Self-Study, Department of Earth and Space Sciences, 2022

Name of Unit:

Department of Earth and Space Sciences
College of the Environment
University of Washington, Seattle

Official Titles of Degrees and Graduate Certificates offered by the Unit:

Bachelor of Science in Earth and Space Sciences

Degree Options:
ESS B.S. – Geology Option
ESS B.S. – Biology Option
ESS B.S. – Physics Option
ESS B.S. – Geoscience Option

Bachelor of Arts in Earth and Space Sciences
Minor in Earth and Space Sciences
Climate Minor
Arctic Minor

Master of Science in Earth and Space Sciences

Doctorate of Philosophy in Earth and Space Sciences
Doctorate of Philosophy in Earth and Space Sciences and and Astrobiology

Certificate and Dual Degree Options:

Graduate Certificate in Climate Science
Graduate Certificate in Data Science

Date of Previous Review: November 1st, 2010

Academic Unit Leadership: Maya Tolstoy (Dean), Eric Steig (Chair)

Self-study coordinator/author: Eric Steig

Date Submitted: September 5, 2022

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Section I: Overview of Organization

1.1 Department Mission and Organizational Structure

1.1.1 Overview and Mission

The Earth and space sciences – geology, geophysics, geobiology, geochemistry, and planetary and space sciences – play a critical and unique role in the advancement of knowledge, improvement of the quality of life, and understanding humanity's place in the universe. Research in Earth and space sciences is intrinsically interdisciplinary, drawing on methods and theory from chemistry, physics, biology and computational sciences. Earth scientists are concerned not only with curiosity-driven research but also with the dissemination of Earth sciences knowledge in the service of society. Limited resources, geologic hazards, and related environmental change are among the most serious challenges we face. Earth scientists have a responsibility to use their expertise to provide the training and education required to address these challenges, and to include a more diverse community of scientists, students and stakeholders than in the past.

Faculty in the Department of Earth and Space Sciences have historically excelled in the development of novel observational methods, the advancement and application of theory, and in education towards both academic and non-academic careers. We have made progress in reduce barriers to participation in our community. Our goals to continue and to further improve in that tradition are reflected in our Mission:

- To provide challenging and supportive learning experiences that ensure students understand the unique role of science in the production of knowledge, and which prepare students for successful careers – whether through the further advancement of science as researchers, the dissemination of knowledge as teachers, or the application of knowledge and critical thinking to address practical challenges.
- To advance scientific knowledge of the Earth and other planets, involving processes, origin and history, in areas including the interior, the surface, the atmosphere, the cryosphere, and the biosphere.
- To engage with society, both locally and globally, to increase science literacy, to inform public policy related to education, resource management and environmental stewardship, and to provide key geosciences services related to geological hazards.
- To increase access, and reduce barriers to participation and retention, in the realization of this mission.

In 2001, the separate Geological Sciences and Geophysics programs were merged to become the Department of Earth and Space Sciences (ESS). ESS left the College of Arts and Sciences to join the UW College of the Environment at its inauguration in 2009. Today, ESS is a strong, vibrant, interdisciplinary department with 19 tenure-track, 3 teaching and 5 research faculty, nearly a hundred graduate students, one-hundred and fifty undergraduate majors, and a small support staff. Thousands of undergraduate students take ESS courses annually. Our faculty are research leaders, publishing widely and responsible for about $14M of external funding annually. Our alumni populate geologic consulting firms across the region and the faculty in geoscience departments across the nation.

1.1.2 Undergraduate Program

Earth and Space Sciences offers Bachelor of Science (B.S.) and Bachelor of Arts degrees. The B.S. has four different areas of concentration (or tracks): Geology, Geoscience, Physics, and Biology. A summary the degree options is provided in Appendix E. We also offer an ESS minor, and a number of our classes count towards credit for an undergraduate Climate Minor administered by the multi-department Program on Climate Change, and an undergraduate Arctic Minor administrated by the School of Oceanography.

