Summary of VIGRE PROPOSAL: This program is designed to be a model for the pursuit and management of mathematics research and education at major public research universities, though it will also exploit unique strengths at the University of Minnesota, both in core mathematics and in multidisciplinary research.

The impact will be a successful system, and model for others, which draws more young people to the study of mathematics through aggressive recruiting and exposure to the myriad of new opportunities in the field, and which provides them with a strong support structure and superior training for tomorrow's workforce.

There are four intellectual aspects to the proposal: the first two are the major thrusts, the third focuses on recruitment and retention, and the fourth concerns management.

1) The department will broaden mathematical horizons for all its students and postdocs by exposing them to a variety of theoretical and applied fields in which mathematics is making a significant impact. Once they choose their fields of focus, they will receive in depth training to prepare them for the complex workplace of the future. To accomplish this, the department will offer activities including the following: new degree options in mathematical biology, biomedical engineering, and bioinformatics; research in multidisciplinary centers; industrial and laboratory internships; coursework in teaching development for graduate students and K-12 academic-year and summer enrichment programs for professional teachers.

2) The increasing success of the mathematical sciences in attacking physical, biological and social problems can tend to fragment the activities within departments and distract attention away from the core of our discipline. This issue is addressed through a series of community building, vertically integrated activities. The department will offer an integrated research team-REU program during the summer, (involving undergraduates, a few high school students, pre-oral exam graduate students, advanced graduate students, postdocs and faculty) with follow-up during the academic year, a Math Honors program that leads to a Masters degree, special expository lectures, a Math Club, and an e-newsletter. For graduate students, activities include a Junior Colloquium and working seminars, to increase the interaction of students and faculty and to give the students training in speaking, writing; professional ethics, and grant writing. Postdocs will also be involved in many of these programs, as well as training in teaching, writing grant applications, and giving interview talks.

3) The opportunities listed above will be used to recruit new students to the field, in conjunction with an activist recruiting program for students from underrepresented groups. A significant source of new students will be the highly successful University of Minnesota Talented Youth Mathematics Project, which impacts K-12 students all over the state. Retention of students at all levels is another important priority. Community building activities will help with this, and for graduate students new support activities will include a four-week orientation program, summer mini-courses, qualifying exam workshops, and a sophisticated new mentoring system.

4) With such a proliferation of opportunities available, many of them multidisciplinary, it is a major challenge to coordinate them, and to provide the sophisticated mentoring needed for students and postdocs to make appropriate career choices. A Minnesota VIGRE office will be formed, staffed by the co-PIs, together with elected representatives of the graduate students and the postdocs, to provide central oversight, coordination, mentoring, and publicity, through a combination of personal intervention, computer databases, a central interactive VIGRE web site, and an e-newsletter. The department will use the archiving and interactive features of the VIGRE web site to collect data for assessing the success of the program at all levels. The web site will also play a fundamental role in outside dissemination of information about this project.

Funds are requested for 75 person-years graduate traineeships, 48 person-years postdoctoral fellowships, and 20 undergraduate fellows per year in the summer REU program. Without this support the envisioned program could not be undertaken. Funds for recruitment of graduate students and postdoctoral fellows are also requested. Cost sharing for these components will be substantial and this information is included in the "Budget Justification" section.

Introduction

There are four aspects to our proposal: 1) career-enhancing training in the ways in which the mathematical sciences impact the world of the 21st century; 2) integrative community-building that emphasizes the essential unity of the mathematical point of view; 3) aggressive recruiting and retention efforts; and 4) a carefully worked out management structure. The following places these ideas in context.

1) This is a glorious age for mathematics, in terms of research opportunities and accomplishments internal to the field, and in terms of the influence of mathematical ideas and methods on society at large[1-5]. Moreover, due in large part to rapid advances in computer technology, sophisticated mathematical models of physical, biological and social phenomena have now become practical tools for the understanding and control of both natural and human systems[6-11]. There are employment and research opportunities in many areas that didn't even exist, or were considered off limits to mathematicians, e.g., internet modeling and neuroscience. However, many young Americans, unaware of these prospects, do not take the proper K-12 or college coursework to exploit the opportunities in the mathematical sciences. Even math majors and graduate students are often unaware of the options available to them. Furthermore, in spite of the growing opportunities in mathematics, we are witnessing a leveling off in the number of U.S. students who pursue studies in mathematics at undergraduate and graduate levels[12]. This pipeline issue is becoming increasingly serious because the massive infusion of foreign talent at graduate and the postdoctoral levels that occurred in the 1980s and 1990s is rapidly diminishing.

Our plan is to address this issue by communicating to students the promise and excitement of mathematics research. We will broaden horizons and expand areas of opportunity for our students and postdocs by first exposing them to a wide variety of fields in which mathematical ideas and research are making a significant impact, and then by providing them with in depth training in focus fields of their choice. We will make available new interdisciplinary degree options, industrial and laboratory mentorships, multidisciplinary research opportunities in centers and institutes, and graduate and professional teaching development coursework as well as K-12 academic-year and summer enrichment programs. Also, we will use these opportunities to attract new students to mathematics.We will enhance our mentoring process to ensure that all graduate students and postdocs are involved.
Minnesota is well situated to pursue this strategy. We have very strong research groups covering most major fields in mathematics, and as part of a unique college that integrates math, science and engineering, excellent teaching and research interactions with these fields. Our participation in the NSF Institute for Mathematics and its Applications (IMA), the Army High Performance Computing Research Center (AHPCRC), the locally funded Digital Technology Center (DTC), and the Minnesota Center for Industrial Mathematics (MCIM), helps us interact with other scientific/technical fields and with industry. We are located in a major metropolitan area with a concentration of high tech industry and have forged connections with many of these companies and the school systems. Through the IT Center for Educational Programs (ITCEP, an outgrowth of our department) we have a very strong K-12 outreach program, including the University of Minnesota Talented Youth Mathematics Program (UMTYMP), and Math Education programs through the postdoctoral level. There is a flowering of University interdisciplinary research and educational programs involving mathematics, e.g., bioinformatics, mathematical ecology and nanoscience.

2) Even as we endeavor to introduce students to the ever-increasing significance of mathematics to the biological, physical, and social sciences, it is a challenge to maintain a connection with the core of our discipline. We must ensure that all students of the mathematical sciences are

conversant with common sets of mathematical skills and with the mathematical approach to the analysis of problems. We address this issue through a series of new community-building, vertically-integrated activities: For undergraduates we will offer an REU program during the summer (also involving a few high school students, as well as pre-oral exam graduate students, advanced graduate students, postdocs and faculty) linked to ongoing research teams and with follow up during the academic year; a Math Club with a career development bias; a Math Honors program leading to a Masters degree; special expository lectures; and an e-newsletter. Graduate students will be able to take advantage of the Junior Colloquium. Also there will be working seminars, to increase student/faculty interaction and provide graduate students and postdocs training in teaching, ethics, speaking, writing, grant applications and interview talks.

3) Recruitment of more US students to our programs requires intervention at all educational levels, and special attention to previously underrepresented groups. Our faculty played a crucial role in writing more rigorous state K-12 mathematics standards, passed into law in 2003, and are continuing to interact with state legislators and officials, to ensure that Minnesota students receive satisfactory training and are prepared to pursue college level math studies. We created UMTYMP, that each year provides a challenging alternative to grade 8-12 math courses for approximately 470 of Minnesota's most talented students, including substantial numbers of females and minorities. Historically, large numbers of UMTYMP students haven't pursued math as a college major. We have decided to recruit UMTYMP and related K-12 outreach graduates aggressively; they will form the core of our new Math Honors and REU programs. To recruit for our graduate program, we will send faculty to visit local colleges, as well as selected schools that produce substantial numbers of technically trained minority undergraduates. These visits, together with the fact that our AHPCRC is affiliated with four Historically Black Colleges, will enable us to establish a pipeline for minority undergraduates to enter our REU and graduate programs. A new female graduate student position in the department will aid in the recruiting of female graduate students and in the networking of female students and faculty. Retention is also an important issue. For this reason, we are introducing a new mentoring program and, for graduate students, a four-week orientation, summer mini-courses, and qualifying exam workshops."

4) With so many opportunities available, it is a major challenge to provide sophisticated mentoring, so that students and postdocs can make appropriate choices. Moreover the organization of the university into disciplinary departments makes it difficult to interrelate activities and disseminate information about evolving interdisciplinary project-based programs. We will use a combination of experienced faculty, elected grad student and postdocs, and modern technology to help address these issues. We will create a Minnesota VIGRE office, run by the three co-PIs, that will provide central oversight, assessment, and mentoring, through a combination of personal intervention, computer databases, and an e-newsletter. A public web site will provide current information about the Minnesota VIGRE program, be a reference tool for undergraduates, graduate students, postdocs, and faculty, contain daily updated information about forthcoming VIGRE-related activities, disseminate information about Minnesota VIGRE to prospective students and postdocs, serve as an archive, and provide feedback mechanisms for participants. Where appropriate, reporting and record keeping will be kept confidential.

Our vision is an integrated system that speaks with one voice in the aggressive recruitment of young people to the study of mathematics, a community of learning involving faculty and students of all levels that provides a strong support structure, superior training in the basic mathematics disciplines, and exposure to the myriad of new opportunities, and a guidance process that pairs graduate students and postdocs with teams of senior mentors to facilitate their academic progress and help them with career choices.

Outcome of Curriculum Review

The department held a faculty retreat in fall 2001, to assure broad participation of faculty (beyond the Curriculum Committee) and generate ideas. The faculty response was very positive and many of the ideas outlined in this proposal took shape at that retreat. In fall 2002 we inaugurated the mathematics honors program and the undergraduate math club, and worked on a restructuring of graduate advising. We intend to hold a retreat every fall to evaluate the progress made toward these goals and discuss and develop new ideas in a continuing effort to improve our program. This year, to refine the ideas, Willard Miller has held individual one-hour meetings with most of the faculty, many of them recurrent meetings, as well as communicated with the faculty as a group, and is meeting with representative groups of graduate students and undergraduates.

A. Undergraduate Program

A unique feature of our college, the Institute of Technology (IT), is that mathematics, the physical sciences, computer science and engineering departments are united in a single administrative structure. This close contact between math, science and engineering has led to a high degree of responsiveness on the part of the mathematics faculty to the needs of science and engineering students in our service courses. A major component of our undergraduate teaching consists of five different calculus sequences for math, science and engineering majors, for the College of Liberal Arts students, for IT honors students, for biological science majors and for business school majors. Upper division courses are offered for math, education, science, liberal arts, and engineering majors. We teach math courses to students from the College of Education who plan a career in elementary school teaching. We also have a strong undergraduate program in actuarial science; about 1/3 of our math majors go into this program. The IT honors program, different from our new honors program in mathematics, attracts some of the brightest students in the College and mathematics is one of its core components. About 15% of our undergraduate courses are devoted to developmental mathematics. The university switched from the quarter system to semesters in 1999 and all of our courses were reevaluated and redesigned at that time.

A.1. Highlights of recent curriculum development

IT Calculus: total of 850 students in the fall, 800 students in the spring. This started as the default IT calculus sequence 4 years ago. It has 2 lectures per week, 3 recitations, with the faculty instructors visiting the recitations on a rotating basis. During the first year, the recitations are "workshops" where students practice their pencil and paper skills. During the second year, the recitations include 1.5 - 2 hours a week in the computer lab, using Matlab and Mathematica. Instructors and TA's all meet together once a week, and all exams are in common. *This sequence provides a rich teaching opportunity for all, and is particularly useful for training graduate TAs and postdocs in new methods of teaching.* It is undergoing continual revision as new workshop and computer projects are developed.

Calculus for Biology: presently 140 students in the fall, 100 students in the spring. This very successful course is based on Claudia Neuhauser's 2003 (2nd edition) textbook on calculus for biology and is routinely being revised by her.

