research foundation-funded GIS and digital image processing center.

The report demonstrates balances between teaching and research and between GIS and remote sensing. The lab is arranged in a modular format with groups of hardware types. The mix of computers includes DOS, Macintosh, UNIX, and VMS based machines. This is another example of a lab in which GIS teaching is supported by research. In this case, the report highlights the relationship of various individuals and organizations to the lab.

Glassboro State College

John F. Frisone
Department of Psychology
Richard A. Scott
Deptartment of Geography and Anthropology

September, 1991

Glassboro state college social and behavioral sciences computer lab

I. CONCEPTUAL STAGE

Origin

The idea for the Glassboro State College Social and Behavioral Sciences Computing Laboratory grew out of a need perceived by the two laboratory directors, Dr. John F. Frisone of the Psychology Department and Dr. Richard A. Scott of the Department of Geography and Anthropology. The two directors had met initially during the early 1980s at a time when Dr. Frisone headed an IBM PC users group on the Glassboro State College campus. This group met on a monthly basis to discuss problems and opportunities in the then rather new world of personal computing. Although we can not remember the exact date, sometime during the 1985-1986 academic year, in the course of a chance encounter in one of the college's parking lots we began, as was and is very common, to discuss computing. Each of us had considerable experience working with students in courses in which we attempted to teach computer applications (Frisone in a methods and statistics course and Scott in a computer cartography course). Each of us had experience with trying to teach students to operate complex software packages using a method that started with an in-class demonstration of the program and then followed with an assignment accompanied by detailed written instructions describing, step-by-step, how to carry out required procedures. We and our students had experienced the frustrations that stem from the lack of directed hands-on instruction inherent in this approach. In addition, the existing open computer labs in which machines are there for any student or faculty member were heavily used, frequently lacked the kinds of specialized software packages we wished our students to learn, and in many instances had inconsistent groups of software loaded in inconsistently performing machines. Departmental facilities were more appropriate, but neither department had a space in which numbers of computers were available for students to use over the course of the day.

During our discussion we realized that there were many similarities, and some differences, in the kinds of computer equipment, software, and data that students in our departments needed to use. Additionally, we realized that other departments housed in our building might also benefit from availability of a lab in which their students would have access to appropriate software and data. Specifically, in addition to geography and psychology students, those in sociology, political science, and history, to one degree or another, could benefit from such a lab. To us creating a single lab designed for students in related disciplines had obvious advantages from the standpoint of scale economies and interdisciplinary interaction among faculty and students.

At this time, although the Department of Geography had taught a course in computer cartography since 1975, there were no courses in GIS at Glassboro State College. Of course, inasmuch as our plans for the lab explicitly included the needs of a computer cartography course, many of the requirements for teaching GIS at the undergraduate level were addressed in our plan. The first GIS courses at the college, following the NCGIA core curriculum model, were taught during the Spring and Fall semesters of 1990.

To provide a context for the discussion that follows and to help you evaluate the relevancy of our situation to yours, we would like to tell you a few things about our institution. Glassboro State College is a comprehensive four year school that focuses strongly on high quality teaching at the undergraduate level. In recent years the college has placed more emphasis on research and publication, but in all phases of faculty evaluation teaching is given more weight than research. Normal teaching load is four three-credit courses per semester; however, released time from teaching is granted to those who wish to spend more time on research or other activities such as directing a computer lab. One manifestation of the emphasis on teaching is small class size. Most general education courses are limited to thirty-five students. If warranted by the nature of the subject, writing classes for instance, the size limit is even smaller. Upper level courses often have enrollment limits of fifteen to twenty-five.

The college enrolls about 9,500 full and part-time students in four schools: Business Administration, Education and Related Professional Studies, Fine and Performing Arts, and Liberal Arts and Sciences. These students range very widely in quality of preparation and background. For instance, the average student in the 1991 entering class scored 980 on the SAT and ranked at the seventy-sixth percentile of his or her high school class. In the past year students in the geography program who took the GRE earned combined verbal and quantitative scores ranging from 880 to 1460.

All of the departments that participate in the Social and Behavioral Sciences Computing Laboratory are housed in the School of Liberal Arts and Sciences. The geography program, which offers a BA. requiring completion of thirty-six semester hours, has grown modestly in recent years and now has about 63 majors. Of the departments participating in the laboratory, Geography is by far the smallest. We do, however, offer three courses in computer applications and are consequently heavy users of the lab.

Need Assessment

Our first step in planning a course of action leading to improved computing resources for our faculty and students was to survey our colleagues in our own and other social science departments to ascertain the kinds and amounts of equipment that would be required to serve the departments involved. Our initial estimate based on these interviews was that each semester 275 students enrolled in 18 courses would require use of the computers. Informal discussion with colleagues and our experience with assigning computer exercises in our classes led us to the conclusion that a reasonable average per student time allotment would be three hours per week. Since most college labs are open 12 hours per day at least five days per week, we made the assumption that our lab would follow this sixty hour per week schedule. Based on these estimates we concluded that a laboratory with 14 computers could meet the estimated demand.

Because of the frustrations we and our colleagues had experienced in maintaining software on stand alone micro-computers (loading up-dates on each machine, restoring lost files that were purposely or inadvertently erased by users, copying exercise data sets onto the hard drive of each machine or providing each student with a diskette containing the exercise data, and many others), we decided that the computers in our lab should be tied together in a local area network (LAN). The LAN configuration provides many significant benefits at relatively little additional cost, especially if part of the cost calculation includes faculty time spent in maintenance of software and databases. With the network and its associated user interface, software and data loaded on the file server are available to each node. Even more important the networking software allows assigning each user a "privilege level" that determines the kind of file access he or she has in the various hard disk directories. The ability to protect files and directories greatly reduces the likelihood of purposeful or inadvertent erasure of data and software. It also greatly reduces the likelihood of software piracy.

II. PROPOSAL STAGE

Mandate

The stated objective of our lab, as described in the proposal, is to:

> ... establish an advanced social and behavioral science computer laboratory. This laboratory will allow for the introduction of the computer into the curriculum of advanced methodology courses in the social and behavioral sciences. Students will be able to obtain realistic "hands-on" experience with the methods currently used in their disciplines. The hardware and software obtained will be capable of performing statistical analysis, charting, graphing, and map making.[1]

We feel strongly about this mandate and in our handouts and in our workshops for faculty we emphasize that our lab is not designed to serve as an instructional aid analogous to a slide projector. That is, we did not design the lab to serve as a classroom in which the computer is used to illustrate concepts being discussed in a lecture. We also point out that the lab is not intended to support computer aided instruction in which the computer is used as an inanimate teaching assistant there to help students learn subject matter. We emphasize that our goal is to teach students to use the computer as a tool for helping perform the work required to carry out research in their academic disciplines. Making the intended purpose of the lab clear at the outset avoids problems such as having instructors attempt to schedule classes in the lab on a full-time basis so that they can use that "really neat" computer assisted instruction package that just came out.

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[1] John D. Frisbone and Ricahard A. Scott, proposal abstract of Advanced Social and Behavioral Sciences Computer Laboratory, submitted to the New Jersey Department of Higher Education Computers in the Curriculum Grant Program, June 1, 1987. This state funded grant program, now ended due to budgetary constraints, provided funding, on a competitive basis, for proposals submitted by private and public institutions of higher education throughout the state of New Jersey. Our proposal was one of 38 funded from a pool of 153 applicants.

Components

The proposal format followed a formula required by the New Jersey Department of Higher Education (NJDHE) Computers in the Curriculum request for proposals. A major portion of the proposal is the "Project Narrative." This narrative includes the following:

1. Statement of the objectives of the project.
2. Discussion of the relationship of the project objectives to the current activities and priorities of the college.
3. Proposed equipment and software required to meet the project objectives.
4. An outline of the activities that will be required to complete the project.
5. Estimate of the number of students affected by implementation of the project.
6. Overview of immediate outcomes and long range benefits.
7. Summary of the college's commitment of human and financial resources to the project.
8. Plans for continuing project activities after the end of the grant funding and plans for obtaining additional funding to continue activity.
9. Plans for evaluating the success of the project, and a plan for administration.

The proposal also required a detailed description of the computer equipment we planned to purchase. Given that we wished to set up a lab configured as a local area network and that we had determined that 14 network nodes would meet projected demand, our basic equipment request was for fifteen IBM PS/2 computers: one Model 60-071 with a large hard drive to serve as a file server and fourteen Model 50-021 computers to serve as network nodes. Also required by the network configuration were fifteen network adaptor cards, two multi-station access units, and cables. To keep costs down we proposed that ten of the computers be equipped with monochrome VGA monitors and that only five have color VGA monitors. In addition, we proposed one dot matrix printer for each two network nodes, several modems, a laser printer for the full network, a digitizer, and a plotter.

Proposed software included PC-DOS, IBM Net Bios Networking Program, statistical analysis packages (Systat and Statpac), mapping and GIS packages (e.g., Map Analysis Program, AtlasAmp, Surfer, EPPL-7, and Atlas Mapedit), word processing (WordPerfect), database management (dBase III Plus), and spreadsheet (Lotus 123). Decisions concerning items to include in the list of proposed software were based on the experience of the two proposal writers, college policy (i.e. the college adopted WordPerfect as a campus-wide word processing standard), advice from the project consultant, Dr. David Cowen of the University of South Carolina, and informal survey of instructors who were likely lab users.

Budget

The budget request sought funds from two sources: the granting agency, the NJDHE Computers in the Curriculum grant program and the college in the form of institutional support. The total amount requested was $117,327, which included $93,878 from the granting agency and $23,449 in institutional support. The budget request includes money for faculty released time, clerical support, faculty summer salary, consultant's fee, travel, equipment, software, dissemination effort (i.e., letting other schools in the state know about the project), and indirect costs (space, heating, etc.)

Table 1 provides a detailed listing of the hardware and software in the original proposal, submitted in June of 1987, which requested project funding for a one year period. We reproduce it here so that the proposed equipment and software components can be compared with the items actually purchased with the grant monies.

Support

At the time we were writing the proposal we considered only two sources of project support: the college and the NJDHE Computers in the Curriculum grant program. Several of our colleagues had obtained rather generous grants from the DHE grant program and had established micro-computer laboratories for their departmental faculty and students. With these examples of success and a set of ideas we believed could form a rather compelling argument for funding, we decided to apply for a DHE grant to be funded in the 1987 fiscal year. The panel of reviewers rejected our first grant proposal, which we submitted in the spring of 1986. Interestingly, they commented that the networking configuration seemed expensive and unnecessary and that the computers we wished to order (IBM AT machines) were too expensive and high in performance for an undergraduate lab. The very next year (fiscal year 1988) we submitted a second proposal, which was essentially the same as the first, with revisions that responded to the previous year's criticisms. For example, we explained why moderately expensive, powerful machines were required for the graphics and statistical applications we had in mind and we provided additional support for the LAN idea. Between the time of our first proposal (June 1986) and the second (June 1987), the NJDHE had instituted a new grant category for networking projects. Suddenly, our proposal, which one year previously had received criticism for including what was then perceived to be superfluous networking, was viewed positively, in part, because it incorporated the very same feature. To us the moral of this is that if you have done your homework and know that your proposal is strong, do not be intimidated by the rejection of a committee that may not be as close to the "cutting edge" as you are. Given time they might see the light. One advantage of waiting a year is that we were able to equip the lab with PS/2 computers rather that the older AT models. These machines have proved to be very reliable and benefit from our campus-wide IBM service contract that provides coverage for all PS/2 machines.

A number of individuals and administrative offices assisted us in the process of writing and designing the proposal. In addition to the Grants Office, we found that consulting those who had previously obtained funds from the same program was very useful. Those who have experience with a similar project can be helpful in providing realistic estimates for dollar amounts to request for "fuzzy" kinds of budget items such as released time, clerical support, consultants, travel, telephone, postage, and space. These items are fuzzy, not because one is unable to get an estimate for how much a unit of each costs, but rather because one has a difficult time knowing in advance how many units will be required.

Hurdles

Rather than emphasize hurdles, we would like to stress the support we obtained, especially during the writing of the initial proposal, which was rejected. The problems we encountered at the stage of our second proposal, which was successful, were the result of the grants director being promoted to serve as executive assistant to the provost. Although he still had some oversight of the grants office, day-to-day responsibility for administering that office fell to a faculty member serving only three-quarter time. Although she lacked the expertise of her predecessor, this individual was helpful in assisting with some of the details of the proposal. A good grants office can smooth the proposal writing process.

Documents

The NJDHE specifications concerning required proposal components were very specific. The proposal had to contain a "Cover Sheet" that specified summary information concerning the project, its directors, and the total amount of money requested both from the granting agency and from the college. Also required was a one page "Abstract" providing a concise summary of the project. The majority of the proposal consisted of the "Project Narrative," which had to follow a strict outline stipulated by the NJDHE.[2]

Following the project narrative is detailed information concerning the budget for the project and detailed specifications for the hardware and software. We believe that, given a proposal narrative that makes a good case for a computer laboratory project, the segment of the proposal that reviewers will scrutinize most closely is the equipment and software descriptions and budget. From these, knowledgeable reviewers can determine much about the proposer's level of expertise, planning effort, and currency of knowledge. We urge those who write grants for computer laboratories to devote much effort, research, and thought to equipment and software specification and to be as precise as possible to the point of specifying exact model numbers. Doing this embosses your proposal with an air of expertise and yet in most instances does not commit you to the items you specified--in an area in which technology, markets, and pricing change so quickly no sensible grant program would forbid changes from the original proposal. Finally, the proposal included resumes of each of the project directors and a brief description of the college.

III. ACQUISITION STAGE

Acceptance and Budget

The NJDHE accepted our proposal with only minor required changes in the budget. We had originally requested $93,878 from the Computers in the Curriculum grant program and $23,449 from Glassboro State College for a total of $117,327. The NJDHE Computers in the Curriculum program awarded us $84,500. They made funding contingent on our cutting hardware and software costs, and decreasing the amount of released time requested or assigning more of the cost of the requested time to Glassboro State College. To meet DHE requirements we convinced the college to assume more of the

[2] Required topics are listed in section II 2. COMPONENTS.

cost of the released time, which we did not wish to decrease. We did reduce the amount of summer salary each of us would receive during the year of the grant. These changes had the effect of increasing the college contribution to $23,994 for a total project cost of $108,494.

We were able to reduce the costs of hardware, as NJDHE requested, with no reduction in the quantity of equipment purchased. This fortunate outcome was the result of declining hardware costs resulting from IBM's inauguration, during June of 1987, of a forty percent discount program for academic institutions. Even though the final budget was almost $9,000 less than our original request, we were able to purchase a more powerful file server than proposed (a PS/2 Model 80-071 rather than a Model 60-071), equip all of the nodes on the network with color monitors, and acquire two digitizers instead of one. We further reduced costs by eliminating some redundancy in the software and by using "shareware" packages in lieu of commercial software in several instances.

Purchasing

Because of the IBM discount program and the comprehensive service contract that the college purchased from the company, the Office of Academic Computing urged that new purchases take advantage of these pricing and service features whenever possible. Thus for most of our equipment we interacted with a single vendor, IBM. Because there were so many potential sources, other items that we purchased, the digitizers for instance, required much more research and effort per item. The purchasing process as we experienced it brings to mind the computer programmers dictum that ninety percent of the code takes ten percent of the time, while the remaining ten percent of the code takes ninety percent of the time.

We did learn a few things about mail order purchases. First, at each vendor get the full name of everyone with whom you speak. Mail order houses seem to have a high rate of employee turnover. If you were given a price or statement of policy over the phone, and then call back later to continue dealing with the vendor, you will sometimes find that the individual you spoke with originally is gone. If you can tell the current sales representative the name of the person you dealt with originally, then there may be a record of any agreements or the vendor may have assigned a current employee to take care of any outstanding business of the former employee. Second, get all estimates and statements of policy in writing. This seems obvious, but in the press of the moment one can easily forget. Third, for technical advice bypass the vendor and seek out the manufacturer's technical staff. Some vendors seem to have sales staff that are long on technical talk and jargon but short on accurate and detailed technical knowledge. If you have questions about equipment or software performance or compatibility, our experience is that the technical representatives of the manufacturer are better able to provide answers than most sales people. Fourth, try to establish a uniform ordering process with all vendors with which you work. Glassboro uses a campus-wide computer network for generating requisitions and purchase orders. Most vendors will ship equipment on receipt of a purchase order. At the other extreme, some vendors require payment in advance. In most cases we were able to convince vendors that we had no choice but to send a purchase order that would be paid promptly on receipt of the goods. The few cases in which we had to get payment in advance required filling out forms by hand and in-person visits to our purchasing department to get special consideration from an overworked staff. Get vendors to adapt to your system. Your sanity will improve greatly.

Physical Plant

At a very early stage in writing the proposal, we had wondered where our lab would be located if a grant were funded. Not wishing to go through the considerable effort of writing a successful grant proposal without assurances as to the college's willingness to provide appropriate space for the facility, we went to the college's grant officer to ask where the lab would be located. His response was, "You get the computers and we'll take care of the space". With only this oral agreement, we went merrily on our way writing our grant proposal. Let us say that the oral agreement did hold: we were provided with space for our lab, but the number of telephone calls, memos, and meetings devoted to inquiry and pleading about where the space would be and then when it would be ready to accept the computers could itself be the topic of a paper.

Even though the college had slightly shrunk in size over the years, there was and is no "space dividend". As the number of students declined and the number of faculty fell through attrition, much of the classroom space that otherwise would have been surplus was reassigned for use as computer labs and other computer facilities. In our building, Robinson Hall, the college had converted two classrooms into offices for Academic Computing and had converted three other classrooms into computer labs: two became one large open lab and one became a lab for mathematics education. Because all of the departments that would use the SBS Laboratory are housed in Robinson Hall, locating the lab in that building was a foregone conclusion. The only questions were where and when.

In many respects the space question is an example of the classic zero sum game. Someone had to lose space if we were to gain a place for our facility. Although we are not aware of all of the behind the scenes negotiating that occurred, we do know that the decision concerning where our computers would reside took a long time. We had ordered the vast majority of the hardware at the beginning of the 1987 fall semester shortly after the first installment of money arrived from NJDHE . The decision of where to locate the lab was not final until after this equipment began arriving. Of course, preparing a computer lab requires much more than assigning space. Just to mention a few major details: the room had to be painted, the electrical capacity had to be checked, and security systems had to be installed. When work started on these final preparations, the fourteen computers that would serve as network nodes had begun to arrive and had to be stored, under less than ideal security conditions, in the Psychology Department office. There was also the question of just what is included in "the space". Our colleagues in the Physical Sciences Department, who had won a grant under the same program a few years earlier, had told us that, at no cost to the grant, the college's maintenance staff had built tables and desks on which to place the equipment. Possibly, we lack the charm of the physicists. Nevertheless, rather late in the game we discovered that the college was not going to build desks or do anything beyond painting and security. At a very late date we had to find room for computer tables in an already tight budget. The result was that we were forced into a position of placing fairly expensive computers and related equipment on very cheap tables in a facility to be used heavily by a large number of people who might not be as careful as they should be about sitting on tables and the like.

There are several lessons here. Space is such a difficult and emotional issue that those with the power to make decisions may wish to avoid or at least put them off until the last possible moment. Many individuals seem to have very strong territorial attachments to the space they inhabit. They may resist giving up that space even if an equivalent alternative is available in the same building. At the same time the computers do have to go somewhere. In retrospect, we should have been much more insistent and more formal in our dealings with the administration. Our failure to push hard enough resulted in delays in getting the lab up and running. Also our expensive equipment had to be stored in a less than secure environment for a period of time first while the administration was making the final decision and then while we were goading the Maintenance and Security Departments to prepare the space. Because these final preparations were rushed, some of the work was not done to as high a standard as we would have liked. For instance, the amount of surface preparation done prior to painting was inadequate to the point that damaged acoustic tiles that had been installed on one wall to improve the sound proofing required for the humanistic psychology classes held previously in the room were left in place because removing them would have delayed the painters for a week at which time they had other jobs scheduled. The damaged tiles remain as a reminder of the previous function of the room, as a conversation piece (students new to the facility invariably ask why they are there), and as not so subtle reminders of the "space issue" as we encountered it. The moral to all of this is to get agreements on space up front and in writing.

IV. OPERATIONAL STAGE

Configuration

The Social and Behavioral Sciences Laboratory complex consists of three areas (Figure 1): an office for the two laboratory directors that also houses the file server, currently an IBM Model 80-071 with about 200 Mb disk storage; a faculty work area that contains four network nodes and some room for expansion; and the SBS Lab itself with 14 network nodes (IBM Model 50 each equipped with a local printer), two network printers (labeled Printers on the diagram these are an HP Laserjet II and an IBM Quickwriter), two digitizers (Kurta IS/1 12 x 17 inches), and a plotter (IBM 7372).

To help you understand the use of our lab in teaching GIS we would first like to describe the two GIS courses we offer. Our introductory GIS course provides a broad overview of GIS including the hardware and software components, database models, sources of data and problems in combining disparate sources, GIS analysis techniques, raster and vector issues and contrasts, GIS application areas with example cases, and an overview of GIS system planning. The laboratory component of the introductory course is built around the use of OSU-MAP to solve locational problems. In a word, GIS analysis is at the center of all of the laboratory activities. We have found that answering the question: "What kinds of problems can a GIS solve?" through the example of the lab exercises is something that grabs the students' interest. On many occasions students have kept their instructor in the lab until after midnight because they have become so involved working on the exercises. The advanced GIS course is much more technical and focuses on the inner workings of GIS. Topics in this course include coordinate systems, geocoding and cartographic transformations, raster and vector mode data structures and algorithms, characteristics of attribute data and attribute database management systems, and advanced case studies in GIS problem solving. The laboratory sessions for the advanced course focus on techniques and problems associated with database building. Initially, the students work with maps of small synthetic areas (Rasterville County) in order to learn the principles involved in creating a database for OSU-MAP. To introduce the students to a more realistic situation, as a final project in this class the students, working in pairs, create a four layer database of the Glassboro campus and then use this database to carry out a GIS analysis project.

In the introductory course about one-half of class time is in the lab. The other half is held in an ordinary classroom located adjacent to the Geography Department. All of our computer applications courses meet once a week for a single three hour session during the night time class period. A typical session of the computer cartography or introductory GIS class is divided about equally between work in the classroom and work in the lab. In the advanced class, class time in the lab is about thirty percent; however out of class time spent on projects is greater than in the introductory courses.

Students have no significant problems with access to the lab because of conflicts with those involved with research. Up until now research activity has been very limited. We are, however, currently working on an agreement with the New Jersey Pinelands Commission that would use our facilities and our advanced students to do digitizing for ARC/INFO databases the Commission is building. This activity will take place in a small graphics lab located within the Geography Department and may cause some frustrations for students who wish to run OSU-MAP on the machines located there.

In teaching these GIS courses, the lab serves two main purposes. First, it serves as a facility in which an instructor takes a class of students and leads them step-by-step through a workshop covering the use of the OSU-MAP program in GIS problem solving or data base building. Note that initially these workshops are very directive and tightly led. Gradually, as the students gain facility with the computers and the software, the instructor conducts the workshops in a much less directed style and serves as a facilitator for those needing help. Second, following each workshop, students use the computers to complete assignments that require them to apply the material covered in that workshop. As part of the requirements of each of the two GIS courses, students also use the lab facilities to complete a final project.

For GIS instruction, in addition to the computers themselves, the graphic peripherals are of great importance. In the introductory course, with its strong emphasis on GIS analysis techniques, students use these devices in creating the "hard copy" of GIS layers required for the completion of laboratory projects. For generating maps the OSU-MAP program provides two choices: the dot matrix printer, and the vector plotter. At the outset students seem to prefer the printer because of its ease of use and availability--each network node now has its own printer. In time, as students learn how to use the plotter, they come to prefer its ability to generate higher quality images that can use color to communicate. The main problem with using the plotter is that there is only one in the lab. However, there is a second plotter in the small graphics lab located within the office suite of the Department of Geography. Given that enrollment in the GIS courses is limited to fifteen, two plotters seem adequate to handle the demand.

In the advanced course, with its emphasis on algorithms and database building, the laboratory peripherals that get the heaviest use are the digitizers students use to convert maps and air photos into GIS layers for OSU-MAP. The two Kurta IS/1 digitizers are adequate for this purpose.

Extras

The layout of the computers within the lab reflects the concepts and philosophy behind the proposal. Since our intention is to provide a facility in which students can learn to use computers in research within their academic disciplines, we laid out the lab to maximize ease of one-on-one interaction between a faculty member and students working there (see Figure 1). One alternative arrangement we considered was to set up four single rows of computers, all facing in the same direction with an aisle separating each row. This arrangement has the advantage of allowing an instructor to stand at the front and be seen by the students while they are directed in the use of the machines. We have both worked in labs set up in this way and have found it to be very effective if the instructor has a large monitor or, better yet, a projection monitor to use as an electronic chalkboard on which to display commands and results. This arrangement encourages a mode of instruction that provides a nice security blanket and enables students to follow along with ease. For our facility there are several problems with this arrangement. First, our budget did not include funds for a projection or large monitor. Second, with an arrangement of four parallel rows of computer desks, the aisles would have been too narrow to permit an instructor to "float" from student to student and provide individual help. Third, we felt that an arrangement that encouraged students to focus on the instructor and discouraged individual interaction would prolong the period of student dependency on the instructor. Our goal is for students to learn to use the machines as tools in carrying out research tasks, not for them to learn how to follow step by step instructions in an instructor-led environment. Of course, inasmuch as many of our students are computer neophytes, we are forced to begin instruction in a strongly instructor-led mode. Our lab is poorly equipped and improperly laid out to facilitate this style of instruction. This encourages faculty to shift quickly to modes of instruction in which students work independently at problem solving while the instructor serves as an expert available to assist those who need assistance.[3]

Having said all of this about "ergonomic" considerations, we do not wish to suggest that the layout of the lab we decided upon just jumped out at us. "Cut and try" best describes the process we followed in determining the precise layout. After assembling the computer tables we literally moved them into several different configurations. At each juncture we discussed and debated the advantages and disadvantages and then moved on to another alternative. We also consulted with other lab directors at this time to get their opinions. We would like to emphasize that choosing an arrangement for the computers is no small decision in the case of a networked lab. Because each machine is connected to the file server, which in our case is in the next room, rearranging the computers would be a major undertaking. There is a strong incentive to get it right the first time.

Other Configuration Factors

For those who are contemplating a local area network configuration, we urge careful consideration of physical security for the file server. Our file server is located in the lab directors' office, a space to which only college security and the lab directors have access. When he first opened a new computer lab, a colleague in the business school had his file server near the laboratory monitor's desk in the same room the students were using. This arrangement resulted in inadvertent system shut down and made the presence of a monitor crucial to the secure functioning of hardware and software. Also the data and software security that are inherent in the network configuration are greatly compromised when unauthorized personnel have access to the server. In addition to the computers in the directors' office, faculty work area, and the SBS Lab proper, after our lab was established the college provided funds to tie most faculty offices in the Sociology and Psychology Departments into the network. This implies that the data and programs on the server need to be available at all times of the day and night. For this reason and to allow continuous remote access via modem, we leave our file server running twenty-four hours a day. We would not feel at all comfortable doing this if the server were in a more public area.

Use

Although we have some information on the numbers of students using our lab, we have little data on how they are using it. We can report on the responses users made to a survey that we administered as part of the final report to the granting agency and on the number of student and faculty network user names we assign each semester, which is typically 200 to 300 students and 10 to 15 faculty. The relationship between these numbers and lab use is, however, unclear. Some faculty members provide the directors with a diskette containing the names of all students in their advanced methodology classes, but subsequently use the lab very little. Smaller classes (GIS and Computer Cartography come to mind) sometimes use the lab intensively. Our impression is that a relatively small proportion of users demand a disproportionate amount of time on the computers.

Our survey, administered to students as they were working in the lab, asked a number of questions about usage. Table 3 presents tabulations of some of the results. The reported use per week exceeds the level we assumed when planning the lab (three hours per week per student) by about two hours. Note, however, that the survey sample is biased in that we selected informants from students as they were using the lab. Students who use the lab for shorter periods of time or use it less frequently have a higher probability of being missed by our survey.

Of the survey results that concern patterns of use, the only surprise was the relatively large percentage who said that they used the computers mostly in stand alone mode. We suspect that this result reflects our administering the survey at an early stage in the life of the lab before there had been sufficient time for instructors to have us install software on the network and for students to learn to use the network. We suspect strongly that a survey administered now would show that a much higher percentage of respondents use the computers predominantly in network mode.

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[3] The results of student evaluations indicate that students prefer the less directed approach to laboratory sessions. Those who need help can get it, while those who are able can work at a faster pace. Put another way, the slower students are not feeling the frustration of trying to keep up with the group and the faster students are not feeling the frustration of waiting for those who are having problems.

Operation

During the school year, the SBS Lab is open from 8:00 a.m. until 11:00 p.m. Monday through Thursday. Friday hours are from 8:00 a.m. until 5:00 p.m. Although we have experimented with limited week-end hours, the need to cover prime time during the week along with staffing limitations preclude week-end coverage. In the summer of 1991 we experimented with keeping the lab open during the day with a student monitor covering part of the open time. So far there seems little student demand for summer use of the lab.

The laboratory staff includes the two directors and four student laboratory monitors. The laboratory directors each receive released time from teaching in order to attend to a variety of consulting and instructional duties assigned by the Office of Academic Computing. Thus, only a part of our released time is given for running the SBS Lab.

The student workers receive funding from two sources: the Office of the Dean of the School of Liberal Arts and Sciences and the Office of Academic Computing each provide funds for two student workers. These workers have the title "Laboratory Monitor" and have as their primary responsibility day-to-day oversight of the lab. They are there to make sure that equipment is treated properly and remains on the premises. They keep printers supplied with paper and ribbons, report equipment and software problems to the directors, and answer questions users might have. In addition they sign users into and out of the lab. We require students who are not accompanied by a faculty member to sign a users log and to leave identification with the monitor. This practice serves two purposes. First, it provides a certain increase in security, but of even greater importance, it provides a record of the level of demand for the laboratory. When we go to the dean or to the director of Academic Computing to ask for money, being able to provide data on lab use is of considerable help.

We recommend careful selection of the student monitors. They are the face you present to the larger world. If you have done everything else well and hire unreliable helpers no one will care that yours is the model, state-of-the-art computing lab. They will just be upset that the help is unreliable or unfriendly. In our operation, which is staffed by and used by undergraduates exclusively, the primary requirement for the job is maturity and responsibility. Computing knowledge is a plus, but not required. To ensure that monitors live up to expectations, we recommend clear written statement of their job responsibilities and basic training in the operation, care, and feeding of lab equipment. At the beginning of each term we send each student monitor a letter outlining our expectations along with a schedule that shows his or her work assignment and the work assignment of all other monitors. The schedule includes names and telephone numbers of each monitor and of the directors. This information facilitates communication and removes the excuse, "I didn't know your home number". Because the computer background of the monitors varies greatly, we train them as needed on a one-on-one basis.

In summary, we are quite satisfied with these staffing arrangements, but do have several cautions. Running the SBS Laboratory without released time would be very difficult given the relatively heavy teaching load of our institution. At the same time reducing teaching load by one course per semester for each director merely to run the lab would, in the view of the administration, be excessive. The way around this is to negotiate a three hour reduction by agreeing to do things in addition to running the SBS Lab (e.g., organize and teach computer workshops). The obvious danger in this arrangement is that the directors end up working much harder than they would if they were teaching a full load and running the lab without released time. Be aware that operating a computer lab, done properly, will consume more time than imagined in the planning stages.

To date, our lab has experienced very little "down time". We have had an occasional power failure, one of which occurred just when our grant consultant, Dr. David Cowen of the University of South Carolina, was in the final moments of a site visit. Fulfillment of his recommendation that the file server be supported by an uninterruptable power supply has served to prevent any serious consequences of subsequent failures. Another problem we encountered during the early phases of our operation was the result of our allotting an inadequate amount of disk storage for user files. Near the end of our first full semester of operation the network began to grind to a halt and users became distressed by the sudden appearance of warning messages about an impending shortage of storage. Since we reconfigured the disk volumes to allow more space for user files we have not encountered this problem. Another problem that has resulted in some user frustration and down time is viral infection. On our campus the "Stoned Virus" has made several appearances in our student labs, usually near the end of the semester when all equipment receives very heavy use and many users are in a tight time bind. Dr. Frisone has written an assembler language program that is able to detect this virus, remove it from the offending diskette, and then re-boot the computer to remove the virus from the computers RAM. The antiviral program is activated every time the computer is turned on or re-booted. Since installing this program, we have had no problems with viruses.

Inasmuch as our lab is relatively new, we have had relatively few hardware failures. Under the terms of the service agreement Glassboro has with IBM, repair or replacement of any defective PS/2 equipment is accomplished within 24 hours. With the exception of a floppy disk drive, the only equipment failures we have experienced have been several of the IBM 8512 VGA Color Displays. Apparently, there was a defective batch of this model. IBM's policy is to replace all of these that fail even beyond the normal warrantee period. For other than IBM PS/2 equipment, we have a campus service technician who is available to our lab and is able to handle most problems. There is no charge to the lab either for the IBM service contract or for the work performed by the service technician, as these costs are covered from the budget of the Office of Academic Computing.

Given the level of expertise Dr. Frisone has in networking, we have had very little need to rely on Novell or IBM for technical support to solve networking software problems. With respect to the GIS software package that we use (OSU-MAP) we have gotten help from time to time from Dr. Duane Marble of Ohio State University. He was especially helpful in giving us assistance in getting the program to perform on the network.

Operating expenses are handled on a very informal basis. This was not our intent: we would prefer to have an annual operating budget. With the goal in mind of procuring such a budget, during each of the first two years in which the lab was operating we scheduled meetings with the Dean of Liberal Arts and Sciences (an ally throughout this effort), the Executive Assistant to the Provost, and the Director of Academic Computing. Getting these individuals to agree to come together in one place and time is a very difficult undertaking given their busy schedules. That the purpose of the meeting was to ask for money makes the schedules of the intended givers even tighter. That the form of money we were requesting was of the "ongoing budget" nature tightens their schedules even more. To her credit, the Dean made both meetings; however in both instances one of the other parties had something "come up" at the last minute. We concluded that our lab would just have to learn to operate without a line item in the college budget--read account number--under which funds are allocated on a yearly basis and under which equipment, supplies, and labor can be purchased.

So how do we operate without a budget? We have developed informal, handshake agreements with those who do have budgets. Academic Computing provides paper, printer ribbons, laser cartridges, an occasional box of diskettes, the odd piece of equipment (e.g., a larger hard drive for the file server), released time, and funds to hire two student workers. The Dean of Liberal Arts and Sciences provides two student workers, and three to six semester hours of released time, depending on budget. The Department of Geography donated a printer and provides supplies in the form of diskettes, plotter pens, and plotter paper. The Department of Psychology, which is very large, has supplied equipment needed to round out or upgrade the lab. For instance, they have donated several printers and made a very favorable "trade" that will enable us to upgrade the file server. They have also provided software for statistical analysis and testing. The Sociology Department has provided some software and supplies. Although this arrangement is far from ideal, so far even with increasingly tight budgets the arrangement has worked. The lab equipment is maintained and upgraded. We have supplies for the computers and workers to maintain security and assist users.

Our efforts to maintain security of equipment and software involve electronic, human, locational, and programming measures. The lab is protected by an electronic security system provided by the college at the time of start-up. When activated, the system detects opening of doors and motion within the room. A breach of the system causes an alarm to sound and a telephone silently to alert campus security. In addition to electronic security, a major responsibility of the lab monitor is to protect the equipment against misuse, abuse, and "disappearance". The location of the laboratory near to the Psychology Department office, which is staffed by two secretaries, also contributes to security. Sometimes during the day because of schedule conflicts among our student workers, we have periods for which we are unable to provide a laboratory monitor. Slowly we have gotten used to the idea of leaving the lab open and unattended. During these periods students use the lab and come and go as usual, but there is no one present in an official capacity to provide help. To date, we have had no instances of abuse or theft of equipment. After close of business in the Psychology Department, we do not permit the lab to remain open without a monitor except in a few cases in which a responsible student is lent a set of keys and agrees to close the lab when he or she leaves.

The LAN software, which provides privilege levels for user access, has helped maintain the integrity of program and data files stored on the file server. Users have no way of accessing the files of other users. Applications program directories are carefully protected against inadvertent or purposeful destruction.

In addition to storing data and software on the file server, we keep a complement of general use software on the hard drive of each node of the network. This permits students who have no user name and password for the network to use the computers on a stand alone basis.(see figure 2) One obvious problem of storing software in this way is its vulnerability. We increase node security by hiding the names of the directories in which the software is stored and by making the program files read only. To date, other than one instance of virus infection, we have had no instances of equipment, data, or software loss.

Responsibilities

Each of the directors has a very different set of responsibilities for the operation of the lab. Dr. Frisone's laboratory responsibilities focus on keeping the hardware and software up and running on both the file server and the network nodes. He also spends countless hours writing programs and adapting programs of others to the network environment. Dr. Scott participates in this process, but relies heavily on the expertise of his co-director in these matters. Dr. Scott is responsible for offering workshops designed to teach faculty and students how to the use the lab's computers, along with the networking and applications software. He also handles the hiring, scheduling, training, and supervision of student laboratory monitors. Even though our responsibilities for the lab are very different, we make decisions and operate by a consensus that emerges from thorough discussion.

We feel at a total loss to discuss "strategies to avoid over commitment". We both enjoy our work in the lab tremendously and feel a sense of accomplishment in creating and running a facility that provides a large number of faculty and students with access to computers, data, and software, and the training in how to use them. We are proud that our lab's configuration of hardware and software have served as a model for others on our campus, but we have no ideas concerning how one avoids over commitment. This is not to say that we have to do everything by ourselves. Clearly, we have had help in all phases of this project. The point that needs to be made strongly is that the amount of work that one could do to improve the lab and how it is run far exceeds the time available. The result of this situation is a more or less continual sense that there is more to be done than is getting done.

V. EVALUATION STAGE

Comparison

As far as overall design, objectives, and operations are concerned there is a high degree of correspondence between the original design of our project and the lab as it operates today. There are some significant differences, especially in hardware and software, between the outcome of our project and the original proposal and between the outcome and the proposal as accepted by the granting agency. In Table 2 we have reproduced the equipment and software budget that the granting agency accepted as a part of the grant contract. There are several noteworthy differences between the list of equipment and software in the grant contract and the list in the original proposal: first the file server was upgraded from a 80286 processor to an 80386 processor, thus providing a higher performance machine with a longer likely useful life. Second, price decreases allowed us to equip all machines with color monitors rather than just a portion of them.

There were also several important differences between the equipment and software list approved by the granting agency and the items we purchased. After final approval of our grant and the issuing of the contract, we discovered that the IBM Personal Pageprinter laser printer would not function in a network environment. We replaced this item with a Hewlett Packard Laser Jet II. The Summagraphics digitizer was replaced by two Kurta IS/1 digitizers. The Kurta product had a more attractive price, a simpler design, and a longer warranty. The most important difference between the accepted list and the products we purchased was the networking program we selected. The original proposal and the accepted contract both listed the IBM Net BIOS Networking software. Prior to purchasing that program we discovered an IBM software product that works with Novell's Advanced Netware/286, Version 2.12. This product, the IBM Classroom Local Area Network Administration System serves as a user friendly front end program for Netware. The entire purpose of the program is to facilitate using Novell in an academic environment. For instance, the program has easy to use menus that allow LAN system operators to load new software or updates of software on the file server. Just as easily, system operators can install lists of new users from diskettes provided by instructors. Once software and students are installed on the server, instructors can create a "class" and then assign available software packages to that class. Next the instructor can access a list containing all students installed on the system and assign students to each of the classes he or she has created. When students sign on to the network they see a listing of the classes to which their instructors have assigned them. Students select a class by highlighting its name and pressing the Enter key. At this point the student will see a listing of software available for the class selected. To run a program the student highlights the desired selection and presses Enter. From this point on the program runs just like its stand alone counterpart.

The IBM Classroom LAN Administration System has many more features than we can describe here. Suffice it to say that this program has made our job of administering the network much easier than we imagined it would be. Instructors and students alike give the program high marks for ease of use and completeness of features. One interesting sidelight is that we no longer offer faculty workshops on how to use this package. It is so easy to use that faculty members either teach each other or learn from the tutorial documents we have written.

