2 years for the faculty member to become a sophisticated user. This learning process is greatly enhanced if there is adequate support staff. Our departmental computer network facility at the University of Georgia has one full time systems specialist (a computer science major) and three to five half time student assistants. All are kept extremely busy. It is important that these staff be responsible for all the support work necessary. In my opinion, it is inefficient for faculty to be utilized in this manner.

CONCLUSION

The report is to be highly commended, most especially as it pertains to the acquisition of equipment and all that that entails (including support personnel). There should be many people presently struggling with bits, bytes, memory, CPUs, and the like, who will be much indebted to those responsible for this report.

ACKNOWLEDGMENT

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Comment

Douglas M. Bates

I am very pleased that this workshop was held to exchange opinions on the role and funding of computing facilities in statistical research and I am happy to see this report being published here. The members of the workshop are to be commended for their thoughtful and incisive comments on an issue which is important to many of us and which will become even more important in the future.

As mentioned in the report, departments such as ours which have been fortunate to receive computer equipment grants through programs such as Scientific Computing Research Equipment in the Mathematical Sciences from the National Science Foundation and the University Research Instrumentation Program from the Department of Defense have undergone dramatic changes in the way that research is conducted and reported. These changes have not always been painless. This report is particularly helpful in describing the monetary and time costs to a department which is going to start building its own computing resources. A lot of frustration will be avoided if everyone has a realistic expectation of how much time, effort, and money is going to have to be expended to build the facilities.

This is not to indicate at all that I think building departmental computing resources is not worth all this time, effort, and money. Once you have had the opportunity to use such facilities for research, communications, and text preparation, you never want to turn back. The ability to quickly and interactively follow possible avenues of solution to problems in data analysis and presentation then collaborate on the report with colleagues at distant places via electronic mail and finally prepare the report yourself in a typeset form is addicting because it helps you to be more productive.

It is noteworthy that this report mentions the importance of the communications and text preparation aspects of having departmental computers. We tend to visualize computers as being primarily for number crunching. This is an important use because it cannot be done without the computer, but, if we look at what we do as researchers, we spend much more time writing and rewriting our reports about the results than we do actually computing the results. Facilitating our writing and communications is not a trivial use of computers: it is a very important use.

My own experience is that I don't think that I get the writing done any faster with the computer but I do think that the end product is better. Computer text processing can also help in avoiding proofreading for errors created in transcriptions of the text. The Society for Industrial and Applied Mathematics is currently experimenting with allowing authors to submit the final version of their manuscript in *troff* form thereby avoiding a potential source of transcription errors and a proofreading stage for the authors.

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Combining these developments with advances in computer networks can lead to electronic submission of manuscripts, grant proposals, and so on.

Networks will become even more important in the very near future. As a supplement to this report I would recommend two articles from a special issue of *Science* on "Frontiers in Computing": the article on workstations (Crecine, 1986) and the one on networks (Jennings et al., 1986).

The next logical step in computing resources, powerful graphics workstations, have undergone cost reductions even between the time that this report was written and the time it was published. In the report the cost of a workstation is given as $20,000 to $40,000. Both Sun Microsystems and Digital Equipment are now selling powerful monochrome graphics workstations with local area network interfaces for around $10,000 with the usual university discounts. When the network becomes sufficiently large to incorporate a file server, the incremental cost of adding a "diskless" node can be as little as $5,000.

Such cost reductions will have ramifications for researchers in both large and small statistics departments, not the least of which is that the real cost of computing will shift even more from the cost of the hardware to the cost of the software and operations. Much statistical software is still sold on a "per CPU" basis. This will represent a severe impediment to a department which may have 20 or more CPUs—it is simply not reasonable to spend $5000 to purchase a workstation only to find that it will cost several thousand dollars a year in software licenses before you can use it effectively. There are two approaches to solving this problem of the cost of software: we must persuade software vendors to issue site wide or department wide licenses and we must rely more on public domain software.

I think that this is an area in which our professional societies can help. With easy access to networks, we can physically facilitate software distribution. For example, Jack Dongarra at Argonne National Laboratories and Eric Grosse at AT&T Bell Laboratories operate "netlib" for numerical analysts. Anyone with access to ARPAnet or USEnet (and possibly others) can send an electronic mail message to netlib requesting the index of available routines or requesting a particular routine. A program running at these sites interprets the message and sends the requested routines back via electronic mail. This is the type of facility that we must work toward because statistical research is a software- and data-intensive activity. Merely having computer hardware is not enough. If we are going to provide facilities for easy network wide distribution of data sets and software, though, we will have to have some form of quality control on the software for it to be helpful. I think this work can best be coordinated through our professional societies.

There are great challenges here, but also great opportunities. We know that the cost of computing hardware is going to decrease to the point that very powerful and sophisticated computing resources are within the budget of any researcher who wishes to take the time to learn how to use them. The report is, again, right on the mark in stressing the importance of standardization of such facilities so they are easily usable. If we can make an effort also to provide, at a reasonable price, the software to enable these facilities to realize their potential, we can look forward to a very exciting and productive time in research.

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Comment

Edward J. Wegman

I am pleased to have the opportunity to comment on and amplify aspects of this report. The committee that spawned this report had its origins in three-way discussion among Ron Pyke, Ingram Olkin, and me during the 1984 Annual IMS Meeting held in Lake Tahoe, California. It is thus with some avuncular pride that I am able to congratulate Bill Eddy and his colleagues on a job done very well.

In 1983, the Department of Defense began its University Research Instrumentation Program (URIP). As Division Head of the Mathematical Sciences, I saw

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