Math Honors: presently 10 students in fall, 8 in spring. This is our new honors program (distinct from IT honors). It is theoretical in nature, with three special courses. The third semester, a 5xxx level course, is being taught for the first time this coming year, and open to all honors students

Math for Elementary Education Majors: presently 130 students in the fall, 130 students in the spring, plus some in the summer. This is a recently developed group-format course that by its nature undergoes continual revision. College Algebra is a prerequisite. The course, required of all Elementary Education majors, is a challenging teaching opportunity. It meets 4 hours a week,

with both the instructor and a TA present at all times. Most of the class format is group work, with students working together in groups of size 3-5. Tests are taken individually.
University students who want to teach high school or middle school math are now required to earn a bachelor degree in mathematics. We have recently developed classes designed especially for these students: Math 4707 (**Combinatorics**), Math 5335-36 (**Geometry**). These students are also required to take Math 4242 (Linear Algebra) and Math 5651 (Probability and Statistics).
Other recently developed or revised upper division courses include **Cryptology and Number Theory** (5248), **Mathematics of Wavelets** (5467), and **Sequences, Series, and Foundations: Writing Intensive** (3283W).

A.2. Need for Further Development

The discussions of our Undergraduate Instruction and Curriculum Committee for the past two years and at our department retreat last year led to recommendations for developments of new components in our undergraduate program and related curriculum development. A summary:

a) An undergraduate honors program in mathematics. (**started in 2002**)
b) A strong REU program coordinated with graduate and faculty research teams, especially for honors students. Special efforts to attract minority students. Academic year follow-up. (**new)**
c) A series of math research talks accessible to well-prepared undergraduates. **(started in 2002)**
d) An industrial program and degree option, with internships (through the college career development office) for undergraduates interested in applications of mathematics. (**new**)
e) A 3-semester REU for math-biology, joint with mathematics and biology. (**new)**
f) A math-biology program and degree option, with internships for undergraduates. (**new**)
g) A five-year degree program after high school, leading to a master's degree in mathematics, aimed at honors students **(proposed)**
h) Development of writing-intensive senior projects for liberal arts students. **(started last year)**
i) Enhanced social activities facilitating interactions among faculty, postdocs, graduate students and undergraduates, Undergraduate Honors Lounge and an undergraduate-graduate-faculty lounge for small group meetings and mini-courses. **(instituted in 2002)**
j) Establishment and expansion of the Undergraduate Math Club. **(started in 2002)**
k) Publication of a biweekly e-newsletter *The Math Path* aimed at informing undergraduate majors and students in upper division math classes about VIGRE-related activities. **(new)**

B. Graduate Program

The department offers a PhD in Mathematics and a PhD in Applied and Industrial Mathematics. In addition to the M.S. in Mathematics (Plan A[thesis required] or Plan B), an M.S. in Industrial and Applied Mathematics, a joint M.S. with the College of Education, and an M.S. with Emphasis in Actuarial Science are offered. A complete review of the graduate curriculum was done in 1999 upon conversion to semesters and all courses were revised at that time. Our faculty population has been changing rapidly due to many retirements and about a half dozen courses are being introduced or updated annually**.** Our review convinced us that our curriculum was being renewed in a satisfactory manner, but that more attention was needed to reduce the current 6.25 year average time to PhD; to increase the proportion of qualified U.S. students in our graduate pool with special attention to recruiting underrepresented groups; to promote better bonding of graduate students with faculty, postdocs, and undergraduate students; to focus the prelim exams more on emerging and less on traditional fields; to better prepare students for their future careers through more training in speaking, ethics, paper and grant writing, and broader responsibility for teaching; and to ensure that *all* graduate students have opportunities to utilize their mathematics expertise in early career research, educational outreach, curriculum development, and interaction with the other sciences and engineering, and the business and industrial community.

Proposed VIGRE Project

A. Research and Educational Opportunities for Undergraduates

A.2. New Math Degree Options

Major curriculum development is in progress. At present the School of Mathematics offers undergraduate specializations in actuarial mathematics, computer applications and in preparation for teaching mathematics in the secondary school. These specializations earn a designation that appears on the diploma. We are in the process of developing new specializations, involving internships, designed to attract mathematically talented students with interests in biology and engineering, who might not otherwise major in our department.

a. Professors Hans Othmer and Claudia Neuhauser are taking the leadership in developing a **Mathematical-Biology Option** for a Bachelor of Science Degree in Mathematics, with three tracks: 1) Environmental Sciences (Ecology), 2) Genomics (Focus 1: Biochemistry, Focus 2:Plant Genomics), 3) Physiology. Students enrolled in the genomics option would be immersed in the newly created Bioinformatics Program (leading to a masters degree), a joint venture of our college and the life sciences. In addition to the usual math requirements, these students will take courses in mathematical ecology, genomics, or neuroscience. Professor Neuhauser has a related multiyear REU grant. Graduate courses are being developed as part of an interdisciplinary bioinformatics graduate program; a new course on the analysis of complex networks was introduced recently.
b. Professor Carme Calderer is coordinating the introduction of Industrial Mathematics options for undergraduates. We will offer options in industrial math in areas where there is great present research and development activity, strong job prospects both regionally and nationally, high student interest, and distinction in departmental and university research programs. The first option is in **Biomedical Engineering**, with 4 tracks: (Materials, Instrumentation, Biomechanics, Imaging). A course entitled Mathematics of Industrial Problems will be required for this option. The introduction of new industrial mathematics options and revision of existing ones will be an ongoing process.

Furthermore, industrial or laboratory summer internships (through the college career development office) are part of the requirements for each of these new degree options. In the development of the new undergraduate mathematics options, we are carrying out a process of consultation with local industry, including that in the biomedical field, in order to seek advice and curricular feedback. These options for undergraduates will create a stronger interest in multidisciplinary areas at the graduate level.

A.2. Math Honors Program

In Fall 2002 we introduced a new Math Honors Program, intended for talented freshmen and sophomores who are interested in a fast track to the graduate program in mathematics. [This is in addition to the ongoing college honors program.] Initially, we admitted 10 students, and hope to expand on this base as the program matures. Most of these students are graduates of the University of Minnesota Talented Youth Mathematics Program (UMTYMP) who have enrolled in our department. Professor Jay Goldman is mentoring these students at present and two courses have been added that are targeted to them. More faculty members will be asked to help as the need develops. We are actively recruiting in the UMTYMP to increase the number of students who major in math (most don't) and will extend active recruitment more

widely as a sizable core is achieved. There will be two other activities related to the Math Honors Program: (a) special math research talks aimed at undergraduates, described below in A.3, and (b) summer REU mentoring as part of a faculty-graduate student-postdoc research team, with academic year follow up, as described in A.4. These activities will be open to all math majors but the Math Honors students will form the core. Math Honors students would be offered a stipend for summer support in the REU or similar program if they successfully complete their coursework during the regular academic year.

To foster communication and exchange of ideas among students, we have made provision for an **Undergraduate Lounge** in our building, where the honors students, graduate students, as well as postdoctoral and regular faculty, can meet informally in a good social environment.

A.3. The Undergraduate Math Club, & special talks for undergraduates

The Undergraduate Math Club, open to all math majors, was started in fall 2002, under the leadership of Carme Calderer. Since many of our undergraduates commute or have outside jobs, we have found that "special events" programming is the best way to involve them. Among the (pizza-enhanced) activities planned for next year in the club are:

a. Graduate school information week
b. Mathematical Careers Clinic
c. Tutorial sessions on preparing for actuarial examinations
d. Workshop on resume writing and job identification
e. Putnam and NCS/MAA exam preparation (Gennady Lyubeznik, coach)
f. "Special events" expository but research-related mathematics lectures aimed at undergraduates.

Graduate students and postdocs, as well as faculty, will be involved in several of these activities, both as presenters or mentors, and as participants.

As one of the activities of the Undergraduate Math Club we will schedule expository talks that will cover a broad spectrum of mathematics and be of interest to the intended audience. These include appropriate talks by senior graduate students, faculty and postdocs, as well as outside academic and industrial researchers. We will also publicize to our undergraduates certain other lectures aimed at them, such as some of the talks in the IMA Public Lecture Series, in the Junior Colloquium (by graduate students, postdocs or faculty), by our Ordway Lecturers, and in the Digital Technology Center Lecture Series. The IMA Public Lectures are particularly valuable for undergraduates, since they usually are held in connection with workshops on topical applications of mathematics, so that graduate students, postdocs and leading researchers internationally are also participating. Willard Miller, in consultation with Carme Calderer, will take responsibility for this undergraduate lectureship series and will solicit advice from faculty and about the choice of topics and people to be asked to speak, as well as the appropriateness of talks. The designated talks will be advertised to our undergraduates by posters in Vincent Hall, online, and through *The Math Path*. Refreshments will precede most of these events. Our best undergraduate mathematics students, especially those in the Math Honors Program, will be given incentives to participate in these programs and to take full advantage of informal discussions with peers, faculty and graduate students.

A.4. The Research Team- REU Program (A highly integrative activity)

The Research Experiences for Undergraduates (REU), nominally a ten-week summer activity, will be an important component of our VIGRE program. We will organize about half a dozen research teams, each team with a nucleus of senior faculty, junior faculty, postdocs and advanced graduate students working on research in a theme area. (We expect that these

groups will roughly coincide with the personnel of the working seminars, described in section B). Each group will offer projects to involve undergraduates and beginning graduate students. By bringing excellent undergraduate mathematics students in the summer to participate in the research programs of the research teams, we make it possible for them to see mathematics as a living subject in the hands of experts. This will also be an opportunity for 1st and 2nd year graduate students to get a taste of research before they make a final decision as to their thesis area. The research teams will maintain continuity in theme projects over a number of years, so undergrad REU students and graduate students will have opportunities to maintain participation in these projects during the academic year and/or to resume involvement in successive summers.

We have experience with standard REU projects; we funded an REU program internally, with partial support from individual NSF faculty grants in the summers of 2000, 2001 and 2002. Professor Paul Garrett directed it over the last two summers. Other faculty members who directed individual projects included Professors Adams, Gray, Reiner and Roberts. Each year 15-20 students from local colleges and from universities across the U.S. and Canada participated in the program. In 2002 we had 55 students apply to participate in the REU program and were able to offer minimal support to only 15 of them. Topics studied in past REU projects have ranged across all parts of mathematics and its applications, including finance, topology, cryptography, traffic modeling, number theory, combinatorics, computational algebraic geometry, modeling of neural response, and modular forms. VIGRE funding is crucial for our program; this year the department cannot fund the program and there are only a few informal summer REU projects offered by Professors Ciocan-Fontanine, Olver, and Reiner, on an individual basis, the Bioinformatics Summer Institute with Professors Othmer and Odlyzko as participants, and the 10-week Undergraduate Summer Internship Program run by the Minnesota Supercomputer Institute (MSI).

We have and will encourage students to approach their projects as young professionals, getting away from the unfortunately passive traditional picture of what students should do. The program is designed to provide a stimulating social environment as well, such as common lunches and a picnic outing involving all students, faculty, postdocs and graduate students in the programs; also inviting those potentially interested in future participation. Programs such as REU, including interdisciplinary REUs, are important for developing a pool of future mathematicians, as well as affording an opportunity for development of teaching and mentoring. For example, both of Othmer's 2003 summer REU students in biology projects have decided to go to graduate school in mathematics. Even beyond the use of the REU program as a recruitment vehicle for our graduate program, the more relevant point is that vigorous REU programs should benefit the national mathematics program. The reports of past student REU projects will be posted on the VIGRE web site.

For the VIGRE REU summer program, we expect to have approximately 20 undergraduate students, involved in a half-dozen research teams together with faculty, and some VIGRE postdocs and graduate students working in the area. Also Post-Secondary Educational Opportunity (PSEO) students would have an opportunity to participate. The program would involve a core of math honors students, with the rest chosen from area colleges as well as applicants from around the country. We will place particular emphasis on recruiting minority students, with a view to enticing them to study graduate mathematics at Minnesota. We will exploit the contacts with the black colleges that belong to the Army Center High Performance Computing Research Center (AHPCRC), (as a pipeline for students interested in computation) as well as visits by our faculty to colleges with a good record of training minority students in mathematics at the undergraduate level.