ESS teaches thousands of students, generating more than 25,000 student credit hours (SCH) annually. The efficiency of the department, as measured by the number of student contact time compared with the total number of full-time equivalent tenure-track faculty (FTE) has consistently increased over the last decade (Fig. 1). The number of declared ESS majors has ranged from 150-200 students in any given quarter, with most students in the Geology and Physics B.S. tracks, though with recently-increased interest in the broader Geosciences track (Fig. 2). The department graduates about 50 to 100 majors annually. The most recent two years show a small decline owing (unequivocally) to the impacts of pandemic-related restrictions on delivery of field and laboratory experiences.

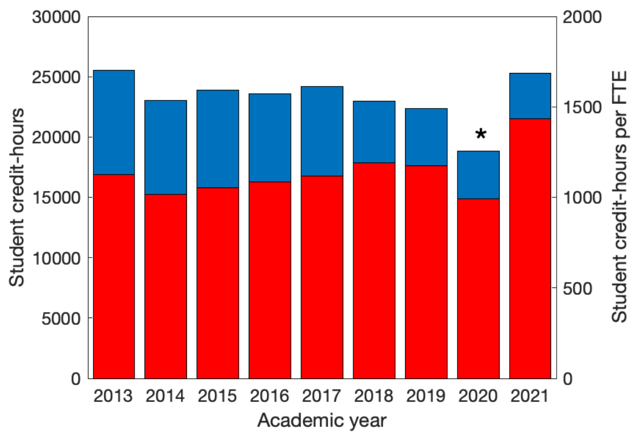

Figure 1. Student credit-hours (SCH) data since 2013. With the exception of the first year of the COVID19 pandemic (*), SCH have (blue) have been consistently between 20,000 and >25,000, despite the decreasing number of faculty. SCH per faculty member (red) have increased by ~25%.

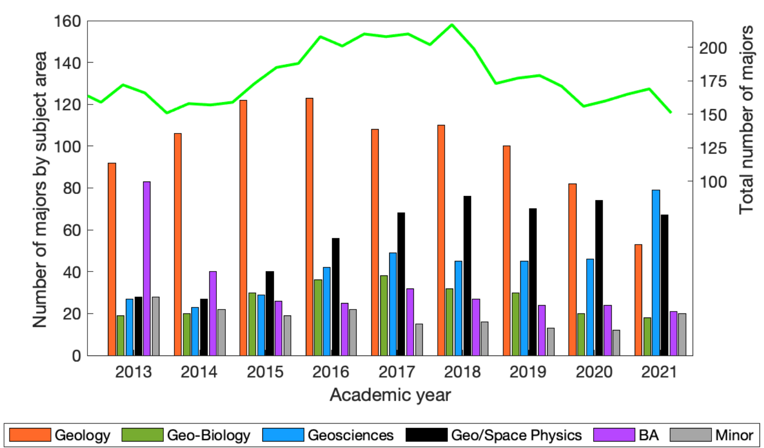

Figure 2. Number of majors in ESS each quarter (green line), with annual numbers by BS or BA option (bars). A decline in those choosing the geology option majors is largely offset by the increase in the geophysics and the geosciences options.

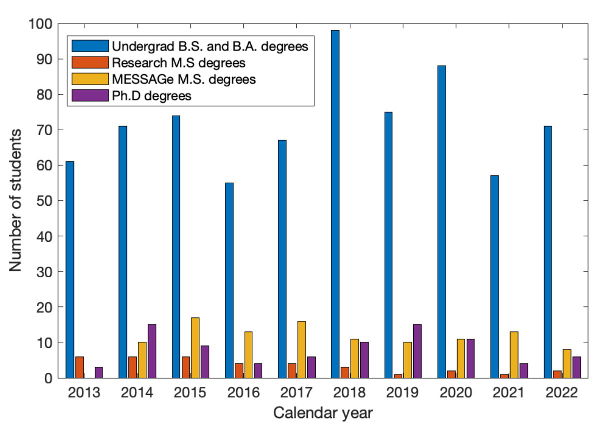

Figure 3. Number of graduating students by degree type. Note that the 2022 year is not yet complete.

1.1.3 Applied Masters Program

ESS offers a tuition-based M.S. degree, the Masters in ESS Applied Geosciences (MESSAGe). MESSAGe is designed to educate students to become working professionals in Engineering and Environmental Geology. The program has trained more than 100 students in the past decade, most of whom are now practicing geologists in our region. MESSAGe has graduated an average of 12.6 students a year since its inception (Figure 3). Because students are in the program for 18 months, there are typically 15-20 students in the program at any given time. Owing to one retirement and two key faculty on medical leave, we have not admitted new students for 2022 (see Section IV of this report).

