

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.

ADDITIONAL REFERENCES

- CRECINE, J. P. (1986). The next generation of personal computers. *Science* **231** 935-943.
- JENNINGS, D. M., LANDWEBER, L. H., FUCHS, I. H., FARBER, D. J. and ADRION, W. R. (1986). Computer networking for scientists. *Science* **231** 943-950.

Comment

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I am pleased to have the opportunity to comment on and amplify aspects of this report. The committee

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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