

Overview: The Centre for Advanced Studies

by S. G. Perelgut
G. M. Silberman
K. A. Lyons
K. L. Bennet

The Centre for Advanced Studies (CAS) was founded in 1990 to facilitate the transfer of research ideas into products. This essay describes the original goals of CAS, how they have been applied, and how they have evolved. CAS has successfully moved concepts into products, matched students with appropriate jobs, demonstrated IBM's commitment to leadership by integrating current research into products available to customers, and supported academic research by doctoral students and faculty from more than 30 universities. More than 150 professors have received CAS funds. As we move into our eighth year, CAS is poised to expand beyond North America and to involve additional IBM sites.

The IBM Corporation has undergone a significant shift, from being a hardware and software company selling discrete units to being a provider of complete solutions to customer problems. The laboratories within IBM work with customers to identify problems, design solutions, and implement these solutions. The evolution of the Internet, and especially the World Wide Web, means that consumers now have better access to current research and hence are more likely to be interested in cutting-edge technologies. This has effectively reduced the time available to turn research results into products. At the same time, the increasing interconnectivity has led to projects that incorporate technologies from laboratories around the world.

While product cycle times have been compressed, applied research has also sped up. Companies fund fewer long-term research projects in favour of short-

er-term developments that can be integrated with products sooner to gain a competitive edge. New ideas are being generated and some can "shake up" the world rapidly, frequently following an exponential curve for adoption with twice as many adherents every year.

All of these trends led the Executive Advisory Board for the IBM Software Solutions Toronto Laboratory to recommend setting up a centre devoted to finding appropriate research and compatible products under development and to bring the two groups together.

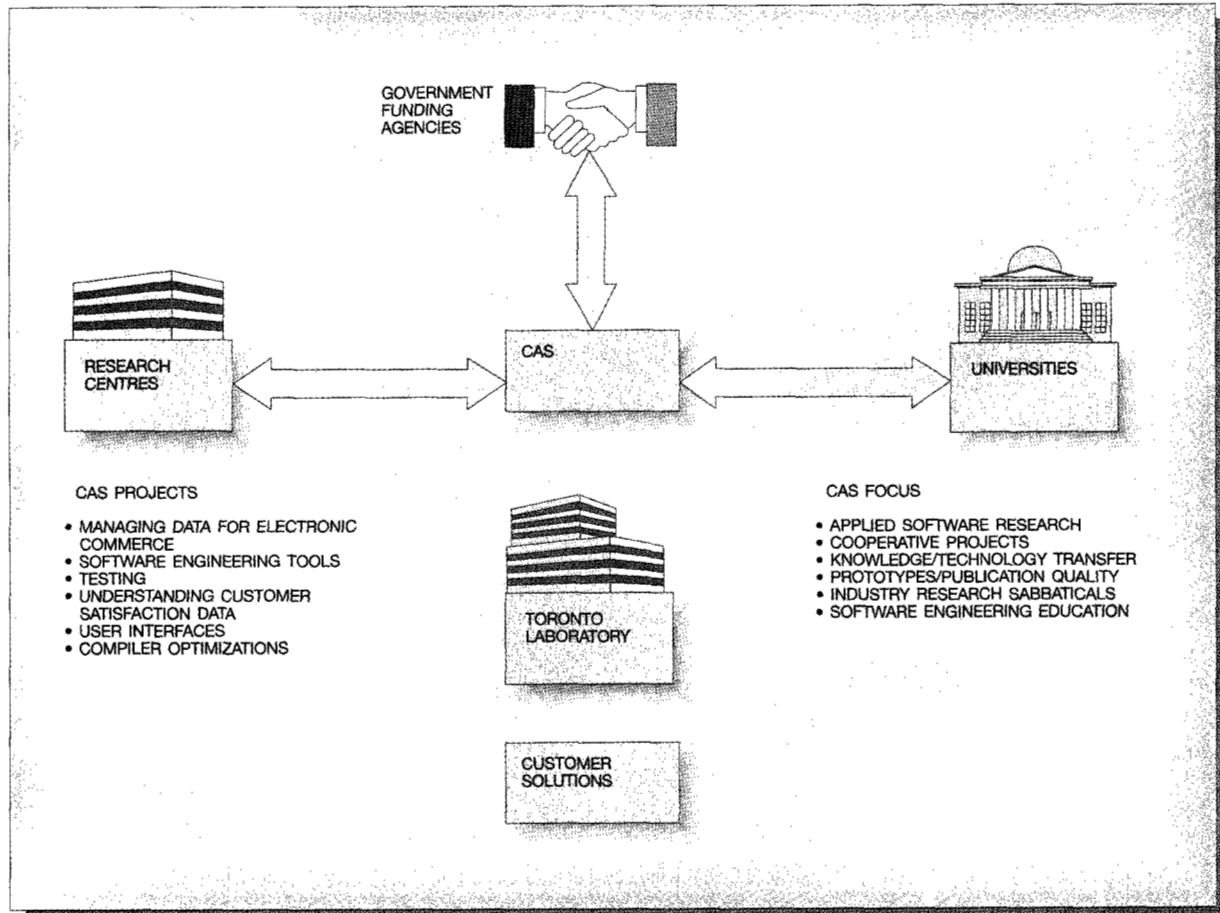
Since the research frequently originates at universities, the ideal approach is to support researchers through grants and to provide them a place to work and a project to work on during their Ph.D. research or sabbatical years (see Figure 1). The benefits of this approach increase when the researchers are "on site," working regularly in close proximity to development groups.

CAS in the past

The Centre for Advanced Studies (CAS) was formed in 1990 primarily to take commercial advantage of world-class research projects. It has a mandate to support collaborative research, involving the IBM

©Copyright 1997 by International Business Machines Corporation. Copying in printed form for private use is permitted without payment of royalty provided that (1) each reproduction is done without alteration and (2) the *Journal* reference and IBM copyright notice are included on the first page. The title and abstract, but no other portions, of this paper may be copied or distributed royalty free without further permission by computer-based and other information-service systems. Permission to *republish* any other portion of this paper must be obtained from the Editor.

