Self-Study Report

Geophysics Program

March 1999

Self-Study Report for Geophysics

Context

Name of unit authorized to offer degrees
Graduate Program in Geophysics

College
Arts and Sciences

Exact titles of degrees offered
Minor in Geophysics, Master of Science, Doctor of Philosophy

History and Description of Geophysics

A Geophysics group was formed in the 1960's in response to demands to fill a gap by faculty from several different units on campus. A National Science Foundation development grant was awarded to the University in 1969 and one of its major objectives was to develop a first-rate program in geophysics. Geophysics has accumulated many of the attributes of other science departments in the College of Arts and Sciences; the one major exception is that Geophysics has offered only graduate degrees. The highest priority of the faculty remains to carry out innovative research and to achieve the highest standards in graduate student education. Ancillary goals include enhanced undergraduate contributions and service to the citizens of the state. The mission statement of the program is given in Appendix F2.

Geophysics research and education is rooted in rigorous physical sciences with strong environmental connections. Four central areas are emphasized in our program: solid earth geophysics, space physics, glaciology, and atmospheric physics. Although faculty tend to identify with one of these areas, the boundaries are indistinct and do not isolate faculty or students. At times Geophysics has also provided a base for miscellaneous geoscience initiatives and faculty that did not easily fit within other units.

The Geophysics Program's emphasis appears to be unique among universities in the United States. Where they exist, geophysics departments often have just solid earth programs. At other US universities, solid earth geophysics is often found in geology departments; space physics, with its emphasis on the ionosphere and magnetosphere, is usually placed in physics departments. This situation is different in other countries, where solid earth geophysics is typically taught in physics departments. Most UW Geophysics faculty identify with a science heritage rooted in physics.

The diversity that makes our program unique has definite advantages. Most notable is that graduate students who are attracted to our program have backgrounds in physics and mathematics and want to apply their knowledge to the geosciences in a broad sense. These students often do not have adequate enough backgrounds in geophysics to pre-select a specialty before graduate school. Our program provides a variety of choices that appeal to this type of student. In addition, there is strong emphasis on cooperation with other units on campus. A quarter of all graduate students with research supervisors in Geophysics will graduate with degrees in other units. About two-thirds of all grants and contracts administered in Geophysics have faculty or student participants in other units.

The Geophysics Program has traditionally carried a low student credit hour vs faculty FTE ratio, due in part to the strong research focus of this elite program and lack of an undergraduate degree. However, Geophysics faculty have made great contributions to public service through its environmentally oriented research and outreach efforts. Furthermore, a variety of non-traditional teaching by Geophysics faculty (courses offered each year through the University Honors Program and the development of undergraduate research opportunities) are not accounted for in the student credit hour summaries.

Unit Roles and Responsibilities

The highest priority of the faculty remains to carry out innovative research and to achieve the highest standards in graduate student education. Ancillary goals in service to the citizens of the state and the nation are inherent in the research and educational mission of all faculty. The faculty are working to better define a role in undergraduate education.

Research in Geophysics

Overview

All academic faculty in Geophysics have funded research programs. Over $5 million a year of research support is generated through 70 grants and contracts. Approximately thirty graduate students are directly supported by research. In comparison with other science units in the College of Arts and Sciences, Geophysics has a high rate of outside funding per academic faculty member.

In the following sections, examples of current research activities are highlighted. Not all programs and activities are described in detail. The purpose is to demonstrate a wide breadth and high quality of the research in Geophysics.

In addition, complex and interrelated issues concerning the future of Geophysics are introduced.

Seismology

Overview

Seismology, a central discipline within the solid earth sciences, is a key component of the Geophysics Program at the University of Washington. The largest fraction of graduate applicants to geophysics express an interest in seismology. The funding available for RAs has allowed us to accept only the most qualified applicants in this field. The faculty report "Guidelines for the Future" (Appendix F3) identifies a critical need for an additional position in Earthquake seismology. This is partially a consequence of a position lost through retirement (S. Smith). In addition, there is a need to respond to the rapidly evolving scientific opportunities in the field and we should maintain and expand interactions with the faculty in Civil Engineering who are members of an NSF Science and Technology Center for Earthquake Engineering.

Having just two academic seismology faculty creates a situation barely sufficient to cover the graduate curriculum. It is hard to expand undergraduate offerings. A single additional retirement would cripple both teaching and research activities. In addition, a serious lack of state funding for seismic monitoring, a direct benefit to the state, is creating a serious problem for Geophysics. Increasing external expectation now exceeds our ability to provide critical information to state/local governmental agencies, media, industries, and the public.

