COMPUTING RESEARCH NEWS

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Have scientists breached the social contract?

BY Peter Likins

The following is the keynote address Likins delivered at CRA's Snowbird Conference '92 in Snowbird, UT.

When Vannevar Bush began drafting the "social contract"[1] between America's scientists and her government, Franklin Delano Roosevelt was in the White House. But when Bush's report, *Science—The Endless Frontier,* was completed in July 1945, it was delivered to a very different man, President Harry Truman. Had the text been written specifically for the straightforward, plainspoken successor to the sophisticated and eloquent FDR, the "social contract" might have been more explicit. We can now only imagine the conversation required for the interpretation to President Truman of this famous report:

> ***It was assumed that some invisible hands would reach into the laboratories of our nation's scientists and turn their ideas into social benefits.***

"Look, Harry. Here's the deal. The US government promises to finance all legitimate research required to satisfy the curiosity of America's scientists, and they in turn promise to deliver military security, public health and economic prosperity to the American people."

One can search the archives in vain for such language, of course, and both parties to the deal would deny all obligations. Allowing only a little bit for hyperbole, however, this is the bargain that was implicitly understood. Whatever was actually said, this is what people heard, and this is what they have been counting on.

There are advantages in stating the social contract so baldly. Certain premises and implications become more apparent. It is easier to see why the social contract is breaking down.

What about the vote in the House of Representatives to cancel next year's budget for the superconducting supercollider? Isn't that a breach of the social contract? And every academic scientist knows that federal funds are harder to get today, and more restricted. Isn't that a breach?

But what about the other side of the bargain? Is every research project proposed by every research scientist "legitimate research," no matter how many scientists line up for funds? (It turns out that a generous diet for research scientists produces only one guaranteed product…more research scientists.)

What about military security; isn't that yesterday's problem? Besides, America's scientists seem to generally oppose military spending, even for research.

This promise of public health also needs to be re-examined. Even if our scientists have made remarkable discoveries in the life sciences and medicine, there are still millions of Americans who receive inadequate health care by global standards, and all of us pay exorbitant fees for medical services.

Finally, what happened to the promise of economic prosperity? Something is wrong with our economy, and it will not suddenly be OK again just because a bunch of economists tell us the recession is over.

Have America's scientists breached the social contract? Has the government? Should we reaffirm the terms of this contract, or write another one? Should we ignore the problem at the policy level, and just keep trying to win the battle for diminishing resources? That is what we have been doing, and it is not going well.

What does all of this have to do

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[1] *Science - The Endless Frontier* was not submitted as a proposed "social contract," but Bruce Smith of the Brookings Institution has used this sociopolitical term to characterize the product of the efforts of Vannevar Bush and his contemporaries to define the future of American science.

Inside CRN

CSTB report: CS&E research funding may not be easy to come by in future

Attendees of CRA's Snowbird Conference '92 got a preview of a new report on the future of computer science and technology teaching and education.

The report, *Computing the Future: A Broader Agenda for Computer Science and Engineering,* was unveiled by the National Research Council's Computer Science and Telecommunications Board (CSTB) at the Snowbird meeting. It urges computer scientists and engineers to embrace computer challenges that arise in many areas outside the computer science and engineering (CS&E) discipline.

The report noted that the success of academic CS&E may not necessarily continue in the new environment of the future. The rapid technological advances of the past have created new CS&E problems and opportunities. Although intuitive insight may have led to progress in the early days of the field, CSTB said a more systematic approach will become increasingly important in the future. "Thus the importance of CS&E research to computing practice can only be expected to increase in the future," the report said.

CSTB also pointed out that critical federal support for CS&E research may not be as easy to come by in the future. About 46% of the $680 million the government invested in CS&E went to academic research. Although the figure suggests the government recognizes the importance of CS&E research to its mission, funding has not kept pace with the need to create, control and exploit the potential of increasingly powerful computers. Nor has funding kept up with the growth in the number of CS&E researchers. In addition, the report said the government increasingly is asking researchers to demonstrate how their work will benefit the nation.

"In the academic community, the ratio of funding per researcher has dropped by over 20% since 1985," the report said. "Such trends have led to substantial concern within this community that resources are inadequate to support a research agenda vigorous enough to support advances and address problems as they arise."

The computer industry, another major influence on academic CS&E, also has been undergoing massive changes, with a shift away from mainframe sales to smaller computers used by the masses, CSTB said. This trend will increase the importance of introducing new products on a shorter time scale while meeting customer demands for greater functionality. "New computing technology will have to be fitted to customer needs more precisely, thus placing a premium on knowledge of the customer's application," the report said. "New applications of computing will also lead to new CS&E research problems."

In addition, the report noted that computers no longer are considered an unalloyed positive force in society. Concerns about unemployment, privacy and reliance on fallible computers have tarnished the image of automation.

Road map

In mapping out a response to the new challenges, CSTB recognized that CS&E's unique paradigm of scientific inquiry can be applied easily to a variety

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The listing of NSF-supported Science and Technology Centers on Page 226 of the CSTB/NRC report inadvertently omits the Science and Technology Center for Research in Cognitive Science at the University of Pennsylvania, which is funded jointly by NSF's Computer and Information Science and Engineering Directorate and the SBE Directorate.

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Opinions and Letters

We can teach software better

BY Mary Shaw

In recent issues of *CRN*, Bill Wulf and David Patterson asked some questions about undergraduate computer science programs: Are we teaching the best content in the best way, and can we do so without fragmenting the discipline or creating administrative obstacles? [Wulf 91, Patterson 92] As they observed, the last two decades have seen radical changes in hardware technology, networking, system interconnection and sophisticated applications, but our curricula generally ignore these changes.

Software production problems lead the list of complaints about developing computer applications. Wulf and Patterson asked why our current programs do not teach these improved technologies to the students who will need to apply them.

I would like to look specifically at education in software development: programming, programmed systems and the engineering of software. This is not the whole of computer science, but it includes a large share. The typical software curriculum features dinosaur courses, classroom presentations that do not use new technology, naive approaches to software development, innocence of engineering design considerations, a severe shortage of examples relevant to anyone but a systems programmer and ignorance of the system context of most useful software.

Ideas, not artifacts

We should organize our courses around ideas rather than artifacts. This helps make the course objectives clear to both students and faculty. Engineering schools do not teach boiler design; they teach thermodynamics. Yet two of the mainstay software courses—compiler construction and operating systems—are system-artifact dinosaurs.

We do not need 40 students per university per semester who think they are compiler builders, as the description of the usual compiler course would suggest. Indeed, most of the faculty who design these courses will say, when pressed, that the real objectives include:

- understanding the structure of a well-understood, medium-sized system,
- describing interactions of several modules,
- learning more sophisticated algorithms and data structures (related to symbol tables, parse trees and graph traversal) and
- studying the practical problems of applying a well-understood piece of theory, such as syntactic analysis.

Compilers were among the first large, well-understood software systems, so this was the logical choice when these courses were developed. Unfortunately, the course title, investment in textbooks and old habits make it difficult to replace the compiler with other good examples.

In the Carnegie-Mellon curriculum design, we proposed to redistribute the conventional comparative programming language and compiler material, plus new material, to three new courses [Shaw 1985]. A junior-level course about the nature of languages and interfaces would introduce programming language structures, "little languages" and user interface problems.

Second, a follow-on course about transducers of programs would cover editors, macro systems, programming environments, test data generation and program generators, as well as compiling techniques sufficient to handle a simple language.

We specified a senior elective for the specialized programming language and compiler topics such as code optimization, fine points of language design and detailed interactions between languages and their use.

In that curriculum design, we also proposed re-organizing the topics usually covered in operating systems and database courses, bringing in selected topics from hardware and formal methods. We planned courses on time and resource allocation, issues of large data, communications and networks and classes of program organizations.

For example, one course on time and resources would bring together ideas about coordinating multiple processes competing for resources. This includes synchronization mechanisms (locks, semaphores, monitors, rendezvous), scheduling (deadlock, starvation, fairness, contention), real-time response, hardware interrupts, clocks, transactions, programming language constructs for concurrency and temporal logic. These reorganizations were somewhat speculative; their challenge has not yet been answered. I continue to believe they are good ideas.

This is not to say we should abandon the applications. Some engineering schools have gone too far, producing students who know only principles and cannot design a boiler. However, we are far from having that problem. We do need a healthier balance that emphasizes important ideas and places them in the context of good practice.

Software development

Any student who claims to have an education in software must be good at software development. This includes proficiency in both programming and engineering design. The best software engineering education we can provide undergraduates emphasizes these topics, which are integral to the computer science curriculum. These changes do not require separate software engineering courses, let alone separate curricula. Moreover, they will improve the curriculum for all students who learn about software, not just the majors.

Programming skills provide the foundation of a software systems education. Even a cursory look at what programmers know and do reveals problems in the current software curriculum. Shortcomings include:

Programming from scratch: Most courses teach students to code from scratch, rather than by modifying existing programs or by working from model solutions. Students rarely read good programs. It is as if we asked students to write good prose without first reading good prose.

Equating program text with software: A complete software product includes not only the code, but also the analysis that led to the design, user documentation, test suites and records of design decisions that will be important to the maintainer. Students too often focus on

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Letters to the Editor

Hopper was not a co-inventor of Cobol

Dear Editor:

I find it regrettable that an organization supporting research does not do it properly before publishing material. I wonder if I should put the same credence into other articles in the newsletter as I do for the article about Grace Hopper in the March issue.

I refer specifically to the sentence, "Hopper was a co-inventor of the Cobol programming language." While this is a common myth, it is just that—a myth.

I refer you to my biography of Grace in the April 1992 issue of the *ACM Communications* in which I briefly, but accurately, indicated her (non)role in Cobol. I refer you (or your readers) to the long paper I wrote for the first ACM SIGPLAN History of Programming Language conference titled, *The Early History of Cobol.* The paper appears in the book, *History of Programming Languages,* Richard L. Wexelblat, editor, Academic Press, 1981. I wrote that paper based on the original material from the Cobol development in 1959-60, which I had because I was on the committee.

