## 1. Introduction

Our current VIGRE grant achieves horizontal integration across the departments of Applied Mathematics, Mathematics, and Statistics, as well as vertical integration of educational levels. We will extend this horizontal integration internationally, using our membership in the Pacific Institute of Mathematical Sciences (PIMS) to involve Canadian partner universities in collaborations that will enrich and broaden the opportunities for our students and postdoctoral fellows.

PIMS, which was formed in 1996, is rapidly becoming a major international force in the mathematical sciences. PIMS is a distributed institute with operations at seven Canadian universities and at the University of Washington, its only US site.

The Banff International Research Station (BIRS), which began operation last March, is the latest PIMS initiative. Formed in partnership with MSRI and funded by NSERC, the Alberta government, and NSF, BIRS runs a variety of research programs involving the best researchers from around the world, including summer schools, two-day workshops, two-week research meetings, and a series of forty five-day international workshops held throughout the year.

As the only US university formally affiliated with PIMS, the University of Washington has played a significant role, helping to organize more than a quarter of the workshops held at BIRS during its first year of operation. As the foremost US research university in the Pacific Northwest, University of Washington is uniquely positioned to take full advantage of the explosion in mathematical activity generated by PIMS.

Our current VIGRE grant is focused on the recently developed undergraduate degree program in Applied and Computational Mathematical Sciences (ACMS), which is administered jointly by our three departments, together with Computer Science and Engineering. Created in 1997, and expanded and improved using VIGRE funds, the ACMS program now contains eight pathways of specialization. During the period of our current VIGRE grant, the number of undergraduate degrees in the ACMS, Mathematics, and Statistics programs combined has increased by more than 50%.

We are in a strong position to take our efforts much further. Here are some highlights of what we will do (as described in detail in Section 3).

**Integration with PIMS.** Through PIMS and with the help of VIGRE funds, we will create new international research opportunities for our students, postdocs, and faculty. These include training workshops for graduate students, enhancements to the variety of existing Pacific Northwest Seminars, exchange programs for students and faculty, and support for the newly formed PIMS Collaborative Research Groups (CRGs). We will use VIGRE funds to support graduate student travel to BIRS workshops, where our students will have the opportunity to meet and learn from top researchers from around the world. We will expand the number of outside speakers to our local seminars, by using VIGRE funds to bring BIRS participants to Seattle, enriching the mathematical environment here for everyone. Used these ways, VIGRE funds will be substantially leveraged with PIMS support.

CRGs offer an excellent opportunity for developing cross-disciplinary research collaborations and cross-disciplinary curriculum development. For instance, the Departments of Mathematics and Physics have recently cooperated in building a strong research group, which is part of the current CRG in String Theory. The CRG in String Theory has ambitious plans which would be greatly enhanced with VIGRE funding. Among these are two BIRS workshops in 2004, a joint Pacific Northwest String Theory Seminar (with its first meeting planned to meet in Seattle in early December, 2003), development of introductory undergraduate courses in string theory and mathematical physics, and creation of an undergraduate cross-disciplinary program in mathematical physics.

**Critical Transitions for Graduate Students.** VIGRE support for graduate fellows is crucial in helping graduate students to navigate key career transitions: the first year of graduate school, the

introduction into individual research, and completion of a Ph.D. thesis and finding a rewarding job. We will hold regular forums for graduate students on all aspects of professional life, using VIGRE funds to bring in panelists when appropriate. Two forums on finding academic and industrial jobs were held last year, both planned by our VIGRE postdocs.

We will use some VIGRE fellowships to recruit the most talented graduate applicants, with other VIGRE fellowships to be awarded to more senior graduate students. To maintain the vitality of our VIGRE program and to ensure full participation of fellows, VIGRE fellowships to senior graduate students will be made competitively and will be partially based on a proposal describing the applicant's plans for participation in the VIGRE program.

**Undergraduate Research Experiences.** Over the period of our current VIGRE grant, the numbers of undergraduates involved in research projects with faculty has increased dramatically in all three departments, involving 21 students supported by VIGRE this past academic year. Most of these involved vertically integrated teams of faculty, graduate students, and undergraduates. Some lead to published research papers (Section 2.3). In addition, VIGRE has supplemented a highly successful REU program by providing funding for undergraduate alumni from previous years to mentor current participants. We will use VIGRE funds to increase the number of UW students who participate in this important aspect of undergraduate training. We plan to increase the number of research opportunities for our undergraduates by partnering with outside organizations, such as the Applied Physics Laboratory and Northwest Research Associates (Section 3.9).

**Curriculum Development.** We will implement a five-year concurrent BS/MS degree program. This program will provide strong preparation for graduate school or industrial work for our best majors in the mathematical sciences. We will use ideas and lessons developed for courses in mathematical communication taught during the current VIGRE grant in creating writing modules for our mainstream courses.

**Cross-Departmental Committees.** We will achieve further horizontal integration by forming cross-departmental committees of graduate fellows, postdocs, and faculty to generate ideas and activities for orientation, undergraduate research involvement, web site content, and overall planning. By promoting discussion among students from all three of our departments, these committees will help unite the mathematical sciences community on campus

**Recruitment and Retention.** We plan to step up dramatically our efforts to attract talented undergraduates into the mathematical sciences, leading to further increases in the number of majors. Over the past five years, the Mathematics Department has made major improvements to its first-year calculus series. Our calculus students are now both better trained and more willing to consider a career in the mathematical sciences. To actively recruit the best of these students, we will use VIGRE funding for several initiatives, including informational workshops and peer mentoring by majors. The recruitment and retention of underrepresented groups presents unique challenges, and we plan to make use of the many programs at the University of Washington targeted for these groups, such as the NSF-funded ADVANCE program.

In December, 2001, VIGRE helped fund a Workshop on Statistical Genetics and Computational Molecular Biology [4], with additional support from PIMS and the Burroughs-Wellcome Fund, aimed at attracting the 84 students attending (both undergraduate and beginning graduate) to work in this area. We will hold additional such workshops, focused on active research areas represented in our departments.

**Collaboration with other VIGRE Sites.** We will host several workshops for VIGRE sites in the western US, modeled on one we held last April. By exchanging information and ideas with other VIGRE sites, we intend to improve the quality of VIGRE programs throughout the region.

## 2. Results from Prior Support

The Departments of Applied Mathematics, Mathematics, and Statistics were jointly awarded one of the first VIGRE grants, entitled "Integration of Research and Education in the Applied and Computational Mathematical Sciences". Denoted NSF Grant DMS-9810726, the total award amount is $2,510,800, with supplements of $91,476 for curriculum development, $147,910 for outreach, and $109,308 for an increase in graduate fellowship stipends in years 4 and 5. The award period is from September 1, 1999 to August 31, 2004. The PIs on this grant are Loyce Adams, Anne Greenbaum, Peter Guttorp, and Randall LeVeque.

Four years of VIGRE support has made a significant impact on the three departments involved in this endeavor:

- The number of majors in the mathematical sciences has dramatically increased.
- The graduate programs in the mathematical sciences have grown in both size and quality.
- Undergraduate research projects, some with industry, have been initiated in all three departments.
- Communication among our departments has improved substantially, particularly at the graduate level, and cross-departmental committees of VIGRE fellows and postdocs are helping to run the VIGRE program.
- The VIGRE program has grown from one focusing only on applied aspects to one encompassing all aspects of the mathematical sciences.
- Panel discussions on job interviews (for graduate students) and on graduate studies (for undergraduates) have been a success.
- The curriculum has been reformed at both the undergraduate and the graduate level in all departments.
- K-12 outreach activity has increased in all departments.

### 2.1. **Improvements to the ACMS Undergraduate Program.**

A key feature of this grant is the *horizontal* integration achieved across departments by use of our Applied and Computational Mathematical Sciences (ACMS) degree program. VIGRE has been crucial in strengthening, enriching, and broadening the ACMS program, which has now grown from zero to around 160 majors. In describing the results achieved so far from our VIGRE grant, it is therefore convenient to start with the ACMS program.

The BS degree in Applied and Computational Mathematical Sciences (ACMS) was introduced Autumn Quarter, 1997. It was jointly developed and is administered by the departments of Applied Mathematics, Mathematics, Statistics, and Computer Science and Engineering.

ACMS students take a set of common core courses to provide them with a solid foundation, from which they can pursue one of eight "tracks" or pathways of specialization. The program core includes the standard courses in calculus, linear algebra, differential equations, and computer programming, as well as courses in numerical methods, discrete modeling, continuous modeling, and probability and statistics. Currently there are eight pathways (see [1] for details):

- Biological and Life Sciences
- Discrete Mathematics and Algorithms
- Engineering and Physical Sciences
- Mathematical Economics
- Operations Research
- Scientific Computing and Numerical Algorithms
- Social and Behavioral Sciences
- Statistics

With VIGRE support, some of the pathways have been reorganized, and some new ones introduced such as one in Mathematical Economics (working closely with the Economics Department). Anne Greenbaum, Randy LeVeque, and Tim Chartier (a VIGRE postdoc) produced new case studies for the discrete modeling courses. Materials developed by Ka-Kit Tung for continuous modeling are being published as a book by Princeton University Press.

A key feature of the program is the Friday afternoon ACMS Seminar, which students may take for credit. This seminar offers undergraduates, as well as VIGRE fellows and other graduate students, a wide view of the mathematical sciences and has proved to be an excellent method for horizontal integration. VIGRE postdocs and fellows have given talks in this seminar, undergraduates supported by VIGRE have described their research projects, and outside visitors have shown students how mathematics impacts the real world. Some impression of the broad sweep of topics covered in the ACMS seminar can be gleaned from the web site [1].

2.2. **More Majors in the Mathematical Sciences.** A striking event of the past few years has been a dramatic increase in the numbers of undergraduate majors and degrees awarded in the mathematical sciences (Figure 1).

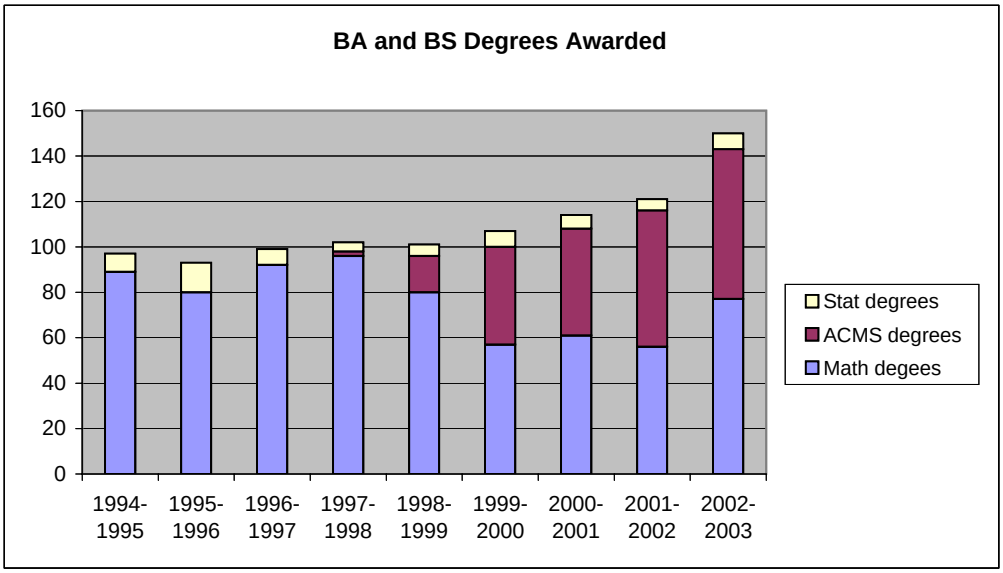


FIGURE 1. Number of undergraduate degrees in the mathematical sciences at the University of Washington.

The ACMS program was designed in part to replace the "Mathematical Sciences" option for the Bachelor of Sciences in Mathematics degree, which accounted for approximately half of all majors in the Mathematics Department. The Department of Statistics initially planned to phase out its BS in statistics in favor of the Statistics pathway within the ACMS program. As these options were phased out, we anticipated a decrease in the numbers of Math and Statistics majors. This did occur as the number of ACMS majors climbed. However, during the period from 2000 to 2003 the total numbers of majors in *all three programs* have increased dramatically. As Figure 1 shows, during the period of the VIGRE grant, the number of undergraduate degrees awarded in the mathematical sciences has increased by about 50%. Since approximately 95% of undergraduate majors in the mathematical sciences are US citizens or permanent residents, this represents a dramatic increase in the number of US citizens majoring in the mathematical sciences over the period of the current VIGRE grant.

