Institute for Computational Mathematics
Annual Report
July 1, 1995 - June 30, 1996

prepared by

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INTRODUCTION

It is the mission of ICM to encourage and facilitate interdisciplinary research involving advanced scientific computing. In support of this mission ICM acts as a locus for interactions among researchers from Kent State University, industry and other universities, both in the United States and abroad. Although ICM is a unit within the Department of Mathematics and Computer Science, its associated membership includes faculty from several disciplines within the University. ICM provides its associate and visiting members with excellent computing facilities and a stimulating supporting environment for cooperative scientific efforts in computational mathematics.

ICM activities for the current reporting period are summarized herein under 7 major headings: Research Activities, ICM Visitors, Publications, ETNA, Symbolic Net, ICM Technical Reports, and Goals.

SECTION I: Research Activities

Research Directors:

Professor Richard S. Varga continues his research in the areas of complex approximation theory, linear algebra, and potential theory in the complex plane.

During the reporting period, Professor Varga visited the Bell Laboratories in Murray Hill, New Jersey, during the period July 1–August 20. He worked there with Drs. Freund, Landau and Odlyzko, continuing cooperative research between the ICM and Bell Labs. He also organized, with Professors Lothar Reichel and Arden Ruttan, a Special Session on "Numerical Linear Algebra and Scientific Computing," at the American Mathematical Society meeting in Kent, Ohio, on November 3–4, 1995. There were 21 half-hour lectures given at this Special Session, with participants coming from Argentina, China, and Germany, in ad-

dition to participants from the U.S.A.. Professor Varga also gave three invited lectures (Oct. 2-4, 1995) in the J. James Woods Lecture Series at Butler University in Indianapolis, IN, on topics covering analysis (the Riemann Hypothesis and zeros of the partial sums of e^z) and linear algebra (Gerschgorin and his circles), and participated in a Workshop on Modeling and Computations in Science and Engineering at Northwestern University (May 3–4, 1996), where he gave a talk entitled "Weighted polynomial approximation in the complex plane."

During this reporting period, Professor Varga served as a reviewer of NSF/CBMS proposals for Regional Conferences in 1997, and he continues his extensive editorial work, which involves serving as co-editor-in-chief of Numerische Mathematik and ETNA and as editor for seven other journals, one of which is French and one Chinese. Professor Varga has been involved in cooperative research efforts with Professor A. J. Carpenter (Indianapolis, IN), Dr. A. Krautstengl (Prague), Dr. G. Starke (Karlsruhe), Professor T. Manteuffel (Boulder, CO), Drs. A. Kroó and J. Szabados (Hungary), and visiting professor, Dr. I. Pritsker (a recent Ph.D. from the University of South Florida). Dr. Varga received partial external grant support in this period from NSF and also from NATO.

A complete list of Professor Varga's research publications for the reporting period is contained in Section III of this report.

Professor Paul Wang is an internationally recognized expert in the areas of Computer Algebra and Symbolic Computation. Dr. Wang's NSF funded research on parallel and distributed symbolic computation has been renewed to 1997.

His research on protocols, in general, and on the design of an efficient protocol for exchange of mathematical formulas and data, in particular has progressed very nicely. With graduate student Simon Gray and collaborator Norbert Kajler (France), the Multi Protocol (MP) project has generated three papers in refereed journals and the MP software package is being prepared for release.

Dr. Wang has also been building tools under PVM (Parallel Virtual Machines) to apply parallel computing in Symbolic Computation and to make such computations easier and more widely available to scientists and engineers. The tools are tested and ready for release. With graduate student Iyad Ajwa, he is applying these tools to investigate the parallelization of the Gröbner Bases algorithm, an important technique in the application of polynomial ideal theory.

Paul Wang's research group continues to make important contributions in Symbolic and Algebraic Computation (SAC). This central status in the SAC field has led to the NSF funding on `SymbolicNet`, a SAC research information center on the World-wide Web established and maintained by ICM. In the 1995–1996 period, `SymbolicNet` has been enhanced by improvements of content, addition of new facilities, such as live demos, and by increased cooperation with other sites. In January 1996, `SymbolicNet` was rated a *MAGELLAN Three Star Site* by the Magellan Company of The McKinley Group. (The highest rating is Four Star.) ICM will continue to improve and maintain this important Web service which pro-

vides SAC information worldwide and adds to the research visibility of Kent State University.