1.1.4 Graduate Research Program

We offer Doctor of Philosophy (Ph.D.) and Master of Sciences (M.S.) in our research program. Most research graduate students intend to complete a Ph.D.; an M.S. is not required *en route* to the Ph.D. The graduate research program also includes three options that provide additional transcript credentials: a dual Ph.D. degree in ESS and Astrobiology (requiring research rotations and additional coursework with the Astrobiology graduate program); a Graduate Certificate in Climate Science from the Program on Climate Change (requiring additional coursework and a capstone project in climate science communication); and a new graduate option in Data Science with the UW eScience Institute (requiring specific courses from our department and others).

In the last decade, the total number of students in the graduate research program (not including MESSAGe) has declined from more than 100 to about 75 (Fig. 4). This change directly reflects a reduction in the number of ESS faculty. The average number of graduate students per tenure-track faculty member has remained essentially steady at ~4.5 students/FTE. ESS hired 1 new faculty member in 2020, 2 more in 2022, and will have hired four to six more by 2024. The number of graduate students is expected to increase once again as new faculty come on board.

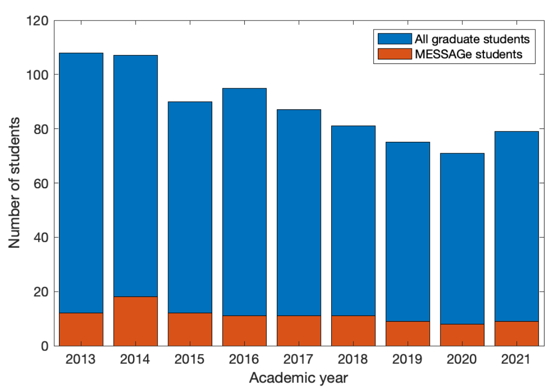

Figure 4. Number of graduate students in Earth and Space Sciences since 2013.

1.1.5 Advising, Fiscal, and Technology Support

ESS has eleven staff supporting the academic mission (see the organizational chart, Appendix A). These staff include 2½ positions for academic advising, including a Director of Academic Services who also serves as graduate counselor, an undergraduate counseling services coordinator, and a part-time program coordinator responsible for course scheduling and related activities. There are two staff in administration and three in fiscal support, including a full-time department administrator, an assistant to the chair who also addresses academic appointments and visas, and three staff who handle grants and contracts, travel, and reimbursement. There are three full-time computing staff who support computer labs and classrooms, research computing, and the Pacific Northwest Seismic Network (PNSN), which is the largest single user of their services.

Staff are supported by a combination of general operating funds and indirect-cost return from external grants and contracts, and an internal ESS user-services fee for computing support (direct charge to grants), in proportion to the fraction of time each staff person spends on academic vs. research-related work. Individual research laboratories also employ lab managers, technical staff, software engineers, and field technicians, funded by external grants.

1.1.6 Shared Governance

The governance structure of ESS includes the Chair, two Associate Chairs, a faculty Executive Committee, and several standing committees that include faculty, graduate students and undergraduates. ESS governance allows input at multiple levels so that the department can respond proactively and equitably as situations and opportunities develop. The Chair reports to the Dean of the College of the Environment. The Chair is selected by the Dean from candidates identified by an external search committee with input from the faculty.

The Department Chair works with the Department Administrator to develop financial plans for each biennium. In helping to form this plan and handle day-to-day issues, the Chair is advised by the Executive Committee, currently is made up of four ESS faculty members: the undergraduate program coordinator and graduate program coordinator (who serve as Associate Chairs), and the two elected ESS representatives to the College Council. (Different chairs have used different criteria for determining the make-up of the Executive Committee; in the past, for example, emphasis has been placed on involving junior faculty.) The role of the Executive Committee is also to solicit input from other faculty, students, and staff.

Standing committees handle regular business including admissions, curriculum, budget oversight, and diversity. They report to the faculty at the scheduled faculty meetings. Faculty are recruited to serve on the standing committees by the Department Chair.

