Design-Aided Computing:
Adapting Old Spaces To New Uses

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Abstract

The introduction of computer-aided design to an architecture school requires many departures from tradition — not only in the curriculum, but also in the facilities. Although there is an abundance of technical information available for the design of new computer rooms [1,2,3], building one from scratch is a luxury that few architecture schools can afford. To catch up with the computer revolution — and, it is to be hoped, come to lead it — colleges must engage in the adaptive re-use of spaces that are often not particularly well-suited to the special needs of computing.

This paper describes some of the issues that should be considered when an architecture school takes its first plunge into computing. It is not a technical reference, but rather an overview. General guidelines are discussed, followed by a detailed case history of our own mixed experience. The emphasis is on the need for developing specific plans regarding computer applications before making any big commitments.

Introduction

It’s ironic that colleges of architecture — Meccas of professional space planning — should encounter any difficulties in setting up space for computer-aided design. It appears to be a fairly straightforward problem — the kind of problem architecture students are expected to be able to solve before they graduate. But appearances may be deceptive. It’s the fortunate few who have an opportunity to influence the design of new facilities for architectural education. The great majority must try to adapt old facilities to new uses, the requirements of which may be substantially different from those of “traditional” classrooms, shops, and studios.

Finding space

The first question to consider is: How is the computer equipment to be used — for teaching, office work, or research; and by whom — students, instructors, or non-instructional staff? Installing computer equipment before considering its intended use can lead to unimagined frustration later on.

At one extreme is the large central computer lab, where everyone goes to do all their computer work. At the other extreme is the computer on every desk throughout the building, with no central lab for such activities. The best approach is usually somewhere in between. Although the central lab is less "friendly", it is necessary for instruction and whenever there is a many-to-one relationship between users and equipment.

In general, it’s a good idea to segregate student use from faculty and research use. It’s nearly impossible for a faculty member to accomplish much work in a room full of frustrated students. Although this may seem like a cynical consideration, most instructors would agree that it’s essential to establish definite office hours for meeting with students outside of class. But an instructor is fair game the moment he steps into a student computer room; separate “office hours” cease to exist. Some students won’t make a serious effort to solve a problem on their own if there is an in-
structer handy to solve it for them.

If the goal is basic computer literacy, with word processing, spreadsheet analysis, and simple graphics, then desk-top micro-computers will suffice. A classroom may be set aside as the student computer lab, and faculty members may keep their own micros in their offices. Such general-purpose computing might even be supported by the university at large. This frees the architecture department from the responsibility of setting up a computer room of its own, but it also usually forces architecture students and instructors to commute to other buildings for computer-related activities.

More advanced uses require more planning. If electronic mail and shared databases are to be provided, the micros must be connected to some type of network, which may require the installation of new cables between offices. A similar situation occurs when widely scattered micros or dumb terminals are connected to a large mainframe. The installation of the cables becomes a major task, and the locations of terminals, once established, are not easily changed.

Serious computer-aided design requires more specialized equipment: bigger computers, better displays, digitizers, plotters. As the price and physical size of computer equipment increases, so does the need for a central place to put it. Also, the more specialized the equipment, the more the architecture department must tend for itself. An average classroom may not be sufficient, since additional floor space is required for the larger equipment. If one large space can’t be appropriated, it may be necessary to occupy two smaller spaces: one for the many, small, inexpensive machines used by everyone; another for the few, large, expensive machines used by upper-classmen and faculty members. Rank has its privileges.

In addition to the machines and furniture, there must also be storage space for reference materials and supplies. Frequently-used documentation requires shelf space or a separate reference table. Paper, ribbons, pens, ink, solder and small tools (more on that later) require shelf or cabinet space. Magnetic storage media, such as floppy disks and tapes, must be stored in some safe but convenient manner.

Preparing space

Finding the space in which to put the equipment is only the first step. There are many requirements besides raw volume that must be satisfied before the space can function adequately as a computer room. At the very minimum, a micro-computer requires a clear desk top and a convenient, reliable source of electricity. A room with many micro-computers requires many desks and electrical outlets. The total electrical requirement may be far in excess of what the room was originally intended to accommodate, and it may be necessary to supplement or replace the existing wiring. Also, computer equipment is far more sensitive to fluctuations in the supply of electricity than most other appliances. If the supply is less than perfectly reliable, it may be necessary to install surge protectors.