The ACMS program, in which VIGRE has played a substantial role, accounts for much of this increase. The serious and sustained efforts in revising our first-year calculus course (described in Section 4) and other changes to our courses in the mathematical sciences have made majoring in the mathematical sciences much more attractive.

Our programs attract some of the most talented students on campus. Since 1999, our students have won a number of awards, including two President's Medals (the University's highest honor for a

graduating senior), a Goldwater Scholarship, two NSF Graduate Research Fellowships, three teams designated Outstanding Winners of the COMAP Mathematical Contest in Modeling: the Society for Industrial and Applied Mathematics (SIAM) Award, the Mathematical Association of America (MAA) Award, and the INFORMS (Institute for Operations Research and the Management Sciences) Award.

2.3. **Undergraduate Research Projects.** Using VIGRE funds we have substantially increased the number of undergraduates involved in projects, often in teams with faculty, graduate students, and sometimes postdocs. This past academic year 21 undergraduates were supported by the VIGRE grant. A recent trend is that more faculty in the Mathematics Department have been supervising such projects. Here are a few examples to illustrate the variety of projects and the participation of both regular faculty and VIGRE postdocs in our three departments.

A team of two undergraduates (Caleb White and Youngbae Lee) worked with a graduate student (Yoonsoo Kim), Patrick Perkins (the director of the UW Math Study Center) and Rekha Thomas (Mathematics) on a project using integer programming to improve the scheduling of tutors in the Study Center, resulting in the paper [5]. The students developed the models, devised computational tests comparing their methods with earlier heuristics, did the analysis, and wrote the paper.

Tim Chartier, a VIGRE postdoc in Mathematics, worked on four separate undergraduate projects during his tenure here at the UW. For instance, Chartier worked with Reuben Fries to develop an applet to demonstrate the card shuffling result of Bayer and Diaconis [11]; the applet is used in the Discrete Modeling course for the discussion of shuffles. His work with undergraduate Miranda Antonelli on multigrid methods for immersed interface problems has resulted in a paper that has been accepted for publication in International Journal of Pure and Applied Mathematics [9].

VIGRE funds supported two different teams under the direction of Nathan Kutz (Applied Mathematics). In one example, a collaborative effort in modeling the dynamics and stability of a Bose-Einstein condensate trapped in a periodic potential included a VIGRE postdoc (Deconinck), a VIGRE graduate student fellow (Patterson), and a VIGRE supported undergraduate (B. Warner) [6]. In a second example, two VIGRE graduate fellows (A. Kim and D. Yong) worked in conjunction with a VIGRE supported undergraduate (K. Spaulding) to model the behavior of pulsed light in a ring laser cavity [7, 8].

David Hiller (undergraduate, Mathematics) joined the Spectral Methods research group in the winter quarter of 2003, with support from VIGRE. The group is lead by Marina Meila (Statistics), and also includes the graduate students Deepak Verma (Computer Science), Liang Xu (Mathematics), and Qunhua Li (Statistics). Hiller worked on methods to measure how "well clustered" are the elements of a given vector, a problem of central interest in spectral clustering. Hiller's work continued this summer, supported by the University of Washington NASA Space grant.

These projects complement the summer REU program on Inverse Problems [15] run by Jim Morrow (Mathematics) since 1988. Until the summer of 2002, nearly all of the support for this program came directly from the NSF REU grant. In the summer of 2002, the VIGRE program supported an additional student, two full-time undergraduate assistants, and a half-time faculty member. In 2003, the VIGRE program supported three students, two full-time undergraduate assistants, and one half-time assistant. The assistants are alumni of the program and know how to work with the REU students, helping them with mathematical ideas, answering questions about Latex and computing, taking meals with the students and interacting with them day and night. Everyone connected with the REU program has said that the last two years have been phenomenal. The difference has been the VIGRE support.

The REU program has had a marked effect on the students. As we mentioned above, in the last two years the University of Washington has had three teams of students win the MAA, SIAM, and INFORMS prizes in the Mathematical Contest in Modeling. This is without precedent (see [12] for details). Six of the seven team members were alumni of the REU program (there is some overlap

on the teams). The REU program successfully trained them to state, analyze, and solve difficult problems. The REU students are winners of NSF Fellowships, Goldwater Scholarships, graduate school awards and some have gone on to faculty appointments at universities such as UCLA, MIT, and NYU.

2.4. **Successfully Mentored VIGRE Postdocs.** Each department successfully mentored its VIGRE postdocs.

Lisa Korf (Mathematics, 1999–2002), whose specialty is Optimization, is active in a number of outreach activities. Since 1999, she has served as a mentor for the UW WISE (Women in Sciences and Engineering) program, and has participated in the PIMS Modeling and Industrial Problem Solving Workshops held at UVic and UW in 2001, and other activities. Korf was the faculty mentor of an Applied Mathematics graduate student on a project at Boeing. At the end of her VIGRE appointment, she was hired by the UW Mathematics Department on a tenure-track position. She is the recipient of an NSF grant in Applied Mathematics, starting July of 2002.

Tim Chartier (Mathematics, 2001–2003) works in Numerical Analysis. In 2001, he teamed with Anne Greenbaum of Mathematics and Randy LeVeque of Applied Mathematics to teach and develop materials for our modeling course, Math 381. He and Greenbaum later advised two of the four UW modeling teams in 2002. While at the UW, Chartier developed a collaboration with Loyce Adams of Applied Mathematics leading to two research papers. After two years of VIGRE support, Chartier was appointed to a tenure-track job at Davidson College.

Jean-Yves Courbouis (Statistics, 2000–2003) was mentored by Paul Sampson and Peter Guttorp. He participated in several working groups sponsored by the National Research Center for Statistics and the Environment (NRCSE), particularly in dynamic graphics, where he worked with several undergraduates, and in sampling, where he participated in a successful center proposal with Oregon State and Colorado State to the EPA. He now works on a project with the National Marine Fisheries Service, jointly with Peter Guttorp.

Oliver Will (Statistics, 2001–2004) is mentored by Elizabeth Thompson and Matthew Stephens. His research is in statistical genetics and genomics, and he is active in the Mathematical Genetics working group.

Bernard Deconinck (Applied Mathematics, 1999–2000) specializes in nonlinear waves. His mentors were Robert O'Maley, Nathan Kutz, and Randy LeVeque. Deconinck was particularly active in mentoring graduate students. For instance, at the request of graduate students and in addition to his regular teaching duties, he ran an informal special topics course on applications of the inverse scattering method to the solution of soliton equations. Deconinck and Nathan Kutz supervised a number of undergraduate research projects. He was awarded an NSF Math Sciences Postdoc in 2000-2003. In Autumn, 2003, Deconinck will assume a tenure-track assistant professor position in the UW Applied Mathematics Department.

Peter Blossey (Applied Mathematics, 2000–2003), who specializes in fluid dynamics, was mentored by Peter Schmitz. Blossey has collaborated with Peter Schmid and William Criminale. He organized several workshops for graduate students (see below) and has given several talks in the undergraduate ACMS seminar. Since finishing his VIGRE postdoc, Blossey has been working as a postdoc with Randy LeVeque during the summer and recently accepted a Research Scientist position in the Atmospheric Sciences Department at UW.

Brian Walton (Applied Mathematics, 2002–2004) works on problems in mathematical biophysics and applied probability. Walton, his mentor Hong Qian, and graduate student Rafael Meza are studying diffusion approximations to birth-death processes. In addition to ongoing collaborations stemming from his graduate studies, Walton has actively pursued new interdisciplinary connections including active participation in the Mathematics Department's probability seminar and the interdepartmental Mathematical Biology seminar hosted by the Biology department.

2.5. **Professional Development and Industrial Training Workshops for Graduate Students.** To provide a forum for discussing important topics related to the professions of mathematics and statistics, VIGRE has supported two recent forums, open to all graduate students. The forums were organized by Chartier and Blossey, both VIGRE postdocs. The topic for the first was "Finding an academic job." A panel of recently appointed faculty from each of our three departments together with the Mathematics Chair at Seattle University told of their experiences and gave advice. Approximately 55 graduate students participated. The second forum, attended by about 40 students, focused on jobs in industry and national laboratories and how to find one. The panel, included a representative from Microsoft, two from Boeing, and one from Livermore National Laboratory (brought to the UW campus with VIGRE support).

We also collaborated with PIMS to host the Fifth Annual PIMS Industrial Problem Solving Workshop (see Section 3.1 for details).

2.6. **Mathematical Communication.** Using VIGRE support as well as matching UW help, taught several courses in mathematical communication. These courses have helped us develop and refine our ideas of what is effective, and how to reach the largest numbers of students. Some of the materials we developed have already been integrated into a basic course in Mathematical Reasoning. Other materials will be integrated into writing modules for our mainstream courses. In the mathematical modeling courses at the core of the ACMS program, VIGRE helped us develop project-based modules with a heavy emphasis on presentation of results.

2.7. **Impacts on our Graduate Programs.** In addition to the workshops mentioned above, VIGRE continues to help us improve and broaden our graduate programs.

The quality of applicants has increased. In Mathematics applicants, around 175 annually, are divided into groups using a point system. In 2002 the top group contained 39 people, and all but three of entering PhD students came from this group. In 2003 the entire entering PhD class came from this group, which numbered 44. In Statistics, the number and quality of applicants has gone up, going from 78 to 112 from 2000 to 2003, and using VIGRE funds Statistics has been more successful in landing more of its first-round choices (7 out of 10 in 2003), making them competitive with the best departments in the country.

VIGRE funds have enabled our graduate students to participate in conferences and workshops vital to their future careers. In this past year alone, our grant VIGRE helped funded 44 trips by graduate students to conferences, some of them major international meetings. A dozen graduate students have been placed in internships using our VIGRE framework. VIGRE funding has also facilitated funding students in Statistics with research interests in statistical theory.

As a result of their participation in our third-year review, the VIGRE graduate fellows asked to set up working committees to help plan VIGRE activities. There are now four cross-departmental committees (with both VIGRE graduate fellows and VIGRE postdocs) that are concerned with undergraduate involvement, web page content, orientation, and general planning.

Graduate students and undergraduates have been supported by VIGRE to participate in such outreach activities as the NSF-funded projects *Creating and Extending the Community of Mathematics Learners* whose co-PIs include Warfield (Math) and Morita (Stat), and the UW GK-12 project, with Adams (AMath) as PI and Warfield as a co-PI.

2.8. **Seattle VIGRE Workshop.** On April 12, 2003, we held a Workshop for VIGRE sites on the West Coast and in the Southwest. All nine sites sent at least one representative, and Richard Millman from NSF also participated. The goal of the workshop was to exchange ideas and information, share ideas that have worked (and some that have not worked as well as anticipated), and develop new ideas to increase participation in the mathematical sciences, especially at the critical transitions. A report on this discussion, prepared by William McCallum from Arizona, was distributed to participants and to the NSF, and is available at [16].

# 3. Project Description

We will build on the successes and experiences of our current VIGRE grant to create an integrated program that will attract and retain high quality US citizens and permanent residents into the mathematical sciences at all levels. The key features of this program are the following:

**Integration with PIMS**. Membership in PIMS offers us an extensive array of rich scientific opportunities for our students and postdocs. These include year-long thematic programs, Collaborative Research Groups, summer schools and training camps, workshops at the Banff International Research Station, and a wide range of Pacific Northwest seminars. VIGRE will enable our students and postdocs to participate fully in these activities, leveraging the considerable resources now available through PIMS.

**Critical Transitions for Graduate Students**. We will use VIGRE graduate fellowships to offer help to graduate students at three critical transitions: the initial year, the transition from courses to research, and thesis completion and finding a rewarding job. We will run Professional Forums for graduate students on a wide range of professional issues not normally systematically discussed.

**Well-mentored Postdoctoral Associates**. We will assure that VIGRE postdocs have both the scientific and professional help they need to be successful.

**Increased Undergraduate Research**. More faculty in all three departments are participating in undergraduate research projects. VIGRE funds will enable us to support more undergraduates, and to enhance the existing REU summer program in Inverse Problems.

**Better Recruitment of Undergraduate Majors**. We will use several strategies to attract more high quality students into the mathematical sciences.

**Improved Training in Mathematical Communication**. We will integrate the lessons about mathematical communication from our previous VIGRE grant into mainstream courses.

**Implementation of a Five-Year BS/MS degree program**. This combined degree program will provide strong preparation for graduate study or industrial work for our ACMS and other mathematical sciences majors.