Another minor difference between the lab as we proposed it and the lab as it operates has to do with governance. Originally, we had proposed a Project Advisory Team consisting of the two directors and one member of each of the participating departments. We did meet early in the project with each of the departments, but the Project Advisory Team, in retrospect, seems entirely unnecessary. Members of the participating departments all know the directors quite well and have no reservations about letting us know about their needs. Moreover, responding to requests of faculty in the participating departments often requires a technical discussion concerning a specific problem the individual wishes to have solved. This is not the sort of activity that lends itself to committee work.

Overwhelmingly, the changes we made from the original proposal were for the better. That most of the changes were in the direction of improvement should not be surprising given the circumstances. The amount of money we were awarded was less than we requested, but we were operating in an environment in which prices of the equipment we proposed to purchase were falling rapidly. Thus, in most cases we were making changes that involved upgrading the specifications of the original proposal. In addition we learned a lot as we proceeded and did not hesitate to make mid course corrections that would result in improvement.

Reflections

As we view our lab after three full years of operation, we feel certain that it has had a positive impact on the quality of instruction students receive in the use of computers in their disciplines. Recently, after a long and difficult workshop session a student asked one of us, "How did you teach this stuff before you had the lab?" The intent of her question was to convey that, even with the lab, mastering the use of the computer was difficult. She could not imagine how difficult the mastery would have been without the laboratory. Answering her question evoked memories that had been long suppressed! We believe that the major objective of our project, which was to incorporate the use of the computer in advanced methodology courses in the social and behavioral sciences, has been a resounding success. We also are very pleased with the hardware and software we selected. The computers have been very reliable and service is prompt on those rare occasions when there is a failure. The Novell Netware working with the IBM Classroom LAN Administration System has provided a computing environment that is almost ideally suited to our needs.

Of course, not everything turned out as we had hoped. One of the dreams that we had very early on was that a computer lab shared by faculty from a variety of social science disciplines would become an informal meeting place in which ideas, joint ventures, cooperative efforts, and cross disciplinary fertilizations would be born. By and large this has not happened. True, there is sharing of word processing and statistical software, but the kind of cross disciplinary excitement that we imagined has failed to occur. We are not sure why this is so, but one possible explanation lies in the under use of the faculty work area, which is the result of placing network nodes in many faculty offices. Instead of coming together in a common area, faculty members are now more likely to work alone in an office within their departmental areas where they are more likely to interact with members of their own academic disciplines and less likely to encounter someone from another field.

If we were to repeat the process, there are many things that we would leave unchanged. The networking environment along with the IBM LAN Administration System has very few drawbacks and saves much time in system maintenance. The GIS software we are using (OSU-MAP) is appropriate to an undergraduate level of instruction and works smoothly in a networking environment. We have no questions about the improved learning opportunity that students enjoy as a result of our facility. The main things we would do differently all have to do with the issues revolving around space. First, we would be much more assertive in hounding the administration to take action to secure a space for the lab. Second, we would insist on much more clarity concerning what is meant by the provision of space. We would want a formal written agreement. Third, we would insist on more thorough preparation of the space. Painting was done at the last moment and no permanent provision was made for enclosing and carrying the networking cables. We strung the cables, as best we could, under the tables and along the walls holding them in place with plastic wire ties affixed to adhesive pads glued to the walls and tables. Slowly, this arrangement is beginning to fall apart. Our maintenance staff could have provided a much better solution to cable carrying, if they had been given enough time.

Had we had a better crystal ball, we would have pressed the administration to open a passage between the student lab and the faculty work area and assign all of the space to students. At the time we received the grant, networking on our campus was in its infancy. We believed that a separate area in which faculty could work in privacy preparing exams, computer exercises, or writing papers would be necessary. However, because computerization on our campus has proceeded much more rapidly than we foresaw and many faculty have computers in their offices, the faculty work area is not used heavily. As more and more faculty get their own network nodes, the prospect is that the faculty work area will be used less and less. At the same time we imagine that more and more of these computer literate faculty will wish to have their students use the lab, which will then become more crowded. When that time arrives we can only hope that the dollars will be there to punch a hole in the wall so that the student lab can be enlarged (see Figure 1).

With respect to GIS, our plans for the future include continuing to use the SBS Lab for introductory workshops and student projects and problem solving. We have discovered that because of the location of the Geography and Anthropology Department in relation to the lab (the lab is on the first floor of the building, whereas Geography is located at the opposite end of the building on the third floor) students often feel frustrated when they encounter a problem while working in the lab and have to go to their instructor's office, which is at the other end of the building and up two floors. To solve this problem and also to provide a more specialized facility for advanced students, the Geography and Anthropology Department is carving a small advanced level GIS lab out of their office suite. Initially, this lab will contain four computers with which students can access the OSU-MAP program along with an array of graphics peripherals (plotter, ink jet plotter, two digitizers). Soon the four computers will be tied into the SBS Lab network. This facility will allow students to work on assignments while their instructor is nearby, thus ending one source of frustration for them. In addition to the OSU-MAP program, the software on two of these computers includes ERDAS and PC-ARC/INFO, which will be available for students in smaller advanced classes and for pre-internship training. We hope that in the future this lab will be equipped and used jointly by the Geography and the Computer Science Departments, which have a long history of cooperation: geography students are encouraged to take programming and computer literacy courses; the computer cartography course serves as a restricted elective for computer science majors.

VI. RECOMMENDATIONS

Proposal Stage

1. If your department is small, consider a multi-department lab and proposal. Economies of scale gained in the use of space, machines, software, data, and lab staff are significant and will permit you to have access to a facility that your department could not justify for its exclusive use.

2. If you have a grants officer on your campus, use his or her expertise early and often.

3. Discuss your plans with colleagues who have been successful with similar grants. They have detailed knowledge and advice from a faculty viewpoint.

4. Try to get released time for yourself built into the operation of the lab. Running a computer lab will take more time than you imagine.

5. Consider the advantages of a local area network. Although the expertise required to maintain a network is greater than that required to maintain stand alone computers, the benefits gained in time saved in software maintenance, in dealing with data and program corruptions, and in many other areas are very significant.

6. Have a very clear idea about the details of how your facility will function. Do not make the mistake of thinking of your lab as only a collection of hardware and software that faculty and students will be rushing to get their hands on as soon as it is available. To avoid having your equipment just sit there, include plans for administering your lab, for maintaining it, and for providing a high quality instructional program in how to use the hardware and software you have brought together.

7. Have a clear idea about the kind of lab you will be constructing. Is it for teaching or research or both? What style of teaching do you wish to encourage? Whether or not you intend it, the way you lay out your lab along with the kinds of equipment you purchase will very likely encourage a particular style of teaching. Think about what kind of teaching you would like to take place in your lab and design it accordingly.

8. In specifying equipment and software be complete and be specific as to number of items, versions, and model numbers. This means that you will have to do a lot of homework even before you begin to write, but we believe that the degree of expertise you gain and communicate to the reviewers will pay off.

9. Get agreements on space up front and in writing. In putting our lab together we spent an inordinate amount of time trying to get the administration to make a decision concerning where our lab would be. Remember that space is an emotional issue and if you are going to have a space for your lab, unless you are moving into a new building, someone or something will probably have to move to accommodate your facility.

10. Get your administration to specify in writing exactly what they will and will not do in preparing the space to accept the computers you are obtaining.

11. In your grant proposal specify powerful, adaptable, expandable computers that represent the current state-of-the-art. Even these machines will be obsolete in just a few years. Anything else is already obsolete. Getting the funds to replace all of your machines will be a major undertaking. Powerful computers will enable you to postpone the inevitable.

12. If you teach at a liberal arts college or other institution that is primarily undergraduate and teaching oriented, you can probably benefit from the knowledge, experience, and expertise of colleagues at research universities who may have more up-to-date information on software and hardware coming on the market.

13. Specify equipment and software that represents industry standards rather than proprietary equipment and operating systems. This will help you avoid too close an attachment to one hardware or software vendor.

Acquisition Stage

1. Keep on top of developments in hardware and software and be prepared to make changes from the items you specified in the proposal.

2. Get vendors to adapt to your school's system of placing orders. Most will do this if not doing it means losing a sale.

3. Especially if you are setting up a LAN, take great care and experiment with alternative layouts of the equipment in your lab. Once the room is set up, making changes will be very time consuming and will disrupt operations. Careful planning at this stage will save you much time later.

Operational Stage

1. As soon as you have your lab up and running make sure that you provide a tour of the facilities and a demonstration of the hardware and software to those who have helped you along the way and to those who will be providing continuing assistance. Having seen your operation in action will be a plus when you return to these individuals for the funds you will need to run the lab after the grant runs out.

2. Most probably you will not be able to be in your lab during all of its hours of operation. The face you present to the world will be that of those who work for you as lab assistants or monitors. Take the time to train these individuals and to inform them of your expectations in writing.

3. Establish procedures for reporting equipment of software failures quickly and clearly. Instructors and students using the lab expect that everything will work all of the time. Do your best to make it seem that way.

4. Either through a lab log or software monitoring, keep track of the amount of use your facility is getting. We keep a daily log that students sign when they arrive at the lab and initial when they leave. The information we gather in this way is useful when we go the our dean or the academic computing director to ask for lab workers, supplies, or equipment upgrades.

5. Do an annual survey of lab users to find out what does and does not work in the way you run your operation.

TABLE 1 - PROPOSED BUDGET FOR EQUIPMENT AND SOFTWARE

QUANTITY	DESCRIPTION	UNIT PRICE	TOTAL COST	GRANT REQUEST	INST. SUPPORT
1	IBM Personal System/2 Model 60-071	$4,280	$4,280	$4,280	$ 0
14	IBM Personal System/2 Model 50-021	2,444	34,224	34,224	0
5	IBM Color Display/8513	465	2,329	2,329	0
10	IBM Monochrome Display/8503	170	1,700	1,700	0
15	IBM Token-Ring Network Adaptor/A	540	8,109	8,109	0
2	IBM Token-Ring Multi-station Access Units	382	764	764	0
15	IBM Token Ring Connecting Cables	25	375	375	0
1	NET BIOS Network Program	385	385	385	0
15	PC-DOS 3.3	81	1,224	1,224	0
1	PC-DOS Technical Reference	57	57	57	0
5	Hayes 1200 External Modems	379	1,899	1,899	0
1	IBM Personal Pageprinter Printer	1,495	1,495	1,495	0
1	Personal Pageprinter Adapter	1,326	1,326	1,326	0
7	IBM Proprinter II	373	2,613	2,613	0
8	Printer Cables	31	248	248	0
15	80287-10 Numeric Data Coprocessors	357	5,355	5,355	0
1	Summagraphics Bit Pad 1 Digitizing Tablet (15" x 15")	1,295	1,295	1,295	0
1	Summagraphics Four-button Cursor	155	155	155	0
1	Bit Pad 1 Power Supply	135	135	135	0
1	Bit Pad 1 RS-232 Cable	95	95	95	0
1	7372 IBM Color Plotters	1,900	1,900	1,900	0
1	Map Analysis Program	1,000	1,000	1,000	0
1	EPPL-7	700	700	700	0
1	GCTP Cartographic Converter	200	200	200	0
1	IBM Asynchronous Communications Server Program	495	495	495	0
1	Crosstalk XVI by Microstuf	600	600	600	0
5	McGraw Hill Psych World	540	2,700	2,700	0
2	SPSS/PC	900	1,800	1,800	0
2	Systat Statistical Program with Large Module	550	1,100	0	1,100
2	Statpac	498	996	0	996
1	Atlas-AMP Mapping Program	449	449	449	0
1	Surfer Mapping Program	425	425	425	0
1	Atlas MapEdit Boundary Editor	149	149	149	0
10	WordPerfect	125	1,250	0	1,250
2	dBase III Plus	425	850	0	850
2	Lotus 123	375	750	0	750
	TOTAL		$83,427	$78,481	$4,946

TABLE 2 - ACCEPTED BUDGET FOR EQUIPMENT AND SOFTWARE

QUANTITY	DESCRIPTION	UNIT PRICE	TOTAL COST	GRANT REQUEST	INST. SUPPORT
1	IBM Personal System/2, Model 80-071 W/8513 Color Display	$5,454	$5,454	$5,454	$ 0
14	IBM Personal System/2, Model 50-021 W/8513 Color Display	2,514	35,196	35,196	0
15	IBM Token-Ring Network Adaptor/A	531	7,965	7,965	0
2	IBM Token-Ring Multi-station Access Units	528	1,056	1,056	0
15	IBM Token Ring Connecting Cables	21	315	315	0
1	NET BIOS Network Program	123	123	123	0
1	LAN Support	35	35	35	0
3	PC-DOS 3.3	84	252	252	0
1	PC-DOS Technical Reference	123	123	123	0
5	IBM 300/1200 Internal Modems	277	1,385	1,385	0
1	IBM Personal Pageprinter Printer	1,320	1,320	1,320	0
1	Personal Pageprinter Adapter	1,326	1,326	1,326	0
7	IBM Proprinter II	357	2,499	2,499	0
8	Printer Cables	32	224	224	0
15	80287-10 Numeric Data Coprocessors	315	4,410	4,410	0
1	Summagraphics Bit Pad 1 Digitizing Tablet (15" x 15")	1,295	1,295	1,295	0
1	Summagraphics Four-button Cursor	155	155	155	0
1	Bit Pad 1 Power Supply	135	135	135	0
1	Bit Pad 1 RS-232 Cable	95	95	95	0
1	7372 IBM Color Plotters	1,330	1,330	1,330	0
1	Map Analysis Program	1,000	1,000	1,000	0
1	EPPL-7	700	700	700	0
1	GCTP Cartographic Converter	200	200	200	0
1	IBM Asynchronous Communications Server Program	840	840	840	0
5	McGraw Hill Psych World	540	540	540	0
2	SPSS/PC	900	1,800	1,800	0
2	Systat Statistical Program with Large Module	550	1,100	0	1,100
2	Statpac	498	996	0	996
1	Atlas-AMP Mapping Program	449	449	449	0
1	Surfer Mapping Program	425	425	425	0
1	Atlas MapEdit Boundary Editor	149	149	149	0
10	WordPerfect	125	1,250	0	1,250
2	dBase III Plus	425	850	0	850
2	Lotus 123	375	750	0	750
	TOTAL		$75,742	$71,852	$4,946

TABLE 3

USE OF THE SOCIAL AND BEHAVIORAL SCIENCES COMPUTER LAB

	Mean	Standard Deviation
Number of hours per week you used lab.	4.91	2.94
Number of your classes using the lab during this academic year (1988-89).	2.23	0.41

	Percentage
Percentage of respondents who were taken to the lab by their instructors for a workshop session.	77%
Percentage of respondents who said they used the computers mostly in a stand alone mode (i.e., not attached to the server). 77%	

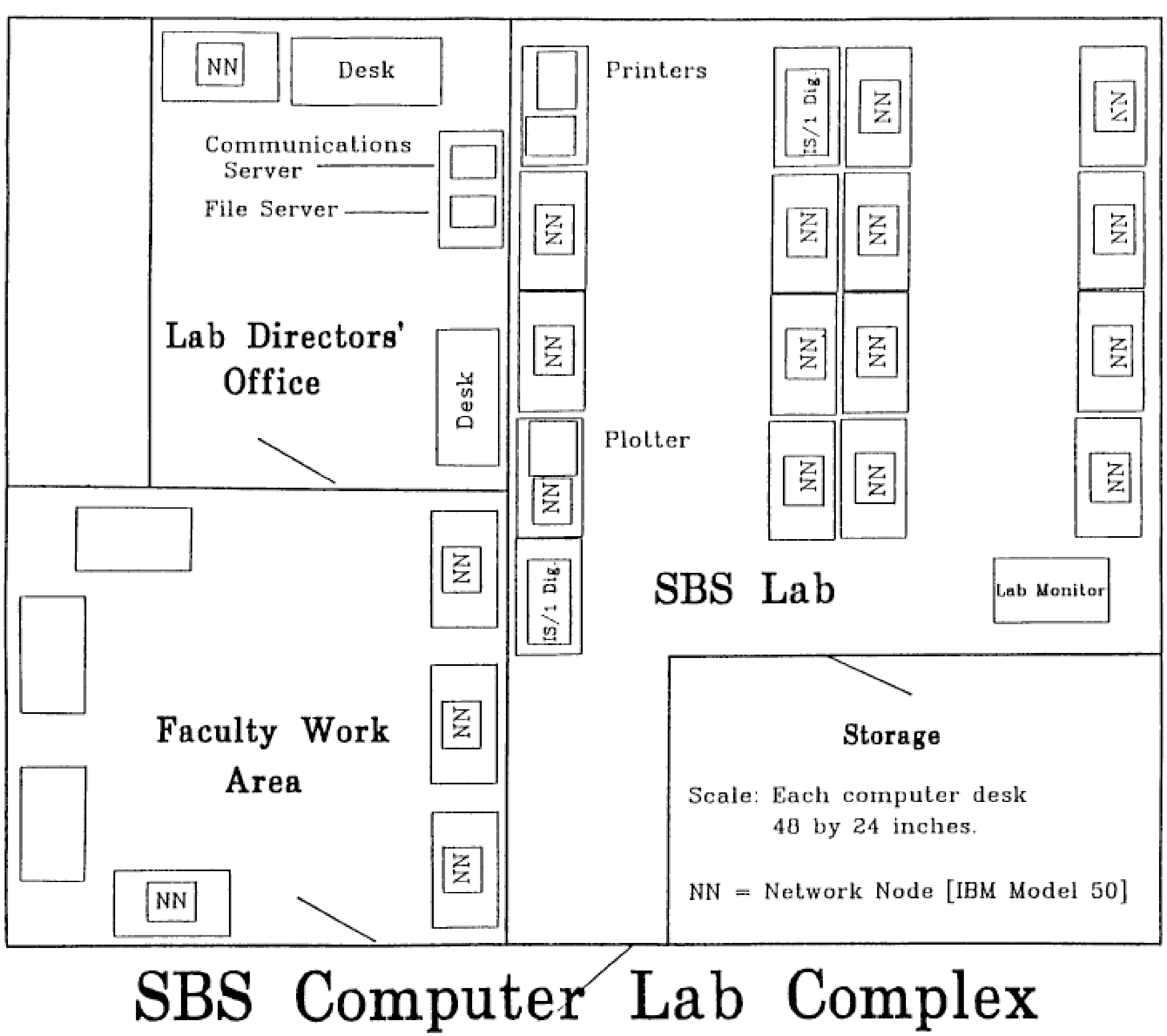
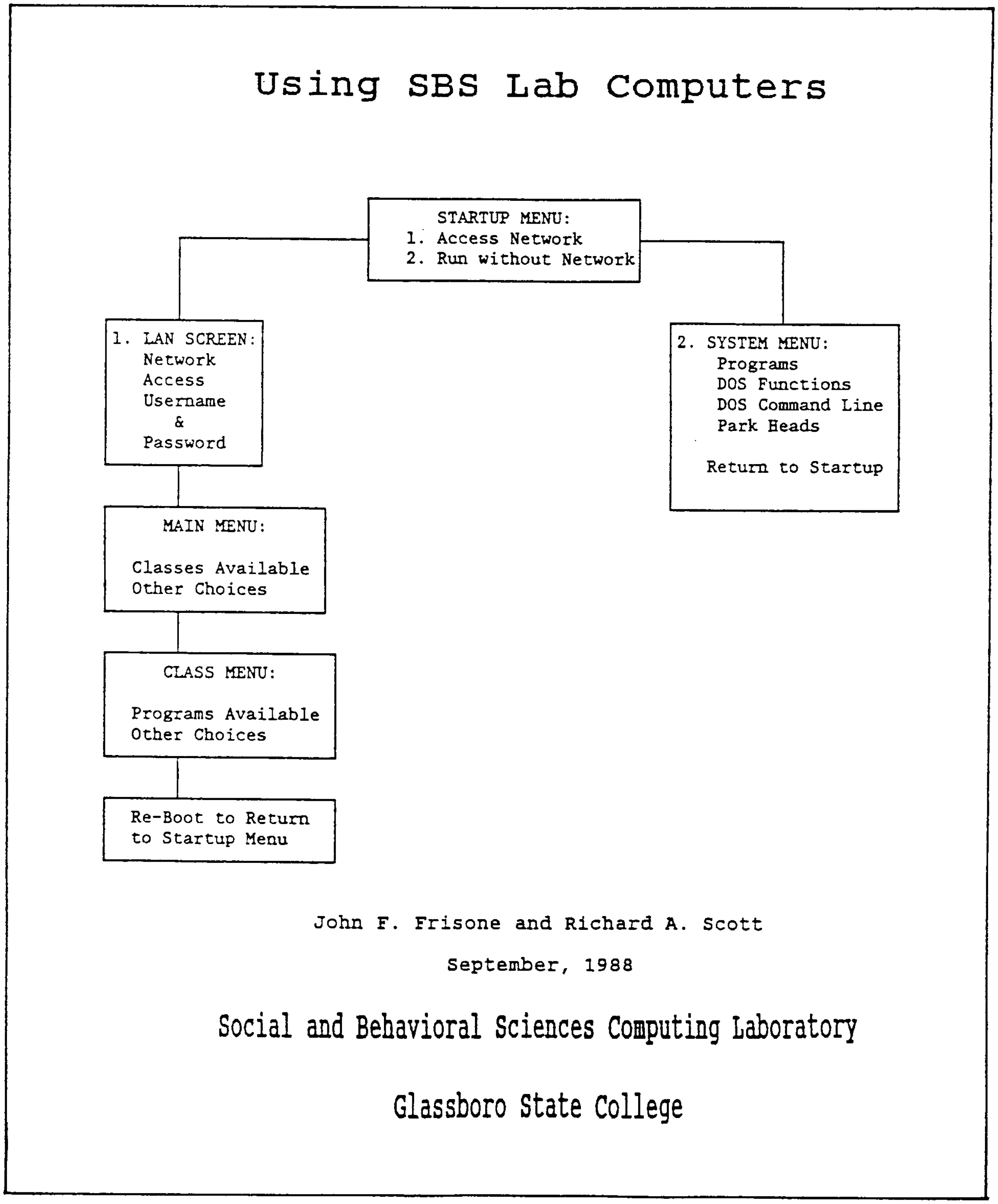


FIGURE 1
SBS COMPUTER LAB DIAGRAM

FIGURE 2
SYSTEM USE FLOW CHART

Below is the cover of the lab use manual given to students in the Social and Behavioral Sciences Computing Lab. The flow chart demonstrates the hierarchical security provided by the server on a network.



Using SBS Lab Computers

STARTUP MENU:
1. Access Network
2. Run without Network

1. LAN SCREEN:
Network
Access
Username
&
Password

MAIN MENU:
Classes Available
Other Choices

CLASS MENU:
Programs Available
Other Choices

Re-Boot to Return
to Startup Menu

2. SYSTEM MENU:
Programs
DOS Functions
DOS Command Line
Park Heads

Return to Startup

John F. Frisone and Richard A. Scott

September, 1988

Social and Behavioral Sciences Computing Laboratory

Glassboro State College

Southwest Texas State University

Susan M. Macey
Department of Geography and Planning

September, 1991

DEVELOPMENT OF A GIS TEACHING LABORATORY
REPORT TO THE NCGIA

I. CONCEPTUAL STAGE

Background

Southwest Texas State University (SWT) is a four-year comprehensive university in central Texas with an enrollment nearing 22,000 students, 19,000 of whom are undergraduates. The Department of Geography and Planning enrolls approximately 5,000 undergraduate students annually in its courses, and it serves 390 majors in both arts and science bachelors degrees. The Master of Applied Geography program currently enrolls 140 students annually, and continues to grow. These numbers and the work of the faculty have resulted in a relatively high profile for the department both on campus and outside.

Geography and Planning is the only department providing instruction in cartography and geographic information systems (GIS). The general trend in these courses has been towards higher enrollment and increased computer use each semester. Until the last year, the computing facilities of SWT and the Department of Geography and Planning have necessitated a largely mainframe orientation. Disadvantages of the system included the outdated nature of the software, the lengthy period needed to teach students the operating system, and the limited display options. The system did not enable students to gain substantial experience in the types of hardware and software that they will be required to use in graduate study and in many professional geography careers.

For these reasons, the department and university have devoted considerable resources to bring the physical facilities of the department up to current standards, starting with the hiring of an additional faculty member, the author, in 1988 to complement the expertise of the department in computer cartography and GIS. An expectation in this hiring was that the new faculty member would pursue funding opportunities to enhance the department's computer laboratory facilities.

The department's main goal is to integrate the latest technological advancements into its existing teaching program. To accomplish this goal, a mix of hardware platforms with appropriate input/output devices and software was desired to give the widest possible practical experience to students. The limited departmental budget for hardware and software required focussing efforts on exploring outside funding potentials. This was done by the author in conjunction with the Office of Research and Sponsored Projects at SWT. Initially, the National Science Foundation Instrumentation and Laboratory Improvement Program was targeted as the major public program that provided direct support for the acquisition of instructional computer equipment. This NSF grant was eventually unsuccessful.

At the same time, cooperative efforts with vendors were pursued. The author made several contacts with hardware and software vendors at the Government Technology Conference in Austin in February, 1990. Vendors were appraised of the status of SWT in the region, and our interest in exploring mutually beneficial projects. This was followed up by telephone contact with those individuals in each company deemed the appropriate person to handle such inquiries. In these contacts, our position as one of the largest Geography departments in the country, the applied nature of our program, and our interest in keeping our students current was stressed. The benefits to the vendor, in terms of providing trained personnel and future customers, were also outlined. The Intergraph representative was the only one who responded positively and saw the potential of such a mutually beneficial arrangement at that time. Negotiations proceeded from that point. This report will discuss the process that followed to establish a microcomputer laboratory incorporating UNIX-based desktop workstations and MSDOS-based microcomputers to support the teaching of GIS courses through the joint cooperation of Intergraph Corporation and SWT.

Present and planned courses

The department is the locus of cartographic and geographic information systems (GIS) curriculum at SWT. The department offers several undergraduate cartography related courses, including map compilation and graphics, GIS, and special topics in cartography, as well as graduate courses in applied cartography, computer cartography, and GIS. (See Table 1 for course descriptions and average enrollment.) These are four credit-hour laboratory courses which make extensive use of hands-on practical training as a vital extension of the theory presented in lectures. The present number of student users of departmental computer facilities averages 150 per semester.

With the department's emphasis in applied geography, it was considered imperative that our program shift away from dependence on 'mainframe' facilities both to maintain relevance to students' academic and professional aspirations, and to meet the expectations of persons who would consider our students for graduate schools or professional employment.

In addition to the current course offerings, the author will be developing an advanced undergraduate GIS course in Spring, 1992 which will examine more technical aspects of the field and give students further practical training in the more sophisticated aspects of GIS.

Departments involved

While several departments on campus have computer laboratories, the specialized nature of GIS has not lent itself to joint facilities. Likewise, the time demand generated by our courses calls for the department having its own facilities. While the department must generally secure the hardware and software, the university administration recognizes the importance of technological training. They have been generous in paying for the retrofitting of new laboratory space through student computer users fees.

Preexisting facilities and use

The department had slowly been acquiring DOS microcomputers and peripherals through use of computer laboratory fees and capital equipment funds channeled through the Dean's office. When the author arrived at SWT in 1988, the student computer laboratory had only eleven alphanumeric dumb terminals, two low-end microcomputers (an AT and an XT), an 81/2"x11" digitizer and a desktop plotter (HP7475A). GIS courses were taught using MAP(Map Analysis Package) on the VAX, though the department had pcARC/INFO. Over the last three years all alphanumeric terminals have been replaced by graphics terminals. Three more DOS machines, a dotmatrix printer, a 48" x 60" digitizing tablet, and several GIS software packages (ATLAS*GIS, IDRISI, and MAPINFO) have been added.

One drawback of the old laboratory was the limited space. Only eleven stations could be accommodated. As microcomputers were acquired, it was necessary to disable dumb terminals. Thus, while we had more equipment, it was not possible to set up all of it at one time. The room is also used for lectures in addition to the laboratory sessions.

Need Assessment

The need for expanded facilities had been evident for some time. The objective was to acquire state-of-the-art hardware and software that would keep our practical training up to date while complementing the equipment that the department already had or could periodically purchase. The addition of microcomputers was seen as the logical step to end dependence on the university's overburdened VAX minicomputer. The broad availability of GIS software, plus the affordability of hardware made DOS-based machines the first choice. It was hoped that UNIX-based equipment could be acquired down the road as price reductions brought it within financial reach. Thus, the opportunity of a cooperative venture between SWT and Intergraph Corporation was fortuitous and allowed us to move to a UNIX solution earlier than anticipated.

II. PROPOSAL STAGE

Mandate

The proposed project had three major objectives geared to improving the geography curriculum by:

1) enhancing the critical scientific thinking of students through the practical application of principles,
2) integration of state-of-the-art technology with traditional geography course material in order to substantially upgrade the quality and timeliness of skills, and
3) providing an example for the integration of GIS education into college curricula nationwide.

Objectives one and two will be translated into action through the development of teaching modules and their integration into courses. The "module method" will allow the tailoring of instruction to the specific needs of students and the relating of computer applications to a particular aspect or subfield of inquiry. Modules designed for GIS courses will be formalized in the 1991-92 academic year, and will include such topics as data entry, map and image editing, spatial analysis and transformations.

Components of the proposal

In line with the objectives, a laboratory to incorporate a mix of UNIX-based workstations and the department's five existing DOS-based microcomputers was proposed. Five desktop UNIX workstations and two servers were to provide the core. The plan was to network the existing microcomputers and UNIX machines, so that data and peripherals could be shared. A color copier, laser printer, desktop scanner, and tape drive were figured into the proposal to expand current input-output capabilities.

As the laboratory would serve a number of courses in the Cartography/GIS concentration, a suite of software packages were included in the proposal. As well as the UNIX operating system, the network, and the peripheral related software, these packages included MicroStation (an Intergraph CAD package), SoftPC (the DOS window), and Intergraph's MGE/MGA (the Modular GIS Environment, incorporating digital elevation modeling, mapping, and projection management as well as GIS functions).

The university has a technical support service which covers maintenance of all classroom computers at no cost to departments. Any work not covered by the warranty or maintenance agreement will be handled through this service. Room alterations necessary to accommodate the new equipment and to establish an efficient teaching environment have been funded by the university. These alterations included enhancing room security through structural changes and upgrading electrical circuits. An instructor or teaching assistant will be onsite at all times to assist students and assure the security and care of equipment.

As well as these components, an evaluation plan and section on dissemination of results was included in the proposal. The evaluation plan included two parts: student evaluations of their course experiences; and faculty evaluation of students, including formal exams and exercises, and informal reporting. Dissemination of the results will also take two forms: presentation of papers at the annual Association of American Geographers conference and the International GIS/LIS Conference; and submission of papers for publication.

Key individuals

The project director, Dr. Susan Macey, has been the liaison person connecting the department, the university's Office of Research and Sponsored Programs, university administration, and Intergraph. She has had formal training in cartography, spatial data analysis, and computer cartography. Her GIS knowledge has been gained through personal development, training courses, and workshops.

Dr. Dennis Fitzsimons, an associate professor in the department of Geography and Planning, has his primary area of expertise in cartography. He was co-investigator on the project, and has served as a valuable backup to the project director.

Dr. Paul Fonteyn, Vice President for Research and Sponsored Programs was of extraordinary help in framing the grant proposals, and in bringing them to the attention of the upper echelon of the university hierarchy. He also provided guidance on bureaucratic procedures and requirements.

On the technical side, Robert Goss, Director of Computing Services was most helpful in interfacing with the Intergraph technical support people to coordinate site requirements in the new laboratory. Physical Plant personnel were also brought together with Intergraph technicians to discuss electrical requirements.

On the corporate side, initial contact was made with the local sales representative, Duane Guidry, who explored and pushed for what was a new level of corporate support for education. Intergraph's Educational Program was in its infancy, so that much ground breaking was necessary. The size of the potential venture was unique, so that authorization had to be channelled through several divisions of the organization with ultimate approval needed from the top level. Mr. Guidry was supported by his district manager, Tom Clemons, and the Executive Vice President for Mapping Sciences, Douglas Gerull. (GIS falls under the Mapping Sciences division of the company.) Due to the amount of funding involved, the proposal ultimately went to Intergraph's President, Eliott James, for final endorsement.

Avenues of Support

SWT's program of matching funds gave us an opportunity to negotiate for a substantial donation from Intergraph Corporation. It enabled us to propose the acquisition of the core of a new laboratory, rather than just the donation of one or two machines.

Within the university administration, support was easily obtained. The nature of the grant - approximately a 2 1/2 to one match - needed little selling. The proposal itself had to be channeled through all levels from the department chair, to the Dean who presented it to the Council of Deans for matching grant approval. From there the Vice President for Academic Affairs presented it to the Board of Regents for final approval. The proposal also had the blessing of the President of the university who has been very supportive of faculty efforts to obtain outside funding.

Overview of proposed budget

The proposed budget for the project is set out in Table 2. There were several parts to the budget. The funding for hardware and software was to come from two sources, a matching grant from SWT and a donation from Intergraph Corporation (IC). In addition, the university was to pay for the retrofitting of the laboratory space, and a maintenance fee.

Procedures and Documentation

Two proposals were actually prepared for this project: one for the university's matching grant program (Appendix A) and one for Intergraph Corporation (Appendix B). These proposals are not as lengthy or complex as those which normally would be required by a public funding agency. The matching grant proposal was accompanied by a standard one page university application form, letter of interest in a cooperative effort from Intergraph Corporation, and memorandum of support from the departmental chair. The proposal to Intergraph was channeled through Mr. Guidry. Supportive material, including testament on the value of the project from the mapping sciences and marketing divisions of the company were added by them.

The procedures to receive funding have been alluded to above. On the university side, approval had to be obtained at the school and university levels. There were several formal and informal meetings in the summer of 1990 from the department level on up at which the content and benefits of the proposal were explained. This helped ease the passage of the proposal. Approval on Intergraph's side followed a similar pattern. While straightforward, the process did take several months as certain meetings on both sides followed regular calendar dates: for example, the university Board of Regents only meets quarterly.

Hurdles

The greatest 'hurdle' in this project was trying to convince certain faculty members in the department of the merits of the proposal. All faculty members were invited to several meetings, including the initial meeting with the Intergraph representative, where the merits and scope of the proposal, and the specific equipment acquisitions were discussed at length. The content and status of the proposal was also an agenda item in a number of faculty meetings. This exposure of a grant proposal for general discussion was unprecedented. Even though the complementary nature of the project was stressed, opposition was never totally overcome. Not being a computer oriented person, the chair had difficulty evaluating the project when faced with a conflicting opinion. Had the merits of the project not been recognized by the school and the higher levels of the administration, the proposal may have died at this stage. Thus, the greatest support came from the top down, rather than from the bottom up.

Institutional 'hurdles' were much easier to deal with as they mainly consisted of working out where the 'piece of paper' had to be channeled next in the bureaucracy. This was a learning experience for the author who had not previously processed a grant at SWT. The chain of procedures for approval seemed cumbersome at the time, though they are probably no worse than those anywhere else. The early development of positive relationships with those in the chain of command was perhaps the most valuable side benefit of the project and one that enabled minor paperwork processing setbacks to be taken in stride and overcome.

On Intergraph's side, the bureaucracy was largely handled by Mr. Guidry, the local sales representative, who 'protected' us from the more arduous aspects of dealing with such a large and complex company structure. On those occasions when things seemed to be ’stuck in the bureaucracy’, personal contact proved the most effective way of getting things moving. Again, support at the highest levels of the company worked for the project.

III. ACQUISITION STAGE

Budget

The general configuration of the proposal was maintained throughout the process. Within the bounds of the proposal objectives and bottom line of the budget, there was room for adjustment to specific models and specifications. Indeed, as the process of completing the bureaucratic requirements for the project proceeded, the specifications on the hardware were updated as the latest model/version became available. Price reductions allowed for the addition of a CD-ROM disk, and four additional copies of the microcomputer version of MicroStation software (purchased in anticipation of more microcomputers becoming available). The final budget is set out in Table 3.

Under the proposal, the main cost was for hardware. Software to accommodate our broad cartography and GIS needs did, however, increase the budget request above the level necessary for a straight GIS laboratory. Funding for training was a bonus that might not have been allowable under a standard capital equipment grant. As this was a new facility, the university paid for the retrofitting of the classroom space. This expenditure is not always allowable under a grant, so that assurance of the availability of in house funds for this purpose should be secured in advance.

Purchasing

A prerequisite for the smooth acquisition of equipment was the processing of the appropriate paperwork. On the university side, the appropriate purchase order forms and supporting documents (in this case sole source rationale), had to be completed, as well as forms for the donation side of the project. This was done in Spring, 1991. There were several vendor forms that had to be processed simultaneously. Given the newness of this project and the different divisions of the company that were involved in it, it was not possible to process all the forms at one time. The strong relationship with the local sales representative, and his commitment to the project greatly facilitated the handling of these forms. Delivery and installation took place in April and May, 1991.

Reasons for the final choice of products/services

The primary goal of this project was to expand the capabilities of the department’s training in GIS. It was felt this could best be achieved by complimenting, rather than duplicating the equipment currently held. To this end, the UNIX workstation platform was chosen. The specific choice of Intergraph over other UNIX systems was largely pragmatic. The author and Mr. Guidry discussed individual items. However, the precise designation of model was largely left to Intergraph’s technical personnel. The Interpro 2000 series workstation is built on industry standards and combines high quality performance with desktop size. The two servers were required to accommodate the broad range of peripherals desired in the new laboratory.

While the greatest benefit of the Intergraph equipment was in adding UNIX capabilities to our "toolbox", the specific machines decided upon also have the capability of running DOS applications in a window environment. While only running at 286 speed, this means that the current DOS software could also be loaded on them. Copies of the DOS version of Intergraph’s MicroStation software were also obtained so that all machines in the new laboratory would be able to run this package.

The peripherals (see Table 3) were chosen to complement those already onsite. A desktop plotter and dot matrix printer will still provide the basic working output, with the new color copier and laser printer, being used when high quality output is desired. The tape drive and CD-ROM disk will provide backup and data input capabilities previously not available. The desktop scanner will also add to the range of input possibilities available.

Physical Plant

Perhaps the easiest part of the process of setting up the new laboratory was the acquisition of the space. The room was largely under the control of the department, so that requesting its conversion from class use to laboratory space meant few changes for other departments. The conversion did cause some dislocation in the department as the request for the change was not made until after classes had already been scheduled. The department has two classrooms of the same size that can accommodate the classes previously held in the laboratory room. At the same time, computer laboratory space in the department has been doubled.

IV. OPERATIONAL STAGE

Configuration

Maximum use has been made of the limited space available in the new laboratory. The Intergraph workstations and servers have been aligned down one wall, leaving the central island for DOS based and other machines (see Figure 1). The specific room was chosen for several reasons. First, it fell mainly under the control of the department and would not require disruption of other departments. Second, it was an interior room and therefore would have better security. Third, it is kitty corner from the old laboratory, so that potential linkage in the future would be relatively easy.

The main drawback is the floor area, allowing room for expansion to a maximum of only eighteen workstations and associated peripherals. While maximizing the number of work spaces that could be set up, the vertical alignment and limited space have necessitated holding introductory sessions for exercises in a regular classroom. In order to maximize the use of laboratories for practical work, the department purchased a trolley, overhead projector, and computer projection panel that can be moved to any nearby room for demonstration purposes. In this way, the need for holding lectures in the laboratory facility is eliminated.

The primary consideration in software utilization is to reduce the amount of training time needed to learn how to operate the machine, versus the learning and application of software specific to the course goals. Machines have been configured so that students can access the particular software package or module by using just a couple of key words or commands. As the laboratory is only in its initial stage of use, exercises in the GIS courses will not attempt to make students fully functional in the full suite of software on the new machines. Instead, the main emphasis will be on the core Intergraph MGE/MGA GIS environment module, in conjunction with the DOS-based software previously used. Students will still receive practical training in pcARC/INFO and IDRISI, as well as an introduction to the other GIS packages the department owns. Individual student projects will allow in depth examination of particular aspects of the MGE/MGA package or one of the other software packages of the student's choosing. Certain software will remain specific to one platform or the other. Therefore, student activity may be focussed on one set of platforms for one class or exercise, while the other machines are free for students in another course. A full set of manuals on all software is kept in the laboratory for reference purposes.