The following Professors have already indicated an interest in participating in the first round of Research Team-REU projects: Adams, Baxter, Calderer, Ciocan-Fontanine, Frank, Garrett, Gray, Gulliver, Keel, Krylov, Leung, Li, Lyubeznik, Miller, Neuhauser, Ni, Olver, Reiner, Sell, Shen, Sperber, and Sverak.

A.5. The Math Path

The coordinators will publish the e-newsletter ***The Math Path***, biweekly, in cooperation with the Director of Undergraduate Studies, Professor David Frank, and the director of the Math Club, Carme Calderer. *The Math Path* will be prepared from material posted on the VIGRE web site; it will be an online newsletter with hyperlinks, aimed at math undergraduates, students in upper division math classes, and high school students in UMTYMP calculus classes, and will provide information about upcoming special lectures, Math Club activities, REU opportunities during the academic year and during the summer, social events and other VIGRE-related activities. Its format will be based on the successful IMA UPDATE, and it will be disseminated via an email message to an alias, with a hyperlink to the online newsletter. It will also be printed out for posting on bulletin boards.

B. Graduate Traineeships

Currently we have a total of 127 graduate students working on their Master's and Ph.D. degrees. About 100 are graduate assistants (GAs) supported by teaching and research assistantships (TAs and RAs). The number of research assistants is only about 6-8 per year. The graduate school supports one or two of these RAs; the rest are supported by individual faculty grants or industrial internships. Of the 100 GAs, 31 are U.S. citizens or permanent residents and 20 are women.

Our Ph.D. program is very flexible, granting degrees in fundamental as well as multidisciplinary mathematics. The basic background required of all degree candidates is the same: competent preparation must be demonstrated in four out of five fundamental areas of mathematics, which are algebra, manifolds and topology, Riemannian geometry, real analysis, and complex analysis. Those intending to specialize in applied and industrial mathematics take the two basic courses, Methods of Applied Mathematics (Math 8401-8402) and Numerical Analysis and Scientific Computing (Math 8441-8442), as early as possible. One-year MCIM internships are arranged with industry for those who are more inclined toward working on real-world problems. About 20 students do such internships every year. For an internship to be successful, the faculty advisor, the industry mentor and the student must work very closely. The internship work often leads to a Ph.D. thesis topic. There are unique opportunities available to our applied math students to be exposed to cutting edge research at workshops and seminars at the IMA, the AHPCRC and the recently established locally funded Digital Technology Center (DTC). Faculty advisors encourage their students to take advantage of these opportunities. Two of the centers are in close proximity to the School of Mathematics and the AHPCRC is less than a mile away.

Once the undergraduate honors program gets well underway, a second phase will follow. It will consist of establishing an undergraduate-graduate track of five years. With the additional year, students will also complete a Master's degree in mathematics, with some of the work counting toward a possible future Ph.D. We believe that this will help ease the transition between the undergraduate and graduate programs and will help students to decide on pursuing a Ph.D.

B.1. Traditional Mentoring and Performance Evaluation of Graduate Students

Each first year student is assigned an 'initial' faculty advisor who acts as a mentor to see the Ph.D. student through the written prelims. A student is expected to pass these exams within

the first two years of residence. By then the student should choose an 'interim' advisor. The basic role of this advisor is to help the student prepare for the Ph.D. preliminary oral exam (and paper) in the area of specialization of the candidate. Quite often the interim advisor becomes the thesis advisor. The Director of Graduate Studies (DGS) plays a very significant role in this mentoring process, making sure that timely progress is taking place. On occasion, the DGS arranges a switch of advisors if necessary. Every year, before the renewal of Teaching Assistantships for the following year, the Graduate Studies Committee makes a detailed evaluation of each TA/RA based on faculty advisor and teaching evaluations.

B.2. Proposal to Improve Graduate Training

a) ***Improved mentoring (orientation):*** All of our new TAs currently attend a two-week orientation before the start of the fall semester. Students with English as a second language report four weeks earlier for a rigorous English and communication skills program. With VIGRE, we will require new students to participate in a **special four-week mentoring program** supervised by Professor Paul Garrett, the present DGS and VIGRE co-coordinator, and Scot Adams, the DGS-elect. The students will be paid a stipend for expenses to attend the orientation and a range of **mini-courses** that are under development by senior faculty. In the **mini-courses**, students will review fundamental mathematical concepts by seeing them in action. Rather than aiming at an outline review of theory, we will develop general concepts through specific problems and applications. (Sample topics for mini-courses are described below.) At least one mini-course will focus on "what I wish I knew before I became a grad student": hints on how to study a topic at the graduate level, habits of the mind, how to write up assignments, how to give a mathematics talk, etc. Some VIGRE postdocs may participate by assisting faculty in planning content, and by supervising corresponding problem sessions. At the end of the mini-courses, we will provide students with a suite of assessment materials to determine their choice of coursework. The co-coordinators and representatives of the other educational and research centers and programs will meet with the new graduate students and potential interim advisors as groups, to inform them about the opportunities in the VIGRE program. Also each student will meet with a small group of faculty, including the DGS and the VIGRE PI to assess the student's experience with the mini-courses, further advise on coursework and assign the student's initial adviser. The group of initial advisors will be involved in these meetings and their duties and responsibilities will be made clear to them. (In particular the advisors for the VIGRE graduate students will have been trained in advance.) The initial adviser will work with the student through the time of passage of the written prelim exams. We will monitor this mentoring process carefully, and reassign a student in case the original advisor match turns out to be sub optimal. We will emphasize the importance of the Minnesota VIGRE web site as a primary source of (updated) information for students, postdocs and faculty.

b) ***Improved mentoring (follow-up summer activities):*** We will galvanize our VIGRE graduate students into a high level of activity in summers during their fellowships. Three/four week **summer workshops and mini-courses** are being developed for more effective use of summer time for graduate work. This will help engage and focus the efforts of VIGRE graduate students. The mini-courses are of three types. Some of the topics will be slight extensions of undergraduate material, thus effectively providing some impetus to review. The second will concern limited projects allowing a relatively short-term sense of closure, and will build upon standard material at a Writtens level. Some samples of mini-courses: a) **linear algebra**: **continuity,** b) **integration, differentiability on $\mathbf{R^n}$** c) **integers,** d) **complex analysis,** e) s**ets, ordinals, cardinals** g) **topology,** h**) fixed-point theorems, i**) **Fourier analysis,** j) **differential equations,** k) **counting** l) **groups** m**) rings, fields.** The third type will be one-month (June) thesis level courses, with at least one visiting faculty member

involved. Also we will run summer **Qualifying Exam Workshops** to give students practice toward Written Qualifying Exams that test first year graduate material. These problem-solving sessions will benefit beginning graduate students and those finishing their first year. For the latter group, the workshops will be a systematic review of academic-year coursework.

c) ***Teaching loads of VIGRE TAs****:* VIGRE funding will allow lighter teaching duties for VIGRE TAs (on average 50% of the regular assignment). This will enable them to devote more effort toward their education in mathematics and their education in how to *teach* mathematics. At the same time, it is vital that they fully experience the issues of collegiate teaching, and develop skills and viewpoints necessary to make their teaching successful. The lighter teaching load will also give them more time for research and a range of optional vertical integration, teaching development and outreach activities described below. Involvement in enrichment programs will be determined person-to-person and will be designed to take less time than that freed up by the teaching reduction. Every effort will be made to shorten the time to Ph.D. and develop a stronger mathematician.

d) ***Better teaching preparation for academic careers****:* Currently, we ask a few advanced TAs to be the teacher in a course. All VIGRE TAs will be required to have full responsibility for at least one course in the 4^{th} or the 5^{th} year; the faculty mentor and the DUGS will always be available for consultation. They will serve as the main instructor and will be assisted by junior TAs. We will make an effort to provide such an opportunity to *every* TA interested in an academic career. Senior TAs and postdoctoral faculty will also participate in curriculum development alongside regular faculty members. This will be accomplished through team-taught courses and participation in the undergraduate curriculum committee meetings. Further, graduate students will have the opportunity to participate in the preparation for college teaching and outreach programs of ITCEP (see below). All our students will be encouraged to participate in the "Preparing Future Faculty" program, run be the university.

e) ***Improving teaching and communication skills:*** In addition to evaluations by faculty of the teaching by the TAs mentioned earlier, we will introduce teaching evaluations by students in the 4^{th} or 5^{th} week of the semester. Such evaluations will provide timely feedback to the TAs, and give real-time information to help them improve their teaching and communication skills.

f) ***Seminar participation and presentations. Community building***. Beginning with their first year the graduate students will be required to participate in activities in which they make formal presentations and receive faculty feedback: The most significant of these are the **Junior Colloquium,** and (following the second year) **working group seminars** with faculty, graduate students and postdocs in their area of primary research interest. **The Junior Colloquium** will be a weekly seminar, organized by a committee of graduate students and faculty, with Victor Reiner acting as chair. (The All Topics are Considered [ATaC] seminar of 1995-2002 is a partial model for this seminar.) It will have the following functions:

   i. Providing grad students with a place in which to give talks, both for practice giving talks, and to give other students a sense of what they are interested in, or have been working on. Note that these talks need not be about the student's research. (In fact, some successful ATaC talks were given by graduate students on introductions to general topics/ideas/tools.) The faculty members of the committee will provide feedback to the student speakers. One-half or more of the talks will be by graduate students and every VIGRE graduate student will be asked to speak here, or in an equivalent activity, at least once during their first two years.
   ii. Providing faculty members with a place to advertise themselves and their subjects. This makes it easier for graduate students to decide on thesis field and adviser.
   iii. Provide a place for talks of general math interest at a friendly, more accessible level than the Thursday departmental colloquium. This would be the sort of talk we might expect Ordway lecturers to give. Some of these talks will be appropriate for undergraduates and will be advertised to them via email notices.

iv. Refreshments will precede the Junior Colloquium, with opportunities for undergraduate and graduate students, postdocs and faculty to interact informally.

Following their second year graduate students will be integrated into ongoing **working group seminars** with faculty and postdocs in their area of primary research interest. Based on experience, we expect the graduate student- postdoc interaction to be especially intense. REU projects will be associated with these groups. The main goal of the seminars is to learn mathematics, but they will facilitate mentoring and **development of research skills**, and help with **improving communication skills**. Initial student presentations will probably be reports on published research papers of interest, and only later on the student's research. Postdoctoral and regular faculty members in the particular area will help with preparation and will provide supportive critiques, and the faculty will critique postdoc speakers. Monitoring student involvement in this program is the responsibility of the adviser (a participant in the seminar), backed up by the coordinators. Several seminars in the School already take this form; we will encourage the spread of this model department-wide. Initially we expect to have working group seminars in Algebra/Number Theory, Combinatorics, Differential Geometry, Math Biology, Math Physics, Numerical Analysis/ Applied Math, PDE, Probability, and Topology. **As part of the preliminary oral exam procedure, students prepare a paper in their proposed thesis research area, monitored by their interim advisor, and will also prepare an expository version of this paper for publication on the Minnesota VIGRE web site**. As mandated by the university, we will provide all our students **instruction in professional ethics**. **Every graduate student, supervised by the faculty advisor) will be required to write at least one grant application**, ether internal to the university (fellowship, travel support, etc.) or to an outside funding agency, e.g., the NSF (fellowship, research grant, etc.). **Every graduate student will be required to talk part in a research meeting, to make a poster presentation or give a talk, and will receive travel support for this.**

Faculty Research Interests in the School of Mathematics (E=Emeritus)