**Better Recruitment and Retention of Women and Underrepresented Groups**. We will use support from the UW's ADVANCE program to enhance opportunities for women in the mathematical sciences, and a variety of other UW programs to attract and retain members of other underrepresented groups.

**Cross-Disciplinary Undergraduate Program in Mathematical Physics**. Based on the Collaborative Research Group in String Theory, the aim is to create courses and activities on the interface between Mathematics and Physics, possibly leading to a degree program.

**More External Opportunities for Students**. We will actively seek ways for our students to be involved in research outside our departments, such as the UW's Applied Physics Laboratory.

**Enhanced Outreach and K-12 Activities**. VIGRE graduate fellows will be offered opportunities to participate in activities such as the UW's GK-12 initiative, Math Day, and the Elementary Quantitative Literacy program.

## *Proposed VIGRE Activities*

3.1. **Integration with PIMS.** The Pacific Institute of Mathematical Sciences (PIMS) is a regional consortium of six partner universities (five Canadian universities and the University of Washington) together with two affiliate Canadian universities. Created in 1996 on a shoestring budget, and with dramatically increased funding within the last two years, PIMS is rapidly becoming a major international force. The University of Washington joined PIMS in 2000 to become the first, and so far only, PIMS site in the US.

We will use the PIMS connection to offer our graduate and postdoctoral fellows a broader exposure to mathematical sciences through participation in joint scientific workshops and seminar series, and by visits to the UW by eminent researchers serving as PIMS Distinguished Chairs or visiting the PIMS/MSRI-operated Banff International Research Station. In addition we will cooperate with other PIMS universities to organize workshops intended to draw talented undergraduates from the region into graduate studies in mathematical sciences, and Young Researchers Retreats intended to help beginning researchers build a peer group of young mathematicians or statisticians with similar interest. VIGRE funds will be highly leveraged by PIMS contributions to these activities.

There is a long tradition of UW participation in regional conferences and workshops, some of which, like the Pacific Northwest Geometry Seminar (PNGS), were formed in the early 1970's and are continuing to flourish. PIMS now helps fund a number of these, such as the Northwest Probability Seminar, the Pacific Northwest Numerical Analysis Seminar, the Northwest Optimization Conference, the Pacific Northwest Statistics Meeting, and the PNGS.

The Fifth Annual PIMS Industrial Problem Solving Workshop, which took place in June, 2001 at the UW, illustrates the influence that PIMS has here in Seattle. This was the first major PIMS event held south of the border. About 100 people participated, including 58 graduate students who had taken part in the Graduate Modeling Camp held at the University of Victoria the previous week. Participants split into six groups to attack industrial problems brought to the workshop, spanning a broad range of applications and mathematical techniques.

Seven Industrial Problem Solving Workshops have already been held, successfully bringing together over a dozen Canadian and US companies and hundreds of faculty, postdocs and graduate students from Canada, the US, and Europe. Problems investigated range from cancer imaging to fingerprint identification. At least three companies have established long term collaborative relations with research groups at PIMS universities. (See the web site [13] for details.) We plan to work with other PIMS sites to extend and broaden these workshops, holding more of them in the United States, thereby giving our students extended exposure to applied and industrial experiences.

After a successful review by NSERC in 2002, PIMS has embarked on a plan that will create and support collaborative multi-university teams of mathematical scientists. The objective is to build upon new inter-university networks and use them as nuclei for providing global leadership and for generating and sustaining the scientific programming of PIMS in the years to come.

PIMS seeks to build areas of expertise and pool talent across universities by capitalizing on existing academic links and research strengths, especially those with the potential for forming cutting edge Collaborative Research Groups (CRGs). The research programs of these groups will be supported through a new PIMS program that helps to organize concentrated activities in 5 to 10 research areas each year. The program, run on a competitive basis, will support multi-site activities of selected CRGs over a 1-2 year period of concentration. There are currently six CRGs having concentration periods, with more to follow:

- Number Theory
- String Theory
- Scientific Computing
- Mathematical Ecology
- Dynamics and Related Topics
- Probability and Statistical Mechanics.

UW faculty have leadership roles in all six of the current CRGs [14]. The formation of these and future CRGs provides an excellent opportunity to leverage VIGRE funding across international borders. VIGRE funding will enable the UW to take full advantage of current and future PIMS CRGs.

PIMS has established a well-funded postdoc program, with 23 postdoc appointments in 2003 alone. We will explore opportunities to extend VIGRE postdoc funds by combining a VIGRE appointment with a PIMS appointment, likely in the context of a CRG. This would provide a postdoc with broader training, and leverage our use of VIGRE postdoc funds. To show how this

could work, a PIMS postdoc Grace Chiu, funded by a PIMS postdoc at a Canadian university, is spending this year in Seattle working with Guttorp.

The new Banff International Research Station (BIRS) has begun operation this year, and holds 40 five-day workshops per year as well as other research activities, such as Research in Teams, Summer Schools, and half-week workshops. As a member of PIMS, the UW has substantial input into the scientific program for BIRS. Sending our students to BIRS conferences as participants provides another opportunity to give them access to state-of-the-art research.

The UW will take advantage of the stream of high-level visitors to BIRS, as well as the PIMS Distinguished Chairs associated with the CRGs, to expose our students and faculty to leading researchers, by funding additional travel from BIRS and PIMS sites to Seattle.

Another avenue of interaction makes use of the UW's Home Tuition Program, which would allow a UW graduate student to visit UBC for up to a year, to participate in various PIMS activities there, while still being supported by the UW. We will seek to expand this program to other PIMS universities.

Included with our proposal is a supporting letter from PIMS Director Ivar Ekeland, outlining his enthusiastic support for this partnership and the role PIMS can play in supporting and amplifying our VIGRE activities.

We next present a few examples of how VIGRE funding can be used to integrate PIMS activities with local UW initiatives to effect change in the mathematical sciences at the UW.

3.1.1. *String Theory.* The Departments of Mathematics and Physics have recently cooperated in building a strong group in string theory. Within the past two years, Physics has appointed Andreas Karch, Matthew Strassler, and Mina Aganagic, while Mathematics has just appointed Charles Doran and has a priority to hire at least one more person in string theory. String theory is also a significant new initiative at UBC with G. Semenoff (senior faculty), Moshe Rozali and Jim Bryan (junior recruits in 2001) and M. Van Raamsdonk, a group having complementary strengths to the one at UW.

The CRG in String Theory has ambitious plans which can be greatly enhanced with VIGRE funding. Among these are two BIRS activities during the summer of 2004 and a joint Pacific Northwest String Seminar (with its first meeting planned to for Seattle in early December, 2003). At the UW, the string theory group intends to develop a cross-disciplinary undergraduate program in string theory, a joint Mathematics/Physics seminar funded by UW support for distinguished visitors, and possibly a postdoc position (see Section 3.8).

3.1.2. *Inverse Problems and Applications.* This is the focus of a Thematic Program at PIMS for 2003, with Gunther Uhlmann from the UW as principal organizer. The Thematic Program includes a series of workshops on different aspects of inverse problems and applications. During the last twenty years or so there has been remarkable developments in the mathematical theory of inverse problems in which several of our faculty have actively participated. These developments together with the enormous increase in computing power and new powerful numerical methods has made possible to make significant progress on increasingly more realistic and difficult inverse problems. The first workshop of the Thematic year was a Pan American Advanced Studies Institute (PASI) on "Partial Differential Equations, Inverse Problems and Non-Linear Analysis" supported by NSF and PIMS and held at the Centro Modelamiento Matematico (CMM) of the University of Chile in Santiago. Five UW graduate students went to the PASI with partial support from VIGRE. Other conferences of the Thematic year included a BIRS workshop on Scattering and Inverse Scattering (to which five of our graduate students went, two with partial support from VIGRE), a Geophysical Inversion Workshop held at the University of Calgary (to which two of our graduate students went with partial support from VIGRE), a workshop at UBC on Inverse Problems and Medical Imaging,

jointly sponsored by PIMS and NSF, in which two of our graduate students participated, one with partial support from VIGRE.

3.1.3. *Scientific Computing.* The exponential increases in speed and memory capacity of computers are widely recognized. But less well-known, and at least as important, is the exponential increase in the power of the mathematical algorithms that run on them—scientific computing has become a critical technology, with applications ranging from weather prediction, to the design of automobiles, to the analysis of DNA. The importance of mathematics has largely increased because for many of the industrial applications of computing, the central questions are mathematical ones. Over 40 faculty at PIMS universities are involved with the CRG in Scientific Computing, including the following from the UW: Randy LeVeque, Loyce Adams, Dale Durran, Anne Greenbaum, Greg Hakim, Nathan Kutz, Bob O'Malley, Peter Schmid, Jim Burke, and Chris Bretherton.

There is a long-standing inter-departmental numerical analysis journal club at the UW, where faculty and students meet weekly to discuss important papers and research results in a variety of areas of numerical analysis. In addition, there is an ongoing annual Pacific Northwest Numerical Analysis Seminar. The seventeenth annual PNWNAS will be held at UW on Oct. 4, 2003. The PNWNAS is a one-day conference for numerical analysts in the Pacific Northwest, usually with one or two outside invited speakers. Attendance varies with location, with as many as a dozen UW graduate students attending when the seminar is held locally, and at times only a few when the seminar is held further away. Recently, this conference has received some PIMS funding. VIGRE funding will enable more UW students to attend when the seminar is held off campus.

In addition, several UW faculty members of the CRG are helping to organize workshops at BIRS. Randy LeVeque, together with Bob Russell and Steve Ruuth from Simon Fraser University, organized a workshop entitled "Computational Techniques for Moving Interfaces" in 2003, and Anne Greenbaum, along with Jim Varah (UBC) and Gene Golub (Stanford), is organizing a workshop on "Model Reduction Problems and Matrix Methods," to be held at BIRS April 4–8, 2004. Graduate student participation in these workshops is a priority, and VIGRE funds will be used for graduate student travel.

3.1.4. *Statistical genetics and genomics.* Statistical genetics, computational molecular biology, and the quantitative analysis of gene expression data are three of the most active areas of modern quantitative genome sciences. All three are strongly represented at University of Washington, and there are active collaborative research links both among UW groups and with UBC and Simon Fraser University. Statistical genetics research at UW spans a broad range from genetic linkage detection and mapping from data on related individuals, population structure and linkage disequilibrium mapping, and molecular phylogenetics and evolution. Related work in computational molecular biology involves the pattern recognition problems of DNA sequence alignment and analysis and the prediction and design of protein structure. Gene expression microarray data are not only increasingly available, but are being used to address questions of population variation in gene function. These areas are united not only by the underlying genome sciences subject matter, but also by the requirement to model and analyze large amounts of data with a complex structure of dependence. To accommodate complex dependence patterns, hidden Markov models and MCMC methods are widely used in either a likelihood or Bayesian framework. We will pursue student exchanges between UW, SFU and UBC. In addition, there will be a BIRS workshop on Statistical Science for Genome Biology in the summer of 2004. The group has held two successful workshops for undergraduates and first year graduate students in western North America (see Section 3.1.6 below).

3.1.5. *Environmetrics.* Environmetrics is the quantitative analysis of environmental problems. Current work in environmetrics, mainly at the UW, the University of British Columbia, and the University of Victoria, deals with issues ranging from assessment of complex deterministic models of

climate, atmospheric dynamics, or air quality, to social analysis of environmental justice and the setting of environmental standards. Among the technical tools that are used in the field are models for space-time processes, Bayesian hierarchical models, visualization tools, and Markov chain Monte Carlo techniques for integration and optimization. The field is strongly interdisciplinary, and UW participants come from a dozen departments in six schools and colleges. Leadership in this area is provided by Peter Guttorp and Paul Sampson from the UW, Jim Zidek and John Petkau from UBC, Francis Zwiers from UVic, and Carl Schwarts from Simon Fraser University.

This group is currently discussing with the PIMS leadership the formation of a CRG in Environmetrics. The plan calls for an annual Pacific Northwest Environmetrics seminar, summer courses on special topics in environmetrics, exchange of graduate students primarily between UW and UBC, and a BIRS summer school in space-time modeling.

3.1.6. *Recruitment workshops.* A workshop on Statistical Genetics and Computational Molecular Biology, jointly funded by VIGRE, PIMS, and the Burroughs-Wellcome Fund, was aimed at undergraduate students in western North America considering graduate study and research in statistical genetics or mathematical and computational biology. Over a period of three days, fifteen researchers gave presentations intended to give a comprehensive view of current research. Based on the success of the first workshop, VIGRE, PIMS, and Burroughs-Wellcome are supporting a second workshop this fall.