All machines are networked through two servers to each other and to the array of peripherals. The SUN NFS protocol is used as the local area network. All machines will also be linked to the VAX using the TCPIP networking protocol when the university converts to this system this Fall. This setup allows for optimal sharing of data and peripherals. The VAX connection will enable data sharing and utilization of the laboratory for VAX-based software, if needed.

The design of the benches followed the standard computer laboratory form used by the university's physical plant, conforming to the height for keyboard operation, and most efficient layout of space. An island with central vertical panel was used to increase the number of work spaces available. The standard work space allocation was increased to allow for desktop digitizers to be added between machines in the future. The retrofit costs included a major upgrade of the electrical system, involving the installation of a new transformer and panel. The old classroom lighting was retained to reduce costs. A thermostat was installed in the room to allow temperature control of the space. Funding for new chairs was not forthcoming. Secondhand chairs were obtained from surplus property.

Use

The laboratory was established to enhance GIS training and will be devoted full-time to teaching use. This semester, Fall, 1991, will see the first class use of the facility. Class time is broken down into two hours of lecture and four hours of lab per week. Lectures and lab explanation sessions are held in an adjacent classroom. Exercises are designed to enable students to complete them in four to six hours. Two weeks are allowed for each exercise. Enrollment in the undergraduate GIS course this semester has more than doubled to fifty students. This has necessitated opening up an additional laboratory section for a total of three. The laboratory will be open during the daytime, Monday to Friday, and at least two evenings a week for the graduate class. Teaching assistant support is available to monitor the laboratory for fifty hours per week. Sign-up sheets will be used for each machine. Students have first preference in their own lab time slot. However, exercises are structured to be as self explanatory as possible so that students can work at their own pace with little or no assistance. Use of peripherals is kept to a minimum. Emphasis is placed on the practical use of the programs' functions and understanding applications. Digitizing is covered in the Computer Cartography course.

The majority of users in the Fall semester will be undergraduate and graduate GIS students. In Spring semester, computer cartography and advanced GIS students, enrolled in the Topics in Cartography course, will utilize the laboratory (see Table 1 for average enrollments).

Operation

Sufficient staff to monitor the laboratory during evenings and on weekends would help cater to working and/or commuting students. In an ideal situation, a full time staff person would also be available to oversee the running and operating needs of the facility. It is unlikely these options will be available in the near future.

Downtime and maintenance is not anticipated to be a problem. The Intergraph equipment is under a one day call maintenance contract. The microcomputers and peripherals are serviced by university technical support personnel. Previous experience suggests very few problems will be encountered.

Operating expenses for disposable supplies will come from laboratory fees charged by the university. As the facility is new, the amount of this fee for the GIS courses may have to be adjusted when a record of usage is available.

Security is a perennial concern. The department has not allocated funds for hardware security, beyond the addition of a deadbolt. The university is trying to institute minimal security standards in all its computing facilities through making available inexpensive cable locking devices. This program is expected to be initiated in Fall, 1991. Software security has been enabled in the software configuration on each of the UNIX-based machines. Each student will have to log on with an account number and a password which will only allow access to that software being utilized in the exercise.

Software installation on the UNIX stations is relatively easy, requiring minimal effort to upload the programs from CD-ROM. Installation on the microcomputers is more laborious. Usually, several disks have to be loaded, and then parameters tailored to match the hardware configuration of the machines and the peripherals.

With growing numbers of students using the facilities, techniques for preventing software corruption become more important. Two issues have been explored. The first is the growing potential for viruses to be introduced into the laboratory. A bootup virus checking program can handle the basic hazard, though the risk of unknown viruses entering the system still exists. To reduce virus potential, student generated files are written to the hard disk. As the data is unlikely to be useful with other software packages, there should be no reason for student disks to be used in the laboratory. Students are told to use specific file names, prefixed with their initials, so that they can easily be identified and deleted at the completion of the exercise.

A second problem, student corruption of files, has not been great. In the past, inadvertent deletion has occurred on only rare occasions. Education (with a heavy stress on student responsibility) has probably reduced potential for more serious problems. The fact that it is "your lab" is stressed. The setup of the new UNIX stations allows software control of students' access to particular programs and functions. Programs to restrict software access on microcomputers are available, but attempts to get the department to purchase security-oriented software have not been successful.

Responsibility

Responsibility for administration of the laboratory resides with the project director. Besides setup and monitoring of equipment, her tasks include preparation of instructional manuals and handouts; preparation, full-scale testing, and evaluation of teaching module material; preparation, distribution, and analysis of evaluation forms; preparation and delivery of workshops and mini-courses for faculty and teaching assistants.

While many of the tasks are more efficiently performed by one person, the burden can be lightened by having a second faculty person closely involved. Particularly for the ongoing functioning of the laboratory, having a second fully-trained person onsite is a bonus. If possible, the person with primary responsibility should have release time for the initial semester of laboratory setup and operation, to establish a sound footing. Graduate assistant or staff support would also be useful.

Relationships

Currently, the author is the only member of the department with courses utilizing the new equipment. It is anticipated that materials for more advanced courses will be developed by the author and Dr. Dennis Fitzsimons in Spring, 1992. Given the high time demand of the current GIS courses, it is likely that only one or two more classes will incorporate large scale use of this equipment. It is anticipated that the new courses will be upper division classes with small enrollments (only ten to fifteen students per semester). In the long-term, it will be necessary to cap course enrollments until sufficient staffing is available to provide greater access.

The new facility provides a core from which the department can expand its potential both in terms of materials incorporated into current courses, and leverage for future funding both within the university and outside. On the practical side, at least two in house workshops are planned to familiarize faculty and graduate assistants with the actual operation and capabilities of the new systems. These workshops will graphically show them the potential for use in their own work. Thus, rather than remaining terra incognita, as so often happens with computing environments, the new facility's power will be experienced firsthand.

While the laboratory is currently devoted to meeting the needs of the department's courses, its unique facilities have gained attention both within the university and in the outside community. In the short run, this will translate into students from other departments and local agencies taking our GIS courses.

Because of the innovative nature of the grant under which this laboratory was established, valuable lessons have been learned about ways of successfully interacting with industry. This report is one venue through which this process can be communicated. An Open House is planned for Fall semester, so that faculty from other departments and from schools in the surrounding area can see the new facility firsthand and learn about its setup and operation. It is hoped that this personal contact will form the basis for development of a support network in the local area.

V. EVALUATION STAGE

The final outcome closely matches what was initially envisioned - a laboratory housing a variety of hardware and software to maximize the practical training we can give our students. In practical terms, our students will have the opportunity for firsthand training in state-of-the-art GIS technology. On a broader scale, the laboratory is seen by the university as an example of what can be done to foster university-industry cooperative efforts for educational purposes. The prestige and public relations value of obtaining such a substantial grant is appreciated by the administration and has enhanced the department's position in the school.

One impediment to the completion of the picture is the decision by the department chair to divide the department's microcomputers between the old laboratory and the new. Only two of the department's seven microcomputers were assigned to the new laboratory. One additional machine will be purchased for the laboratory by the Dean. This means that the full benefit of consolidating equipment in one location to facilitate teaching and make the most efficient use of resources has not been possible. New resources will have to be found to 'fill out' the new laboratory. This will take time. Thus, the full potential of the new laboratory will not be immediately realized.

One faculty member is still opposed to the new facility and has persisted in presenting a negative view of its value and utility for the department. It is unlikely that this opposition will be overcome. Some faculty view the laboratory as a potential contract money earner, though no proposals have been directly brought to the author's attention. Such work could interfere with the prime function of the laboratory as a teaching facility and would have to be carefully scrutinized. The time demand such a use would impose on the author and the facility precludes it as a viable option in the near future.

The process of setting up the laboratory has been long and time consuming. Without release time, the project director has found it difficult to devote time to other career areas, such as research. With a full teaching load (eleven hours) in Fall, 1991 full development of some of the teaching modules will have to be postponed until Spring semester.

However, the groundwork has been laid for further developments. Future plans include submission of further proposals to vendors to acquire more software and UNIX-based hardware to complete the laboratory. At the same time, the full potential of the new software will be explored so that it may be used to enhance current course offerings.

Recommendations

Several points which may help those pursuing the development of a new laboratory are suggested by the author's experience:

- seek support at all levels of the university hierarchy, and don't be discouraged by lack of support at any one level,
- explore all potential funding sources - approach vendors directly, even if no established educational support program exists,
- leverage in the form of matching programs can increase chances of success and return for your effort,
- enroll a colleague to provide practical and moral support through the process,
- be flexible and prepared to make adjustments to the working plan at all stages,
- be prepared to devote time to the project - the old adage "if you want something done, do it yourself" still holds,
- be tenacious and enthusiastic - if you aren't, you can't expect anyone else to be, and
- capitalize on your assets whatever they may be.

PROPOSAL TO THE UNIVERSITY

SWT APPENDIX A

MATCHING GRANT FUNDS PROPOSAL TO
ESTABLISH STATE-OF-THE-ART MICROSTATION
GEOGRAPHIC INFORMATION SYSTEMS
LABORATORY

Dr. Susan Macey
Dr. Dennis Fitzsimons
Department of Geography and Planning

To accomplish our primary goal of providing students with a core of professional expertise, a microstation laboratory to support the teaching of GIS theory and principles will be established. The acquisition includes the latest Geographic Information Systems technological advancements in both hardware and software. It encompasses state-of-the-art UNIX-based microstations which are connected by servers to each other and the department's IBM microcomputers, greatly enhancing the capabilities of the latter. In conjunction with our current software (pcARC/INFO, and ATLAS*GIS), Intergraph's MicroStation GIS Environment and SoftPC will provide the foundation for complete GIS management and map production. Thus our students will receive the widest possible practical experience in the GIS field through the integration of innovative exercises with existing coursework.

This comprehensive training will prepare our students for GIS doctoral work at any of the top universities, or for professional employment with a wide spectrum of private companies such as Rand McNally, as well as government agencies ranging from the City of San Marcos, Bexar County, and the Texas Department of Highways and Public Transportation, to the U.S. Defense Mapping Agency. Our students already are engaged in such important geographic information systems work as the Hays County 911 Mapping Project. The proposed facility will further enhance our capability in providing such vital support to our community.

In addition, this facility will provide increased NSF and other research grant potential, and support the current National Geographic Society and Texas Alliance activities of the department.

PROPOSAL TO INTERGRAPH

SWT APPENDIX B

PROGRAM TO ESTABLISH MICROSTATION
GEOGRAPHIC INFORMATION SYSTEM LABORATORY

MATCHING GRANT PROPOSAL
TO INTERGRAPH CORPORATION

Dr. Susan Macey
Dr. Dennis Fitzsimons
Department of Geography and Planning

INTRODUCTION

Our main goal is to integrate the latest technological advancements into our existing teaching program in the highly dynamic field of Geographic Information Systems (GIS). We will develop instructional exercises that will form the core of technical training that uses state-of-the-art microstations and software that to not only enhance the learning of principles, but also provide students with a core of professional training second to none.

To accomplish this goal, a microstation laboratory to support the teaching of the GIS courses will be established through the joint cooperation of the Intergraph Corporation and Southwest Texas State University (SWT). A mix of microcomputers workstations, with appropriate input/output devices (plotter and scanner), and software is proposed to give the widest possible practical experience to students.

THE PRESENT SITUATION

Southwest Texas State University (SWT) is a four-year comprehensive university in central Texas with an enrollment slightly greater than 20,000 students. The current computing facilities of SWT and of the Department of Geography and Planning do not enable students to gain experience in the types of hardware and software that they will be required to use in graduate study and in any professional geography career. It is imperative that our program shifts to an emphasis on microcomputer workstations to maintain relevance to students' academic and professional aspirations and to meet the expectations of persons who will consider our graduates for graduate schools or professional employment.

The program of the Geography and Planning Department at SWT has been ranked as the premier undergraduate program in the nation (de Souza, et al., 1981) and continues to be "an outstanding example of careful implementation of the mission of a comprehensive state university in practice--perhaps the premier example in the United States" (Shelley, 1988, pg. 11). The department is the locus of geographic information systems curricular instruction at SWT. It enrolls approximately 5000 undergraduate students annually in its courses, and it currently serves 360 majors, as well as ninety-two graduate students in the first Master of Applied Geography program to be offered in the United States. The three-pronged goal of the department is to:

1) provide undergraduates with an academically sound education
2) prepare them to enter first-rate graduate schools
3) provide advanced practical training for students entering the professions.

Of the approximately ninety students that graduate each year, a growing number are going on to world class graduate schools--Harvard University, Texas A & M University, University of Texas, and the University of Wisconsin, and on to professional employment with prestigious organizations. A selected list of employers where graduates have been placed includes the following:

- City of Austin
- Councils of Government
- Defense Mapping Agency

- Environmental Systems Research Institute (ESRI)
- Ferguson Mapping
- National Geographic Society
- Texas Air Control Board
- Texas Department of Highways and Public Transportation
- Texas Water Commission
- Zycor, Austin.

The general trend in both the undergraduate and graduate GIS courses has been toward higher enrollments and increased computer use each semester. This project will allow us to substantially build on this program by providing state-of-the-art facilities for practical training on microstations from Intergraph Corporation, the world's largest GIS hardware/software/service vendor.

OBJECTIVES

The proposed program has <u>three major objectives</u>:

1) enhance the critical scientific thinking of students through the practical application of principles,
2) integration of state-of-the-art technology to substantially upgrade the quality and timeliness of skills,
3) provide an example for the integration of GIS education in colleges nationwide.

These objectives will be achieved through the development and integration of laboratory exercises into existing undergraduate and graduate GIS courses. The exercises will be tailored to progressively build students expertise.

EQUIPMENT

<u>The Equipment Request</u>

To accomplish the primary goal, a microstation laboratory to support the teaching of the GIS courses will be established. A mix of microcomputers workstations, with appropriate input/output devices (digitizers, plotters, printers and scanner), and software is proposed to give the widest possible practical experience to students. The Intergraph MicroStation GIS Environment is the foundation for complete GIS management and production. The department has two IBM microcomputers currently available in the laboratory and two on order. Current peripherals include a Hewlett-Packard 7475A desktop plotter, Hitachi 48" X 60" digitizer, Houston Instruments Hipad digitizer, and IBM Proprinter. These will be integrated with five Intergraph microstations, servers and associated peripherals in the new laboratory to provide the two-to-one student-microstation ratio deemed necessary for the department's practical-oriented GIS courses.

Alterations necessary to accommodate the new equipment and to establish an efficient teaching environment will be funded by the university. These alterations include enhancing room security through structural changes, upgrading electrical circuits, and upgrading the current terminal server to enable data exchange with the VAX. Clerical support will be provided by the department.

FACULTY EXPERTISE

<u>Dr. Susan Macey</u> is an assistant professor of Geography. Her formal training includes cartography, spatial data analysis, and computer cartography. Dr. Macey currently serves as the national chair of the Association of American Geographer's (AAG) Energy and Environment Specialty Group. Under her direction, SWT has become one of the beta test sites for the National Center for Geographic Information Analysis (NCGIA) Geographic Information System core curriculum.

<u>Dr. Dennis Fitzsimons</u> is an associate professor of Geography. His areas of expertise include cartography and computer cartography, as well as geographic information systems. Dr. Fitzsimons has won three teaching awards and served as the national chair of the AAG's Cartography Specialty Group.

CONCLUSION

An important side benefit of this project will be the knowledge gained on the development, and implementation of innovative GIS practical training. Several evaluation measures will be employed. First, student evaluations of their learning experiences in using the exercises will be conducted, using forms specially prepared by the principal investigators. Evaluations will seek information on ease of operation, level of comprehension achieved, relevance of exercise material to course content, and usefulness of exercises in achieving course objectives. Faculty evaluation of students through formal examinations and exercise results, will provide information on student achievement levels.

Dissemination of the results will take two forms. The principal investigators will present a summary report and a synopsis of the program at the Association of American Geographers' Annual Meeting, and the 1991 Fifth Annual International Geographic Information Systems/Land Information Systems Conference. These papers will, in turn, be submitted for publication to the Journal of Geography, the preeminent venue for educational outreach in U.S. geography, which reaches both a national and international audience.

REFERENCES CITED

de Souza, A., Vogeler, I., and Foust, B. (1981) "The overlooked departments of Geography", Journal of Geography, Vol. 80, pp 170-175.

Shelley, F. (1988) "Southwest Texas State University", pp. 11-14 in Ad Hoc Committee on Geographic Education at the Collegiate Level Report to AAG Council. October 1988 Council Meeting, St. Paul, MN.

TABLE 1
COURSE DESCRIPTION AND ENROLLMENT

Course Size*	Average # Students per year	Times offered
UNDERGRADUATE COURSES		
3411 - Map Compilation and Graphics An introduction to map compilation projections, instrumentation, and graphic techniques in presenting statistics for planning and geographical analysis.	38	2
3415 - Cartographic Production An introduction to the technical equipment and materials used in processing map images. Emphasis is placed upon techniques applicable to monochromatic maps and the organization of complex art work for multicolor or series map production. Projects include production planning, organization and management, and execution.	14	1
3416 - Air Photo Interpretation Introduction to aerial photography, photometrics, and instrumentation utilized in aerial mapping.	23	1
4412 - Remote Sensing Basic photometrics and the development of indicator sets in imagery analysis.	20	1
4422 - Computer Cartography The use of computer software to display information about the earth's surface and various types of statistical data on maps and graphs.	22	2
4426 - Geographic Information Systems An introduction to the principles and applications of geographic information systems.	11	2
4440 - Topics in Cartography Advanced or specialized techniques in cartography, photogrammetry, remote sensing, or other related topics. Specific topics will vary.	15	2
GRADUATE COURSES		
5408 - Applied Cartography Advanced or specialized techniques in cartography at the graduate level.	15	1
5417 - Computer Cartography The use of the computer to produce graphic compositions for geographic research (graduate level).	15	1
5418 - Geographic Information Systems Analysis, interpretation, and applications of GIS at the graduate level.	15	1

* Average is based on the last five years (10 semesters). While no one course is required, students in all three of the department's concentrations (Cartography/Geographic Information Systems, Resources and Environmental Studies, and Urban and Regional Planning) must take at least one course out of 3301, 3411 and 4426. Cartography/Geographic Information Systems concentration students must take six of the eight courses listed above.

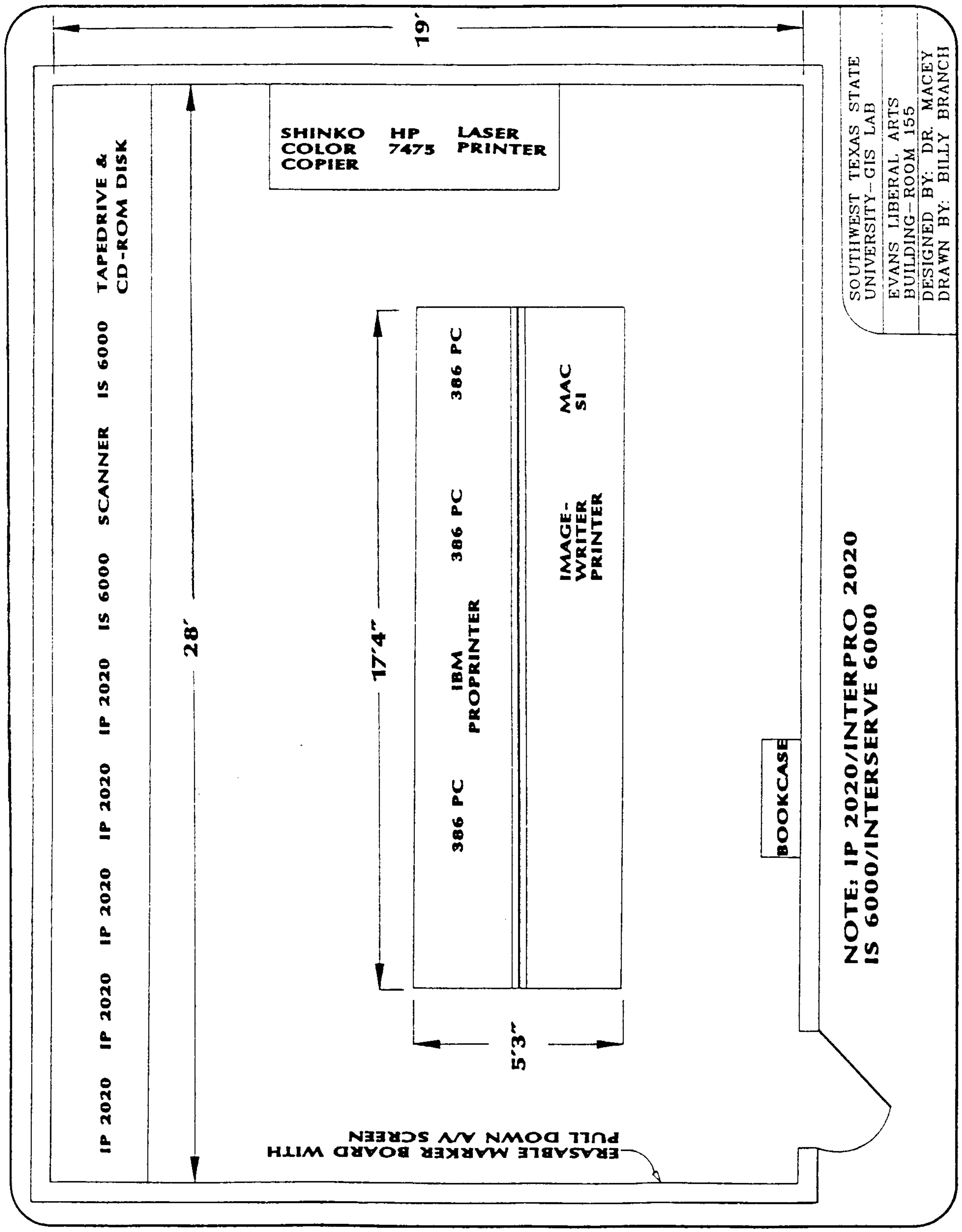
TABLE 2
PROPOSED BUDGET

Description	#	Unit Price	Funding Agency SWT	IC	Total
Hardware					
InterPro 2020 Microstations	5	$22500	$56250	$56250	$112500
InterServe 6000 Series	1	19900	9950	9950	19900
InterPro 6040 Series Server	1	28400	14200	14200	28400
Color Thermal Hardcopier	1	12000	6000	6000	12000
Intergraph 403L Scanner	1	2600	1300	1300	2600
Cartridge Tape Drive 2.3GB	1	5500	2250	2250	4500
DEC Compatible Video Terminal	1	1000		1000	1000
PC Ethernet Interface	5	500		2500	2500
Ethernet Cabling		1100		1100	1100
Software					
GIS Environment, SoftPC, interpreter and interface				215730	215730
Retrofit of laboratory space					
Electrical		6700	6700		6700
Carpentry		2625	2625		2625
Erasable marker board conversion		175	175		175
Maintenance fee					
One year contract		7200	7200		7200
Total Cost			$107650	$309280	$416930

TABLE 3
FINAL BUDGET

Description	#	Unit Price	Funding Agency SWT	IC	Total
Hardware					
InterPro 2020 Microstations with 200mb hard drive	5	$15900	$15900	$63600	$79500
InterPro 6040 Series Server with 355mb hard drive	1	25000		25000	25000
InterServe 6000 with 355mb hard drive	1	15900	15900		15900
DEC Compatible Video Terminal	1	965	965		965
Shinko Color Thermal Copier	1	12000	12000		12000
Intergraph Laser Printer 811	1	5000	5000		5000
Intergraph 84L Scanner	1	2600		2600	2600
Cartridge Tape Drive 2.3GB	1	5500	5500		5500
Compact Disk CDROM Drive	1	1000	1000		1000
PC Ethernet Interface	4	500	2000		2000
Ethernet Cabling		2185	2185		2185
Software					
Informix Database Engine			9300	6250	15550
Intergraph Scanning software	1	5000		5000	5000
Interplot and HP driver	1	5500	5500		5500
Microstation 32	6	100	600		600
Microstation 32 Raster Editor	2	4000	4000	4000	8000
MGE/MGA	6	12000	12000	60000	72000
Microstation GIS Translator	1	3000		3000	3000
Microstation Imager	1	15000		15000	15000
Microstation Map Finisher	1	6000		6000	6000
Microstation Modeler	1	5000		5000	5000
Microstation Project Manager	2	5000	5000	5000	10000
PC Network File System	4	500	2000		2000
SoftPC	6	1000	1000	5000	6000
Retrofit of laboratory space					
Electrical		6700	6700		6700
Carpentry		2625	2625		2625
Erasable marker board conversion		175	175		175
Maintenance fee					
One year contract		7200	7200		7200
Training				17200	17200
		Total Cost	$116550	$222650	$339200

FIGURE 1
COMPUTER LAB



University of Victoria, British Columbia

C. Peter Keller
Department of Geography

September, 1991

ESTABLISHING GIS FACILITIES AT THE UNIVERSITY OF VICTORIA, BRITISH COLUMBIA, CANADA.

Following is a summary of past and ongoing initiatives to establish GIS teaching and research laboratory facilities at the University of Victoria, located in British Columbia, Canada. Since 1985, the University of Victoria has established three GIS facilities; a ten workstation DOS based junior teaching laboratory, a ten workstation AIX (IBM UNIX) based senior teaching laboratory, and a research laboratory. All three laboratories are located in, and are managed by the university's Department of Geography. However, the facilities are accessible to the rest of the university community for a user fee. The objectives of this paper are to relate the procedures involved in establishing the teaching GIS facilities, and to share some observations and experiences gained.

Discussion of any new initiative, including the establishment of GIS facilities, ought to be placed in the broader context of the political and economic environment in which the initiative is to happen. This is true especially if comparisons are to be made to other facilities, or if the experiences narrated here are to be used to develop GIS facilities elsewhere. Efforts to establish GIS facilities at the University of Victoria therefore should be viewed within the overall context of the role of GIS to industry and government in the Province of British Columbia, to the size, strength and importance of the University of Victoria relative to other universities within the province, and to the internal organization of the university itself.

To achieve the objectives of this paper, brief background information will be given to cover the above. This is followed by a chronological summary of events related to the establishment of the GIS facilities, commencing in 1985 when the author was first appointed at the university. Detailed descriptions of the design of laboratories and equipment are included. The paper concludes with the author's personal reflections about experiences gained when establishing the facilities.

BACKGROUND INFORMATION

Province of British Columbia

Occupying an area of 366,255 square miles, the province of British Columbia has a low population density (8.46 people/square mile for a population of 3,100,000) with the bulk of the population living in the south in or near the cities of Vancouver (pop. 1,400,000) and Victoria (pop. 260,000). The economy of the province is heavily resource oriented, with considerable wealth in timber, minerals, water, fish and wildlife. Given the importance of the natural resource base to the economy, and given the low population density, industry and government have to rely heavily on advanced technologies to maintain an inventory of and to manage natural resource assets. GIS, among other technologies, therefore plays an important role in the province, as evidenced by the existence of a number of research and development companies within British Columbia specializing in development and marketing of GIS and remote sensing, and by considerable GIS implementation initiatives in most government departments. Although now considerable in size, the GIS community in British Columbia was still small when the author first came to the province in 1985. This implied that, through time, personal contact could be made with most key-players in industry and government, resulting in the development of a strong sense of cooperation between the university, government, and industry.

University of Victoria

The University of Victoria is one of three universities in British Columbia, but the only university located on Vancouver Island and in Victoria, the capital of the province. The university has an undergraduate enrollment of approximately 14,000 students, with 1,200 graduate students and 2,900 faculty and staff. It therefore is a small to mid-size university, approximately equal in size with one of the two Vancouver universities, Simon Fraser University, but considerably smaller than Vancouver's University of British Columbia.

The University of Victoria traditionally has specialized in the Arts and Sciences, Humanities, Music and Law. However, over the last decade, the university also has established a prestigious Faculty of Engineering, and has recently opened a School for Earth and Ocean Sciences and a Business School. The university does not have a Faculty of Medicine. The university supports an active co-operative program which gives students an opportunity to work with industry.

Department of Geography

The Department of Geography at the University of Victoria is located in the Faculty of Arts and Sciences. The department has always maintained a strong tradition in resource management, with the majority of its 15 faculty listing resources as one of their specializations. In the last academic year (1990/91), the department granted 67 undergraduate degrees (8 general, 55 major and 4 honors), and had 174 students declared as geography majors. The department has an active graduate program with 79 students presently enroled (56 M.A./M.Sc. and 23 Ph.D.). The department has one of the most active co-operative programs, having placed 132 students in the 1990/91 academic year. The co-operative program has played a key role in securing support and funding for departmental GIS initiatives.

Over the years, the Department of Geography has spawned or actively assisted in a number of resource related initiatives at the University of Victoria. They include some years ago the establishment of an undergraduate Environmental Studies Program and a Center for Asia and the Pacific, and more recently a School for Earth and Ocean Sciences, a Center for Regional Studies, a Center for Sustainable Development, and a planned graduate Environmental Studies Program. The geography department faculty continues to maintain an active interest and a leadership role in some of these initiatives, although others have gained independence, notably the Center for Asia and the Pacific, and the School for Earth and Ocean Sciences. It is not unforeseeable that the department will spawn a Computing Center for Spatial Sciences in the future.

The Department of Geography has always maintained a number of undergraduate "techniques" courses to support its strength in resource management and related fields, including cartography and statistical analysis (see Table 1 for a list of techniques courses for the 1990/91 academic year). Cartography was traditionally pen and ink based, but the individual in charge of the cartography courses made the decision to purchase a Tektronix 4050 workstation in order to introduce computing at the senior undergraduate and research level in 1983. However, resignation of this individual soon thereafter left a two year gap in which cartography courses were taught by sessional staff, allowing for little continuity and no establishment of new digital facilities. A decision finally was made to hire a new cartographic/GIS faculty member whose duties would commence in the 1985/86 academic year. The new appointment was given the mandate to teach existing courses in cartography and spatial analysis, to establish an active research program related to cartography including graduate teaching and supervision, and to take over responsibility for the department's computing resources.

DEVELOPMENT OF GIS FACILITIES

The Beginning

This paper highlights the development of GIS facilities at the University of Victoria since the arrival of the new cartographic appointment to the Department of Geography in July of 1985. The following is a narrative of events, including technical details.

When interviewing for a new job, applicants are in a unique position to be able to negotiate space, work conditions and start-up funds that are considerably more difficult to secure once appointed. An important first step towards developing a GIS facility at the University of Victoria therefore was to include in the initial job negotiations an agreement of understanding with both the Dean of Faculty and the departmental Chair, that space would be made available in the geography department for a digital cartography/GIS laboratory, and that the university's administration would be supportive of efforts to establish such a facility. It is common practise in Canada for a university president to hold discretionary funds to be allocated as seed money to new faculty members, and it was agreed that, upon arrival, a proposal was to be submitted to attempt to secure some of this money.

A seven page proposal to access the President's discretionary funds was prepared soon after arrival in July. The proposal argued for the need for Cn$30,000[4] to purchase equipment that would benefit both departmental teaching and the applicant's research program. A request was made for funds to be allocated independent of the department's annual equipment budget, to purchase hardware and software necessary to allow senior students access to digital cartographic equipment, and to establish the beginnings of a digital cartography/GIS research program. Highlights of the proposal included the following:

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[4] On September 20th, 1991 the exchange rate was 1 US dollar for 1.14 Canadian dollars.

TEACHING

- Trends in geography and cartography towards automation.
- The impact of these trends on industry and government.
- The academic merit of giving students hands-on experience on computers.
- The present and forecasted job market for students with skills in digital cartography and GIS.
- A brief description of how students would use the equipment proposed.
- A rational as to why existing university computing facilities were inadequate for teaching advanced cartography or GIS.
- The need to offer a competitive program in cartography and GIS to support the department's strengths in natural resources.

RESEARCH

- A summary of the applicant's research program to date.
- A summary of the applicant's proposed research program.
- The need for the applicant to have a digital laboratory to attract graduate students.
- A rational as to why existing university computing facilities did not meet all the applicant's research requirements.

While waiting for a response from the President's office, a number of other strategic moves were initiated. First, course descriptions and course titles of all cartography courses were changed to stress digital cartography and, where appropriate, GIS. Second, a decision was made to offer a new course in GIS. Recognizing that attempts to place a new course in a university curriculum can be associated with considerable red tape (and can prove problematic if another department feels that the subject matter infringes on its territory), a decision was made simply to take an existing course, and to change its title and description to become the new GIS course.

Second, the urgent needs to find space and to draft plans for renovation of the promised new GIS lab were stressed to the department's Chair. Planning for the new facility therefore was under way early in the fall.

Third, in recognition of the fact that any GIS initiative would benefit from cooperation with the community, considerable efforts were undertaken to meet with, and to establish liaison with representatives from local industry and the provincial government.

Fourth, the new appointment had been placed in charge of the Department of Geography's computing portfolio, which at this stage involved management of mainframe accounts and representation on a university Research Users' Computer Committee, and a university Teaching Users' Computing Committee. Following a number of informal meetings with other members of the two university computing committees to learn about computing elsewhere on campus, a departmental computing plan was drafted in close cooperation with the department's Chair. At this stage, nobody in the department (faculty or staff) had access to a personal computer. It was recognized that office procedures (especially the workload on the department's secretarial staff) would benefit greatly if faculty and staff were to be given access to their own computers, and it was recognized that possible opposition to the new computing laboratory to be introduced in the department might be reduced if individuals were guaranteed their own computers. The plan therefore became to automate the department's faculty and staff by allocating everybody a low-end personal computer that would be compatible with machines to be purchased for the department's secretaries. In consultation with the Dean of Faculty, the plan was accepted. It was to be implemented over a three year period using funds from the Dean as well as money originally allocated to the department to access cycles on the university's mainframe. Drafting and implementing this plan fulfilled a useful secondary purpose in that it allowed for the development of a solid working relationship between the individual in charge of departmental computing, the Chair and the Dean. The importance of the latter would prove essential in future negotiations.

A positive response from the President's office to the Cn$30,000 start up proposal in early November implied that equipment could be ordered, and renovations could proceed to merge two small offices into a digital cartography/GIS laboratory. At this point in time (1985), the decision was made to purchase a combination of mainframe peripherals and microcomputers for the lab. The following hardware therefore was ordered:

- enhanced IBM AT with the best graphics capabilities available
- Hewlett Packard 8 pen plotter
- wide carriage dot matrix graphics printer
- Tektronix 4107 high resolution color monitor
- Tektronix full size digitizing tablet

Following installation of the hardware, a research program was initiated which included two graduate students, and the first course using this equipment was taught January to April, 1986. The following software was used in this course:

Mainframe:	SYMAP	**Microcomputer**:	ATLAS*GRAPHICS
	SAS GRAPH		UDMS
	DI3000		WORDPERFECT
			LOTUS 123

Recognizing that none of the software contained true GIS capabilities, negotiations were conducted with the Laboratory for Computer Graphics and Spatial Analysis at Harvard to install their ODYSSEY GIS software on the University of Victoria's IBM mainframe. The software looked interesting and could have been purchased at a very reasonable price. However, some modifications would have been required to input and output statements in the code to make it run on the IBM mainframe, and some additional work was required to write a device driver for the newly acquired TEKTRONIX peripherals. These were minor problems compared to the annual amount the Department of Geography was to be charged by the University of Victoria's Computing Services to install and run the software on the mainframe. Plans to support ODYSSEY therefore had to be abandoned because of accounting problems internal to the university. Negotiations for the department to become a beta test site to a small local company building their own GIS software, GEOMAP (later to be renamed PAMAP), proved more feasible, and GEOMAP was installed for the first time on the IBM AT in early 1986. The decision to cooperate with a local GIS vendor certainly has proven beneficial over the years to both the University of Victoria and the vendor, and based on personal experience, it is recommended that anybody setting up a GIS facility actively seek out and cooperate with local industry initiative as long as there is an understanding of mutual benefit.

The joint teaching/research laboratory soon proved unmanageable given only one PC and only one color graphics terminal to access the mainframe. Also, the need to access the hardware for teaching implied continual interruption of the research program. Efforts to develop a separate teaching laboratory therefore commenced.

The Junior Teaching Laboratory

Events leading towards the establishment of the university's first proper GIS teaching laboratory did not follow conventional methods.

By spring of 1986 it was becoming increasingly apparent to the university that moves had to be made towards establishing microcomputing facilities. Facilities developed by the university's Computing Services up to this point were always booked beyond capacity by traditional computer users, and were therefore difficult to access. These facilities also lacked a support mechanism required by faculty new to the concept of incorporating computing in the classroom. Recognizing the above, the Dean of Social Sciences in March of 1986 made the decision to form an ad-hoc committee to evaluate computing needs for the social sciences. The committee, consisting of a faculty representative with computing interests from each of the six social science departments (anthropology, economics, geography, political sciences, psychology, sociology) was to report back to the Dean on present and future social science computing needs, and to propose how needs identified could be met.

Each department commenced by an in-house survey to assess computing needs. As the Department of Geography's representative, I opted to prepare a lengthy report outlining needs for a microcomputer based laboratory to support statistical and spatial analysis, digital cartography and GIS, as well as supporting packaged programs for other courses, including climatology, hydrology, geomorphology, urban geography, economic geography and tourism geography (note: the proposal at this point did not include remote sensing since the department only offered a course in airphoto taught by sessionals, and no faculty member expressed interest in developing a remote sensing course). Computing equipment specified in the report had to support digitizing, high resolution graphics, printing and plotting. The proposal was supported by sections outlining the following:

- Trends in geography.
- The need for a microcomputer facility to support the department’s co-operative program.
- Relevant course descriptions.
- Student usage estimates.
- Examples of laboratory exercises to be run.

Department estimates showed that geography alone would become a major user of a ten workstation microcomputer laboratory, occupying nearly half of available laboratory time during working hours in the first year of use, not including drop in time, and not supporting wordprocessing.

Attempts to combine the computing needs of the different departments in the social sciences soon proved that geography and psychology would be the major users, and that geography had unique requirements that would considerably escalate the cost of any proposal. Following extensive debate, a decision finally was reached to propose that the university develop two social science microcomputing facilities, a 20 workstation general use laboratory with an adjacent 10 workstation drop-in room, and a 10 workstation laboratory specializing in graphics equipment, including digitizing. Anthropology proved to be a strong supporter of geography in pushing for this strategy. The two lab concept found the Dean’s approval, and was presented to senior administration.

Senior administration in principle had no difficulty with the general use laboratory, giving approval to commence with detailed planning and renovations. However, they found it more difficult to agree on the development of a specialized graphics laboratory. Throughout the following months, considerable efforts and energy therefore were invested by myself, the geography Co-operative Coordinator, the Chair of the geography department, and the Dean of Faculty to lobby for support. The Co-operative Coordinator proved an especially strong ally given her recognition that the co-operative program would benefit from the ability to market students with GIS skills, and given her general political skills and enthusiasm for the GIS initiative. An initiative to get contacts from industry and government to apply pressure to senior administration in support of the facility proved to be of tremendous benefit throughout this time. A detailed summary of the lobbying and politics to secure agreement for the specialized laboratory is beyond this document. It should suffice to note that some members of senior administration (including the President) feared the precedent of building a microcomputer laboratory to meet what would essentially be the requirements of one department (and at that a department traditionally non-computing oriented), while others (including the Vice-President Academic) were strongly in favor of developing departmental computing facilities of excellence.

While negotiations were progressing, the cartographic/GIS faculty member applied for and was granted an internal university "Academic Development Grant" to attend a workshop on GIS curriculum development held in another part of Canada. The grant amounted to approximately Cn$2,000.

The Dean and Vice-President Academic finally agreed to explore possibilities of funding an independent graphics microcomputer laboratory for the social sciences out of discretionary funds. The idea was to announce this laboratory as a social science graphics computing facility, to be located in and managed by the geography department, with geography holding highest access priority. Perhaps not coincidental, geography at the same time was asked to conduct an internal departmental review.

Throughout the departmental review process, geography repeated the computing needs already stressed in the previous report to the Social Sciences Computing Committee, but included the identification of a priority to attract faculty to teach a course in remote sensing. The department also outlined a proposal how its map library and cartographic staff could benefit from a graphics microcomputer laboratory, and submitted plans outlining how it could meet the space requirements for a departmental microcomputer facility.

A decision was made to proceed with technical planning of a potential microcomputer graphics facility. Planning included considerable investment of efforts towards detail of design to show seriousness of intent, and to ensure that a high quality laboratory would result. Experience had been gained from the design of the general social science microcomputing laboratory, design responsibility for which had been given primarily to myself and a faculty member from Anthropology. In the general lab, considerable thought had been invested in the design of a room that would be ergonomic, functional and practical; have access for the handicapped; have an environment that is conducive to learning; and be sufficiently different from the university’s traditional "basement computer pits" to appeal to a social science student. The design of the graphics laboratory followed similar principles, including detailed specifications of furniture design, color schema, lighting panels, floor covering, security, heating etc.