Hopper's name is noticeably absent from a list on Page 214 that was prepared by the committee when it turned in its final report in December 1959. The list said, "The following people have participated in the work of the Short Range Committee at one time or another."

In essence, people who worked for Grace were on the committee, but she herself did not participate in any of its deliberations. Therefore, she cannot possibly be a co-inventor of Cobol, unless you want to consider the Wright brothers as co-inventors of the 707 airplane.

I hope you can find a way to publish a correction without it sounding insulting to Grace Hopper—a person I admired enormously.

Jean E. Sammet
A programming language consultant in Bethesda, MD

CRN ***welcomes letters from its readers. Letters may be edited for space and clarity. Send them to Joan Bass, managing editor, CRN, 1875 Connecticut Ave. NW, Suite 718, Washington, DC 20009. E-mail: jbass@cs.umd.edu. Letters must include your name, address and telephone number or E-mail address.***

Expanding the Pipeline

UC leave policies considerate, practical

By Francine Berman

The birth of a baby, the adoption of a child or the responsibility of caring for a seriously ill family member all necessitate substantive leave over and above the normal flexibility of academic life. Many institutions are recognizing that these periods are part of life and these institutions are making professional accommodations for these periods. This is not only considerate, but practical. A number of studies show that workplaces that provide daycare, flex-time and other kinds of support experience less absenteeism and have more loyal, productive, and longer-term workers.

The University of California has instituted several enlightened and progressive academic leave policies that support parenting, with minimal disruption to the job. Programs available include family leave, child-bearing leave, parental leave and active service/modified duties. Primary care-givers also can stop their tenure clock during the initial period spent caring for a newborn or newly adopted child. These programs and policies are helping to create a hospitable environment for working parents. Together with on-site daycare, these benefits provide an appealing package to current and prospective academic employees. I will briefly describe the programs available at the University of California.

Family leave: The current interim family leave policy (which eventually will be replaced by a permanent policy) provides up to four months of unpaid family leave within a two-year period to employees for the purpose of caring for a newborn, newly adopted child or a seriously ill family member. This leave is considered distinct from childbearing/ pregnancy disability leave, which is available only to women. Family leave generally is used by a parent who wants to spend time with a newborn or newly adopted child or care for a sick child. However, the university may deny the leave if the other parent is unemployed. Sabbatical credit is not accrued during this leave.

Childbearing and pregnancy leave: Childbearing leave is granted to female faculty at full pay for up to six weeks. The employee has no university obligations during this time, and she does not accrue sabbatical credit. This leave is intended to be used after the birth of a new child or the addition of an adopted child to the family.

Parental leave without pay: Parental leave without pay can be taken for up to one year by either parent. This leave is subject to approval by the chancellor, but it generally is given on request. No sabbatical credits are accrued during this time.

Active service/modified duties: Active service/modified duties is not considered a leave. The faculty member negotiates a modified set of duties with the department chair for as long as a quarter. Generally, faculty do not teach or serve on committees, but they continue activities, such as supervising students or running a lab during this period. Active service/modified duties may be taken immediately before or after the birth of a newborn or the addition of an adopted child up to age 5 by a faculty member who is the primary care-giver for the child. Sabbatical credits and full pay are accrued during this period.

Stopping the tenure clock: This policy provides parents who have been primary care-givers with new babies or newly adopted children the opportunity to stop their tenure clock for up to three quarters to account for time spent focusing on family responsibilities.

The period after the birth or adoption of a child changes the dynamics of family interaction and requires time and energy for adjustment. Stopping the tenure clock is an institutional recognition that a faculty member's productivity may be less than optimal during this period, and provides the necessary flexibility to assess the faculty member's long-term productivity equitably with his or her peers.

This policy can be abused. In particular, employees who have not been the primary care-givers could use this policy to extend their time to prepare for tenure. In the worst case, the policy could extend the tenurable period for most people, while providing no extra flexibility for new parents.

This potential abuse is limited by careful application of the policy to academics who have used one of the previously mentioned leaves, or have been primary care-giver to a newborn or newly adopted child and request an extension of the review period in writing.

Rearing children is a natural part of life for many of us, and it requires the involvement and participation of both parents. Institutions that support their employees as whole people—with families, as well as job responsibilities—earn the loyalty and productivity of their workers. Flexible leaves, good on-site daycare and reasonable benefits are critical to the support and respect of faculty who, in turn, will provide support and stature for the university.

Francine Berman is an associate professor of computer science and engineering at the University of California, San Diego. Her research focuses on tools and models for parallel programming environments and heterogeneous processing.

The Computing Research Association is pleased to announce the relocation of its headquarters. As of Aug. 1, 1992, CRA's new address is:

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Cooperative research fellowship offers international experience

The National Research Council and the Alexander von Humboldt Foundation in Bonn, Germany, have announced a new cooperative, one-year research fellowship at a leading German research institution, followed by an award for up to three years at a US federal laboratory.

The international postdoctoral arrangement was created to encourage more American scientists and engineers to gain international experience. The program covers many disciplines, ranging from fisheries biology to computer systems engineering.

Applications should be submitted to both the NRC and the von Humboldt Foundation. Successful candidates will be awarded two research positions to be held in tandem, first in Germany for a year, then in the United States for up to three years. Applicants must be US citizens and less than 40 years old when selected.

Applications may be submitted at any time. Selection committees for the organizations meet three times a year to evaluate applications.

For more information, contact the National Research Council, 2101 Constitution Ave. NW, Washington, DC 20418; tel. 202-334-2760; fax: 202-334-2759. Or contact the Alexander von Humboldt Foundation, North American Office, 1350 Connecticut Ave. NW, Suite 903, Washington, DC 20036; tel. 202-296-2990; fax: 202-833-8514.

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the code, do ad hoc testing, neglect the user documentation and ignore everything else.

Learning abstract skills at the expense of specific content: Our curricula are strong in techniques for formulating solutions from first principles. We present too few well-known examples of good solutions for study and emulation. We fail to teach respect for, and reliance on, existing results such as code libraries.

Programming before reasoning: Although the situation is improving, coding and debugging still seems to win out over specification, analysis and careful construction or derivation.

Curing the problems

We can cure these problems without major disruption to our course structure by changing the emphasis within individual courses.

Study good examples of software systems: Doing this properly requires case studies organized for presentation. Instructors should do careful, guided reading of good code and make assignments that start from running code provided with the assignment.

Learn more facts: Software developers will not use resources they do not know about. Teach more specific facts, such as available subroutine libraries and interface standards. Reinforce these

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Association News

Six new members elected to serve on CRA board

Six new members have been elected to serve on the CRA board of directors. Joining the board are H.T. Kung of Harvard University; Edward D. Lazowska of the University of Washington; David S. Wise of Indiana University; Lennart Johnsson of Thinking Machines Corp.; Steven S. Muchnick of Sun Microsystems Inc.; and Mark Weiser of the Xerox Palo Alto Research Center.

Michael R. Garey of AT&T Bell Laboratories; Juris Hartmanis of Cornell University; Gregory R. Andrews of the University of Arizona; and C. William Gear of the NEC Research Institute were re-elected to the board. Garey is serving another term as board treasurer and Andrews is the new board secretary.

Retiring from the board are Paul Young of the University of Washington, who is a former board chair; John Brzozowski of the University of Waterloo, who served as the board secretary; Laszlo A. Belady of the Mitsubishi Electric Research Laboratories; Gideon Frieder of Syracuse University; Jack McCredie of Digital Equipment Corp.; Raj Reddy of Carnegie Mellon University; and Susan L. Gerhart.

Gerhart recently was named as the director of the Division of Computer and Computational Research in the National Science Foundation's Directorate for Computer and Information Science and Engineering. Bruce Barnes had been serving as the acting director.

Lennart Johnsson: Director of computational sciences at Thinking Machines Corp. and a Gordon McKay professor of the practice of computer science at Harvard University. Degrees: a master of science in engineering physics and a doctorate in control engineering from Chalmers Institute of Technology in Sweden. Research interests: design of communications systems, graph embeddings and the automatic mapping of data and control structures to parallel architectures, linear algebra and fluid and solid mechanics applications and architectures, algorithms and software for high-performance parallel computers.

H.T. Kung: A Gordon McKay professor of electrical engineering and computer science at Harvard University and a professor of electrical and computer engineering at Carnegie Mellon University. Degrees: a bachelor of science from the National Tsing Hua University in Taiwan and a doctorate from Carnegie Mellon University. Research interests: high-speed networking, parallel architecture and algorithms.

Edward D. Lazowska: Professor and associate chair of the computer science and engineering department of the University of Washington. Degrees: a bachelor of arts in computer science from Brown University and a doctorate in computer science from the University of Toronto. Research interests: design of distributed and parallel systems.

Steven S. Muchnick: A Distinguished Engineer at Sun Microsystems Inc. Degrees: a bachelor of arts and a master of arts in mathematics from the University of Michigan and a doctorate in computer science from Cornell University. Research interests: programming, programming language implementation (particularly optimization) and computer architecture.

Mark Weiser: Head of the Computer Science Laboratory at the Xerox Palo Alto Research Center. Degrees: a master of science and a doctorate from the computer and communications sciences department at the University of Michigan. Research interests: operating systems, programming environments, user interface, distributed computing, ubiquitous computing and garbage collection (automatic storage reclamation).

David S. Wise: A professor in the computer science department at Indiana University. Degrees: a bachelor of science in mathematics from the Carnegie Institute of Technology and a master of science and a doctorate in computer science from the University of Wisconsin. Research interests: functional programming languages and algorithms for multiprocessing.

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with assignments that require students to use them.

Incorporate reference material as it becomes available: There is a dearth of good reference material to help software developers avoid re-invention. As such material becomes available, use it. Instructors should teach students to use reference manuals, library documentation and other materials more effectively.

Present theory and models in the context of practice: Emphasize durable ideas that will transcend a major shift of technology. Students often learn theories and models best when these appear in concrete examples; good examples will themselves be worth remembering for reuse.