Name	Rank	PhD	Institution	Research Areas
Adams	Full	1987	Chicago	dynamics of Lie groups, Riemannian geometry
Agard	Full	1965	Michigan	analytic function theory, mobius groups
Anderson	Full	1980	Princeton	algebraic number theory, algebraic geometry
Arnold	Full	1979	Chicago	numerical analysis, applied mathematics
Aronson	Full, E	1956	MIT	PDE, applied math
Baxter	Full	1969	Toronto	probability, ergodic theory
Bobkov	Full	1988	Leningrad U	geom.& funct. anal, isop. inequalities, prob., real anal.
Bramson	Full	1977	Cornell	probability, interacting particle syst., queuing theory
Calderer	Full	1980	Heriot-Watt	applied mathematics, liquid crystals, calc. vrts, PDE
Chacholski	Assist	1995	Notre Dame	algebraic topology
Ciocan-Fonta	nine,Ast	1996	Univ. of Utah	algebraic geometry, quantum cohomology
Cockburn	Full	1986	Chicago	numerical analysis
Conn	Assoc	1978	Princeton	differential geometry, Lie algebras
Feshbach	Full	1976	Stanford	algebraic topology, cohomology of groups
Frank	Assoc	1967	UC, Berkeley	algebraic topology
Fristedt	Full	1963	MIT	probability, combinatorics, game theory
Garrett	Full	1977	Princeton	automorphic forms, number theory, harmonic analysis
Gershenson	Assoc	1961	Chicago	algebraic topology
Goldman	Full	1965	Princeton	Combinatorics
Gray	Full	1977	Cornell	probability, interacting particle syst.
Gulliver	Full	1971	Stanford	PDE, calculus of variations, Riemannian geometry

Harris	Full	1960	Harvard	finite group theory, group representations
Hejhal	Full	1972	Stanford	analytic number theory
Jain	Full	1965	Stanford	probability theory
Jiang	Assoc	1994	Ohio State U	automorphic forms L-funcs, number theory, rep theory
Jodeit	Full	1967	Rice	real analysis, inequal., harmonic analysis, int. eqns.
Kahn	Full	1961	Yale	algebraic topology, cohomology of groups
Keel	Assoc	1995	Princeton	PDE, harmonic analysis
Keynes	Full	1966	Wesleyan	mathematics education, dynamic systems
Krylov	Full	1966	Moscow State	probability, PDE, control theory
Leung	Assoc	1992	MIT	differential geometry, complex geometry
Li	Assist	1996	Brandeis	symplectic geometry
Littman	Full	1956	NYU	PDE, control theory, boundary control
Lowengrub	Full	1988	Courant	numerical analysis
Luskin	Full	1977	Chicago	numerical anal., scientific computing, comp. physics
Lyubeznik	Full	1984	Columbia	commutative algebra, algebraic geometry
Marden	Full	1962	Harvard	complex anal., hyperbolic 3-manifolds, Riemann surf.
McGehee	Full	1969	Wisconsin	dynamical systems
Messing	Full	1971	Princeton	arithmetic algebraic geometry
Meyers	Full	1957	Indiana	PDE
Miller, E.	Assist	2000	UC, Berkeley	algebraic geometry, combinatorics, commutative alg.
Miller, W.	Full	1963	UC, Berkeley	Lie groups, special functions, mathematical physics
Miracle	Assoc	1959	Kentucky	Analysis
Moeckel	Full	1980	Wisconsin	dynamical systems, celestial mechanics, ODE
Neuhauser	Adj	1990	Cornell	probability theory, interacting particle systs., ecology
Ni	Full	1979	Courant, NYU	PDE
Nykamp	Assist	2000	Courant, NYU	math biology
Odlyzko	Full	1975	MIT	comp. complex., crypt., no. th., combinatorics, prob.
Olver	Full	1976	Harvard	math. phys, appl. math, diff. eqns, Lie grps, diff. geom
Othmer	Full	1969	U of M	math biology
Polacik	Full	1989	Comenius U.	PDE
Prikry	Full	1968	UC, Berkeley	logic, set theory, measure theory
Reiner	Full	1990	MIT	Combinatorics
Reitich	Full	1991	Minnesota	applied mathematics, PDE
Rejto	Full	1959	NYU	func. anal., appl math, math physics, math. modeling
Richter	Assoc	1963	Princeton	recursion theory, set theory
Roberts	Full	1969	Harvard	algebraic geometry, commutative algebra
Safonov	Full	1981	Moscow State	PDE, diffusion processes
Santosa	Full	1980	Illinois-Urbana	inverse problems, optics, optimal design, wave prop.
Scheel	Assoc	1994	Freie U., Berlin	dynamical systems,PDE, nonlinear waves
Sell	Full	1962	Michigan	ODE, dynamical systems, scientific computation
Shen	Assist	1998	MIT	image & vision analysis, wavelets & PDE methods
Sperber	Full	1975	Penn.	arithmetic algebraic geometry, algebraic number th.
Stanton	Full	1977	Wisconsin	combinatorics, orthogonal polynomials, special fcns.
Storvick	Full	1956	Michigan	analytic function theory, integration in function spaces
Sverak	Full	1987	Charles, Prague	PDE
Voronov	Assoc	1988	Moscow State	math physics, algebra, alg. geom.& topol., rep. theory
Wang	Assoc	1994	UC, Irvine	Riemannian geometry, PDE
Webb	Full	1979	London Univ.	group theory, rep. theory, cohomology of groups
Weinberger	Full, E	1950	Carnegie Tech	PDE, applications of math
White	Full	1973	UC, San Diego	Combinatorics
Zeitouni	Full	1986	Technion	Probability

g) *Participation in Enhancement programs:* **Every VIGRE graduate student will participate in a range of vertical integration, research, teaching development and outreach**

activities described in Section C. Involvement in Enhancement Programs will be determined person-to-person and will be designed to take less time than that freed up by the teaching reduction. Typically a VIGRE graduate student will be involved in two of these activities per year, after passing the Writtens.

h) *Ordway Lecturer program***.** This is a new program to be launched fall 2003, funded by the Ordway endowment of the School. Outstanding mathematicians who are also superior lecturers are being invited for one week visits and will each give a series of at least 3 lectures, accessible to graduate students, on a given research topic. There will be no more than two Ordway Lecturers in any academic year, and they will be well advertised. During the week of a Lecturer's visit there will be a reduced schedule of regular seminars, and a banquet is part of the event. Ordway Lecturers and other distinguished Ordway visitors will each be asked to meet with our graduate students, with no faculty present, to discuss their research fields.

Lighter teaching loads made possible by VIGRE funding will make our graduate training more attractive to U.S. citizens and permanent residents. Our vibrant curriculum and extracurricular activities will be advertised on the web and will provide added attraction. Better bonding between faculty and TAs will occur as a result of improved mentoring, team-teaching, summer mini-courses/workshops, and participation in the undergrad honors program and Junior Colloquium.

B.3 Typical Timeline for VIGRE Graduate Student

Summer 0: 4-week orientation. Initial adviser assigned. Mini-courses & self-assessment
Year 1: Qualifying exam prep, 50% teaching load, Junior Colloq., summer mini-course
Year 2: Finish basic courses, pass written exam, choose interim adviser, 50% teaching load, Junior Colloq. presentation, summer mini-course
Year 3: Take specialty courses; begin thesis work, pass preliminary orals with paper, working seminar presentation, 50% teaching load, outreach/integration activity
Year 4: Working seminar talk, full course teaching responsibility, thesis work, ethics training, outreach/integration activity, grant application, conference poster presentation
Year 5: Working seminar talk, thesis work & writing, outreach/integration activity, faculty development program, REU activity
Year 6: Department, not VIGRE, would support if student not finished but making good progress.
Non-VIGRE graduate students will have exactly the same opportunities, but the requirements for participation in outreach/integration activities and summer mini-courses will be reduced, due to teaching duties.

C. Graduate Student/Postdoc Enhancement programs

C.1 Details on opportunities for participation in ITCEP programs

The IT Center for Educational Programs develops and administers educational programs for K-12, undergraduate and graduate students, K-12 pre-service/in-service teachers, and faculty in mathematics and its related science and engineering applications. Main programs include a) University of Minnesota Talented Youth Mathematics Program, b) K-12 academic-year and summer enrichment programs, c) Graduate and professional development coursework..

Professor and Director Harvey Keynes and Associate Director Andrea Olson will mentor graduate students interested in opportunities that focus on: excellence in teaching, involvement with creative academic programs, curriculum development, educational scholarship/professional activities (i.e., new curricula/curricula supplements, professional

development materials, and relevant statistical/evaluative studies and publications), that are directed toward ITCEP's main program areas. Specific opportunities for graduate students in ITCEP programs include

1. Teaching opportunities, including being a workshop leader or course coordinator for an UMTYMP calculus sequence course, especially Calc2 or Calc3
2. Taking Math 8001, Preparation for College Teaching (new approaches to teaching and learning, issues in math education, expectations of a mathematics professor)
3. Teaching Assistant in Math 8001

ITCEP can offer VIGRE Post-Doc opportunities that focus on excellence in teaching, and involvement with creative academic programs, curriculum development, and educational scholarship/professional activities (i.e., new curricula and curricula supplements, professional development materials, and relevant statistical/evaluative studies and publications), which are directed toward ITCEP's program areas (see http://www.math.umn.edu/itcep). The options include

1. Post docs who are basically focusing in a core math area, but interested in exposure to other opportunities could choose to be involved in at least one of the following activities during their three years at the University:
    a. Presenting outreach/enrichment talks/modules to ITCEP/UMTYMP students
    b. Presenting outreach/enrichment talks/modules to K-12 teachers
    c. Participation in Math 8001 activities – case studies, module critiquing.
2. Post docs who are interested primarily in applied and/or industrial math could choose to be involved in at least one of the following activities during their three years:
3. 1.a & 1.b as stated above using topics from applied/industrial mathematics
    a. Working with ITCEP Post Docs/staff to provide scientific/appropriate linkages to modules that connect math to science/engineering*[1].
    b. Applied/Industrial/Science mentors to undergrad/grad/teacher teams working on *connected* module/curricular development.
4. Post Docs with serious interest in college teaching/course development could be involved in at least two to three of the following activities during their three years:
    a. 1a & 1b, 2c (math/science resource/connection leadership)
    b. Major teaching role in Math 8001
    c. Pairing with ITCEP Professional Development/staff . Professor Keynes plays role of teaching/outreach mentor
    d. Involvement in at least one of the following opportunities: i. summer coursework for K-12 enrichment students or K12 teachers ii. Major teaching assignment in UMTYMP Calculus course.

C.2 Opportunities for grad student/postdoc participation in MCIM programs

[1] Working with ITCEP Post Docs/staff to provide scientific/appropriate linkages to modules that connect math to science/engineering. Working cooperatively, IT faculty, Post Docs, and graduate students will identify key mathematical concepts and scientific/engineering connections to be developed for K-12 teacher discovery and understanding. These lessons will then be presented to the teachers in two to three hour workshops, which may be hosted at an IT Center. These professional development materials will encourage the investigation and exploration of science, technology, and engineering concepts at relevant, accessible levels for K-12 teachers while maintaining the real perspective of the science and the underlying mathematics. The innovative *connected* modules will present rich mathematical ideas that promote understanding and encourage meaningful discovery of scientific connections.

VIGRE postdocs and graduate students interested in industrial mathematics will be encouraged to participate in the programs offered by the Minnesota Center for Industrial Mathematics, a research and educational center within the School of Mathematics. Present activities include:

- **Industrial Problems Seminar.** Weekly during each semester, the IMA and MCIM jointly run this seminar, featuring speakers from industry, IMA industrial postdocs, and students. Industry speakers typically talk about their own research problems, highlighting the manner in which mathematics enters into their solution. These talks provide the audience with a clear view of the mathematical research that is carried out at industrial R & D facilities. The speakers are available for one-on-one discussions with students; in fact, these discussions often lead to summer internship opportunities for students. IMA industrial postdocs are also encouraged to speak in the seminar; they dedicate half of their effort to an industrial project with a partner company, under the supervision of a company scientist. Students attending these talks get exposed to exciting mathematical research with a more immediate impact, and they also get valuable insight into the interests of and the working environment in the postdoc's company. Finally, the seminar also features student speakers. These speakers are typically students who have recently returned from their summer internships, and the talks relate to their internship project. Students attending these talks also learn about what to expect during an internship, and gather pointers on making the most of the opportunity. (Advertised to undergraduates, as appropriate.)
- **Industrial Internships.** The MCIM arranges internships for mathematics graduate students. Most internships take place in the summer but some may occur during the academic year. Often, MCIM arranges for company supported research assistantships. Students interested in obtaining internships must attend the Industrial Problems Seminar, and make appointments to talk to industry speakers. They are also asked to prepare a web-based resume that can be accessed by interested companies. The MCIM directorate studies the interests and background of each student requesting internship and attempts a company match. Every attempt is made to make sure that the internship experience is rewarding and valuable. This means that from the company MCIM expects:
    - o a good project -- one that poses interesting and substantial math challenges, and has the potential to lead to further study upon the intern's return to the university,
    - o a responsible mentor -- one who looks out for student interests and understands that the student is there not only to contribute, but also to learn.