One of the most amazing capabilities of computers is the conversion of valuable electricity into waste heat. Having increased the intake of electricity to the space, the output of heat from the space must also be increased. The absence of fans on some of the smaller machines may mislead a person into thinking that they don’t generate significant amounts of heat. In fact, the designers of these machines have merely decided to rely on the “normal” airflow in a room for ventilation, rather than supply their own. The heat from one machine may not amount to much, but small machines often appear in large clusters, and taken together, the heat can be quite significant. Room air conditioning is very important. If the room isn’t properly ventilated, even quiet little desktop micros will gradually produce a region of hot air, that is not only uncomfortable for people but also hazardous to the machines themselves. It may be necessary to increase the airflow through the space, or even redesign the HVAC system somewhat. If the space can’t be zoned
separately from other spaces with dissimilar uses, additional ventilating and cooling equipment may have to be installed in the space, alongside the computer equipment. This in turn increases the demands for floor space and electricity.

Table 1
Power Consumption and Heat Production for Selected Equipment
(4, 5)

<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>Volts</th>
<th>Amps</th>
<th>Watts</th>
<th>BTU/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apollo DN420 node</td>
<td>120</td>
<td>12</td>
<td>1440</td>
<td>4913</td>
</tr>
<tr>
<td>Apollo 19&quot; b&amp;w display</td>
<td>120</td>
<td>2</td>
<td>240</td>
<td>819</td>
</tr>
<tr>
<td>Apple Macintosh</td>
<td>120</td>
<td>1</td>
<td>60</td>
<td>205</td>
</tr>
<tr>
<td>DEC LA36</td>
<td>115</td>
<td>1.3</td>
<td>150</td>
<td>510</td>
</tr>
<tr>
<td>DEC PDP 11/60</td>
<td>120</td>
<td>24</td>
<td>2880</td>
<td>9827</td>
</tr>
<tr>
<td>IBM PC</td>
<td>120</td>
<td>2</td>
<td>200</td>
<td>682</td>
</tr>
<tr>
<td>Tektronix 4014</td>
<td>115</td>
<td>5</td>
<td>420</td>
<td>1433</td>
</tr>
<tr>
<td>Tektronix 4113</td>
<td>120</td>
<td>2.75</td>
<td>330</td>
<td>1126</td>
</tr>
</tbody>
</table>

Where watts are not listed on the equipment, volt-amps are assumed. (An a.c. power factor of 1 is assumed.)
1 watt = 3.412 BTU/h

Table 2
Rates of Heat Gain from Occupants of Conditioned Spaces
(from ASHRAE table 18, chapter 26) (6)

<table>
<thead>
<tr>
<th>Degree of Activity</th>
<th>Male Total BTU/h</th>
<th>Adj. Total Sens. BTU/h</th>
<th>Adj. Lat. BTU/h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BTU/h</td>
<td>BTU/h</td>
<td>BTU/h</td>
</tr>
<tr>
<td>Seated, light work,</td>
<td>640</td>
<td>592</td>
<td>296</td>
</tr>
<tr>
<td>typing</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Adjusted heat gain (total, sensible, and latent) is based on equal numbers of men and women, with the postulate that the gain from an adult female is 85% of that for an adult male.

Fans and air conditioners, disk drives, printers, and plotters also generate a considerable amount of noise, so the relationship of the computer room to neighboring spaces must also be contemplated. While a fan-less micro-computer may be quiet enough to occupy a carrel in a library or other study area, a dot-matrix printer probably isn't. In fact, even if such loud equipment is
isolated in a separate room away from quiet areas, the noise can travel through the partitions and ceiling plenum and cause annoying distractions in other rooms. Increased sound absorption may have to be provided.

The lighting in the room must also be appropriate for computer-related tasks. "Traditional" classroom lighting is good for viewing plots and print-outs, but it may be unacceptable for working at CRTs. The distribution of the light must be considered, as well as the raw footcandles. CRTs are essentially self-illuminating, vertically-oriented workspaces, and the usual footcandle specifications and zonal cavity calculations don't necessarily yield satisfactory results. Glare from ceiling lights and windows can be a real nuisance. Also, if the room is too bright, color displays may look disappointingly pale. Ideally, light should be directed at table tops, and blocked from CRTs. Desk lamps, rather than ceiling fixtures, may be the best answer. The light shouldn't be too localized, however, since excessive contrast will cause eye strain.