Paul Wang continues to develop the industrial connections of ICM. He has worked with Loral Defense Systems Akron (now part of Lockheed/Martin) on Object Technologies. He is also involved with Goodyear Tire and Rubber (Akron) in Object-oriented Design training. It is important for local companies to have ready access to the expertise available at KSU and ICM does its part in this direction. With the help of Kent Continuing Studies, a survey of local companies was conducted in order to identify the most needed areas for training and consultation in computing. As a result, Dr. Steve Chapin will be offering a summer intensive training course on "Network and System Security" for local industry. Many other areas of interest have been identified. ICM plans to expand efforts in this direction in the coming years.

Dr. Wang has submitted an NSF grant proposal to seek funding for Simon Gray as a postdoc at ICM. The grant will enable ICM to extend research in *Parallel and Distributed SAC Computations*, including protocol work, system interface, integration, and performance testing. The research on MP should contribute in significant ways towards the establishment of a common standard for the electronic exchange of mathematical data and formulas. Dr. Wang is also seeking Kent internal funding for a full-time postdoc position to add manpower to ICM. This will allow increased capacity to attract external funding needed to initiate collaborative projects with other departments and disciplines.

A list of Professor Wang's research publications for the reporting period are included in Section III of this report.

Numerical Analysis and Approximation Theory:

Researchers in these areas include Professors Alfred Cavaretta, Paul Farrell, E. Charles Gartland, Lothar Reichel, Arden Ruttan, Meera Sitharam and Richard Varga. The work of Professors Farrell, Sitharam and Varga is described elsewhere in this report.

Professor Alfred Cavaretta's primary mathematical interests are spline functions, numerical analysis, numerical quadrature, differential inequalities, approximation theory, classical analysis and optimization. He has recently submitted for publication two research papers, one on convergence of stationary and non-stationary subdivision (with A. Melkman of Israel) and one on lacunary interpolation by cosine polynomials (with A. Sharma, Univ. of Alberta, and C. R. Selveraj, Penn. State Univ.).

Professor Chuck Gartland has been on sabbatical leave during the 1995-96 academic year. During this period he has continued his highly successful research program of investigation of numerical solutions of problems in liquid crystals. His current research projects include investigation of liquid crystal tensor models, stripe phase instabilities in liquid crystals, liquid crystal display optics, nonlinear optics of liquid crystals and automatic code generations and problem-solving environments for liquid crystals. Two doctoral students continue their dissertation research under Dr. Gartland's direction, and one of his Master's student com-

pleted her work this year. Dr. Gartland and his doctoral students are supported by NSF ALCOM funding. During this reporting period, Professor Gartland delivered four invited lectures on his research activities.

Professor Lothar Reichel, a leading authority in numerical linear algebra, continued his research activities, with six new research articles to appear. He remains a co-principal investigator on an NSF grant with Richard Varga, and also continues as Editor-in-Chief of the ICM-based electronic journal, ETNA. During the reporting period, he has delivered 7 invited colloquia at a number of distinguished universities both in this country and abroad. He is currently directing two Ph.D. dissertations and two Master's theses.

Professor Arden Ruttan's most recent research in numerical analysis has been on optimal successive overrelaxation methods, best rational approximations and finite discretization modeling for liquid crystal phenomena. During this reporting period, he has been a senior research investigator on the ALCOM grant and is a co-principal investigator on the Eisenhower Professional Development Program. He was also active in obtaining some $20,000 in equipment funding and $5,000 in funding for the American Mathematical Society's regional meeting at KSU in the Fall of 1995. Dr. Ruttan is also managing editor of the electronic research journal ETNA, and is currently the systems director for the department.

Computer Science:

In this area, the major foci of the ICM associated faculty are parallel and distributed computing and scientific computations. Brief descriptions of the activities of these faculty members are given below.

Professor Johnnie Baker's research activities focus on the development of a computational model for associative computing and the establishment of algorithms and software for this model. This associative model is designed to provide a common platform for the development of appropriate algorithms and software for massively parallel computers in general and an extended version of SIMD computers in particular. Current work is underway to compare this model to other parallel models of computation. Other current research includes developing improved constant time algorithms requiring fewer processors for the reconfigurable mesh, embedding and emulating hypercubes on 3-D mesh architecture, and developing parallel algorithms and improved sequential algorithms that require less memory and running time for modeling organic compounds at the molecular level. Dr. Baker is currently directing two doctoral dissertations and is the departmental Coordinator for Computer Science. During the reporting period, he delivered two invited lectures and organized a special session on foundations and mathematical aspects of computer science for the American Mathematical Society Meeting held here at KSU in the Fall.