Faculty

Prof. Crosson, a founding member of the Program, has made significant contributions to regional and network seismology. Prof. Creager is an internationally recognized leader for his work delineating structure and dynamics of lithospheric slabs in the mantle, properties of the core-mantle boundary, and properties of the inner core. The two have recently initiated a collaborative study of crustal structure and earthquake fault locations in the Pacific Northwest as part of a large program (Seismic Hazards in the Puget Sound or SHIPS) spearheaded by the United State Geological Survey. Research Professor Steve Malone has managed the Pacific Northwest Seismic Network (PNSN) since the 1970's and is now a national leader, serving as chairman of the "Council of the National Seismic System." He has additional research interests in volcano seismology and monitoring. Research Associate Professor Anthony Qamar is a leader in the expanding effort to monitor crustal deformation in the Pacific Northwest using GPS technology (the PANGA program).

Profs. Creager and Malone are principal investigators for the IRIS (Incorporated Research Institutions for Seismology) Data Management Center, hosted by the University of Washington. A truly phenomenal volume of data is archived and made available world-wide to scientists through the Internet. An outside reviewer recently described this effort as "one of the most successful university science consortium in history." The UW faculty are credited with being instrumental "in creating the environment that assures that the Data Management Center is responsive to the community."

The Regional Seismic Network

The regional seismic network (PNSN) is a key educational and research tool within Geophysics. It is also a critical element of UW outreach for societal needs. By all accounts, PNSN is a highly efficient and economically run regional network. It began operation in 1969 with NSF funding. Since then, operational funding has been primarily from federal sources. State/University support has been variable but critical particularly in the area of interpretation and distribution of information to the public. During the 1970's a 10 year NSF Science Development Grant funded a full-time State Seismologist, with the understanding that the state would pick up support when the grant ended. During the 1981 round of budget cuts, state support was reduced to $18K per year. In 1989 significant cuts in the Department of Energy support for network operations required that the state contribution to the network be increased to $68K in order to prevent a complete shut-down of a large part of the network. After funding fluctuations during the 1990's, state support remains near $77K per year. In contrast, other nearby states with similar or lower seismicity (Nevada, Utah, Alaska) provide support for regional networks at levels between $200K and $500K per year. The principal funding agency, the United States Geological Survey, has continually expressed the concern that state support in Washington is inadequate.

Public Outreach

Beginning with the eruption of Mt. St. Helens in 1980 demand on PNSN for public notification and information increased dramatically. For example, each local felt earthquake or damaging earthquake elsewhere brings in floods of inquiries from government agencies (state and local), the press, and the general public. During the previous year over 5,000 phone calls were logged to the seismic laboratory: 350 of the calls were from emergency management/governmental officials, 300 from media, 200 from educators, and 300 from businesses. Many calls were completed using an audio library, which offers an update on the most recent earthquakes located by the PNSN, a description of earthquake hazards in the Pacific Northwest, and a scientific view of earthquake prediction. 1,500 people toured the laboratory and 400 attended off-campus presentations. Dozens of live television news interviews were given from the laboratory in the wake of seismic events. PNSN staff have also organized many press conferences to discuss research findings related to Northwest seismic risk. Faculty and staff have provided technical information, interviews, and oversight in the production of several local television specials including the Channel 7 production "On Fragile Ground," broadcast September 16, 1998. We also worked with National Geographic editors on text and figures for the May, 1998 National Geographic article on the Cascadia Subduction Zone.

Technology-based delivery of information has been extensively developed to meet growing demands for information. Web based earthquake location information provided by the PNSN is mirrored on many other sites, in a variety of formats. Nearly 2 million "hits" per year are recorded on the UW PNSN web server alone.

Other clear societal contributions are resulting from the incremental expansion of capabilities. PNSN has assumed new monitoring responsibilities for coastal tsunami warnings and mudflows from Mt. Rainier. All of this has been undertaken without additional state support and the current staff must work at maximum efficiency to (just barely) meet current responsibilities.

Many significant local industries are keenly interested in even small to moderate earthquakes. Two examples (of many more) are given here. Currently, using only an estimate of earthquake size (the magnitude) and location, railroads must stop trains and inspect tracks, and Boeing must realign large manufacturing "jigs." These companies would like more detailed information concerning not just where and how big earthquakes are but how strong the shaking was at their site. Significant savings (many millions of dollars) are possible if the companies can reduce "down-time" on the basis of better information. The network, enhanced for scientific reasons, can also provide such data for industries, utility agencies, and state/local emergency services. Although PNSN is slowly augmenting equipment that can be scientifically justified, there is no state support or funding mechanism to meet the outreach needs.

Network Future

Faculty planning for the future of PNSN, initiated in 1992, identified the need to upgrade the existing network (consisting of about 120 vertical component instruments with limited dynamic range and frequency response) with 3-component broad-band and strong-motion instruments. The new technology is essential for the next generation of the science. Scientific goals include the high-resolution delineation of crustal structure in order to understand the processes that have shaped our environment and to identify zones of enhanced seismic risk. The new generation of detectors will also provide data on details of ground motion that are essential in evaluating engineering designs.