Figure 1 The Centre for Advanced Studies



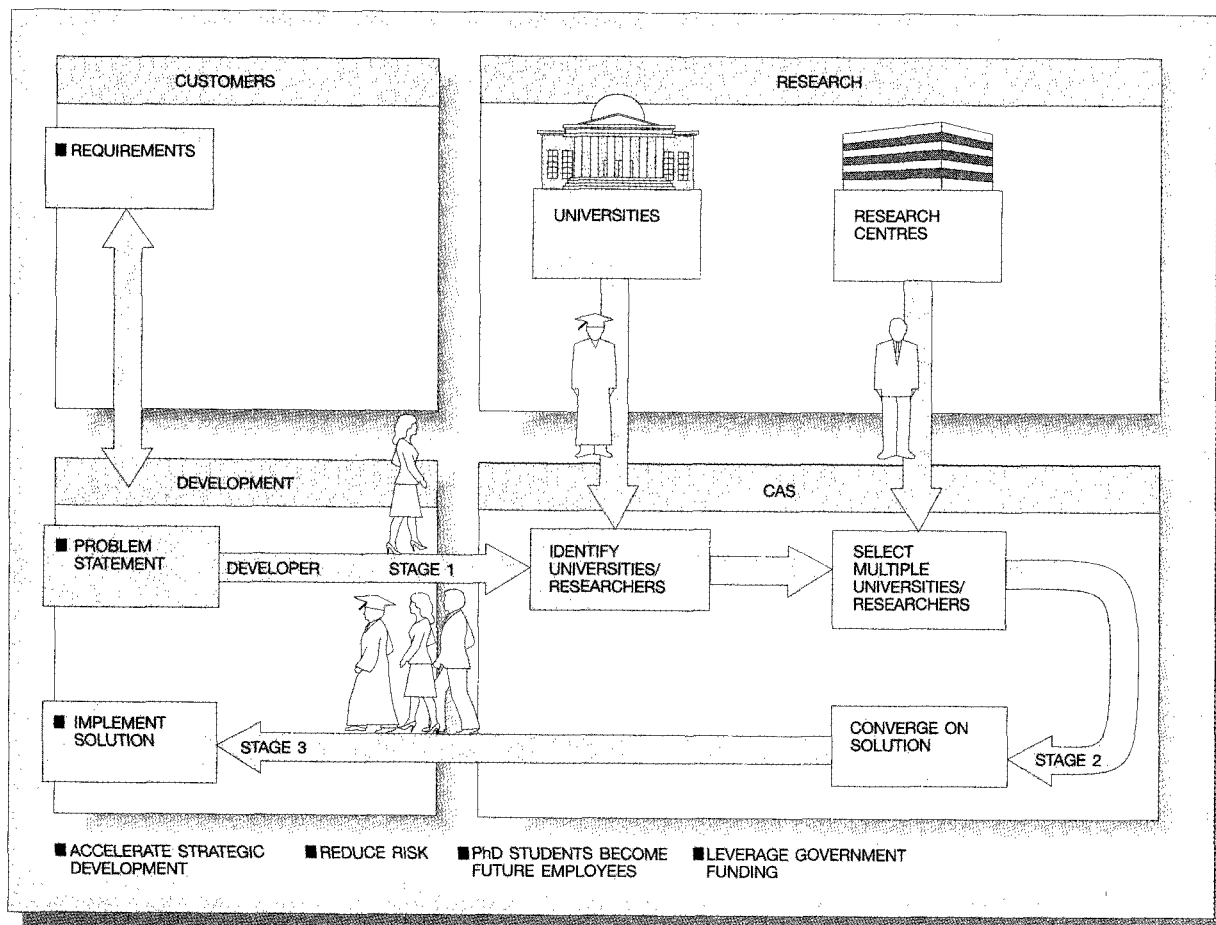
Software Solutions Toronto Laboratory and other IBM laboratories, where that research applies to specific, existing, or planned products. This model differs from the models traditionally employed by other industrial and government funding agencies. CAS has led the way with this approach; there are a number of similar efforts that have started since 1993. (See the September 1996 issue of *Communications of the ACM*.¹⁾)

Meetings were held throughout 1990, involving small groups from IBM Research, universities, and the IBM Toronto Laboratory. The framework for CAS evolved during this period, balancing the needs of both researchers and IBM software developers. A process was established for proposing new projects for solving identified problems (see Figure 2).

The proposal process starts with the requirements of customers using IBM Toronto Laboratory products. The development organisations regularly track these requirements and formulate them into problem statements. Working with CAS, the developers approach university researchers working in appropriate areas, eventually selecting one or more researchers from one or more universities. CAS, the development organisation, and the researchers work together and converge on a proposed solution, and in most cases a working prototype, that is then implemented as a product or a product feature by the development organisation.

Working together accelerates strategic development while reducing the risk normally associated with research into new techniques and methodologies. As

Figure 2 The original CAS project life cycle



an added benefit, government policy in Canada and other countries encourages this sort of collaboration between academia and industry by matching IBM's investment with government funds. This is done in recognition of the increased importance of shortening the "pipeline" from research to products, and in keeping this pipeline filled.

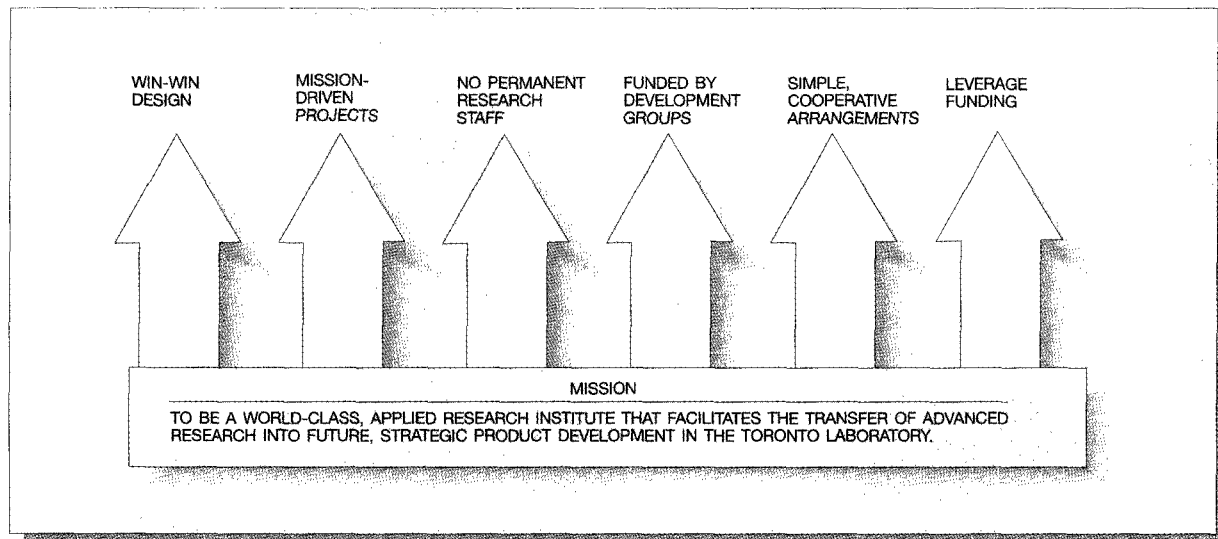
CAS operation. The first problem faced by the original CAS team was to balance the top goals of both researchers and developers. These goals are quite different. Researchers place high value on scientific freedom to pursue self-selected research goals as well as peer recognition. Software professionals place their highest values on timely delivery of product, staying within budget, high quality, and personal productivity. As an earlier paper suggests, researchers

want a breakthrough in their discipline, while developers want a market success.²

These conflicting goals are at the heart of a number of impediments to cooperation. The impediments must be overcome before beginning successful collaboration. Traditionally, the main impediment was a lack of contact—researchers and developers rarely had a chance to get together. The lack of contact was made worse by the natural suspicion of key persons in either domain for those in the other domain. There were other problems:

- Researchers frequently work on a smaller-scale problem than developers, who have scorn for "toy" solutions based on their experiences with solutions that do not "scale up."