  To the company, MCIM delivers:
    - o a well-prepared mathematics student ready to tackle a new problem, and open to new ideas and application areas.

These internships teach students "soft" skills, such as communication and teamwork; they also expose the students to the relevance of mathematics to real-world problems. We are often surprised by the level of excitement in their internship project that students return with upon completion of their work. Many projects open new avenues for investigation and eventually lead to MS and/or PhD theses. Internships also offer advantages for students seeking employment. The internship tends to stand out in a resume, and often becomes a focal point of discussion during an interview. For students seeking industry jobs, the internship provides evidence of the candidate's interest and commitment to working in industry. Students seeking academic jobs, on the other hand, find that an internship is often (and justly) interpreted as ability to work across disciplines.

Since 1994, MCIM has placed over 70 students in internships, at a rate of about 8 per year, and has developed a long and reliable contact list in 25 companies throughout the country. Due to the high-quality students that it has placed, the Center enjoys a reputation as a trust-worthy source of excellent and highly motivated students. As a result, a number of companies (Honeywell, 3M, Schlumberger, Siemens, Symbol, etc) consistently return to search for qualified interns through MCIM and this, in turn, has helped in making the overall program very stable.

C.3 Opportunities for grad student/postdoc participation in IMA programs

The Institute for Mathematics and its Applications (IMA) was founded by the NSF in 1982, with the primary mission of increasing the impact of mathematics by fostering research of a truly interdisciplinary nature, linking mathematics of the highest caliber and important scientific and technological problems from other disciplines and industry. Allied with this mission, the IMA also aims to expand and strengthen the talent base engaged in mathematical research applied to or relevant to such problems. Affiliated with the IMA are 33 universities and government laboratories, and 12 corporations. The IMA main facilities are located primarily in Lind Hall, a few hundred feet from the math department, with a conference area in a nearby building. IMA employs a variety of programmatic mechanisms. A partial list is:

- Annual Thematic Programs. The largest undertaking of the IMA involving about 1,000 participants who come from academia, industry, and government for a week to the academic year. Six 2-year postdocs are hired in conjunction with each annual year. Programs include periods of intense activity such as workshops, tutorials, and short courses, separated by periods for less structured interaction during which there are seminars, working groups, public lectures, etc. Planned annual programs include
    - 2006-2007: Applications of Algebraic Geometry (proposed)
    - 2005-2006: Imaging
    - 2004-2005: Mathematics of Materials and Macromolecules
    - 2003-2004: Probability and Statistics in Complex Systems
- Summer Programs. Each summer the IMA runs a summer program of a few weeks, which involves on the order of 100 participants. Planned programs include
    - 2004: *n*-Categories and Applications
    - 2003: Probability and PDE in Modern Applied Mathematics
- Special workshops and Hot Topics workshops. Short programs that can be launched quickly to respond to areas of particular interest or opportunity. Examples:
    - 2004: Compatible Spatial Discretization of PDE
    - 2003: Agent-based Modeling and Simulation
    - 2001: Minorities and Applied Mathematics - Connections to Industry
    - 2001: Analysis and Modeling of Industrial Jetting Processes
    - 2000: Connecting Women in Mathematical Sciences to Industry
- Participating Institution Graduate Student Summer Programs. Each year IMA partners with a PI to run a course for graduate students from all the PI institutions.
- Industrial Math Modeling Workshop. Teams of graduate students work with industrial mentor to solve a problem he/she supplies. Each team is responsible for written and oral presentations of their solution at the end of the 10-day program.
- IMA Postdoctoral Program. In conjunction with each annual thematic program, the IMA hires six postdocs. Postdocs immerse themselves in the annual program.
- IMA Industrial Postdoctoral Program. IMA industrial postdocs are hired for one or two years, splitting their effort between the IMA and one of its industrial partners.

IMA postdocs take the initiative to organize activities such as the weekly Postdoc Seminar and the Brown Bag lunch. The IMA visitors and directorate provide guidance to postdocs on career development issues as well as scientific issues. They give occasional seminars on topics such as how to give a talk, or early career issues, or connecting with industry. They regularly listen to and critique presentations of the postdocs (popular before job interviews).

There are manifold opportunities for VIGRE postdocs and graduate students to participate in most IMA activities, ranging from attending a seminar or workshop talk to participating in a full annual theme program and the IMA Postdoc Seminar. To facilitate participation, the IMA

and math department frequently offer seminars and graduate courses on a theme year topic in the preceding year. The details of the level of involvement of a VIGRE graduate student or postdoc will be worked out with the IMA directors through the advising/mentoring process.

C.4 Opportunities for grad student/postdoc participation in DTC programs

The **Digital Technology Center (DTC)** is a hub of innovation and excellence at the University of Minnesota in the digital technologies serving the industrial, educational, and public needs of the state of Minnesota and the nation. The DTC integrates research, education, and outreach in digital design, computer graphics and visualization, telecommunications, intelligent data storage and retrieval systems, multimedia, datamining, scientific computation, and other digital technologies. The DTC's first-rate laboratory facilities offer researchers the tools to make progress in these areas. The DTC houses the Supercomputer Institute for Digital Simulation and Advanced Computation for supercomputing research, the Laboratory for Computational Science and Engineering for computational science and engineering and visualization, and the Usability Laboratory for evaluations of computational solutions. Additional, specialized laboratories assist with research projects. All together about 30 faculty members are involved, along with their students. Among the nine major research areas at the DTC the most relevant to mathematics are:

1. Bioinformatics and Computational Biology (Hans Othmer, Alexander Grosberg)
2. Databases and Datamining (Vipin Kumar)
3. Networks (Zhi-Quan Luo)
4. Graphics and Visualization (Victoria Interrante)

and the work of the members Andrew Odlyzko (Electronic commerce, coding theory, and probability) and Guillermo Sapiro (Image processing, computer vision, computer graphics, applied mathematics, differential geometry, partial differential equations). VIGRE Post Docs and graduate students will have opportunities to become involved in these projects. The **Supercomputer Institute for Digital Simulation and Advanced Computation,** a unit of the DTC offers computer time, software, and technical support on supercomputers to faculty and students. It also provides grants for research scholarships for Supercomputing research at the University of Minnesota, and runs a 10-week Undergraduate Summer Internship Program.

C.5 Opportunities in other areas

Graduate students and postdocs will be able to participate in other program areas, including **1) The nationally significant programs of the AHPCRC** (Professors Cockburn, Luskin and Reitich), with an emphasis on research that contributes to homeland security. **2) The NSF-funded Nanoscale Interdisciplinary Research Team** (NIRT) project "**Nanoscale shape memory actuators and swimming bugs --- theory, computing, and MBE synthesis**" with Luskin and his co-investigators, Professors James, Aerospace Engineering & Mechanics, and Palmstrom, Chemical Engineering & Materials Science. The research program involves the fundamental study of first order structural phase transformations at the nanoscale. As part of the project, a new graduate course is being developed on multiscale modeling and computing with applications to materials science and biology, and units on numerical methods for molecular simulation are being developed for core numerical analysis courses. Project participants will have opportunities to contribute to design and teaching of a **new unit on mathematical modeling and computing in materials science for UMTYMP students. 3) The Math Biology** projects overseen by Professor Othmer: The two major areas in his NIH-funded research program are (i) **problems in pattern formation in development biology**, and (ii) **problems in complex networks**, such as signal transduction or gene control networks. His NSF-supported research is focused on directional sensing, cell motility and tissue movement. In all projects there is a large component of mathematical modeling, since there are no existing standard models for these processes. This requires that students and post-docs learn the underlying biology so that (i) they

can read the experimental literature, and (ii) formulate valid models. The mathematical background needed varies from project to project, but a solid foundation in ODE/PDE, dynamical systems and bifurcation theory, numerical analysis and stochastic processes is a good start. **4) The Nanoparticle Science and Engineering IGERT,** with opportunities in stochastic modeling research, a masters minor in nanoparticle science, and advising in a numerical modeling course.

D. Postdoctoral Fellowships

We typically hire two Dunham Jackson Assistant Professors annually, temporary three-year positions with a teaching load of three semester courses per year. In addition, we also hire two-year temporary assistant professors depending on our teaching needs and available resources. All positions are funded by grants or faculty leave money; there are no recurring funds to support these positions. On average, there are 8-12 postdoctoral fellows in residence each year.

In addition to the formal weekly seminars, faculty members hold informal seminars with their own Ph.D. students and the postdocs whom they mentor. This provides opportunities for close contact between faculty members, postdocs and graduate students. The Junior Colloquium and the REU program will bring the postdocs in close contact with undergraduate students together with graduate students and faculty, thus creating integration across all levels. In addition to mentoring our postdocs, our faculty also takes the responsibility to mentor some of the 10-12 IMA postdocs in residence. Given our faculty size, our many very productive younger faculty, and oversight by the PIs, we will be well equipped to train and mentor VIGRE postdocs.

D.1 Components of the VIGRE Postdoc program

- Each VIGRE postdoctoral fellow will be assigned a mentor, a regular faculty member whose research interests substantially overlap with those of the fellow. The faculty mentor must agree to the mentoring responsibilities, described in a written charge to the mentor, before an offer is made. The faculty mentor will coordinate teaching assignments, help with seminar talks and writing of grant proposals, and coordinate the research, teaching, and outreach options for the postdoc, described below. Willard Miller will meet regularly with each postdoc and mentor to ensure that the process is working well, that they understand the opportunities provided by VIGRE, and that the postdoc is integrated into the department.
- VIGRE funding will allow a lighter teaching load of one course per semester for a VIGRE postdoctoral fellow and, as a result, create significantly better opportunities for research, teaching preparation, educational development and interaction with fellow faculty and students at the graduate and undergraduate levels.
- Each VIGRE fellow will teach at least one upper division/graduate level course during the three-year tenure and have the option of an industrial internship**.** Teaching performance in all courses, will be monitored by our curriculum committee, and student course evaluations. The resulting improvement in the fellow's preparation for careers in academia and industry will be significant. There will be some opportunities to teach special topics courses. VIGRE fellows will be encouraged to participate in the university's one-year "Preparing Future Faculty" program.
- The postdocs can benefit from the Ordway Visiting Professor program, funded by the Ordway endowment. Every year 6-8 distinguished researchers are invited, each to spend one month in residence, interacting with faculty and students and giving at least two talks. This is an important way for our faculty, postdocs and students to establish and strengthen research ties with leading mathematicians around the world.
- **Each postdoctoral associate will be involved in one of the working group seminars** related to their field of research, and, for one summer as a research/outreach option, in an

REU program related to that research team. This latter will involve developing projects with faculty mentors and participating graduate students, and working with the undergraduates.