Graduate students elect members to the department committees each Autumn quarter. The Chair meets with the graduate student representatives in at least once per year, and as needed, to determine issues that need to be addressed. The department also has an active undergraduate group that organizes their activities through GeoClub. The GeoClub officers are elected and participate in faculty committees that directly affect the undergraduate program.

Faculty meetings are held in accordance with the Faculty Code and occur once a month during the academic year, or more often if necessary on an *ad hoc* basis. The first part of each meeting is open to all members of the department, including elected graduate student representatives.

1.2 Budget & Resources

1.2.1 Budget Outline

The department budget comprises two primary sources: the general operating funds (GOF) that are provided to the department from the College of the Environment, and which ultimately come from tuition dollars. The amount of the GOF budget is (in principle) determined through Activity Based Budgeting (ABB) formulae with are in turn tied primarily to student credit hours. A portion of GOF funds (roughly $600,000/year) is an allocation specifically for the Pacific Northwest Seismic Network (PNSN). A further portion of the GOF fund (about $200,000/year) comes from the tuition-based revenues from the MESSAGe applied M.S. program. Total GOF funds (excluding the PNSN allocation) have averaged $4.8M/year over the last 10 years. This amount has increased by less than 3% per year over the last ten years, at best keeping pace with inflation (though significantly below the Washington State inflation rate), despite increases in relevant department activity.

The other main source of revenue for the department is ICR (indirect cost return or overhead) from grants and contracts (Figure 5). Total grants average about $12M/year over the last decade, and have generally increased despite the decrease in faculty lines. The majority of the funding is from the National Science Foundation (40% in FY22), the USGS (33% in FY22), and NASA (10%) with additional significant funding from private foundations (e.g., 3% each in FY22 from the M.J. Murdock Charitable Trust and the David and Lucile Packard Foundation). The balance (11% in FY22) is from a variety of smaller private foundations, government agencies and subcontracts from other universities. The amount of ICR provided to the department averages 5% of the total grants and contracts. Note that many of our grants (particularly funds from the USGS, which is primarily to support PNSN) have low overhead rates because they primarily support off-campus field work. This results in a lower ICR than would be obtained from, e.g., laboratory-based NSF funds. In a typical year, the department earns $600,000 in ICR.

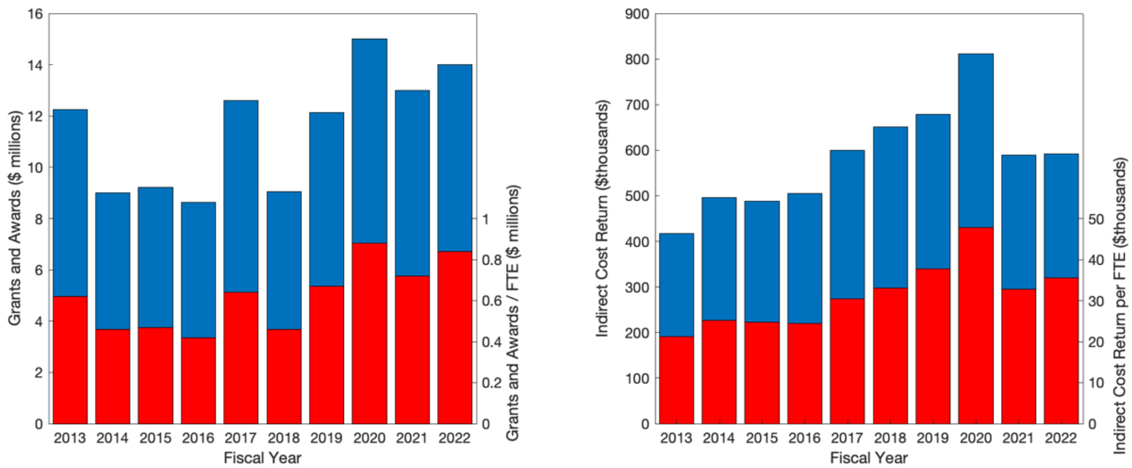

Figure 5. Left: Total grant income (blue) and grants/FTE obtained by ESS. Right: indirect cost return (ICR) to the department, and ICR/FTE.