Figure 3 CAS principles



- Professional accountability is quite different in academia and in the corporate world.
- The ultimate goals are quite different, since researchers want publication and recognition while developers want a successful product.
- The development environments are different, from group cultural issues such as starting time to hardware incompatibilities.
- Many other reasons are listed in the previously cited paper.²

Reconciliation of these problems was proposed through the creation of the Centre for Advanced Studies. CAS was formed to recognise the fundamental differences between university research and development problems and to bridge the gaps.

Figure 3 shows the principles that were defined for CAS:

- *Win-win design.* CAS was formed with the assumption that researchers need to understand the objectives of a development community, while developers need to acknowledge the crucial part played by ongoing research in an appropriate environment.
- *Mission-driven projects.* All CAS projects were to be directly related to products being developed at the IBM Toronto Laboratory and to have a timeframe of less than five (and preferably fewer than

three) years. Projects would be supported by the appropriate development group(s). The short development timeframe would lead to a *focus on prototypes*—practitioners are not easily swayed by theoretical solutions that have never been implemented.

- *No permanent research staff.* CAS was formed with a goal to have staff assigned for periods ranging from six months to three years. The assignment was to be for a specific project, and a successful result lead to a follow-on assignment with the development organisation, to finish the resulting product.
- *Projects funded by development groups.* At least part of the funding would come directly from the development group benefiting from the project. Following this principle would ensure that projects were relevant to the group and help establish the value of the project in the group's plans.
- *Foster simple, cooperative arrangements with experts and emphasise personal contacts and networking.* In the end, it is the work of individuals that counts. The goals were to keep all contracts very simple and to avoid issues of intellectual property rights from the start. Also, CAS would avoid paying overhead, mostly by funding students instead of researchers or institutions. Government funding through matching grants and associated programs would be used to cover real costs associated with overhead.

- *Leverage funding.* Projects sponsored by CAS have higher-than-average risks. It was expected that these projects would usually be supported through grants, either from within the corporation or from various government funding agencies.

CAS initiatives. During its first four years, CAS initiated 15 research projects. The number at this time is between 55 and 60. During the last three years, a number of other initiatives have been undertaken in support of the stated goals, including:

- *Research fellowships.* CAS supplies university researchers with interesting problem topics that are relevant to the IBM Toronto Laboratory missions. Once one of the topics is agreed upon, CAS provides a fellowship for one or more Ph.D. students to work under that researcher's supervision on the problem. The fellowship includes three or more months spent in CAS, where the student meets peers, other researchers, and developers. The original intent was to focus research more closely on identified development problems, and this has been a clear success.
- *Sabbaticals.* Before CAS was founded, the IBM Toronto Laboratory did not have exceptional success in attracting university researchers to spend sabbatical leaves at the laboratory. CAS provides both a focus and an introduction for the researcher to meet and interact directly with development groups. CAS now hosts a number of visitors on sabbatical leave.
- *Visiting scholars.* While not as prominent, this program has successfully hosted leading researchers in some fields without forcing their direct involvement in any specific product. This is considered an investment in the future.
- *CASCON (Centre for Advanced Studies conference).* The first CASCON was held less than a year after CAS was formed. The focus of this conference is on bringing together researchers, government employees, developers, and customers in a forum where ideas can be freely shared. This goal has been repeatedly met, and CASCON is regarded as a premiere event on many researchers' calendars. Researchers on current CAS projects use the time to meet and present results. The software development teams show their current work and examine competitive products. Researchers present tutorials and workshops on their areas of expertise. And customers see the direction that research is taking and help steer it to the areas they consider critical for them.

CAS in the present

CAS is now in its seventh year and it is still evolving. The original reasons for forming the centre have not changed and the original goals are still in place. After seven years, some patterns have started to take hold. For example, most projects involve one development group but many universities. All projects use government funds to leverage IBM's investment, sometimes by factors of 7 or more, although more typically factors are 2 or 3.

For the first six years, Dr. Jacob Slonim, one of the founders of CAS and its leader, ran the centre. Recently, Dr. Gabriel M. Silberman was appointed program director of the Centre for Advanced Studies, beginning July 1997. As part of the search for a new director, the mission and performance of CAS was closely examined and evaluated by a team of leading academics, consultants, and the senior management of the IBM Toronto Laboratory. This process served to revalidate both the goals of CAS and its value to IBM in general, and to the laboratory in particular.

Current CAS operation. Experience has helped CAS refine its principles of operation, but other factors have been involved as well. For example, after seven years of operation, university researchers are now very familiar with the IBM Toronto Laboratory and with CAS. As a result, researchers are now initiating proposals, identifying promising research at earlier stages, and introducing it to the development groups who can then decide what might best meet anticipated customer requirements. Nevertheless, proposals are not solicited from the academic community at large, since a key element for success is familiarity with the laboratory environment and its developers.

Developers have come to recognise CAS as an excellent resource for dealing with technologically risky proposals, using CAS teams to leverage both research and government funding. The trend for companies, IBM included, to prefer research that has shorter pay-back times and smaller costs has also changed the scope of CAS projects.

Examples of recent projects. *POET* (Partial Order Event Tracer) started as the *Shoshin* subproject, which was part of the *MANDAS* (Management of Distributed Applications and Systems) project that was itself an outgrowth of the Consortium for Research on Reliable Distributed Systems (also known as

CORDS). Projects tend to "spin off" new projects that take advantage of technology as it is created. CORDS was a very large project involving 14 universities, 39 faculty members, 54 students, and 15 IBM employees. CORDS produced over 150 conference submissions as well as more than 40 journal articles and 24 technical reports. MANDAS was a logical continuation from CORDS, focusing on creating a prototype environment for designing, building, and managing distributed applications. In its first year (1995), MANDAS resulted in two licensing agreements with IBM including the rights to create derivative works: LQM (layered query model), and POET. The LQM work addressed generating template files solely from data reported by instrumentation.

The objectives of POET cover three areas: distributed debugging, the design of management interfaces for distributed applications and systems, and the visualisation and monitoring of applications. The result is a powerful debugging toolset for distributed applications. POET has been incorporated into the IBM Component Broker³ product, adding functionality that would not have been available without the university involvement. Two of the students working on fellowships as part of the Shoshin project were subsequently hired by IBM, satisfying another of the principles under which CAS operates.

A second example is the work done with *DataJava* as part of IBM's DB2* (DATABASE 2*) product, developed at the IBM Toronto Laboratory. Customer surveys indicated that there was a sudden and growing interest in having Java** applets included in database offerings. Since Java was relatively new and not yet part of mainstream products, this was a perfect example of how CAS could help. The DataJava project involved a principal investigator from CAS working with two developers, a professor, a fellowship student, and another funded student. The first version of DataJava was shipped in an early release, resulting in IBM having a key competitive edge in the market. This same team has worked to refine the features that will be incorporated in the next release, expected to be available in 1997.

Current CAS principles. Most of the CAS principles described earlier are still valid in the current environment.