Engineering skills

Practical, useful software does not happen by accident. It requires design skills not unrelated to traditional engineering design. Some of the engineering shortcomings of our curricula are similar to the programming shortcomings: failure to study good systems, failure to develop reasoning skills and failure to understand maintenance and support issues. Other shortcomings include:

Using the first design: Problems often have more than one solution. The best solution in a given setting often depends heavily on facts about the user or the intended use of the system.

Designing for the implementor: Implementors often choose solutions that match their own tastes, not the needs of the customer.

Failing to understand problem scale: Class assignments usually emphasize functionality, but neglect performance requirements, especially scale requirements such as size and throughput.

Writing throwaway exercises: When assignments are discarded as soon as they are graded, students have no incentive for creating comprehensible, well-documented, maintainable software.

Ignoring reliability, safety and other system requirements: Class assignments usually focus on getting correct results for correct inputs. Assignments occasionally require performance measurement or rudimentary checking of inputs. Students rarely do systematic analyses of reliability and safety. Similarly, class assignments address asymptotic performance of algorithms and sometimes speedy code, but many students never confront a requirement for practical real-time response.

Correcting the flaws

We can address these flaws, too, within the existing course structure.

Require consideration of at least two serious designs: Make students choose between design alternatives. Require these choices to address customer needs.

Require consultation with users: Use projects with actual clients. Unless users have a voice in reviewing a design, students will not understand that users' needs and preferences are different from their own.

Teach back-of-the-envelope estimation: Students often believe they cannot do any analysis until all the facts are in hand. Teach them to do quick estimates of usage levels, throughputs, sizes and bandwidths. Show them how this can provide early guidance about scale and performance.

Modify and combine programs, as well as create them: Teach students to work with program structures devised by others, reuse components, adhere to standards and value good documentation.

Test student implementations with bad data: Run test cases chosen by the instructor, not just demonstration data from the student. Include not only correct inputs, but also erroneous and even malicious inputs. Do this not only for isolated assignments, but as a matter of course.

Make assignments with embedded system requirements: Bad data is not the only source of real-world demands. Make assignments that expose students to nondeterminism, end-to-end time requirements and race conditions.

Relevant content

Patterson suggested several new courses that should be made available to more students. I would add real-time systems, architectures of software systems, parallel computation and human/computer interaction. Each of

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People in the News

Phil Louis joins CRA staff

The Computing Research Association welcomes Phil Louis, the new staff assistant and database manager. Phil started as a part-time staff assistant in the spring and became a full-time employee in July.

Phil maintains the various databases, including board member information, the *CRN* subscription list, the Forsythe list and a general database of all organizations with an interest in computing research. He also will process the Taulbee Survey and update *CRN*'s US mailing list.

He comes to CRA from the US Air Force, where he served most of his tenure in Europe. Phil was the command administrator for the unit information management section. He was decorated for his participation in Desert Storm shortly before he relocated to Washington, DC.

J.F. Traub honored by CRA

Joseph. F. Traub, the Edwin Howard Armstrong professor of computer science at Columbia University, is the winner of the 1992 CRA Award for Service to Computing Research. Traub was honored for his leadership and service as the founding chair of the Computer Science and Telecommunications Board (CSTB) of the National Research Council. He held the position for six years.

Under his leadership, CSTB became a major policy voice for the computing research community and has produced many important and influential reports and studies. His most recent report, *Computing the Future: A Broader Agenda for Computer Science and Engineering*, was released at the Snowbird Conference '92.

John Rice, chair of the CRA board of directors, announced the award at the conference in July. Traub was out of the country, so the award will be presented to him later this fall.

Gwen Bell is new ACM president

Gwen Bell, the founding president of the Computer Museum in Boston, has been elected president of the Association for Computing Machinery. Her term runs through June 1994. During her last two terms on council, she served as the representative for the Eastern region and on the publications board.

Stuart H. Zweben, a professor at Ohio State University, is the new vice president and John H. (Jack) Esbin, commissioner of the Division of Computing Services for the city of Toledo, OH, is serving as secretary.

Michael R. Garey, a CRA board officer, was elected member-at-large. Garey, who has been active in ACM for 25 years, is the director of the Mathematical Sciences and Research Center at AT&T Bell Research Laboratories in Murray Hill, NJ.

Newell recognized for AI work

Allen Newell has been awarded a National Medal of Science for his pioneering work in artificial intelligence, the theory of human cognition and development of computer software and hardware for complex information processing. He is the U.A. and Helen Whitaker professor of computer science at Carnegie Mellon University.

The president periodically gives the award in recognition of outstanding contributions to knowledge in the physical, biological, mathematical or engineering sciences.

Newell is considered to be one of the founders of artificial intelligence and cognitive science. His idea was that computers could process symbols and numbers, and could, if programmed properly, solve problems the way humans do.

Newell's focus in cognitive science has been on problem solving and the cognitive architecture that supports intelligent action in computers and humans. He has worked in many areas, including list processing, computer description languages, hypertext systems and psychologically based models of human/computer interaction.

Newell received a bachelor's degree in physics from Stanford University and a doctorate in industrial administration from the Carnegie Institute of Technology (now Carnegie Mellon University).

Hinton wins ITAC/NSERC award

Geoffrey Hinton, an Information Technology Research Center (ITRC) researcher at the University of Toronto, has been awarded a 1992 Information Technology Association of Canada (ITAC)-Natural Sciences and Engineering Research Council (NSERC) Award for Academic Achievement.

Hinton was honored for his part in the development of learning techniques for neural networks and for making his discoveries available to industry through a neural network software package called Xerion.

ITAC funds half of the $50,000 award as a salary supplement. NSERC funds the other half, which must be used for research.

Hinton is leader of an ITRC project on handwritten character recognition, and is the coordinator for artificial intelligence, cognitive science and intelligent control.

Oxford wins Queen's Award

By Geraint Jones

The Oxford University Computing Laboratory (OUCL) has been awarded its second Queen's Award for Technical Achievement.

For those of you who have never heard of Queen's Awards: Where were you two years ago when OUCL last felt inordinately pleased with itself for having won a Queen's Award? It is an institutional equivalent of an Officer of the Order of the British Empire or a knighthood. Each year on the Queen's birthday, for the past 27 years, awards have been announced for export and for technological achievement. The recipient earns the right to display an emblem and receive some recognition. The award is given for a significant and advanced technology innovation that has achieved commercial success and improved efficiency.

This award is made jointly to OUCL and IBM United Kingdom Laboratories Ltd., for their collaboration in the use of formal methods, and specifically the use of the mathematically based Z notation language, in the production of transaction processing software, and specifically in the Customer Information Control System (CICS) products in IBM's Enterprise Systems Architecture (ESA) environment.

For a decade now, OUCL's Programming Research Group and IBM United Kingdom Laboratories at Hursley Park have been collaborating closely on the development of modern software engineering techniques and their use in industrial practice. OUCL has been offering advice on mathematical techniques relevant to IBM's work and helping IBM apply the techniques.

Central to this collaboration has been the use of Z, which in essence is elementary set theory and logic engineered into a notation suitable for the specification, development and documentation of software systems. Z also includes techniques and styles of use.

The aim of applying this "ruggedized" mathematics to the development of computer programs is to reduce the cost and risk of the development process and improve the quality of the product, which itself reduces the cost of maintenance.

Before this collaboration, the use of Z had been confined mainly to small exercises conducted largely at Oxford. The collaboration began tentatively with small experiments to see whether Z really could be used in an industrial environment.

Case studies that evolved from these experiments have proved to be useful foundations for subsequent work, but the most useful outcome was a significant transfer of culture, in both directions, between the academics and the practitioners.

It was then decided to use Z to develop the next release of a transaction processing system, CICS/ESA V3. 1. Z was integrated into IBM's existing and well-established development process. This has demonstrated that it is possible to manage a large and important software development project using mathematics.

Informally, (and this is disputable) I understand that one of the benefits of the exercise was precise documentation for the developers of the next version of CICS of what users of existing versions might reasonably be expecting.

Many measurements of the process of developing CICS/ESA V3.1 were conducted by IBM, and the company estimated that the most important benefit of the experiment was that it was able to reduce development costs by almost $5.5 million dollars.

Early results from customers indicate significantly fewer problems, and problems that have been detected are less severe than would be expected otherwise.

The mingling of cultures has benefited both Oxford and IBM. A choice example is the resolution of a problem in describing the correctness of a data-refinement step. One of the CICS designers knew that the step was valid, but the theory of refinements was unable to formally justify it. Research into this problem gave rise to a new theory (complete in the technical sense), and a (complete in the usual sense) formal justification of the actual refinement.

Industry in general has benefited from IBM's support and encouragement of the standardization of Z. The syntax and semantics in the standard are based closely on work funded by IBM. Throughout the project, there has been a policy of open publication, both of techniques and results, to an extent that has been unusual for IBM in projects of this kind.

This openness has contributed more than a little to the acceptance of formal methods in other parts of the industry, and in particular, to the spread of Z.

It is pleasing to be able to acknowledge that IBM's contribution to this work included not only its own staff's time and financial support of staff at the laboratory, but also the bravery to commit to an experiment involving a substantial product development, and the persistence to see it through.

There has been a good understanding at all levels of management in IBM of what formal methods can do and this has enabled them to direct the laboratory's research at the most pressing problems.

Education has been an important part in this work. OUCL has taught these methods both to the

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Snowbird Conference '92

Board meets at Snowbird

BY John R. Rice
CRA Chair

CRA's Snowbird Conference '92 was extremely stimulating; Greg Andrews and Peter Freeman, the conference co-chairs, are to be applauded for putting together such an excellent program. The first-day speakers collectively presented the message that fundamental changes are occurring in the research relationships among academia, industry and government. The patterns of research funding that most of us have known for our entire professional lives are likely to change. I encourage you to read a copy of the keynote address given by Peter Likins [See Page 1] and the summary of the report, *Computing the Future: A Broader Agenda for Computer Science and Engineering,* released by a National Research Council committee chaired by Juris Hartmanis [See Page 1].

There were talks on recent research advances from the four National Science Foundation-funded Science and Technology Centers in computing research, and a luncheon address by Herbert Edelsbrunner, the winner of the 1991 Alan T. Waterman award. These talks focused on research advances and their impact (now or in the future) on science and engineering.