Other sources of revenue to the department include income from endowments and current-use gift funds. New gifts that are for current use (rather than being contributions to endowments) average $140,000/year; these largely comprise restricted funds for specific uses, such an annual class trip to Greenland that one of our glaciology faculty leads. The portion of that total that is essentially unrestricted averages $28,000 per year. New endowment gifts are $200,000 on average a year, and our current total endowment is $7.6 million. Income from existing endowments is about $250,000/year. We spend the majority of our endowment and current-use funds each year on supporting students (as stipulated for most of the funds we have available), providing about $275,000/year for research expenses, awards, scholarships, fellowships and RA-quarters each year. In addition, we currently have one endowed Chair and two endowed Professorships in the department, providing discretionary funds between $10k and $40k/year for those individuals, with a fraction of the Endowed Chair funds going to the department for discretionary use in support of geological hazards-related research.

Our primary expenses from the general operating funds are faculty salaries, TA support, staff and lecturers. After accounting for the expenses associated with tenure track faculty, teaching faculty and lecturers, our remaining budget must cover the nominal expenses allocated for TA support and staff. However, in practice, TA expenses for large-enrollment undergraduate laboratory courses are larger than our budget, and we often subsidize our TA budget by using a greater fraction of indirect cost returns on staff than is strictly warranted given staff responsibilities towards the academic and educational program. Some details on this issue are provided along with the budget summary for the last 7 fiscal years is provided in Appendix B.

Expenses from ICR include building infrastructure, research staff salaries, and start-up costs for new faculty and for faculty retention. Start-up funds are our single largest expense, and ICR is the only significant source of revenue for this expense. (Start-up funds are typically matched 1:2 by the College of the Environment – i.e., the department pays $^{2}/_{3}$ of costs, the college pays $^{1}/_{3}$.) For reference, a typical start-up package for new faculty is between $400k and $1M, with ESS covering approximately $^{2}/_{3}$ of the cost. These expenses are typically expended over a period of five years – this means that for each new hire, there is an annual cost to the department of ~$50,000 to ~$135,000/year. A significant challenge for all UW departments is that building maintenance costs are largely a department responsibility; in general, this exceeds the available funding and needed upgrades are deferred indefinitely.

1.2.2 Budget Evaluation

Most budget planning is done by the Chair in consultation with the department Administrator. There is a faculty oversight committee that meets each year to evaluate how money has been spent. We also provide regular budget updates to the faculty at monthly faculty meetings. Decisions to make changes to the budget (e.g., to reduce TA expenses, or to increase salaries) are made deliberatively with the full faculty, and subjected to a vote.

In practice, because our budget is tight, we have little room to make discretionary decisions with our general operating funds. A major source of pressure on the budget is faculty salaries. Increases in faculty salaries have generally been funded internally (i.e., with no increase to our permanent budget). There were $31^1/_3$ FTE in 2001. By the 2021-2022 academic year, this had been reduced to $17^2/_3$. Recent hires will increase the FTE to $20^2/_3$ by September 2023. Increases in funds are largely consumed by unfunded faculty raises. While salary increases are necessary for faculty retention, they have come at the expense of available funds for staffing, and our staffing numbers have significantly declined. An independent budget evaluation led by the Chair of Atmospheric Sciences in 2021 showed that ESS had the least College-funded staff support per FTE of any department in the College, despite being the greatest source of ABB revenue to the College.

There is more room for discretion on the use of funds from ICR. As noted above, the major expense is start-up funds, and we have collectively made the decision that investment in new faculty is warranted: indeed, given the decline in total faculty numbers, it is necessary if we are to maintain our income stream from teaching and research.

An additional constraint is that, historically, there has been very little transparency from the College with respect to the allocation of ABB funds; in particular, there is no clear link between the number of students we teach (and hence the amount of ABB generated by us for the College) and the funding we receive. This makes planning difficult, and provides a strong incentive to reduce our teaching and our TA allocations to reduce expenses. However, reducing our teaching would result in a net loss to the College. The large non-science-major classes taught by the department represent a large service to the general University community, but the expenses to support of teaching faculty and TA salaries are drawn from the department. This is a long-term problem that was also highlighted in our 2010 Self Study Report. A priority of the current Chair is to work with the Dean's office to develop models that better align incentives with allocations.