- To further integrate teaching and research of VIGRE postdocs with faculty, graduate, and undergraduate students, (and broaden their horizons) we have planned activities such as:
  1. *Participation in the* ***Junior Colloquium and Undergraduate Math Club.***
  2. *Participation in the summer* ***mini-courses and preliminary exam workshops****.* The Fellows will work closely with faculty who offer the mini-courses and conduct preliminary exam workshops, and work with the graduate students enrolled in these activities. Helping to develop courses/sample problems will be part of the experience.
  3. *Participation in the* ***Institute for Mathematics and its Applications*** **(**IMA**),** ***Digital Technology Center*** (DTC), ***Minnesota Center for Industrial Mathematics*** (MCIM), ***Army Center*** (AHPCRC), ***Nanoscale Interdisciplinary Research Team*** (NIRT) and other interdisciplinary programs: Many of the programs and personnel and seminars at these centers will benefit all postdocs and graduate students, but they will be of particular interest to those who are more inclined toward applications of mathematics.
  4. Participation in the educational and outreach activities of the ***Institute of Technology Center for Educational programs*** *(ITCEP)* (at the K-12 level, as well as the undergraduate to postdoctoral level). These programs will be of particular interest to those who are more inclined toward mathematics education and course development. A participant in these programs will also be assigned a teaching/outreach mentor. ITCEP postdocs and participating VIGRE postdocs will be paired.

In addition to participating in a working group seminar, each VIGRE postdoc will normally participate in the equivalent of two of these or similar programs each year (one with a strong educational component) with time commitment less than their teaching reduction, and based on their own interests, discussions with their mentor and the director of the corresponding program. Willard Miller will monitor and coordinate this educational enhancement activity. In some cases the postdoc will be involved primarily with a small research team in her field of study, and the options will be used to broaden the horizons of the postdoc. In other cases a program will be central to the postdocs's interests.

The coordinators will ensure that (during their tenure) each postdoc gets help from senior faculty on writing grant proposals and training on giving a talk as an applicant for a position. This training will be adapted to the postdoc's particular interests and expertise. University mandated ethics training will also be provided.

D.2 Typical Timeline for VIGRE Postdoc

At time of offer: Assigned a faculty mentor (in the postdoc's research area) with a written charge that spells out the responsibilities of the mentor.
Year 1: Teach 2 one-semester courses, grant proposal training, 2 research/outreach options
Year 2: Teach senior/graduate level course and 1 other course; grant proposal training, REU and 1 other research/outreach option, ethics training, faculty development course
Year 3: Teach 2 one-semester courses; grant proposal training, job interview and job talk coaching, 2 research/outreach options
Non-VIGRE postdocs will have exactly the same opportunities, but the requirements for participation in outreach/integration activities and summer mini-courses will be reduced, due to teaching duties.

Recruitment and Retention

1. K-12.

Standards: State K-12 mathematics standards are an extremely important issue for the department. Our faculty has been vigilant to ensure that Minnesota K-12 students receive proper training in the mathematical sciences and are prepared to pursue more advanced mathematical studies when they enroll at the university. Professors Larry Gray and Bert Fristedt have been active in meeting with parent groups and legislators to urge upgrading of standards. This year the Commissioner of Education named Professors Miracle, Gray and Fristedt to a statewide Mathematics Committee to write new math standards. They contributed to the document, testified before legislators and participated in public hearings; the standards are now law.

Talent Pool: The K-12 students enrolled in ITCEP programs statewide constitute an important talent pool. As of 2002-03, 271 former UMTYMP students reported enrollment in undergraduate and graduate programs at 70 different colleges and universities. The highest concentrations were: 147 at the University of Minnesota, 46 at Stanford, 42 at MIT, 28 at Harvard, 28 at UW-Madison and 26 at CalTech. Many UMTYMP graduates are enrolled as mathematics, science, engineering, or computer science majors, **but presently only a small minority major in math.** According to a 2000-2001 survey, 229 alumni are currently employed full-time. One of the first alumni, Professor Markus Keel, is now teaching in UMTYMP.

2. Undergraduate Students. To increase the number of high quality math majors we plan to exploit further our connection with UMTYMP. This program, started by the department over 20 years ago, provides a challenging alternative to grade 8-12 mathematics coursework for Minnesota's talented mathematics students. The percentages of females and minorities in these classes exceed the corresponding percentages in our undergraduate classes. **However, historically, most have not majored in mathematics at the college level**. We have started aggressively to recruit these students. Graduates of this program form the core of our new math honors program. This spring two UMTYMP grads in the honors program talked to the twin cities UMTYMP calculus classes about the advantages in studying math at Minnesota via the honors program. We will follow up with faculty in recruiting events. We will also actively recruit the several hundred high school students in ITCEP science/math enrichment programs to become math majors. Our community building programs described in Section A will aid in retention.

3. Graduate Students. For effective recruitment of U.S. citizens and permanent residents for graduate studies in our department, we are taking the following steps.

A. Establishment of an undergraduate honors program in mathematics, as discussed above. This will be a very vibrant program supported by scholarships from internal resources. We will recruit some of these students for graduate studies in mathematics. This program should help other graduate programs as well, since many of these students will likely go elsewhere.
B. Creation of a Minnesota VIGRE web site, linked to the departmental web site. The site will be updated daily and will be (in addition to the Co-PIs) a source for information about the VIGRE program at all levels, forthcoming activities (and archives of past activities). In addition to its role in the VIGRE program, it will be an attractive tool in recruiting graduate students. We will continue to advertise our graduate programs through other available media.
C. We will hold an open house each fall semester for faculty and undergraduate students from area colleges to give them a firsthand description of what we have to offer. This will give our programs an effective exposure at an early stage of recruitment.
D. Every spring semester we will invite a select group of U.S. applicants for graduate studies to visit our campus and the School of Mathematics. We are requesting the NSF to provide funds for the continuation and expansion of this important program.

E. We will focus on recruitment of women, both by special attention from the admissions committee and through personal contacts. Starting this fall, the Deans Office will fund a female (second or third year level) graduate student TA position in the department. Her duties will be twofold: 1) she will work with the DGS to recruit women and minorities for the graduate program. 2) she will be responsible for networking with the other women in the department, particularly the female graduate students. Occasional funding is also being provided to bring in outside female mathematicians as colloquium speakers who with also meet separately with our female students. The aim here is to provide a increasingly supportive environment for women. The college is also exploring ways of subsidizing female faculty positions to aid the engineering, science and math departments in their hiring.

F. We will adopt an activist approach to attract more minority students, by exploiting already established connections between our faculty and a group of Historically Black Colleges and Universities (HBCUs), through the Army High Performance Computing Research Center (AHPCRC) at the U of M. AHPCRC partners include Clark Atlanta, Florida A&M, Howard, and Jackson State Universities. There is a steady flow of HBCU faculty and students to the Center, for research projects in computational science and engineering. [Professors Luskin and Cockburn are affiliated with the Army Center. Professor Reitich is coordinator of the Computational Electomagnetics Portfolio and is also involved in the AHPCRC minority programs. Our college has a special relationship with Florida A&M University; our department will support the FAMU-RISE proposal. Miller participated in the 2003 CIC-SROP Conference.] The AHPCRC holds a two month Summer Institute in HPC for undergraduates from the US and Puerto Rico. Reitich and his graduate student Ms.Young Ae Han have helped run this program the past two years. We plan to take advantage of the residence of these students and acquaint them with REU opportunities and opportunities for graduate studies in math at the U of M, and to contact, routinely, visiting minority faculty to develop pipelines from their undergrad programs to our graduate/postdoc programs.

G. The School will cooperate with our college's minority programs director Frank Snowden to directly contact minority students and faculty from HBCUs to link their undergraduate programs to our graduate and postdoctoral programs. Each year Dr. Snowden leads a team to visit schools such as Florida A&M, Clark Atlantic, Jackson State, Howard (the 4 AHPCRC partners), Spelman, Xavier, and North Carolina A&T to recruit students for our graduate programs. Starting this year the School of Mathematics will send a faculty member to accompany him to those schools that represent special opportunities for us.

H. In recent years we have often recruited a few promising U.S. students who were not fully prepared to do graduate work at entrance time. Our experience with such students has been positive and, as in the past, we will give them special mentoring in their first year to bring them up to the desired level by the end of the year. Those who are judged ready for graduate work may be offered a VIGRE teaching assistantship for their second year.

I. Our orientation, mini-courses, qualifying exam training, special mentoring, and training in speaking and writing, discussed in Section B above are meant to help in retention of students.

4. Postdoctoral Fellows

We have an established program of recruiting postdocs. Our recruiting committee is chaired by the Associate Head, currently Professor Rick Moeckel. The head appoints the other members of the committee. An effort is made so that postdocs are hired in all strong areas in the School over a given period of time. A significant factor in recruitment of the best postdocs is the availability of good faculty mentors. The regular department committee will select VIGRE postdoctoral fellows, with input from the VIGRE coordinators. Already, many excellent candidates apply and accept two or three-year positions. With better advertising on the web and other sources, recruitment will improve further. Typically, retention has not been a problem. More attractive work conditions, as described above, will make retention almost 100%.

Organization and Management Plan

Professor Willard Miller will coordinate this program and have overall responsibility for managing the various aspects of the program, its assessment, and preparation of progress reports. He will take particular responsibility for overseeing the welfare of the VIGRE postdocs. Professor Paul Garrett will take particular responsibility for overseeing the REU project, the summer orientation and mini-courses, in collaboration with the probable new DGS Professor Scot Adams. Associate Professor Conan Leung will take particular responsibility for the welfare of the VIGRE graduate students, again with Scot Adams, and for the organization of working seminars. Miller and Garrett will manage the VIGRE web site. The Co-PI team is highly experienced in virtually every aspect of management for this complex project. Miller has been Head of the department, Associate Dean for Finance and Planning, and Acting Dean, of the college, as well as Associate Director and Director of the IMA. Garrett is the immediate past DGS of the department, and designed and maintains the departmental web site. Leung is experienced as an advisor and working seminar organizer and brings a more youthful point of view to the management team.

The management and assessment team will have 5 members, the 3 co-PIs, a representative of the VIGRE graduate students and a representative of the VIGRE postdocs. Their respective constituencies will elect the graduate student and postdoc representatives annually. They will provide an important conduit to their constituencies about the operation of the VIGRE program and provide valuable feedback. This management team will meet biweekly to assess progress in the program. Annually, the team will meet with all of the graduate students and, separately, with all of the postdocs.

The co-coordinators will create a "virtual" Minnesota VIGRE office to provide oversight, publicity and coordination for VIGRE-related activities, through a combination of personal involvement, computer databases and scheduling software, and design and maintenance of a VIGRE web site. Through this mechanism they will be able to provide overall management of the program, both within and outside the department. They will be able to inform the students, postdocs and faculty about the components of the program though personal and group meetings and via the detailed and interactive VIGRE web site. They will use computer data bases and scheduling software to keep track of the progress of every graduate student and postdoc in the VIGRE program and will follow up personally to see that students, postdocs and faculty mentors remain engaged and on target. They will publish *The Math Path*, biweekly, in cooperation with the Director of Undergraduate Studies, David Frank, and the director of the Math Club, Carme Calderer. (*The Math Path* will be prepared from material posted on the VIGRE web site; it will be an online newsletter with hyperlinks, aimed at math undergraduates, students in upper division math classes, and high school students in UMTYMP calculus classes.) The centralized data collection, information dissemination and interactive web site will facilitate the management and evaluation of the VIGRE program. The web site will be designed to have several complementary functions:

- It will provide information about all aspects of the Minnesota VIGRE program, organized so that the integrated structure of the program is clear. It will be the primary reference tool for undergraduates, graduate students, postdocs, faculty (and faculty mentors) seeking that information.
- It will contain up to date information about forthcoming VIGRE-related activities: talks, Math Club events, REU and internship opportunities, new courses and degree options, social events, etc.

- It will serve to publicize Minnesota VIGRE to our students and staff, and to prospective students, postdocs and faculty. Online articles about completed REU projects, internships, educational projects, and materials from talks will be utilized.
- It will have articles and other information designed to interest young people in pursuing a career in the mathematical sciences.
- It will have an archival function.
- It will provide a feedback mechanism for participants in the program to submit evaluations.
- Confidential information will, of course, not be accessible on the public web site, but will be handled through more secure channels.