Because of the changes occurring in our field, it is crucial that we explain why computing research is important, and why it should be favored in the coming readjustments of priorities among the sciences for public funding.

The meeting concluded with 11 workshops for heads of research-oriented departments in academia and industry.

The CRA board of directors also met at Snowbird and plowed through an agenda of 23 items. Two highlights from the administrative area are: (1) CRA is solvent and membership is increasing (though slowly, because most research-oriented academic departments already are members). Our income in 1991–92 was about $420,000, and we spent about $400,000. (2) Our headquarters moved on Aug. 1 to bigger, nicer and less expensive office space.

Plans for the first Federated Computing Research Conference (FCRC) were discussed at length, and I am optimistic that this new venture will develop into a major asset for the computing research community. David Wise, a board member from Indiana University, was appointed conference chair. He is leading a hard-working group from CRA, the Association for Computing Machinery and the IEEE Computer Society.

Reports were received from several other CRA committees, but I will discuss only one in some detail.

A group from CRA's Executive and Planning committees (Peter Freeman, Michael Garey, Nancy Leveson, David Patterson, John Rice, Fred Weingarten, Mark Weiser and Bill Wulf) met with an agenda of about a dozen topics the day before the Snowbird conference. The topics ranged from concrete proposals to "do something now" to philosophical issues about the long-term future. A group of these topics were discussed, and three near-term actions were given highest priority.

A. *Human resources in computing research.* There is a large demand for better data on the source, production and employment of computing researchers. Our Taulbee Survey is great, but overall, there is much less data for computing than for other sciences. We believe external funding can be found for a significant effort in this area starting this fall. The idea is that the Taulbee Survey will continue as it is, while new projects are added. I am pleased to announce that Earl Schweppe of the University of Kansas has agreed to replace David Gries of Cornell University in directing the Taulbee Survey. We all owe David and his assistant Dorothy Marsh our thanks and gratitude for many years of dedicated service in this project.

B. *Advertising in Computing Research News (CRN).* We have completed a survey that shows *CRN* readers are highly satisfied and are attractive (in principle) to advertisers. We might be able to substantially reduce the $70,000 annual subsidy *CRN* receives by increasing the effort made to attract display advertisers. This fall, we will conduct a study to assess this possibility, but we will focus our attention on maintaining the attractive nature of *CRN* and on more accurately assessing the financial implications.

C. *Awards.* The computing research profession has fewer awards than the longer-established professions in science and engineering. Our research leaders thus have weaker credentials than other leaders, and this can be an important factor at the level where science policy and priorities are set. Many people, including myself, have said in recent years that we have to do something about this. Alas, nothing really has happened, and CRA must act on this. I am pleased to announce that Laszlo Belady of the Mitsubishi Electric Research Laboratories Inc. has agreed to chair the CRA Awards Committee. I ask you to help him in his effort. It also was announced at Snowbird that Joseph Traub of Columbia University is the 1992 recipient of the CRA Distinguished Service Award. A formal presentation will be made this fall when he returns from Europe.

Attendees of the Executive and Planning committees meeting also debated what CRA can and should do to identify research trends and set priorities. We concluded that the real task is to *identify unique opportunities for research advances that exist because of new technological advances and new national needs.*

Specifically, our community already is behind schedule in proposing a follow-up to the High-Performance Computing and Communications initiative. The group recommended that CRA give this activity a high priority. This recommendation is particularly pertinent given the probability of changes in the funding structure for science and engineering research. The Computer Science and Telecommunications Board/NRC report, *Computing the Future,* has thrusts that need further development. CRA has proposed that NSF fund a series of CRA/NSF workshops on research trends and opportunities.

Handler: Industrial policy does not work perfectly

Sheryl Handler, the president and chief executive officer of Thinking Machines Corp., stirred up some controversy at CRA's Snowbird Conference '92 when she criticized federal industrial policy.

Handler's dinner keynote address focused on the need to blur lines between basic and applied research and the need to keep the government from dictating how research is performed.

She said industrial policy as proposed by some democrats in Congress could exert undue influence on the future of scientific research.

But Handler drew strong objections from audience members who said Thinking Machines has been a notable benefactor of US industrial policy. They pointed out that the company received a grant from the Defense Advanced Research Projects Agency (DARPA) to build its CM-5 parallel processor.

Handler denied that DARPA funded the CM-5. She said the company spent between $50 million and $60 million to build the machine, and that DARPA gave the company only $8 million. DARPA also promised to buy the machine once it was proven to work. "Stories that DARPA funded our research are not true," she said.

Her main objection to programs like DARPA's centered on the rigidity of the government goals and requirements for successful research. She said better results are produced when those goals are not so clearly defined and creativity is encouraged. She argued that many of the companies that participated in DARPA's programs subsequently went out of business. "If you look at a lot of the programs DARPA funded, most of them didn't work,'' she said.

Conference attendees continued to argue that DARPA and other agencies have produced successful results. Handler, who said she was surprised that an audience of mostly academic researchers would object so strongly to her views, eventually eased her criticism of DARPA and industrial policy in general. She acknowledged that research programs at DARPA and the National Institute of Health have been successful because they are based on ideas formulated at grass roots level of the government. She said industrial policy only becomes troublesome when high-level officials are involved.

"I think the reason DARPA is successful is because decisions are made at a low level, almost in secret," she said. "When programs are decided at a high level, political processes kick in."

She also admitted that she has "an extreme view" on the issue because very few others have spoken out against it. "I am only hearing positive things about industrial policy," she said. "I am hearing no negatives."

Handler said she was "horrified" by a draft congressional report that she said blamed many of the country's woes on scientists who made their own decisions on research. The report said non-scientists should review scientists' work to make sure researchers are not wasting time and money, she said. She refused to say which congressional committee sponsored the report.

The government will become increasingly involved in scientific research in the future, Handler said. Policymakers in Washington, DC, are seeking to blame scientists for the faltering economy. She added that some politicians believe that scientists have become arrogant about their position in society.

A better method of meeting the research challenges of the future would blur the lines between basic research, applied research and product development. Handler said many hold the misconception that "real research" happens at universities and products are developed by commercial industry. "Maybe the delineation should not be as crisp and clear as that," she suggested. "At Thinking Machines, the line is so blurred."

She said Thinking Machines employs about 120 Ph.D.s out of 600 employees and spends about one-third of its revenues on R&D. She described the atmosphere at the company as "comfortable chaos."

Handler said she advocates "a seamless web" between researchers and product developers. Her company did not begin with a product in hand. But officials spent 18 months talking to scientists with problems that needed to be solved.

She added that she battled repeatedly with her chief scientist over the direction of the company, but eventually settled on a course they knew was right: to build the Connection Machine. "To make the machine meaningful, it had to become relevant to real needs," she said. "Science tells us what problems beg to be solved, then we know what computers to build. Science requirements yield better products."

Handler said her company has been working in a variety of research areas that are not commonly associated with a hardware company. For example, Thinking Machines researchers are working in the area of short-range molecular dynamics, protein structure determination and surface calculation for silicon. The company also has been working with the Census Bureau to classify the agency's data. Through a process called historical analogy, unclassified databases can be sorted based on an analysis of previously classified census data.

Snowbird Conference '92

The king is dead! Long live the king!

BY Juris Hartmanis and Herb Lin

As Peter Likins notes in his remarks on Page 1 of this issue of *CRN*, the old compact between science and government is breaking down. In an era of $400 billion federal budget deficits, funding increases for basic research are hard to justify.

Government probes of the major research universities, from those involving Stanford University for alleged improper charges to federal research accounts to those involving the Massachusetts Institute of Technology for alleged price-fixing in undergraduate financial aid awards, should be regarded as a signal that the days of research as a sacred cow beyond the reach of criticism are over. In short, government will never again (if it ever has) be able to support all scientifically worthy research.

What of the future? Science and technology still are critical to the nation's economic growth and competitiveness. National security will continue to depend in no small part on advanced technology. Health and the public welfare, too, will be influenced strongly by science and technology. So the contributions of science to society outlined by Vannevar Bush are not in question. Rather, it is the other part of the bargain—that researchers themselves should be the only ones to decide the course and purpose of their research—that is in doubt.

The connection between scientific research and social benefits assumed by Bush now must be demonstrated explicitly. In an era when the public funders of research demand greater accountability, an attitude of "trust me, I will deliver" no longer will suffice to justify funding. More to the point, mere repackaging of old research agendas to look politically correct will not work.

The recent report from the Computer Science and Telecommunications Board and National Research Council, titled, *Computing the Future: A Broader Agenda for Computer Science and Engineering* [See Page 1], is a first step toward a new and broader vision of the computer science and engineering (CS&E) discipline.

The report looks to senior CS&E researchers to spearhead a cultural change that truly will embrace interdisciplinary and applications-oriented work and elide the traditional lines between basic and applied research and between research and development. A discipline that is proud of, rather than indifferent to, its connections to and usefulness in other problem domains is one that ought to have no trouble in explicitly demonstrating the link between research and social benefit.

This broader vision is consistent with Likins' call for a three-legged compact between government, industry and academia. Indeed, an embrace of other problem domains most easily is pursued in the context of a partnership among these three parties. The old model of technology transfer—academic researchers throwing the blueprints over the transom to product developers in industry—ought to be recognized by now as an oversimplified and misleading model of how research can be made useful. Academia and industry must work together as intellectual equals, each bringing good ideas and sharp insights to the table. Government should make such linkages easier to accomplish.

If the new and broader vision is to succeed where the old compact is failing, it must represent a substantive rather than a rhetorical change. Lip service to endorse applications and interdisciplinary work is easy; what really counts are those things that reflect the core values of the discipline.

Substantive change will be recognized when Ph.D. students in CS&E do interdisciplinary or applications-oriented dissertation research, assistant professors receive tenure for interdisciplinary or applications-oriented research, and the best graduate students in CS&E are encouraged by their faculty to take positions doing interdisciplinary or applications-oriented research in industry or government. Otherwise, those who pursue the new agenda will be regarded as second-class citizens in a community that is resisting change.