Maintaining space

While the initial cost of acquiring and installing computer equipment may not be surprising, the cost of maintaining it catches many people off guard. Computers often seem to be among the least reliable machines of modern times. Both hardware and software require constant maintenance. The more heavily they are relied on, the more frequently they fail. It's a testimony to their great usefulness that people continue to get them fixed.

Hardware failures due to electrical surges or excessive heat can be reduced significantly if the space is properly prepared before the hardware is installed. Still, things go wrong: keyboards get sticky or worn and cease to function properly (especially if food and drink are allowed in the area); fuses blow; CRTs burn out; cable connections become loose and unreliable; print heads wear out; ribbons need to be replaced periodically. It's also not unusual for hardware manufacturers to introduce new components for old machines — either to correct a defect in the original equipment or to upgrade its performance. Although the cost-effectiveness of maintenance contracts in general is debatable, the college should consider its own particular situation when deciding whether or not to purchase one. Computer equipment is often subjected to harder-than-average use in an academic environment, especially if it is accessible by many people for many hours each day with no "authoritarian" supervision. Some brands of equipment have a better reputation than others for performing under stress. In any event, it's helpful to have one or two people within the college who are capable of handling the smaller repairs on their own.

Software is also subject to failure from time to time, and it's not uncommon for the operator's manual for a new system to include a summary of the known bugs. (The unknown bugs are left to the operator to find on his own.) New versions of system software must be installed periodically to ensure that the system runs as reliably and efficiently as possible. Applications software — the whole computer system's reason for existence — must be obtained and kept up-to-date. Back-up copies must be kept for all files. If a floppy disk fails and a backup disk is pulled into service, a new backup must be produced. Disks and tapes must be clearly labelled and kept in some kind of order.

Someone within the college must see to it that the computer system is kept running. Often, when an architecture school takes its first plunge into computing, it's the result of persistent lobbying on the part of a few enthusiastic faculty members, who are more than happy to take on the added responsibility of keeping a computer system running smoothly. They enjoy soldering new cables, and don't mind replacing a fuse once in a while. Many write their own application programs, which they are proud to offer to fellow faculty members and students. In the beginning, it's a small responsibility, and doesn't interfere much with the rest of their schedule. Ironically, if their efforts are successful, demand for computing steadily increases, and they find more and more of their time taken up by maintaining the system for others. As maintenance becomes a full time
responsibility, the enthusiasm of the original group may diminish, or they may simply be unable to keep up, and maintenance may lag. It might be necessary to delegate this responsibility to a non-faculty technician.

Aside from the computer system, the space itself must be maintained. Scheduling is important, both for energy efficiency and for security. If it’s determined that the room will only be open during certain hours, the building HVAC system can be adjusted to handle a lighter load during the off hours — assuming that the computer equipment is powered-down at the end of the day. If no definite use pattern can be established for the space, it may be impossible for a central air system to keep it comfortable, and a room air conditioner may have to be installed.

Security is a major concern. The equipment must be protected against theft and vandalism. Legitimate access to the equipment should be restricted as little as possible, especially if there is a high ratio of people to machines. The mere presence of other people is enough to deter most would-be thieves. However, the equipment should be kept behind locked doors during periods of low demand, when it would be easy for a thief to slip away unnoticed. Also, small machines that are particularly easy to carry away should be chained down.

If the architecture department is financing the equipment on its own, without extra support from the university-at-large, it should cut costs by denying access to people not connected with the department — not out of meanness, but necessity, to prevent fiscal hemorrhage. This may require special department ID cards or computer room passes.

Upgrading space

A college may have very humble intentions when it acquires its first computer equipment, but if its initial efforts are successful, it should expect a demand for more. Enlightened faculty members who develop their own software will eventually realize how much more they could do with larger memories, faster processors, better graphics. Some students — it is to be hoped — will also develop a keen interest in the new technology. With little practical experience in doing architecture the traditional way, they are often more enthusiastic and creative than many of their instructors in applying computers to architecture.