Table 2 is a list of the hardware that was proposed and finally installed in the laboratory. Figure 1 shows the design of the room layout, consisting of two five workstation benches and side space for storage and peripherals. Figure 2 shows more detailed drawings of the furniture. The philosophy was to maintain each personal computer as an individual workstation, thereby eliminating the costs and headaches associated with the development of a local area network, but connecting each workstation to the mainframe via a KERMIT link, and using a serial and a parallel switch box to link the five computers located on each workbench to a common printer and plotter. Figure 3 shows the wiring plans.

Following are examples of some of the design specifications taken into consideration when planning the room:

- The workbenches were specified to be of a height to allow ergonomic operations of keyboard and tablet.
- A shelf was designed in the middle of the bench to allow for storage space for books etc., and to function to separate the two sides of the bench.
- All cables were to be run through accessible ducts along the middle of the bench and along the wall.
- The bench surfaces were to be of a color to minimize light reflection (although they were finally built using white formica).
- Space between the benches and between the benches and other furniture was calculated to allow for easy access, and to allow for movement of an instructor behind students.
- Fluorescent ceiling lights were located to be parallel to the benches and slightly behind monitors to reduce glare, and switching was arranged to allow only half of all light tubes to be illuminated if required.
- Panels covering the fluorescent lights were specified to be of a design to reflect light in a controlled direction to minimize glare (initial panels installed did not meet this specification, and had to be replaced due to excessive screen glare). Figure 4 shows the lightning plans.
- Window blinds were specified to allow screen glare from outside light to be minimized.
- The room was to be carpeted with a static resistant carpet.
- Notice boards were specified on walls to allow for the display of posters and assignments.
- Chairs with rollers and adjustable heights were requested for ergonomic reasons (they since have proven popular with students for races down the length of the department's main corridor).
- Air-conditioning including dust control was requested (but eventually refused for reasons of excessive cost).
- A security number lock was ordered for the door to control access.

In September of 1987, the department was informed that funds would be made available over a two year period to develop a specialized graphics facility, and that renovations should be initiated by geography to house the facility within the department. A little snag occurred at this stage. Perhaps somewhat naively, we had failed to recognize that relationships with individuals in charge of Buildings and Maintenance at the university had soured over the fact that faculty were insisting on active participation in questions of design specifications and design detail when building the general social science laboratory. This fact, in conjunction with some continuing objections by individuals at the senior administrative level to develop what would essentially be a departmental lab (although labelled a social science facility under geography management), led to a somewhat unhappy period of initial renovations that was stopped soon after it commenced. However, under the two phased agreement, five workstations were ordered in November of 1987, and in January of 1988 the digital cartography and GIS course used the partially renovated room on a 'make do' basis for the first time. Laboratory exercises were designed using ATLAS*GRAPHICS, IDRISI and the PAMAP GIS. A program was started to develop "in-house" teaching software, developed by myself with the help of my graduate students and research assistants.

Students' response to the equipment proved overwhelmingly supportive, and that year's active geography Undergraduate Student Society took upon themselves the initiative to write a letter to senior administration requesting and encouraging continued support for completion of the facility.

At this stage it is worthwhile to report on a number of other events of relevance to the GIS initiatives that went on in the Department of Geography. First, the department made the decision to search for a replacement faculty appointment in physical geography that would also show an active interest in remote sensing.

Second, a decision was made to offer the department's cartographic drafting staff the opportunity to audit the digital cartography/GIS course to gain experience with the new equipment purchased. Cartographic staff also was given free time and full access to hardware and software throughout the following summer to explore possible integration into their duties. This strategy proved highly successful, with cartographic staff now fully automated.

Third, efforts to introduce faculty and staff to microcomputers, and to supply them with machines, was progressing rapidly, resulting in such an abundance of requests for assistance with software and hardware failures that, as the person in charge of the department's computing portfolio, I was beginning to spend the bulk of my time on computing related matters. The need for technical support staff therefore was recognized, and an official request for such an appointment was channelled through the Chair to the department at large, and subsequently to the Dean. Pressure from undergraduates, graduates, staff and faculty to use computing equipment introduced was such that time also had to be spent drafting a departmental computing policies to set priorities, and to reduce conflicts over access.

Fourth, the possibility of attracting funds through a one-time provincial funding initiative led the Co-operative Coordinator, the geography faculty member in charge of the department's map library and myself to draft a lengthy proposal outlining the need for, and the possible structure of a university wide large GIS/digital cartography facility, to be funded by and to operate in close cooperation with industry and government, and to serve the anticipated future GIS needs of the entire university community. Nothing came of this initiative.

Throughout the summer of 1988, renovations continued to complete the GIS laboratory, including the acquisition of the remaining equipment. The lab was ready by early September, and a decision was made to thank individuals who had supported the initiative by organizing an official opening that would include software demonstrations followed by a hosted lunch. Invitations went to senior administrators of the university, individuals from government and private industry, select local and provincial politicians, and the media. Timing was opportune given that the GIS initiative had just secured a number of joint research projects with industry and government, and it being close to elections. Funds invested hosting the official opening were well spent given that the event attracted considerable attention, including coverage in the local newspaper and on television.

The lab has proven a tremendous success not only for digital cartography and GIS, but also for other application areas. However, it is important to observe that the GIS course (GEOG 428, offered every term), and more recently the introductory cartography course (GEOG 323) and a new remote sensing course (GEOG 422) are the dominant uses of the facility (over 90% of time), with a number of geography courses having been forced to revert back to using the general social science microcomputer laboratory because of pressures of access to the GIS lab.

It is worthwhile to point out, too, that software for the laboratory was rarely purchased outright. Wherever possible, considerable efforts were invested to develop a working relationship with vendors, and to negotiate free access to the software through some joint work, or to purchase at reduced rates. The argument that vendors would benefit from student exposure to software proved one of the most convincing to get price reductions, an argument that appears to have found widespread acceptance amongst GIS vendors judging by recent educational discounts offered. Software in the lab has continued to change through time, although a number of programs have been supported since the beginning. These programs include continually updated versions of the PAMAP GIS, ATLAS*DRAW and ATLAS*GRAPHICS. IDRISI was added in 1988 and EIDETIC imaging software and COREL Draw in 1990. Thanks to tremendous commitments of time and efforts by my graduate and research students, the lab also has benefitted from extensive "in-house" software development. A strict policy of no wordprocessing, and "no unofficial software" has been enforced in the lab since the first day of opening. Table 3 shows a list of software presently supported on the machines.

The big mistake made when negotiating for and setting up the lab was that little thought had been given to operating costs, equipment maintenance and amortization. The reality that hardware and software would need to be upgraded every three years to remain competitive and to keep up to the pace of progress in technology had been recognized from the outset, but its importance had not been fully appreciated at the time of negotiating the facility. Rather naively, therefore, no provisions had been made for an operating or amortization budget. Operating expenditures and hardware upgrades therefore now are funded by renting the facility to industry and government for training programs, by accessing the general departmental operating budget, and by charging a minimal user fee to students ($5.00 per course).

The laboratory hardware is not insured against theft or hardware failure. A decision was made to self-insure against hardware failure, a decision which so far has proven to be cost effective. The only security against theft is a deadbolt and a numberlock on the door of the laboratory. Students registered in a course utilizing the laboratory are asked to sign a form which outlines the rules of the lab. Rules include a paragraph informing the students that, as a privileged user, they are responsible for policing reasonable behavior. In exchange for their signature, students are given the number combination for the lock (which is changed every term). The deadbolt locks the door at night, but students can sign out the key overnight if they agree to supervise the facility while it is open, and if they accept responsibility for damage or theft. Perhaps surprisingly, the junior laboratory has functioned with such sparse security for over four years now without theft, vandalism or other damage.

Despite the lack of a proper operating and amortization budget, a number of hardware upgrades have been made since 1986. In the summer of 1990, another 42Mb hard drive and 2Mb of RAM was added to each of the computers. A laser printer was added in 1988, and was replaced during the summer of 1991 by a Hewlett Packard LASERJET IIIP with a postscript cartridge. One of the MODEL PS 2/60s units recently was replaced with an IBM clone 33Mhz 486 processor, mainly to speed up the printing of COREL Draw output files on the laser printer. Plans are to replace all other IBM PS 2/60 units with high speed 486 IBM clones over the next few years.

Since the official opening, demand for the facility quickly surpassed all expectations, and pressures placed on the laboratory have made it inadequate since the year it was built, soon leading to efforts to establish a second laboratory. The story of the second lab is outlined below.

The Advanced Teaching Laboratory

To appreciate the activities that led to the development of the second laboratory, it is necessary again to present background information to set the scene.

First, a new faculty member was appointed with an active research and teaching interest in remote sensing in 1988, and the department elected a new Chair in 1989 from within the department. Following departure of the Vice-President Academic in 1988 to become president of another university, this position was filled internally, and following retirement of the President in 1990, a new president was appointed from the outside. A number of other changes occurred at the senior administrative level, but the Dean of Social Sciences was voted in for a new term. Overall, the political scene therefore changed considerable in a few years.

Second, I was elected to the position of Chair of the university's Research Computer Users' Sub-Committee, thereby becoming a voting member of the university's Committee on Computing. The latter committee functions to advise senior administration on all issues related to campus computing. Over the next two years, considerable experience and insight would be gained sitting on this committee, information that would prove invaluable when politicking for the second lab.

Third, the introduction of computers to faculty members and staff in the department had progressed considerably, and received endorsement from the new departmental Chair. Continued requests for additional staff, strongly supported by the newly appointed remote sensing faculty member, eventually led to the hiring of a full-time computer assistant in the late fall of 1989. Ceilings on enrollment in the department's undergraduate technical courses led to a situation where technical courses had permanent enrollment waiting lists, and technical courses proved increasingly popular with non-geography students. Graduate students from other departments also started to take an increasingly active interest in GIS.

A regular scheduled graduate course in GIS and an undergraduate course in remote sensing were proposed and accepted late in 1988. A proposal was drafted by faculty in charge of the department's techniques courses to re-structure the technical component of the undergraduate program. The goals were to redesign the program to better reflect student demands, to more adequately address needs of the co-operative program, to address changes in the discipline, and to ensure a logical flow between the different technical courses. Introductory cartography began to make use of the microcomputer graphics laboratory more extensively in 1988.

Soon after arrival, the new remote sensing appointment submitted two proposals to senior administration, one to access the presidential discretionary funds for new faculty (introduced earlier), and a second to develop a remote sensing teaching laboratory. Following the President's decision to fund part of the money requested through the discretionary grant, and following failure to secure a positive reaction to a new remote sensing laboratory, a decision was made to merge the GIS/digital cartography research and teaching laboratories with the new remote sensing initiative, calling the joint facilities the "Spatial Sciences Laboratories". Merging the facilities implied the need to expand the size of the research laboratory, and led to the recognition that the department should aim towards the development of a second teaching facility, to consist of UNIX based equipment. Renovation plans therefore were made to free the space occupied by the old GIS teaching laboratory to house the research lab, and to divide the department's traditional cartography laboratory to make room for two digital teaching laboratories. Drafting tables and light tables needed to teach remaining labs in traditional cartography had to find place in an airphoto/resources lab.

Efforts to secure funds to develop the advanced teaching laboratory continued throughout the 1989/90 academic year, although they were slowed by the imminent retirement of the university's President, the need for the new Vice-president Academic to settle in, and time required to develop a working relationship with the new departmental Chair. I also spent some time on leave to work on a research project in Asia.

Despite continued failure to secure approval of funding for additional teaching hardware and software, a decision was made in the summer of 1990 to go ahead with renovations of the department to expand the spatial science research facility, by now desperately crowded with graduate students and research assistants, and in the process to create space for the second teaching laboratory.

By fall of 1990 the new President had arrived. A position paper to be submitted to him was drafted jointly by myself and the remote sensing faculty member with assistance from the Department of Geography Co-operative Coordinator. It outlined the University of Victoria's future needs for facilities in "Spatial Sciences", focusing on cartography, GIS, spatial analysis and remote sensing. The position paper included the following:

- A summary of general trends in the spatial sciences (GIS, digital cartography, remote sensing, sustainable development, global change, ...).
- The trend towards interdisciplinary teaching and multidisciplinary research centers (including environmental studies, sustainable development, resources studies, regional planning, global change, ...).
- A justification on how established and new programs and center initiatives on campus could benefit from spatial science laboratory facilities.
- Graphed enrollment trends and forecasted demands for spatial sciences facilities in geography.
- Graphed trends in co-operative employment showing the rising demand for students with skills in the spatial sciences.
- A detailed summary of technological trends in GIS and remote sensing.
- A section demonstrating why existing facilities at the university were no longer adequate for the purposes of teaching or research, stressing technological details including size of data files, transfer speeds, memory requirements, ...).
- A section outlining trends in other universities to develop spatial science facilities, including in specific a summary of ongoing initiatives in the two other universities in British Columbia.
- A section utilizing another university in Canada as a case study to demonstrate in detail what other universities were investing in the development of spatial science facilities.

The report concluded by proposing the development of a new 11 workstation spatial science laboratory facility. The proposal included specifications of hardware and software, a purchase and operating budget, a method of obtaining matching funds, and an amortization strategy. The proposal requested a one time budget of Cn$622,730 reduced to Cn$283,985 through a matching grant strategy and vendor contributions, and a number of annual operating and amortization budgets, ranging from Cn$162,000 to Cn$105,000/annum. A strategy to recover some of the operating and amortization costs through facility rental and a user charge-back mechanism were suggested.

A position paper channelled through the usual line of authority runs the risk of disappearing in a pile on somebody's desk, therefore receiving little attention. A decision therefore was made to prepare a demonstration of spatial sciences software in the existing research and teaching facilities, and to invite members of senior administration (including the President, Vice-president Academic, Dean of Faculty, Director of Computing Services and Associate Vice-President Administration) to a one hour presentation combining a software demonstration with delivery of an oral and written presentation of the position paper. Although considerable politicking had preceded mailing of the invitations to secure positive reactions, we still were surprised to find that everybody agreed to attend. The meeting appropriately was held in the newly renovated empty departmental second computer teaching laboratory, demonstrating that space and renovation costs no longer were major criteria in establishing the second teaching facility.

Reactions to the meeting were mixed. Although sympathetic to the needs for advanced and specialized spatial science computing facilities at the university, it became obvious that there existed divergent opinions concerning the control and administration of such an initiative. Should it be a university facility under interdisciplinary committee management with an appointed director, or should it be a geography facility accessible to the university at large for a user-fee? The first would imply considerable additional administrative overhead costs, and would not guarantee that the social sciences and the geography department's teaching needs would be met in the long term should the director prove unsympathetic to the social sciences. On the other side, concern was expressed openly that the second option involved investment of considerable financial resources into a potentially unstable program. It appeared that instability was seen to arise from the fact that out of the two key faculty concerned with the proposal, one had only recently been appointed to the university (and therefore was perceived not to have established a lengthy track record), and the second had recently been promoted with tenure, and was perceived to be at a stage in career where he could opt to accept an offer from industry, government or another university.

There followed a seven months period of considerable politicking within the university, a detailed discussion of which again is beyond this paper. It should suffice to note that geography continued to lobby for the facility, stressing why it was needed, and what benefits the university would derive. As for the first laboratory, prominent individuals from industry and government with an interest in GIS again proved strong allies in supporting the department's position. Other initiatives on campus, of course, recognized that financing of the new laboratory would have possible repercussions on funding of other projects, resulting in expected opposition.

After numerous official and unofficial meetings, senior administration eventually agreed that an advanced spatial science facility should be developed at the university, and that it should be administered by geography. However, the department was told that funds for the facility certainly would not be available until the following fiscal year, and even then, availability of funds would be dependent on the amount of money to be allocated to the university by the provincial government. The department, in reply, stressed the urgency to finalize a decision at the earliest opportunity to allow faculty members and staff ample time to order, install and learn the software and hardware before commencement of teaching in the fall of the 1991/92 academic year. The department also kept up negotiations with hardware and software vendors in an effort to reduce costs further, and to capitalize on new releases.

The new fiscal year commenced April 1991, and in the middle of June the department got approval to spend Cn$350,000 on software and hardware, with purchase orders going out the day following go-ahead. The administration at this stage did not commit itself to an annual operating budget or an amortization strategy, opting instead to negotiate details concerning ongoing budgets sometime after facility installation.

Table 2 list the equipment ordered. Usual delays in delivery of hardware have resulted in computers and networks being installed four weeks behind schedule in late August of 1991. Training courses on the some of the software, originally scheduled for the middle of August, therefore have had to be deferred to September and October. This is unfortunate since the fall teaching term at the University of Victoria usually commences the week of the Canadian labor day weekend in early September. This implied that vendor training on hardware and software had to fall into the teaching term, with the first course (a fourth year GIS course) scheduled to use the new laboratory at the same time.

Table 4 summarizes the planned course content and laboratory exercises for GEOG 428, the fourth year GIS course that will make first use of the new facility. The course has an enrollment ceiling of 20 students per term, allowing for two laboratory sections with ten students each. One of my graduate students usually functions as a laboratory instructor. Laboratory exercises in the 1991/92 academic year will utilize the PAMAP, GENASYS and SPANS packages (see Table 4). Individual exercises are custom designed by myself and my graduate students utilizing data from research projects and contract work. On top of the scheduled two hour laboratory period, students spent on average between two and six additional hours in the lab completing exercises. Labs and a project make up a considerable proportion of the final grade, which is determined as follows:

Two hour final examination	50%
Laboratory exercises	30%
Project	20%

The project consists of a written assignment. During the last class before reading break, students are given a written request for proposal (RFP) to solve a real world spatial problem utilizing GIS. The problem generally involves integration of vector and raster data, reclassification of attribute data, multiple overlay, spatial query, buffering and network analysis.

Students are expected to write a written reply to the RFP, explaining what steps they would take to solve the problem, how they would create the necessary database, what system or systems they would use in the process, how they would take best advantage of analytical capabilities, how they would manage uncertainty and error, and what hours/time/costs they would associate with the job. The deadline for submission of the project is the last day of classes.

An official opening of the new laboratory is planned for late October. Ongoing efforts are continuing to re-structure the department's undergraduate techniques courses to make better use of the facilities, to introduce a second GIS course, and to generally adapt to changes in the discipline. The two teaching laboratories are accessible to geography students who wish to use the software to complete projects for other courses. Although planned as teaching laboratories, both the junior and the advanced facilities do function as overflow buffers for the research laboratory, and are used for research outside regular scheduled laboratory classes. However, access to complete teaching assignments always has highest priority during teaching terms. Negotiations are progressing to allow undergraduate and graduate students from other departments and research centers on campus to access the facilities for a user fee.

REFLECTIONS

The objectives of this paper have been to narrate the procedures that led to the establishment of GIS teaching facilities at the University of Victoria, and to share some observations. No doubt, considerable experience has been gained establishing the junior and advanced spatial science teaching laboratories, the general social science microcomputer laboratory, and the research laboratory. However, experiences ultimately are personal, and it should be kept in mind that "what works for some does not necessarily work for others". The following therefore merely is one man's opinion.

With any initiative, it is all too often personalities and personal inter-relationships that make the difference between success and failure. A key ingredient to successful establishment of a GIS facility therefore appears to be the ability to understand and to cooperate with key individuals in the system, and to build the necessary liaison to ensure wide support. At the University of Victoria, efforts spent building liaison with members of administration, individuals in other departments, and contacts in industry and government, certainly proved invaluable. A decision to become actively involved in the university's computing committees proved essential.

Few institutions can afford the risk of investing large amounts of capital and resources in the unknown. It therefore is crucial to demonstrate that a request for investment in a GIS facility is supported by a team that has demonstrated ability and competence. To burden a junior appointment, who has few if any contacts and little knowledge of university politics, with the task of setting up departmental GIS facilities on his or her own is courting disaster. This is true especially if that person has to compete against other departmental initiatives for funds. (How often are junior appointments in chemistry or physics asked to commence their appointment by finding space, funds and staff to set up teaching laboratories?) Efforts to set up the junior laboratory at the University of Victoria would not have succeeded without full support from the Chair and the Dean, support that was earned in part by efforts invested in helping plan the general social science laboratory. The advanced teaching laboratory initiative relied on the growth and reputation of the department's GIS research laboratory for support. It is important to note here that this paper has not addressed the growth and ongoing activities of the department's spatial sciences research laboratory, which itself contains a number of DOS and UNIX based computers, and an assortment of peripherals. It will have to suffice here to note that the research laboratory is very active, supporting at present 15 graduate and research students.

A window of opportunity when setting up GIS facilities is to negotiate space, funds and staff as part of a start-up package when commencing a new faculty appointment. This sounds easy, but how many junior appointments have the experience and nerves to bargain for departmental GIS facilities up front when it may result in not getting the job. This is a time where early advice, guidance and full support from the department is crucial.

Observation suggests that the tendency in the past has been for departments to look to hire some faculty to "introduce GIS to the department", hoping that the new appointment would disrupt the status quo of the rest of the department as little as possible. This has led to situations where the bulk of the time of the newly appointed faculty member is spent writing proposals for teaching facilities, administrating the process of setting up a new laboratory, and helping the entire department to become familiar with GIS; most of the work that could easily have been done by a technician, and work that is given little if any credit when being evaluated for tenure and promotion. In the process of setting up the GIS facility, the status quo of the department will no doubt be disrupted, and the new appointment will most likely bear the bulk of all criticism and ill feelings associated with the changes. Three issues therefore are important to recognize.

First, it should be recognized and accepted that any GIS initiative implies competition for departmental resources, disruptions and change.

Second, a GIS initiative will require technical back-up support, just like a chemistry laboratory needs a laboratory technician. After all, a faculty member's time spent supervising renovations, unpacking computer boxes, mounting software, testing peripheral device drivers and writing code for teaching software modules is time spent away from research, teaching and family.

Third, official mechanisms need to be put in place to ensure that a faculty member's time and effort spent setting up GIS facilities receive credit towards tenure, promotion and salary increments. It is very disheartening to discover that time and efforts to establish departmental GIS facilities imply that other members of the faculty get salary bonuses because they published more papers that year, and to discover after the fact that university tenure and promotion committees give little if any credit for administrative and technical work involved in planning and developing a teaching laboratory.

An issue that appears to be increasingly of concern to university administration is the question of how many GIS facilities to support on campus, and under whose management. It is impossible to discuss this subject adequately here. Let it simply be noted that it is this author's natural bias for such a facility to be housed in and managed by a Department of Geography, assuming that the department has the necessary competence and is given the necessary resources. It should be kept in mind, however, that there appears to be some truth in the fact that "who is willing to put in the work and who shouts loudest will get".

To conclude, there exists no recipe or magic formula that will ensure success when setting out to establish a GIS facility. However, if such a recipe had to be written, I would like to repeat the following key ingredients and advice in the following recommendations.

Recommendations

- Learn to understand and to cooperate with key individuals in the university system, and build the necessary liaisons to ensure wide support.
- Become actively involved in the university's computing committees and develop contacts with industry and government.
- Build a GIS team that has demonstrated ability and competence. This implies that you should not burden a junior appointment, who has few if any contacts and little knowledge of university politics, with the task of setting up departmental GIS facilities on his or her own.
- Ensure full departmental support (often easier said then done) and wherever possible, negotiate space, funds and staff as part of a start-up package when hiring a new faculty member.
- Recognize that getting involved with GIS will considerably disrupt the status quo of a department, and decide on a strategy to minimize ill feelings accordingly.
- A GIS initiative requires the hiring of additional staff to offer necessary technical support. Enthusiasm, dedication and volunteer effort on behalf of graduate students alone will not suffice.
- An official mechanism needs to be in place to ensure that a faculty member's time and effort spent setting up GIS facilities will receive credit towards tenure, promotion and salary increments.

Cooperation with other members of the university community as well as key individuals in industry and government perhaps is the most essential ingredient. Securing the necessary space, funds and staff requires not only team support, but considerable persistence and politicking. Competence in GIS is a pre-requisite to make correct decisions when ordering equipment, and to make the facility work once hardware and software are purchased. Of course, a little opportunism and luck always help.

TABLE 1
TECHNIQUES COURSES IN GEOGRAPHY

Undergraduate Geography Techniques Courses (University of Victoria)

1st Year

None

2nd Year

None

3rd Year

Geog 321	Introduction to Statistics
Geog 322	Air Photo Interpretation
Geog 323	Introduction to Cartography
Geog 324	Directions in Geography
Geog 325	Survey Methods

4th Year

Geog 422	Digital Remote Sensing
Geog 423	Advanced Cartography
Geog 425	Survey Methods
Geog 426	Spatial Analysis
Geog 428	GIS

Graduate Geography Techniques Courses (University of Victoria)

Geog 500	Colloquium and Field Work in Geography
Geog 522	Research Design in Geography
Geog 523	Research Methods in Human Geography
Geog 524	Mathematical Analysis of Spatial Systems
Geog 525	Research Methods in Physical Geography
Geog 528	Seminar in Geographical Information Systems

TABLE 2
LABORATORY HARDWARE

Junior Teaching Laboratory

10 IBM Model PS 2/60 Computers (Microchannel)

with:
- 42Mb hard drive
- 1.44Mb 3.5" floppy drive
- 1Mb RAM
- 1 Parallel port
- 5 Serial ports
- NEC Multisync monitor
- Summagraphics 12" X 12" digitizing tablet
- Keyboard
- 360Kb 5.25" floppy drive (one computer only)

2 EPSON FX-286e dot matrix printers
2 Hewlett Packard 7475a plotters
2 BAYTECH automatic serial switch boxes
2 BAYTECH automatic parallel switch boxes

Advanced Teaching Laboratory

10 IBM RISC 6000 Workstations (Model 320H)

with:
- 32Mb RAM
- 400Mb Hard drive
- 1.44Mb 3.5" floppy drive
- 16" Color monitor
- 11" X 11" digitizing tablets
- Ethernet port

1 IBM RISC 6000 Workstation (Model 550)

with:
- 21" Color Monitor
- 600Mb hardrive
- 64Mb RAM
- Tape drive
- Compact disk
- Ethernet card

1 Hewlett Packard LASERJET III printer with postscript cartridge

1 Hewlett Packard 'E' size plotter

Note: Workstations to be connected and linked to peripherals through an ethernet network, using the RISC 6000 Model 550 as the fileserver. The ethernet includes connections to the research laboratory, the university's mainframe computer, and terminals located in the offices of the cartography/GIS and remote sensing faculty.

TABLE 3
EXAMPLES OF SOFTWARE SUPPORTED

Software Name	PC Lab	AIX Lab	Research Lab
ATLAS DRAW	X		X
ATLAS GRAPHICS	X		
COREL DRAW	X		
* COLOR	X		X
EARTHPROBE			X
EIDETICS	X		X
GENASYS		X	X
IDRISI	X		X
* OSDIS		X	X
PAMAP	X	X	X
PCI		X	X
* POLLUTE	X		
QUIKMAP	X		
SAS	X		X
* SOLAR	X		
SPANS		X	X
SPSS	X		X
* SPATANA	X		X
TERRASOFT			X
* THERMAL	X		
TRANS CAD	X		

*In house software.

TABLE 4
COURSE CONTENT AND LAB STRUCTURE FOR GEOGRAPHY 428: GIS, FALL 1991

Date	Class #	Lecture Topic	Lab Topic
9/11	1	Introduction, GIS vs. CAD vs. ... Historical Evolution of GIS	
9/17 9/18	2 3	System Components, Spatial Data Topology, Vector Encoding	**P.** Cart. Input + Map Creation
9/24 9/25	4 5	Raster Encoding Object Oriented Encoding	**P.** Griding + Attribute Data
10/1 10/2	6 7	Spatial Query Basic Programming Challenges	**G.** Topology Building + Spatial Query
10/8 10/9	8 9	Topological Overlay Classification of Functional Capabilities	**G.** Vector Overlay **P.** Raster Overlay
10/15 10/16	10 11	Functional Capabilities continued Terrain Modelling	**G.** Raster Analysis + Proximity, Buffer
10/22 10/23	12 13	Terrain Modelling Accuracy of Spatial Data	**P.** DTM and Analysis
10/29 10/30	14 15	Managing Error Generalization	**G.** DTM and Analysis
11/5 11/6	16 17	Data Sources Data Exchange and Standards	**G.** Network Analysis + Plotting/Output
11/12 11/13		Reading Break Reading Break	
11/19 11/20	18 19	Modelling Implementing GIS	**S.** Complex Modelling
11/26 11/27	20 21	Applications Applications	**S.** Complex Modelling
12/3 12/4	22 23	Temporal and 3D GIS Trends in GIS	**S.** Complex Modelling + Printing/Output

P. Using PAMAP GIS **G.** Using GENASYS GIS **S.** Using SPANS GIS

Note: Each lecture is supplemented by assigned readings.

FIGURE 1
THE ROOM LAYOUT

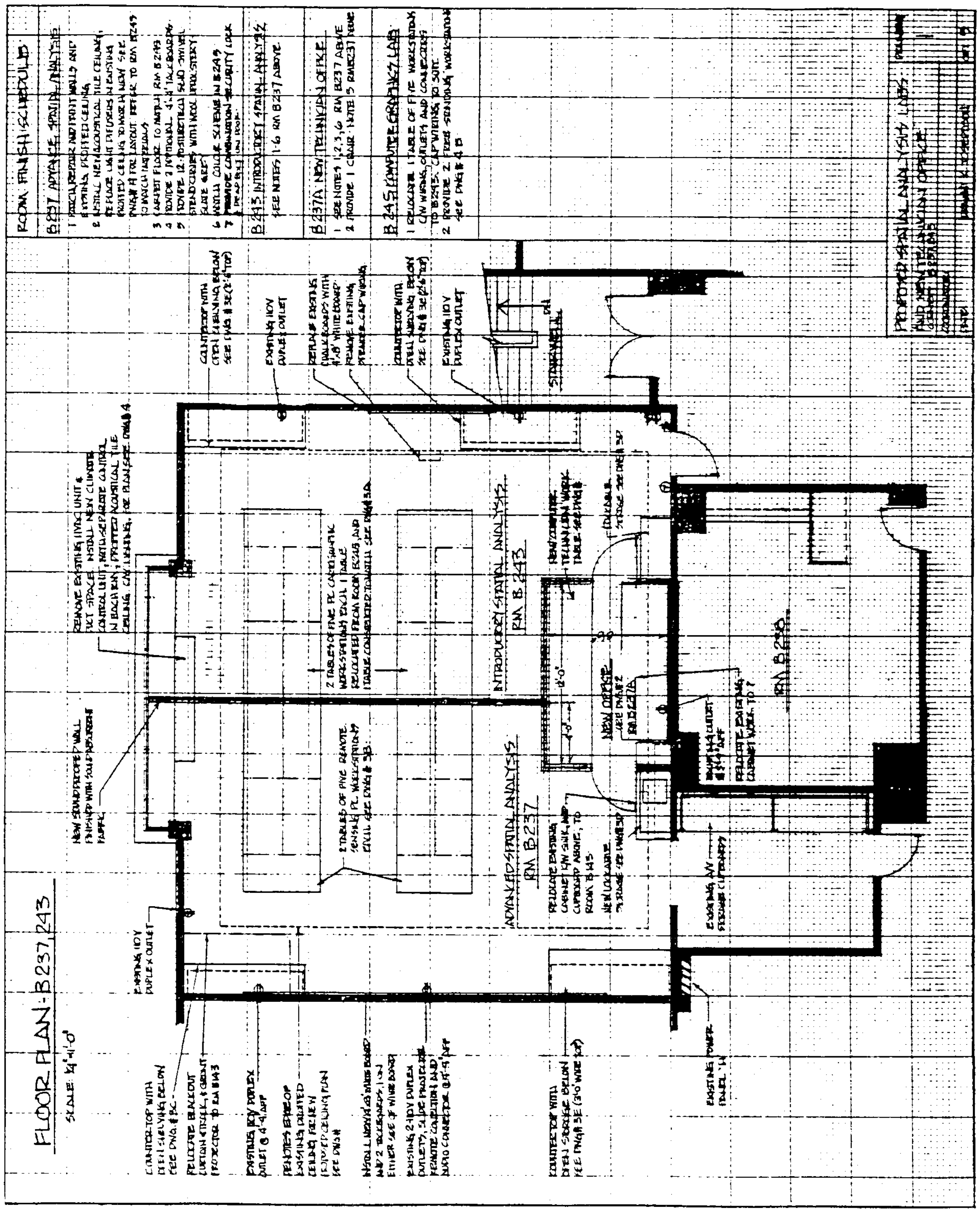


FIGURE 2
DETAILED DRAWINGS OF FURNITURE

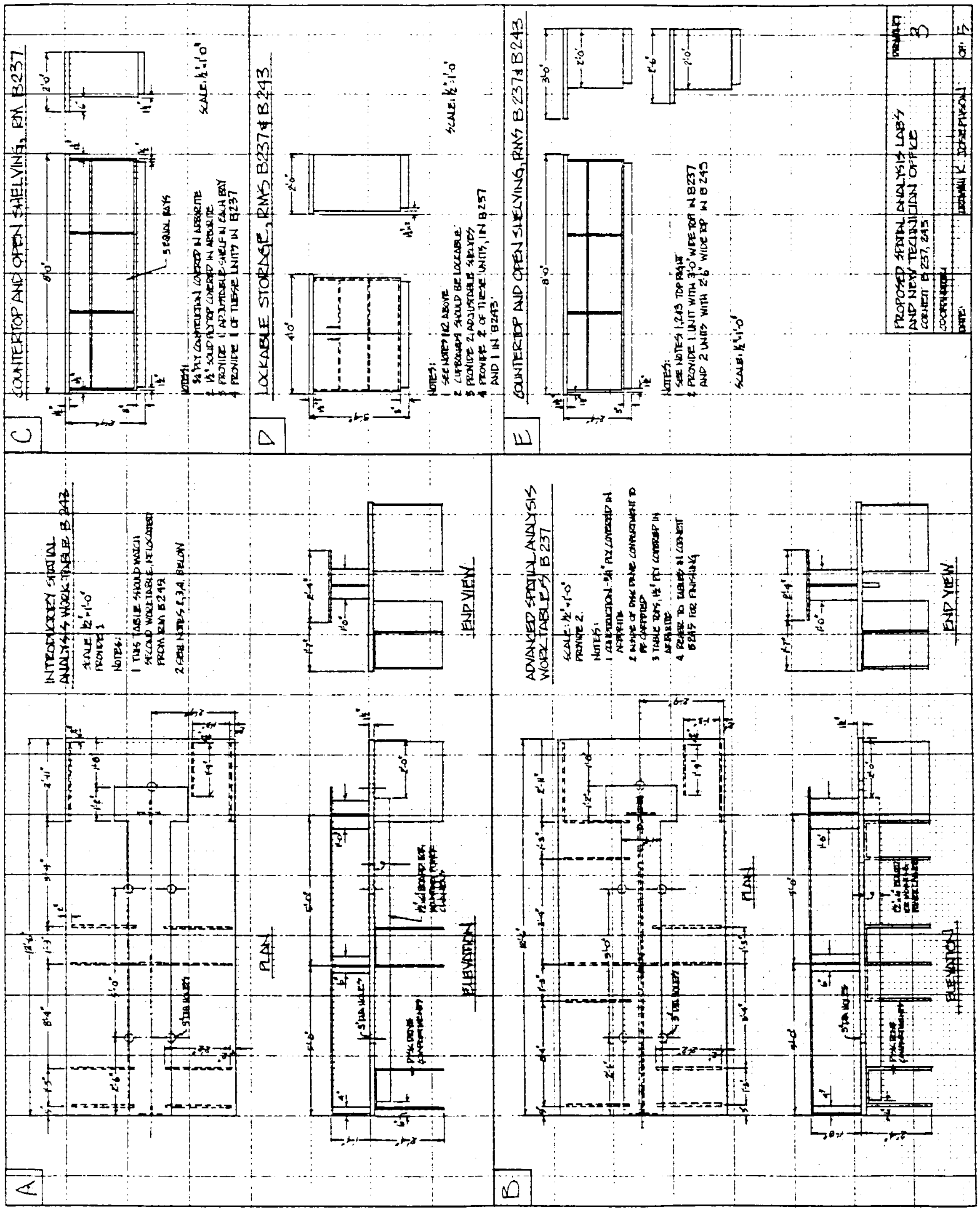


FIGURE 3
WIRING PLANS

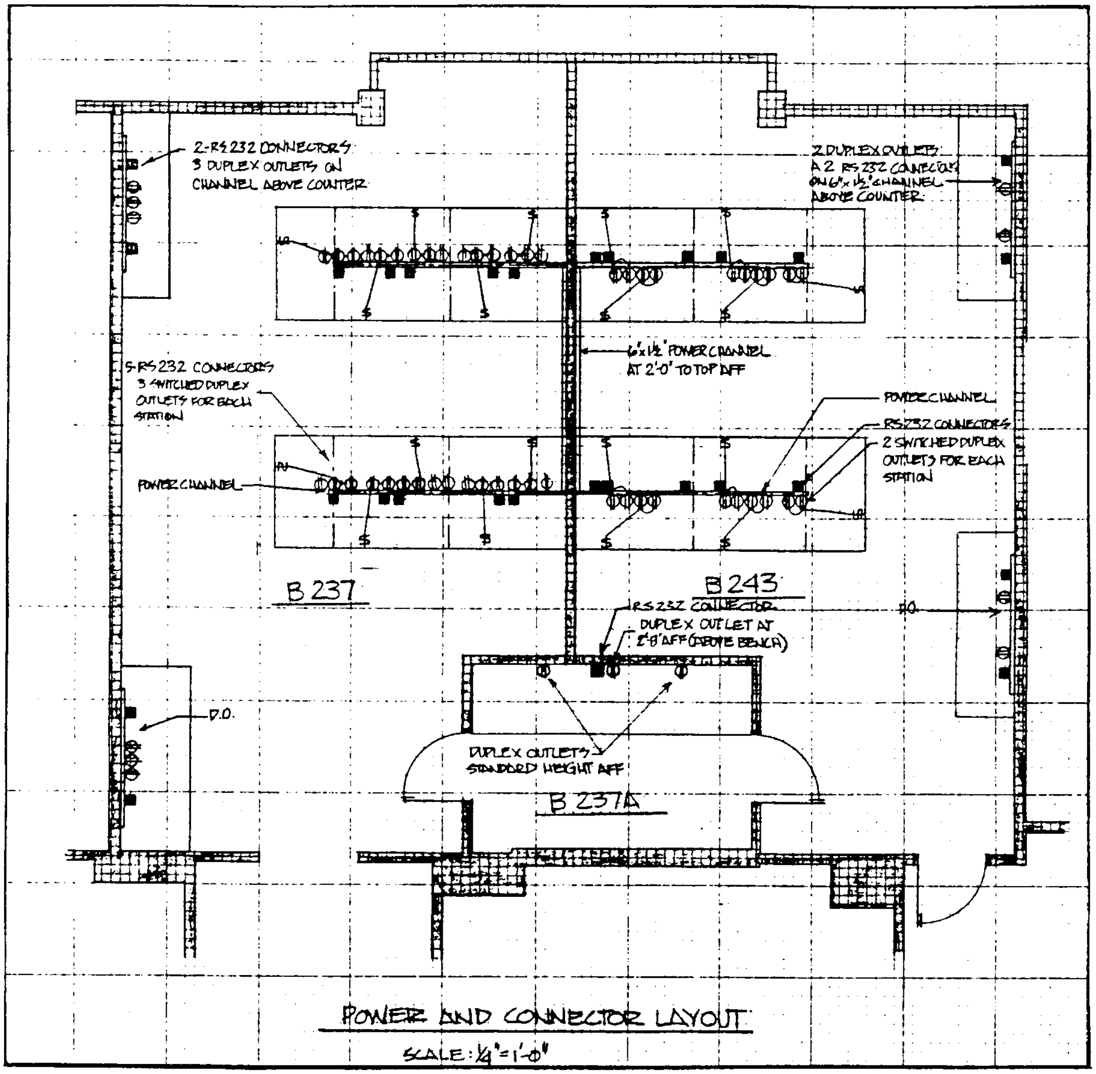
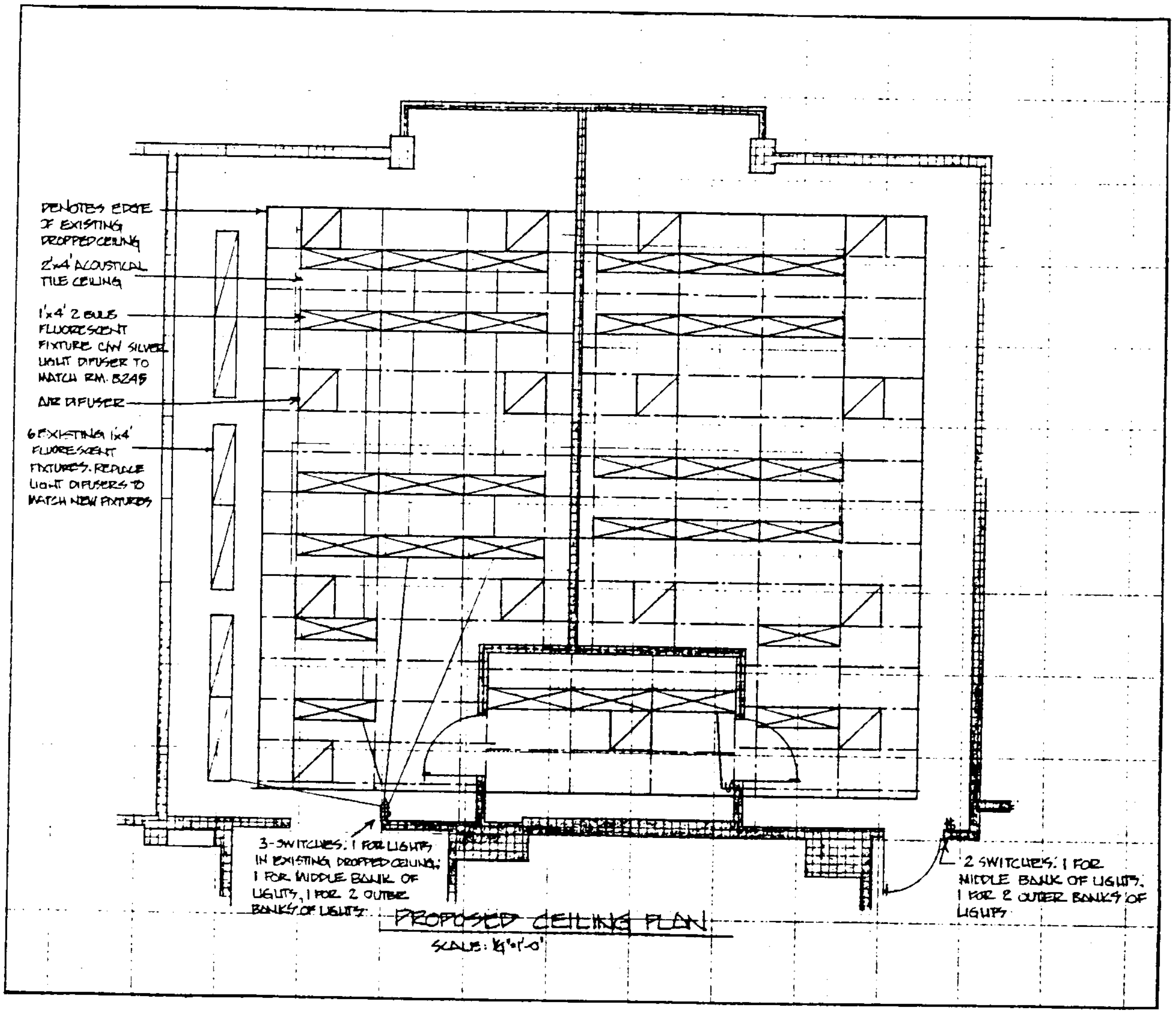


FIGURE 4
LIGHTING PLANS



Central Washington University

William C. Smith
Department of Anthropology

September, 1991

The Central Initiative: Origin and Development of the GIS Laboratory at Central Washington University

The Geographic Information Systems Laboratory at Central Washington University can claim distinction on several grounds. To begin with, our GIS Lab is an interdisciplinary facility, designed to serve the entire University. Furthermore, this is one of the few facilities of its kind to be developed specifically for use in undergraduate GIS education. Also, CWU was the first university in the nation to adopt and support GRASS (the Geographic Resources Analysis Support System), one of the most popular and best-known GIS software systems in general use today. Each of these factors proved to be critically important during successive phases of our program's development; all continue to be equally important today.