A broader agenda for computer science and engineering is appropriate for many reasons. One obvious benefit is that embracing interdisciplinary or applications-oriented research will multiply the intellectual opportunities for CS&E researchers. Progress in highly theoretical fields often has been stimulated by the development of new techniques invented to solve hard problems suggested by outside applications, as well as by the inner logic of the subject.

Consider the words of John von Neumann, a pioneer of modern computing: "As a mathematical discipline travels far from its empirical source, or still more, if it is a second- and third-generation only indirectly inspired from ideas coming from 'reality,' it is beset with very grave dangers. It becomes more and more purely aestheticizing, more and more purely l'art pour l'art. This need not be bad, if the field is surrounded by correlated subjects, which still have closer empirical connections, or if the discipline is under the influence of men with an exceptionally well-developed taste.

"But there is a grave danger that the subject will develop along the line of least resistance, that the stream, so far from its source, will separate into a multitude of insignificant branches, and that the discipline will become a disorganized mass of details and complexities… [W]henever this stage is reached, the only remedy seems to me to be the rejuvenating return to the source: the reinjection of more or less directly empirical ideas. I am convinced that this is a necessary condition to conserve the freshness and the vitality of the subject, and that this will remain so in the future."

CS&E, too, can prosper by learning to balance the development of the science base for computing and systems design against a response to outside challenges and technological developments.

> ***It is not unreasonable to argue that it is the computer scientists and engineers who should lead the charge into the information age.***

As importantly, the involvement of CS&E researchers in other problem domains will help ensure that the computing aspects of those other domains are addressed with the most powerful intellectual tools available. But without the participation of computer scientists and engineers, specialists in other problem domains may not be able to articulate the computing aspects of the problem they want solved, let alone solve them.

A broader agenda will enable our discipline to address economic realities faced by the field. Given the pressures on research budgets for all science and engineering, a new research agenda will enable CS&E researchers to make a better case for receiving support from nontraditional sources.

A relevant point of information is that more than 42% of the entire federal science and engineering research budget (more than $10 billion out of the total $24 billion) for fiscal 1991 was obligated by 12 federal agencies whose individual science and engineering research budgets each allocated less than 1% of the money to computer science research.

In addition, a broader agenda is responsive to the shift in the computer industry from selling thousands of million-dollar computer systems to selling millions of thousand-dollar systems. As the general-purpose computer gives way to increasingly specialized applications, the nation will require relatively fewer people who build computer technology and relatively more people who know what to do with computers (for example, to write applications software or integrate complex systems for specific tasks).

In short, the importance of domain-specific knowledge relative to programming skills will increase, and the educational agenda of academic CS&E should reflect that.

The CS&E community has a golden opportunity to help define the new compact between government and all of science. To the extent that CS&E is willing and able to demonstrate its utility for solving problems of social import, it can be an important part of articulating the portion of a new compact that expects demonstrable connection between social benefit and scientific research in any discipline that is publicly supported.

CS&E can be the real trailblazer into this new world. Let the physicists argue the case for the social relevance of the superconducting supercollider, and the aerospace industry the case for the social relevance of the space station. Computer scientists and engineers can argue the case for the electronic library. Posed in those terms, it is not really much of a contest.

To put the issue in somewhat more parochial terms, the world of government science policy has affected the fates of all scientific disciplines, though it has been dominated by the physicists. Given the Cold War and the central concerns of nuclear Armageddon, it is not surprising that the physicists' exploitation of quantum mechanics and relativity in the creation of nuclear weapons gave them a special niche in the science policy community.

But as the prospect of Armageddon recedes and concerns over economic competitiveness and development rise to the top of the nation's agenda, it is not unreasonable to argue that it is the computer scientists and engineers who should lead the charge into the information age.

A few decades from now, it should not be unreasonable to imagine that the director of the National Science Foundation or the President's science adviser would be a prominent computer scientist or engineer with an international reputation for the development of an utterly revolutionary information technology.

Whether or not the particular vision of a new compact described in the CSTB/NRC report comes to pass is much less relevant than the community's response to the impending demise of the old one. Today, the CS&E research community has a fundamental choice: defend the old, or get out in front of something new.

Arguing that the field deserves adequate funding or that only basic research has any intrinsic intellectual value or that funding levels per investigator are lower than they ought to be may be emotionally satisfying to some people.

However, a more useful way to proceed is to shape the new compact. Get out in front. Lead. Debate. Argue. But do not look back.

Juris Hartmanis, a professor of computer science at Cornell University, chaired the Computer Science and Telecommunications Board's Committee to Assess the Scope and Direction of Computer Science and Technology that produced the report Computing the Future: A Broader Agenda for Computer Science and Engineering.

Herb Lin was the principal CSTB staff officer on the report.

Snowbird Conference '92

Moving from science policy to science politics

BY Fred W. Weingarten
CRA Staff

The following article is based on a speech I delivered at CRA's Snowbird Conference '92.

As you can tell from your programs, my original subject was science and technology policy in the presidential campaign. However, we have seen a nearly total lack of discussion on that topic. It is possible that the nomination of Sen. Al Gore (D-TN) as vice presidential candidate on the Democratic ticket may focus more attention on technology questions, but the vice presidential candidate does not usually set the national agenda for a presidential campaign.

Instead, I have prepared some broader comments on current trends in politics and their effect on computing research. As it turns out, Peter Likins, in his keynote speech [See Page 1], could not have provided a better foundation for my remarks.

From a Washington perspective, I would agree whole-heartedly with his thesis that the nearly 50-year-old, implicit contract between government and science has broken, and never will reappear in its old form. I would like to extend the analysis in two directions.

Beyond science itself, the contract included universities as the principal institutional locus for basic research. Of course, universities receive the bulk of support for direct basic research projects. In addition, many facilities commonly thought of as fully funded government research laboratories, such as the Jet Propulsion Laboratory, Los Alamos National Laboratory and the National Center for Atmospheric Research, are operated through universities and consortia.

The government and the public have lost interest in the bargain. For all its warts, the government still reflects public attitudes. We can assume that Congress and the administration would not be engaged in what are, in some cases, aggressive political and legal attacks on the integrity of higher education and science if the public still strongly and, more importantly, without question, supported those institutions.

Policy to politics

The lines between science policy and science politics are not clear. Pure, non-political policy does not exist, and all politics result in some form of policy. Traditionally, science policy was established in an environment in which it was assumed that a more or less predictable, continually growing level of government support for research would be available. Further, the science community was assumed to have the major voice in directing the expenditure of that money, mainly through institutions like the National Science Board or the National Academy of Science. Science policy, in this overly simplified view, was a quiet, bipartisan agreement among politicians and the US scientific leadership, which in the past was dominated by physicists. Reflecting the traditional operating style of science, science policymakers focused to a great extent on objective measures, indicators and internal peer review as a basis for their decisions.

Science politics, on the other hand, takes quite a different form. Science politics is the unending series of partisan, contentious and bruising debates over research priorities and programs. These debates often are a tumultuous mix of concerns ranging from purely scientific to intensely subjective, value-laden and ideological. These concerns, which lie completely outside the comfortably civilized style of the past, can be awkward for the scientific community to deal with.

Uncomfortable as this new style is to the scientific community, it is my view that, like it or not, science politics rather than science policy will be the new state of affairs.

> ***The lines between science policy and science politics are not clear. Pure, non-political policy does not exist, and all politics result in some form of policy.***

I believe it comes from a basic shift in public opinion, and in particular, changes in two basic values that are driving the political debate.

First, voters are far more skeptical about tax expenditures. Interestingly, polls do not indicate a broad-based absolute rejection of taxation, so much as a demand that increases be clearly and directly tied to immediate social benefits. This reflects a predominantly suburban electorate that is college educated and fiscally conservative. These voters are ready to listen, but need to be convinced about the need for increased taxes.

Second, the public seems to be increasingly skeptical about large institutions—not just government, universities and companies—but education and science. Look at the recent wave of government attacks on university overhead and the antitrust suits over admissions policies, or at policymakers' concern over fraud and abuse in scientific research. Whether merited or not in individual cases, these attacks also seem to be tapping a broader public readiness to distrust.

Implications of change

One can draw a few broad observations about the implications of these changes for computing research:

• Most importantly, computing research is front and center in the new science and technology debate. We no longer have to invite ourselves to the table, we are there. Computing research, along with other high-impact fields such as materials and biotechnology, have the strongest claim of social impact. The High-Performance Computing and Communications program is the first of what likely will be a series of special research initiatives in which computing will play a central role. Our field will have a major voice in defining the "new contract," to use Likins' term.

• We must learn how to operate more effectively in the political arena. We need to understand that what some of us consider to be irrational forces in a political debate can be very real pressures for politicians. These pressures challenge the scientific community to do a better job—to engage, rather than withdraw or deny the legitimacy of others. This admonition may seem obvious to some, but too often, academicians and scientists have treated the political system with arrogance and contempt. It still is widely believed that the scientific community considers support an entitlement to taxpayer money, an entitlement that does not include accountability.

• The scientific community needs to do a better job of communicating with a general public that no longer has

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of applications, such as global change research and computational biology. The board also noted that differences between CS&E basic and applied research are artificial because both require the same judgment, creativity, skill and talent.

The board also concluded that the growing ubiquity of computing in our society has put a premium on the largest possible diffusion of CS&E expertise. But CS&E undergraduate programs, the primary vehicle for such diffusion, are highly variable, the report said.

Taking these observations into account, CSTB outlined a set of overall priorities for CS&E. The first priority is to sustain the core effort in CS&E that creates the theoretical and science base on which computing applications build. "This core effort has been deep, rich and intellectually productive and has been indispensable for its impact on practice in the last couple of decades," the board reported.

The second priority is to broaden the field. Because of its wide applicability, CS&E can broaden its self-concept. "Given the pressing economic and social needs of the nation and the changing environment for industry and academia, the committee believes that academic CS&E must broaden its self-concept or risk becoming increasingly irrelevant to computing practice," the report said.

The third priority is to improve undergraduate CS&E education. The quality of undergraduate CS&E education is inextricably tied to the state of computing practices throughout society. This priority is needed to transmit recently developed core knowledge to the next generation and to provide the intellectual CS&E basis to people pursuing a broader research agenda, CSTB said.