The introduction of computing to an architectural curriculum can be expected to have a major impact. Besides requiring the addition of one or two new classes or changing the way old classes are taught, it opens the door to research. While there has always been a role for research in architecture, computer applications demand it. There are many unsolved problems in the area of computer-aided design — the very concept is still only vaguely defined. As students and faculty gain experience with the new technology, there will be an ever-increasing demand by some for more opportunities to explore its full potential.

If the college attempts to meet this demand by acquiring more equipment, the cycle repeats itself. More space must be found. Who will use the new equipment? How will they use it? Should it be placed in an existing computer room, or should another space be found? Should old equipment be discarded?

This last question is perhaps the most difficult of all. It’s hard to accept the fact that something that cost several thousand dollars only a few years ago may be obsolete today. It would be less painful if the equipment retained some resale value, but often the new technology is smaller, smarter, and less expensive than the old. It’s almost unthinkable to throw away anything that works, but what about the things that don’t currently work? While computer hardware is subject to failure from time to time, it is rarely beyond repair. At what point is it no longer worthwhile to pack-up a 100 pound terminal and ship it 1000 miles for repairs?
It's easy to put off decisions about what to do with old equipment, especially if it's heavy, bulky, and difficult to move. It may tend to accumulate on shelves and in unused corners of computer rooms — reducing the space available for new equipment. Perhaps the best thing about the current generation of micro-computers is that they will be easy to dispose of when something better comes along.

Summary

As technical advances are made in every aspect of building engineering, construction, and management, the volume of information that an architect must manage is growing at a staggering rate. Architecture has entered the Information Age, and it must evolve to flourish in the new environment. Computing must be incorporated into the architectural curriculum. It is to be hoped that future facilities for architectural education will include spaces specifically designed to accommodate the new technology. Older facilities may require modifications to spaces originally intended for other purposes. In any event, the facilities must be kept up-to-date. It is a never-ending task, and not one to be taken lightly.

Our experience

(Nothing in the following text should be construed as an endorsement either for or against any particular equipment selection. Equipment model numbers and room numbers are given for reference purposes only.)

Computing first arrived at the College of Architecture and Design in 1967, with the introduction of an elementary FORTRAN programming class and the acquisition of two model 33 Teletypes, connected through modems to the University's mainframe computer. Within the next few years, a class in computer graphics was started, and additional equipment was obtained: a Computek graphic terminal, two Tektronix 4005 graphmatic terminals, a Calcomp drum plotter. The "computer room" was an area in a prototype Unistruct structure, erected next to the Architecture and Design building and called into service as general overflow space.

In 1974, the reorganized College of Architecture and Urban Planning and the School of Art moved into the just-completed Art and Architecture building. The new building included excellent lab facilities for visual studies, building technology, and architectural research in general, but no particular accommodations for computing. A classroom — room 2222 — was designated as the computer room, and the existing equipment was moved in. A DEC PDP 11/05 micro-computer, GT40 graphic terminal, and digitizing table were soon added to the inventory.

In 1977, The Architectural Research Laboratory obtained a major research contract to develop a geometric modeling relational database system (ARCH/MODEL) for Townsend and Bottum, an engineering firm involved in power plant design, and more equipment was moved into room 2222. Herman Miller partitions were used to divide the room roughly in half. The front half was used primarily by students, while the back half was reserved for research use.

The front half of room 2222 included three DEC LA36 printing terminals, the two Tektronix 4002 graphic terminals, and the Computek graphic terminal. Later, the old Tektronix and Computek terminals were removed, and a DEC LA120 high-speed printing terminal, a Hewlett Packard 2621 terminal, two Tektronix 4010 graphic terminals, and a Chromatics CG1399 micro-computer were moved in. Later still, the Chromatics was retired, and 4 Visual 550 graphic terminals were added.

The back half of room 2222 included the DEC PDP 11/05 micro-computer with GT40 graphic terminal and digitizing table, a DEC PDP 11/60 mini-computer with DEC LA36 and Hewlett Packard 2648 terminals and another digitizing table, a Tektronix 4014 graphic terminal that could be con-
nected either to the 1/160 or to the University's mainframe, and a Versatec electrostatic printer connected to the 4014.

The modems were replaced by an RDC (remote data concentrator = a small communications computer). All of the terminals in the front of room 2222, plus the 4014, 1/160, and 1/60 in the back of the room, were connected to ports on the RDC. The RDC was also kept in the back of room 2222, and was in turn connected through a dedicated line to the University's mainframe at the Computing Center down the street.