Professor Arvind Bansal's research interests include artificial intelligence, logic programming, programming language, parallel and heterogeneous computing, integration of symbolic and numeric computing, and computational biology. Professor Bansal holds a NASA GSRP

grant which supports his Ph.D. student for a three-year period. He has spent the 1995-1996 academic year on sabbatical leave in Melbourne, Australia.

Professor Kenneth Batcher and his students continue their studies of parallel algorithms to route Clos Networks on Clos Network machines. Research also continues on automated restructuring of code to extract parallelism from serial code and to investigate the effects of different types of routing schemes for current-switched traffic in a non-hierarchal network, where the normal constraints of symmetry and Poisson traffic do not hold. Professor Batcher continues as director of several doctoral and master's candidates.

Professor Steve Chapin currently heads the Heterogeneous Operating System Software (HOSS) and MESSIAHS research efforts here at KSU, and is working in the area of distributed operating systems and heterogeneous distributed processing. During the reporting period, he has published one research paper and had one other accepted for publication. Professor Chapin has recently been awarded a one-year $94,000 research grant by Sandia National Laboratories.

Professor Paul Farrell is currently a co-principal investigator of the NSF Center for Advanced Liquid Crystalline Optical Materials (ALCOM) and is a member of the IMACS Technical Committee on Partial Differential Equations. His research interests are parallel numerical computation and algorithms, application of numerical methods to singularly perturbed differential equations, semi-conductor devices, Navier-Stokes equations and liquid crystal problems, scientific visualization, data communication and networking, automatic code generation for parallel architecture, application of expert systems in numerical computing, and mathematical text processing. During the reporting period he published two research papers, had four others accepted for publication, delivered a paper at the Oberwolfach Conference on Numerical Methods for Singular Perturbations and attended an NIST Workshop on Modeling and Simulation of Structure Formation in Liquid Crystals. He also aided in obtaining a $6,000 KSU Research and Graduate Studies Equipment Grant for enhanced graphics.

Professor Cheng Lu's research interests are source coding, data compressions, image processing and document image processing During this reporting period Professor Lu has published one research paper and had two others accepted for publication. He also directed to completion 3 master's theses and one doctoral dissertation.

Professor Hassan Peyravi's research focuses on interconnection networks for large scale parallel and distributed processing, and on computer communications networks. During this reporting period, he has published one research paper. He is a consultant for the Space Communications Division of the NASA Lewis Research Center and has just received a $75,000 NASA research grant, in support of his research.

Professor Jerry Potter's research interests include the continuing development of the associative computing paradigm, the integration of associative SIMD computers with other architectures in a heterogeneous supercomputer environment, the development of techniques

for compilation on massively parallel SIMD computers, natural language and artificial intelligence processing on SIMD computers, and the development of techniques for the introduction of parallel programming at the high school level. During this reporting period, Professor Potter published one research paper and had one other accepted for publication. He is currently directing two doctoral dissertations.

Professor Michael Rothstein directs his research activities toward algorithms and systems for symbolic and algebraic computation, parallel computations, symbolic-numeric interfaces, high-level languages, object-oriented programming, scientific user interfaces, and functional language implementations. During this reporting period, he attended the ISAAC'95 conference in Montreal, where he was a contributor to a poster session.

Professor Meera Sitharam's research interests include areas of complexity theory, logic, finite structures, approximation theory, splines computational geometry and motion planning, parallel algorithms, computational theory of learning, and graph theory in numerical analysis and graphics. During this reporting period, Professor Sitharam has had two research papers accepted for publication and delivered two talks at the regional meeting of the American Mathematical Society here at KSU in the Fall. She is currently directing one Ph.D. student and has recently received continued support from NSF for her Research Initiative Award.

Computational Chemistry:

This interdisciplinary research program continues in cooperation with Upjohn Laboratories. **Professor Victor Nicholson**, ICM, and Professors C. Tsai and R. Gregory of the KSU Chemistry Department are conducting this research in which the emphasis is on the development and application of computer algorithms and software to investigate the relationship between molecular structure and chemical activity. This effort involves applications of topology, graph theory, organic chemistry and biochemistry.

SECTION II: ICM VISITORS

Listed below are the names of visitors to ICM during the period from July 1, 1995 through June 30, 1996. These visits have been very beneficial to both ICM and the visitors. The visitors always gain an appreciation of the high level and calibre of the research activity here at Kent State University. All of these visitors received full or partial support from ICM.