Win-win design. This is even truer today than when CAS was founded. Industry is able to bring extensive resources to bear on specific problems that affect the corporate bottom line. This focused effort means that

companies like IBM can be doing work that is more sophisticated than that underway at universities. Thus, companies can actually advance the state of the research, making the exchange of technology a truly two-way process.

Software consumers are better informed through media attention and because of the Internet. As a result, there is increasing demand for solutions that

**Most of the CAS principles
described earlier
are still valid in
the current environment.**

push the envelope of technology. This coincides with government and corporate policy initiatives that support short-term applied research. CAS has proven itself to be an excellent vehicle for achieving these goals.

A third way that CAS has created a win-win situation is by broadening the lines of communication between academia and industry. Professors and Ph.D. students doing research jointly with IBM bring a positive message back to the university. This shows up in classroom dialogue as well as career counselling. The result is a better understanding by faculty and students of the type of work done at the IBM Toronto Laboratory. Similarly, developers working with researchers see how research can be directly applicable to real-world problems. This has led to an increasing number of developers returning to university for full- or part-time postgraduate degrees.

Mission-driven projects. CAS-supported projects have expanded beyond simply enhancing existing products or creating new ones. Researchers who have worked with IBM developers through CAS-supported projects have proposed additional projects that improve the development environment. CAS now supports projects to help with the software development infrastructure, including software testing, user-centred design, marketing, etc. Other projects being proposed include examining electronic cultures and devising means to better procure goods through electronic commerce. One example is a data-min-

ing research project: survey data from customers using products developed at the IBM Toronto Laboratory are searched in an effort to improve product marketing, packaging, features, and support. This is an example of how the laboratory gets an extra benefit by being among the first places where cutting-edge technology is used in real-world applications.

No permanent research staff. The perception among the IBM employees currently working in CAS is that many act as project managers instead of researching a specific topic. Given the original life-cycle model, this should not have been possible. Under the original model, the IBM employee would come from a development team with a specific problem based on a customer requirement. The newly minted CAS member would then work on a solution before returning to the development group. This would be a focused effort with few distractions from the specific project.

As researchers have become more familiar with the IBM Toronto Laboratory, and as development groups have learned the benefits of working with outside researchers, the number of successful project proposals has exceeded the number of employees available to work in CAS. As a further factor, the researchers have become familiar with specific CAS members, forming relationships that carry over into new project proposals. The end result is that CAS researchers are now managing multiple projects.

Projects funded by development groups. This was one principle that did not hold up very well. Conceptually, the idea that a project should be funded by the group that hopes to benefit from it is a good one. The problem arises from corporate funding priorities and from product delivery pressures. Since CAS projects do not offer immediate payback, nor do they usually affect current product deliverables or timetables, they may be given a lower priority. Similarly, when a project is under severe time pressure due to shortened deadlines or staffing issues, such as the sudden departure of a key employee, it makes short-term sense for the project to borrow resources from longer-term efforts, such as those involved with CAS.

Because of this, CAS has been funded at the laboratory level, allowing for modest growth on a year-to-year basis. Nevertheless, some development groups are still willing to directly support many projects, creating a dual system for funding and room for growth in those areas of particular interest for developers.

Foster simple, cooperative arrangements with experts and emphasise personal contacts and networking. Unlike the previous point, this one stands virtually unchanged. Researchers are now so in tune with CAS and with the IBM Toronto Laboratory that they regularly propose new projects. The contracts generally do not include payments to cover overhead, and CAS is quite successful in helping to negotiate matching funds through grants. The matching funds can then be applied to the overhead costs.

The current proposal model is illustrated in Figure 4 (a revision of Figure 2; note the horizontal line connecting university personnel to requirements). It also serves to make the relationship between researcher and CAS member critical. Experience has shown that the initial direction toward small contracts that do not spend excess energy on intellectual property rights has been beneficial and has not caused undue problems.

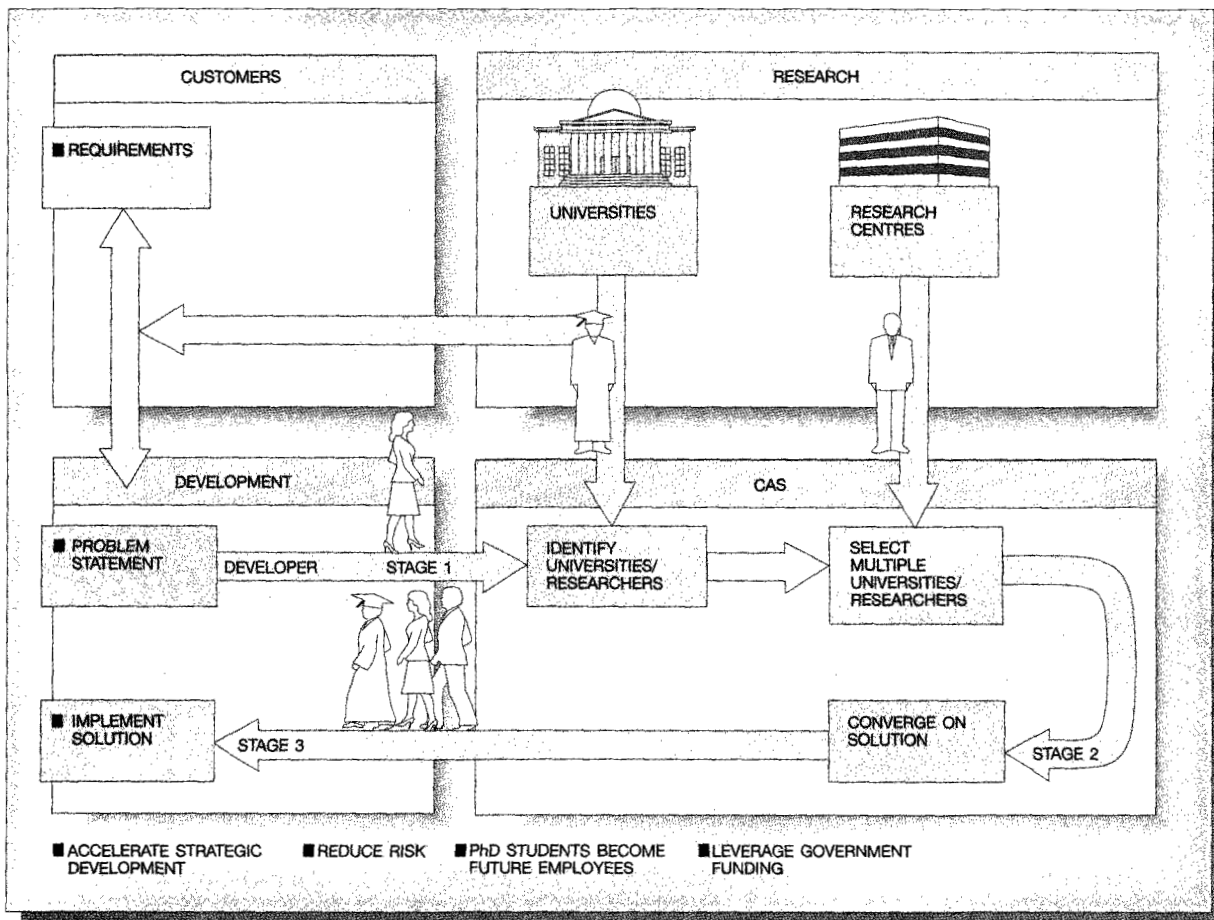
Leverage funding programs. Funding programs, especially those from government agencies, continue to supply some of the resources used in CAS research projects. CAS projects have been successful for IBM, for the researchers, and for the computing community in general through the publication of papers, such as those appearing in this and a previous issue of the *IBM Systems Journal*, as well as papers in many other publications and at conferences throughout the world.