The board said academic CS&E researchers need to broaden their horizons beyond research in core areas where they traditionally have been successful. Researchers need to focus on problem domains that derive from non-routine computer applications in other fields or from technology-transfer activities.

Computer scientists and engineers should regard as scholarship any activity that results in significant new knowledge, the report said. They should not worry whether the activity is related to a particular application or falls into traditional categories of basic research, applied research or development.

Universities also should support CS&E as a laboratory discipline, one with theoretical and experimental components, the report said. CS&E departments need adequate research and teaching laboratory space; staff support; funding for hardware and software acquisition, maintenance and upgrades (especially on cutting-edge systems); and network connections.

To ensure that US CS&E departments' educational programs reflect a broader concept of the field, CSTB said departments should require Ph.D. students to take a graduate minor in a non-CS&E field or to enter the CS&E program with an undergraduate degree in a non-CS&E field. CS&E Ph.D. students also should perform dissertation research in non-traditional areas, the report said. Departments should offer undergraduates not majoring in CS&E a wide range of computer-related courses. Departments should develop programs to reward faculty for designing innovative and challenging new curricula that keep up with technological change and make substantive contact with applications in other domains.

The academic CS&E community must reach out to women and minorities who are not well-represented in the field. Departments especially should focus on incoming undergraduates. The report said women and minorities will "broaden and enrich the talent pool."

CSTB urged the federal government to support the High-Performance Computing and Communications (HPCC) program throughout its 5-year life cycle. The government also should initiate an effort to support CS&E research in academia related to the missions of federal agencies participating in the HPCC program. This effort would cost the government $100 million per fiscal year, the CSTB report said.

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with the changing relationship between industrial and academic research? Can we think sensibly about university research without discussing both government and industry partners in this enterprise?

What is perhaps most striking about the social contract established in 1945 is the relegation of industry to an implicit role. It was understood that scientists cannot provide military security, public health or economic prosperity, but it was assumed that some invisible hands would reach into the laboratories and libraries of our nation's scientists and turn their ideas into social benefits. After almost 50 years of experience, we have less faith in such modern alchemy.

We designed a two-legged stool in 1945, and it served us well as long as a healthy private sector was there to prop up the system. But our nation's industrial leadership in the global economy has been challenged, and on some fronts displaced by other countries. We can no longer assume that our economy will be so dominant that scientific success will automatically be transformed into social benefit. We must recognize the advantages of a well-designed, three-legged stool.

It seems that Vannevar Bush was quite correct in arguing that scientific progress in the modern era is necessary for long-term social and economic progress. Science is necessary in the long-term, but surely not sufficient. Something more is needed if science is to contribute to military security, public health and economic prosperity.

If we are to develop a new social contract to justify public expenditures in scientific research, this time we must be clear about the whole package deal. Most importantly, we must be explicit in our expectations of industry, and recognize the critical roles to be played by engineering, technology and the system that delivers the benefits to the people.

We should acknowledge that scientific inquiry, like philosophical inquiry and artistic creation, has intrinsic value that can be important to culture and civilization. Our society can afford to support the best people in certain academic domains with no evident potential for utility, within limits that belie any sense of entitlement. The resource claims appropriate for such activities must vary with the strength of the nation's economy, and generally remain modest. Major resource commitments should represent global consensus and involve international collaboration. These issues can be set aside for now as we struggle to define the new social contract, because in some sense they stand above the contract.

In 1992, as in 1945, the social benefits we can expect to flow ultimately from science are in three domains: military security, public health and economic prosperity.

Military security is the easiest of the three social benefits to discuss operationally, because the federal government is both the single source of funds and the ultimate customer, directly responsible for the delivery of services to the people. The roles of academic and industrial institutions in the US military security system are relatively well-defined. One might argue about the magnitude of resource commitments appropriate for this area, or criticize the efficacy of expenditures, but the system that produces military security in the United States is not a controversial subject today.

Our health care system is much more hotly debated, but the controversy is not focused on the role of academic researchers in this system. It is difficult to dispute the view that American medical researchers have been true to their commitments to the people who finance their work and have delivered both immediately useful results and the kind of understanding that holds promise for future progress in medicine. Our public health failures largely have been in health care delivery and finance. They are important here only because of the danger that efforts to solve these problems will accidentally damage our medical research systems.

We must deal realistically with the promise of economic prosperity in the social contract that sustains the scientific research system in the United States. This is complicated and controversial territory, requiring a deep understanding of the relationships among scientific discovery, engineering development, technological production and market distribution.

The old model presumed a linear, sequential relationship progressing from scientific discovery through the indicated steps to market distribution. Indeed, examples of this kind of model, illustrate the possibility that a scientific discovery can trigger a natural process that culminates in new products.

But this model of science pushing products into the market is simplistic at best, and often simply wrong. The sequence may be reversed, with market demand pulling new scientific discoveries from the research community. But most often the process is iterative, with feedback loops connecting scientific discovery, engineering development, technological production and market distribution, and different stages of the process may be accomplished at different times by different organizations or nations.

Most new products do not involve any new science at all. Even for new products that rely on scientific breakthroughs, the economic benefit (the profit) usually flows to the player who builds and sells the product, and not generally to the innovator in science. This is a complex economic process, and experience in other countries demonstrates that the role of government in this process can be both subtle and pervasive.

The historic role of the federal government in the United States has included the transfer of the benefits of federally sponsored scientific research in some domains, but not others. The government assumes essentially full responsibility in such areas as defense and space exploration, and substantial responsibility has been accepted in the field of health care.

In areas directly affecting the economy, the government has demonstrated a sharp ambivalence, with deep involvement in supporting private agriculture and related industries, but initially no involvement in the commercial manufacturing or service industries.

This pattern gradually is changing, as evidenced by such major initiatives as Sematech and such programs as the manufacturing technology centers sponsored by the Commerce Department. But the changes come slowly, seemingly as exceptions to policy rather than revisions of policy. As a nation, we still are undecided about the proper role of the federal government in transferring the benefits of scientific and technological research into the commercial economy.

Before we can intelligently consider the changing relationship between academic and industrial research, we must decide on the government's role. I speak with no authority on the matter, but I do detect a growing pragmatism in Washington, and increasing receptivity to good ideas for cooperative endeavors involving industry, academia and government.

I urge you to keep all options open, and accept no a priori constraints. Consider the implications of all of the Federal Coordinating Commission for Science, Engineering and Technology (FCCSET) initiatives, not only the High-Performance Computing and Communications initiative. The first FCCSET initiative, on global warming, had important implications for the computer science research community. The newest FCCSET initiative, "21st Century Manufacturing," has important applications for computing and communications. Keep in mind the unsettled nature of the social contract, and do not accept the old premises.

There are good reasons for both government and private industry to support research in computing and communications, but the support will not be forthcoming unless good reasons are advanced. We are entering a new era, and the rules have not been written yet. Your challenge is to draft your own rules and try to establish a new social contract.

Peter Likins is the president of Lehigh University and a member of President Bush's Council of Advisers on Science and Technology.

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an unquestioning willingness to provide money. The communications must convey a sense of value and stress the important social benefits of scientific research, yet avoid pandering to unrealistic expectations of instant solutions. The field needs to stay focused on long-term, basic research.

I also believe we need to encourage research on social impact and technology assessment. With foresight, we can anticipate the inevitable problems that can arise with technological revolutions.

Glimpse of contract

What will the new contract look like? Perhaps we can derive a few hints from some recent science and technology initiatives, particularly the HPCC program.

Research programs will be tied to explicit social objectives. Rather than a single, generic contract between government and research, the pattern will be a series of ad-hoc agreements, along the lines of the HPCC program, focused on particular technologies or social problems.

Industry will be incorporated more explicitly in a three-way partnership. Science policy primarily has treated industry as a user, a recipient of new technology developed by funded researchers—hence, the use of the term technology transfer. In the future, industrial and academic R&D will be interwoven, although the nature of and ground rules governing that new relationship are just beginning to take.

A continual tension will exist between short-term and long-term research. CRA stood firm in the HPCC debate over an explicit piece of the program supporting basic research and human resources. The fight will be ongoing; we need to continually seek a reasonable balance between research that is likely to show short-term payoff and that which helps build the fundamental knowledge base.

The international flow of information and expertise will be an increasingly troublesome issue. A fundamental tension exists between the political desire to appropriate benefits of research to the nation that supported it, and the scientific desire to share discoveries with colleagues elsewhere in the world.

The scientific community always has viewed itself as international; and sharing information is fundamental to the research process. It is only natural that, as national goals drive research priorities, political concerns about protecting national interests will arise continually.

New types of research institutional structures may arise to house and administer research or to manage the increasingly complex infrastructures that support modern science and technology. Although universities may continue to be deeply involved in basic research, they will not be the only, or even the principal, base. We may see the emergence of new types of consortia, or distributed laboratories that use networking and shared facilities as a basis for their work. In the process, support of single investigator research projects may gradually decrease as a proportion of the federal research effort.

I have not yet formed any conclusions. The debate is just starting. In listing the changes I think may be occurring, I am not endorsing them or suggesting they will occur without problems.

But our job, both individually and through organizations such as the Computing Research Association and other scientific and professional societies, will be to help inform and guide the debate. We will not always get our way, but we live in changing times, and what we do not do ourselves will be done for us by others—and in our name.

Policy Issues

DARPA's HPCC funds restored

The House Armed Services Subcommittee on Research and Development tried, but failed, to delete $45 million in funds earmarked for computer systems research in the Defense Advanced Research Projects Agency (DARPA) high-performance computing and communications (HPCC) programs. Subcommittee members argued that the money was not being well-spent. A subcommittee report said the funds would be better spent training Defense Department employees to use existing supercomputers, rather than in developing faster machines.

The funds were restored by the House Appropriations Committee after a series of protest letters from professional societies and researchers. The issue is not settled, however. A Government Accounting Office committee has requested a study of DARPA's HPCC research priorities.