The format easily adapts to other topics, and we plan to organize one such workshop per year, on topics chosen by the Executive Committee. The participants will generally be undergraduates or first year graduate students from universities in the western parts of Canada and the United States. In addition, we will apply to hold one summer school (10-12 days of student centered activities) each summer at BIRS.

In October, 2000, The University of Washington hosted the SIAM Northwest Regional Mathematics in Industry Workshop [3], funded by a grant from the NSF to SIAM. The goal was to facilitate discussion between faculty, students, and mathematicians working in industry and national laboratories, and featured talks by representatives from local industry and national laboratories describing both their technical work and the opportunities for collaboration with academia and for summer internships. We plan to organize additional such workshops, seeking external funding to leverage VIGRE funds.

In order to help postdocs, new faculty, and recent graduates to develop a peer group, we will organize, jointly with PIMS and the other Western VIGRE sites, an annual three-day Young Researchers Retreat. Each participant will present a short description of their research. In addition, carefully chosen senior faculty will discuss professional issues such as the editorial process in scientific journals, approaches to grant-writing, new directions in mathematical sciences, etc. This Retreat format is similar to the highly successful North American New Researchers Conferences organized by the Institute for Mathematical Statistics [17]. Different years will focus on different areas of the mathematical sciences.

3.2. **VIGRE Graduate Fellowships.** A major component of our VIGRE effort is to support graduate students at the critical transitions of their graduate careers. These are:

(1) The first year, when students are making the sometimes difficult adjustments to taking challenging courses in a competitive environment, while juggling all the parts of graduate student life.
(2) The transition from course work to independent research, especially in the context of a team of other students and faculty.
(3) Completion of thesis work and finding an appropriate and rewarding job.

VIGRE graduate fellowships will help substantial numbers of our students through each of these transitions. Each fellowship will consist of two quarters of VIGRE support during the academic

year, plus two months of summer support. The third academic quarter will typically be supported by a teaching position. This way even our best students remain involved in teaching to some extent, in addition to providing needed flexibility to the departments in teaching assistant assignments, especially in the autumn quarter.

*The First Year.* First year awards, made on the basis of academic excellence and promise, would help us attract the best applicants and also provide recipients with two quarters of non-teaching support. This will help them succeed in the foundational graduate courses, as well as progress through the system of prelim examinations. We will also strongly encourage these students to regularly attend the ACMS Seminars to broaden their outlook on the mathematical sciences, to actively participant in VIGRE committees, to attend VIGRE-sponsored forums on professional issues, and to be mentored by more senior VIGRE fellows about the nuts and bolts of graduate student life.

*From Courses to Research.* Perhaps the most difficult transition for graduate students is going from textbook-based course work, where everything seems easy (or at least elegantly laid out), to original work, where everything seems hard. Suddenly the answers, and even the questions, are elusive. Frustration is normal. Here VIGRE graduate fellowship can be pivotal. By being involved in a well-mentored team, instead of a more traditional one-on-one relationship with an advisor, our VIGRE graduate students will have broader support, perspective, and a group with whom to share experiences. At this point we want graduate students to be actively mentoring undergraduate students as well, and this can provide some additional perspective in addition to giving real service. We intend to involve as many VIGRE fellows as possible in PIMS Collaborative Research Groups, providing them with larger and more diverse working groups.

*Degree Completion and Successful Employment.* By the time a graduate student has established a research agenda, and is making good progress, the important final stage of graduate education begins. Working out ideas, formulating results, and learning how to present these both orally and in writing, all are likely new skills to be learned. A VIGRE fellowship at this point will provide the time to become well prepared for a future professional career.

We will conduct Professional Forums on a variety of topics, especially relevant for students about to complete their degree, but attractive and interesting to all graduate students. This past academic year we ran two such forums, organized by two VIGRE postdocs, with panels of four people each on the topics of "Finding an academic job" and "Finding an industrial job", which were very well attended. Topics for future forums include "How to write a grant proposal," "Getting a paper written and published," and "How to apply for a job." A good source of such topics is the new book by Steven Krantz, *A Mathematician's Survival Guide: Graduate School and Early Career Development* from the AMS. Since students from three departments are involved, we have found that a panel format works very well. The culture and faculty experiences are somewhat different in the three departments and a panel allows the expression of multiple viewpoints and increases the dispersal of information. This is valuable for all students and postdocs, and is often illuminating for faculty as well. It is particularly valuable for students who may eventually be employed in a department with a different culture than where they are currently working (e.g. Statistics and Applied Mathematics students may end up working in a mathematics department, and vice versa).

One use of VIGRE funds will be to bring in outside members of the panels, broadening the array of information our students hear about these important professional issues.

To have a significant impact on the graduate programs, we estimate needing 7 fellowships for Applied Mathematics, 11 for Mathematics, and 7 for Statistics. Originally, our current VIGRE grant focused only on the more applied mathematical sciences, and so allotted 6 fellowships to each of the three departments. But within the past two years, our vision has expanded to fully include the faculty and students of all three of our departments. Moreover, over the period of our current

VIGRE grant, the number of Ph.D. students in our programs has increased from an average of about 115 PhD students in the late 1990's to 135 last year, an increase of more than 15%. The increased number of fellowships in our request takes reflects this.

VIGRE fellows will participate, together with other graduate students, in rigorous teaching training before doing any teaching. They will be provided essential information about the relevant course, help with constructing lessons, practice teaching, and an introduction to the faculty teaching the course. Mathematics has a well-developed three-day program for all incoming graduate students who will be employed as TAs. New TAs are mentored by a more experienced TA and a faculty TA Coordinator throughout their first quarter of teaching. This mentoring includes classroom visits and one-on-one discussions about teaching performance and techniques for improvement. The program also has in-class videotaped sessions, which are discussed in groups with teaching professionals from the UW's Center for Instructional Development and Research. This program is quite suitable for VIGRE fellows as well. Applied Mathematics uses the Mathematics program, while Statistics has a similar one of its own, crafted for the special features of its department.

In addition, VIGRE fellows will be involved with mentoring of undergraduates or work in the GK-12 program, and participate in at least one of the cross-departmental VIGRE committees, to help create, organize, and plan VIGRE activities.

3.3. **VIGRE Postdoctoral Fellowships.** We envisage VIGRE postdoctoral fellowships as providing support during another critical transition, this being from student to well-functioning professional. VIGRE Postdocs will be selected according to fit with an active research group, interest in VIGRE goals, and willingness to be involved in VIGRE-related activities. Each VIGRE postdoc would teach approximately a half-time load, leaving adequate time for career development activities including grant proposal writing. Each will have a designated faculty mentor, responsible for making sure the postdoc is well integrated into the department and receives any guidance and help needed.

These positions will be for three years. The first year will concentrate on integration within a department and mentoring, and establishing connections both within the University and also externally. The second year will build on the first, making sure each postdoc has an active research agenda established, and clear direction. The third and final year will concentrate on becoming an established professional, with a tenure track job (or equivalent industrial job if appropriate), and submission of a research grant proposal.

In addition, we will ask each postdoc to participate in VIGRE activities. Among these are:

- Give talks in the ACMS Seminar on topics of interest to undergraduates in the mathematical sciences.
- Plan and participate in the forums on professional issues mentioned above that we will give for graduate students.
- Participate in team projects with graduate students and undergraduates.
- If appropriate, spend significant time visiting a research institute, national laboratory, or industrial setting.
- Participate in the cross-departmental VIGRE committees to help plan and organize activities.
- Meet regularly with the faculty mentor, and at least once a quarter with the VIGRE Director to assess progress and discuss any issues of concern.

3.4. **Undergraduate Research Projects.** The involvement of undergraduates in research is a high priority at the University of Washington. This has been highlighted in speeches by administrative leaders, the creation of an emphasis about research in the Office of Undergraduate Education, the establishment of the Mary Gates Endowment ($20 million), which supports research by undergraduates, and an annual Undergraduate Research Symposium to showcase projects from around the campus.

Under our current VIGRE grant, we have achieved a real cultural change toward involving an increasing number of undergraduates in research experiences in the mathematical sciences. To consolidate and accelerate this initiative, we plan to use current examples to attract even more faculty to become involved, highlight the possibilities for undergraduate research in both courses and the ACMS seminar, provide VIGRE stipends to students working on projects, and encourage undergraduates to travel, with VIGRE support, to appropriate conferences and meetings to discuss their work.

Based on the overwhelming response of participants in this summer's UW REU program (see Section 2.3), we propose VIGRE funding to allow us to bring back some alumni to serve as assistants in the summer immediately following their participation in the REU. The alumni would then have completed a year of graduate school and would usually have a year of teaching experience by that time. REU Director Morrow has already approached some alumni who indicated that they are willing.

3.5. **Recruitment of Undergraduate Majors.** We plan to step up dramatically our efforts to attract talented undergraduates into the mathematical sciences.

Over the past five years, the Mathematics Department has made major improvements to its first-year calculus series. As we discuss in greater detail in Section 4.3, these include reduced class size, use of worksheets to stimulate students, availability of course materials on the web, better coordination among faculty and TAs, and continuous improvements through student feedback to outside evaluators. We believe that our calculus students are both better trained and more willing to consider a career in the mathematical sciences. To actively recruit the best of these students we will organize informational workshops and encourage peer mentoring by majors.

Much informal encouragement already occurs, but to be more systematic and effective we will do the following:

- Invite all students who distinguish themselves in calculus and introductory statistics to an afternoon workshop about majoring in the mathematical sciences. Attendees will hear from more senior undergraduates about life as a major in the mathematical sciences, what their career opportunities are, and research project possibilities as well. VIGRE fellows will plan and organize this activity. Other possibilities include holding smaller versions of this sort of activity in the dormitories.
- The Math Study Center and the Statistics Tutoring Center not only provide help to mathematics and statistics students, but also serve as a social gathering places for students of all abilities. We will train the tutors working in these Centers to spot bright students, and suggest they think of majoring in the mathematical sciences. We will back this up with convenient hand-outs briefly describing the majors, together with web sites to find out more.
- Prepare materials for faculty teaching calculus and statistics to give a brief classroom presentation about majoring in the mathematical sciences, again with pointers to web sites for further details.

In order to recruit more students from underrepresented groups into the mathematical sciences at all levels, we propose taking advantage of the University of Washington's extensive efforts toward minority recruitment and retention, such as GEAR-UP and the Early Identification Program. We will use VIGRE fellows and postdocs, together with faculty, in showcasing opportunities in the mathematical sciences. To build stronger female participation, we are actively collaborating with the NSF-funded ADVANCE program at the university, whose aim is to increase the participation and success of women faculty in science and engineering departments, and which will provide additional support for women funded by VIGRE. The letter from Dean Denise Denton of the College of Engineering, in the Supplementary Documents, outlines the support that ADVANCE can provide to VIGRE.

3.6. **Mathematical Communication and Professional Development.** Using funds in our current VIGRE grant, supplemented with UW matching funds, we developed and taught courses in Mathematical Communication. These courses focused on providing training to students in how to present mathematical arguments, practice in giving oral presentations, nuts and bolts about LaTeX, and preparation of graphics and their inclusion in documents.

At the undergraduate level, some of the material we developed has already been integrated into Math 300 (Introduction to Mathematical Thinking), a one quarter course in which students grapple for the first time with notions of proof, induction, and theory. Student projects are also a basic part of our Discrete Modeling course (Math 381) and Continuous Modeling Course (AMath 383), both of which have been substantially improved using VIGRE funds from our current grant.

We will use what we have learned and developed in ways that will have broader impact, following the example of Math 300 mentioned above. In particular, we will introduce serious writing components in our basic senior-level undergraduate courses. This fits extremely well with a recent initiative announced by the College of Arts and Sciences to emphasize the importance of writing ability (see [18] for the full report).

For graduate students our basic vehicle will be the Professional Forums mentioned in Section 3.2 above). We will supplement this with close mentoring of VIGRE fellows. For graduate students in Statistics, writing and professional communication will be incorporated with the courses on Statistical Consulting.

3.7. **Implementation of a Five-Year BS/MS Degree.** We propose an initiative to better prepare our top students for graduate work, namely an integrated five-year concurrent BS/MS degree program. This is particularly important for students in the ACMS degree program, where an additional year of work in a Master's program would serve as a "capstone," giving them time to see many further directions and applications of their earlier work, often with the same professors. Graduates of this combined program would be much stronger applicants to graduate school or industrial jobs.

