computers, workstations, and minicomputers. My own feeling is that microcomputers have a slight advantage in that they will add minicomputer features when the price of the machine will bear it while minicomputer manufacturers have to face the prospect of (for them) radical price reductions. Furthermore, microcomputers have a tradition of providing remarkably powerful software at prices attractive to individuals. Microcomputers are rapidly approaching the threshold where they may substitute for a minicomputer's non-server functions. Mainframe and minicomputer software vendors moving into the microcomputer and workstation environment face great uncertainty about how to price their packages in addition to shedding the "mainframe feel" for a workstation environment.

The authors highlight the support issue. This includes annual maintenance expense of course, but the primary headache is system support at the university level for the diverse set of hardware. We seem to be making a full circle. Whereas once we had fully centralized computing support, researchers led by computer scientists were eager to escape that style of computing. Now with large inventories of microcomputers and networks of minicomputers and workstations, some centralized expertise once again is appropriate and necessary. While the fate of computer centers was uncertain a few years ago, it now seems clear that they can serve a useful university wide role of advisor for computer purchases and central provider of software and hardware maintenance.

The irony of this circle is that the new supercomputer centers would appear to be a return to an older style of computing. Access to supercomputers is critical for many identified problems. But the relatively narrow bandwidth of these machines limits their utility for problems in graphics. Furthermore the computational advantage between supercomputers and some workstations is not large and the time lag narrowing. Careful planning is required by granting agencies to assure that adequate resources for non-supercomputing equipment remain available even when unexpected budget shocks are felt. Relatively modestly priced hardware is available that permits a comfortable experimental and developmental environment before moving to a supercomputer.

5. FINAL REMARKS

While the number of statisticians proudly proclaiming their ignorance of computing has diminished, a surprisingly large group of apathetic folks remain. I hope this report will stimulate them to get involved. Many surprising attitudes remain. For example, some researchers find electronic mail as intrusive as the telephone. I can't imagine having to return to the endless cycle of returned phone calls on simple matters. Another finding in the survey that particularly surprised me was the current lack of use of symbolic algebra software. Finally it is difficult to divorce use of computers for statistical research from other day to day requirements. Do the authors believe these can or should be separated?

ACKNOWLEDGMENT

Comment

Prem K. Goel

First of all, I must congratulate the workshop members for producing such a comprehensive report on the use of computers in statistical research and the editors of *Statistical Science* for publishing it and facilitating its dissemination. This report will be extremely help-

Prem K. Goel is Professor of Statistics and Director of the Statistical Consulting Service at The Ohio State University. He served as Director of the Statistics and Probability Program at the National Science Foundation during 1982–1983. His mailing address is Department of Statistics, The Ohio State University, 1958 Neil Avenue, Columbus, Ohio 43210.

ful in convincing decision makers about the need for a "dedicated" computing facility and to statistics researchers in making the right choices. The report correctly emphasizes the role of computers in ongoing statistical research and the opportunity for cross-fertilization with other sciences. Because of computers, statistical research has come full circle. It is now fashionable in the research community to talk about developing useful and powerful data analytic methodology rather than just proving asymptotic properties of procedures which would not have been implemented on large data sets, in any case, without access to cheap and fast computing power. However, only a very small proportion of the research

community is convinced of the need for access to dedicated machines, while others are quite skeptical about any use of computers in research. For them, I would like to quote Ralph Waldo Emerson, who said that "Skepticism is slow suicide." There is still time for them to wake up. Now about some of the specifics in the report.

Since most of the agencies providing funds for the instrumentation programs deal with mathematical sciences as a unit, it would have been helpful if the report had also dealt with (i) future opportunities for the interaction of mathematicians and statisticians and (ii) the need to explore the possibility of establishing joint statistics/mathematics computing facilities. Given an appropriate relationship between the two groups, it may be beneficial for some statistics departments to join forces with the mathematics departments in their universities in this venture. This cooperation may lead to better and cheaper, although shared, facilities for both groups, because most of the capital and recurring expenditures can easily be shared. Furthermore, it may also be easier to convince the university administration to come up with the required funding.

At Ohio State University, we have been very successful in this cooperative arrangement. Because of our joining force with the mathematics department, especially the scientific computation group, we have been able to obtain more computing power and software packages along with a better support system in the Mathematical Sciences Computing Laboratory than we could have afforded if we had gone alone. I must add that in the beginning there were some skeptics on our faculty about having a shared facility with a much larger mathematics department faculty, who could easily swamp the machine. However, with the cooperation of the Dean's Office and a desire for better facilities on the part of both parties, we did reach an understanding, which led to a substantial cost savings to the university. In order to avoid any misunderstanding, the operational policies of the Computing Laboratory are decided by a five-member committee. We are very glad that we pursued the cooperation route instead of getting our own facility. Of course, every department has a unique situation and must decide for themselves, but I would suggest that one look into this possibility before making a decision.

In Section 3.4 of the report, it is mentioned that "research in statistical methods per se is greatly enhanced by the easy access of the research community to supercomputers." Since this access is easily available through federal funding agencies and most major universities are about to provide

communications/network facilities for accessing supercomputer installations, I believe that scarce departmental resources should not be allocated to the supercomputing effort.

Section 4 of the report is excellent. However, one point needs to be emphasized much more than it has been. Any department contemplating acquiring computer facilities should think very carefully about the immediate and future equipment and software needs and go through a rigorous budgetary planning exercise. A lot of things may be overlooked otherwise. As mentioned in the report, talking to people who have already gone through the experience is very helpful indeed. An advance commitment from the university administration as well as the departmental faculty for the recurring expenditures is very essential. It is quite easy to get one-time funds as compared to a commitment for year to year expenses. Before leaping in and sending a proposal to the funding agencies for an instrumentation grant, one must be fully prepared to meet recurring expenditures from well identified sources because "zeal without knowledge is a runaway horse."

Finally, I think that $10,000 per researcher per year as a ball park figure, as asserted in the summary, may be very much on the low side for a group of 5–7 researchers if it includes the capital costs for equipment and site preparation; software, hardware, and physical plant maintenance; supplies and support staff. As mentioned in the report, support staff itself could cost $40,000 per year or more. I would hope that funding agencies will be more generous in the future in providing funds for maintenance and programmers' costs via research grants.

Now that some leaders have already demonstrated the possibility of a computer revolution in statistical research, amply evidenced by the exhibits and sessions at the Annual IMS/ASA Meeting in Chicago, it is about time for the whole statistical community to think hard about the tremendous opportunities still ahead of us and to make the right choices for the proper growth of statistics. Shakespeare aptly summarizes it as follows: "There is a tide in the affairs of men (*if he was alive now, he would have said men and women*) which, taken at the flood, leads on to fortune." I think that *the flood is here now.*

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