This report has been prepared at the request of the National Center for Geographic Information and Analysis, as a means of documenting the course we have followed in developing our GIS program (cf. Smith 1990). Hopefully, the information provided here will be of use to others embarking upon a similar enterprise.

ORIGINS

Central Washington University is one of six state-supported institutions offering baccalaureate and graduate degrees. As a comprehensive regional university, CWU provides bachelor's and master's degree programs in the liberal arts and sciences, professional and technical fields, business, applied sciences and engineering technologies, and in teacher education. Central has about 350 faculty who are expected to engage in some level of research and public service effort in addition to their primary teaching responsibility (12 credit hours per academic quarter). Located in Ellensburg, a rural town of about 14,000, in the center of the state and about one hundred miles east of Seattle, CWU serves some 7000 students drawn almost equally from urban and rural areas of Washington.

GIS programs at CWU had their origin in a series of archaeological research projects conducted during the 1970s and early 1980s by the Central Washington Archaeological Survey, a university-sponsored research unit under my direction. For the most part, these were standard survey and excavation efforts, funded by federal agencies under the terms of environmental protection and historic preservation legislation. In 1984, however, we were invited to participate in an unusual project on the Yakima Training Center, a U.S. Army installation located near CWU, between the Cascade Mountains and the Columbia River. The project was unusual for two reasons: it involved predictive modeling of potential site locations, and because it offered us the opportunity of working with a new kind of computer technology. We soon learned that researchers at the U.S. Army Corps of Engineers Construction Engineering Research Laboratory (CERL), located in Champaign, Illinois, were developing a new computer system known as a "GIS"; that this system was to be used for environmental monitoring purposes at the Yakima Training Center; and that a prototype including software, hardware, and a preliminary database, would be placed at CWU for our use during the year-long project. This was an offer I could not refuse. I began working with this system (referred to only as "the installation GIS", later known as GRASS) in September, 1984.

Almost immediately it became apparent that (apart from its archaeological applications) the GIS was a research tool of great potential value. But how could I justify the cost of such a system in the context of a small, state-supported, regional university whose principal missions are undergraduate teaching and, secondarily, regional public service? Clearly, a GIS initiative would succeed at CWU only by:

- serving multiple departments;
- emphasizing undergraduate teaching; and
- performing useful services such as professional training (through Continuing Education), database development, consultation, etc.

Furthermore, it seemed likely that these goals would take precedence over research in areas such as GIS systems development and GIS applications (for example, in archaeology: cf. Smith 1985, 1986).

Working from these assumptions, I demonstrated the system for colleagues in Geology, Geography, Biology, and other departments. A small core group of potential users quickly identified themselves. Together we drafted plans for launching a "GIS Laboratory".

THE INTERDISCIPLINARY ANGLE

Our first step was to form an "Advisory Committee" (later identified in the program charter as the Administrative Board), consisting of the Dean of Graduate Studies and Research, the Dean of the College of Letters, Arts, and Sciences, and the Chairs of participating academic departments. The Central Washington Archaeological Survey (with an established track record in generating external funding) provided the prototype for this organizational structure. Later, because of the Lab's program of continuing education short-courses for professionals in government and industry, the Dean of Extended University Programs joined this group. Our main faculty team consisted of William C. Smith (Professor of Anthropology) as Director, John Q. Ressler (Professor of Geography), and James R. Hinthorne (Professor of Geology). At the time, Ressler and Hinthorne also served as chairmen of their respective departments. Our academic rank and administrative experience helped to ensure support from our departments and from the University's higher administration. (See table 1).

Our initial funding for hardware (some $35,000 to purchase the Masscomp workstation with Unix operating system, 2 mb RAM, one graphics monitor, and a 150 mb hard drive; the same system that had been loaned by CERL) was derived primarily from funds generated by prior archaeological projects. As public domain software, GRASS of course was free. Had this not been the case (and had the Archaeological Survey not been so successful in generating externally funded contract research), money for GIS hardware probably would not have been available.

Hardware maintenance was underwritten by the Vice President for Academic Affairs, who happened to have a personal interest in innovative technologies. The Department of Anthropology provided space in an under-utilized lab room. The department secretary provided clerical support. Because of our strong commitment to teaching, the Dean of the College of Letters, Arts, and Sciences provided funds to cover nominal operating costs (telephone, supplies, student help, etc.). System management was an unexpected burden shared by Smith and (increasingly) Hinthorne. Initially, we received no released time for our GIS administrative efforts.

In the Fall of 1985, bolstered more by enthusiasm than by experience, we scheduled a three-day GIS short-course through Continuing Education. We also offered Introduction to GIS, a 4-credit, 400-level (senior) course, cross-listed by all three of our respective departments (Anthropology, Geology, Geography). Responses were encouraging. We concluded that there was interest in GIS out there in the "real" world and our students were beginning to recognize a potential job market. Within a year the demand for both undergraduate courses and professional short-courses was too heavy for our limited facilities. Additional hardware and space were essential; but how were these resources to be acquired?

THE UNDERGRADUATE MANDATE

In 1985, with help from Ressler and Hinthorne, I submitted a proposal titled "Undergraduate Instruction in Geographic Information Systems" to the National Science Foundation, under the College Science Instrumentation Program (CSIP). That program (like its successor, known as the Instrumentation and Laboratory Improvement Program) was intended specifically for support of undergraduate science education. The proposal requested a grant of $50,000 (CSIP maximum at the time), to be matched by an equal amount of CWU funds, for additional computer equipment. Our explicit purpose was to realize the teaching potential of a GIS Lab hitherto used mainly for research. Our proposal was rejected in 1986, resubmitted, and finally approved by NSF in 1987. Analysis of comments by NSF reviewers suggests that three factors were mainly responsible for our success:

- we proposed to improve an already established GIS laboratory;
- we proposed to expand that lab's role in undergraduate teaching; and
- we proposed to continue working with public domain software, rather than investing in expensive commercial systems.

My subsequent experience as a reviewer for the ILI program confirms the importance of these crucial factors.

NSF funding had a major impact on our GIS program. The most obvious effect, of course, was more hardware, and as a result, more students. We added a second Masscomp CPU, three more color monitors, a 9-track tape drive, a digitizer, and two additional hard drives (bringing our storage capacity to about .5 gigabyte). We were now able to expand our course offerings, adding two more 400-level courses (GIS Database Development and Advanced GIS Applications). All three courses were team-taught by Ressler, Hinthorne, and myself (later Nancy Hultquist, Assistant Professor of Geography, joined this group to help teach the introductory GIS course).

Expanded course offerings led to a rapid expansion of undergraduate enrollments, helping to fulfill the terms of the NSF award. These courses have continued to evolve in structure, content, and instructional methodology (for details as of Summer 1991, see Table 2).

The award's indirect consequences, in a sense, were even more pervasive, and continue to affect our program today. Enrollments were booming; the Dean of the College was happy. Our Continuing Education short-courses were generally filled; the Dean of Extended University Programs was satisfied. We had earned the endorsement of a prestigious granting agency; the Dean of Graduate Studies and Research was not displeased. Nevertheless, operating costs were high, and we were under increasing pressure to generate more external funding. But with our limited GIS experience, how could we seriously hope to establish an effective GIS research program?

THE GRASS CONNECTION

Surprisingly, our role in the GRASS development community provided a springboard to GIS research opportunities; these, in turn, continue to support and enhance our teaching program. Since many readers may be unfamiliar with GRASS, it will be useful be review briefly the origin and development of this powerful, unusual software system (also see Westervelt 1991).

GRASS (Geographic Resources Analysis Support System) was originated by researchers at the U. S. Army Corps of Engineers Construction Engineering Research Laboratory (CERL) at Champaign, Illinois. A GRASS Information Center is maintained by CERL [(217)373-7220]. Ongoing development of GRASS is supported by a Steering Committee representing fourteen major federal agencies. The system is now used at several hundred universities (and a total of more than 2000 installations) throughout the world. Annual user meetings are held in the U.S.A. and in Europe.

As "public-domain" (non-commercial) software, GRASS is distributed at cost by several service organizations, for a variety of workstation-level hardware platforms (e.g., Sun, Masscomp/Concurrent, DEC, HP, Macintosh, etc.) running under the UNIX operating system and the X-windows environment. Version 4.0 of GRASS, released in mid-1991, consists of about 300,000 lines of C code. The system includes nearly 200 user programs, with functionality for raster, vector, and point data analysis, image processing, database development, display and hardcopy graphics, report generation, etc.--in other words, a fully functional GIS working environment. GRASS is bundled with a wide range of public-domain software, including a powerful relational database manager (RIM), and includes import/export routines for communication with most major GIS, CAD, and imagery programs. Moreover, GRASS is in effect a GIS programming language of some 300 subroutines; this, together with the shell-scripting capabilities of UNIX, enables the user to generate specialized functions and applications.

Having used GRASS since 1984, and having offered GRASS instruction since 1985, the GIS Lab became one of the first non-military sites for "beta" testing of the software. In 1987 we successfully competed for a major contract with CERL, to provide "research support in the disciplines related to GIS, land planning, computer design and programming". Projects completed under the terms of this contract included preparation and publication of a tutorial volume known as The GRASS Problem Solving Manual (Ressler, 1989) and development of programming enhancements for inclusion with the standard release of GRASS software (James R. Hinthorne, principal investigator). These enhancements included: an interface between GRASS and RIM (the University of Washington's public domain relational DBMS), image analysis functions (supervised classification, Fourier and inverse Fourier transform, canonical components analysis, principal components analysis, RGB to HIS color transformation, zero crossing edge detection), and improvement of various other functions, including the X-windows graphics driver. These projects enabled us to hire a systems analyst/programmer, David B. Satnik. Furthermore, the indirect revenues thus generated were used by our Dean of Graduate Studies and Research to provide further support for equipment and operating costs.

As our level of GIS systems development activity expanded, it became increasingly evident that our existing hardware configuration was inadequate to support both teaching and research functions. Through an opportune meeting with our regional representative from the Digital Equipment Corporation (manufacturer of CWU's VAX cluster of computers) I learned of a special "Innovators Program" under which academic software developers could purchase DEC Ultrix (i.e., Unix) RISC workstations at very attractive discounts. My proposal (to port GRASS to the Ultrix platforms) competed successfully with others, was funded by DEC, and allowed us to acquire four new workstations, raising our CPU count to six and our total disk space to about 3.5 gigabytes. Our port of GRASS to Ultrix was completed in mid-1990; since that time CWU (through the Office of Continuing Education) has served as the worldwide distribution center for that version of GRASS.

Recognizing that our original lab space was now inadequate to house these new systems, the CWU administration agreed to move the GIS Lab from the Anthropology building to Lind Hall (the Geography/Geology/Physics building). Because that building was being remodeled, we were able to tap capital improvement funds to properly furnish the new lab space with tables, chairs, movable room dividers, appropriate wiring (including 220 volt), lighting, air conditioning, etc. The basic layout of the Lab remained unchanged: a U-shaped arrangement of tables, centered upon a demonstration monitor, flanked by a whiteboard and a mapboard mounted on 6' high movable room dividers. The room dividers made it possible to subdivide our workspace functionally and flexibly, while helping to control noise. Although limited in size, we find this to be an excellent arrangement for teaching. Some of the advantages of this U-shaped plan are worth pointing out (see Figure 1):

- we can easily shift from one instructional mode to another (lecture, demonstration, individual or team practice, one-on-one tutorial) within the same workspace;
- each student has full use of a terminal; but when appropriate, additional chairs can be added, enabling each terminal to support a team of two students (effectively doubling the lab's capacity);
- instructors or assistants can easily move around behind student workstations for one-on-one instruction.

As a result of this move to Lind Hall, our main lab space almost doubled, allowing us to add a pen plotter and a second digitizer. Additionally, we gained two small office spaces. These provided much-needed storage for supplies, tape archives, documentation, teaching materials, and administrative records, allowing the Director (and, later, the Systems Manager) to engage in GIS research, while remaining on call, in close proximity to the Lab.

Now that the Lab was physically more presentable, University public-relations people began steering VIP tours in our direction. Some VIPs had clout: county commissioners, state legislators, congressmen and their key staff members. Despite our research commitments and our primary undergraduate teaching mandate, we found ourselves responding more and more often to a critical question: What are the practical applications of GIS?

THE PUBLIC SERVICE FACTOR

Not long after the summer of 1988, we were asked to help the U.S. Forest Service Intermountain Fire Science Laboratory in preparing a digital map of Yellowstone National Park, showing the areas burned each day during that catastrophic fire season. Our part of the project was simply to digitize and join vector polygons from multiple rough field maps, convert these to raster format, and provide hardcopy maps plus tabular land area reports on daily burn areas. Not only was this effort an interesting one for our students, it served also to pay them a modest stipend, and encouraged us to undertake several other small public service projects under contract to various agencies.

Our major public service effort, thus far, began in 1989. Under the terms of the Washington State Timber/Fish/Wildlife (TFW) Agreement, cooperative resource management efforts are being explored by a diverse group of organizations including the Yakima Indian Nation; U.S. Forest Service; state departments of Natural Resources, Ecology, Fisheries, and Wildlife; Plum Creek Timber Company; Washington Environmental Council; and Audubon Society. Together these organizations are developing a comprehensive resource management plan for the Upper Yakima River Drainage Basin (a 1200 square mile area of northwestern Kittitas County, home of CWU). The GIS Lab has been funded, collectively, by these organizations, to develop a digital database and to provide GIS services for the Upper Yakima TFW study area. In this effort we were aided by Professor Curt Wiberg, biologist and director of the CWU Yakima Basin Center. The Upper Yakima database soon came to require over 500 mb of disk space. Staff persons from TFW organizations meet frequently in the GIS Lab to access the database and to use GRASS analytical programs in meeting management objectives. Most of our TFW funding has been used to provide half-time support for graduate student Ron Owens, who has been responsible for data entry and for aiding TFW staff persons in their use of GIS. Since many of these staff persons have had little GIS training, we regard the TFW project as an educational exercise as well as an experimental public service effort.

THE BLEEDING-EDGE SYNDROME

A popular cliche in discussions of innovative technology in the notion of being at the "cutting edge" of technological change; and equally familiar is the notion that all too often, the "cutting edge" becomes the "bleeding edge" for those fortunate (?) enough to find themselves there. At CWU we do not think of ourselves as being on the cutting edge; yet we have shed our share of blood in an effort to stay abreast of new technology, and to maintain the momentum with which our program has developed.

At this writing (mid-1991) expansion of undergraduate enrollment has again exceeded the capacity of the GIS Lab. Fortunately a spirit of close cooperation between the GIS Lab and the Department of Geography helps to facilitate use of that department's Macintosh Microcomputer Laboratory, housed in a room adjoining the GIS Lab. Arranged in a similar U-shaped layout, the Mac Lab includes ten Macintosh Plus computers, with 4 MB RAM and 40 MB hard disk drives, networked to a Mac SE fileserver, two 90 MB hard disk drives, an Apple LaserWriter, and a Mac SE equipped with an LCD overhead projection system. In 1989 we began to employ this Mac Lab in teaching Anthro/Geog 431 (see Table 2) using MAP II software (Pazner and others 1989; cf. Smith 1990). Subsequent courses (Winter and Spring Quarters) are still taught in the Unix-based GIS Lab. In 1989-90 we began to incorporate elements of the NCGIA curriculum into these courses (Smith 1990). A special summer course is offered for graduate students and faculty who need access to the GIS Lab for research purposes. Total enrollment exceeds 320 student credit hours per year, in a physical facility designed to accommodate no more than about 15 persons.

Our hardcopy output equipment presently includes the following devices: a Hewlett Packard DraftPro 8-pen plotter, a Tektronix 4696 color ink-jet printer, an aging but still useful ACT-II color ink-jet printer, and a DataSouth DS-180Plus line printer. The adjoining Macintosh lab is equipped with ImageWriter dot-matrix printers and an Apple LaserWriter. Students learn to use this equipment during GIS courses; but in practice, their hardcopy output generally is limited to reports produced for individual or team projects. We hope in the near future to expand our emphasis on high-quality GIS cartographic production and to acquire a large-format electrostatic plotter in support of this emphasis.

We operate two digitizers: a Geographics drafting-table digitizer and a Hitachi 48"x36" Digitizing Tablet. Students in our Database Development course receive demonstrations, one-on-one tutorials, and extensive hands-on experience with both machines. Some students seem particularly adept at manual digitizing; after training, they are often employed on research and public service projects. To date, we have worked primarily with the digitizing software provided by GRASS; but when our X-windows implementation of LT-Plus (see below) is complete, we will offer training with that package as well.

Hardware maintenance for standard equipment (e.g., Macintosh, IBM compatible, etc.) is provided by CWU Electronic Maintenance Services. Most of our hardware, however, is "non-standard" and must be maintained by vendor service contracts. Charges are underwritten in part by the University, but the GIS Lab is expected to generate external funding (through research, public service, and professional training) to cover an increasing percentage of these maintenance costs.

Recently we have supported GIS applications research by several graduate students in Central's MS program in Resource Management (a program initiated by John Ressler). One of those students, Rick Roeder, won the University's Distinguished Thesis Award in 1991 for his work on "Evaluation of Groundwater Supplies in the Middle Yakima River Basin." Other student research projects have included GIS-based radio tracking of endangered species such as sage grouse, and a comparison of GIS and traditional techniques in a case-study of the Soil Conservation Service's Conservation Reserve Program. We would like to expand our graduate program, but we find it difficult to balance our commitment to both undergraduate and graduate teaching.

Several times each year we offer intensive 40-hour short-courses through the CWU Office of Continuing Education. These are attended by professionals from academia, as well as from government and industry. Participants have come from all parts of the United States, others from Canada, Australia, Europe, and Latin America. Recently members of our faculty group have been able to give GRASS demonstrations in various foreign countries (Switzerland, Hungary, Chile, Canada). Similarly, the Lab frequently plays host to visiting scholars, offering brief GRASS demonstrations or tutorials, and informal GIS consultation. We value these contacts primarily because they help us (and our students) to become aware of a wide range of GIS activities and applications in many parts of the world, but we often experience scheduling conflicts between short-courses, tours, demonstrations, and other GIS Lab functions.

Encouraged by the response to our Ultrix port, we have recently ported the GRASS software to several other platforms, including a MIPs machine and an Apple Macintosh IIfx (running A/UX); other ports (e.g., IBM-compatible 486-level systems, running SCO Unix) are planned. Like the Ultrix port, most or all of these will be distributed by CWU Continuing Education. Recently we were able, once again, to compete for a major GRASS software development contract with CERL. The first project under that contract is to adapt LT-Plus, (a powerful, friendly public domain program originated by the U.S. Forest Service and Soil Conservation Service, with routines for data import from manual digitizing and scanning, raster and vector editing, etc.) for use with GRASS under X-windows. LT-Plus is expected then to become part of the standard GRASS release. In support of this project and the SCO Unix port of GRASS, we have recently acquired an IBM 486 compatible, with 8 mb RAM and a 650 MB hard disk drive.

Our public service agenda has expanded as a result of grants received from the National Center for Resource Innovations (NCRI), a private non-profit organization based in Washington, D.C. As one of its major objectives, NCRI encourages effective GIS use at the rural county and local government level. NCRI supports regional centers in North Dakota, Georgia, and Arkansas. Central Washington University has recently been designated as NCRI's Northwest Regional Center; other regional centers are planned for the future. With NCRI funding, we have initiated cooperative programs with two central Washington counties; it is hoped that others will be added subsequently. In Kittitas County we aid GIS efforts in several ways: we provide consultation to the County Planner, one of our graduate students has been employed by the planner's office, our initial TFW database is being expanded to cover the entire county, and the county has acquired hardware in order to install and operate GRASS. A major part of our effort (led by Hinthorne and Satnik, working with Professor David Kaufman, director of CWU's Applied Social Data Center) involves design and implementation of GRASS/RIM programs to facilitate use of the U.S. Census Bureau's TIGER vector files and associated demographic data.

With funds from these and related projects, we have been able to enhance the hardware and software complement of the GIS Lab. Our hard disk storage capacity now stands at about 5 gigabytes, with a 2.3 gigabyte 8mm tape backup system. We operate a Unix network of nine workstation CPUs, plus multiple color graphics X-terminals and monochrome terminals, digitizers, printers, plotters, etc., linked by Ethernet and fiber-optic cable. These linkages extend to the CWU VAX cluster, and support remote GIS workstations for a variety of users in several other buildings across campus. In addition to several versions of Unix, our system software includes Network File System and Yellow Pages. User software includes the statistical package S-Plus and productivity packages IslandWrite, IslandPaint, and IslandDraw (names in italics identify commercial, copyright protected software). Despite these enhancements, we recognize that the current rate of hardware and software development will soon require us to seek further funding to support further enhancement. (See Table 3).

The administrative structure of the GIS Lab has evolved, in an attempt to keep up with evolving program complexity. My assignment now includes 25% release time for GIS administration. GIS instruction (both regular and short-course) is still team-taught; but John Ressler, as Associate Director for Training and Education, has accepted major responsibility for organizing our teaching programs. Jim Hinthorne, as Associate Director for Research and Development, has played a major role in systems design and applications projects. Both continue to carry standard teaching loads. Nancy Hultquist, Assistant Professor of Geography, is a welcome new member of our GIS faculty. David B. Satnik is now our full-time Systems Manager, with responsibility for software and database management, supervision of hardware maintenance, and user support. Given the complexity of our Unix network, his skills are now essential. Moreover, his background in mathematics, physics, and computer science, plus his knowledge of GRASS and his natural communication skills, have quickly made him an essential member of our team. We all work well together, and thoroughly enjoy our joint venture. Yet we have had little time to pursue the individual research interests that led us initially to create a GIS program.

CONCLUSION

Since the beginning of our GIS program in 1984, our major objective has been to reach an appropriate balance between our teaching, research, and public service efforts. Yet we have found that this balance must be dynamic, not static. Repeatedly, in response to circumstances, opportunities, and perceived needs, we have found it necessary or desirable to overemphasize one component of the program, sometimes at the expense of others. Yet we have also found (perhaps not surprisingly) that these diverse activities can be mutually supportive. Our efforts have been driven, moreover, by the relentless, exciting pace of technological change. Certain aspects of our GIS program are distinctive, if not unique. Nevertheless I believe that other faculty (particularly those working in academic settings similar to ours) will confront many of the same challenges, and enjoy many of the same rewards, that we have experienced.

To those of you about to embark on a similar venture, we offer the following suggestions and comments:

1. Design your GIS program so as to reflect and enhance the mission and roles of your institution. In the context of a state-supported comprehensive regional university (such as CWU), this will probably mean a major emphasis on undergraduate teaching. But strive to maintain a viable balance between teaching, research, and public service.

2. Seek broad departmental support. Unless your own academic department is exceptionally strong, powerful, and well-funded, this may require a multidepartmental effort, with perhaps an extra-departmental structure of some kind. In most universities, expensive programs such as GIS are easier to support administratively when they serve a wider range of departments, faculty, and students.

3. Encourage graduate student participation. You will need graduate students, of course, as teaching/research assistants. But moreover, you may find that graduate students from other departments are able to help stimulate involvement by their own faculty, thus promoting a spirit of genuine interdisciplinary collaboration.

4. Offer a program of professional GIS short-courses through your institution's Continuing Education Division. Such programs provide modest amounts of external funding; but more significantly, they serve to put you and your students in touch with GIS professionals who reflect a wide range of interests and applications.

5. Become actively engaged in research. Even if undergraduate teaching is your principal responsibility, you will find research to be an essential antidote to classroom burnout. Besides, research may well provide your best source of external funding; and in most universities, external funding tends to help generate internal funding.

6. Support your local GIS coordinator(s) in county and city government, and in the regional offices of state and federal agencies. This kind of public-service effort may help you to acquire a substantial working GIS database (the cost of which can easily exceed both hardware and software costs). Moreover, such relationships often help to open up opportunities for research, as well as internships and future employment opportunities for your graduates.

7. Be aware of the potential value of public-domain software. Select your software first, then acquire the necessary hardware (not vice-versa!). Remember that yesterday's "industry standard" is likely to be tomorrow's dinosaur.

8. Recognize that your GIS laboratory (and your entire GIS program) will not be a once-and-for-all effort. Given the rate of technological change, your hardware and software will be somewhat obsolete by the time they are installed. Be prepared for the continual pressure to upgrade your facilities. But recognize also that as GIS hardware and software continue to develop, your GIS interests and abilities will be encouraged to expand and evolve.

9. We at CWU wish you well!

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TABLE 1
GIS PROGRAM CHARTER

DRAFT

Program Charter

1. IDENTIFICATION

   The name of this program is *Geographic Information Systems (GIS) Laboratory.*

2. PURPOSE

   The purpose of the GIS Laboratory is to provide a facility (including computer hardware, software, documentation, data, and workspaces) for use by faculty and students (undergraduate and graduate) in conjunction with teaching, research, and public service efforts related to spatial analysis, with applications in the natural and social sciences and in resource management.

3. ORGANIZATION

   3.1. The GIS Laboratory is an interdisciplinary facility, developed to serve students and faculty of the entire University.

   3.2. The GIS Laboratory operates under the authority of an Administrative Board consisting of the Dean of CLAS, the Dean of Graduate Studies and Research, the Dean of Extended University Programs, and the Chairs of the Departments of Anthropology, Geography, and Geology (depending on level of involvement, other departments may be added in future).

   3.3. The GIS Laboratory is supervised by a Director, designated by a letter of appointment from the Dean of CLAS. Normally the Director will be a regular faculty member of one of the participating academic departments. The Director will serve a term of appointment of one to four years, and will report to the Administrative Board.

   3.4. The Director is expected to:
   - use GIS in his/her own teaching/research; and when appropriate, participate in GIS team-teaching with other faculty.
   - assist faculty and students in use of GIS.
   - ensure that GIS Laboratory facilities (space, hardware, software, documentation, data, etc.) are maintained in good order.
   - develop grant/contract projects for external funding in support of GIS efforts.

   3.5. The Administrative Board may also appoint other faculty to serve as Associate Directors (specifically, an Associate Director for Training and Education, and an Associate Director for Research and Development). The Associate Directors will assist the Director in development of the GIS Laboratory and its various programs and projects.

   3.6. Routine hardware maintenance will be provided by Electronic Maintenance Services. When necessary, specialized maintenance will be acquired through vendor contracts.

4. REVIEW

   The status of the GIS Laboratory shall be regularly reviewed by the Director, Associate Directors, and Administrative Board. Such review shall occur on a biennial basis, or more frequently as deemed appropriate.

5. ACTION

APPROVED

______________________________ *Dean, College of Letters, Arts and Sciences*

______________________________ *Provost and Vice President for Academic Affairs*

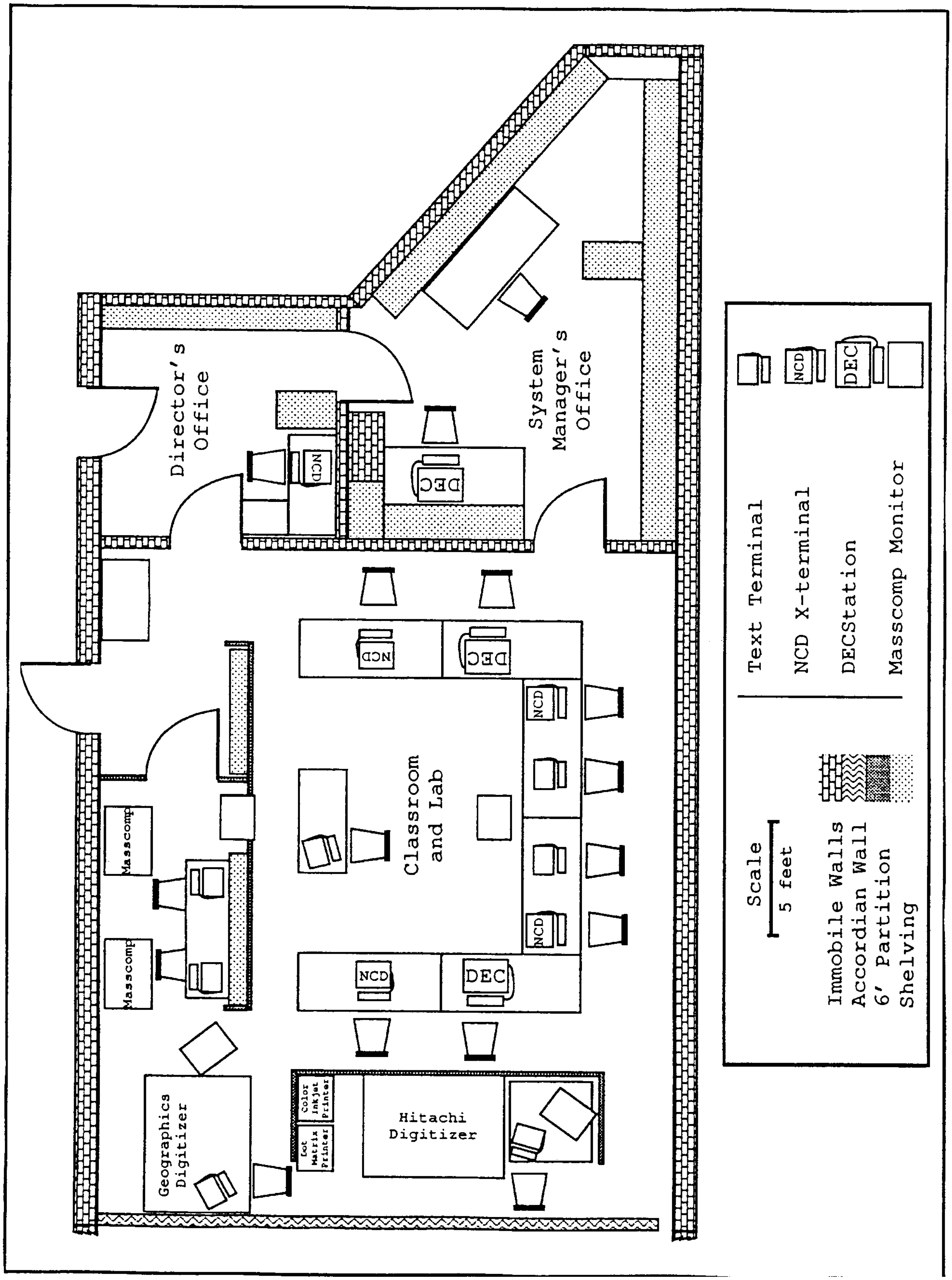
TABLE 2
LIST OF COURSES

COURSE DESCRIPTIONS	LOCATION	ENROLLMENT	PERCENTAGES: DEMOS LECTURES EXERCISES PROJECTS
ANTH/GEOG 431. **Introduction to Geographic Information Systems** (4 cr; Fall). Prereq: permission of instructor. Basic principles and uses of geographic information systems (GIS). Practice with use of GIS in solving land management and evaluation problems.Two hours lecture and four hours laboratory per week.	Macintosh Laboratory	25-35	10 35 50 5
GEOG 432. **Database Development** (4 cr; Wntr.). Prereq: permission of instructor. Creation of GIS data-bases including procedures for digitizing printed maps and processing files such as terrain, census and satellite data. Two hours lecture and four hours laboratory per week.	GIS Laboratory	10-15	15 20 15 50
ANTH/GEOG/GEOL 492.1. **Advanced GIS Applications** (4 cr; Spr.). Prereq: Anth/Geog 431 and permission of instructor. Individual and/or team projects involving use of GIS in fields such as Anthropology, Biology, Geography, Geology, and Sociology. May be repeated for credit.	GIS Laboratory	10-15	5 20 15 60
RESOURCE MANAGEMENT 598. **Special Topics** (5 cr; Summer). Prereq: permission of instructor. Lectures and practical experience with geographic information systems, intended primarily for graduate students, faculty, and others needing access to GIS technology for research purposes.	GIS Laboratory	5-12	15 25 20 40

TABLE 3
GIS LAB BUDGET AND INVENTORY

ITEM	1965-66	1991-92
Personnel (salaries, wages, & benefits)	$2000	$70,000
Goods & Service (supplies, telecom, travel, and hardware maintenance.)	9000	14,000
Inventory (hardware, software)	35,000	280,000

FIGURE 1
ARRANGEMENT OF GIS LABORATORY



West Virginia University

Gregory A. Elmes
Department of Geology & Geography

September, 1991

DEVELOPMENT OF GIS TEACHING LABORATORIES AT WEST VIRGINIA UNIVERSITY

I. CONCEPTUAL STAGE

Origins of the Geo-data Processing Laboratory

West Virginia University is a comprehensive, land-grant institution offering 176 degree programs from bachelor's through the doctoral degree. It is the principal research university in West Virginia. Fifteen colleges and schools are located on two campuses in Morgantown, linked by the Personal Rapid Transit (PRT) system, constructed as a research demonstration by the U.S. Department of Transportation. Approximately 22,000 students are enrolled in 1991, taught by over 1300 full-time faculty. More than one third of the students are from out-of-state, and the university has representatives from 75 foreign countries. West Virginia University has had 22 Rhodes Scholarships.

Geography is a degree program within the Department of Geology and Geography, itself one of fifteen departments in the College of Arts and Sciences, the largest college at WVU. Currently BA and MA degrees are offered in Geography, with emphases in GIS and geographical analysis, regional development and planning, and energy and environmental studies. A proposed PhD program in GIS and Regional Development is being evaluated by the Board of Trustees of the University of West Virginia. In any given year there are between thirty and fortyfive undergraduate majors in Geography and twenty-five graduate students in residence. Currently there are eight full time faculty in geography, and two visiting and two vacant positions (to be filled 1992). Several geology faculty members offer coursework in geomorphology, water resources and hydrology that contributes to undergraduate and gradaute studies in geography.

The Department of Geology and Geography at West Virginia University has constructed a Geo-data Processing Laboratory (GPL) for the storage, handling, synthesis, and analysis of diverse types of spatial data. The acquisition of computer software and hardware has been enabled through a series of projects funded by university, college and departmental sources; and from external monies from federal and state governments and from private industry. It has always been our objective to build first class facilities for instruction and research in geographic information systems and digital mapping, with additional, primarily research-oriented, facilities in remote sensing and image processing, spatial statistics and seismology. Although it is not yet in its planned permanent form, the laboratory already provides an integrated teaching and research facility within the university, serving approximately forty undergraduate and twenty graduate students per year, primarily from within the department. As the capacity increases additional students are expected from the Colleges of Agriculture and Forestry, and Engineering. Increased enrollment will be possible when the facility is completed as planned in 1993. Development of the laboratory has been among the strategic goals of WVU in the late eighties and early nineties and as a result has had a very high profile in the college and department.

Because joint departments of Geology and Geography are somewhat unusual in higher education, considerable cooperation has been necessary to implement the laboratory between faculty members with very different perspectives on teaching and different research priorities. Considerable altruism was demonstrated by some faculty who had computer equipment for research purposes and have permitted more general access to it in the interests of building an integrated facility. The origins of the laboratory can be traced to the two areas: research funding to geology faculty members that provided a kernel of hardware and geoscience software upon which to build; and geography faculty contributing the initiative and guidance based on the explosive growth in GIS and remote sensing in the past decade. In addition, much of the nearly $2.5 million in external funding awarded to Geography faculty members since 1987 has been directed to the growth and support of the GIS facilities.

In the first instance geographic information systems were introduced to the Department of Geology and Geography as a result of a joint research project between Drs. Trevor Harris and Gregory Elmes in 1984. A large spatial database, the Sussex Land Use Inventory, containing over one hundred thousand point data locations, was the basis for modeling land use allocation using combinatorial programming methods. In manipulating these data, difficulties were encountered that led to the identification of needs for 1) rapidly interpretable results, 2) comparison of multiple alternative solutions, 3) visualization of the results of sensitivity analysis, and 4) computer-assisted cartographic output. The integration of GIS with spatial modeling was clearly indicated as a research focus. Dr. Harris (then at Brighton Polytechnic, UK) had begun teaching GIS in the context of methods of geographical analysis. He had presented a paper at First Symposium on Spatial Data Handling in Zurich, 1984, describing the production and analysis of the Sussex Land Use Inventory. In 1986 Drs. Harris and Elmes presented a joint paper at the Second Symposium on Spatial Data Handling in Seattle. These research-related activities generated a strong desire to introduce GIS into the geography curriculum at WVU and to teach GIS with excellent facilities.