Our best measure of whether we are allocating funds wisely, and making the right hiring decisions, is the success of the department, measured by teaching success and research output. Our student credit-hours (SCH) have remained at about 30% of the total College teaching over the last decade, even as other units have increased their teaching contributions. Our total SCH are about 40% higher than the next closest unit in the College. Although these numbers are largely owing to 100-level classes, they are also higher than all but one other College of the Environment unit at the more advanced (200, 300, 400) levels, and have remained so throughout the last decade, including throughout the pandemic. The success of our faculty at securing external research funding has also increased. While year-to-year grant success is volatile, the average rate of increase in ICR over the last decade has been about 6%/year. Measured per faculty FTE, that increase is nearly 9% per FTE over the same period (Figure 5).

Funding for summer-quarter teaching poses a unique challenge for the department. Summer funding at UW is handled separately from academic year funding and is not part of our general operating funds. Prior to FY21, we taught an intensive field class in Montana, a capstone requirement for most of our undergraduate majors. This class involved three faculty instructors, along with 5 to 8 TAs, to ensure field safety and close mentoring of the ~50 undergraduates that took the class each year. The cost was roughly balanced by income from tuition, with travel and lodging costs subsidized for most students by our endowment funds. Cost overruns, when they occurred, were covered by Summer Programs, which made a profit on other classes (including one of our own – a summer version of ESS 101). In FY20, the Provost's office changed the formula for summer teaching, levying a 65% tax on all income. This has made it impossible for us to teach the class as we have previously done. Other pressures have also motivated us to pursue other options for our undergraduate capstone, discussed in Sections II and IV.

1.2.3 Advancement and Funding Strategies

ESS faculty are successful at obtaining grant funding through PI-driven individual or collaborative proposals. In addition, we work closely with the Advancement office within the College of the Environment to steward fundraising. Some recent examples of success include the following:

- Our department was chosen among competing applicants from across the university for an opportunity to submit a proposal to the M.J. Murdock Charitable Trust Foundation, which was led by two our newest faculty. This resulted in a $473,000 grant to fund the new UW Photonic Sensing Facility, which uses fiber-optic sensing for seismology, glaciology, and other projects.
- We have recently been chosen to submit a proposal to the Keck Foundation to acquire a new Ion Microprobe facility for studies of igneous and metamorphic processes and their relationship to subduction zone earthquakes and volcanoes.
- We have been successful in capitalizing on opportunities from the increased focus by NSF for large, interdisciplinary, multi-institution grants. These include the ESS-led “M9” project which involved a broad team of University of Washington researchers with the goal of reducing the catastrophic potential of Cascadia megathrust earthquakes on the social, built, and natural environments. This led to the recent launch of a new “Geohazards Initiative” with $2M of support from a private donor to promote and support development and deployment of earthquake early detection systems.
- The ESS glaciology group co-leads a new NSF Science and Technology Center grant called the Center for Oldest Ice Exploration (COLDEX), which aims to obtain paleoclimate records extending through the last 2 to 5 million years of Earth history.

Over the last few years of the pandemic, our outreach activities to potential supporters of the department have taken a back seat to other, emergent issues. In addition, the retirement of several faculty who have previously led such activities has made it difficult to continue at our historical levels of engagement. Re-engaging with our supporters will be a priority in the coming year, and will include continuation or renewal of activities such as in-person events for alumni at national meetings, our annual student Research Gala and Department Awards Ceremony (in which supporters participate), development of a department newsletter and launch of a new department web site.

A particular challenge for the department is raising funds for infrastructure. Equipment purchases for new faculty are necessary as part of start-up, and building renovations are historically unsupported by the University. One important example is the loss of the freezer system that is critical for our cryosphere work: despite an explicit promise to new faculty made by the university in 2001, to date, this has not been addressed. There is currently support from the Dean’s office, with funds from the Provost, to support such a renovation, but additional fundraising is needed to make this a reality. It is in the department’s interest for supporters and potential donors to be made aware that start-up funds for new faculty, and building infrastructure, are our most critical fund-raising needs.