1. Norbert Kajler, RIACA/CAN, The Netherlands, July 17–August 4, 1995.
2. Sanjiva Weerawarana, Purdue University, August 9–11, 1995.
3. Naveen Sharma, Xerox Corporation, August 11, 1995.
4. Igor Pritsker, Postdoctoral, August 21–May 1997.
5. Klaus Giebermann, Universitat Karlsruhe, August 20–27, 1995.

6. Amos Carpenter, Butler University, October 19–20, 1995.

7. Marlis Hochbruck, Univ. of Tubingen, Germany, November 3–9, 1995.

8. Andras Kroó, Hungarian Academy of Sciences, Hungary, January 16–May 9, 1996

SECTION III: PUBLICATIONS

J. Baker

A Constant Time Sorting Algorithm for a Three-Dimensional Mesh and Reconfigurable Network, Parallel Processing Letters, to appear Fall 1995 (with Mark S. Merry).

A Constant Time Algorithm for Computing the Hough Transform on a Reconfigurable Mesh, Image and Vision Computing Journal, to appear (with Mark Merry).

A Constant Time Algorithm for the Channel Assignment Problem using the Reconfigurable Mesh, Parallel Algorithms and Applications Journal, to appear vol. 7, no. 3 & 4, (with Mark Merry).

Solving a Two-Dimensional Knapsack Problem on a Mesh with Multiple Buses, International Conference on Parallel Processing, August 1995.

A Parallel Graham Scan Convex Hull Algorithm for the Associative Model, Parallel and Distributed Computing and Systems Conference, October 1995, to appear (with Maher Atwah and Selim Akl).

S. Chapin

Implementing Scheduling Algorithms using MESSIAHS, to appear in a special issue of *Scientific Programming* on Operating System Support for Massively Parallel Computer Architectures (with Eugene H. Spafford).

P. Farrell

A Uniformly Convergent Finite Difference Scheme for a Singularly Perturbed Semilinear Equation to appear SIAM J. Numer. Anal. (with J. J. H. Miller, E. O'Riordan and G. I. Shiskin).

Discrete Approximations for Singularly Perturbed Boundary Problems with Parabolic Layers I to appear in J. of Computational Mathematics (with P. W. Hemker and G. I. Shiskin).

Discrete Approximations for Singularly Perturbed Boundary Problems with Parabolic Layers II to appear in J. of Computational Mathematics (with P. W. Hemker and G. I. Shiskin).

Discrete Approximations for Singularly Perturbed Boundary Problems with Parabolic Layers III to appear in J. of Computational Mathematics (with P. W. Hemker and G. I. Shiskin).

C. C. Lu

Compression of Gray Scale Images using Alphabet Reduction Models, International Journal of Modeling and Simulation, vol. 15, no. 3, pp. 107–112 (with M. K. Tsay and C. H. Kuo).

Conditional Entropy Coding using High-Order Statistics, to appear Proceeding of Signal and Image Processing, IASTED SIP-95, pp. 410–413 (with C. H. Kuo).

Parallel Implementations of Huffman Coding using Associative Memory, to appear International Journal of Modelling and Simulation.

An Efficient Repetition Finder for Improving Dynamic Huffman Coding, IEEE Transactions on Communications (with C. H. Kuo).

L. Reichel

Adaptive Richardson Iteration Based on Leja Points, to appear J. Comput. Appl. Math. (1996) (with D. Calvetti).

Incomplete Partial Fractions for Parallel Evaluation of Rational Matrix Functions, J. Comp. Appl.. Math., 59 (1995), pp. 349–380 (with D. Calvetti and E. Gallopoulos).

Application of ADI Iterative Methods to the Restoration of Noisy Images, to appear SIAM J. Matrix Anal., 17 (1996) (with D. Calvetti).

A Hybrid method for Symmetric Positive Definite Linear Systems, to appear Numer. Alg. (with D. Calvetti).

Iterative Methods for Computing a Few Eigenvalues of a Large Symmetric Matrix, to appear BIT (with J. Baglama and D. Calvetti).

An Adaptive Richardson Iteration Method for Indefinite Linear Systems to appear Numer. Alg. (with D. Calvetti).

M. Rothstein

On the use of Feedback to Compute Group-Homomorphic Images, ISSAC'95 Poster Session, Montreal, Quebec, Canada (3 pages).

M. Sitharam

Pseudorandom Generators and Learning Algorithms for Boolean Functions to appear Computational Complexity Journal.