Dr. Elmes formalized his understanding of GIS by taking the M.Sc. course in GIS at the University of Edinburgh on a sabbatical leave taken during 1986/87. In requesting the leave, the argument was made that if GIS was to be taught at WVU it should be from firm pedagogic foundations, with comprehensive faculty preparation rather than from an ad hoc or 'course conversion' basis. Participant observation in the newly developing graduate program in GIS and remote sensing at the University of Edinburgh, then in its second year, was a valuable contribution to the conceptual plan of WVU GIS teaching facilities.

Computer hardware, particularly a DEC VAX 11/750 mini-computer purchased with funds from research grants in geology, provided a basis for development of computer-oriented instruction including statistics, graphics, and GIS. Inconveniently-located university computing facilities combined with a lack of graphics capability had lead to an early decision to create an in-house laboratory based around mini-computers. Geology offered support to the Geography program to develop a GIS component. Major factors were the clear employment possibilities for well-trained majors, and the potential for significant research funding. Development opportunities were seen both to increase enrollment potential and to provide a means to create a stronger identity for Geography in the university community, and in the state at large.

Other Factors

The development of a Geo-data Processing Laboratory at WVU owes much to the serendipitous timing of several elements: research funding opportunities, Dr. Elmes' eligibility to take a full year of sabbatical leave, university strategic planning, and West Virginia's state legislation. The state of West Virginia "Higher Education Industry Partnership, Economic Development Act of 1986" directed funds to WVU for use in promoting regional economic development. The existence of a seismic research unit with basic computing facilities provided a catalyst to compete for funding to improve overall geoscientific data processing and analytic capabilities in the department. Regional development is also a major focus of the masters program, and of the proposed doctoral program in geography. The contribution of GIS to regional development studies is potentially far-reaching, in theoretical and modeling aspects, as well as in empirical applications.

II. PROPOSAL STAGES

Mandate

The overall 'proposal' for a GIS laboratory has been a conceptual framework for creative discussion, rather than a single written document. Many separate proposals have been prepared and submitted within the overall context of developing GIS laboratory facilities for research, research training, production, and instruction. The major goal has been to establish a first-class laboratory for teaching GIS and remote sensing to undergraduate and graduate students at West Virginia University. Using the core of existing research facilities, the Department of Geology and Geography initiated the development of an integrated laboratory for spatial data analysis, geographic information handling, and image and signal processing. The pedagogic concern is primarily to develop a reputation for quality undergraduate teaching in geographic information analysis, and to provide quality research and teaching facilities for our growing graduate program in geography. Creation of GIS teaching facilities was a logical step in the growth of the department, as both geology and geography share a focus on the interpretation, analysis, and understanding of temporal and spatial data.

Original Components

Geology faculty members with research interests in seismology and geochemistry had acquired a PDP 11/44 and a graphics processor during the 1970s, through the sponsorship of the Department of Energy. The Gas Research Institute had also supported research projects resulting in the availability of a digitizing tablet. A VAX 11/750 upgrade from the PDP machine gave the Department high-powered, in-house computing facilities in the early 1980's. The upgrade included two 9 inch tape drives, two RA81 450 Megabyte disk drives, and serial ports for twenty remote, VT100-type terminals. A Benson monochrome electrostatic plotter and Hewlett Packard 4571 pen plotters were obtained for graphical output. Planning for a GIS laboratory began from these components.

Stages

Development of the laboratory has been a complex, multifaceted process and no separate proposal exists for a teaching laboratory. Instead the existing and planned facilities have been developed in stages, usually in response to perceived opportunities to augment the existing arrangements. To assist in understanding the development process the following set of steps is presented but it should be cautioned that the post hoc imposition of stages on actual events implies a greater linearity than was apparent in reality.

a) GIS Lab Initiation 1986/87 The proposal to develop teaching facilities began with informal discussions with Dr. Alan Donaldson and other members of a departmental computer-users committee. Departmental faculty members had recognized that the need for computer-based instruction in statistics, multivariate analysis, and computer cartography conflicted with the intensive use of the existing hardware for research projects. A brief survey of the departmental faculty elicited a set of instructional priorities for computer-based developments.

b) West Virginia Higher Education Industry Partnership Equipment Funds, 1987/8 A request was made for capital funds for signal processing equipment under the West Virginia Higher Education/Industry Partnership, Economic Development Act of 1986. In the first instance, the request was directed to the establishment of a first class signal processing facility comparable to that available in the oil and gas industries. Such facilities were unavailable in West Virginia. The proposal formally raised the issue of developing an integrated Geo-Data Processing Laboratory.

c) WVU Strategic Initiative Program Proposal, 1988 The WVU strategic planning project invites proposals from throughout the university to identify vital areas for development and assist their implementation. The establishment of a GIS facility was proposed and rated one of the top initiatives by the WVU Planning Council. The submission of the NSF proposal (see d) served to focus awareness of the potential of GIS among departmental and college administrators, resulting in a concurrent submission to the WVU Strategic Development Fund program. The WVU strategic initiative proposal was similar in content to the NSF proposal, emphasizing both the need for equipment to upgrade GIS functionality and the need to educate students from a variety of disciplines with interests in spatial data handling.

d) NSF Proposal 1988 Additional funding for the GPL was sought under the Instrumentation and Laboratory Improvement Program of the National Science Foundation. The submitted proposal emphasized the needs of undergraduate students in relation to education and training in geographic information systems. The development of the existing facilities was central to the application. After much delay due to congressional budget crisis, this proposal was not funded. In spite of the failure to receive funding, the rigor of the NSF proposal process was valuable in concentrating efforts, focussing attention, and subsequently as a starting point for other projects.

e) WVU Strategic Initiative Program Proposal, 1990 A second strategic initiative was proposed and accepted to fund a planning oriented project. The project was designed to link GIS and regional economic planning, two of the emphases at the BA and MA degree levels, and the primary focus of the proposed Ph.D. program.

f) NSF Research Facilities Proposal, 1990 Following the acquisition of equipment and development of a instructional curriculum in GIS, the physical conditions of the building housing the laboratory and classrooms became limiting factors. The physical constraints included such infrastructural deficiencies as insufficient electrical circuitry, atmospheric control, lighting, and available space. A proposal to the Research Facilities Office of the National Science Foundation was successful in providing funding (to be matched by WVU) for the upgrading of three existing laboratories as a full-service GIS facility.

g) Continuing Implementation, 1991 Current plans include the upgrading of computer storage and central processing facilities through the acquisition of a DEC VAX 4000, terminal servers, and RISC-architecture workstations. While the latter are designated research machines, increased cpu speed and power will increase the availability of existing processors for teaching. Development of the physical aspects of the laboratory has given way to important issues concerning the role of GIS in teaching and research, future appointments, system management and support, and internal and external security.

Budgets

As far as a documentary record exists, the formal budget planning process for the laboratory is contained in five documents. These are the Higher Education/Industry Partnership request, two WVU Strategic Initiatives, and two NSF proposals. The 1990 Strategic Initiative resulted in $26,000 of discretionary money. Other monies ($50,000) were released from the college in 1988 as part of the departmental operating budget. (See Table 1).

Support

Development of the laboratory has necessitated support at all levels of the university administration. The major channel of support has been the normal route from department chairman to the dean's office and then to university administration. Planning support has also come from colleagues in other departments, particularly in relation to the development of a program of instruction in GIS. Additional internal financial support has been sought from the WV Energy and Water Research Center and the Economic Development Council, two organizations at the university-wide level. External funding sources have been essential in demonstrating the potential range of applications of GIS to administrators and in obtaining collateral support form the university.

The role of funding from the USDA-Forest Service has been catalytic. Major equipment purchases for Forest Service projects have been used as leverage to gain support from other channels to extend instructional capabilities. Recent awards from USDA-Forest Service have provided digitizers, plotters and personal computers, all of which may be used for instruction. A contract with Appalachian Power Company has likewise made key peripherals available, including workstations, a digitizing tablet, and a color electrostatic plotter. Grants and contracts enable the laboratory to purchase software support for ARC/INFO and SPANS, and contribute to maintenance contracts on the hardware.

Key Personnel

Those faculty who were directly instrumental in development of the laboratory are identified below:

Dr. Frank Calzonneti (Associate Dean for Research, Professor of Geography) provided essential support at the college level through communication of college and university priorities. He represented the laboratory in his capacity as Chairman of the College Computer Committee and as a member of several College and University Planning and Development committees. He is a strong proponent of additional faculty positions in GIS / Remote Sensing.

Dr. Alan Donaldson (Chairman, Department of Geology and Geography, Professor of Geology). As chairman, Dr. Donaldson quickly recognized the potential benefits in enrollments, research, and departmental image created by the advent of GIS. He provided strong moral support for the program within the Department and has acted consistency on our behalf with university administration, even in circumstances that have initiated major changes for members of geology faculty. Limited departmental funding has meant that budgetary support from the chairman is mainly in the form of flexibility and realignment rather than the injection of large new sums of money. His mediation of conflicts of interest and adjudication of competing needs has been an essential role without which the physical facilities would have emerged more slowly.

Dr. Gregory Elmes (Associate Professor of Geography) initiated GIS teaching at WVU following a sabbatical leave to acquire formal GIS qualifications. Dr. Elmes has been awarded substantial internal and external funding to develop and support GIS facilities in the laboratory. Evaluation of NCGIA core curriculum during 1988/89 resulted in the adoption of a program of GIS instruction by the university senate. Currently he teaches 'Introduction to GIS'; 'Technical Issues in GIS'; and 'Spatial Analysis'.

Dr. Trevor Harris (Associate Professor of Geography) was appointed in January 1990, the first additional faculty position specializing in GIS. Dr. Harris has been awarded a major NSF grant for facilities renovation and has a large grant for GIS-based power-line corridor siting and environmental impact assessment. He teaches 'Applications in GIS' and will teach computer-assisted cartography and remote sensing courses when his research commitments are completed. Dr. Harris is well-established authority in the use of GIS in archaeological research and has published in the use of expert systems in environmental models.

Dr. Robert Shumaker (Deputy Chairman, Department of Geology and Geography, Professor of Geology). As an advocate for multifaceted development of computer facilities within the department and a mediator between geological and geographical priorities, Dr Shumaker has provided an important link between the disparate needs of geology and geography. His own research interests have stimulated graphical and database developments in geologic basin analysis.

Dr. Tom Wilson (Associate Professor of Geology, Seismology) originally agreed to make available core elements of computer hardware that have become central for GIS use. Dr Wilson also directly contributed funds from his seismology budget to enable the initial purchase of an ARC/INFO license and related equipment.

At various times, we have had support at administrative and executive levels of the university. It is not possible to estimate the direct contribution of Dr. William Vehse, Interim Provost, Dr. Richard Bajura, Associate Provost for Research, especially of Dr. Jerry Lang, Dean of the College of Arts and Sciences, and Dr. William Bucklew, President of WVU. A conscious effort has been made to involve all of these administrators in our planning process and progress. Internally-generated publicity has been valuable, such as "Plaudits" a college newsletter noting faculty achievements, "Inquiry" an annual report of funded activities, and demonstrations during public open-days.

Hurdles

No significant hurdles were encountered during the proposal stages for the Higher Education/Industry Partnership, or the WVU Strategic Initiative programs, owing to support at the dean's and executive level of administration. Since program goals and target budgets were known in advance, it was possible to tailor the requests to available resources and university priorities. The final responsibility for priority and submission of proposals was at the dean's level. Decisions were made by the university president's office.

Since the first NSF proposal to the Instrumentation and Laboratory Improvement Program (ILI) was ultimately rejected this might be considered to have been a hurdle. Long delays were encountered with the ILI program as congress failed to include funds for doctoral institutions in 1987/88, despite their eligibility to submit proposals. When, after more than a year, the proposal was rejected, the reviewers comments were not found to be very useful for a revision, although it was evident that the proposal suffered from attempting to emphasize both the improvement of teaching facilities and the research platform simultaneously. By the time of the notification, many of the objectives had been fulfilled, and too much time had already been invested to be worth a major rewrite.

In preparing the NSF proposal to the Research Facilities Program, Dr. Harris encountered numerous difficulties in coordinating efforts of different branches of WVU administration, getting essential personnel to perform tasks on schedule, and persuading others to meet stringent NSF deadlines for the multi-staged application process. Although individual units eventually completed their tasks, the university organization as a whole was not geared to the competition and fast reaction times required for major awards of this nature. Considerable problems emerged at the departmental level in the selection of suitable space for renovation. Much of the building was originally designed for mineral preparation and mining engineering. Existing vacant space required too great an investment to be converted for computer instruction. Suitable rooms were already heavily used for laboratory instruction, consequently there was understandable resistance from resident faculty members to disruption of their teaching arrangements.

Documents

The most influential documents prepared during the development of the laboratory facilities included:

a) an internal discussion document describing proposed developments of a Geo-Data Analysis Laboratory which was circulated within the department during Fall 1988. An informal proposal stating the intentions to develop in-house computing facilities to provide teaching and research facilities for GIS and remote sensing, its primary intent was to inform faculty in both geology and geography of the existing potential and to request ideas for direction and growth.

b) Synercom University Grant Program proposal, Fall 1987. The departments of Civil Engineering and Geology/Geography combined to propose inclusion in this software and training support initiative from the Synercom corporation. Details were provided about how the 'donated' software would be used in teaching and research. A software maintenance agreement was contracted between the university and the corporation stating that for $20,000 Synercom would provide AM/FM and GIS software; training and support. Monies from the software agreement were to be channeled back to university faculty to assist in travel and training associated with the project. Unfortunately, this software package was never fully functional on any equipment at WVU. In consequence, participation in the program was dropped after one year.

c) WV Higher Education / Industry Partnership Equipment Funds, 1987/8. A request was made for capital funds focussing primarily on geological signal processing equipment under the West Virginia Higher Education/Industry Partnership, Economic Development Act of 1986. The proposal raised the issue of developing an integrated Geo-Data Processing Laboratory formally for the first time while providing a detailed budget for capital expenditures.

d) WVU Strategic Initiative Proposal, 1988. The strategic initiative program was coordinated at the college level. Documentation developed from the initial discussion materials described in (a) and the Higher Education/Industrial Partnership request was collated and edited by Dr. Calzonetti and forwarded to the University Planning Council. The nature of these materials was directed at educating the council about the significance of a GIS program at WVU and the benefits of developing the existing human and computer resources in the Department of Geology and Geography.

e) NSF Proposal Instrumentation and Laboratory Improvement Program, 1987. By far the most detailed proposal yet developed, the NSF request described the nature of the program in geology and geography, detailed existing facilities and proposed additional equipment to make instruction possible in the existing space by adding workstations and input/output peripherals. The proposal was along standard NSF lines, requiring detailed justification of the proposed activities, evidence of integration into existing programs and precise description of budgetary items. It was combined with the request to the Higher Education and Industry Partnership to provide necessary matching funds. This proposal was not funded.

f) Proposal to WV Energy and Water Center, 1989. Initial funding of the center at WVU appeared to offer units across campus the opportunity to purchase hardware that would be used in connection with the center's activities. A request for an electrostatic plotter was submitted and initially accepted, as no similar equipment was available at WVU. Budgetary delays and changes resulted in postponement of this request. Subsequently the equipment was purchased under other, research-based, funding.

g) WVU Strategic Initiative Proposal, 1990. Following the pattern of the first strategic initiative, the lead was taken by Dr. Calzonetti in the Dean's Office. The documentation again was a generic description of proposed integration of GIS activities with regional planning, the main teaching focus of the geography program. College support in the planning council helped gain acceptance of the proposal.

h) NSF Proposal, Research Facilities Office, 1990. A second major documentation effort, initiated by Dr. Harris, with support from Dr. Calzonetti and other members of the university administration. NSF instituted a two stage competition process for the award, initially requiring a demonstration of need, followed if the application was successful, by a full proposal. The final proposal contained the project justification, evidence of financial support from the university, detailed budget, architectural drawings and plans of the proposed renovations, photographs of the existing facilities and a detailed schedule of work to complete the renovations. Renovations were proposed to four existing rooms to create a linked suite of laboratories for both teaching and research. The emphasis of the Research Facilities Office is self-explanatory therefore teaching facilities were presented as a secondary benefit to the primary benefits to be gained from contemporary laboratory housing for GIS and remote sensing.

A development strategy for the GIS teaching facilities is revealed in the progression of emphasis in these documents, from expanding and strengthening existing capabilities in geoscience and signal processing, to the improvement of facilities for GIS teaching and research. In the economic and managerial climate prevailing at WVU, it has been essential to present teaching improvements alongside research development. Teaching needs and goals have always been included in documentation but a primary role for research has had to be stressed in order to gain funding. The emphasis reflects an institution-wide concern to raise the research level during the last years of the 1980s as well as emphases of national funding agencies. Financial support from the state of West Virginia to the university has been insufficient to permit simultaneous response to needs in teaching, research and service.

III. ACQUISITION STAGE

Accepted Budgets

In the academic year 1987/88, WVU granted the department $100,000 through the Higher Education/Industry Partnership program (see Table 1). These funds were made available primarily to upgrade seismic signal capture and processing capabilities. On receipt of this funding, modifications to budgets as initially submitted were made because of unforeseen opportunities to purchase equipment through excellent budget management in previous years and large discounts available from certain vendors on computer hardware and software. A VAXstation 3500 was purchased at considerable savings over the budgeted cost of the MicroVAX III. Together with savings achieved by Dr. Tom Wilson in seismic equipment purchases and by donated software, the department was able to purchase an ARC/INFO license for the VAX 3500 and VAX 11/750 for $25,900 in 1988. The purchase of the DEC VAXstation 3500 cpu led to the departmental decision to create a computer network that would eventually be compatible with networking plans at the college level.

In conjunction with existing capital funds and Strategic Initiative funds the Department purchased 3 VAXstation 2000s with 19" color monitors, a 386/25 Mhz personal computer, ERDAS image processing software, a color scanner, a high resolution (1024 X 1024) graphics RGB monitor and ink jet and pen plotters.

Because the proposal to the ILI program of NSF was unsuccessful, considerable reorganization of the budget was necessary. Purchase of the electrostatic plotter was tabled. In 1988, the College of Arts and Sciences contributed $50,000 specifically to upgrade computer hardware. An award of $10,000 was also made by the College during the summer of 1989 for plotting hardware to assist in the production of an atlas. Final expenditures are listed in Table 2.

Budget modifications have not yet been made for the NSF award as design documents are not due to be begun until November 1991 and construction is not scheduled to begin until June 1992. Final occupancy is planned for May 1993.

Purchasing

Many purchasing decisions have been guided by a special relationship established by a contract between WVU and Digital Equipment Corporation that permits purchases of DEC equipment at 75% discount. This discount is contingent on funds realized from a grant to the university made by the Department of Defence, Advanced Research Projects Agency (DARPA) and General Electric. The DARPA Initiative for Concurrent Engineering (DICE) program at WVU makes available approximately $1 million per year in market value of DEC products. Other purchases from DEC, CALCOMP, Hewlett-Packard, and Tektronix have been at normal educational discounts that vary from 40 - 65% depending on the vendor and the equipment purchased. TYDAC/SPANS provided a major discount for purchase of multiple copies of SPANS software. We have not made special efforts to acquire beta-test software at low prices, nor have any vendors offered or been requested to provide, free hardware for evaluation.

Negotiations with ESRI resulted in the initial purchase of a multi-user ARC/INFO license for the VAX 11/750 and VAXstation 3500 for $25,000 at a time when advertised prices for commercial users were $75,000. Originally maintenance and support was $10,000 but this has now been reduced through the acquisition of a five seat workstation Lab Kit to $6000.

Physical Plant

All equipment dedicated to GIS and remote sensing will eventually be housed on the third floor in a connected suite of laboratories to be renovated under the NSF grant. The laboratory is currently located in three separate sites on a temporary basis. In part, the acquisition of 3400 square feet of temporary space was made possible by the removal of the College of Mineral and Economic Resources (COMER) to a new building, vacating two and one half floors of White Hall. Thus it became possible, as new equipment was being delivered, to obtain space in Room 120 for GIS instruction (Room 120 was previously used as a PC teaching lab) and in Rooms 116-118 for a GIS research project. The central processing facilities are grouped in Room 422 White Hall, the original site of GPL. The GIS classroom, Room 120, contains ten networked personal computers and peripherals.

The acquisition of Rooms 310-312 in White Hall as the permanent home of GIS laboratory facilities was achieved through cooperation with the chairman of the department who suggested this location initially, and with geology faculty members who have office and teaching laboratory space there at present. The selection of Rooms 310 and 312 in particular resulted in considerable difficulties as introductory geology labs make almost continual use of this space, involving almost 1000 students each year. The situation is ameliorated somewhat by the planned renovation of White Hall in 1993 and the current opportunity to compete for additional space as a result of university reorganization.

IV. OPERATIONAL STAGE

The Teaching Environment

Initially, GIS instruction at WVU developed from a 200-level (Jr./Sr.) special topics course, offered by Dr. Elmes in a personal computer laboratory established for statistical instruction by the college. The focus of the course was the integration of GIS concepts with worked-out examples, drawing on the academic version of PMAP as the principal vehicle for class exercises. Between 1987 and 1989 three introductory courses were taught, each attracting a full complement of twenty-five students. Class size was limited by computer access. Lecture sessions alternated with laboratory sessions on a Tuesday/Thursday schedule with two periods of seventy-five minute duration. The lecture curriculum emphasized system components, database theory and development, GIS functionality and applications. The sequence of laboratory exercises was strongly influenced by J. Berry's instructional package for PMAP, developed at Yale University. Although students were individually responsible for the completion of laboratory exercises and the write-ups, they were encouraged to work in pairs. This laboratory was not available during evening or weekend hours therefore the students had to complete the assignments largely within the allotted class periods. However it was possible for students to enter the laboratory one class period before each session and remain for an hour afterwards. Extended times were especially valuable to computer novices and for producing output. During this initial period it was determined that mentoring worked efficiently and this approach has been utilized subsequently. Students who had familiarity with computers were teamed with those with no previous computing experience. Geography majors were teamed with non-majors. The twenty hours per week assigned to the teaching assistant cannot meet all the demands of students for help in laboratory exercises. Faculty responsibilities do not permit additional laboratory instruction beyond normal office hours, except at the beginning of each semester for a laboratory and computer operations familiarization session.

With the evaluation of the NCGIA curriculum in 1989 and availability of alternate facilities, the emphasis moved from PMAP to IDRISI as an instructional tool. Students now complete the IDRISI tutorial materials in the introductory GIS class. In addition, very basic illustrations of ARC/INFO are provided in exercise format. More advanced applications, using ARC/INFO, IDRISI and SPANS, are demonstrated in the research laboratories to small groups of up to five students from the introductory, technical issues and GIS management courses.

In 1991, enrollments continue to be at the maximum 25 for the Introductory course. Demand for ARC/INFO training by geography majors and graduate students has led to the use of self-paced instructional materials "Understanding GIS; the ARC/INFO method" from ESRI. The Applications course and Technical Issues courses have fewer students, averaging 10-15. The Introduction to GIS is a pre-requisite which keeps student numbers lower than if open admission were permitted. Students in the Applications course use SPANS for a planning exercise, spending up to ten hours in the teaching lab outside scheduled tutorial sessions. As yet the use of the lab by Technical Issues students has primarily been for demonstrations of algorithm problems, computer programming and database concepts. About ten hours of the course are scheduled as laboratory periods.

A seminar in GIS is run for graduate students each fall semester. Currently 12 are enrolled. The role of the laboratory in the seminar is primarily as a focus for individual projects based on locational modeling. The students are introduced to ARC / INFO's NETWORK module, in two two-hour periods, in groups of three. Subsequently they are assigned individual projects which require a minimum of five additional hours.

Configuration

The opening of departmental teaching facilities expanded the accessibility of equipment, as graduate assistants were on hand to monitor use and security. The research/training laboratories, however, are under strict supervision, kept locked at all times, and monitored by systems and project staff. Teaching in these facilities is currently restricted to demonstrations, independent study by senior and graduate students, and 'on-the-job' instruction for research project staff.

Components of the GIS Teaching Laboratory Prior to the availability of dedicated hardware, GIS was taught in a general purpose computer laboratory supplied with XT personal computers and dot matrix printers. Currently the principal teaching laboratory for GIS and image processing is supplied with ten (10) 80386 micro computers networked to the departmental VAX cluster via Ethernet using DEC PCSA communications software (Table 3). The room is approximately twenty-five (25) feet square providing six hundred and twenty five (625) sq. ft. of usable space. Two air conditioners are able to maintain reasonable working conditions despite the south and west facing aspects of the room. Dust and other particulates are a major problem in this coal-producing region. Renovations to windows in the new teaching lab will alleviate the primary source of atmospheric particulate problems. Window security is good with locking grids. Door security is maintained by a mild steel plate but the availability of a single room key, kept in the main departmental office, causes both access and control problems. Automated door locks will remedy this problem once NSF funded alterations are completed.

As shown in Figure 1, the personal computers are distributed on tables around the walls with a central 'island' to provide additional access and for demonstration purposes. Each computer provides sufficient workspace for two students. Output is currently limited to Hewlett-Packard ink jet plotters connected to three of the machines but the recent acquisition of terminal servers is designed to permit plotter access from all computers in the lab. No digitizers are permanently connected, although instruction in data capture is made possible by using small format tablets (24" X 36") which are brought in from other locations as required.

Components of Research Training and Project Laboratories The current configuration of the research training facilities is well adapted to use by graduate students and geography seniors in the GIS/Spatial Analysis track. The central processing facility and the location of the Geo-Data Processing Laboratory is illustrated in Figure 2. Approximately 1250 square feet (25 X 50) is available, sub-divided by an enclosure for the VAX 3900 computer and associated console, tape drives, disk drives, and tape storage. This partitioned area is accessible only to authorized personnel: the system manager, the GIS administrator, and selected faculty members. It has been equipped with powerful air conditioning, originally necessary to maintain temperatures below 78 F (25 C) for the mini-computer. Contemporary computers are tolerant of fluctuations in temperature and humidity but the partitioned area is protected against air-borne particulates. Because the room faces due south, working conditions outside of the partitioned area were extremely poor from June until September in terms of temperatures and humidity, for humans and machines, until the recent replacement of ageing window air conditioners.

Equipment in the main work area is organized by function (see Figure 2 and Table 3). Geology students work closely with the VAX 3500 and VAXstation 2000 workstations. In the center of the room are image processing facilities and the color scanner. All output devices are clustered to one side to minimize interference with others. A group of VT 320 computer terminals and a networked PC/XT provide non-graphic communications. Workspace for the GIS VAXstation 2000s and Tektronix 4107a workstations is unfortunately cramped. A CALCOMP 9100 digitizer is attached to a VAX workstation. Small format Tektronix and CALCOMP digitizing tablets are available for other workstations as required.

In Fall 1991 a VAX 4000 and three terminal servers will be acquired to bear the networking responsibilities, applications programming, and word processing throughout the department. The VAX 3900 will then be free exclusively to process ARC/INFO.

Pending completion of renovations, two other locations are used for research projects and training. Currently assigned to a single research project, the equipment in these rooms will come into more general use in 1992 (Figure 3). A further room (211A), is principally used for GIS coding and algorithm development (Figure 4). It also serves as a graduate research assistant office, providing accommodations for four students, all of whom currently work on the same project. From a learning perspective such arrangements are vital as more experienced students pass on their expertise to others. Grouping students by project responsibilities however tends to create difficulties in disseminating information between groups. The renovated facilities will provide both the opportunities that now exist for peer learning and additional opportunities for information sharing across research projects. At the graduate level, more than half the current 'instruction' in GIS is provided through these informal channels. Faculty provide resources (equipment, manuals, primers) and challenges (research tasks, thesis development) to which well-motivated students respond productively. Attrition has been low. Two students of a cohort of thirty-five have found this approach inappropriate.

Extras

There are few amenities or niceties. Food and drinks are prohibited at all times in the laboratory facilities. Smoking is prohibited in all WVU buildings. Chairs, tables and other work-related amenities are old and have been scrounged from other places. Storage facilities for documentation and tapes are primitive; two ancient steel cabinets serve in Room 422. Unused equipment, floors and walls are all too often used as temporary storage facilities.

Usage

The Teaching Laboratory (Room 120) is used by the following courses as a lecture room, for demonstrations, and for exercise and project sessions (see Table 4 for course listings). During the Fall semester:

Geography 151: 6 hours per week for lecture, with 18 hours total additional lab exercise requirements
Geography 200: 6 hours per week lecture use, plus 12 hours additional use for worktable exercises
Geography 496: 8 hours per semester demonstration, plus graduate student project use (may use Research Laboratory for this purpose)

During the Spring semester:

Geography 251: 6 hours lecture plus 18 hours total laboratory exercise use
Geography 252: 6 hours lecture plus 18 hours laboratory exercise use
Other courses (E.g. Advanced Geographic Analysis; Geo-Statistics: 3-6 hours per week

No courses are scheduled during the summer as the WVU budget does not permit teaching of courses beyond introductory geology and geography however six students used the facility for independent study of ARC/INFO in 1991. They made use of both the teaching and research Laboratories. In future it anticipated that workshops and training sessions will become regularly scheduled summer activities.

In usual circumstances the facilities are open to general use from 8:00 a.m. to 6:00 p.m., and to registered GIS and graduate students from 6:00 p.m. until midnight. Weekend hours are negotiated on the basis of gradaute assistant willingness to monitor. Student usage outside scheduled class assignments at present is predominantly for word processing, although the proportional use for GIS, graphics, and for statistical analysis is increasing . Research students have 24 hour access to all facilities. Approximately 8-10 students use the facilities on weekday evenings. Numbers and duration of use increases significantly towards the semester's end.

Demonstration and instructional use of ARC/INFO and ERDAS in the research facilities (Room 422) creates conflicts during the normal workday with ongoing project and research activities. Terminals have been reserved on an ad hoc basis from time to time but space and equipment limits groups to 5 or 6 students for a demonstration at a single workstation or peripheral, and 9 to 10 students for an exercise requiring access to the three workstations. Masters and doctoral dissertations are developed using laboratory facilities; students are expected to schedule their times of laboratory use to minimize conflict with funded research projects.

Since 1987 the lab has had professional relationships: with APCO (Appalachian Power Company), with Putnam county in southern West Virginia, and with the USDA Forest Service. The relationship with APCO (Appalachian Power Company) is in the form of a funded project to establish corridors for power transmission line rights-of-way. In 1991 the lab began a working agreement with Putnam county to develop a GIS for economic development and regional planning, under the auspices of the Strategic Initiative Program.

In conjunction with the Forest Service establishments in Morgantown and Radnor, Pennsylvania, four major projects associated with forest monitoring and management have been used as vehicles for research, hardware acquisition, software support and instruction. While this relationship cannot be guaranteed, the project lives are from two to five years, permitting financial planning for the lab in the near term. Such contracts may have led to some complacency in providing permanent financial foundations for the lab. Unwritten departmental policy encourages taking on new initiatives in the hope that continuing arrangements will be established later.

Operation

Currently, six tenure track faculty, a visiting professor, and fifteen graduate students are active on a daily basis in the laboratory for instruction, research projects and/or research training. Senior teaching and research personnel making regular use of the lab include Drs. Elmes, Harris, Hohn, Shumaker, and Wilson. Other faculty members use the laboratory less frequently for research purposes and occasionally for teaching.

Staffing Laboratory staffing remains a critical issue. The university as a whole is severely understaffed, in both faculty and classified positions, resulting in overloads for all personnel. Of the six faculty members referred to above, two teach GIS while the other four users are primarily engaged in non-GIS related research projects.

One faculty member, Dr. Steve Kite, has expressed a desire to gain GIS expertise while on sabbatical leave in Fall 1992 and to use the lab for surficial geology and geomorphological modeling classes. One faculty position is temporarily filled with a visiting instructor who will teach remote sensing in spring 1992. This position is scheduled to become a full-time, tenure track position in Remote Sensing and Resources in the 1992/93 academic year.

Four technical support positions may be identified; a full-time, College of Arts and Sciences electronics technician who is housed in the department; and two part-time systems managers, one taking primary responsibility for GIS, the other for geological research needs. Both positions are part-time and funded by soft money. In addition, a master's student has been taking full-time responsibility for ARC/INFO administration but will return to his studies in Fall 1991.

System Maintenance Responsibility for system maintenance is divided between the four technical staff. Operating systems upgrades and revisions are the province of the systems managers who coordinate their workload between themselves. Full backups have been regularly scheduled on the operating system disks, averaging one a month. Teaching and research projects are backed up as deemed necessary by project leaders. Full system backups occur only two or three times per year because of insufficiently developed system management policies and a lack of clear channels of authority. The system management takes no responsibility for users' files except as directly arranged for each project.

It is the users' responsibility to ensure backup of their permanent work, either on tape cassette, 9-track tape reel, or floppy disk. The current policy is that student accounts on VAX machines are permitted two versions of each filename, with 5000 blocks of storage space. Faculty and staff accounts are permitted unlimited versions and use storage space to their requirements if it is available. Student accounts are serviced at the end of each semester and obsolete accounts and unused files are purged.

All students are asked to keep their microcomputer work on floppy disks. Student work saved on the hard drives of the DEC 386 machines is not protected and may be removed at any time by the instructor. All microcomputer hard drives in the teaching lab are purged of all non-essential files at regular intervals by a teaching assistant.

Several periods of VAX system instability have been experienced. These episodes have usually resulted from a lack of disk space and disk fragmentation, either for system operation or for users needs. The problem of disk storage resolves into several components; 1) the speed at which twenty students can generate GIS layers and thus claim space even if individual file size is small; 2) the enormous demand for space by large area GIS projects with multiple layers; 3) the size of image files in remote sensing; 4) the file management practices of ARC/INFO running under VMS; and 5) failure of users to self-police their proliferation of temporary and obsolete work. Recently the problem of disk fragmentation has been addressed by the test of a software product, Diskeeper. During product testing more than 600,000 blocks of space were released. Access and elapsed times were also improved. A Diskeeper license will be purchased to manage disk use.

Software Security Software security issues are publicized at the beginning of each class that uses the laboratory and during an evening workshop that is mandatory for all users. Essentially we still rely on an honor system. Some GIS software products have a software key that makes their illicit use more difficult. We do not currently maintain surveillance over floppy disks entering or leaving the laboratory except by means of a virus checker on each pc and Macintosh machine. Macintosh machines have had recurring problems of virus infection in spite of contemporary virus 'detectives' and 'inoculators' such as SAM. WVNET provides regular information on new virus alerts via electronic mail to Dr. Elmes. The illicit storage of numerous computer games has been a problem, as they are restored as quickly as they are discovered and removed.

Operating Expenses While no accurate breakdown of actual operating expenses exists at the present time, it is evident that hardware and software maintenance and support rapidly exceeds initial acquisition costs. The current practice is for research projects to request pro rated costs for software licenses and maintenance agreements. The department has established a budget line into which such monies are transferred and from which maintenance support and repairs are paid. GIS and graphics software support alone is in excess of $10,000 per year. The current arrangement places an inordinate burden on faculty to win new research contracts and the department is in the process of identifying the actual running costs and establishing a budget. A contract with DEC and WVNET, the state educational computing network, provides all DEC software free of charge to the laboratory. However, documentation must be purchased.

Maintenance agreements are current on all functional equipment, either as factory warranty, extended maintenance contracts, or under a university-wide service agreement with DEC. For a one-time $25.00 registration fee any micro cpu or peripheral device will be repaired or replaced by DEC. This agreement covers equipment from all manufacturers.

Supplies such as tapes, pens, ink and paper are currently funded by the department unless specifically covered under a research contract. Students are expected to provide floppy disks and pay for hardcopy output.

Physical Security Some physical security issues are still being settled. The new rooms will all have electronically operated locks. Today Room 422 has a manual combination lock, the code for which is changed regularly. Only authorized personnel have a key for the cpu room. Security in other rooms is essentially maintained by limiting the access to keys and by posting research and teaching assistants to monitor their use. A log of users is kept for the teaching laboratory in Room 120. The assistant on duty is responsible for lockup and return of the key to a secure place in the departmental office. Computer thefts are a problem on campus. This year action will be taken to physically secure the microcomputers and peripherals using a cable and lock system.

Responsibilities

Currently two faculty members bear the greatest responsibility for issues arising from teaching. These responsibilities have involved hardware and software installation, troubleshooting, monitoring lab usage, and instruction on procedures and protocols. Overcommitment is accepted as standard practice. As yet we have not had many ad hoc requests for assistance from faculty. No doubt we should anticipate such requests and prepare an appropriate policy. Requests from other departments to use the laboratory usually emerge in the form of graduate students who have committed themselves to a research project and who need basic instruction in GIS as to how the project may be accomplished. There is often little understanding of either the conceptual basis of GIS or the effort involved to complete a project. The usual response is to make the laboratory resource available to them on the understanding that they will sign up for a relevant GIS course, or follow a self-paced course of instruction, such as is provided for ARC/INFO, GRASS, and IDRISI. While a great deal of the burden of these and similar issues has been taken by a few extremely hardworking graduate students, permanent, more satisfactory arrangements are necessary. Solutions will involve a policy of course requirements and dissemination of that policy to student advisors.

The role of the Department of Geology and Geography in providing fundamental instruction in GIS and image processing exists as an unwritten agreement with colleagues in the Colleges of Engineering, and in Forestry and Agriculture. This agreement is reinforced by course priorities established in the university catalog.

Hurdles

On the institutional front, one of the greatest difficulties has been encountered in the arcane rules and procedures of the state purchasing process which controls many university operations. Purchase orders, invoicing and payments have frequently been delayed, largely as a result of a lack of communication or knowledge about correct procedures. Delays have resulted in lost opportunities and thus dollars. A case in point is the negotiation of software licenses. State law was written to provide for payment on completion for services rendered. Software support and maintenance agreements were interpreted by state officials as a service. Consequently the state refused to pay in advance for software licenses. Resolution of the legal difficulty necessitated action at the state attorney general's office to permit software licenses to be paid in advance under carefully monitored situations. Reference has been made to the failure of the Synercom University Grant program to gain a foothold despite acceptance by both parties and the expenditure of $10,000 by the university. One element of this failure was the year-long legal battle between the state attorney general and lawyers for Synercom corporation, also over the interpretation of support agreements and payment schedules. The largest contribution was the failure of Synercom's GIS package to perform as advertised on the VAX/Tektronix platform for which it had been acquired. The Department of Civil Engineering had a similar experience with a larger VAX computer as well as workstations. With few operational capabilities, and little follow-up support from the vendor, the package made little contribution to teaching or research.

A persistent problem has been the procurement process. GIS equipment and software tend to be expensive, even after vendor discounts. At WVU items over $1000, purchased with university, i.e. state funds, have to be submitted to an external bidding process which extends the purchasing period by a minimum of two to four weeks, and may result in the substitution of equipment. On several occasions opportunities to purchase have been lost or delayed extensively, because of the detailed specifications necessary to purchase equipment that is exactly compatible to needs. The University Research Corporation was formed partly in order to ease the purchasing restrictions and equipment under $10,000 may now be purchased directly, providing funding is from external sources.

The condition of the physical facilities as regards the quality of space, electrical power supply, and air cleaning and conditioning have presented major barriers to the operation of a satisfactory facility. Visually it is difficult to create an image of a state-of-the-art, efficient facility. This negatively affects both faculty presentations and student response. Installation of equipment has often been slow because of heavy demands on qualified technical staff. Many technical tasks have been assigned to graduate assistants. Documentation of site-specific operating procedures is virtually non-existent. As a result too much demand is made on the informal passing of information vital to lab operation from one generation of graduate students to the next.

The realization of an operational lab has raised intra-departmental conflicts over space; concerns by some faculty about the emphasis of GIS in the geography program; and questions of authority over laboratory operations. Of these, collegial resistance to GIS on ideological grounds has been the least expected and the most difficult to resolve. Arguments concerning the surveillance role of GIS in society, the re-emergence of logical positivism, the debate over applied research versus basic research, and the value of training versus education have all been used to counter the success of GIS as a technological and instructional innovation. The prior relationships between geography faculty members have not survived intact. There is a sense however that GIS development is going to proceed, if in the face of intellectual disagreement.