A well-founded initiative, with external funding nearly in-hand from regional industries and utilities, has been under consideration at the university since 1992. The Earthquake Engineering faculty in Civil Engineering (partners in an NSF Science and Technology Center) were incorporated into this effort. In return for affiliation fees or "in-kind" services, agencies and companies would receive the RACE (Rapid Alert for Cascadia Earthquakes) pager and PC system. This system could provide risk managers with critical information within minutes of seismic events. Furthermore, partnerships with agencies and companies would speed the deployment of new instrumentation. External interests would purchase the detectors and in some cases pay for installation if UW would provide management and operational monitoring. The Governor recently removed augmented funding that had been included in the University supplemental budget request. Temporary (2 years) university support of $75K has recently been promised. A longer-term funding base for monitoring in service of the state remains to be found.

Glaciology

Overview

Academic faculty in glaciology include Prof. Raymond, and (recently hired) Prof. Waddington. Research Prof. Howard Conway augments strength. The position now filled by Prof. Waddington had long been identified as essential in order to maintain critical mass in this field. Principal collaborations of the group include Bernard Hallet (Quaternary Research), Steve Warren (Geophysics and Atmospheric Sciences), Dale Winebrenner (APL and Appl. Math.), John Wettlaufer (APL), Marcia Baker (Geophysics and Atmos. Sci.), David Battisti (Atmos. Sci. and JISAO), Chris Bretherton (Atmos. Sci. and Appl. Math.), John Sahr (E.E.), and John Stone (Geological Sciences and QRC).

The group has active field programs, including major involvement in ice core drilling projects and borehole logging projects in Greenland and Antarctica. A major thrust of their work lies in understanding the dynamics of glacial flow. Current research is directed at key issues concerning the history and future of the large ice sheets related to global warming and sea level change. The research program encompasses internationally recognized preeminence in theoretical modeling of ice flow processes, and the exploration of internal structures in the ice sheets using ice-penetrating radar. This expertise is also a critical contribution to efforts to reconstruct past climates on the basis of data obtained from ice cores.

Research Agenda

Glacial ice holds a promise to provide a highly resolved record of prehistoric climate. Annual layers of snow (compacted into ice) have evidence for past climate in the form of trapped air bubbles, dust and chemical deposits, and isotopic ratios of elements. At the base of major ice sheets as in Antarctica, the ice can be as old as 300,000 years. In principle, cores through such sheets can be read much like tree rings. One "simply" counts down through the layers, year by year, and identifies "proxies" trapped in each ice layer with the climate in past times. However, the realization of these simple ideas is much more complex, and the UW Geophysics group provides key science in efforts to unravel the complications.

Glaciology is an example of an interdisciplinary subject that draws from a number of classical disciplines. Ice in the environment involves interactions with atmosphere, oceans, and solid earth, using methods from physics, mathematics and chemistry. One of the climate proxies in glacial ice is the ratio of stable oxygen isotopes ($^{18}O/^{16}O$). Qualitatively, the isotope ratio in ice is proportional to average temperature at the time of snow accumulation. However, the constant of proportionality is not a fundamental law of nature. An approximate calibration, based on contemporary data, indicated that temperatures during the last ice age were perhaps 7 degrees colder than now. In a clever application of inverse theory applied to borehole temperature logging along with quantitatively accurate ice sheet dynamics calculations, a better calibration now indicates that the constant of proportionality is larger, thus temperatures were apparently 15 degrees colder in the polar regions during the last ice age.

Whether the ice layers remain in chronological order (with all layers present) is one of the most important questions in interpreting ice core data. UW faculty and students have recognized conditions under which ice layers can be disrupted, or even overturned in folds, as a result of flow deformation. At first, such complications were ignored by the community. However, both as a result of the persistent UW effort in developing the theory of deformation, and in careful field work to identify examples, the situation has changed. On the basis of assumed stratigraphic continuity, a European group made an incorrect interpretation concerning the variability of climate during the previous interglacial period (120,000 years ago). The complications were identified and associated with ice deformation in a letter to *Nature* co-authored by both American (UW specialists) and European ice drilling participants.

Issues and the Future of Glaciology

Major issues facing this group include:

1. fragmentation of space (offices and labs in separate buildings and on widely separated floors),
2. insufficient space for current students, research staff and faculty (students and research staff are crowded into only 2 offices, research associates share offices),
3. inadequate facilities for construction and maintenance of equipment (no bench space is dedicated to electronics work or equipment layout and testing by students or faculty - the limited available lab space also serves for office use).
4. uncertainty of access to engineering support (a custom ice-penetrating radar transmitter was designed in-house and has been supported and modified by a partially state-supported electronics engineer (John Chin). Access to requisite expertise will be difficult and uncertain, following his imminent retirement).
5. poor access to affordable machine shop services (students and faculty building custom field hardware must manufacture equipment after hours in the absence of an affordable professional staff to do the job).