Evaluating Spectral Norms for Functions Computed by Constant Depth Circuit with Symmetric Gates to appear Computational Complexity Journal.

R. S. Varga

On Classes of Inverse Z-Matrices, Linear Algebra Appl. 223/224 (1995), 521-552, jointly with R. Nabben.

Adaptive k-step Iterative Methods for Nonsymmetric Systems of Linear Equations, ETNA 3(1995), 50-65, jointly with T. A. Manteuffel and G. Starke.

Minimal Gerschgorin Sets for Partitioned Matrices II. The Spectral Conjecture, ETNA 3(1995), 66-82, jointly with A. Krautstengl.

Minimal Gerschgorin Sets for Partitioned Matrices III. The Sharpness of the Boundaries and Monotonicity as a Function of the Partition, ETNA 3(1995), 83-95, jointly with A. Krautstengl.

P. Wang

Design and Implementation of MP, a Protocol for Efficient Exchange of Mathematical Expressions, to appear Journal of Symbolic Computation, 1996 (with Simon Gray and Norbert Kajler).

Parallel Groebner Bases Algorithm with PVM, the Fourth U.S. PVM Users' Group Meeting, Santa Fe, New Mexico, Feb. 25–27, 1996 (with I. Ajwa).

Tools to Aid PVM Users, the Fourth U.S. PVM Users' Group Meeting, Santa Fe, New Mexico, Feb. 25–27, 1996.

The CL-PVM Package, to appear SIGSAM Bulletin, 1996 (with L. Li).

Parallel Polynomial Operations on SMPs: An Overview, Journal of Symbolic Computation, (to appear).

SECTION IV: ETNA

Electronic Transactions on Numerical Analysis (ETNA) is an entirely electronic journal which was created by Richard Varga, Lothar Reichel and Arden Ruttan in 1993. To cover the overhead of publishing ETNA, funding was sought and received from the Provost, the Dean of Research and Graduate Studies, the Dean of the College of Arts and Science, the Dean of Libraries and Media Services, and the Department of Mathematics and Computer Science. The total funding for ETNA's first three years is $39,000.

ETNA has just completed its third volume. As of now, ETNA has approximately 1000 subscribers, and over 5300 papers have be downloaded from ETNA to individuals all over the world. The countries which have requested ETNA manuscripts include

Argentina	Australia	Austria	Belgium	Brazil
Canada	Chile	Cyprus	Croatia	Czech Rep.
Denmark	Egypt	Finland	France	Germany
Greece	Hong Kong	Hungary	India	Ireland
Israel	Italy	Japan	Korea	Netherlands
Norway	Poland	Portugal	Singapore	Slovakia
South Africa	Soviet Union	Spain	Sweden	Switzerland
Taiwan	Turkey	United Kingdom	United States	

ETNA has been a ground-breaking journal which has set the standard for electronic journals, both with regard to paper quality and to electronic formats. It has received international recognition by being featured in articles in SIAM News about electronic publishing and by being mirrored (i.e. copied in its entirety to another site and made available from that site) at the Technion in Israel and by ELibEMS in Germany. In addition, ETNA is fully reviewed by Mathematical Reviews.

SECTION V: SymbolicNet

`SymbolicNet` is a World Wide Web (WWW) service for information related to symbolic computation. It has been established (Fall 1994) by the ICM and is supported by a specific NSF grant.

It is easiest to access `SymbolicNet` using Mosaic or Netscape:

xmosaic "http://SymbolicNet.mcs.kent.edu/"

Using the above mentioned URL, a user may browse through the different categories on the `SymbolicNet`. Example categories include *announcements, calendar of events, conferences and workshops, reference literature, research groups, specialized areas, Computer Algebra systems, Interactive Demos, Positions Available, ACM/SIGSAM, Joining SymbolicNet,* and more.

There is a directory of email addresses of people in the field of symbolic computation. This database has an automated search mechanism. Users can also join `SymbolicNet` as members to obtain timely notifications (by email) when new time-critical information become available. Currently, there are 200 members (from all over the world) who have registered to received `SymbolicNet` information. User suggestions on other useful categories and services

are actively sought.

The `SymbolicNet` homepage is titled "**Symbolic Mathematical Computation Information Center**" because it serves as a starting point for discovering information about SAC on the Web. It is an evolving service provided to the Computer Algebra community. While maintained by ICM/Kent, `SymbolicN et` also links to information supplied and updated by individuals and cooperating sites.