The existence of large-scale, concurrent projects has also been problematic, in that no mechanism was in place to resolve the competition for computational resources and physical devices. Frequently instructional needs have conflicted with research projects for lab time and resources. At other times, GIS research has competed for resources with other types of research, and on several occasions, different GIS projects have competed for the same facilities. During times of intense competition for resources the use of batch procedures and the 24 hour scheduling of workstations and plotters is essential.

V. EVALUATION STAGE

Comparison

Because the development of the laboratory has been both incremental and evolutionary it is not possible to state categorically whether the final outcome differs significantly from the original design. It may be possible to provide a fuller response to this question in the summer of 1993 when the renovations to physical plant are complete and a new layout is in place. Certain elements of the conceptual plan have definitely been accomplished. The concurrent development of facilities for teaching and research has been necessary and appropriate. The concept of a computer network to provide specific capabilities for different purposes within geology and geography has been implemented. The GIS curriculum as planned emphasizes education in principles and applications rather than training to use a software package. The need to train students in particular GIS software, for their own projects or to work on faculty members projects, will have to be addressed more formally than at present.

The decision to network mini and micro machines was made early in the development process and has proved valuable. By creating an integrated lab the department has more powerful capabilities than if separate facilities were provided for geology and geography, although not without cost in areas of control, supervision, and management. In acquiring hardware we did not anticipate being able to buy a set of Intel 386/33 Mhertz microcomputers until the 75% discount on DEC equipment became available. By taking this opportunity we have not been able to buy as many digitizers and printer-plotters as we had planned. Student evaluations recorded the negative impact of this lack of output facilities for their exercises. As GIS is highly visual, students expect to be able to produce graphical evidence of their work beyond the CRT screen. The cumbersome alternatives to digitizer inputs have resulted in students working with pre-existing datasets. At upper level courses, the restriction is more acute but may be overcome by careful resource allocation. Unfortunately, although students are often willing to work at odd hours, only graduate assistants have 24 hour access to the building. Even though the lab can be staffed at night, students are often unable to get to it.

The laboratory is abundantly provided with software. The use of ARC/INFO, IDRISI, and SPANS is highly beneficial at different stages in GIS teaching. As a result of limited staff we lack an in-house ability to offer the programming language courses which were planned as a pre-requisite. Arrangements with the Computer Science Department to accept a limited number of GIS students have fallen through because of wholesale revision of the computer science curriculum. As a result of departmental policy and extreme limitations of resources, instruction in basic computer languages such as Pascal, C or FORTRAN is not available at WVU to the non-specialist student. Such instruction will have to be provided internally for the GIS program.

Reflections

The lab is competitive with facilities at much larger universities but still has great potential for improvement. We are particularly pleased with the award of the NSF monies to construct a completely modernized shell for the facility. The use of the NCGIA curriculum as a starting point for course development was important in establishing a leading instructional role in the university community. The availability of the course documentation, in conjunction with materials from GIS course preparation undertaken by Dr. Elmes and those taught by Dr. Harris, have provided a rich resource which was instrumental in rapid adoption of new courses by the university.

If the process were to be repeated, a greater proportion of the effort should be spent in establishing procedures, drafting formal letters of agreement between interested parties, in and developing measures of attainment. The energy invested in building a laboratory cannot simultaneously be invested in other academic activities. It is important to establish a record of achievement for professional development. Objectives should be defined in small increments and progress demonstrated with tangible products from each stage. It was easy to overlook the time required for essential details in the conceptualization of an overall scheme and equally easy to neglect to document developments that appeared minor to the investigator but are significant to administrators. Under ideal conditions far greater attention would be given to permanent budget priorities and arrangements. A formalized statement of the operating budget is essential even under the centrally-organized, financial control experienced in our department.

The question of technical support for the laboratory remains to be formalized. Informal arrangements with soft-money, half time positions have had a mixed success, with one of the greatest drawbacks being a lack of overall system authority in a single individual. A supportive, well-qualified systems manager is seen to be critical to the success of the GIS laboratory. A budget for full-time technical staff assigned to systems management and systems programming should be funded at a very early stage.

Matters of hardware acquisition have been ruled by a conscious choice to maintain the VMS operating system. The choice was sub-optimal for GIS research applications but made necessary because of a number of other demands made on laboratory resources. Convenience of instruction is a significant consideration. Currently about half the research use of total computer resources is for GIS. About 80% of instructional use is related to GIS in some fashion. The remainder is for coursework in statistics and geo-statistics. If informal use is considered, i.e. students using word processing and statistical packages for other course-related requirements, the proportion would be closer to 50%. The greatest concern about transition to another operating system was that the in-house experience in running VMS was not matched by any equivalent experience in UNIX. The learning curve was thought to be prohibitively long for a successful fully-operational transition within a year. The VAXstation 2000 workstations have proved to be extremely slow for ARC/INFO even with memory and disk upgrades but they are more than adequate for teaching, if small databases are used. The VAX station 3100 is a more suitable machine for large-scale GIS and it and similar acquisitions will be essential for graduate thesis work on applied topics. It will be possible to convert to UNIX-based, RISC architecture incrementally but the choice to migrate to ULTRIX (VAX UNIX operating system) was available in 1988 system-wide and should perhaps have been taken then.

Future Developments

Physical Facilities Difficult decisions will be taken in the next two years as to the future of the Geo-data Processing Laboratory as a whole and its relationship to the various GIS-oriented components. Building renovation plans will dominate the immediate future, 1992-93. New processing units will immediately impact operating procedures and the distribution of software when added to the network. To provide greater student access, equipment will be reallocated between the renovated facilities and the current research lab (Room 422). Reallocation will present dilemmas to faculty and between research and instructional needs. In the teaching lab additional personal computers are anticipated, and input and output capabilities must be strengthened through the addition of several low-end digitizing tablets and printer-plotters. Computer screen projection facilities for the teaching lab are important but high resolution, 256 color equipment is prohibitively expensive. A monochrome VGA/EGA system will probably be the first purchase.

Instruction Geography at WVU has undergone great changes in a five year period. The majority of faculty members are new appointments with two or fewer years in the program. As a result a clearer focus of our educational goals is evolving and the relationship of GIS to those goals is not yet firmly established. In GIS instruction we continue to identify student needs and expectations. Prior computing experience and computer programming skills would greatly enhance the instruction in GIS. As yet the majority of students are from within our program. We expect to increase the diversity of students gradually through good reports of our current course offerings. There is little incentive to do this at present as the introductory course is fully subscribed and is a pre-requirement for continuation to any other GIS courses. Pre-requisites remain a difficult problem in a program where most majors begin as juniors and most graduate students have no prior training in GIS. A required sequencing of preparatory and GIS courses risks small enrollments in upper level courses. Yet it is impractical to provide a quality education in GIS without course sequencing.

An essential task is to add separate lab sections to the three existing courses in GIS, and to ensure the creation of lab sections for Remote Sensing and Advanced GIS when they are submitted to the university. A decision is pending on how to instruct for specific GIS software. Current full time faculty cannot add training courses to their schedules without dropping other courses or reducing research commitments. Two new positions are being discussed. A new full-time position in remote sensing is advertised for 1992. Negotiations are in progress at the College level for a full-time university extension post. This post will combine the dual emphases of the geography program on GIS and regional development. It is anticipated that the appointment will add the ability to offer training courses and workshops in a variety of GIS applications both internally and externally to the university. If both these appointments are successful, WVU will have one of the stronger teaching faculties in GIS in North America.

Recommendations

1. Document all stages of development and have a written plan, no matter how small the enterprise. The plan should detail major pedagogic goals, methods of instruction, demand for space and resources. Record the reasons for implementation differences from the plan. Such documentation is essential to inform colleagues, to be used for publicity, and to provide a paper trail of decisions taken to aid in the continual competition for resources.

2. Do not under-estimate the value of a dedicated, senior-level systems/laboratory manager.

3. Use student abilities wisely in meeting the diverse demands of teaching in a computer environment; team 'computer literates' with the 'computer shy', encourage cooperation in groups of two. Larger teams seem to produce workers and hangers-on.

4. Field trips to operational GIS sites, GIS research and development, and digital data production centers have been invaluable in exposing students to the realities of GIS in the 1990's. The major benefit has been to put the laboratory in perspective. (i.e. We have better access to software than many locations but are not equipped with the most powerful computers available.) External speakers from non-academic institutions have also helped to communicate the various career opportunities and diversity of GIS use today.

5. Production-oriented work will be necessary in many sites to provide initial funding and continual hardware / software support. Although students benefit somewhat from production-related employment, the requirements of teaching and production are frequently in opposition.

6. With regard to training for both career and production work, effective knowledge of specific GIS packages is essential, but the need for detailed instruction in commands and functions has not meshed well with coursework directed at the broader objective of education in GIS. Mature students can develop skills with self-paced tutors if there is sufficient free time in the laboratory. Depending on your perspective, training courses for familiarity with specific packages, appears to be a necessary evil.

7. Beware of GIS text books.

8. The NCGIA core curriculum provides more than sufficient basis for initiating undergraduate education, and a strong foundation for graduate education, particularly as regards adding new courses to an existing program which can subsequently be revised to meet your specific needs.

TABLE 1
BUDGETS

Higher Education / Industry Partnership 1987, Development of Signal Processing

Seismic Field Equipment	14,940	
Seismographic Station	5,200	
Microcomputer	5,800	
MicroVax III CPU	40,000	
Array Processor	24,500	
Storage (Disk Drive)	12,000	
Tape backup	12,000	
Networking Software	5,000	
TOTAL	119,440	(100,000 Awarded)

WVU Strategic Initiative 1988/89, Upgrade to Geo-Data Processing Laboratory

Image Processing Hardware	30,000
Image Processing Software	15,000
GIS Software License	37,000
Electrostatic Plotter	46,000
Disk Storage	10,000
Graphics Workstations	19,000
TOTAL	157,000

Proposed Sources

USDA-Forest Service Grant	12,000	(Awarded)
Submitted NSF Proposal	57,340	(Unsuccessful)
WVU Strategic Funds	87,660	(Awarded)

Actual Funding Received, 1988/89

WVU Strategic Funds	87,660
USDA-Forest Service Grant	12,000
College Funds	60,000
TOTAL	159,660

National Science Foundation, Research Facilities Modernization Program, 1990

Demolition	21,500	
Construction	90,750	
Utilities	104,425	
Ethernet	10,000	
Security/Environment	53,400	
BUILDING SUBTOTAL	277,075	
Contingency	41,560	
Architect/Engineer Fees	27,700	
Inspection	27,700	
Project Management	18,700	
TOTAL PROJECT	392,750	
NSF Share (50%)	196,375	(Awarded)
WVU Share (50%)	196,375	(Awarded)

TABLE 2
EXPENDITURES

Geo-Data Processing Laboratory

Capital Expenditures, 1989

Image Processing Hardware and software ERDAS, DELL 386/25 Mhz, Targa Graphics board, Mitsubishi RGB Monitor, Howtek Color Scanner	$44,000
Memory Upgrade (Mass Storage) GIGARIG 1.2 Gigabyte disk drive and controller	$12,000
Graphics Workstations 3 DEC VAX 2000 Workstations, 19 inch color monitors	$19,000
Calcomp 1044 Pen Plotter	$4,000
Calcomp 9100 Digitizing table, backlit and power stand	$12,000
Calcomp Plotmaster, thermal wax plotter	$8,000

Capital Expenditures 1990

DEC VAX 3900 minicomputer 128 Megabyte RAM, 9 Gigabytes disk storage, 9 Track 6250 BPI streaming tape dive	$37,000
10 DEC 386/33 Mhz personal computers 8 MegaByte RAM, 80 Mbyte Hard disk, ethernet card, VGA Monitor, Mouse	$28,000
2 Hewlett Packard Paint Jet Printer/Plotters	$3,000
DEC ScriptPrinter Laser printer	$3,000

TABLE 3
LIST OF HARDWARE AND SOFTWARE

Teaching Laboratory (Room 120 White Hall)

Hardware

10 DEC 80386 personal computers, 33Mhz, 80 Megabyte hard disk, 8 Megabytes RAM, 80387 Math Co-processor, Ethernet card, two button mouse, VGA monitor

3 HP Paintjet Printer/plotters

2 Digitizing tablets (as required)

1 Overhead projector

Software

DEC PCSA networking communications software

Microsoft DOS 5.0 (10 Copies)

OS/2 (10 copies)

Diversified Computer Systems (DCS) Graphics Emulators

(Tektronix 4105/4107) (10 copies)

SPANS (10 copies)

IDRISI (Site License)

Word Perfect 5.1 (10 Copies)

ERDAS (1 Copy)

PMAP

GRASS

DBASE 3

ORACLE

Graduate Research/Training Laboratories (hardware)

Rooms 116/118 White Hall (Ethernet to Room 422)

VAX 3100 workstation (180 Mbyte disk, 16 Megabytes RAM)

CALCOMP 9100 digitizing table, backlit with power stand

DEC 80386 personal computer, 33Mhz, 80 Megabyte hard disk, 8 Megabytes RAM, 80387 Math Co-processor, Ethernet card, two button mouse, VGA monitor

CALCOMP 6XXX Color electrostatic plotter

Room 211A White Hall (Ethernet to Room 422)

MACINTOSH IIX

45 Megabyte Removable Hard disk, 300 Megabyte Hard disk

Hewlett Packard Ink Jet Plotter

CALCOMP 5XXX 24 x 36 Digitizing Tablet

Iverson 80486, 25 Megahertz computer

Geo-Data Processing Laboratory (Room 422 White Hall)

Hardware

VAX 3900 mini computer

VAXstataion 3500 mini computer

3 VAX 2000 workstations (180 Mbyte disk, 12 Megabyte RAM)

Hewlett-Packard Apollo 720 Workstation (Fall 1991)

DEC RA 90 Mass storage (3.2 Gigabytes).

DEC High Speed Line Printer

Dell 80386/25 mhz, 8 Megabytes RAM, Targa graphics board, 300 Megabyte hard disk

Mitsubishi RGB monitor

Howtek Color Scanner

CALCOMP Plotmaster thermal wax plotter

CALCOMP 5913 thermal wax plotter

CALCOMP 1044 High speed pen plotter

Tektronix 4962 Ink Jet plotter

Hewlett-Packard Draft-Pro pen plotter

CALCOMP 9100 digitizing table, backlit with power stand

Numonics 2100 digitizing tablet

Tektronix digitizing tablet

CALCOMP 5XXX digitizing tablet

Benson Monochrome electrostatic plotter.

Software, available over network

VMS version 5.2

ARC/INFO Version 5.01, Multi-user & Workstation Licenses

UNIRAS

SURFACE 3

SAS

Word Perfect for VAX

AIMS (signal processing software)

FORTRAN, C , PASCAL, ADA programming language compilers

ORACLE

Network communications

The department's computer system is networked as a VAX cluster with ethernet connections. The anticipated configuration of the system as it will be upon the installation of the VAX 4000 is shown (Figure 5). Network communications currently are DECNET to West Virginia Educational Network (WVNET), and thin wire Ethernet, with repeaters, to other laboratory components and Faculty research offices. RS 232 Serial lines are available to all floors. When the University 's Ethernet system is in place all connections will be standardized.

TABLE 4
PRESENT AND PLANNED GIS COURSES

Current Courses

The following GIS-related courses have been fully implemented, i.e. accepted by the university senate, included in the university catalog, and taught at least once:

Geog 151	Introduction to GIS (3 hr. Fall, Dr. Elmes)
Geog 251	Technical Issues in GIS (3 hr. Spring, Dr. Elmes)
Geog 252	Applications in GIS (3 hr. Spring, Dr. Harris)
Geog 261	Cartography (Includes GIS/Computer cartography components) (3 hr. Spring, Dr. Pyle)
Geog 496	Graduate Seminar in GIS (Variable credit. 1- 6 hr. Fall/Spring, various staff)

Revised Course

Several courses have been identified for revision to mesh more closely with the GIS sequence. They will provide supplementary and integrated GIS instruction, or in-depth focus on a limited number of related topics, but major course revision is unnecessary, and the process of re-submission to the senate curriculum committee should be relatively pro forma:

Geog 200	Spatial Analysis - will be developed to incorporate analytical and exploratory components of GIS. (3 hr. Fall, Dr. Elmes)
Geog 262	Advanced Cartography - computer cartography (3 hr. Spring, Dr. Harris)

Planned Courses

Additional courses remain to be re-organized or developed from scratch to reflect the experience of the first three years of GIS instruction and/or new faculty specializations. For formal recognition in the catalog these courses will require full documentation and passage through the university senate, in practice most can be offered initially under existing course numbers:

Geog 2XX	Laboratory sections for GIS lectures (1hr)
Geog 2XX	GIS software training
Geog 3XX	Graduate Remote Sensing course
Geog 3XX	Revision of 'Technical Issues in GIS' for graduate study only
Geog 4XX	Graduate seminar in remote sensing / image processing

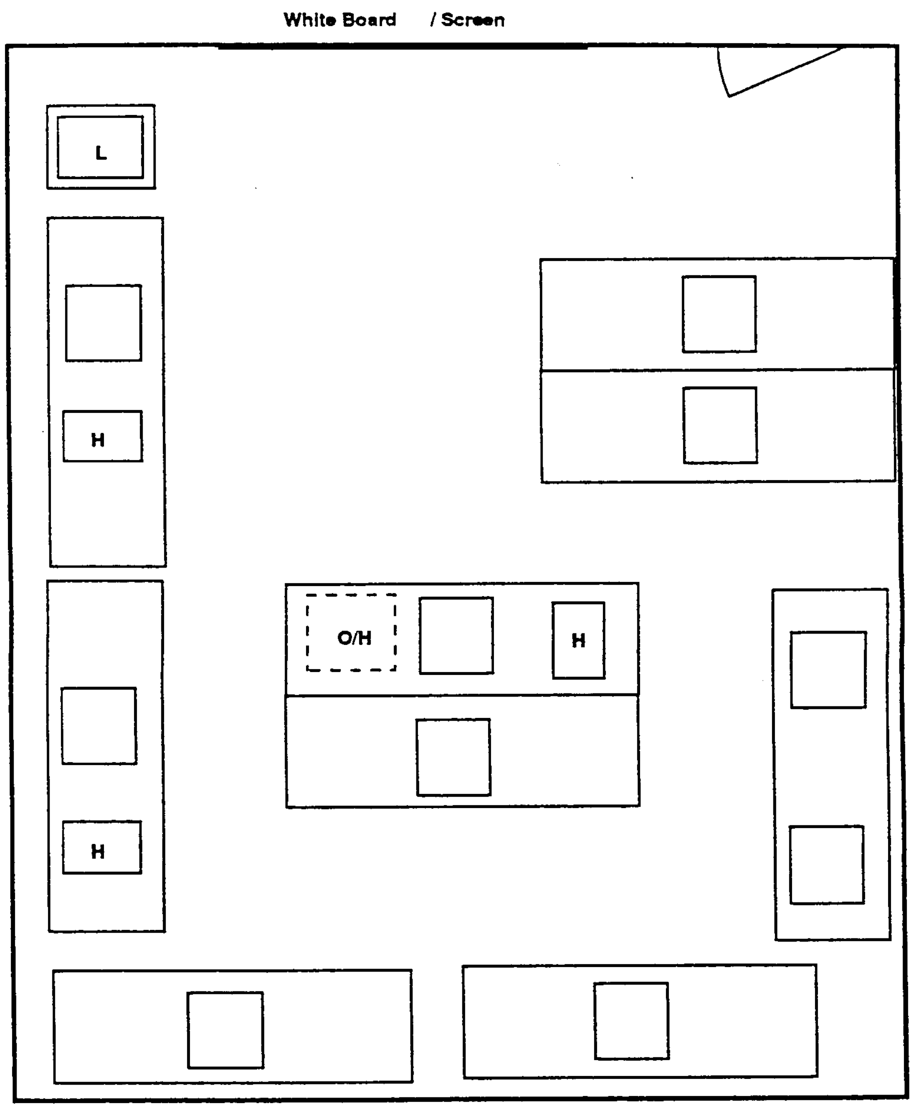
Doctoral Program

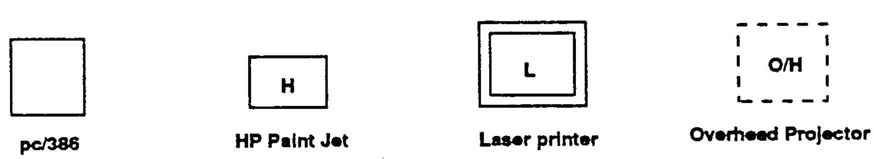
A proposal for a doctoral program specializing in GIS and Regional Development has been submitted to the university administration. Certain events, including a radical change in the governance of higher education in West Virginia, have contributed to the delay of final review of the application for two years. The proposal is expected to proceed through the Board of Trustees for a decision in the 1991/92 academic year. The proposal has passed all levels of internal review and has support from external reviewers.

For comparison with other systems of higher education, course numbering conventions at WVU are as follows:

X-1XX	Freshman / Sophomore
1XX	Freshman / Junior
2XX	Senior / Graduate
3XX	Graduate lecture courses (Seniors with special permit)
4XX	Graduate seminar courses / research

FIGURE 1
TEACHING LABORATORY
ROOM 120 WHITE HALL





Seating omitted for clarity

FIGURE 2
GEO-DATA PROCESSING LABORATORY
ROOM 422 WHITE HALL

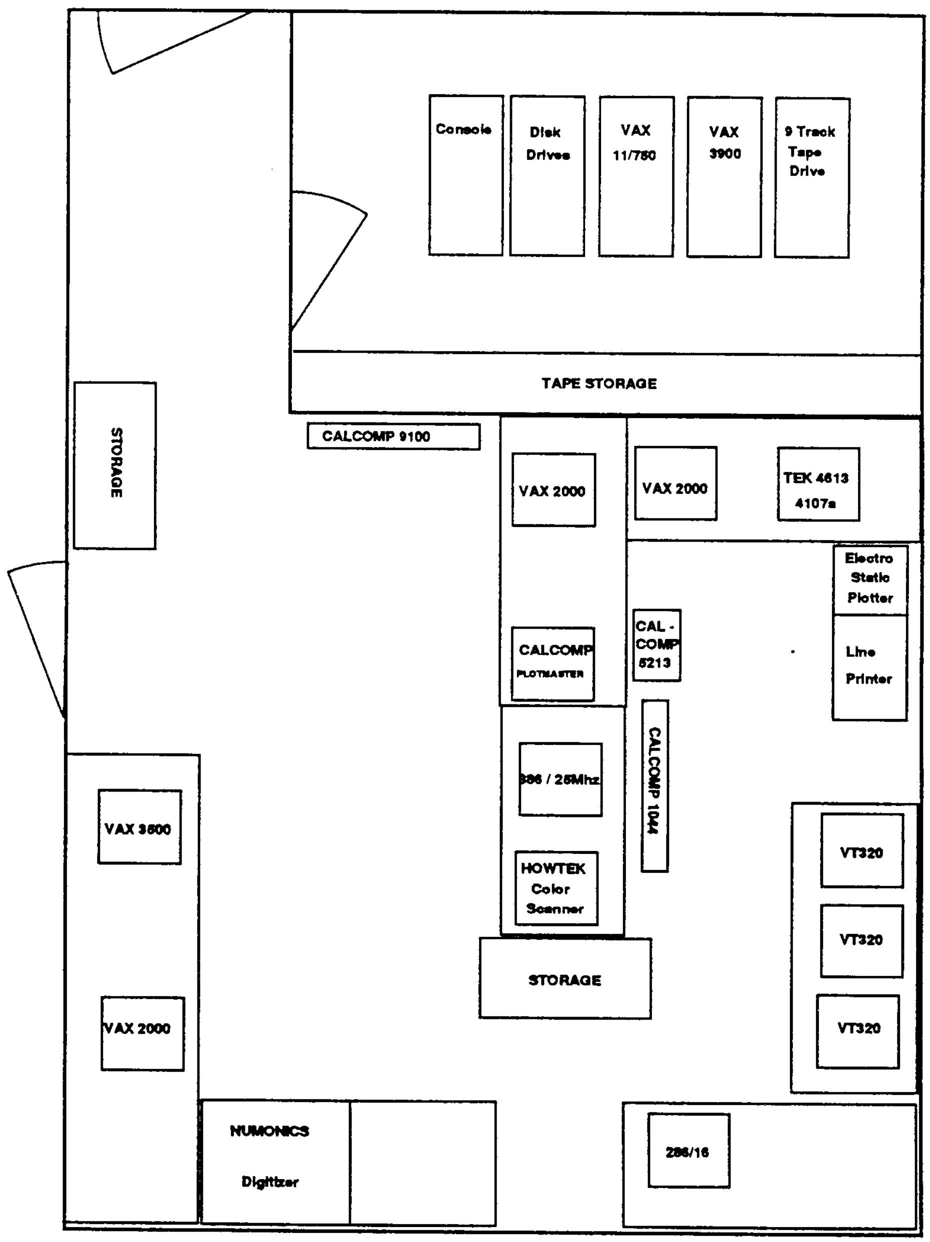


FIGURE 3
GRADUATE RESEARCH/TRAINING LABORATORY
ROOMS 116/118 WHITE HALL

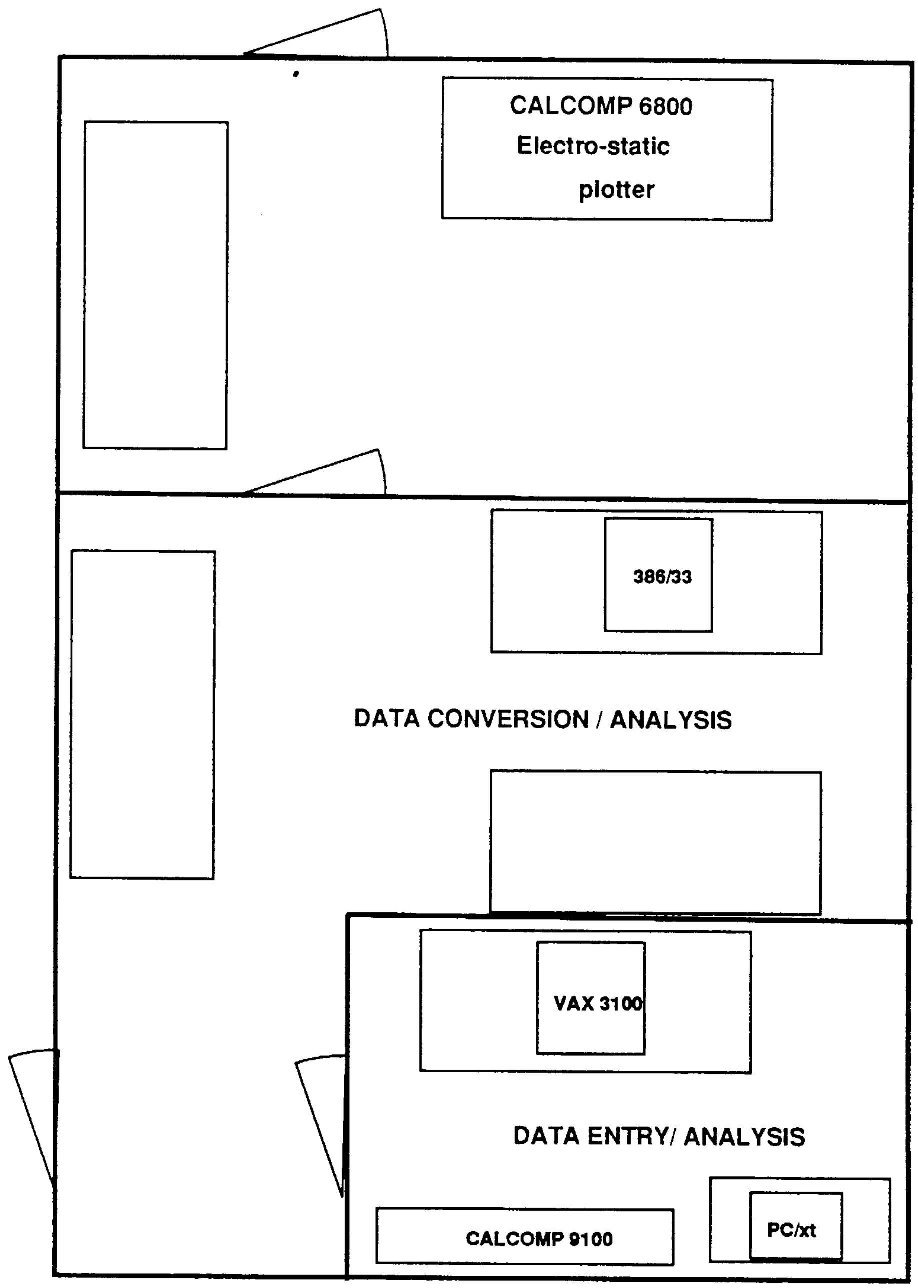


FIGURE 4
GRADUATE RESEARCH/TRAINING LABORATORY
ROOM 211A WHITE HALL

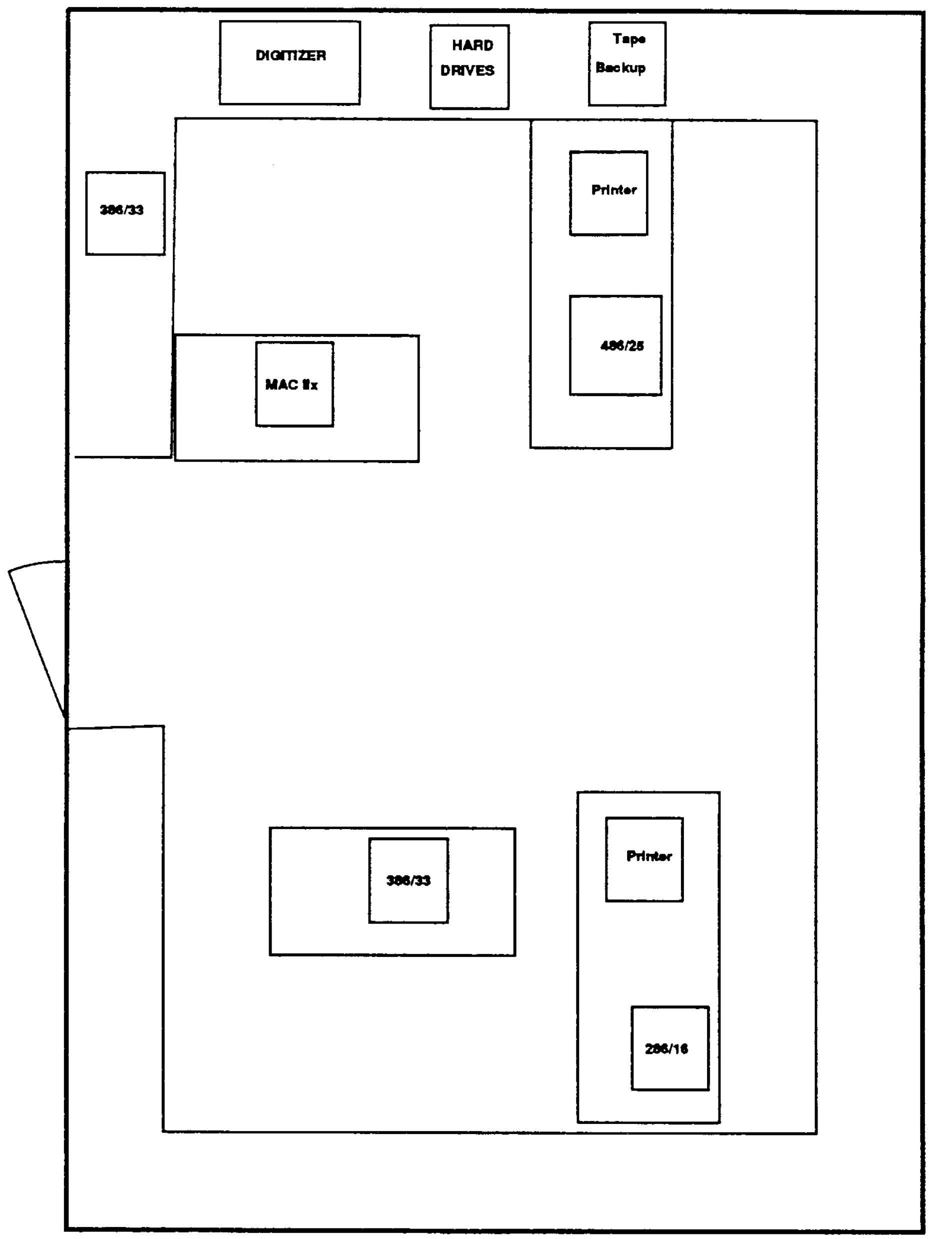
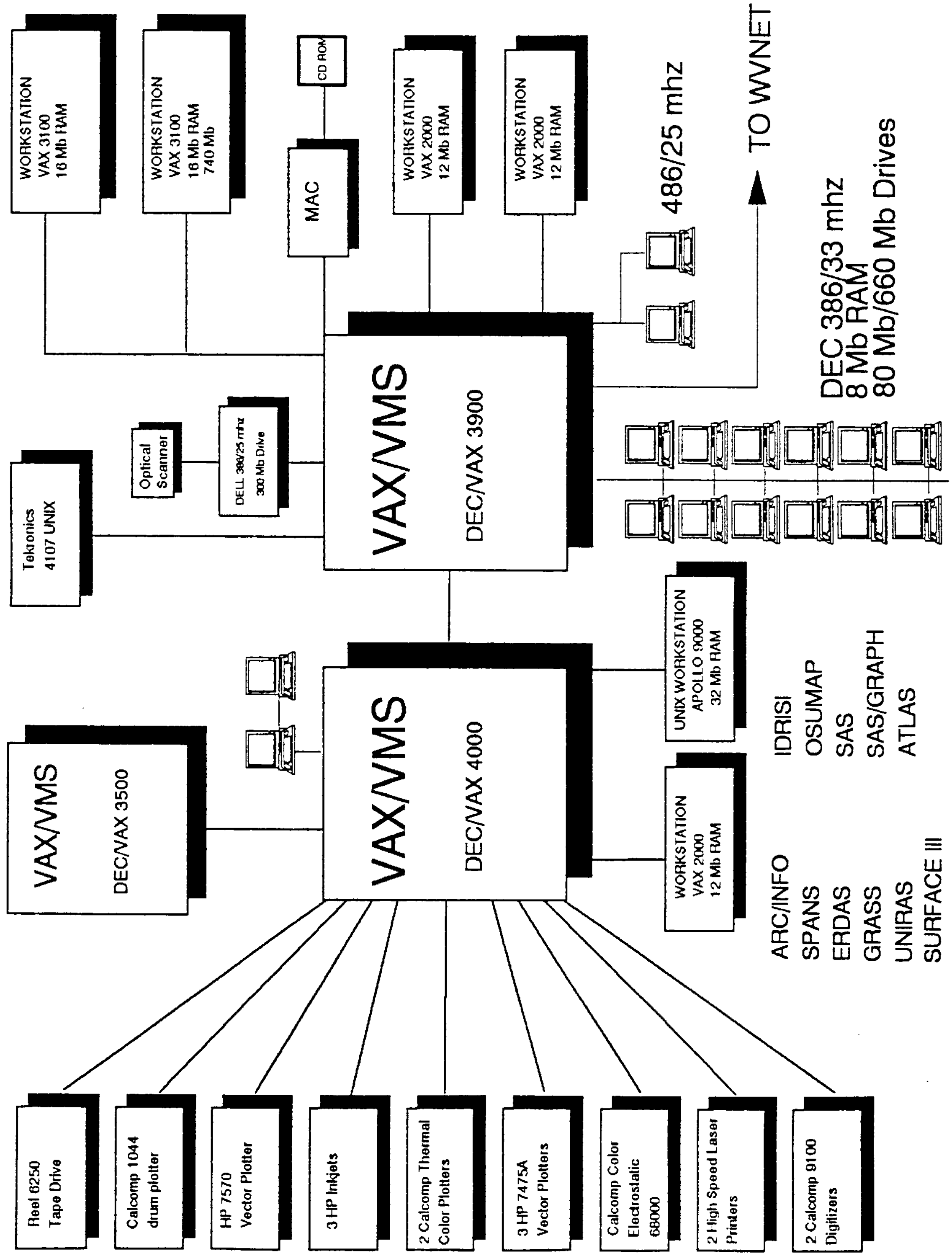


FIGURE 5
NETWORK DIAGRAM



San Diego State University

Richard D. Wright and Ernst C. Griffin
Department of Geography

September, 1991

THE CENTER FOR EARTH SYSTEMS ANALYSIS RESEARCH (CESAR): AN INTEGRATED GEOGRAPHIC INFORMATION SYSTEMS AND DIGITAL IMAGE PROCESSING LABORATORY

The Department of Geography at San Diego State University houses the Stephen and Mary Birch Center for Earth Systems Analysis Research (CESAR). Originally proposed in the summer of 1986 as a facility emphasizing remote sensing, CESAR instead evolved into a state-of-the-art, integrated geographic information systems (GIS) and digital image processing (DIP) laboratory. CESAR serves a dual function as both an instructional facility and a research laboratory supporting externally funded grants and contracts. Specific courses at the upper division and graduate levels as well as independent student research occur within CESAR. Simultaneously, a wide variety of funded activities are in place. In mid-1991 the total value of projects in progress was nearly $2 million and included international, national, state and local-level projects funded by public and private sector institutions.

To provide a context of the academic environment in which CESAR functions, a thumb-nail sketch of the university and department seems appropriate. San Diego State University is the flagship campus of the 20-member California State University system. A comprehensive university with some 33,000 students, SDSU offers bachelor's degrees in 76 areas, the master's degree in 56, and the doctorate in 8, including geography. Several departments in the university have gained national stature for the quality of their programs. The faculty attracted nearly $45 million dollars in research awards in 1990-1991. Within the Department of Geography there are 20.5 faculty positions to serve some 165 undergraduate and 50 graduate majors. Approximately 5,000 students per year take classes in Geography. The department's primary specialties include GIS, cartography, remote sensing/DIP, and spatial statistics as applied to problems in urban and behavioral geography, biogeography, environmental geography, and Latin America. The Bachelor of Arts, Master of Arts, and Doctor of Philosophy (offered jointly with the University of California, Santa Barbara) as well as a Certificate in GIS are awarded in Geography.

I. CONCEPTUAL STAGE

Prior to 1987 the department's ability to conduct a program of research and instruction involving digital cartography, GIS, DIP, and remote sensing was severely limited by inadequate facilities. Although courses in automated cartography and remote sensing had been offered for more than a decade, the level of technology employed was very low. For example, as late as 1986, image processing was limited to two or three small software packages, such as MICROPIPS, running on a single IBM PC. Automated cartography (AC) and GIS courses were supported largely with Harvard software (e.g., SYMAP and GRID), DISSPLA, basic plot subroutines, and other graphic packages residing on the university's CYBER mainframe computer. These programs were accessed by telephone lines via 300-baud modems and displayed on four "dumb" terminals. In-house graphics capabilities consisted of a Tektronix 4027 CRT, a Hitachi 42-inch digitizer, and a 12-inch Zeta plotter. All of the equipment was housed in a room of less than 200 square feet. The two courses taught annually in remote sensing and automated cartography enrolled a total of approximately 20 students. Because no staff support was available for these activities, technical supervision was provided by the two faculty with expertise in RS/AC and by some of the graduate students enrolled in the courses.

In a broader context, during the mid-1980s the department was grappling with ways to develop an identifiable focus which would allow it to move forward. We were seeking ways to attract and retain outstanding young faculty while also improving our program's stature, locally within the university as well as nationally within the discipline. At the same time it was also becoming clear that a revolution was occurring in both software and hardware, technically as well as cost-wise, that presented exceptional opportunities for geographic research and instruction. Departments that developed programs which placed them at the forefront of these changes could have the potential to make enormous strides quite rapidly. This fortuitous conjunction in a time of departmental soul-searching and accessible technological innovation was the catalyst which was to lead to the conceptualization of CESAR.