In each recent new ice core project, geophysicists and geochemists have worked together to develop new ways to infer additional climate information by innovative combinations of what had been thought of as uniquely geochemical or geophysical methods. For example, geochemical annual layering combined with ice flow modeling provided a new measurement of past precipitation rates, and borehole temperature measurements combined with stable isotopes in ice cores provided high resolution calibrated temperature records. Geophysical measurements and model studies of airflow in polar firn caused reassessment of geochemical records of aerosols in ice cores. This synergy can be expected to continue. For example, future research combining wind ventilation and selected geochemical measurements in near-surface snow promise to reveal previously unknown records of post-depositional changes to the geochemistry. However, goals of the Glaciology Group to enhance ice-core studies in collaboration with other units cannot be realistically undertaken without better laboratory facilities and university infrastructure. The group in Glaciology is concerned that they cannot maintain its preeminent position in ice sheet dynamics and ice-core climate-change research under current and anticipated future conditions at University of Washington.

Space Physics

Overview

Academic faculty in Space Physics include Profs. George Parks, Robert Holzworth, and Robert Winglee. Research faculty include Profs. Gonzalo Hernandez and Michael McCarthy. An important activity in the group is developing particle, field, and remote sensing instruments. Packages are flown on balloons, sub-orbital rockets, and satellites. Ground-based observations are undertaken at a number of remote installations (including the South Pole).

This group has been able to offer an exceptional graduate educational opportunity, available at only a small number of top universities. In addition to the benefit of a comprehensive space physics curriculum, students have been able to participate in all stages of experiments (design, construction and testing, data acquisition and analysis). They are key participants for a number of programs including the Ultraviolet Camera on the Polar spacecraft and the particle detectors on the WIND spacecraft.

Space Physics Research

The focus of NASA funded space-based research in the coming years will be:

- to understand the connection between the Sun and the geospace environment,
- to undertake more detailed exploration of the other planets, and
- to explore beyond the solar system.

In one example of the interconnectivity of fundamental space physics research with other earth sciences and societal issues, the Sun can accelerate particles to energies of several MeV. These particles, of fundamental interest in themselves, are hazardous to interplanetary travel and can destroy near-Earth satellites. The high energy particles also participate in upper atmosphere chemistry, producing oxides of nitrogen which chemically interact with ozone. Middle atmosphere electrodynamics are also affected. The UW group has two electrodynamic probes to be launched in 1999 and field and particle detectors that will be launched in 2000 to study these forefront problems.

A particularly strong example of synergy in the space physics group is their work on a new propulsion system for deep-space probes. Following on theoretical techniques developed to model the dynamics of plasmas, Prof. Winglee has proposed a new method through which the momentum of particles flowing outwards from the Sun can be transferred to a space probe. Rather than deploying an impracticably large physical "space sail," a small static magnetic field can be "stretched" kilometers from a probe and will then work much like the physical sail. The space physics experimental group is now working on the project and Phase II funding is anticipated. Ultimately this might grow into a very large funded effort.

The general concept of "Space Weather" (variable radiation levels in the near-Earth environment) is helping to galvanize research and educational activities in space physics. As the next solar maximum approaches, the public will need to be better informed about issues of solar activity. As exemplified by the recent loss of a major telecommunication satellite, failures in global communications and power distribution can occur as a result of solar disturbances. In educational outreach, Geophysics now offers a non-majors course (the "Sun-Earth Connection") taught by space physics faculty.

Issues and the Future of Space Physics

The principal funding agency in space physics, NASA, has changed the way business is done. In previous years, an investigator proposed only an instrument. Now, after NASA "down-sizing", an investigator proposes an entire mission including instruments, launcher, telemetry, and post-launch operations. This means that universities involved in space programs must have strong infrastructure to support and manage large missions. Funding levels of $80M to $160M are typical for small to mid-sized Explorer missions. The University of Washington will need to consider how to adjust to this new funding environment.

In common with all other groups in Geophysics, the activities in space physics are maintained at barely critical mass levels. Potentially, a single retirement could reduce funded research in Geophysics by a factor of 2 which would have a severe impact on the entire program. Bridging strategies in response to upcoming retirements must be a critical element of planning.