Canadian government funding, as that of other governments, has turned toward encouraging academics to work directly on problems that are relevant for industry. Thus, a researcher who is working with CAS is a highly suitable recipient for these funds. Government agencies have come to understand and respect CAS, both for its unique model that closely matches the government initiatives and for the continued success in moving government-sponsored research directly into products.

This familiarity recently made itself apparent when CAS was instrumental in helping establish, and then incorporate, the Consortium for Software Engineering Research (CSER). Through CAS, IBM Canada plays a key role in this multimillion-dollar consortium that is dedicated to solving problems related to software engineering.

CAS also works with a number of Canadian centres of excellence, both federally and provincially supported. The success of these centres is unquestioned

Figure 4 The current CAS project life cycle



and the umbrella organisations for many of the federal centres, known as networks of centres of excellence have recently been given permanent status.

Current CAS initiatives. The current initiatives include those described earlier.

Research fellowships. CAS currently has 30 research fellowships as well as a number of students funded through leveraged grants. Research fellows, particularly those in the final years of their Ph.D. programs, find it refreshing to talk to other students in similar situations but from different universities and, sometimes, from different fields of research. There is a constant flow of information as they learn more about one another's interests and areas of work.

This year, in order to encourage this type of interaction and to make the research known to the IBM Toronto Laboratory community, all research fellows on site were strongly encouraged to present their area of research interest and their particular project with CAS. Each was given approximately 20 minutes to make a presentation; the invited audience included the entire Toronto Laboratory. There already appear to be a number of synergistic ideas, and the students were universally pleased with the outcome. We expect these student presentations to be a regular summer event.

Another way research fellows are encouraged to share their work is through poster displays as part of CASCON. The researchers are provided with a highly visible display area and a standard setup.

CASCON attendees can then visit, learn about the particular topic, and interact with the researchers to discuss possible new applications for the research. This was initially tried at last year's CASCON with an extremely favourable response, leading to the adoption of posters as a regular feature for future CASCONs.

Researchers also participate in CASCON through published papers and through demonstrations.

Sabbaticals and visiting scholars. CAS continues to support a number of professors during their sabbatical year. As relationships have formed between researchers and developers, these visitors have moved from the CAS office area and are now likely to be found sitting in borrowed office space next to developers working on projects related to their area of interest. This is an interesting development in that proximity leads to increased interaction. While the research fellows lose regular contact with CAS members, the development teams gain by more frequently consulting the "free" research help available. The researchers benefit from working on detailed problems and this generates mutual respect between the developers and the researchers.

Industry faculty support. The Canadian government has a program to encourage industrial support for non-Canadians taking tenure-stream faculty positions at Canadian universities. Through CAS, IBM contributes \$25 000 for supported, non-Canadian faculty.

CASCON. The CAS conference now features demonstrations of current research, keynote addresses by prominent researchers and public figures, and a large number of tutorials, workshops, and panel discussions. There are a number of features that make this conference unique. CASCON is still open only to invited participants, although the criteria for invitation is kept fluid.

First, CAS sponsors the conference in conjunction with the Canadian National Research Centre and a number of the Canadian centres of excellence. The sponsorship covers the entire conference, including site rental, equipment for the demonstrations and presentations, and food. Demonstrations all have a similar look, with IBM responsible for the signs (one banner title, one list of highlights, and one list of researchers). CAS also arranges for all but the most arcane equipment, networking, etc.

Second, the conference brings together researchers, developers, and end users. Roughly half of the more than 1100 attendees come from the IBM Toronto Laboratory, with the remainder split about evenly between researchers and end users. This mix is perfect for furthering the CAS mission of making research results part of useful (and profitable) products.

The published proceedings⁴ have a definite value as archival records, especially to academic researchers and students. The effort required to support paper submission, a serious refereeing process, and publication on both paper and CD-ROM is enormous. This year, besides moving to an all-electronic, Web-based submission and review system, the main burden of managing the paper review and selection process has been taken over by NRC (the National Research Council of Canada), still with very strong CAS participation on the program committee.

Tutorials, workshops, and panel discussions cover a wide variety of topics—as diverse as the researchers, developers, and customers who chair the sessions and participate in them. There is an attempt to focus each session along the functional divisions of the IBM Toronto Laboratory, something that is difficult with up to five parallel sessions, plus paper presentations, poster displays, and demonstrations of current research.

Influencing university curricula. CAS uses its excellent contacts with leading academics to encourage universities to use IBM products. For example, the IBM Toronto Laboratory is the key site for development of VisualAge* for Java. This is a premiere visual-builder environment for Java applications and applets developed and sold by IBM. CAS is taking a leadership position, together with its academic partners, in promoting the use of Java in introductory programming courses around the world. This is an excellent example of using CAS as a vehicle to strengthen the programs of study at the universities, with high-quality, relevant tools and technology available to the next generation of computer scientists and developers.

With the new sense of trust built up between CAS, its members, and university faculty, this relationship allowed the identification of minor impediments that might otherwise have been stumbling blocks for using VisualAge for Java. The existing partnership between universities and IBM made it easier for developers to find extra resources to address these

problems and produce a better overall programming environment.

CAS was a founding member of the Consortium for Graduate Education in Software Engineering (ConGESE). This is a cooperative effort involving six universities (Carleton, Ottawa, Queen's, Toronto, Waterloo, and Western Ontario), the Information Technology Research Centre (ITRC), Bell Northern Research (now Nortel), and IBM. ConGESE provides education intended to lead to a master's degree in computer science for software professionals. ConGESE administers the courses and arranges the curriculum. The universities supply faculty and are ultimately responsible for granting the degree. The companies supply willing students who have requested entry to the program through normal academic channels. (The universities are ultimately responsible for approving each applicant and for granting the degree.)

Impact on elementary and secondary curricula. The current and projected shortage of information technology workers is a problem faced by academia, industry, and governments around the world. One of the initiatives of CAS is to expose junior high and high school students to careers in information technology, with the goal of encouraging young people to enter this exciting profession. Recently, with the participation of the IBM Toronto Laboratory User Technologies team and volunteers from a variety of areas in the laboratory, a pilot computer camp was held for students in grades 7 and 8. The students travelled to Toronto and spent a half day in the User-Centred Design Lab. In the first part of the session, volunteers from several areas of product development (such as user-centred design, development, test, multimedia design, information development, and support) described briefly how they participate in the design and development of a piece of software. The students learned that there are many facets to software development besides programming. In the second part of the session, the students developed their own Web page using tools developed at the laboratory. A volunteer gave guidance to each student as he or she worked on Web page development. The computer camp organizers received positive feedback from the participants, and plans for the next set of computer camps are currently underway.