SECTION VI: ICM TECHNICAL REPORTS

As of September 1995, ICM technical reports are available on the World-Wide Web, by using URL http://www.mcs.kent.edu/cgi-bin/publish/access.

ICM-199509-01 CL-PVM: A Common Lisp Interface to PVM, Liwei Li and Paul S. Wang.

ICM-199509-02 PVM Guide, Paul S. Wang.

ICM-199511-03 Structures and Structural Phase Transitions in Confined Liquid Crystal Systems, Eugene C. Gartland, Jr.

ICM-199601-01 Finite Element Analysis of the Landau-DeGennes Minimization Problem for Liquid Crystals, Timothy A. Davis and Eugene C. Gartland, Jr.

ICM-199601-02 The CL-PVM Package, Liwei Li and Paul S. Wang.

ICM-199601-03 Mesh Tools for Automatic Generation of Finite-Element Code in Two Dimensions, Eugene C. Gartland, Jr. and Jiahua Que.

SECTION VII: GOALS

Our ultimate goal is to build ICM into a first-rate research center so that it will become a major national center for pure and applied research in computational mathematics. More immediate 3-year and 5-year) goals, as set forth in the 1993-94 Annual Planning Report, are:

Three-Year Goals

1. Over the past several years ICM has developed cooperative research projects with LCI, Akron University's Department of Electrical Engineering, NASA, the Upjohn Corporation and ICM, Paris. One strategic three-year goal is to expand these efforts and, in addition, to include new constituencies. For example, we hope to enter into a cooperative research venture with the University of Karlsruhe. It is expected that funding for this venture will be obtained from NSF and DFG (Deutsche Forschungsgemeinschaft). Given sufficient available faculty research time, many other such ties could be developed.
2. A second three-year goal is to complete the move toward becoming a center for the on-line dissemination of research information in both numerical and symbolic computation. This involves Internet-based information retrieval of important reference software related to these two areas. ICM is well on the way to achieving this goal (see Section V).

3. A third three-year goal is to establish the reputation of the new electronic journal ETNA (Electronic Transactions in Numerical Analysis) as a first-rate journal for the publication of mathematics research in numerical analysis. This journal, supported by Kent State University with editorial staff from ICM, is the first completely electronic journal in numerical analysis. ETNA's associated editors are distinguished mathematicians with international reputations, and manuscripts must meet the highest of mathematical standards. Within three years this journal should bring highly favorable attention to both ICM and KSU. Progress toward this goal is described in Section IV.

4. A fourth three-year goal is the involvement of ICM in the securing of a major departmental external grant. It is hoped that ICM could serve as the umbrella under which a major grant for support of infrastructure and research in symbolic computation could be secured. The mix of faculty expertise in ICM places it in a very advantageous position for such a grant.

5. A fifth strategic three-year goal is the expansion of our visitors program which involves involves visiting researchers from around the world. These visits are extremely beneficial to both ICM and the visitors, and they certainly raise the level of visibility of ICM as well as KSU. We want to encourage more visits from both university and industrial researchers. One way to do this is through ICM-sponsored conferences such as the highly successful recent conference in Numerical Linear Algebra and Scientific Computation. It is hoped to have one such ICM conference every 2 or 3 years, with proceedings published and made available internationally.

Five-Year Goal

The major five-year strategic goal of ICM is to raise its level of visibility both internally and externally and to increase its level of financial support through some additional internal funding and major external funding. Within five years, it is hoped that ICM will have sufficient funding to support some faculty or summer research projects, some graduate students, and some long-term visits by appropriate researchers.

The particular mix of faculty expertise and computer support in ICM places it in an extremely favorable position with regard to national emphases in computational mathematics. With some additional funding, ICM should be able to capitalize on this fortuitous mix of resources and obtain major external funding. However, in order for ICM to secure external funding, it must show not only that it has sufficient faculty expertise, but also that the university is willing to provide certain basic infrastructure support. Careful examination of the kinds and amount of such internal support will need to be made. In addition to funding problems, there is the problem of available faculty research time. Most ICM faculty engaged in cooperative efforts are already overloaded with other commitments. It is important that a mechanism for released-time be developed if the faculty research activities are to be expanded.

The ICM research directors and associated faculty will continue to seek external funding and to advance the reputation of the Institute. However, in order to sustain its forward

motion, ICM cannot sustain further cuts in its operating budget. In times of financial stringency, it is especially important to retain unique centers such as ICM, whose benefits to the Department and the University far outweigh their costs.