The Space Grant Program

Overview

A key characteristic of the Geophysics faculty has been a willingness to provide leadership for new initiatives and to explore new funding approaches. Beginning in the late 1980's, the Geophysics Program recognized a need to enhance educational contribution in addition to the graduate offerings. In the absence of state funded positions, the Geophysics faculty unanimously agreed to hire a research faculty member to concentrate on educational issues, with funding through the NASA Space Grant Program. The vision of undergraduate experiential learning through participation in research was pioneered by Space Grant prior to it becoming a University-wide initiative.

The Space Grant Consortium's mission is to provide basic science and space-related education and research opportunities to learners of all ages. Space Grant actively recruits talented high school seniors to the UW through a statewide scholarship competition. The program has raised the visibility of the UW through partnerships with its consortium member institutions and projects throughout the state. In fiscal year 1998 Space Grant received $431K from NASA and raised over $500K in matching funds. While most Space Grant activities focus on higher education, the program also offers outreach activities for K-12 and the general public. In 1998 Space Grant undergraduate research and scholarship programs, with new matching funds from the Office of Undergraduate Education (Mary Gates Endowment), were substantially expanded. Space Grant also ran the first year of a three-year undergraduate research program focused on Earth System Science called OUR Earth. Future program goals include the development of research skills courses and modules for undergraduates.

University program highlights include:

- Four new graduate Fellowship Awards
- Four of seven UW Goldwater scholars in 1997 and 1998 were recruited to UW by Space Grant
- 26 new undergraduate recruits for a total of 64 Space Grant Scholars
- 61 undergraduate researchers participated in the summer program
- 14 students from across the US worked on projects with 11 faculty for OUR Earth
- 194 students registered for the Seminar series "Rocks and Stars"
- 6 public lectures and one weeklong interactive exhibit at the Burke Museum featured space science and planetary exploration
- 5 (1 to 3 day) teacher workshops and 2 sessions for UW Math Day to explore Internet-based science teaching resources
- 59 mini-grants were awarded to K-12 teachers

The Future of the Space Grant Program

The successful efforts of Space Grant staff and Geophysics faculty to create and grow innovative educational initiatives such as the Summer Undergraduate Research program have been largely funded through external sources, including the NASA Space Grant program grant and grants to participating faculty. The College of Arts and Sciences, while enthusiastic about these efforts, has dedicated little financial support to their growth or sustenance. The administration of these projects has and will tax the staff currently serving Geophysics and Space Grant, while demand for these activities by students and faculty continues to explode. It is necessary that the College recognize and offer substantial support to this program that is so successfully serving the mission of the university and the priorities of its current administration.

Additional Research Activities in Geophysics

Geophysics groups described in the previous section highlight a breadth of fundamental research with environmental and societal impact. Other faculty within Geophysics are equally vigorous and successful in their research. Prof. Marcia Baker and Research Assistant Prof. Brian Swanson have an active collaboration involving Physics and Engineering concerning microscopic processes of ice formation in the atmosphere. Prof. John Booker and Research Assistant Prof. Martyn Unsworth are engaged in theoretical and field experiments to map electrical structure of Earth's crust and mantle. Ultimate goals include both understanding global scale dynamics and addressing problems of near surface pollution. Prof. Ron Merrill's research concerning Earth's magnetic field closely links faculty with interests in space physics and the faculty interested in processes occurring deep within the Earth. Prof. Michael Brown and Chemistry collaborators Prof. Leon Slutsky and Research Assoc. Prof. Evan Abramson have a mineral physics laboratory where unique experimental capabilities enable them to measure a number of physical properties under conditions of elevated temperature and pressure. Such previously unavailable data are critical in efforts to understand dynamic processes within Earth and other planets.

Interconnectivity of Geophysics

The Geophysics curriculum (Appendix C) is intermeshed with that of six other academic units. Eleven of the graduate courses in Geophysics are cross-listed with Atmospheric Sciences. Six courses are cross-listed in Geology. Three are cross-listed with Astronomy and Oceanography. One each are cross-listed with Civil Engineering and Aeronautics and Astronautics. These interactions support the core values of Geophysics to foster interdisciplinary research and teaching.

Active cross-unit research collaborations occur with faculty in many units including Physics, Chemistry, Atmospheric Sciences, Quaternary Research, Astronomy, and Electrical Engineering (Appendix D). Four Geophysics graduate students are supported through the Applied Physics Laboratory, Atmospheric Sciences, Oceanography, and Electrical Engineering. Seven graduate students in Physics, Astronomy, Geology, and Atmospheric Sciences are supported by Geophysics faculty.

It is apparent that key elements of the Geophysics course offering are associated with faculty both inside and outside the four earth science units. Important research collaborations have been forged across the university. A diverse group of graduate students in other departments have chosen to work closely with Geophysics faculty.

Outcome Assessment for the Geophysics Program

Research

The current exceptionally high level of external funding awarded to our faculty is one manifestation of the recognition we have within the scientific community. In addition, three faculty are Fellows of the American Geophysical Union, one is a Fellow of AAAS and another is a Fellow of the American Meterological Society.