Executive advisory board. Twice a year the chairs of departments of computer science are invited to meetings with the director of the IBM Toronto Laboratory. These meetings are intended to influence the

direction of the IBM Toronto Laboratory, reciprocating the CAS influence on the direction of computer science curricula in the universities.

CAS-supported projects. Recently, CAS regrouped projects into basic areas reflecting the IBM Toronto Laboratory missions. All projects are now placed in one of four broad categories. There are two benefits: first, the projects are now aligned with development in very obvious ways, and second, researchers belong to smaller, more focused groups. This encourages closer teamwork and helps build intra-group relationships.

The projects involve working with three IBM research centres (Thomas J. Watson, Almaden, and Zurich), 13 Canadian universities, 12 United States universities, and one European university. Figure 5 shows the four categories. The user technologies area provides solutions for all of IBM, including the main product divisions in the IBM Toronto Laboratory—application development tools, database, and network computing. The CAS projects are aligned with one or more of these divisions. For example, the projects relating to compiler optimisation are useful in both application development (which includes compilers) and database (for products such as DB2). The "data mining" project is clearly tied to database, but it is also useful for the electronic commerce projects developed in the network computer division.

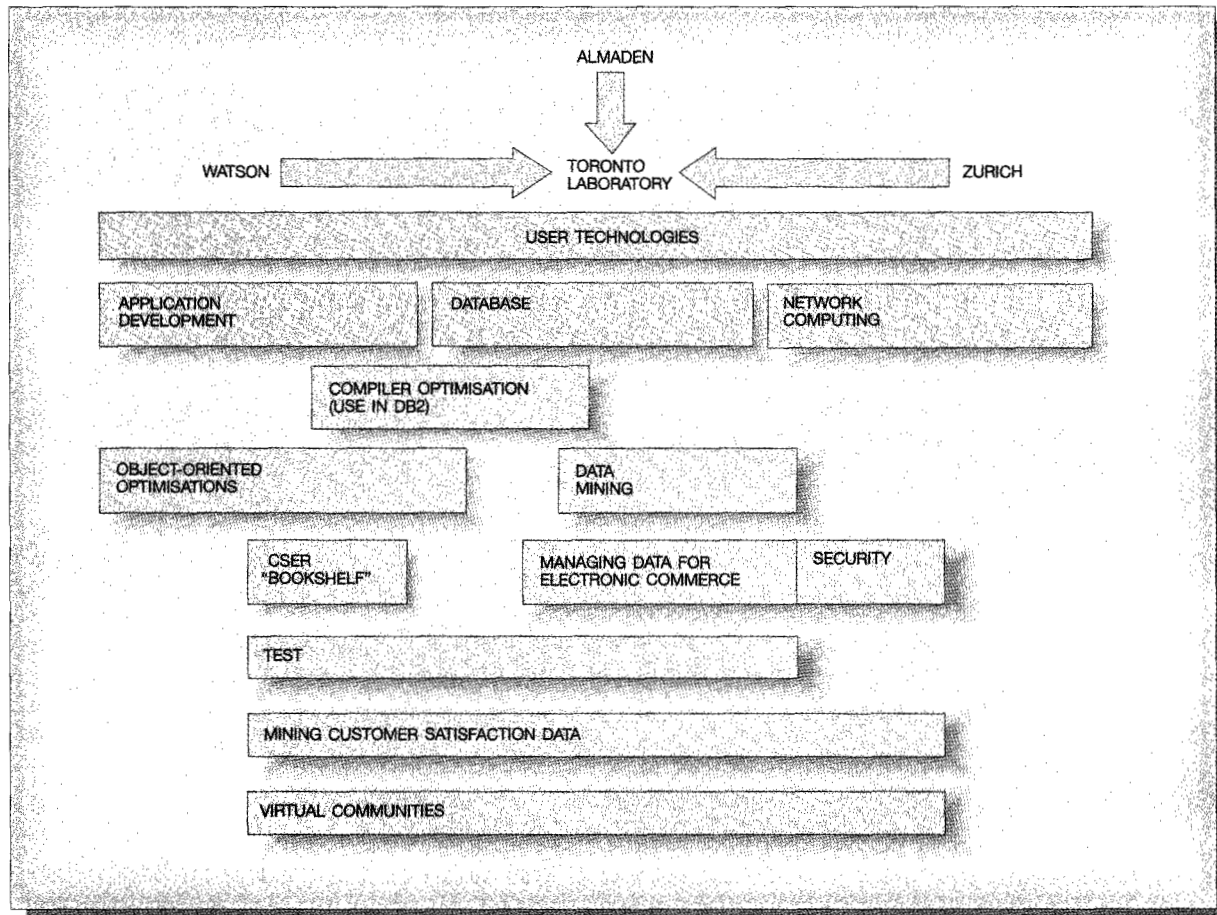
Managing data for electronic commerce. The computing world is moving from host-centric to network-centric computing. The network environment means that issues concerning the management and access of distributed data are no longer restricted to databases; they encompass intranets and the entire Internet.

Furthermore, as speed, power, and bandwidth increase, and digitised voice and video data become more available, the amount of unstructured or partially structured data is exploding.

The combination of these trends, and the popularity of the World Wide Web and applications such as electronic commerce, require research into the optimisation of storage, access, and retrieval of unlimited amounts of data, including partially structured data. Data management is part of the basic infrastructure of a network-centric environment.

Massively parallel systems have traditionally been used to solve scientific and engineering problems.

Figure 5 CAS-supported projects for 1997



We are interested in applying some of the basic ideas in high-performance computing to high-performance data management. We are studying how to use clusters of workstations and shared-memory multiprocessors in a network-centric environment to support data management with virtually unlimited amounts of data and users. In this project, we are concentrating on managing data for electronic commerce applications.

Electronic commerce means that all the transactions required for selecting a product or making a purchase are carried out electronically. In business-to-business commerce, where bids are received and large amounts of business take place over intranets or private VANs (value-added networks), these transactions include catalog search, invitations to quote,

purchase requests, purchase orders, invoices, and payments. In business-to-consumer commerce, World Wide Web (www) technology over the Internet is used to facilitate querying, browsing, and navigating several vendors' catalogs, as well as credit-card and electronic-cash purchases.

Although some of the requirements may be different for the two types of electronic commerce (business-to-business and business-to-consumer), both will need to be able to manage large amounts of multimedia data efficiently in heterogeneous repositories. Both also need to provide interoperability between heterogeneous sources, guarantee secure, private transactions, and move multimedia data over large-scale global networks such as the Internet.

Vendors need to be able to take existing data (some of which may already be stored electronically), enhance it with digitized video, audio, and images, and manage the data. They need high-performance, distributed servers that can handle large volumes of global transactions on this data, reliably and consistently. They also want to be able to interpret the data on line using on-line analytical processing (OLAP), data mining, and decision-support-type queries in order to provide better services to their customers.