The FDP 11/60 presented the first major problem. It required approximately ten square feet of floor space, and generated a significant amount of heat. In fact, it was often referred to has "the space heater". Since room 2222 was originally intended to function as a classroom, and was included in the same HVAC zone as many other classrooms, there was no way the central air system could adjust to the additional heat load. In the summer, with everything running, the temperature often exceeded 90 degrees. Even in the winter it was often uncomfortable. An industrial-strength, centrifugal-type air blower was sometimes placed in the doorway to help ventilate the room, but this was neither particularly safe nor convenient. Smaller residential fans were also placed at strategic points around the room.

The contract with Townsend and Bottom came and went, but the equipment remained. In 1980, a new contract was obtained with the Construction Engineering Research Laboratory of the U.S. Army Corps of Engineers, to develop a computer-aided engineering and architectural design system (CAEADS). With this new contract came new equipment. In 1981, a DEC FDP 11/23 micro-computer with separate floppy disk and hard disk units was added to the back of room 2222 and connected to a port on the RDC.

Later that same year, several more graphic terminals were acquired for CAEADS research, and since room 2222 was filled to capacity, an office in the Architectural Research Laboratory - room 1239 - was designated as another terminal room. A Tektronix 4112, a DEC VT100 with retrographics, a Genisco 1000, and a Visual 550 were moved in, and cables were brought down from the RDC in room 2222. Later, the VT100 was replaced with a Tektronix 4115. This new terminal room was very convenient for research, but there was no space for a printer or any of the other research equipment, which remained in room 2222. This meant many trips back and forth between the two rooms, which are on different floors.

In 1982, the College purchased an Apollo DN420 node (mini-computer, hard disk, and graphic display) and a printer, and placed them in the back half of a conference room in the Lab area - room 1232. The room had a folding partition in the middle, and the room has remained divided ever since.

In 1984, the Computing Center closed its public terminal room, and desperate to provide new public workstations in that area of campus, it was agreed that they would place fourteen Apple Macintosh micro-computers and two printers in the Art and Architecture Library - room 2106. The designation "public" means that they are maintained by the Computing Center and are available for use by any student, faculty, or staff member from any department on campus. In contrast, rooms 2222, 1239, and 1232 are "private", meaning they are maintained by and for the College.) The RDC in room 2222 was replaced by a new SCP (secondary communications processor - new network technology) in room 2222P (a phone closet), and twelve of the Macs were connected to ports on the SCP.

In 1985, the College obtained six more Apollo nodes (one DN460, one DN550, one DN320, and three DN300s) and installed them in the back half of room 1232 along with the original DN420. This required substantial electrical work - nine new pairs of outlets were added. A room air conditioner has yet to be installed. The seven Architecture Apollo nodes were connected to a large
ring network with over forty such nodes, administered by the College of Engineering.

Also in 1985, as a temporary measure for a summer course, the Urban Planning department placed five Zenith micros, an Amdek micro, and six Epson printers in a double classroom – room 2218-2219. Two residential-type floor fans were positioned at the doors to keep the air circulating.

At this time, there are four separate (permanent) computer rooms in the Art and Architecture Building:

Room 2222 continues to be the main student computer room. The back half has been all but abandoned. It is no longer used for research, and has become a dumping ground for broken or obsolete equipment. The PDP 11/05, in particular, has become a “space eater”. Although it is still functional, it is no longer needed. Anything that could be done on it can be done much easier on the new Apollos. The PDP 11/05 is similarly idle. (To boot it up requires that an address and data be manually tagged in through a bank of switches on the front.) The Chromatics terminal is idle because there are no more ports available on the SCP to connect it to the mainframe, and because its graphics are not Tektronix-compatible. (All of our other graphic terminals, except for the Apollo displays, are either Tektronix or Tektronix-compatible.) The Tektronix 4014 is now available for student use, but it is not easily visible behind the partition, and there is no clear work surface near by. The old original computer room is in need of a major overhaul. All told there are twelve usable terminals in the room. If the obsolete equipment and partitions were removed, it could probably accommodate twice that many. The room has no fixed schedule. Users may stay all night if they wish (or must), and often do, especially toward the end of the term. University security guards make regular rounds during the wee hours of the night, and lock the room if no one is using it. They also occasionally “card” the users, at their discretion. There have been some problems of encroachment by students from other departments, but these have lessened as new public work areas have been made available by the Computing Center.