We see a three-pronged approach to finding students for this program. First, we will recruit in high schools in the state of Washington. Second, we will use UW admissions data to identify potential candidates. Third, we will identify likely candidates in freshman seminars, classes, and through individual contacts. The program is intended to be limited to only the top students, who will receive careful advising and mentoring throughout their undergraduate career.

Actual admission to the program (and hence to the graduate school as well) would not take place until the junior year, at the earliest. However, a student wanting to pursue this program would need to know this fairly early in the junior year, and we will adjust our advising accordingly.

Applied Mathematics already has a one-year Master's degree that can serve as one of the vehicles for this program. A successful example of such a program is one offered by the Applied Mathematics Department of the University of Colorado at Boulder [19] (which has sent us many excellent applicants to graduate school). Indeed, we learned about this program in the Seattle VIGRE Workshop held in April, 2003, described previously.

The Master's degrees in both Mathematics and Statistics currently require two years to complete, so students electing the five-year combined BS/MS degree program will need to complete most of the requirements for the BS early in their junior year. The most likely group of students for whom this is feasible is the group of students who successfully complete the Mathematics honors sequence. Statistics students would need to start taking Master's level courses in their senior year, and would need to have taken probability no later than the summer after their sophomore year.

3.8. **Mathematical Physics Degree.** The UW string theory group already has several graduate students in physics (three foreign, one US) doing string theory and two postdocs (both US) doing part-time string theory. With the addition of Doran to the Mathematics faculty, the group in physics is nicely complemented by existing Mathematics faculty, particularly Sándor Kovács (algebraic

geometry), Paul Smith (algebra) and Robin Graham and Dan Pollack (differential geometry), and Mathematics has hiring priorities in both string theory and algebraic geometry. The group plans to develop cross-disciplinary courses in mathematical physics. Ultimately, the group hopes to develop a cross-disciplinary degree program.

3.8.1. *Undergraduate training.* Although only in a very preliminary state, a long range goal of the group is to develop a cross-disciplinary undergraduate program in string theory.

Karch is planning to give a course on string theory, based on a new book for undergraduates by Barton Zweibach. To lay the groundwork he has overseen eight undergrads, who participated in a reading course whose subject matter was Zweibach's book. Strassler and differential geometry faculty are considering the possibility of developing a course on entropy and black holes and thermodynamics.

Doran plans to collaborate with Aganagic to develop a cross-disciplinary undergraduate course in "mathematical physics". The current regular offerings are all in the Physics Department and not easily accessible to mathematics students. Such a course would also be ideal for mathematics students wanting to minor in physics, or planning a five-year program leading to a Master's degree as proposed in Section 3.7 above.

Doran previously supervised both undergraduates and graduate students at Columbia University in mathematical aspects of string theory. Two of the undergraduates are now in grad school: David Kagan (Cambridge University) and Chris Miller (Columbia University). He taught a graduate topics course "Automorphic Forms in Geometry and Physics" in the Columbia Mathematics Department last semester, with attendees from both mathematics and physics graduate programs.

3.8.2. *Graduate training.* Physics has already offered a number of special topics courses, and a basic string theory course, which would potentially be of interest to mathematics students. Aganagic, Karch, Doran, and Strassler are beginning discussions of possible graduate-level cross-disciplinary special topics courses.

Physics runs an ongoing weekly journal club for graduate students in physics, at which students present what they have learned about classic papers. In addition, the University has agreed to fund a joint Math/Physics seminar series in 2003-2004.

3.9. **External Opportunities for Students.** We plan to actively pursue finding ways our students can be involved with opportunities outside our three departments. For undergraduates, we will identify suitable research projects in outside departments, agencies, and companies that will give them real-world experiences with the applications of mathematics. A good example is the Applied Physics Laboratory on campus, which has a staff of over 300 people and many places where undergraduates can get actively involved. APL already has 30 undergraduates working on projects. The newly appointed Director of APL, Jeffrey Simmen, is very enthusiastic about getting students from the mathematical sciences involved, as described in his supporting letter contained in the Supplementary Documents. We can use VIGRE funds, for example, to leverage support from our Space Grant Program in getting more undergraduates working on such projects. Another source of internships is the Northwest Research Associates, a contract-research firm conducting in-depth investigations in the physical sciences and providing consulting services to government and industry based in Bellevue, WA. Their supporting letter, in the Supplementary Documents, describes the scope of undergraduate opportunities there.

The Mathematics of Information Technology and Complex Systems (MITACS) is a Network of Centers of Excellence that receives funds from the Canadian federal government, provincial governments, crown corporations, and national and international businesses and industry, and is based at Simon Fraser University in Vancouver. A major emphasis of MITACS is the training of graduate students and postdocs in the mathematical techniques needed in industry, and for this it uses collaborative projects with industry. MITACS is eager to collaborate with our VIGRE project,

and will support the participation of UW graduate students in MITACS projects, with travel funds provided by VIGRE. The supporting letter from Arvind Gupta, Scientific Director of MITACS, in the Supplementary Documents, gives details of this.

These are just a few examples of what we have in mind. We envision developing an undergraduate internship program, and plan to seek supplemental funding for it.

3.10. **K-12 and Outreach Activities.** We view K-12 outreach activities as critical for the health of the mathematical sciences, both within our departments and in the broader community. In particular, by increasing interactions with secondary schools we can help to improve the preparation of students who enter our University. This will increase chances for successful recruitment and retention of undergraduate majors in the mathematical sciences, the last of the critical transitions we discuss.

Our three departments already have an extensive history of collaborative outreach efforts. *Creating a Community of Mathematics Learners (CCML)*, on which Ramesh Gangolli (Math) and Virginia Warfield (Math) were PIs, was funded through a $2.7M NSF grant during 1996–2001. It involved over 600 teachers from middle and high schools in six school districts in the Seattle region, with the goal of deepening the teachers' understanding of mathematical ideas that underlie the curriculum they teach and to share exemplary curricular materials and teaching methods. *Expanding the Community of Mathematics Learners (ECML)*, on which Gangolli, Warfield, and June Morita (Statistics) are PIs, is another large NSF grant to expand the CCML project into the K-8 classrooms. A VIGRE graduate fellow in Statistics worked with Morita on this project as part of his VIGRE activities.

We will develop interactions between ongoing outreach efforts and our VIGRE program.

*GK-12 Outreach.* Under the leadership of Loyce Adams (Applied Mathematics), who was inspired by CCML and ECML, we have obtained an NSF GK-12 grant that funds graduate students to work as "math specialists" in elementary and middle school classrooms. These students, recruited university-wide from departments in science, engineering, and mathematics, team-teach with the K-12 teachers to assist in the implementation of exemplary mathematics curriculum. For the 2003-04 academic year, seven (or about a third) of these GK-12 fellows are from the three VIGRE departments, and 26 of the 40 K-12 teachers are from inner-city schools with at least 70% African-American students. This program benefits the K-12 classrooms, while providing a significant experience for our graduate students to work closely with graduate students from departments across campus. It gives graduates students preparation in communication and teaching skills, and appropriate mathematical strategies necessary to help diverse populations of K-12 teachers and students. Our students report that both their view of teaching and their ability to teach improve from participation in this program. See the GK-12 website at [27] for program details.

NSF is presently considering a proposal from Adams to continue this GK-12 programfor five more years. If funded, we propose to increase the number of participants from our departments by giving VIGRE-supported students the option of choosing to work in this program as a VIGRE activity. To give fellows the flexibility they need, they will have the option of working in the program on either a full-time or a half-time basis. This would be most appropriate for a continuing student after the first year or two of graduate study, and would be meant to round out other VIGRE experiences, such as TA and research activity.

*Quantitative Literacy and Advanced Placement Workshops.* The Statistics Department has supported the Elementary Quantitative Literacy (EQL) program, which provides professional development in data analysis to elementary school teachers. June Morita, a Statistics faculty member, three Biostatistics faculty members, and students have participated in organizing and facilitating numerous EQL workshops. Morita is the faculty interacting with the group Statistics Teachers of Puget Sound, which supports high school teachers of AP Statistics in Washington State, primarily

Western Washington. VIGRE fellows will have an opportunity to be involved in this outreach, which will also inform the department about optimal design of their entry level courses.

*Tutoring at local schools.* Students in junior and senior level mathematics and statistics classes will be given the opportunity to participate in mathematics tutoring at some local middle and high schools, under the supervision of Morita (Statistics). The tutors will get course credit for their work, and are required to write a summary report of their experiences. Our experience has been that this is a good way of encouraging students to become mathematical sciences majors. In order to train the tutors, a seminar series will be offered every quarter.

Several of the minority schools where Adams (Applied Mathematics) places GK-12 graduate fellows have needs for tutoring. Adams and Morita plan to discuss ways to incorporate tutors from Morita's project into the goals of the GK-12 project. This would ensure the tutoring is directly related to the classroom and the needs of the students.

*Math Day.* Each year over 1200 local high school students come to campus for a day of lectures, demonstrations, field trips, labs, and hands-on experiences in the mathematical sciences. Topics have ranged from how moths fly to the mathematics of juggling. About 100 local high school teachers accompany these students, and in addition to the activities for their students they also participate in discussions of professional issues. We will encourage VIGRE fellows to participate in Math Day.

3.11. **VIGRE benefits everyone.** Our VIGRE project will have a sweeping impact not only on the three participating departments, but on mathematical activities throughout the region. This impact will certainly be felt most directly by those undergraduates, graduate fellows, and postdocs funded by VIGRE. However, the academic lives of everyone in our departments will be made richer and more stimulating by our VIGRE efforts.

For example, all graduate students will have available regular Professional Forums to learn about important issues for their careers. VIGRE-supported curriculum improvements benefit all students. Everyone will be able to experience a steady stream of international experts brought to the UW from PIMS activities using VIGRE support. The PIMS Collaborative Research Groups, strengthened with VIGRE support, will provide all graduate students and postdocs with extensive international opportunities. Graduate students who are US citizens or permanent residents will be able to use VIGRE funds to travel to workshops and conferences, so important for their professional development; this will free other travel funds for the support of international students. VIGRE postdocs will bring new expertise and knowledge to all students in their departments. Finally, the closer cooperation among the three sponsoring departments generated by developing and carrying out our VIGRE project will create better coordination and understanding.

3.12. **Departmental Descriptions.** This proposal is a collaborative effort of three departments, rare for VIGRE sites. As evidence of our ability to provide the resources needed to carry out our proposed VIGRE activities, we provide below brief descriptions of and relevant information about each of these departments.

3.12.1. *Applied Mathematics Department.* The Department of Applied Mathematics consist of 10.5 faculty. There are currently 50 graduate students in its graduate program. It offers both a Masters and Ph.D. degree. In addition to its basic responsibilities for graduate education, it has devoted many resources to developing materials for the undergraduate ACMS program, in particular for the Discrete and Continuous Modeling Courses (Math/Amath 381 and 383). Faculty interests include perturbation theory, asymptotic analysis, fluid dynamics, mathematical biology, atmospheric flow, optimization, nonlinear waves, special functions and numerical analysis. Most faculty hold adjunct or joint appointments in other departments, including Aeronautics and Astronautics, Atmospheric

Sciences, Bioengineering, Computer Science and Engineering, Mathematics, Oceanography, and Zoology.

The core courses for the first-year graduate students include three quarters of numerical analysis (applied linear algebra, numerical methods for ordinary differential equations and partial differential equations), three quarters of methods of applied mathematics (complex variables, nonlinear ordinary differential equations, asymptotics, and partial differential equations), one quarter of applied optimization or calculus of variations, two quarters of application courses of the student's choice, journal clubs and applied mathematics seminars. The Preliminary Examination now occurs in January of the first year of study, and the passage of that exam helps decide if the graduate student is admitted to the Ph.D program. The students who are admitted to the PhD program are asked to form a supervisory committee by the spring of their first year and to be involved in research during their first summer.

The following aspects of the Applied Mathematics graduate program are particularly relevant to the VIGRE program:

*Broad preparation for various careers.* Applied Mathematics has recently revised its Ph.D. requirements and its second year graduate curriculum. These changes will give students a broader education in applied mathematics, while at the same time attempting to lower the time to degree by streamlining course offerings. In particular, a streamlined set of advanced topics courses will now be available every year. By doing this, all our graduate students see the more modern topics in Applied Mathematics, such as multigrid methods, perturbation methods, Green's function methods, integral equations, stochastic differential equations, wavelets, and spectral methods. The department also hopes to broaden the appeal of these courses to students from other departments.