Buyers need to be able to access product information without having to learn how to query and browse each different repository. They want to be able to make purchases that are not traceable to them in a way that their payments are safe and secure.

The objectives of this project are threefold: to study access to heterogeneous multimedia data in a transparent fashion, to provide improved system and network performance for electronic commerce and data mining (as information systems are extended outside an organization), and to research specific issues in electronic commerce such as security and pricing models. Some of this work is based on results from an earlier project that studied the underlying technologies for designing distributed multimedia applications. Results from this earlier project are presented in a paper⁵ in this special issue of the *Systems Journal*.

CAS is also active in supporting the nascent Global Institute for Electronic Commerce, recently founded by Dr. Yelena Yesha of the University of Maryland and NASA's CESDIS (Center of Excellence in Space Data and Information Sciences).

CSEER bookshelf and related software engineering tools. The largest project in this area is investigating the transformation of legacy code to object-oriented code, in conjunction with the Canadian Consortium for Software Engineering Research. This project was started with the consortium to provide an industry-driven focal point for software engineering research and is a spin-off from one of the earliest CAS projects on program understanding. The program-understanding research has been applied in a general way to laboratory products, but this is the first place where a specific focus has been placed on the development of an environment for the construction of software tools such as the software bookshelf,⁶ described later in this issue.

A second project in this area focuses on managing distributed applications and systems. The MANDAS project is being completed after generating a number of ideas that are incorporated in IBM processes and products, as well as a large number of academic papers. The MANDAS paper,⁷ found later in this issue, is an excellent review of some of the work in this area.

CAS also continues to support research on garbage collection in C++ and compiler optimisations. And CAS is supporting some work being done in conjunction with the VisualAge for Java programming system.

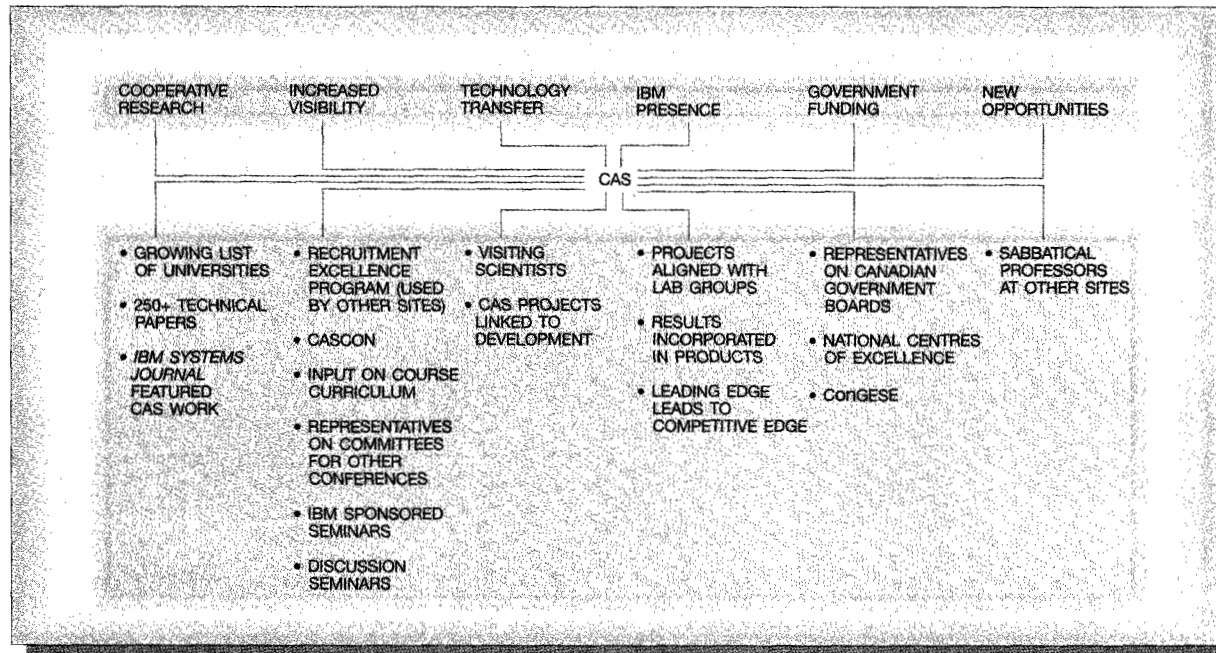
Testing. CAS supports a research project on testing strategies. Testing is an *ad hoc* process today and it consumes more than 50 percent of the cost of developing software. As part of the research, different approaches to testing are being investigated, such as white-box testing and coverage-based reliability models. The research partners for this project, as well as industry representatives, participated in an IBM Academy of Technology study of issues associated with software testing.

User interfaces. One project is investigating how human/computer interaction can be made clearer and more efficient. A second project is being proposed to investigate *virtual communities*. This second project will cross the boundaries between electronic commerce and user interfaces but will initially focus more on the user interface aspects. The initial proposal will focus on commercial aspects of virtual communities and will work with IBM's *Net.Commerce* product development group. This project will later grow to encompass a wider range of research, and it is likely to expand outside of computer science to work with researchers in sociology and linguistics who are investigating computer-mediated communications.

CAS in the future

CAS will continue to be a vigorous and contributing component of the IBM Software Solutions Toronto Laboratory. Our intent is to continue to focus on the IBM products developed at the IBM Toronto Laboratory (as well as those of other IBM laboratories). This includes compilers, database systems, electronic commerce solutions, and user interfaces. The future plans include expanding outside of North America and there are already international projects underway, such

Figure 6 Evolving strategies and relationships



as the virtual communities work with INSEAD (Institute European Administration d'Affairs) in France.

Since CAS projects typically are based upon a three-to-five-year development cycle, we do not expect sudden or massive changes in our mandate. We expect moderate changes; for example, the current focus has drifted away from compiler-specific projects and into the broader area of application development tools. CAS is viewed as a source for lifelong learning for CAS members in particular and for the IBM Toronto Laboratory as a whole.

Other areas where product development groups have expressed an interest in getting help from CAS, and through it the academic community, are similar to those already described. CAS is helping bring together groups outside the original mandate, such as the work being done in bringing Java into universities. This benefits both IBM and the university.

Evolving strategies. CAS is constantly in a discovery mode, learning how best to adapt to our changing society. The original model has been successful and will continue to be used as a guide for future efforts, but new developments require CAS to be flexible and to evolve strategies and relationships (see Figure 6).

For example, the original CAS model was for IBM employees to spend at most three years in CAS: starting on a new project, pushing the edges of technology forward, building a working prototype, and then joining a development team to implement the final product. In practice, staff researchers in CAS have moved from project to project, or participated in several projects, as development interests have changed and interactions with faculty and students have warranted. As a victim of its own success, CAS has forced an administrative responsibility on its staff that requires continuity to ensure smooth operations and proper nurturing of relationships. The original principle of *no permanent research staff* will continue to be examined in light of these concerns.

CAS will continue to look for projects that have a *win-win* design, allowing researchers to take away as much as they offer and allowing developers to learn while they push the boundaries on products and product features.