Service

Many of our research programs have direct societal impact and our faculty has been thoroughly involved in communicating the consequences of their work. A few recent examples include:

1. efforts (well covered in the local media) to identify earthquake hazards in the Puget Sound region,
2. the glacial studies that have contributed to "Global Change" discussions with the reconstruction of ancient climate (Prof. Raymond was called to advise Vice-President Gore on global warming), and
3. national media coverage of UW satellite-based studies related to "space weather."

Education

Comparisons and rankings of the Geophysics Graduate Program are difficult, given the unique nature of our unit. In an obvious oversight, the 1991 NRC rankings of geoscience graduate programs failed to include the UW Geophysics Program. The 1998 US News and World Report rankings of Geophysics (as a subdiscipline of Geology) listed UW in 12th place.

The exit questionnaires completed by recent graduates (Appendix G) give a excellent evaluation of the education received while undertaking their graduate studies. The lowest scores were received in the areas of experience and training in teaching. This is a direct consequence of the reliance of Geophysics on RAs for graduate student support. We do not have access to a sufficient number of teaching assistantships to enable all of our students to receive adequate training.

Graduate placements are summarized in Appendix E. Many of our former students now occupy faculty positions in universities. Others have leadership positions in industry, government, and journalism. For example, one former student now serves in a high-ranking position within the White House Office of Science and Technology while another is a Senior Editor for *Nature* Magazine. Recent graduates have also pursued careers within a variety of local high tech businesses. It would appear that the rigorous training and interdisciplinary research directed at complex systems provides our graduates with flexible and valuable job skills.

Issues Facing Geophysics

The forgoing discussion is given to indicate that Geophysics has an active faculty who are working to capacity. Geophysics faculty members have responded to scientific challenges and societal demands. We have provided leadership on campus in undergraduate experiential learning. Much of the evolution of our activities has been accomplished with no enhancement of our state budget allocation.

In the following, issues to be faced by Geophysics are highlighted.

1. Geophysics is facing a critical period in the faculty age distribution. Six of 13 current academic faculty are age 60 or over. Several retirements are imminent and additional retirements can be expected in the next five to eight years. We currently have less than critical mass (or only marginally acceptable mass) in several disciplines. It is therefore essential that faculty be recruited to replace these retirements.

Furthermore, bridging strategies are needed to maintain excellence. Junior faculty in some cases should be hired prior to the loss of an active program as a result of retirement. In other cases, it may be necessary to hire at a more senior level.

2. Faculty salaries at the University of Washington are below those at peer universities. The recent faculty report to the Provost documented that Geophysics salaries are 50% below those of the peer group. Issues of retention will be a problem among those faculty not retiring in the next decade.
3. Although the level of external grant support in Geophysics is high, the funding of entering graduate students has become increasingly difficult. New accountability standards make it difficult to support students in the first year while they are heavily committed to course work. Furthermore, our research requires a mathematical and physics preparation not obtained by some otherwise capable graduate applicants. We currently have no way to support such students while they take additional courses.
4. We have critical seismic information to distribute to citizens, government, and business. These outreach programs are already straining the existing resources. External demands have exceeded our ability to meet them.
5. We attract more highly qualified graduate applicants in the area of volcanic and earthquake seismology than we have faculty and funding to support. With increased resources, we would have the opportunity to be the premier graduate program in that area.

6. Current facilities and infrastructure are barriers to educational and research excellence.

    a. The inadequacy of Johnson Hall to support modern science programs has been thoroughly documented.

    b. Geophysics faculty are widely scattered, so cohesion is difficult to maintain.

    c. Geophysics lacks access to teaching space to expand undergraduate offerings.

    d. The faculty do not have adequate access to the technical support necessary for modern science.

        Facilities in Chemistry and Physics are frequently over-committed to internal needs, and even when available are too expensive because Geophysics has not been offered the state-funded subsidy for instrument design and construction that is provided to Chemistry and Physics.

Educational Mission

Undergraduate Programs

Geophysics, while not offering an undergraduate degree, has long carried out educational activities at the undergraduate level. The Geophysics faculty has expertise that appeals to undergraduates. A minor in Geophysics was developed in 1997 to provide a path for (principally) physics undergraduates who might choose to investigate career opportunities in Geophysics. The number of students registering for the 400-level core courses has increased and at least one undergraduate has declared the Geophysics minor.