Room 1239 is still used for research-related work, and to pick up the overflow from room 2222. Students seeking extra help in debugging their programs are often allowed to work there, since it’s much more convenient for the instructors. Typically, once the bug is located, the student will return to room 2222 unless there are no terminals available there. Although software development for CAEDS has been moved to the Apollos, the terminals in this room are still used for word processing and mainframe computing by other research projects. This room is part of the Architecture and Planning Research Laboratory, which is open from 8:00 a.m. to 5:00 p.m. Monday through Friday. It is kept locked at night and on weekends. Researchers can get keys, by getting their supervisor’s signature and paying a $10.00 deposit.

Room 2106, the Art and Architecture Library, is in its second semester with the Macs and printers, which are getting heavy use. (Since they are “public” workstations, it’s difficult to say what percentage of the use is architecture-related.) “Tekalike” [7], a Tektronix terminal emulation program, is available in addition to “MacTerminal” [8], the standard Apple terminal emulator. So far, the presence of the printers in the library does not seem to have caused any significant problems. Twelve of the fourteen Macs are located in carrels, and are connected to the University’s mainframe via the SCP. The other two Macs are used to drive the two printers, which are located on a table in the opposite corner of the library, near the stacks and copy machine. These two Macs are intentionally not connected to the mainframe. The stated intention of the Computing Center is that people do their work on the twelve Macs in the study carrels, then bring their disks over to the other two Macs for printing. The Library is open from 8:30 a.m. to 10:00 p.m. Monday through Thursday, 8:30 a.m. to 5:00 p.m. on Friday, 10:00 a.m. to 5:00 p.m. on Saturday, and 1:00 p.m. to 4:00 p.m. on Sunday. There is no access to the equipment when the Library is closed.
Room 1232 is the new CAD lab. CAEADS software has been converted from the University's mainframe (an Amdahl 5860) to the Apollo, which are being used both for continuing CAEADS software development and as workstations in a CAD studio class being taught for the first time this Fall. One of the digitizers has been brought down from room 2222, and an air conditioner has yet to be installed. Most of the cool white fluorescent lamps were removed from the ceiling fixtures, and the remaining few were replaced with warm white lamps, which reduced glare and considerably improved the appearance of the color display. The ratio of users (students and researchers) to workstations is already 2-4 to 1, and it appears that student demand may increase significantly next semester. This room is also part of the Research Lab, and presented a particular dilemma regarding security vs. student access. It was judged to be unwise to leave the Lab unlocked, or to distribute keys to all the students in the class. Yet it was essential that the students have access to the workstations during nights and weekends. The Lab decided to entrust two keys to the Librarian, that students can check out by leaving their University ID cards. If both keys are checked out, someone is probably in the Lab, and late-comers can gain entry by knocking.

In addition to these four clusters, there are several individual Apple Macintoshes, IBM PCs, Zeniths, and Visual 550 graphic terminals in various rooms around the Lab area. Most are connected to the University's mainframe via cables from the SCP in room 2222.

The SCP has a total of forty ports for connecting terminals and personal computers to the mainframe. Through an "understanding", twenty-four ports are for the College's private use, and sixteen are for the Computing Center's public use. The College is currently using all twenty-four of its ports. Twelve of the Computing Center's sixteen ports are used by the library Macs. The other four ports are unused.

Conclusion

What we have learned over the years is that, while it's difficult to project what will be needed several years ahead, failing to plan ahead can lead to chaos. Overall, our efforts at integrating computing into the College of Architecture and Urban Planning have been quite successful. Mistakes have been made, however, and the process might have been a little smoother if we had spent more time devising a grand strategy. Computer technology changes so rapidly that it's difficult to keep up, let alone plan ahead. Still, general assumptions can be made about what classes will be taught, what type of equipment will be needed, and how much space will be required. If these assumptions are used as a guide in selecting space and equipment, many headaches can be avoided.

Of course, the best laid plans are only pipe dreams unless the necessary funds are obtained to turn them into reality. This requires a commitment from the department administration to be assertive in the competition for university dollars.

References

3. Ibid. Commercial: Computer (EDP) facilities.

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