It has also become apparent that CAS cannot afford to have all its employees focused on their own individual projects. First, there are too many potential areas to be examined. Second, a one-person, one-project focus does not allow for the best leverage of

researcher talents and government funding. Third, this focus would add extra risk to a project in that one person would become the indispensable link between research and development. Since CAS is always trying to attract the best minds, CAS researchers become prime targets for "poaching."

While IBM supports pure research in scientific endeavours, CAS focuses on applying research by building a prototype or by incorporating the results into a product. Initially, this application of research was characterised as *mission-driven*, mostly due to the life-cycle process being followed at that time. As more projects are proposed outside the traditional development process, the focus turns to a broader category of *product-oriented research*. This applied research can sometimes lead to further, more open-ended problems. Given the CAS relationship and the benefits that accrue to a researcher with partners in the nonacademic world, it is sometimes desirable for this research to continue as a CAS project, in spite of the looser ties to development plans.

CASCON hosts some very evocative demonstrations. It is an event where technologists can show off the future directions of software research and development. The conference continues to provide a forum for the exchange of ideas among government workers, researchers, developers, and end users. CASCON must also balance the conference value as a showcase for new technology with its role as education for employees of the IBM Toronto Laboratory and its other roles, such as providing a common meeting ground for researchers, developers, and customers.

There have been several CAS initiatives that were developed to foster research and to encourage the transfer of technology from research to development. These programs will continue, and include:

- Research fellowships
- Sabbaticals
- Visiting scholars
- Executive advisory board
- University adjunct faculty

Long-range goals. CAS will grow over the next few years. This growth will be in the form of new members as more developers join to become project mentors. It will also be in the form of more projects, now that the research community and the development community have learned to understand each other and to understand how CAS can be the meeting ground for their joint efforts. CAS will grow by seek-

ing out international partners in order to tap into research performed outside of North America.

*Trademark or registered trademark of International Business Machines Corporation.

**Trademark or registered trademark of Sun Microsystems, Inc.

Cited references and notes

1. The September 1996 issue of *Communications of the ACM* (Volume 39, Number 9) contains a special section on technology transfer, moderated by E. A. Isaacs and J. C. Tang.
2. J. Slonim, M. A. Bauer, P.-Å. Larson, J. Schwarz, C. Butler, E. B. Buss, and D. Sabbah, "The Centre for Advanced Studies: A Model for Applied Research and Development," *IBM Systems Journal* 33, No. 3, 382-398 (1994).
3. See <http://www.software.ibm.com/ad/cb>.
4. See *Proceedings of CASCON '93*, Toronto, Canada (October 1993), *Proceedings of CASCON '94*, Toronto, Canada (November 1994), *Proceedings of CASCON '95*, Toronto, Canada (November 1995), and *Proceedings of CASCON '96*, Toronto, Canada (November 1996).
5. J. W. Wong, K. A. Lyons, D. Evans, R. J. Velthuys, G. v. Bochmann, E. Dubois, N. D. Georganas, G. Neufeld, M. T. Özsü, J. Brinskelle, A. Hafid, N. Hutchinson, P. Iglinski, B. Kerhervé, L. Lamont, D. Makaroff, and D. Szafron, "Enabling Technology for Distributed Multimedia Applications," *IBM Systems Journal* 36, No. 4, 489-507 (1997, this issue).
6. P. J. Finnigan, R. C. Holt, I. Kalas, S. Kerr, K. Kontogiannis, H. A. Müller, J. Mylopoulos, S. G. Perelgut, M. Stanley, and K. Wong, "The Software Bookshelf," *IBM Systems Journal* 36, No. 4, 564-593 (1997, this issue).
7. M. A. Bauer, R. B. Bunt, A. El Rayess, P. J. Finnigan, T. Kunz, H. L. Lutfiyya, A. D. Marshall, P. Martin, G. M. Oster, W. Powley, J. Rolia, D. Taylor, and M. Woodside, "Services Supporting Management of Distributed Applications and Systems," *IBM Systems Journal* 36, No. 4, 508-526 (1997, this issue).

Accepted for publication August 1, 1997.

Stephen G. Perelgut IBM Software Solutions Division, Toronto Laboratory, 1150 Eglinton Avenue East, North York, Ontario, Canada M3C 1H7 (electronic mail: perelgut@vnet.ibm.com). Mr. Perelgut received his M.Sc. degree in computer science from the University of Toronto in 1984. His research interests include compiler design and development, software engineering, software reuse, and electronic communications as they affect virtual communities. He is currently a full-time member of the IBM Centre for Advanced Studies and acting as both a principal investigator on the software bookshelf project as well as program manager for CASCON '97.

Gabriel M. Silberman IBM Software Solutions Division, Toronto Laboratory, 1150 Eglinton Avenue East, North York, Ontario, Canada M3C 1H7 (electronic mail: gabbys@vnet.ibm.com). Dr. Silberman is program director for the Centre for Advanced Studies at IBM's Toronto Laboratory. He comes to CAS from the Applications Systems Technologies department at the IBM Thomas J. Watson Research Center, Yorktown Heights, New York, where he managed the Wideband Processor and I/O Architectures group. He received the B.Sc. and M.Sc. degrees in computer science from the Technion—Israel Institute of Technology, and the

Ph.D. degree in computer science from the State University of New York at Buffalo. From 1980 to 1990 Dr. Silberman was on the faculty of both the Computer Science and Electrical Engineering departments at the Technion in Haifa, and from 1988 to 1990 he was visiting faculty at the Electrical and Computer Engineering department at Carnegie Mellon University. He joined IBM Research in 1990 as a research staff member. Dr. Silberman is a member of the ACM, the International Federation of Information Processing Working Group 10.3, and a senior member of the Institute of Electrical and Electronics Engineers Computer Society. He has served on numerous organising and program committees for professional conferences.

Kelly A. Lyons *IBM Software Solutions Division, Toronto Laboratory, 1150 Eglinton Avenue East, North York, Ontario, Canada M3C 1H7 (electronic mail: klyons@vnet.ibm.com).* Dr. Lyons is a research staff member at the Centre for Advanced Studies in the IBM Software Solutions Toronto Laboratory, working in the area of distributed multimedia applications. She received the B.Sc. degree in computing and information science from Queen's University in 1985, then started working in compiler development at the IBM Canada Ltd. laboratory. In 1987, she was granted an educational leave of absence from IBM and returned to Queen's. In 1988, she received the M.Sc. degree in computing and information science from Queen's University in the area of computational geometry. She received the Ph.D. degree from the Department of Computing and Information Science at Queen's University, on graph layout algorithms, in 1994. In 1996, she was appointed an adjunct professor at York University. Her research interests include distributed multimedia applications, ATM networks, distributed computing, database management systems, digital libraries, graph layout algorithms, and computational geometry.

Karen L. Bennet *IBM Software Solutions Division, Toronto Laboratory, 1150 Eglinton Avenue East, North York, Ontario, Canada M3C 1H7.* Ms. Bennet is the operational manager of the Centre for Advanced Studies. Her research interests include compiler development, electronic commerce, and user interfaces.

Reprint Order No. G321-5654.