We have initiated three 200-level non-majors courses with environmental focus which appeal to broad audiences ("The Sun-Earth Connection," "Earthquakes," and "Glaciers and Climate.") They differ from typical 100-level science courses in having a narrowed focus. We base our educational approach on an "active learner" paradigm. The passive lecture format has been shown inadequate in reaching the larger population of non-science major students. Our 200-level courses are relatively non-quantitative yet continually emphasize the power of quantitative analysis. Concepts dominate over mathematical rigor. Elementary mathematical ideas are introduced but only in the context of showing why math is part of our explanation of the physical world. Important mathematical ideas include powers of ten, conservation laws, linear and non-linear systems, and elementary statistics.

The 200-level courses provide Geophysics with an opportunity to enhance student interest in earth science degrees. In addition, Geophysics 425 "Rocks and Stars" consistently has enrollments that fill available lecture hall space. Student interest is high. Thus, this course will also serve to direct majors and non-majors to new course offerings from Geophysics.

The curriculum committee in Geophysics has recommended that additional courses be offered at the 300 level which could meet needs for a possible Geophysics major as well as providing service to other campus units (Geological Sciences, Engineering, and Oceanography). There is a strong recommendation that Geophysics work with the Program on the Environment in shaping our 200 level courses. They also suggest that Geophysics work with the other Earth Science units in consideration of an Earth Science undergraduate degree.

The Space Grant Program in Geophysics made the enhancement of undergraduate research opportunities a principal goal six years ago. President McCormick's priorities show that our vision in this area has now become thoroughly accepted. We continue to administer one of the largest campus programs that funds undergraduate research and actively recruits the best high school students in the state.

Graduate Degree Programs

Background

During the 9 year reporting period (1989 to 1998 - see Appendix A) 60 students enrolled in the Geophysics graduate program. A total of 65 degrees (29 MS and 36 Ph.D.) were awarded. The mean time to completion for the PhD is 6.2 years. The average time for an MS is 2.8 Years. The average Geophysics enrollment has been near 40 students, with 34 students at the beginning of the 1998/1999 academic year. An additional 10 to 12 students in other departments have had Geophysics faculty as their research supervisor.

Geophysics is a cohesive unit, with this cohesion partly derived from the common philosophy that all of our graduate students should have a strong background in physics and mathematics and a broad understanding of how to apply physics and mathematics to earth science problems. This philosophy is evidenced in the requirement that Geophysics students must take all the core courses before graduation. These courses are organized along two tracks: the solid earth track and the fluids track. They incorporate substantial amounts of physics and mathematics and their applications to a wide range of geophysical problems. In the fluids track, geophysical fluid dynamics is taught in "Geophysics: Fluids," plasma physics and magnetohydrodynamics are taught in "Geophysics: Space," and thermodynamics, statistical mechanics, and radiation are taught in "Geophysics: The Atmosphere." The solid earth track begins with "Geophysical Continuum Mechanics" focusing on applications in solid earth geophysics, then moves to "Seismology," a course that emphasizes wave theory, and finally to "Geophysics: The Earth," which has a strong emphasis on potential theory. Consequently, students are learning a broad range of physical and mathematical tools in each of these courses and are shown how these tools are used to solve particular problems in the geophysical sciences.

Outcome Evaluation

The faculty evaluates their success in providing graduate education in terms of the quality of science conducted by Geophysics students and in the success of Geophysics students in pursuit of satisfactory post-graduate careers. The continued faculty success in obtaining research funding and in publishing high-impact scientific papers are positive measures of the high quality graduate education. An evaluation of post-graduate careers outcome is given in Appendix E. Over one-third of responding Ph.D. recipients between 1986 and 1996 have faculty positions at colleges and universities, despite the truly abysmal academic job market faced by these graduates. Nearly 60% report positions in business and government.

Evaluation of Student Progress

There is a considerable range of opinion among different science departments on how to determine whether a student is qualified to continue on for an M.S. or Ph.D. degree. The current system in Geophysics (adapted during academic year 1993/94) is a "Qualifying Process" that consists of: (1) written evaluations by instructors of the core curriculum, (2) written evaluation by the research supervisor, (3) the overall academic record, and (4) the defense of a research proposition. Prior to 1993, Geophysics administered a comprehensive written examination. Both systems have their merits and faculty have strong opinions favoring one or the other. The negative comments about the current system are that the Qualifying Process is subjective and not effective in distinguishing between students who should continue toward a Ph.D. and those who should not. However, the majority of faculty are pleased with the Qualifying Process. The advantages cited include: (1) the strong incentive for students to begin thinking about and doing research early in their careers, and (2) the better and increased interactions between students and advisors during the first year. It has been argued that the overall morale of students has increased.

The General Examination, intended to be taken early in the fourth year of the graduate program, remains an important checkpoint. The adequacy of a student's preparation for the intended research is evaluated at this time. Unfortunately, most students delay this exam as long as possible. A faculty committee is currently considering recommendations that might reduce the time interval between successful completion of the Qualifying Process and the General Examination.