*Early involvement of graduate students in research.* The Department has four successful *Journal Clubs* that represent the main faculty research areas: numerical analysis, mathematical biology, fluid dynamics, and atmospheric sciences. These clubs are held every quarter, and earn two credits each. Typical activities are reading journal papers, informal research presentations by students, or short treatments of educational topics given by students. New students are encouraged to sign up for two or three different clubs in their first year, and hence they are better prepared to decide early on a research direction. Many Mathematics graduate students also participate in the Numerical Analysis Journal Club and the Graduate Student Seminar.

In addition, Applied Mathematics has restructured the prelim exam system, with an emphasis on testing basics in the middle of the first year of graduate school. This has allowed the graduate students to begin an early focus on research and we expect a reduced time to degree.

*Mentoring of graduate students in computing.* Experience has shown that a big detriment to early research involvement and success in the Applied Mathematics graduate program is the lack of state-of-the-art computational skills by incoming graduate students. We have used our computing staff and returning graduate students to provide one-on-one computer mentoring for all new graduate students. This boot-strap computer mentoring has additional early benefits of involving first year graduate students with more senior students to introduce them to the culture of the department and ease the transition to graduate school.

*Review sessions for first year graduate students.* Applied Mathematics recruits excellent students from a variety of backgrounds, and as a result, we have found that the first year students can have very different preparation in undergraduate ordinary differential equations, linear algebra, and advanced calculus. Starting this academic year, we are offering a series of special review sessions. These will ease the transition to graduate work and help with the preparation for the preliminary exams in January.

3.12.2. *Mathematics Department.* The Mathematics Department offers a variety of undergraduate degrees, a Master's degree, and a Ph.D. The Department has 55 full-time faculty and 83 graduate students. In addition to strengths in the traditional fields of pure mathematics, the Department

maintains strong connections with both the Applied Mathematics and Statistics Departments, through joint appointments, jointly listed courses, and collaborative research projects. The Department has active research groups in numerical analysis, optimization, differential equations, differential geometry, probability, algebraic topology, combinatorial geometry, complex analysis, ergodic theory and symbolic dynamics, non-commutative algebra, number theory, representation theory of Lie groups and Lie algebras, and several complex variables. A recent development is a cooperative effort with the Physics Department to build an interdisciplinary group in string theory. To this end, Physics has recently made three appointments in this area and Mathematics one additional appointment, all coordinated to form a strong group. The Department retains a hiring priority for another appointment in string theory, and this group has received special start-up funding from the College to run a research seminar.

Within the past five years, three members of the Mathematics Department have been awarded the University's Distinguished Teaching Award: Ron Irving for his work on the undergraduate algebra course for teachers, Dave Collingwood for his work with minority students and for his work revising our pre-calculus course, and Jim Morrow for his sustained and successful efforts in developing mathematical talent and other outstanding educational contributions.

The formation in July 1997 of the Theory Group of Microsoft Research [2] has enhanced the research environment of our graduate students. The Theory Group has eight permanent members, all established mathematicians, and several postdoctoral researchers. The permanent members have affiliate appointments in the Department of Mathematics, and group members occasionally teach courses in the Mathematics Department (three courses, including two graduate topics courses, were taught by members of the group this year). The group maintains a vigorous program of long-term and short-term visitors. Research collaborations in the areas of probability, complex analysis, and combinatorics have been established between the Mathematics faculty and members of the group.

The core graduate program consists of five year-long courses: Modern Algebra, Real Analysis, Complex Analysis, Topology and Geometry of Manifolds, and Linear Analysis. The Linear Analysis course was developed primarily by faculty in the areas of partial differential equations, optimization, and numerical analysis. It focuses on advanced linear algebra, applied functional analysis, distribution theory, and related topics and applications. This course has been taken by many students in the Applied Mathematics Department, and complements the first-year courses offered in that Department in differential equations and numerical analysis.

Each student must take three courses from this list, and pass three corresponding preliminary exams. For second- and third-year students, there are advanced graduate courses in a wide range of subjects, as well as special topics courses in areas of current faculty interest.

Graduate students initiated and now run the *Current Topics in Mathematics Seminar*, in which faculty members give expository lectures about their specialty and research. This provides students, especially those in the first two years of graduate work, a broad overview of work in the department in an especially efficient way. Usually, a faculty member gives an informal overview of his or her area, with a view to informing and attracting graduate students without the commitment of an entire quarter's course. A few seminars are devoted to nuts-and-bolts topics, such the use of symbolic manipulation programs and mathematical typesetting and illustration.

3.12.3. *Statistics Department.* The Statistics Department, ranked seventh in the country by the NRC, has 24 faculty and 45 graduate students. The Ph.D. program consists of seven core courses, of which each student must take at least three, and take a qualifying examination in two. The courses are Theoretical Statistics, Applied Statistics, Stochastic Modeling, Statistical Computing, Probability Theory, Statistical Genetics, and Social Science Statistics.. In addition, each graduate student is required to participate in Statistical Consulting and attend weekly departmental seminars.

Since the student's first year in the program generally consists of core courses and preparation for qualifying exams, most students teach their first year, and start working on research projects only after they have passed their exams. Several of the core courses, however, are project-oriented, so as to allow the students to get a feel for research, and encounter a variety of potential research topics.

Much of the current research in the department emanates from scientific problems in other fields. Most faculty members have at least one scientific specialty outside of statistics. The department has several working groups meeting weekly, with participation from graduate students, faculty, and postdoctoral associates. There has been ongoing cooperation with local companies such as Boeing, Microsoft, Amazon, Weyerhauser, and Mathsoft with students spending time (varying from a month to a year) working as statisticians in industry, and industry bringing data and methodological problems to the department.

## 4. Outcome of Curriculum Review

4.1. **ACMS Degree Program.** The ACMS degree program has been broadened and improved. Two new pathways were introduced (Mathematical Economics and Social and Behavioral Sciences), one eliminated (Alternative Focus), and existing pathways reformulated in light of experience. For example, some pathway requirements have been loosened to provide more flexibility and a richer set of electives. It is also easier to use the ACMS degree as a double major or double degree. We have introduced an Honors Program in ACMS requiring a 3.5 GPA and a senior thesis. The most popular pathway continues to be Discrete Mathematics and Algorithms, with its orientation toward computer science.

An extensive set of class notes for the discrete modeling core course Math 381 has been developed by LeVeque, Greenbaum, and Chartier (a VIGRE postdoc), who have team-taught the course. These notes have been used by Laurie Heyeer at Davidson College, where Chartier is now on a tenure-track job. Chartier continues to collaborate with LeVeque and Greenbaum to extend these notes further. VIGRE postdocs Walton and Blossey helped to develop lecture notes for core ACMS courses in numerical methods and continuous modeling. The Applied Mathematics Department intends to revisit the curriculum of its numerical methods course, one of the basic ACMS courses.

The TAs provided by the Office of Undergraduate Education as part of the University's contribution to the current VIGRE grant have been invaluable in teaching the discrete modeling and continuous modeling courses, since these use case studies, and are project based. Giving students the close supervision that they need and deserve requires a substantial commitment in both time and effort on the part of the instructor. But given the high enrollment in these courses, this is only possible with the help of TAs. The Office of Undergraduate Education has agreed to fund TA support for these courses (see the supporting letter from Dean of Undergraduate Education, George Bridges in the Supplementary Documents).

4.2. **Applied Mathematics.** In addition to its involvement with the ACMS curriculum described above, Applied Mathematics has reviewed its first and second year graduate curriculum and made resulting changes in its Ph.D. requirements. The purpose is to give graduate students a broader education in applied mathematics, while also attempting to lower the time to degree by streamlining course offerings. Previously many advanced topic courses were offered every other year or less frequently, but now there is a set of such courses taught every year that are required of Ph.D. students. The Department plans to broaden the appeal of these advanced courses to outside students.

As a result of VIGRE, the prelim system has been substantially revised. First year students on the Ph.D. track now take a preliminary exam in January of their first year, covering undergraduate material in linear algebra, advanced calculus, and ordinary differential equations. The first two year of this new system brought dramatically different results: everyone passed the first year, but everyone in the second year had to repeat at least one exam. To address this issue, the Department plans to initiate a prelim preparation seminar during Autumn quarter. This will be run by faculty and advanced graduate students, with a goal of getting all entering students up to the level needed for coursework early on. A side benefit will be the extra advising and mentoring from peers.

4.3. **Mathematics.** During the past five years, the Mathematics Department has invested heavily in revising its entry-level calculus course offerings. With help from the College, it has cut in half the size of lecture sections (now at 80), decreased quiz section size (now at 27), introduced a longer quiz section that uses collaborative worksheets it has developed, put all materials including past quizzes, exams, homework, and solutions on the web [20], and introduced weekly meetings of all instructors. Each section undergoes a mid-quarter evaluation by a staff member from the University's Center for Instructional Development and Research, including an in-class interview without the instructor present. The student feedback from this and other sources has resulted in

continuous improvements. This coming academic year the University will evaluate these changes, and if the outcome is positive it will provide permanent funding. The Department has revised its business mathematics courses, and introduced a new calculus track intended for students going into the biological sciences.

A new course on *Mathematical Reasoning* (Math 300) was developed to provide a better foundation in mathematical and logical reasoning. This course is now a prerequisite for most upper level undergraduate Mathematics courses. In consultation with the Department of Philosophy, the Bachelor of Arts in Mathematics has been expanded to include a Philosophy Option.

At the graduate level, we have established a advising and mentoring program. Every entering student is given a preliminary advisor, and to prepare faculty to properly mentor beginning graduate students, the Department has written a *Handbook for Instructors and Advisors of First-Year Graduate Students*. The handbook is given to all preliminary advisors and instructors of courses taken by entering graduate students.

Master of Science and Master of Arts Degrees were revised in 2002. Students completing these degrees are now well suited to assume positions at local community colleges or in industry, or enter doctoral programs. To attract good students who might not ordinarily be admitted to Ph.D. programs, the Department not only admits talented applicants who seek a terminal Master's Degree, but also those whose ultimate goal is a Ph.D. but who need an additional year to fill holes in their mathematical background.

The Department recently developed a special topics course in teaching and learning mathematics (Math 501/2/3) designed to prepare students who planned careers teaching at community and four-year colleges. In Spring 2003, the course involved readings and discussions on various issues related to teaching mathematics at the college level at a variety of institutions. The *Current Topics in Mathematics* Seminar, instituted in 2002, has already been discussed (see Section 3.12.2).

4.4. **Statistics.** During 2001-02 Matthew Stephens was funded by VIGRE to work on undergraduate curriculum development. Based on faculty reactions, he further refined his ideas, and a committee will present concrete proposals to the Department this autumn. The likely recommendation will be a new one-quarter probability course, providing an entry point to the major for both theoretical and applied specializations. The Department now offers a broader set of courses for seniors, including Bayesian Statistics and Reliability Theory.

At the same time a group of faculty, including VIGRE fellow Jean-Yves Courbouis, revised the statistical modeling course Stat 390 (which is one of the ACMS core courses) to better serve its the rather audience, including engineering students, ACMS majors, science majors, and others. VIGRE has funded a graduate student to develop computing exercises for Stat 390, and a separate version of Stat 390 designed for students in computer science and engineering is now offered every year.

During 2001-02, Peter Guttorp was funded by VIGRE to work on evaluating and revising the Master's Degree. He contacted a large proportion of the terminal Master's students among the departmental alumni, and discussed their experiences in their graduate education. A departmental committee proposed both a new case-based capstone course and a revised computing requirement for Master's students. This proposal is still subject to departmental discussion. The department has split the senior level applied courses into an undergraduate and a graduate track.

Following a joint retreat with Biostatistics this past spring, a joint committee between Statistics and Biostatistics is working on revising the core applied sequence and the applied preliminary examination.