During the orientation period each year, the management/assessment team and the DGS will meet with the graduate students and their advisors, as a group, and with the postdocs and their mentors, to explain the functioning of our VIGRE program. Just prior to the beginning of each semester, each graduate student (or her advisor) will send a brief fixed-format email message to the VIGRE office, with a copy to the other and the DGS. The message will attest that the student and advisor have met and agreed on a plan for the student's activities for the semester, and a provisional plan for the following semester. The plan will list the courses to be taken or audited, courses to be taught, seminar participation and talks, activities to prepare for the written or oral exams (mini-courses, qualifying exam workshop, etc.), research activities, and planned VIGRE outreach activities; for the upcoming semester and for the following semester. (This can be very brief; a sentence for each item). Just prior to the beginning of the second semester, and every semester after that) the exercise will be repeated, with an updated report on what actually happened the past semester (courses completed, exams passed, talks given, etc.), and an updated plan for the next two semesters. These plans and follow-up reports will be an important management device. Very flexible and brief, and kept confidential, they will provide essential information about the progress and engagement of each student. We will prepare a simple online form for the report, so that the student or advisor can copy it, fill in the blanks and email to the VIGRE office. The co-coordinators will help each student/advisor pair with the plan and arranging outreach activities as appropriate; they will certainly intervene personally when problems occur (such as no plan being submitted). Similarly, for postdoc/mentor pairs we will ask for an updated plan each semester and help or intervene as appropriate.

Establishment of an independent VIGRE office with publicity, coordination and oversight functions will enable us to introduce and build the VIGRE program in a clear, consistent manner and to make sure that students, postdocs, faculty (and faculty advisors and mentors) understand how the program works and the multiplicity of opportunities available though it. By the end of the third year of the VIGRE grant the co-coordinators should have refined the data base and scheduling software, trained the faculty advisors and mentors, familiarized the students with the program, and brought the web site to a mature form, so that the independent "VIGRE office" can start to be phased out and all its activities can gradually be absorbed into the regular department advising and management structure.

The incoming Director of Graduate Studies, Professor Scot Adams, will be responsible for all aspects of graduate studies: recruitment, retention, curriculum development, appointment of graduate advisors, and monitoring of individual student progress through the program (with the cooperation of VIGRE co-coordinators as described above) He will be assisted in this task by the Graduate Studies Committee, currently consisting of Professors Carme Calderer, Bert Fristedt, Harvey Keynes and Victor Reiner, with Adams serving as chair.

Professor Hillel Gershenson, supervises the teaching by graduate students. A large faculty committee, whose members regularly do the teaching evaluations of the TAs. Professor Gershenson will also handle student evaluations of the TAs' teaching.

Professor Willard Miller will oversee the welfare of the postdocs. This will include monitoring the mentoring process and faculty and student teaching evaluations. Each postdoc will have regular contact with their faculty mentor and will get feedback on teaching and overall performance at least twice a year. Professor Miller will also oversee the process of vertical integration of the postdocs.

Professors Carme Calderer, David Frank (chair), Jay Goldman and Harvey Keynes will coordinate all aspects of the math undergraduate honors program. Professor Victor Reiner will chair the Junior Colloquium organizing committee. Professor Calderer will run the Undergraduate Math Club and Professor Gennady Lyubeznik will coach the Putman and MAA exam teams.

Professor Paul Garrett is the Director of the REU program, assisted by the faculty members who participate in the program.

Professor and Director Harvey Keynes and Associate Director Andrea Olson will mentor VIGRE graduate students and postdocs interested in opportunities that focus on excellence in teaching, and curriculum development, and educational scholarship/professional activities that are directed toward ITCEP's program areas. Professors Fadil Santosa and Fernando Reitich will mentor VIGRE graduate students and postdocs interested in the programs of MCIM. Professor and Director Andrew Odlyzko will provide guidance to graduate students and postdocs interested in the programs of the DTC. Professors Douglas N. Arnold (Director), Fadil Santosa (Deputy Director), Scot Adams (Associate Director), and Don Aronson (Emeritus, Associate Director for the Postdoctoral Program), will provide guidance to graduate students and postdocs interested in the programs of the IMA. Professors Hans Othmer and Claudia Neuhauser will provide guidance to students and postdocs interested in the Math Biology and Bioinformatic programs and REU projects in these areas. In particular, professor Neuhauser has received funding for her own REU project, including work during the academic year. Students and postdocs interested in involvement in the Army Center program, the Math Biology program and the Nanoscience and Nanoparticle programs would work with the organizers of these research projects.

Performance Assessment

The VIGRE web site will play a key role in performance assessment, since we will use it for the collection of confidential data such as graduate student/postdoc semester plans and progress reports, and posting of public scheduled activities such as seminars, special talks, mini-courses, orientation sessions, workshops, REU projects, etc., as well as public reports on outcomes of these activities, noteworthy research and special educational projects, and posted archives of these materials. Though statistics will be important, so will prose reports on the activities and the progress of individuals through the program. We explain the criteria and procedures that we will use in assessing the progress of VIGRE goals in our program. (NOTE: Confidential data will **not** be available on the *public* web site, but will be collected through more secure channels.)

This management team (including the graduate student and postdoc representative) will meet biweekly to assess progress in the program. Annually, the team will meet with all of the graduate students and, separately, with all of the postdocs. The program will be discussed at each of the fall faculty retreats.

Research Opportunities for Undergraduates

What do we want to accomplish for an REU project? We want to give undergraduates a taste of what it is to do mathematics research in an academic, laboratory or industrial setting. We should provide well-planned projects in a group setting, involving graduate students and/or postdocs, and faculty guidance so that the student has a good chance to make progress, can benefit from group interaction, and can use the knowledge and experience as a stepping-stone for further career development, particularly in graduate level mathematics. A project, in which the student has a reasonable opportunity to do something new, and the opportunity to continue at some level during the academic year, would be particularly valuable. We would like to be able to involve, at least, all math honors students in these projects, and as many regular math majors (or non-majors that have a deep interest in the subject and are susceptible to switching into math) as possible. We would also like to use summer REU projects as recruiting tools for students from underrepresented groups, to attract them to our graduate program.
How we will measure success? We will maintain a record of the number of U.S. citizens and permanent residents in the REU program, with a breakdown by gender and underrepresented groups. Reports on completed projects, and personnel involved, will be available online. Each student participant will be asked to fill out an online questionnaire to tell us the measure of satisfaction with the project, impact of the project on pursuing graduate work in mathematics, and to give us suggestions for improvements.

What do we want to accomplish in the Math Honors Program? This program is meant to be the fast track for very talented, highly motivated students that wish to pursue graduate study in mathematics. The courses should be rigorous, taught by highly experienced faculty and specially designed for this cohort. We want to provide particular encouragement and support for these students, educationally and socially, to enable them to thrive in this environment. We would particularly like to attract qualified students from underrepresented groups to this program and have them succeed as role models for the next generation of students.
How we will measure success? We will keep records of the number of students in the math honors program with a breakdown by gender and underrepresented groups, their retention, and how many eventually went to graduate programs in mathematics. We will use the interactive web site to develop a method to measure the students' satisfaction with the honors program and to get

feedback on the talks for undergraduates and the math club activities. The research projects and honors theses completed by the undergraduates will be available for review, much of it on the Minnesota VIGRE web site.

What do we want to accomplish with the Undergraduate Math Club? Very few major employers come to the University of Minnesota looking explicitly for pure math majors at the bachelors level. Thus we strengthen the basic degree to provide options: coursework designed to lead to graduate mathematics; coursework leading to the area of computer science; coursework leading to a career in business or finance; coursework applicable to the physical sciences and engineering; coursework leading to the actuarial profession; coursework applicable to the biological sciences; industrial mathematics; or a program suitable for prospective secondary mathematics teachers. One of the functions of the math club is to help students sort out these options in an informal and socially supportive atmosphere. We want to encourage them to "hang around" the department to talk to, and learn from, one another and the graduate students, postdocs and faculty. The club should provide students with useful training and career information that is not part of our course offerings.
How we will measure success? We will use the web site to develop reports on each club event and keep records of the number of students participating, including records on involvement of graduate students, postdocs, faculty, and outside experts. For activities such as Putnam and actuarial exam coaching, we will report on the results. We will use the interactive web site to get feedback on the talks for undergraduates and other math club activities. We will monitor usage of the lounges for undergraduates.

What do we want to accomplish with The Math Path? This e-newsletter is intended to inform the undergraduate mathematics community about programs, talks, math club events, educational outreach, social events, and REU opportunities available to them, and build a feeling of community. It addition to math majors, it will be sent to all students in upper division math classes as well as students in advanced UMTYMP classes, and will serve as a recruiting tool.
How we will measure success? We will seek undergraduate feedback on the Minnesota VIGRE web site concerning the value of the online newsletter and the extent to which students obtain timely, useful information from it. For certain talks, math club activities and REU projects we will query the participants as to their first source of information about the activity.

What do we want to accomplish with recruiting? We want to increase the number of math majors, particularly those of the quality of the math honors program and students from previously underrepresented groups. We want to increase the number of quality US graduate students and postdocs, with particular attention to students from previously underrepresented groups.
How we will measure success? **At the undergraduate level:** We will keep track of the number of UMTYMP students attending our recruiting sessions, and the number of UMTYMP students that enroll in the U of M and in Mathematics each year. We will also report on the total math enrollments, numbers of math majors by gender, and number of math degrees (and years to degree) by gender each year. **At the graduate level:** We will keep a record of how many students attended the fall and spring Open Houses and how many of these enrolled in our graduate programs. We will ask those who decide to go elsewhere to give reasons for that decision, if they choose to do so. We will also report on the total graduate math enrollments, numbers of graduate students by gender and group, and number of degrees (and years to degree) each year. We will also track the efforts of our faculty in recruiting students at all levels: including recruiting trips and talks, contacts made, etc., with an eye toward recognizing and rewarding faculty who engage in these activities.

Graduate Student Training

What do we want to accomplish in the training of graduate students? While the external applications of mathematics are becoming more varied, the essential unity of the subject is ever more clearly shown by internal developments. Graduate education in preparation for a career as a mathematician must be a positive experience, including a broad foundation, touching upon many different aspects of mathematics itself, as well as broader training as a scientist and awareness of (and in many cases involvement in) other scientific and technical disciplines. Mathematicians must also be educators. Learning to do research, to teach, and to maintain robust scientific scholarship requires close contact with active, experienced research mathematicians who can personally communicate the excitement and vitality of 21st century mathematics.

- We want to ensure that a graduate student who meets our quality standards and works hard can attain the PhD in about 5 years.
    - Pass the written qualifying within about 2 years.
    - Pass the preliminary oral exam (with research paper) within about 3 years.
- We want to provide training of sufficient depth and breadth such that our graduates are employable both in the short term and the long term.
    - Our students should have teaching experience and training, including sole responsibility for a class.
    - Our students should be trained to give a research talk, to write a paper., and to apply for a grant. They should have professional ethics training.
    - Our students should have experience in participation at a professional meeting, including a poster presentation or talk.
    - They should have exposure to avenues in which they can use their mathematics expertise in educational outreach, the other scientific and technical fields, business and industry.
    - They should be knowledgeable about ways in which computer and network technology complements their mathematical expertise: numerical and symbolic computation, visualization, etc.
    - They should have experience in working in groups outside of structured classroom activity, particularly those in which they are using their mathematical expertise in interacting with people at various educational levels, e.g, K-12, undergrad, postdoctoral or different fields, e.g., education, the sciences, business and industry.