At this time, observers are only speculating about the source of this falling out between the R&D subcommittee and DARPA. No one believes the official argument given in the report. However, government officials responsible for HPCC programs fear that this falling out is likely to continue to cause problems for DARPA's computer architecture research. If the falling out is not resolved soon it could threaten the future of the HPCC as a cooperative interagency program.

Congress cuts NSF funding

Although the administration requested a 17% increase in research funding for the National Science Foundation, congressional appropriation committees cut funding slightly, by about 1%. Most observers do not believe the funds will be restored in conference between the two chambers.

The cut is a result of the agency's direct competition with domestic programs such as housing and urban development, which were slated for emergency increases. NASA, too, is in the same appropriations subcommittee. The space station, which was fully funded in the Senate this year, commands an ever-growing piece of that limited pie. Some observers believe science funding finally is hitting the more general barriers created by the budget agreement, and that the future is equally gloomy.

NSF officials are unlikely to respond in any way, other than to cut all proposed program increases. The Computer and Information Science and Engineering (CISE) Directorate, which was slated for the largest increase (23%) of any NSF directorate, will suffer the greatest cuts. The cuts are likely to be a severe setback to the High-Performance Computing and Communications program.

Given the political realities of a presidential election year and a ballooning deficit, there is little chance of restoring funds this year. However, if these cuts become the norm, the HPCC program could become crippled or die.

New Gore bill expands HPCC

On July 1, Sen. Al Gore (D-TN) submitted his long-awaited follow-up bill to the HPCC Act passed last November. The bill, S 2937, is intended to build on and broaden the scope of the NREN. The bill contains four specific goals for extending the HPCC program:

- Developing technology applications for "improving education at all levels, from pre-school to adult education."
- "Building digital libraries of electronic information accessible over computer networks…"
- "Improving the provision of health care by furnishing …more accurate and more timely information."
- "Increasing the productivity of America's workers."

The bill is broad and general in scope at this stage, and most likely is intended, as were early versions of the HPCC bill, to be the starting point for debate. CRA and several other organizations have been invited to comment and suggest modifications to the bill. CRA's Government Affairs Committee, chaired by Edward Lazowska of the University of Washington, will be coordinating the association's response.

When the bill was submitted, hearings on the bill were expected in the fall. However, Gore's vice presidential nomination has put those plans on hold.

Ethics restrictions dropped

The Office of Government Ethics (OGE) has dropped provisions restricting federal employee participation in professional society activities from its published *Standards of Ethical Conduct.*

Professional and scientific societies, including CRA and ACM, responded to a draft proposal. The groups argued that the proposed provisions would severely restrict federally employed scientists and engineers from taking part in the normal activities of their societies and associations, including holding office and serving on editorial boards or conference planning committees.

OGE director Stephen D. Potts said that OGE's policy is to encourage federal employees to participate fully in the affairs of their professional societies. He said guidelines in that area may be released later, but associations will have an opportunity to comment on a draft proposal.

Top science jobs hard to fill

"Confusing" and "stringent" postgovernment employment regulations are making it more difficult to fill key leadership positions in science and technology, said a report by a panel of the Committee on Science, Engineering and Public Policy. The report was administered by the National Academies of Sciences and Engineering and the Institute of Medicine.

Science and technology positions have been vacant an average of nine months during the Bush administration, compared to six months in the Reagan years. Recruiters sometimes have to go to the 10th, 20th or 30th choice before finding a nominee.

Although some postgovernment-employment laws are fair, other are excessive and are "confusing appointees and raising fears that they (the appointees) will violate regulations unintentionally," the report said. Some laws "severely and unnecessarily limit appointees' career opportunities after public service."

The report, *Science and Technology Leadership in American Government: Ensuring the Best Presidential Appointments,* proposes strengthening basic postgovernment laws by outlining specific types of unethical postgovernment conduct, such as using insider information.

Appointees from universities and non-profit research organizations should not be required to give up tenure at their home institutions. "Resignation is only called for in those few instances where major decisions affecting the home institutions are pending and are too central to the job," the report said.

Other suggestions to improve the recruitment of highly qualified leaders included:

- Improving the appointment process by allowing cabinet secretaries and agency heads to play a larger role in the recruitment process;
- Reducing the financial costs of public service through neutral investment vehicles, such as mutual funds, that give candidates the opportunity to divest financial assets that might be considered a conflict of interest; and
- Ensuring unbiased scientific and engineering judgment by setting fixed terms of service for some positions and removing some lower-level posts from the congressional confirmation process.

The report is available for $12.95, plus $3 shipping, from the National Academy Press, 2101 Constitution Ave. NW, Washington, DC 20418; tel. 202-334-3313.

Professional Opportunities

Professional Opportunities Advertising Policy

Send copy and payment for Professional Opportunities advertisements to advertising coordinator, *Computing Research News*, 1875 Connecticut Ave. NW, Suite 718, Washington, DC 20009; tel. 202-234-2111; fax: 202-667-1066; or E-mail: jbass@cs.umd.edu.

The format of an ad must conform to the following: (1) the first line must contain the name of the university or organization and will be printed in bold, (2) the second line must contain the name of the department or unit and will be printed in italic and (3) the body of the ad should be in paragraph form. The words in the first two lines are included in the total word count for the ad. Any headings or text requested in all uppercase will be set in bold and counted as two words.

As of July 1, the rate is $2 per word (US currency). A check or money order *(please do not send cash)* must accompany the ad copy. Purchase orders are acceptable. All CRA members receive at least 200 free words per dues year.

Display ads cost $30 per column inch. The ad must be submitted in camera ready, offset (positives or negatives) or mechanical form.

Computing Research News is published five times per year in January, March, May, September and November. Professional Opportunities ads with application deadlines falling within the month of publication will not be accepted. (An ad published in the November issue must show an application deadline of Dec. 1 or later.) Advertising copy must be received at least one month before publication. (The deadline for the November issue is Oct. 1.)

California Institute of Technology

Department of Computer Science

Caltech invites applications for a tenure-track position from candidates with promise for innovative research and teaching. Exceptionally well-qualified applicants may be considered at the associate or full professor level. Initial junior faculty appointment normally is for four years and is contingent upon completion of a doctorate.

The department of computer science seeks to strengthen and broaden its research and teaching program from its present strengths in concurrent computation, VLSI, computer graphics and formal methods of programming into complementary areas.

Please send a resume, list of publications, copies of your best publications and names of at least three references to Alain J. Martin, chair, Computer Science Search Committee, Caltech 256-80, Pasadena, CA 91125. Caltech is an equal opportunity, affirmative action employer. Women and minorities are encouraged to apply.

North Carolina State University

Department of Computer Science

The department of computer science invites applications for a tenure-track opening at the level of assistant professor. Qualifications for the position include a doctorate in computer science and a strong commitment to teaching and research in the area of formal approaches to system specification, analysis and verification. The department is interested in filling the position by January 1993, although applicants who cannot start until August 1993 also will be considered.

Externally funded research activity in the department has increased dramatically in the last several years. The faculty includes a member of the National Academy of Engineering, and another faculty member has recently won Young Investigator awards from the Office of Naval Research and from the National Science Foundation.

Both the master's and the Ph.D. programs are growing, with increased visibility of the latter being a particular priority of the department. The university's College of Engineering also is committed to the department's ongoing emergence as a nationally and internationally recognized center of excellence in computer science. In addition, the department benefits from close connections with industrial organizations in the Research Triangle Park, a large conglomeration of high-tech companies located 15 miles away.

Interested parties should send their curricula vitae, including citizenship information and visa status, and names of four references to Recruitment Committee chair, department of computer science, North Carolina State University, Raleigh, NC 27695-8206.

NCSU is an equal opportunity, affirmative action employer.

Rensselaer Polytechnic Institute

Computer Science Department

Rensselaer's computer science department invites applications for a faculty position in engineering database systems, with emphasis on object-oriented systems. Applications for all academic ranks will be considered. Applicants should have a doctorate in computer science, or a related area, and a commitment to excellence in teaching and research. The department offers B.S., M.S. and Ph.D. degrees in computer science and has excellent computing facilities.

Send curriculum vitae and names of three references to Professor David L. Spooner, department of computer science, Rensselaer Polytechnic Institute, Troy, NY 12180-3590.

Rensselaer is an equal opportunity, affirmative action employer.

Rensselaer Polytechnic Institute

Computer Science Department

Rensselaer's computer science department invites applications for a faculty position in computer systems, with particular emphasis on operating systems, computer architectures and compilers. Applicants should have a doctorate in computer science, or a related area, and a commitment to excellence in teaching and research. The department offers B.S, M.S., and Ph.D. degrees in computer science, and has excellent computing facilities.

Send resumes and three references to Professor Boleslaw Szymanski, department of computer science, Rensselaer Polytechnic Institute, Troy, NY 12180-3590.

Rensselaer is an equal opportunity, affirmative action employer.

Oregon State University

Department of Computer Science

The department of computer science at Oregon State University invites applications for a tenure-track position as assistant or associate professor, to start September 1992 or thereafter. Specialization in software, artificial intelligence, parallel computing or computer graphics is preferred.

Applicants should have completed or expect to complete all requirements for a doctorate in computer science or a closely related field and should have demonstrated potential in research and teaching. Candidates for a senior position should have established research reputations.

Review of applications began July 1, and will continue until the position is filled. Applications from women and minorities particularly are encouraged. Please send vita, statement of research interests and plans and three letters of reference to Walter G. Rudd, head, department of computer science, 303 Dearborn Hall, Oregon State University, Corvallis, OR 97331. E-mail: rudd@cs.orst.edu.

Oregon State University is an equal opportunity, affirmative action employer. The university complies with Section 504 of the Rehabilitation Act of 1973.

Polytechnic University

Department of Computer Science

Applications are invited for the position of head of the department of computer science at Polytechnic University. The department, which offers B.S., M.S., and Ph.D. degrees, is located in the School of Electrical Engineering and Computer Science. Polytechnic is a private technological urban university established in 1854. It is located on three campuses in the New York City metropolitan area. The main campus is in downtown Brooklyn, adjacent to Brooklyn Heights, one of New York's desirable residential communities. The two suburban campuses are located in Farmingdale, Long Island, and in Hawthorne, Westchester County.