## 5. Recruitment and Retention

As described in Section 3.5, we propose stepping up our efforts to attract and retain high quality undergraduates into the mathematical sciences. In addition to the actions mentioned there, we will do the following:

- **FIGs.** The University of Washington has a Freshman Interest Group (FIG) program, whereby entering students are organized into groups of 20 to 25 students which take the same set of basic courses together in the same sections during Autumn quarter. About 75% of entering freshman are in FIGs, which can provide a sense of community in an overwhelming environment (See the web site [22] for more information). We will initiate special Math FIGs, to attract students at the earliest opportunity.
- **Freshman Seminars.** Another effort by the University of Washington to provide a more welcoming face to first year students are the Freshman Seminars. These are small seminars taught by faculty on topics outside the normal range of first year courses. Several faculty have taught such seminars. Randy LeVeque and Peter Schmid in Applied Mathematics taught a Freshman Seminar on computational fluid dynamics, and this past year Sándor Kovács in Mathematics developed a Freshman Seminar called "Beyond the Third Dimension". The development was funded by a supplement to his NSF CAREER award, and he will be teaching a similar Seminar next year. Such seminars are a great way to show beginning students that there is more to mathematics than integrating complicated functions, and to consider majoring in the mathematical sciences. We will encourage more faculty to offer these seminars.
- **Early Fall Start.** The Early Fall Start Discovery Seminars offer incoming freshmen a chance to jump-start their university experience. A month before Autumn Quarter begins, students get the chance to learn basic research and inquiry skills in a supportive, yet challenging, environment. Organized around broad interdisciplinary themes and taught by experienced faculty, these small seminar classes introduce students to the nature and process of research. We will develop some mathematically based Discovery Seminars to attract incoming freshmen to our disciplines.
- **Publicize undergraduate research and intern opportunities**. Our efforts are described in Sections 3.4, 3.9, and 8.

In order to recruit and retain graduate students, we propose the following:

- Use of VIGRE fellowships as recruitment tools.
- Establishment of an "Examples Seminar" in Mathematics, for graduate students and advanced undergraduates to work together understanding the examples that are the lifeblood of every mathematical theory.
- A prelim seminar in Applied Mathematics to prepare incoming students (see Section 4.2).
- Workshops on professional issues, organized and run by VIGRE fellows and postdocs (see Section 3.6).

The recruitment and retention of underrepresented groups presents unique challenges, and we plan to make use of the many programs at the University of Washington targeted for these groups. In particular, there is an Early Identification Program, which identifies minority students who are being successful in their first undergraduate years, and we will give presentations to this group about going into the mathematical sciences. The Engineering College has a well-developed Minority Science and Engineering Program (MSEP) that is another possible resource.

The UW was awarded an NSF Computer Science, Engineering, and Mathematics Scholarship (CSEMS) grant in 2000, which expires in 2004. An application for an additional five-year CSEMS grant is pending, with Tom Duchamp of Mathematics as a co-PI. The UW CSEMS scholarship program is managed by the Student and Community Relations (SCORE) advising center in the College of Engineering. The program grants scholarship awards to 40 needy (i.e. Pell Grant

eligible) students each year, on a competitive basis. Applicants must be enrolled in one of the ten engineering disciplines or a mathematical science (ACMS, Computer Science, Mathematics, or Statistics). Of the recipients, about 33% are women and about 16% are either African American or Hispanic. Students in our three departments are increasingly competitive: the awards for next year have just been made, and 6 of the 40 scholarships (15%) went to students in ACMS, Mathematics, or Statistics Recipients of CSEMS grants are an excellent pool of potential graduate students, and we plan to recruit them more heavily.

In order to assist our female students and postdocs with extra mentoring help, we will utilize tools developed by the UW NSF-funded ADVANCE Center for Institutional Change [23]. These include the Center for Workforce Development's Faculty-Graduate Mentoring program, which aims to prepare excellent women graduate students in science, engineering, and mathematics for faculty careers by preparing students with a realistic view of faculty life, and utilizing faculty expertise for the professional and personal development of students.

Funds from the ADVANCE Visiting Scholars Program will be solicited to bring in stimulating female and minority faculty to one of the VIGRE departments. This can be with a view toward recruiting, to serve as role models, to present interesting scientific material, and to enhance the visibility of the visitors.

The ADVANCE program emphasizes tools toward retention and tenuring of tenure-track female faculty in science and engineering. We will draw on ADVANCE resources toward our workshop program for VIGRE fellows, as well as assist faculty in the VIGRE departments with the ADVANCE Transitional Support Program, aimed at enabling excellent faculty (both male and female) undergoing critical transitions to maintain their research program during these often challenging times. For example, Lisa Korf (a VIGRE postdoc) received ADVANCE TSP support as a summer stipend to help her make the transition to a tenure-track faculty position, and Tatiana Toro (Mathematics) received support this past year.

Included with the Supplementary Documents is an enthusiastic supporting letter from Denise Denton, Dean of the College of Engineering, outlining the specifics of ADVANCE support available to VIGRE departments. This includes one course per year release time for women faculty (funded by ADVANCE). Our departments will also participate in the Women in Science and Engineering mentoring program, which aims to enhance retention of female students pursuing graduate degrees to prepare them with a realistic view of faculty life, and to utilize faculty expertise for the professional and personal development of students.

**Mentoring.** All the efforts described above complement the supportive atmosphere our three departments envision for *all* students. We make sure our students at all levels are *advised* to know hoe to successfully navigate the local hurdles at the University of Washington. Undergraduates have access to advisors. Graduate students are assigned a faculty advisor in their first year to serve this function until the student is paired with a research advisor and team. New postdocs are advised by multiple faculty and other postdocs that already know the local hurdles.

We also make sure our students at all levels are *mentored* to know how to successfully navigate the mathematical and professional hurdles outside the University of Washington in their respective areas. We send our undergraduates, graduate students and postdocs to conferences and often internships in industry or K-12 classrooms. Our undergraduates work in groups with faculty, postdocs, and graduate students. Graduate students have a research advisor and research support group that meets for seminars and journal clubs. Posdocs have an assigned faculty mentor in their are of expertise. At all levels, our atmosphere provides opportunities to learn to express ideas to others through discussion, in writing, and in professional talks. It is through the creation of such an atmosphere that students at all levels are retained in the mathematical sciences pipeline.

# 6. Organization and Management Plan

Since horizontal as well as vertical integration is key to the success of our efforts, a strong management plan is essential. This plan consists of a Director, an Executive Committee having representatives from each department, and an Advisory Panel drawn from other VIGRE sites. It is backed up by over $1.75M in University commitments.

6.1. **VIGRE Director.** The Director has primary responsibility for the overall management of the VIGRE award, and the coordination of efforts among the participating departments and faculty. These responsibilities include oversight of VIGRE fellows and postdocs, curriculum review, promotion of undergraduate research projects, mentoring, internships, and relations with PIMS sites. The Director will supervise routine budget matters, including the award of travel support to graduate students, and will make sure all activities comply with NSF regulations. In addition, the Director will actively participate in the cross departmental committees of VIGRE fellows, postdocs, and faculty to provide overall direction to these groups. The Director will meet regularly with groups of VIGRE fellows from each department, together with their faculty mentors, to discuss current activities and how they fit into the goals of VIGRE. The first VIGRE Director will be Douglas Lind, PI on this proposal.

Managing this award across three departments together with PIMS involvement is a complicated and time-consuming job. We therefore request from NSF $10,000 for course relief for the Director, with an equal amount being provided by the University. The university is also contributing $10,000 for a fiscal support person who works directly with the director on behalf of all three departments. (See supporting letter from Dean Irving.)

6.2. **Executive Committee.** To provide a broad cross-section of input and advice, there will be an Executive Committee. It will consist of the VIGRE Director, the Graduate Program Coordinators from each of the three departments, the ACMS Director, the PIMS Site Director, and one additional permanent representative from each department. The combination of permanent members together with ex officio members such as the graduate program coordinators means that there will be modest rotation of faculty, but enough stability and institutional memory.

The Executive Committee will meet regularly during the academic year. It was have the advice of the co-PIs, which include the present chairs of all three departments and a formed VIGRE Director.

At each meeting, the Director will provide the Committee with a review of the various components of the program. The Executive Committee will set general policy, such as guidelines for the selection of fellows and postdocs.

6.3. **Advisory Panel.** To provide an outside, objective source of advice, ideas, encouragement, and suggestions for change, we will appoint an Advisory Panel consisting of four distinguished mathematicians and statisticians from other VIGRE sites who have been significantly involved in their own university's VIGRE efforts. Members of the Advisory Panel will therefore be very familiar with VIGRE goals and objectives, have wide experiences in implementing these goals, and bring fresh insights and perspectives.

We will convene the Advisory Panel once a year, provide it with an overview and progress report, and have it meet with the Executive Committee to discuss results and suggestions.

Part of the inspiration for this approach came from the Seattle VIGRE Workshop, described in Section 2.8. The workshop proved to be an excellent venue for learning about activities at other VIGRE sites. We have already started using some of them here. For example, the competitive approach to awarding VIGRE fellowships at the University of Arizona was used by Mathematics this past year.

6.4. **Selection of Fellows and Postdocs.** We envisage two types of VIGRE fellowship awards. Each award will consist of two quarters of VIGRE support during the academic year combined with two months of summer support. The fellow will generally be supported by a TA during the third academic year quarter, so that our best students continue to be involved in the teaching program.

The first type is awarded to entering graduate students as a recruitment tool to attract the best possible candidates and to support them during this critical transition to graduate work. Decisions on such awards will be made by the Graduate Program Committees in each department, with oversight by the Executive Committee. Such awards will be based on academic excellence, promise of success in graduate school, and evidence of activities consistent with VIGRE goals.

The second type of graduate fellowship award will be to continuing students, and we plan to make such awards competitive. These awards are intended for students making the transition from course work to supervised research, and for students engaged in crucial stages of their thesis work. Students will be asked to write a proposal for a year of VIGRE support, in which they will not only describe the benefits to their own work, but also how they intend to be involved in various VIGRE-related activities. Support decisions will be based on academic excellence, quality of proposed VIGRE-related activities, and a letter of support by a faculty mentor.

Based on an initial trial of this process by the Mathematics Department this year, we believe that competitive award of VIGRE support has many advantages: students must become aware of VIGRE and how they may fit into it; they must have their faculty mentor write as well, increasing awareness; writing proposals is good practice for later academic life; and there is a general feeling of having "earned" VIGRE support that promotes a more serious involvement.

Selection of VIGRE Postdoctoral Fellows will be made by the Executive Committee, in close collaboration with individual departments. The criteria here will include academic excellence, availability of faculty mentors, departmental research priorities, and record of the candidate in VIGRE-related directions.

6.5. **University Commitments.** If this proposal is funded, the University will provide $353,150 yearly ($1,765,750 total). The Dean of Arts and Sciences' commitments cover $10,000 for Director release, $2,170 fringe for the Director, and $18,000 for VIGRE Postdoc salaries yearly. The departments' commitments are $90,000 for half of the VIGRE Postdoc salaries, $105,000 for 25 VIGRE Fellows' salaries for 1 quarter, $53,075 for tuition for these Fellows for 1 quarter, and fringe benefits of $12,420 and $12,285 for the postdocs and VIGRE Fellows yearly, respectively. The Dean of Undergraduate Education commits 6 TA quarters yearly which is $25,200. The Provost commits $10,000 yearly for financial staff help, and $5,000 yearly for miscellaneous expenses. The UW-NSF ADVANCE program commits $10,000 for female faculty buyout yearly. We describe these commitments further below.

6.5.1. *VIGRE Director Release and Postdoc Overlap.* The Dean of Arts and Sciences will match NSF's yearly release amount of $10,000 for the Director plus fringe benefits of $2,170. The Dean will also help with years when two postdocs overlap by committing $90,000 (18K yearly mentioned above). These commitments are outlined in Dean Irving's letter in the Supporting Documentation Section.

6.5.2. *Fiscal Support and Miscellaneous Funds.* We anticipate quite a lot of coordination and paper work between the three participating departments, the ACMS undergraduate program, PIMS, industry, and other departments where our fellows, postdocs, and undergraduates are working. There is also a significant amount of budget work that is needed to keep the program running smoothly. The Provost is committing $50,000 (10K yearly) for this purpose plus $25,000 (5K yearly). These commitments are outlined in Dean Irving's letter in the Supplemental Documentation section.

6.5.3. *Curriculum Development.* During our current grant, we developed cases for the modeling courses and our Dean of Undergraduate Education provided us with 6 TA quarters annually for these ACMS courses: Math 381, Amath 383, and Amath 352. We have obtained the same commitment for this proposed effort. Being able to place TAs in these courses allows a great opportunity for vertical integration, and has been a factor in our successes in the Mathematical Contest in Modelling as described earlier. Dean Bridges' letter in the Supplemental Documentation section outlines this commitment. These 6 TA quarters are equivalent to $25,200 yearly or $126,000 over 5 years. (Each TA quarter costs roughly $4200.)