How we will measure success? We will keep a record for each student on time to Ph.D., the course(s) that the student taught with full class responsibility, faculty evaluations of teaching and summaries of student evaluations of teaching. Information on placement after Ph.D. and position held five years from Ph.D. will be maintained. Statistics on the breakdown by gender and underrepresented groups, U.S. or non-U.S. student, upon entering and upon completion of work will also be kept. Each graduate student will be asked to fill out a carefully designed online questionnaire at the time that he/she leaves, which will be useful for further improvement of our training. We will track the talks given by graduate students in the Junior Colloquium, working seminars, math club and similar venues, talks or poster presentations at professional meetings, papers written by PhD candidates, and involvement by graduate students in educational outreach and interdisciplinary activities. Through our web site we will establish hyperlinks to email addresses and home pages of our masters and Ph.D. graduates so that we can easily keep in touch with them over the years, follow their career development and get continued feedback from them. We will also solicit articles and "nuggets" concerning noteworthy achievements by students in our program.

Postdoctoral Fellows

What do we want to accomplish in the training of postdocs? We will not make postdoc offers to new Ph.D.s unless there are members of our faculty committed to work with the postdocs in their areas of research and to act as mentors. Most new postdocs have been focusing narrowly on their Ph.D. thesis topics. We want to deepen their understanding of their thesis fields, but also broaden them so that they can move beyond iterations of the thesis and focus more on the principal emerging challenges in their fields. We want to augment their teaching and communication skills and train them in scholarly publication and grant writing. We want to show them ways in which they can use their mathematics training in educational outreach and multidisciplinary research activities.

- We should ensure that every postdoc is deeply involved in the research life of the department: interacting with faculty, other postdocs and graduate students, participating in seminars.
- We should help to ensure that the three-year tenure each postdoc will write several papers that are published in refereed journals, both as sole author and as a collaborator.
- We should help to ensure that the postdoc participates in several conferences (and provide travel support), including speaking and publishing in conference proceedings.
- The postdoc should have a home page with research interests, links to publications, a CV, and course information.
- We want to provide training of sufficient depth and breadth such that postdocs are employable both in the short term and the long term.
    - They should have teaching experience and training, including responsibility for an upper division or graduate class.
    - They should have routine practice in giving a research talk.
    - They should have exposure to avenues in which they can use their mathematics expertise in educational outreach, the other scientific and technical fields, business and industry, and pursue at least one of these avenues in some depth.
    - They should be knowledgeable about ways in which computer and network technology complements their mathematical expertise: numerical and symbolic computation, visualization, etc.
    - They should have experience in working in groups outside of structured classroom activity, particularly those in which they are using their mathematical expertise in interacting with people at various educational levels, e.g, K-12, undergrad, grad or different fields, e.g., education, the sciences, business and industry.

How we will measure success? Information on each fellow will be maintained on courses taught, faculty and student teaching evaluations, success with grant applications, and placement after completion of work. Each fellow will be asked to fill out a carefully designed online questionnaire at the time he/she leaves which will give us information on possible future improvements of our training. We will track the talks given by fellows and their involvement in the Junior Colloquium, working seminars, math club and similar venues, and involvement by postdocs in educational outreach and interdisciplinary activities. Through our web site we will establish hyperlinks to email addresses and home pages of our departing fellows so that we can easily keep in touch with them over the years, follow their career development and get continued feedback from them. We will also solicit articles and "nuggets" concerning highly noteworthy achievements by fellows in our program.

Note: For the graduate students and postdocs, much of what we wish to accomplish can be described as "milestones," such as qualifying exams passed, talks given, training received, papers written, grants applied for, degrees received, outreach projects, etc. We will make sure that the

students, postdocs, faculty advisors and mentors are well aware of these milestones and their progress toward reaching them.

Comprehensive evaluation

As much as possible, we will use email and the web site to solicit, collect and organize evaluations, and make the (non-confidential) information available for a thorough review of the program. At the end of the spring semester each year, Professor Willard Miller, will ask the VIGRE Advisory Committee in the School of Mathematics (presently Professors Scott Adams, David Frank, Paul Garrett, Markus Keel, Harvey Keynes, Conan Leung, and Peter Olver, but these will be rotated in future years so that the co-coordinators are not on the advisory committee) to do a complete review of the VIGRE program and make specific recommendations for new ideas and improvements. The VIGRE graduate student and postdoc representatives will play an important role in the evaluation. The co-coordinators will discuss these recommendations and present them to the department faculty at the fall retreat (to be held every year). Focus groups will be formed in advance so the time at the retreat is used most efficiently. The department faculty will be asked to help implement suggestions that evolve through this yearly self-evaluation process.

About every two years the department will invite two prominent faculty members from mathematics department at other universities, and at least one faculty member from another department at the University of Minnesota, to assess the success of the VIGRE program with respect to multidisciplinary activities, integrative activities, the recruitment and retention of graduate students and postdocs, the effectiveness of the undergraduate honors program and the REU program. The statistics and reports listed above will be used for such assessments, they will certainly include numbers of graduate students and postdocs hired under the program, numbers of members of underrepresented groups, quantifiable progress of graduate students in the graduate program, progress of postdocs, time to degree of graduate students, placement of Ph.D.s and postdocs after they finish their work. The impact of research experiences of undergraduates will be assessed in terms of the influence that these experiences had on their choice of mathematics for graduate studies. The assessment will also involve personal meetings with the students and fellows in residence.

Dissemination

We expect our VIGRE program to be a model for the management of mathematics research and education at major public research universities, where students from levels K-12 to postdoctoral are involved in large numbers, and flourishing core mathematics research and educational programs coexist with an emerging array of multidisciplinary research and educational opportunities. For broad impact on mathematics education and research, we will disseminate the ideas, results, activities, and insights from VIGRE-related activities as widely as possible. The management/assessment team and faculty playing key roles will report on our program at national and regional mathematics meetings and in mathematics publications. However, the Minnesota VIGRE web site will probably play the most important role in the dissemination.

The web site development will be a major undertaking. It will not only describe the details of the functioning of our VIGRE program, with this proposal as the initial blueprint, but it will contain articles about VIGRE, daily schedules of talks and other activities, REU opportunities and reports on completed projects, *The Math Path* newsletter, and archives of all past postings of such activities. We will employ graphics to make clearer the interlocking nature of VIGRE. (A reasonable model for what we have in mind is the IMA web site, in whose development the coordinator played a significant role. There, one can find descriptions of all IMA activities, what is planned, what is going on today, who was here ten years ago today and the abstracts of their talks, the names, present positions and email addresses of the postdocs since the beginning of the IMA, etc. Also there are feedback mechanisms to apply for programs, to evaluate programs, etc.) Of course, we will be careful to separate the public portion of the web site from the confidential assessment material and data on our students.

Since one will be able to reconstruct a virtual day-by-day history of our project from the web site, negative as well as positive experiences will undoubtedly become apparent. It may be especially important to delineate these, to allow others to profit by our mistakes and not be condemned to repeat them. There is a special risk of falling prey to unhelpful traditional myths about undergraduate and graduate mathematics education. To succeed in bringing about a national change of culture in mathematics we must share both our confirmation and our denial of the validity of traditional and speculative approaches to the integration of education and research.

Our own students, postdocs, faculty (and advisors and mentors) will use the web site heavily, but it should also function well as a means of dissemination of information about the VIGRE program to other schools. One difficulty in explaining our program, at least initially, is the complexity of the mentoring program for postdocs and graduate students, meant to enlarge their horizons and expose them to new opportunities to employ their expertise. Ideally, to explain this we should have some historical examples, but our program is new. Thus we have developed a series of "case studies," fictional but plausible and based on our recent experience with postdocs in the department. These illustrate how the variety of options open to the postdocs can be tailored into a coherent career-enhancing program, with the help of experienced mentors and coordinators. We have more than a half dozen of these, most for fellows with traditional training and interests in math research, but one for a fellow deeply interested in industrial mathematics, and one for a fellow with an interest in the development of innovative K-12 and undergraduate coursework and college teaching. Here is an example.

Case study: A VIGRE postdoc with an interest in differential geometry

Amelia arrives in Minnesota on a VIGRE postdoc, with solid preparation and a thesis in differential geometry, involving a novel extension of calibrations to determinant bundles at the level of 2-jets of submanifolds. There is a strong group here in differential geometry, and in the offer letter to her it is suggested that Professor Robert Gulliver, a senior geometer in our department, be her faculty mentor. She immediately begins participation in the working seminar on Differential Geometry. During her first summer she helps graduate students with problems in the qualifying exam workshop, particularly those in differential geometry and topology. Since differential geometry is a field with many relationships to other areas of mathematics and beyond, she has multiple opportunities to make connections. In her second year, she discovers an interest in computer vision and it is arranged that she meet with Professor Guillermo Sapiro (Digital Technology Center), who has done research in this topic and that she participate in some IMA workshops related to computer vision. This contact encourages her to learn some basics of computational commutative algebra -- Gröbner bases and all that. In 2006-7, the IMA has a special year on applications of algebraic geometry and her knowledge of this field grows rapidly. On another front, certain aspects of differential geometry do not require significant background and lend themselves well to visualization (especially, Amelia is pleased to note, calibrations at the level of 1-jets in two and three dimensions). In the spring of her second year she teaches the upper division course on computational algebraic geometry, for which she designs visualization software. She gives a lecture-demonstration on some of these aspects for the Undergraduate Math Club. Consequently, in the summer following Amelia is tapped to help in an REU project, and then to participate in the revision of an UMTYMP calculus course in which the visualization of geometric surfaces is important. By her third year, she's been involved in a number of different mathematical projects, and has noticed that one should be able to use tools of computational commutative algebra to compute effectively all differential geometric invariants of complex varieties at smooth points, and certain interesting invariants of singularities, thus forging a connection between the two fields.

When our program is well underway we will be able to phase out these "case studies" and replace them with actual "case histories." The collection of case histories and vignettes, also at the undergraduate and graduate levels, will be an important feature in dissemination of information about the program.

Although the simplest and most cost-effective medium for distribution of our VIGRE program and plans is the internet, it is also necessary to publicize in other ways the existence of the resources. Paper publications, prepared from internet sources, and exposure at meetings meshes well with internet publication. We hope to share our experiences with the mathematical community with minimal overhead or friction, helping as best we can in the national effort to sustain and increase our national pool of human mathematical capital.

Post-VIGRE Plan

This project is intended to have a permanent impact on the culture and operations of the department. We need the stimulus of a VIGRE grant to get it underway but, at the conclusion of the 5-year VIGRE funding cycle, most of our program would remain in place. If there are no new grant funds for the VIGRE graduate students and fellows, we will still support them for their full term, but might have to scale back our commitments to teaching reduction. However, we expect to have an excellent track record in training of students by that time and we are optimistic that we can use this to obtain resources from university and outside agencies and get commitments to support the aims of the program. The program would continue to evolve as the educational and research opportunities evolve. Activist recruitment of students from underrepresented groups would continue, and we would seek internal support for the annual faculty "tour" to a group of Historically Black Colleges and Universities. We would seek other sources of support for the REU program. The honors program and the Undergraduate Math Club would continue, as would publication of *The Math Path.* The four-week orientation program might have to be scaled back to three weeks and the number of summer mini-courses reduced, but not eliminated. The community building programs, such as the Junior Colloquium and working seminars would continue. We would scale back to a single coordinator. We would change the name of the Minnesota VIGRE web site, and be less ambitious in its continued development, but it and most other aspects of our proposed program would remain if our performance assessment found them to be valuable.

The major contribution of VIGRE will be to accelerate and energize the change of culture and environment that our department has been effecting in recent years. The expansion of the REU program and its integration into faculty/postdoc ongoing research groups, the Math Club, the undergraduate honors program, the Junior Colloquium, a culture of working seminars, and proposed creation of *The Math Path*, and the Minnesota VIGRE web site, and an activist recruitment policy for members of underrepresented groups, are important steps in this direction. The curriculum review and development, both at the undergraduate and graduate levels in mathematics and its applications, have proceeded at a very active pace with new degree options in math biology and industrial math. Our outreach program for K-12 education, and our college and postdoctoral level educational development programs are well known and have been in existence for some time, and we are now linking them much more closely with our research-training program. All this is evidence that we will continue to move forward with the basic VIGRE goals even after NSF support might cease. As long as this support will be available to us, we will make the best use of it to strengthen the foundations so the program can continue to evolve to meet new educational challenges.