The department's growth is evidenced by faculty openings, increased external research funding and its move into a new university building in Brooklyn that is part of the 16-acre MetroTech development of buildings for academic, research and commercial activities. The university has an enrollment of about 4,500 students. As a result of the university's favorable location, faculty and students enjoy close interactions with major companies that manufacture and use computers.

The department of computer science currently has 17 tenure-track faculty members. Its undergraduate program is accredited by CSAB, and in 1991 it awarded 118 master's degrees and seven doctoral degrees. Areas of active research include parallel, distributed and randomized algorithms, computational biology, parallel and distributed computing, computational geometry, software reliability and testing, computer architecture, large distributed databases, network management, and image analysis and understanding. Faculty and students have access to a wide variety of networked mainframes and workstations.

The department's active research program is supported in part by Polytechnic's New York State Center for Advanced Technology in Telecommunications and the Center for Applied Large-Scale Computing, which participates in the Consortium for International Earth Sciences Information Network.

Applicant should have a doctorate and an outstanding record of research and teaching in computer science. Qualified applicants should send their curriculum vitae to the chair of the Search Committee, Professor Richard Mandelbaum, Center for Advanced Technology in Telecommunications, Polytechnic University, Six MetroTech Center, Brooklyn, NY 11201. Polytechnic is an equal opportunity employer, M/F/V/H. Questions can be directed to lshaw@poly.edu.

New head of Illinois center named

Ahmed Sameh is the new director of the Center for Supercomputing Research and Development at the University of Illinois, Urbana-Champaign.

Sameh also will chair a committee that will set up a new computational science and engineering program in the College of Engineering. The goal of the program is to create high-performance computing programs and design machines that will better perform the computations users want.

David J. Kuck, a professor of electrical and computer engineering, established the center in 1984 and served as its director. He is retiring after 27 years at the university.

Sameh has a bachelor's degree in civil engineering from the University of Alexandria in Egypt, a master's degree in civil engineering from the Georgia Institute of Technology and a doctorate in civil engineering from the University of Illinois at Urbana-Champaign.

Los Alamos lab sets up testbed

The Los Alamos National Laboratory in New Mexico has established the Computational Testbed for Industry, which will allow US companies to access advanced hardware, software, networks and visualization tools.

Companies will be able to participate in workshops and information exchanges, try out new applications codes, experiment with different hardware and work with laboratory scientists to test, debug and improve their codes. The testbed also will serve as a forum through which laboratory researchers can learn directly from industry scientists and engineers about the problems that various industries face.

Attention department chairs:

You soon will be receiving this year's Taulbee Survey form. Please fill it out and return it to CRA as soon as possible. Your cooperation is appreciated.

Research News

Shaw from page 4

us probably has a few favorite topics.

We cannot add fresh material to a curriculum that already is full. We have accumulated a lot during the last 25 years; tradition and inertia make it hard to prune. Patterson suggested contracting lower-level courses. We also can add new material by replacing the examples that carry the ideas. After all, our main goal is mastery of the basic concepts of the discipline; the specific examples matter less.

For example, instead of making the introductory programming course optional, we could refocus it on more interesting examples. Most students who enter the university with programming experience can write code, but they often lack much of what the course objectives should specify: real mastery of the concept of algorithm, a certain kind of problem-solving skill, and a systematic approach that leads to readable, understandable and maintainable code.

Why don't we start by studying good programs that do things students find interesting, then move on to changes that make them even more interesting? In addition to introducing algorithmic reasoning and problem solving, we could set better standards of style and teach the use of some of the simpler tools.

Patterson said new course models will not be adopted unless they have textbooks. Certainly there is inertia and social pressure. But any teacher who knows an area can put together a readings collection. Any teacher willing to put in a little effort can use a collection someone else has prepared. Undergraduate seniors and most juniors should be perfectly capable of reading papers from *IEEE Software* and *Computer* because these journals are edited for the practitioner.

I have done two courses this way recently (a software engineering project course and a course on architectures for software systems), and I am happier with the papers than with textbooks. Descriptions with reading lists appear in appropriate places, so anyone who does not want to work from scratch can work from these [SBC 91, SGOSS 92]. It is true that a textbook stabilizes a course, but published collections of readings also can do that.

We do not encourage interdisciplinary study. It is true that a student can construct a double major by using the electives of one major to satisfy the requirements of the second. But this falls short in two ways: it prevents the student from exploring the interesting byways of either major, and more seriously, it offers no way to teach the computational aspects of the other discipline.

A few computer science departments are setting up joint majors with other departments. More should. Both departments must be willing to reduce the normal requirements and develop one or more advanced computational courses that rely on prerequisites in both departments.

What we do not need is fragmentation within computer science. The current pressure for separate software engineering programs and departments rejects the historical productive interaction between the practical and theoretical sides of the discipline. I believe this interaction is one of the reasons for our rapid development over the past 30 years.

None of my proposals even hints that separate curricula or departments are appropriate. In fact, many of these changes would be harder to make in separate curricula than in a unified program. As Wulf argued, separating software engineering from computer science is counter-productive, both intellectually and administratively.

Using our own technology

We are poor users of our own technologies. Except for compilers, editors and the occasional syntax-directed editor, parser generator or grading program, software education makes little use of software technology.

Our courses do not represent the best of computer science. They are only marginally relevant, and they often are neither fresh nor exciting.

Many other possibilities spring to mind: subroutine or component libraries, integrated environments, simulations, program skeletons, test harnesses, spreadsheets and project planning software, educational-strength versions of industrial tools and living case studies.

Some courses take advantage of these opportunities, but this is far from the norm. We have lots of excuses for not using these technologies, such as, "It is not available at my school," "We cannot afford it," and "It is not compatible with my textbook."

These seem to be roundabout ways of saying we do not realize that these technologies are a vital part of modern software practice. Yes, there are practical problems. A single instructor cannot acquire or develop a sophisticated environment for a single course.

But we can do a great deal for a single course, and we should undertake facility development for education as seriously as we take facility development for research. The same problems with getting support for software and maintenance will, alas, reappear.

For a decade or more, we have been talking about distributing software for particular courses, often coupled to particular textbooks. I recall offering code to support the major examples in a textbook in 1981.

However, there was no effective distribution mechanism, and almost no one took me up on the offer. Publishers tell me that the instructor's materials, including answers to exercises and overhead projection masters, are major factors in selling textbooks. We should be targeting the day that portable software support is an even stronger selling point.

We can do many things to revitalize the software curriculum. Most actions do not require complete replacement or separate departments. As it stands, we are serving no one well. Our courses do not represent the best of computer science, they are only marginally relevant, and they are too often neither fresh nor exciting.

References

GSOSS 92: David Garlan, Mary Shaw, Chris Okasaki, Curtis M. Scott and Roy F. Swonger. "Experience with a course on architectures for software systems." *Proc. Sixth SEI Workshop on Software Engineering Education*, Springer-Verlag 1992 (to appear).

Patterson 92: David A. Patterson. "Has CS changed in 20 years?" *Computing Research News*, March 1992, pp.2-3.

SBC 91: Mary Shaw, Bernd Bruegge and John Cheng. "A software engineering project course with a real client." *Software Engineering Institute Educational Materials Package* CMU/SEI-91-EM-4, Carnegie Mellon University, July 1991.

Shaw 85: Mary Shaw (ed). *The Carnegie-Mellon Curriculum for Undergraduate Computer Science*. Springer-Verlag 1985.

Wulf 91: William A. Wulf. "SE programs won't solve our problems." *Computing Research News*, November 1991, p.2.

Mary Shaw is a professor of computer science at Carnegie Mellon University.

Report: Not enough money is invested in pre-commercial R&D

The government must broaden its role in technological development and include pre-commercial R&D, said a report from a panel of the National Academies of Sciences and Engineering and the Institute of Medicine.

The report, *The Government's Role in Civilian Technology: Building a New Alliance,* said the government has to recognize the failure and underinvestment in pre-commercial research. This type of R&D covers the area between basic research and prototype building.

The government has funded the development of many defense-related technologies, but few projects supporting civilian technologies are funded, the report said.

The report included specific guidelines for shaping a new federal focus on pre-commercial research.

- Cost-sharing between government and industry.
- Industry involvement in project initiation and design.
- Distance from the political process.
- Projects open to foreign firms characterized by substantial contribution to the project and the US Gross Domestic Product.
- A diversified set of R&D areas.

The report also recommended that Congress considers setting up a $5 billion Civilian Technology Corporation to increase the rate in which new products and processes are brought to market. Project costs would be shared by the government and participating companies. Projects would be designed and initiated by private companies.

The report is available for $22.95, plus $3 shipping, from the National Academy Press, 2101 Constitution Ave. NW, Washington, DC 20418; tel. 202-334-3313.

Oxford from page 5

students on its master of science course in computing, and on external courses to commercial organizations, including, of course, IBM. (Courses in Z and its use now are being taught at other organizations.) IBM, in consultation with Oxford, has developed its own courses.

This transfer of technology is an important benefit and is a welcome indicator that IBM has accepted that it has a stake in the methods.

To quote from what I said about a collaboration between the laboratory and another company, a collaboration that was recognized similarly two years ago:

"The moral of this tale is that formal methods not only improve quality, but also the timeliness and cost of producing state-of-the-art products. [IBM], bless them, ought to have made a packet out of getting it right, being confident that they got it right and doing so on time. The laboratory also has benefited from the opportunity to develop its work on the underlying theory into something that it has confidence will be useful."

The project started with Ian Hayes and Ib Holm Sorensen serving as the research officers. Today the project is led jointly by Tony Hoare and Jim Woodcock, with Steve King and Jane Sinclair serving as the research officers, and John Nicholls serving as a consultant. Many other people have been involved with the project over the years.

A strength of this project has been the breadth and depth of the Z community in which it was able to flourish.

This work has been well-documented in the scientific literature, and there is a substantial and flourishing bibliography maintained by the gods of comp.specification.z.

For more information, send an E-mail message containing the command "help" to archive-server@comlab.ox.ac.uk.

Geraint Jones is a lecturer in computing at the University of Oxford.