6.5.4. *Course Buyout for Female Faculty.* VIGRE activities that focus on recruiting, mentoring, and retaining women in the mathematical sciences at all levels aligns with our local NSF-sponsored ADVANCE program. Dean Denton of Engineering (UW-ADVANCE's PI) commits course buyout for female faculty to develop appropriate VIGRE activities. This commitment of one course per year for 5 years is outlined in Dean Denton's letter in the Supplementary Documentation section. At $10,000 per course, this is a $50,000 commitment over 5 years.

## 7. Performance Assessment

We will use a variety of tools to assess the success of our program. In what follows, we outline the assessment plan for each part of the program.

7.1. **Undergraduate students.** Quantitative assessment of the program with respect to undergraduate students will utilize the UW data base, where we will track number of majors in the mathematical sciences, and proportion of underrepresented groups. Retention and graduation rates for students involved in VIGRE projects will be compared to the non-VIGRE population, and we will attempt to keep track of the fraction of such undergraduates who ultimately go into research. In addition, the fraction of women and minorities that we are able to retain in the long run will be tabulated.

Much of the qualitative assessment procedures for undergraduates will be similar to procedures already in place for the general undergraduate population. Graduating seniors will be surveyed during their final quarter to solicit their opinions of the program, and its strengths and weaknesses from the student perspective. The UW Office of Educational Assessment will conduct these surveys. In addition, exit interviews will be conducted with all graduating mathematical sciences students participating in VIGRE.

Follow-up surveys will be conducted after graduation to track the employment or continuing education status of VIGRE students. We will attempt to maintain e-mail contact with graduates of the program to assist in this endeavor. All graduating students will receive an e-mail address on the University computing system that will contain a forwarding address that the student can keep up-to-date in the future. Electronic mailings can then follow the student (if they so desire). We hope that this will also help former students keep in touch with one another and maintain ties to the departments that could prove useful in other ways as well.

Undergraduate research experiences will be evaluated using interviews with both the undergraduate and the investigators. Focus will be on what insight in the research process the undergraduate has gained, his or her contribution to the project, and whether the investigator will continue providing undergraduate research experiences.

7.2. **Graduate Fellows.** Departmental procedures for assessment of graduate students include exit questionnaires, provided by the UW Graduate School, and informal polls. Quantitative aspects of the program, such as time to graduation for VIGRE and non-VIGRE students, proportion of underrepresented groups, and program size, will be obtained from UW databases. VIGRE Fellows will be required to write a progress report during each year of support, documenting the manner in which their time has been spent and the benefits they have received from the VIGRE program. Faculty who have interacted with the students in research groups, clinics, internship, or outreach programs will also be asked to comment on the students performance each year. These reports, together with other information such as course grades and progress on degree, will be used by the Executive Committee in recommending renewal of Fellowships and to monitor the success of VIGRE activities.

We will stay in touch with graduating Ph.D.'s (as well as Master's students) through electronic mailings, and via departmental alumni web pages. Maintaining these pages as accurately as possible will allow us to keep track of not only the whereabouts, but also the detailed academic or non-academic careers of many of our graduates. This is a first step in a process that will include two and five-year follow-up questionnaires, seeking information about the usefulness of their VIGRE experiences, their career patterns, and their degree of continued involvement in some of the aspects of the VIGRE program (particularly the culture of outreach).

7.3. **Postdoctoral Fellows.** There are quarterly meetings between each postdoc and the VIGRE Director. In addition, the Director will discuss the postdoc's performance with his or her faculty

mentors. The VIGRE Director will meet with the postdoc's research teams as needed. A key issue in these interviews will be the contribution of each postdoc to the research effort.

The teaching evaluation of postdoctoral fellows will be a combination of peer evaluation through classroom visits and assessment of teaching materials, student evaluations using standard University student evaluation procedures, and self-evaluation prepared by the fellow. Each fellow will be involved in the appropriate departmental teaching evaluation process (typically involving other faculty members), and the fellows and their mentors will summarize the teaching experiences in their meetings with the VIGRE Director.

In order to evaluate the long-term effectiveness of the program, we will contact the previous postdocs two and five years after the end of their VIGRE stay. Of main importance in these interviews will be the extent to which this postdoctoral experience has led to a career in the mathematical sciences, and/or in cross-disciplinary work, and to what extent the program has prepared the fellow for her/his career choice.

7.4. **Internship assessment.** Graduate and postdoctoral fellows participating in VIGRE supported internships will be required to write a final report summarizing their activities. We will also solicit comments from their hosts as to their performance and the success of our internship program.

7.5. **Workshop assessment.** We will use three main tools for workshop assessment. Every day, "one-minute report cards" will be filled out by participants, mentioning one good and one bad thing about that day's workshop. These are mainly used to adjust the following day's activities. At the end of the workshop, an exit questionnaire will be provided to the participants. Finally, a follow-up activity, such as a survey or even a follow-up workshop, will take place 6-18 months after the original event, in order to assess long-term retention and effectiveness.

7.6. **Curriculum revision assessment.** Faculty in each of the three departments involved with curriculum review and changes will consult periodically with the VIGRE Director. The sharing of this information between departments can, in itself, lead to interesting innovation, as well as to some elimination of duplication of efforts in curricular initiatives.

7.7. **K-12 outreach assessment.** The tutoring project will require students to write a report each quarter about their experiences. The tutoring coordinators at the schools involved will be contacted by faculty connected with VIGRE for feedback, program development, and assessment.

We will seek feedback on the performance of the VIGRE fellows in the classroom. Most of this feedback would come in conjunction with classroom visits, and will follow the assessment program developed for the GK-12 project.

7.8. **Annual report.** Every year the Director will compile an annual report of VIGRE activities, including assessment of the activities, performance review of the fellows and postdocs, and updated statistics about the undergraduate and graduate programs involved. This report will form the basis for the required annual report to NSF, but its primary purpose is to assist the Advisory Panel in its annual review of the program. Appropriate parts of the annual report will be made available on the VIGRE web site.

7.9. **VIGRE program review.** Each year the Advisory Panel will convene in Seattle with the Executive Committee for a thorough review of our VIGRE program. During this time the Panel will interview fellows, postdocs, and faculty involved with VIGRE. This meeting will be particularly useful during the third year in preparation for the NSF evaluation. We expect the Panel to ask hard questions, and we anticipate it generating many suggestions for improvement. The Panel will be provided with the annual report, produced by the Director, and will produce written feedback to the Director and the Executive Committee.

7.10. **Other VIGRE groups.** We will continue to share ideas with other VIGRE groups across the country on a continual basis. As mentioned elsewhere, we intend to continue regular workshops with the western VIGRE sites. This allows us to compare our activities and their respective effectiveness against what is happening at other sites.

# 8. Dissemination

Our dissemination plan includes mechanisms for communicating the lessons we learn at the local, the regional, and the national level. The UW has already played a leadership role in this.

**Regional Workshops.** The UW will host Workshops for regional VIGRE sites, such as the Seattle VIGRE Workshop described in Section 2.8. The participation by all nine VIGRE sites on the west coast and southwest gives a strong indication that such meetings fill a real need. We will such workshops approximately every two years, to swap ideas, discuss problems and issues, provide feedback to the NSF about how the VIGRE program is actually working and make suggestions for changes.

**National VIGRE meetings.** As with the current VIGRE program, our VIGRE Director will help organize and participate in NSF run VIGRE meetings and help to educate potential new VIGRE sites about VIGRE best practices.

**Web sites.** Our VIGRE program is described on our recently revised web site [24]. One of our cross-departmental committees of VIGRE fellows worked during 2003–03 on updating and expanding this web site. While much work remains to be done, the site now gives a clearer overview of the program together with many details and photos. This web site is also a good way to achieve horizontal integration, offering an efficient way for participants to learn about VIGRE activities in all three of our departments. To keep the web site current, the web committee will serve as webmaster for the site.

The web site will include links to various aspects of our VIGRE program, including the following:

- **Undergraduate research projects.** To help disseminate the results of past research projects, as well as to enhance participation in undergraduate research, we will enhance the pages describing the undergraduate research projects sponsored by VIGRE. We will include a listing of available projects, with prerequisite course work and contact information for the investigator as well as an application form for undergraduate research funding, with links to alternative sources of research projects, such as the Space Grant program and the Mary Gates Endowment. These pages will also include links to both past and current research projects. Each individual project with be responsible for maintaining its own project web page.
- **Graduate cross-departmental committees.** Each of these committees (described in Section 3.2) will maintain its own web page with a list of membership and descriptions of current projects, providing efficient communication to members of all three of our departments. Each committee will have a designated individual responsible for submitting information and updates to the webmaster.
- **New projects.** Upcoming projects within the VIGRE/PIMS framework will be made available to the public on the VIGRE site. This will include both research projects and outreach projects. Each project will be responsible for submitting material to the webmaster.
- **Evaluation material.** The annual report and other assessment material (see Section 7) will be available on the web, together with annually updated summary measures of the progress of the project.
- **VIGRE links.** We will maintain links to the other VIGRE projects, to PIMS, and to appropriate other links of relevance to participants in the project and the public.
- **Other efforts.** VIGRE fellows will be encouraged to think of creative ways to use the VIGRE web site, for example, to engage others in web-based scientific discussions. Such projects could well be part of a VIGRE fellow's activities.

# 9. Post-VIGRE Plan

**Curriculum reform.** VIGRE has already changed the cultures of our three departments in many significant ways, and has also provided strong motivation for us to work together. This spirit of cooperation will outlast the end of this grant. We intend to continue our efforts to improve the curriculum, especially for the ACMS program. Based on what we have already accomplished under the current VIGRE grant, and what we will further accomplish with new funding, we will have a culture of continued review and improvement for our educational mission.

**Collaborative Research Groups.** The UW PIMS participation will highlight trans-boundary collaboration in several areas of the mathematical sciences. We view this participation as seed money for developing Focused Research Group proposals in the future to make this collaboration more or less permanent. In fact, some of the groups mentioned in this proposal (String Theory and Environmetrics) would have submitted separate Research Training Group proposals had we not chosen to apply for the VIGRE grant.

The culture of having research groups working together will undoubtedly persist. It is a long-standing tradition in all departments, and while VIGRE funding has helped promote some of these groups, other sources of funding will be sought to continue research group work.

**Mentoring.** VIGRE is raising the awareness among faculty of the crucial importance of mentoring, of discussing professional issues with graduate students and postdocs, and of helping them through critical transitions in their careers. Many of the initiatives we are pursuing in this area (such as job panels, and postdoc mentoring) are relatively low cost, and can be pursued with departmental resources. The impact on the graduate curricula in the three departments of thinking in terms of critical transitions will be substantial.

**Recruitment.** The tools we are putting in place for undergraduate and minority recruitment are very much based on sharing undergraduate research experiences, and on having a culture in which graduate students help to interest undergraduates in majoring in mathematical sciences. We will keep working with our graduate students to continue these efforts.

However, the recruitment of top graduate students will undoubtedly be hampered if we no longer have access to VIGRE funds. In some areas of mathematical sciences, the first question a graduate student asks about a program is whether it is VIGRE funded. In order to replace the recruitment aspect of VIGRE graduate fellowships, we will use our extended development efforts to raise funds for graduate fellowships to replace in part the VIGRE funding from this grant.

How to find funding to replace VIGRE postdoctoral positions is an even more difficult problem, as it has generally been difficult to obtain NSF funding for postdocs on DMS single investigator grants. We will attempt to build on the collaborative research groups to increase our non-VIGRE postdoc funding, and use departmental funds as available to maintain the teaching previously done by VIGRE postdocs.

The efforts involved in identifying top undergraduates for recruitment to the concurrent BS/MS degree program will continue. Since this program is expected to be rather small, it is not expected to rely strongly on VIGRE funds (but is a part of the culture-changing aspect of the VIGRE grant). Thus we expect this program to continue essentially unchanged.

**Undergraduate research experiences.** An important culture change in the three departments has been the extensive use of undergraduate researchers. We will aim to continue these activities in several ways. First, we will encourage extended use of undergraduate research supplements to existing and future NSF grants. Second, we will be utilizing UW resources, such as the Mary Gates research fellowships and Space Grant awards to fund undergraduate research activities. Finally, we will start applying to local and national foundations for undergraduate research funding.

**K-12 outreach.** Much of the outreach work in the three departments is already funded by sources other than VIGRE, such as the NSF projects GK12 and ECML (see Section 2.7) and departmental funds. The culture of outreach needs to be maintained by some formal structure. For example, all three of our departments have faculty-level outreach coordinators. We are likely to be able to tie in to other externally and internally funded UW outreach projects [25].

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