Master's Degrees

The goal of the Master's degree is to prepare students for careers in education, government and industry. We offer both a thesis and a non-thesis Master's Degree. The requirements are identical for both options except that in the non-thesis option a manuscript that has been submitted to a scientific journal for publication replaces the thesis. All students obtaining a Master's Degree are required to pass the Geophysics Qualifying Process at the Master's level. It is the student's responsibility to meet the Graduate School requirements for the Master's Degree.

Doctoral Program

The Ph.D. in Geophysics prepares an individual for high-level careers in research, education, and administration. The rigorous geophysics training in physical and mathematical methods has proven directly useful not only in the earth sciences but also in other diverse areas.

Responses to Change

Every section of this self-study report documents the activities of the Geophysics faculty and our responses to change. Within Geophysics micromanagement is de-emphasized; each faculty member is encouraged to carry out his or her best research, by working either alone or in groups. Feedback on progress is made via formal and informal meetings with the chairman and by a variety of written documents. Changes impacting the educational and research environment have been fully recognized individually and collectively. A diverse collection of ideas and initiatives are being actively pursued.

Examples of recent responses in the educational domain include:

1. Geophysics supported the creation of the Washington Space Grant Program and has worked to insure its success.
2. Geophysics created an undergraduate minor. This is a step in the direction of understanding and responding to changing undergraduate needs.
3. Geophysics launched three 200-level courses incorporating innovative teaching techniques to educate non-majors about critical environmental issues.
4. Geophysics is engaged in discussions with the Program on the Environment and other units with an eye towards further evolution of our undergraduate offerings.

Goals

Process to Set Goals

The Geophysics faculty, while fully engaged in individual or group research activities, is unusually cohesive in addressing issues of the unit. There is respect and trust across the group boundaries. Most important questions are typically addressed first in a committee appointed by the chair. In most cases, recommendations of committees are accepted by unanimous vote of academic and research faculty. The faculty committee report (Appendix F) on shaping the future of geophysics, prepared in 1996, is given as an example of Geophysics goal setting.

Goals for 5 to 7 years

The general framework of faculty consensus is provided in Appendix F. Additional group specific goals are mentioned in previous sections. In general, Geophysics research, educational, and service goals are intimately linked. Barriers to progress are also highly coupled. The faculty have, for example, initiated new teaching. However, the lack of adequate class lab space, equipment for the labs, technical support, and TA support makes further development difficult.

A principal priority in Geophysiics is to maintain and enhance research quality in Geophysics. No other graduate, undergraduate, or service activity of the unit can be adequately undertaken without an underlying quality scientific program. The key requirements for this goal will be

1. To meet the demographic challenges,

- We must hire prior to the loss of critical senior faculty
- In one case (space physics) a "beyond junior" appointment is necessary

2. To find solutions to inadequate research facilities and infrastructure,

    - The current building (Johnson Hall) is wholly inadequate for science now and into the future. A new Geoscience building must be returned to the list of university priorities.

    - Although inadequate university-provided infrastructure is a universal theme across the sciences, it should be noted that faculty in Physics and Chemistry have access to state-funded instrument makers and design engineers at subsidized costs to externally funded research. Geophysics faculty remain second-class university citizens. We are allowed time in these shops only on a basis of availability and must pay hourly rates beyond that supported by typical research grants.

3. To develop new strategies to fund graduate students

- Although funding levels continue to grow, the willingness of faculty to support first year students is strained. Geophysics currently has few options beyond research assistantships to fund students.

Geophysics must also develop and achieve long term goals in an evolving educational environment

1. Geophysics will insure that new courses meet university needs for non-major science education through coordination with POE and other earth Science units. Faculty will develop a comprehensive vision of non-majors education.

2. Geophysics will work with other units to develop the concept of an Earth Science undergraduate degree. Such a "Liberal Science" degree will better prepare students entering a variety of non-science fields that rely on scientific resources and information (education, law, urban planning, etc.)

3. The concept of offering an undergraduate major in Geophysics is under discussion. It would be anticipated that the number of majors would be small but that such education would be a natural and appropriate contribution of our faculty.

   - New 300 and 400 level geophysics courses needed for a Geophysics major would also provide educational opportunities for students in geology, oceanography, and engineering. The faculty have identified courses that should be offered but are not.

4. An expanding undergraduate participation would provide new opportunities to fund graduate students (through TAs) and would help the university meet the expected demand for science instruction in the next decade.

5. Geophysics should give consideration to changes in the training of MS students. The fraction of students leaving the program with the MS is high. Most of these graduates participate in research projects that require a high level of individual training from a research supervisor. Since many of these students obtain local employment in either software or geotechnical businesses, it may be possible to identify less faculty-intensive training programs that will better prepare the students.