The combination of RS/DIP/GIS as the technical focus of the department offered a number of benefits. First, we had a small but highly skilled nucleus of faculty (Richard Wright and Douglas Stow) already working in these areas. By adding to this core, we felt we could bring about change without major disruptions in existing activities. Second, the techniques were applicable to problems in both human and physical geography thus allowing us to reach a wide range of student and faculty interests. We also perceived that this would allow us to develop a facility which could broadly benefit the faculty as a whole and act as an inducement to attract new faculty. Third, we felt strongly that students with a background in these areas would be much better prepared for spatial problem solving. We concluded that curricular changes in this direction would be a significant benefit for our majors, both graduate and undergraduate. Fourth, application of these techniques to spatial problems could provide significant advancements to geographic knowledge. This complimented the desire of the faculty to increase their opportunities to do good, basic scientific research. Fifth, image processing and GIS could be used to develop cross-disciplinary research ties on campus, an important consideration from both a scientific and political perspective. Sixth, there are excellent external grant/contract opportunities for faculty working with these techniques. Because of limitations inherent in the California State University system budget, it was important for the department to attempt to broaden its base of financial support. Finally, the public relations or "gee whiz" effect of the techniques was very strong and this could have an important impact upon administrators in control of funding. Virtually all of the university's higher administration is composed of people trained in the sciences and they recognized the importance of computers in research and instruction. Along with several additional positives, we concluded that an initiative to create a major laboratory facility in RS/GIS should be pursued vigorously.

Clearly, the pre-1987 situation had to be drastically upgraded if the department was to conduct a major program of RS/GIS instruction and research commensurate with the expertise and professional aspirations of the concerned faculty. Thus, the Department Chair (Ernst Griffin) along with Profs. Wright and Stow set about to determine what was needed to create an adequate laboratory. A number of hardware and software vendors were contacted for information and a great deal of literature was perused. Several persons who had hands-on experience with various systems configurations in established labs were contacted for their opinions and advice. After a possible hardware/software configuration was agreed upon internally, we invited a consultant (Dr. John Jensen, Department of Geography, University of South Carolina) to critique our thinking. As a result of his visit a revised plan was established which gave us significantly greater flexibility and growth potential than our original design. The cost of bringing in someone intimately familiar with setting up a lab proved to be very worthwhile and cost effective.

Once we felt that we had an adequate idea of what was needed, informal contacts were made with key administrators on campus to solicit their views and suggestions as to how to proceed as well as to try to gauge the degree to which they might support our initiative. Several independent discussions were held with the Dean of the College of Arts and Letters, the Dean of the Graduate Division and Research, the Vice President and Associate Vice President for Academic Affairs, and the Executive Director of the SDSU Foundation. We outlined what we wanted to accomplish, what resources we thought would be required, and what we envisioned the results would be for the department, the College, and the university. We emphasized the merits of RS/GIS as an instructional and a research tool, how our students would benefit if our ideas were implemented, and how the initiative tied into the long-term planning of the department. In turn, we received encouragement and viable suggestions on strategies for formulating a proposal. This may have been the key phase in ultimately having a successful project because it involved key decision-makers early in the process and may have brought them "on board" psychologically.

II. PROPOSAL STAGE

The initial official proposal to create a center emphasizing remote sensing, the precursor of CESAR, was made in two parts during the late Spring of 1986: one through the university's "Lottery Funds" competition and a second directly to the Vice President for Academic Affairs. Although the proposals were made separately, they were integrally related in that the first provided the funding for hardware/software while the second made position monies available. Additional proposals to support CESAR were submitted and funded in subsequent years from the university and externally.

As a part of the law creating a state lottery in California, a percentage of the income generated is divided among the various parts of the educational community. Within the CSU system, a portion of those monies go directly to the individual campuses and are utilized at the discretion of the presidents. Because of their sources, these funds are generally to be used to benefit the instructional mission of the university. Therefore, the department requested $200,000 to develop a center which focused upon advanced undergraduate and graduate instruction in image processing of remotely sensed data and its cartographic analysis through geographic information system technologies. Given the skills of the existing faculty, the specific foci of the Center were to be hydroclimatology, geomorphology, and biogeography with an emphasis upon spatial analysis of form and process. It was argued that the Center would enhance the learning experience of students in geography and closely allied disciplines by providing hands-on experience with "sophisticated computer-based techniques in remote sensing and geographic information systems". The proposal was funded in the Summer of 1986.

The monies provided were used to purchase the initial hardware and software needed to equip the lab. Three ERDAS PC turn-key systems with IP and GIS software modules were the main components acquired for remote sensing activities, along with peripherals such as an electronic digitizer, a video digitizer, a tape drive, an ink-jet printer, and a QCR digital video copy camera. Two hand-held radiometers and polycorders were purchased for field data collection. ARC/INFO software for use on a VAX minicomputer cluster was acquired as the base for our GIS functions along with two Tektronix graphic terminals. A CalComp plotter was also purchased to provide hardcopy.

Simultaneously, the Vice President for Academic Affairs was asked to approve and fund a new entry-level tenure track position that would allow the department to bring in a second specialist in remote sensing of the physical environment so that we could begin to create a node of expertise in that area. The individual hired would be expected to become grant active. To facilitate this latter consideration, a zero-teaching load was to be assigned for the first semester. The Vice President and the Dean of the College of Arts and Letters agreed to fund this position for two years, after which the department would absorb the position costs. Subsequently, Allen Hope was hired to fill this position. As a result, the Center was funded and three faculty with RS/GIS skills were in place.

One of the reasons that the university supported this initiative was because of the excellent possibilities for externally funded projects that could be obtained by researchers using RS/GIS techniques. The department estimated that with qualified faculty the new Center could generate a steady-state grant/contract funding base of $150,000 per year after four years. These projections were evaluated by the SDSU Foundation's Development Office (the university's research auxiliary) and were considered to be reasonable. As a result, the university's administrators may have felt that they were making a "good investment" which could produce tangible returns.

Overall, we faced very few hurdles in pursuing this initiative. The university's administrators at various levels were very supportive of our ideas and worked to help them succeed. We are convinced that this was due to the fact that we had done a great deal of groundwork all along the line. As a result, we were able to anticipate questions, provide pertinent information in a timely manner, and intelligently project the impact of the program. Further, the department had a Five-Year Plan in place and the proposal fell within the objectives defined within the plan. The lesson from our experience is clear: homework is good.

III. ACQUISITION STAGE

Since its inception in 1986 there have been three major purchases of hardware and software for CESAR (See Table 1). Two of these were the result of successful lottery proposals within the university and the third was self-funded through a loan from the SDSU Foundation. These three main acquisition phases will be discussed here. In addition, we have an on-going program of purchases to maintain and up-grade CESAR's equipment base financed through monies generated by CESAR.

Hardware and Software Acquisition - Phase 1

During the first year of funding the equipment and software actually purchased varied little from that which was proposed. The only additions were the numerous odds and ends, such as cables, computer chips, connectors, and supplies, that are essential to the operation of a computer facility. Individually, these items do not cost much, but in total they added several thousand dollars to the expenditure. That the initial purchase plan survived largely intact into the acquisition stage was due in large part to the detailed planning that was done and the short time (approximately three months) between proposal submission and systems purchase.

An important aspect of the proposal stage that expedited the acquisition process was the evaluation of hardware and software. Prior to submitting our proposal, it had been determined that ARC/INFO and ERDAS software would comprise the primary GIS and DIP capability of the new facility. These two packages and the companies that produce them -- ESRI and ERDAS -- rated highest in terms of the factors that we considered to be important when selecting software and hardware for a research/educational facility. Additionally, both companies recognized the potential value of having their software installed at San Diego State University. Thus they were very cooperative in helping us to define our needs as well as potential solutions. Consequently, when the proposed purchases went out for bid ESRI and ERDAS were the only vendors that could provide software/hardware with the capability we needed at a price we could afford.

Hardware and Software Acquisitions - Phase 2

As mentioned previously, while the initial proposal emphasized remote sensing, within a year of its funding CESAR had evolved into an integrated GIS/RS research and instruction facility. In the summer of 1987 a second lottery grant, this one for $93,000, was funded by the university to upgrade CESAR to accommodate more students, larger databases and more sophisticated modeling. These monies were used to purchase Macintosh IIs, 386 PCs, and additional ARC/INFO and ERDAS capability. In addition, at roughly this same time the university provided CESAR with a VAX 750 mainframe minicomputer for ARC/INFO. While somewhat dated, having a VAX in-house within CESAR permitted us to process much larger data sets as well as utilizing "Live-Link" techniques between ERDAS and ARC/INFO. The original VAX 750 was recently replaced with a VAX 780. The university maintains the CESAR VAX and we continue to have full access to all systems in the University Computer Center through an Ethernet link.

The evolution of the facility as an integrated GIS/RS center was hastened by two major grants. Within months after the establishment of CESAR a contract was awarded to Richard Wright by United Enterprises Inc. to develop a land use GIS for a 9,000-acre portion of Otay Ranch in southwestern San Diego County. The primary purpose of this 15-layer database was to demonstrate how GIS technology could be employed in planning and managing the development of the Otay Ranch subdivision. The owners of United Enterprises who are also directors of the Stephen and Mary Birch Foundation, were pleased with the outcome of the Otay Ranch GIS pilot project. As a result of this project a formal proposal was submitted by Richard Wright and Ernst Griffin to the Stephen and Mary Birch Foundation to support the creation of a center for excellence in environmental and land use analysis using GIS and IP technologies. The request, which was funded in September of 1988 in the amount of $632,000 over a five-year period, has several components: an endowed chair contribution, graduate research assistant support, database development for research and instruction, faculty released time for research and curriculum development, hardware and software purchases, and community outreach via a series of summer workshops. This grant was very important to the early development of CESAR in part because it provided a degree of financial stability for several years.

A second grant that has had a major impact on the early evolution of CESAR was a National Aeronautics and Space Administration award to Douglas Stow in the amount of $600,000 over three years for a project entitled "Efficient Updates of Vector-Coded Geographic Information Systems Using Remotely Sensed Data". This on-going collaborative effort with ERDAS, ESRI and the San Diego Association of Governments (SANDAG) involves research to promote the commercial use of satellite image data and image processing systems for updating land use coverages in regional GISs. Techniques have been developed and tested for integrating raster image data with vector GIS coverages. The techniques have been transferred to SANDAG and are now being used operationally to update a 1986 land use inventory to 1990 conditions. Similar techniques are now being employed in another CESAR project for mapping vegetation and identifying sensitive habitats in southern California. This grant, with its emphasis on raster-vector integration, has helped to focus research and instructional activities in CESAR.

Like all grants and contracts accepted by CESAR, these projects incorporate graduate students and often advanced undergraduates in the research process. These students receive practical training in a wide array of research activities which enhance their educational experience. A large percentage of our graduate students' theses and seniors' honors projects emerge from their involvement in sponsored research projects. At the same time, the specialized techniques and databases which result from research activities are frequently integrated into courses taught in the department. Thus there is a clear and symbiotic relationship between the instructional and research goals of CESAR.

Hardware and Software Acquisitions - Phase 3

In recognition of the importance of continuing to upgrade CESAR's computing capability, the department recently completed the third phase of hardware and software acquisition. Since its inception, teaching and research activities have been conducted simultaneously within CESAR. As the volume of grants/contract activity has expanded, so has the number of our faculty who are skilled in IP/GIS and spatial techniques. From the original nucleus of two colleagues teaching two courses per year, we now have seven faculty members teaching more than a dozen courses per year in which IP/GIS are incorporated into the curriculum. This parallel growth of instructional and research activities has placed a good deal of stress on CESAR facilities. Therefore, we decided to separate some of the instructional functions from the research activities in CESAR in order to enhance the efficiency of both areas.

To accomplish this goal additional equipment was needed and a $96,000 purchase of 486 PCs, MAC IICis, and SUN equipment was made. The funds were provided through a loan from the University Foundation which will be repaid within 18 months from fees charged to funded projects using CESAR.

Physical Plant

Concurrent with the receipt of new hardware and software in early 1987, 600 square feet of floor space was dedicated to CESAR by converting the department's remote sensing/aerial photograph interpretation laboratory into a GIS/DIP facility, which roughly tripled the area previously available. The remote sensing/aerial photography interpretation lab was temporarily relocated across the hallway into a portion of the cartography laboratory.

The space dedicated to CESAR was doubled the next year by expanding into an adjacent room, which was obtained in a trade with the Sociology Department. The existing cartography laboratory (1250 square feet) was split into two rooms, one of which was given to Sociology in exchange for the room adjacent to CESAR. The other room, of about 650 square feet, continued to be dedicated to manual cartography, remote sensing, and map and aerial photograph interpretation. Finally, the space devoted to CESAR was increased to 3,000 square feet in December of 1990 when new research and office space, built especially for the Department of Geography, was occupied.

IV. OPERATIONAL STAGE

General Layout

As the room layout shows (See Figure 1), CESAR facilities consist of three main rooms containing computer equipment. The two large rooms on the west, separated by a CPU room and offices for the Technical Manager and other CESAR staff, are devoted primarily to research activities in GIS/DIP but also accommodate specialized graduate and advanced undergraduate courses and independent student research. The adjoining large room on the east, the Spatial Analysis Laboratory (SAL), is used mainly as an instructional laboratory for upper division and graduate courses in GIS, RS, spatial statistics and automated cartography. A darkroom and an office for the Department Cartographer round out these new laboratory facilities.

The three large rooms used in CESAR are well designed for their intended uses. A 30" x 48" computer table for each piece of equipment, a set of four 30" x 72" tables for workspace and small group discussion, map storage cabinets, supplies storage cabinets, bookcases for manuals, light tables, numerous bulletin boards, white boards, adjustable chairs and a projection screen comprise the furnishings for the three large rooms. The importance of numerous bulletin boards and white boards for posting work and equipment reservations schedules, working illustrations, messages, and informative maps and charts cannot be overemphasized. Likewise, it is important to provide adequate wall space and bookcases for the very large volume of reference manuals typically needed to support use of the equipment and the software.

Hardware

The department has put together an impressive facility in terms of hardware capability (See Table 2). On the west side of CESAR, the computer hardware consists of clusters of the following equipment: 1) Tektronix graphics terminals, 2) 486 PCs and 3) workstations (SUN SPARC and IBM RISC). The adjoining spatial analysis laboratory contains eight 386 PCs and eight Macintosh computers (4 Mac IIs and 4 Mac IICis), eventually to be expanded to 20 student stations. All hardware and software in the Center is internally and externally linked via the Ethernet (See Figure 2). These linkages include connections to the in-house VAX 11/780 as well as to the university's VAX 6000-320.

CESAR has been outfitted with several different digitizers and many different types of printers and plotters (See Table 2). All are available to students for meeting the requirements of both laboratory exercises and research. The equipment is available first on a reservation system then on a first-come-first-served basis. Providing adequate hardcopy capability at a low to moderate cost has been and continues to be a difficult problem. The Calcomp pen plotter, the Tektronix thermal printer, and the Laserwriter are the most popular devices for output, but are inadequate for large-size color output requiring extensive polygon fill. Other hardcopy technologies, e.g. electrostatic printers, are being considered, but high purchase and maintenance costs militate against them.

In planning the acquisition of computer hardware, we decided that it would be preferable to install small numbers (4-8) of several different types of equipment rather than large numbers (20 or more) of one or two types. The advantage of this approach is that it maximizes the flexibility and adaptability of the facility for responding to technological change and different research/instructional needs. A negative aspect of this approach is that fewer students can be served. Having a wide variety of computer hardware, with different operating systems, also presents more complex maintenance and management problems.

Software

CESAR's software holdings for GIS, DIP, automated cartography, and spatial statistics are extensive (See Table 3). Heading the list of software are ARC/INFO and ERDAS. The former is available on PCs, workstations, and the two VAXs, whereas the latter is installed on PCs and SUN workstations. As mentioned previously, ARC/INFO and ERDAS are integrated on some stations via the "live link". ARC/INFO gives the department vector GIS capabilities while raster functionalities are provided by ERDAS, SPANS, OSU-MAP, IDRISI, and the MAP II Map Processor. ARC/INFO, SPANS, and ERDAS are employed for both research and instruction. OSU-MAP, IDRISI, and MAPII are used primarily for instructional purposes.

Security

The security measures for CESAR's hardware and software are moderate at best. Systematic backup of data is not done but there are a number of protections for software. For example, all system software is backed up, account passwords are changed frequently, many data sets are available for read access only, and archival data is on tape in a locked room with limited access privileges. There is no special security for the equipment except for that provided by locked doors, the presence of CESAR staff and research assistants, and nightly checks by campus police personnel. CESAR's vulnerability to vandalism and theft, while relatively high, has yet to be a problem in the five years of its operation.

Laboratory Use

CESAR is a department facility. As such, instruction and research use is largely confined to geography faculty and to students enrolled in geography courses (See Table 4).

The SAL portion of CESAR is a combined lecture/laboratory facility. It is used primarily for those junior-level GIS (and related) classes whose hardware and software needs can be met with Macintosh and PC equipment. The lectures for senior/graduate-level students(500-numbered courses) are also conducted in SAL, but their laboratories must be conducted in CESAR to take advantage of CESAR's more sophisticated GIS technology. In the graduate portion (600- and 700-numbers) of the curriculum, classes are taught in the seminar room, with CESAR being used for carrying out class-related GIS research activities.

Approximately 50 percent of the courses listed in Table 4 are offered each semester, and have a combined enrollment of approximately 115. Another 25 students and faculty normally work in CESAR on various research projects, making for a total of 140 users who must be accommodated each semester. To serve this volume of research and instruction, priorities have to be set for the use of most equipment. Students in a particular class have priority status for using equipment during the laboratory portion of their class. At other times students can sign up for two-hour blocks and can continue working even longer at a station until they are bumped by another person. This system maximizes access to the equipment and works fairly well except near the semester's end where there is a large demand by students who have waited until the last minute to complete class projects.

Most GIS courses involve two hours of lecture and three hours of laboratory per week. A typical laboratory session consists of 1/2 hour of demonstration followed by 2 1/2 hours of work on an exercise or project under the immediate supervision of an experienced graduate student assistant. The average student will spend an additional 4-5 hours of laboratory time each week outside of class, for a total of 7-8 hours of laboratory time per week.

Because it is largely a self-supported facility, principal investigators on funded projects who wish to use CESAR in their research are asked to include a CESAR use-charge within their budget proposals. Monies generated in this way are used for maintenance and up-grading activities within CESAR.

Operation of CESAR

During the academic year (September-June), CESAR is open from 8:00 AM to 10:00 PM, Monday through Friday, and from 9:00 AM to 5:00 PM on Saturdays and Sundays. Summer hours are from 8:00 AM to 5:00 PM on weekdays. The only time that CESAR is unavailable for use is on Fridays from 3:00 to 5:00 PM when clean up and preventative maintenance are conducted. After 5:00 pm, Monday through Friday and on weekends, the Center is supervised by graduate assistants who are also working on CESAR research projects. All graduate research assistants involved in CESAR projects are issued keys to the facility and can enter it at any time. Undergraduates can obtain access to CESAR after hours by checking out a key for 24 to 48 hours from the Geography Department Office. CESAR is available primarily to students enrolled in courses in the Department of Geography, typically GIS/RS and related classes, and Geography faculty and graduate students working on research projects. Use by faculty and students outside the department is limited to those who are involved in joint research with members of the Geography faculty.

Responsibilities

The organization of CESAR reflects several aspects of its evolution and therefore responsibilities for the facility are shared. As a departmental facility, the Department Chair is integrally involved in its overall management. As a cooperative instruction and research laboratory, faculty are intimately involved in establishing policies and procedures as well as day-to-day operational oversight. The daily operation of the facility is in the hands of CESAR's Technical Manager. These relationships and their interactions are outlined here.

Department Chair The Department Chair (Ernst Griffin) is the general manager for CESAR with ultimate responsibility for its functioning (Figure 3). He works closely with the Faculty Executive Committee to establish policies and with the Technical Manager to see that those policies are carried out. He interacts with upper level administrators in the University Computer Center, the Office of the Vice President for Academic Affairs, the College of Arts and Letters, and the SDSU Foundation on matters that may affect the well being of CESAR. He is also responsible for public relations with these groups.

Executive Committee The Executive Committee is comprised of five geography faculty (Janet Franklin, Allen Hope, Gerard Rushton, Douglas Stow, and Richard Wright) with expertise in DIP, RS, and GIS as well as various application areas such as hydrology, biogeography, and decision support systems. They direct or co-direct approximately 90 percent of the funded research conducted in CESAR. As mentioned above, committee members work closely with the Department Chair on policy matters. They also provide advice to the Technical Manager on CESAR's daily operations and its technical needs. As principal investigators on projects, they give direction to graduate research assistants and other students who are working on CESAR projects. In addition to the Executive Committee, meetings involving all CESAR faculty users (euphemistically called Cesarians) are held periodically to discuss topics of importance. The entire faculty of the department is also briefed regularly as to the status of CESAR and any changes in policies which may have been made.

Technical Manager The Technical Manager (David McKinsey) is responsible for the day-to-day operations of CESAR. He reports to the Department Chair and the Executive Committee and interacts with personnel from the University Computer Center, Geography faculty, the clerical staff, research assistants, and students enrolled in GIS, remote sensing, spatial statistics, and various classes using GIS/DIP applications. The Technical Manager assists faculty and students in the use of GIS/DIP systems, orders supplies, schedules and records equipment use, gives software demonstrations, performs systems and applications programming, and maintains hardware, software, and the reference manual library. Clearly, the Technical Manager is a key figure in the successful operation of CESAR.

Clerical Assistant One-half of a clerical assistant's position is funded through CESAR activities. The Clerical Assistant maintains financial records on CESAR grants and contracts, prepares purchase orders for supplies and equipment, types project reports, grant and contract proposals, research papers, and CESAR correspondence. This person is supervised by the Chair, but interacts directly with the Technical Manager, PIs, and members of the Executive Committee.

Graduate Research Assistants. Approximately 20 one-half time graduate research assistants are employed in CESAR through the department. Most of these RAs are supported by the grants or contracts on which they are working. In addition to project work, research assistants are assigned evening and weekend blocks of time supervising the use of CESAR. This allows CESAR to remain open for research and instructional activities even when the Technical Manager is not on duty. Research assistants report directly to their faculty supervisors, but interact frequently with the Technical Manager. On matters relating to payroll and such things as office space, research assistants interact with the Chair or the Department Secretary.

University Computer Center (UCC) Personnel The UCC provides a variety of hardware and software support for CESAR. UCC personnel maintain ARC/INFO software on the central VAX 6000-320 computer and assist the Technical Manager in the operation and maintenance of CESAR's VAX 11/780 computer and its GIS software. UCC also offers an equipment repair service for CESAR's Macintosh and IBM PC computers as well as picking-up the cost for a number of software maintenance contracts in support of CESAR. Software and hardware support involves direct communication between the Technical Manager and UCC personnel. Policy matters require direct communication between the Chair and UCC management.

San Diego State University Foundation The Foundation is a non-profit auxiliary of the university. It is responsible for administering all university grants and contracts, including accounting, purchasing, and payroll functions. The Department Chair and the project directors interact with Foundation personnel on a frequent basis. Each PI is assigned a Foundation Project Administrator to coordinate their grant/contract. PIs and Foundation PAs work closely to ensure the smooth administrative operation of projects.

Internal Relationships

It can be concluded from what has been discussed to this point that CESAR is a fairly complex operation. Internally, within the department, a variety of relationships exist which must function in harmony if CESAR is to be successful.

Faculty Involvement CESAR has a core of five specialists in GIS and remote sensing whose professional activities require a well equipped and smoothly functioning facility as well as several additional faculty who utilize GIS within their research and teaching activities. The synergism generated by the interaction of several faculty with vested interests in the Center has provided the energy and dedication needed for a successful operation.

Much of the research conducted in CESAR is of interest to more than one faculty member. The result is that many projects are co-directed by two or more faculty. This has contributed to a high level of cooperation among the CESAR faculty. Several of the projects involve vegetation mapping. To facilitate communication, a vegetation specialty group involving approximately 15 faculty and students was established which meets bimonthly to share ideas, to discuss possible solutions to research problems, and to chart future research directions. Also, a growing interest in modeling within GIS among faculty using CESAR is providing a catalyst for interaction across the traditional physical/human boundaries of the discipline.

Graduate Research Assistants Graduate research assistants play an important role within the structure of CESAR. They are involved in virtually all phases of grant/contract research and also lend their expertise to other students using the facility. Research assistants for CESAR are selected from the pool of applicants admitted to the department's graduate program and ranked for support by the faculty as a whole. From this ranked list, CESAR project directors are given first choice from among the new, in-coming students with appropriate technical skills. After consultation with project directors, those chosen for CESAR assignments are integrated into various projects on the basis of their skills and interests. Because the primary selection criteria for departmental research assistants are academic performance (GPAs and GRE scores), in some instances there are imperfect matches between the technical attributes of those selected for RA support and the technical needs required for specific projects. This is an occasional problem, but one that must be tolerated within limits because of our desire for CESAR to be integrated with the department. These mismatches can usually be remedied within a short time by training RAs in the specific areas they may be lacking.

Graduate student labor is an essential component of the CESAR operation. Because we have had a stand-alone Master's program (until approval of the joint Ph.D. program with UC Santa Barbara in the Fall of 1990), students normally leave the program after two years and thus it is necessary to train new project team members on a frequent basis. The inefficiencies associated with this turn-over are unavoidable given the desirability of graduating Master's students in a timely manner. However, this problem should be somewhat diminished by the growth of the Ph.D. program and the longer tenure of doctoral students.

Another difficulty in relying upon graduate student researchers is that at certain points in the semester control over the timing of work schedules is limited because they have other responsibilities as students. At times, their commitments to courses may detract from the attention they pay to the assistantship assignments. Thus, in the short term there may be some interruptions in the flow of project work, causing temporary delays in meeting project deadlines.

Nonetheless, despite these limitations graduate research assistants have done an excellent job for us. As a group they have been quick to acquire new skills, very responsible in fulfilling their obligations, eager to accept responsibility, and often add useful insight to the projects in which they are involved.

Integration of Research and Instruction Research and instruction are often well integrated in courses at the both graduate and undergraduate levels, especially GIS classes. This allows students to learn by participating in "real world" projects while at the same time the projects benefit through the availability of students to perform fundamental tasks, such as map compilation, database development, data processing, and data output, required in the research.

Technical Manger CESAR's technical manager is highly competent, but at times is overwhelmed by responsibilities that range from supervising the operation of the Center to assisting students and faculty in the use of the equipment. In terms of the operation of the Center, this means that delays sometimes occur in accomplishing certain tasks required for the smooth functioning of the Center and for improving its capability. Also, because the facility has evolved so rapidly, there has been little opportunity to document all procedures and information applicable to CESAR. Much of CESAR's operating and project information is stored only in the Technical Manager's head! The loss of our Technical Manager would cause a major disruption in the functioning of CESAR. To sustain his morale and sanity, the Technical Manager has been encouraged to participate in professional meetings and workshops and given opportunities to work in research projects leading to papers at professional meetings and journal publications. In addition, a half-time technical assistant has recently been added to alleviate some of the work-load of the Technical Manager.

External Relationships

The success of CESAR depends on its relations to a number of other entities both on campus and off. As the activities of the Center have grown, these considerations have taken on added importance and consume greater amounts of time and effort.

Department of Geography CESAR is well integrated with other functions in the department, a situation which contributes to positive attitudes about the Center. For example, all personnel practices, including the hiring of graduate assistants and technical staff, are accomplished within the context of the department's policies on governance. Discussions of the Center are included in department meeting agenda and are intended to familiarize all faculty with potential uses of GIS/DIP in their specialties and to clarify the role of the Center in carrying out the department's mission. The integration of CESAR in the department has been aided by involving faculty who are not skilled in GIS/DIP in joint research that incorporates their systematic training and requires the use of CESAR facilities. As a result, 13 of the department's 20 tenure track faculty use CESAR either directly or indirectly.

On Campus On the SDSU campus, administrators in the College of Arts and Letters, the Vice President for Academic Affairs, and the Foundation are supportive of the department and its GIS/RS programs. This has been translated into improved physical facilities and significant funding for hardware and software. Relationships with other departments have been limited to cooperative research situations. To date, joint projects involving GIS/DIP have been conducted with faculty in civil engineering (hydrology and transportation analysis), ecology, biology, and geology as well as the Systems Ecology Research Group. Although specific plans for expanding cooperative GIS/DIP projects with other departments have not been formulated, it is anticipated that additional joint research will be initiated with specialists in computer science, urban planning, and some of the social sciences within the near future.

Government and Industry Many members of the Department of Geography, including those on CESAR's Executive Committee, have developed strong links with community agencies and private industry. Extensive community service and the many demonstrations of CESAR's capability performed for groups visiting CESAR have raised its visibility. CESAR's mission includes a significant service component. This is accomplished through training workshops and contract research for public agencies and private firms. A good example of a beneficial type of cooperative relationship with private industry is seen in the designation of CESAR as a Beta site for numerous software manufacturers with whom the Center has been involved.

Other Universities CESAR's relationships extend beyond the Campus boundaries to other universities. The department is an associated institution of the NCGIA and several of our faculty have been involved with the GIS Core Curriculum and some of the GIS research initiatives. The high esteem in which the department's GIS/RS program is held by peers at various institutions has facilitated the recruitment of excellent graduate students to the department and their integration into CESAR projects.

V. EVALUATION STAGE

After four years of operation, we are now in a position to evaluate some of the successes and difficulties associated with the evolution of CESAR. The establishment of a firm set of goals and planning for the long-term future of the Center within the broader context of the department's goals is a critical consideration.

Achievement of Goals

Over time, the mission of CESAR has evolved to provide technical support for a variety of the department's programs. These include supporting upper division/graduate instruction and research in the areas of geographic information systems, remote sensing, automated cartography, digital image processing, and spatial statistics. The center also seeks to back research in a variety of geographic application areas such as urban and transportation modeling and environmental analysis. Finally, CESAR has a community outreach mission that involves training in GIS, DIP, and RS for potential users of these technologies in private industry and government agencies.

To carry out its missions, a number of goals have been established for CESAR. These include:

1. Enriching our students' educational experience by providing laboratory equipment and hands-on experience for students in GIS, RS, AC, spatial statistics, and selected systematic geography courses that require technical support.

2. Providing financial support for graduate students in order to attract more and better students to the graduate program. We have created a large cadre of graduate students who have a sense of direct involvement in the department.

3. Providing technical support for graduate student thesis research. Without CESAR or a comparable facility many theses completed each year would not be feasible.

4. Generating funds to be used to maintain state-of-the-art technology in areas of rapid change. Without a dependable source of income for upgrading hardware and software capability, a GIS/DIP facility can quickly become obsolete and uncompetitive in terms of research grants, and inadequate for instructional purposes.

5. Helping to support other department functions that relate to CESAR (i.e. some purchases made with CESAR funds also are used in support of other courses). For example, map and aerial photographs obtained for grants or contracts can be used in support of laboratory exercises on map and aerial photograph interpretation.

6. Contributing to the professional development of faculty and facilitating scientific research which increases the capability of GIS/DIP in spatial problem solving. The hardware and software in CESAR make it possible for faculty with specialties in GIS and RS to compete for research grants and contracts to carry out their research plans.

7. To provide GIS/DIP/RS training to educators, urban and regional planners, land developers, environmental consultants, and other members of the community. This is accomplished through demonstrations and workshops of varying lengths.

8. To develop GISs for public agencies for use in environmental resource management and urban and regional planning.

In our opinion, many of these goals have been achieved since the advent of CESAR. We are proud that in less than five years CESAR has become one of the premier GIS/DIP university instructional/research facilities in the United States.

Future Plans

In the next five years it is unlikely that CESAR will experience the same dramatic increases in floor space and hardware as it has in the past five years. Instead, attention will focus on upgrading and making more efficient use of existing facilities and on replacing outmoded hardware and software with new capabilities as they evolve. We anticipate that several initiatives are likely:

1. The effort now underway to integrate the various platforms via the Ethernet system will be completed in the near future. Additional Ethernet cards, cabling, and software are required to accomplish this task.

2. In addition to networking existing equipment, the capability of CESAR can be enhanced significantly by upgrading some of the existing equipment. For example, the hard disk capabilities of the Sun and Risc workstations are being expanded. The performances of the ERDAS and PC ARC/INFO 386 computers are also being increased by installing additional memory. Other improvements are being achieved by adding 3-1/2" drives to some 386 computers and by installing DBASE 3 to run with PC ARC/INFO.

3. As noted earlier, the lack of inter-project communication was identified as an shortcoming in the functioning of CESAR. To rectify this, a loose matrix organizational structure consisting of a) vegetation mapping, b) GIS, c) biophysical remote sensing, and d) image processing/change detection interests groups has been created to cut across project boundaries. Regular meetings of the vegetation group for interested faculty and students is producing a cross fertilization of ideas among projects.

4. A high priority is being given to obtaining software for analyzing socioeconomic, demographic, and transportation data. This should encourage more involvement in the Center by the department's human geography specialists.

5. Demonstration modules are important for showing the Center's accomplishments and capabilities. The modules on hand need to be upgraded and new ones need to be added to the Center's library.

6. Additional hardware, including tape backup systems, scanning, optical compact disk, global positioning system, and color projection technologies are being considered. There is also a need to expand the Center's color graphics and workstation capabilities and to replace the in-house VAX 11/780 computer with a more powerful machine.

7. Some software packages on hand have yet to be integrated into our GIS curriculum. For example, GeoSQL, SPANS, and GRASS are significant packages that are just now receiving our attention.

8. The initial 1.00 permanent Technical Manager position will be increased to 2.00 positions. This additional position will give some relief to the Technical Manager and bring more knowledge of systems programming and UNIX operating environments to the Center. This will allow a fuller utilization of workstations for GIS/RS applications.

9. Although used intensively, the Center still has some unused research capacity. More attention is being given to ways of integrating spatial modeling and decision support systems methods with GIS/DIP techniques. It is also desirable to expand the graduate instruction and research uses of the facility in human geography applications such as urban, socioeconomic, and transportation.

10. The use of the facility for regularly scheduled upper division/graduate instruction in GIS/RS is nearing saturation, but there are unused weekend and summer hours that could be made available for training workshops focusing on specific applications, analytical techniques, and software packages. Workshops provide an important community outreach function and can help to increase the financial base of the Center. However, the community outreach function will continue to be secondary to the primary mission of research and upper division/graduate student instruction.

VI. RECOMMENDATIONS

Based on our experience in developing CESAR, we can offer a number of recommendations for those wishing to establish a similar facility.

1. A clear statement of the mission and goals of the facility should be articulated early on. This will determine the facility's operating characteristics as well as the type of hardware and software to be purchased. For example, a facility that serves both research and instructional needs will have a different technological mix than one that is intended for instruction only.

2. Establishing and operating a GIS facility is a dynamic process that requires flexibility as well as foresight on the part of those involved. To be successful you must be able to adapt quickly to changes in technology, personnel, and research demands.

3. The Department Chair must be a strong advocate of the facility to the university administration.

4. The department and the university administration must be strongly committed to the creation of a successful facility. Don't be reticent about getting commitments in writing.

5. Two or more faculty members with expertise in GIS/DIP and its applications are needed to mount a successful program and must be able to interact on a frequent basis. Even more than the administration, they must be strongly dedicated to making the facility a success.

6. A permanent staff position and a minimum operating budget should be allocated to the facility to assure operating stability.

7. The initial allocations of space and funding for hardware and software should be sufficient to create substantial capability at the outset of operation. A minimum configuration is likely to hamstring the effort from the beginning. At least one workstation should be provided for every three students. Fewer workstations will not allow adequate student access to GIS equipment during the laboratory session.

8. Project activities should be initiated as soon as possible to place participants on a steep learning curve, to establish a track record, and to have a product that can be demonstrated to administrators, other faculty, and prospective funding agencies. It is important that a cadre of expert users (faculty, staff, and students) be established early on.

9. Devote as much time as possible to demonstrations and other activities which raise the visibility of the facility to individuals both on and off campus.

10. Before the facility is established, agreements should be reached regarding responsibilities for hardware and software maintenance costs. A clear understanding of who is responsible for what will help to avoid conflict later on.

11. Some effort should be made to negotiate cost reductions with vendors on the purchases of hardware and software, especially on annual software maintenance costs. However, remember that you normally can't get something for nothing from the private sector. You must be prepared to offer something of benefit to the company in exchange for cost reductions, such as the development of applications software and laboratory exercises.

12. GIS instruction requires a rich instructor/student ratio. A minimum of one instructor or instructional assistant for every ten students is desirable for introductory GIS classes. Advanced classes involving extensive research projects may require even fewer students per instructor

13. Finally, consult early and widely with those who have established successful GIS facilities. A few thousands of dollars spent on experienced consultants is a wise investment for an undertaking that can eventually exceed several hundreds of thousands of dollars!

APPENDIX

Summary Tables

SUMMARY TABLES

School Abbreviations:

GS - Glassboro State College

SWT - Southwest Texas State University

UV - University of Victoria, British Columbia

- UV1 - Junior Social Sciences Laboratory
- UV2 - Advanced Spatial Science Laboratory

CW - Central Washington University

WV - West Virginia University

- WV1 - Geodata Processing Laboratory
- WV2 - GIS Teaching Laboratory
- WV3 - GIS Research Project Laboratory

SD - San Diego State University

LAB CAPACITY

	GS	SWT	UV1	UV2	CW	WV1	WV2	WV3	SD
# of computers or terminals available for GIS use:	14	9	10	10	14	6	10	3	32
# of hours lab is available per week: X	69	50	40	40	40	188	80	188	76
Total capacity (computer-hrs):	966	450	400	400	560	1028	800	564	2,432
Percent of total capacity used:	50-100	100	40	50	60-80	30	20	40	50 %

TYPE OF LAB USE

Percent of time lab room is in use for:

	GS	SWT	UV1	UV2	CW	WV1	WV2	WV3	SD
Teaching:	20[1]	0	20	20	25	10	50	10	50 %
Funded research:	0	0	5	30	50	90	10	100	100 %
Open Lab:	70	100	65[2]	40[2]	75	20	50	0	50 %

[1]also 10% for faculty and staff workshops
[2]also 10% time rented to vendors

(Note: these may total more than 100%))

TYPE OF TEACHING

Percent of teaching in lab (by instructors or teaching assistants) devoted to:

	GS	SWT	UV1	UV2	CW	WV1	WV2	WV3	SD
Lectures:	0	0	0	0	25-30	0	30	0	20 %
Demonstrations:	10	0	10	10	5-15	10	10	10	10 %
Computer aided tutorials:	0	0	10	10	0	25	10	50	15 %
Lab exercises:	90	90	60	50	15-15	10	40	0	25 %
Project work:	0	10	20	30	5-60	50	10	40	30 %

BUDGET SUMMARY

Total dollar amounts for each category[1]

	GS	SWT	UV1	UV2	CW	WV1	WV2	WV3	SD
Hardware & associated peripherals used for GIS:	59,538	350,000	130,000	240,000	280,000	300,000	38,000	100,000	340,000
GIS software purchased:	650	173,650	30,000	100,000	N/A	45,000	6,000	(2)	93,000
Maintenance (HW & SW):	N/A	7,200	10,000	?	6,000	15,000	(3)	4,000	25,000
Technical salaries:	12,500	0	15,000	15,000	70,000	32,000	(3)	24,000	50,000
Remaining operating costs:	4,080		6,000	?	8,000	7,000	(3)	5,000	8,000

[1]amounts reflect annual costs
[2]same as WV1
[3]same as WV3

HARDWARE FOR GIS TEACHING

		GS	SWT	UV1	UV2	CW	WV1	WV2	WV3	SD
GIS stations:	#	14	9	10	10	11	6	10	0	32
Digitizers:	#	2	1	10	10	2	5	0	1	5
Plotters:	#	1	1	2	1	1	5	3	1	3
Printers:	#	16	2	3	1	3	4	1	1	10
Other:	#		1[1]	2[2]			1[3]			

[1]Color Copier
[2]1 parallel and 1 serial switch box
[3]scanner

SOFTWARE FOR GIS TEACHING

GS

Name:	# of stations
IDRISI	14
OSU-Map	14

SWT

Name:	# of stations
MicroStation	9
MCE/MGA	6
IDRISI	1
ATLAS*GIS	1
pcARC/INFO	3

SD

Name:	# of stations
ARC/INFO	12
SPANS	1
MAP II	8
OSU-Map	5
IDRISI	2

UV1

Name:	# of stations
PAMAP	10
IDRISI	10
ATLAS*GRAPHICS	10
EIDETIC	10
TRANS CAD	1
COREL DRAW	10

UV2

Name:	# of stations
PAMAP	10
GENASYS	10
SPANS	10

CW

Name:	# of stations
GRASS	11
MAP II	10

WV1

Name:	# of stations
ARC/INFO	4
ERDAS	1
SURFACE3	4
GRASS	2

WV2

Name:	# of stations
SPANS	10
IDRISI	10
ARC/INFO	10
A-MAP	10

WV3

Name:	# of stations
SPANS	1
ARC/INFO	2