1.3 Diversity, Equity, and Inclusion

1.3.1 Summary of Plans and Policies

The Department of Earth and Space Sciences aspires to support and value students, faculty and staff from diverse backgrounds, and to ensure that all members of the community feel included – that they have a sense of belonging. The department’s formal Diversity committee is tasked primarily with creating formal policy and best-practice recommendations to the department. The committee has comprised one faculty member as chair, and includes advising and research staff, along with post-doc, graduate, and undergraduate students. Going forward, given the need to focus on policy, the committee should include at least three faculty members, from a range of career stages.

Ensuring that our department is as inclusive and equitable as possible is ultimately an institutional, rather than an individual responsibility. While some universities across the U.S. have begun to make "contributions to DEI" part of the faculty promotion and tenure process, this idea was decisively rejected by a vote of the UW faculty in 2022. Instead, faculty and staff (and students) are encouraged to report on their efforts to support a diverse and inclusive department, we do not require such reporting under under a separate "DEI" category. Such efforts should fall within the regular day-to-day work of striving for excellence in research, education, and service, including supportive mentorship of students, postdocs, and other faculty.

Key policies, practices, initiatives and outreach activities oriented towards ensuring positive and supportive experience for students, include the following:

- Fostering inclusion and support for minority (URM) scholars: The department has supported and funded faculty to participate in, for example, UndocuAlly training, Title IX and Bystander Intervention training. Faculty and other community members regularly participate in UW programs and trainings that benefit mentoring and inclusive pedagogy, including Bias 101, Hiring for Diversity, Universal Design, Professional Staff Organization Diversity Conference, and workshops by the Office of Equity and Justice in Graduate Programs, the UW Technology Teaching Fellows Institute, and the College of the Environment Climate and Environmental Justice Course Design. We also partner with UW Brotherhood Initiative, Louis Stokes Alliance for Minority Participation, and the Office of Minority Affairs and Diversity's Educational Opportunity Program.
- Graduate admissions: ESS reviews graduate applications holistically and we no longer use the GRE. In recent years we have received ~140-180 applicants per year, with around half of applicants self-identifying as woman and ~15% as URM students. Women and URM applicants receive offers of admissions at the same rate (11%) as the general population of applicants, and accept those offers at our average acceptance rate (40%). We make use of numerous partner organizations to broaden our recruitment; for example, we have recruited students with support from the Graduate Student Equity & Excellence program, using their Graduate Excellence Award recruitment funding.
- Addressing harassment in field situations: In 2017, our department co-led a UW-wide committee to produce recommendations to prevent harassment in fieldwork situations. The resulting report includes a number of fieldwork-oriented trainings and learning activities, which we use, as well as common guidelines and standards for recognizing and reporting problems. We have also established and publicized on the department website clear pathways for reporting concerns.
- Learning experiences: We hold regular diversity learning experiences during the weekly department colloquium, which all ESS community members attend. In 2020, we established a policy that at least 1/3 of our department colloquia are by scholars from underrepresented groups; speakers receive honoraria and participate in mentoring events.
- Graduate-student pay equity: We have made adjustments to our graduate student pay scales to keep pace with other units in the College. A problem we have identified, but not yet solved, is that the amount of funding available in different areas of Earth sciences varies greatly; and while all graduate students are typically paid 50% time during the academic year, in summer some are paid at 100% in whereas others are paid at 50% or less. One possible solution to this is to raise the salary rates for all students, and implement a uniform standard where all students are paid the same number of months per year. This would need to be accompanied by a commitment by more faculty to seek research funding that includes summer.

Key policies and practices related to faculty including the following:

- Faculty recruitment. Faculty searches are conducted in such a way as to maximize the diversity of the applicant pool, and to minimize bias in the selection of applicants for interviews. We have tried to keep our disciplinary criteria relatively broad in scope to attract a larger applicant pool, and we advertise both through traditional venues and through social media and listserves, including those that are likely to be seen by potential faculty from underrepresented groups. Most importantly we use a rubric that uses evidence-based practices for reducing bias in faculty recruitment and hiring. Faculty search committees include a graduate student representative, and all members of the search committees are provided with anti-bias training. We have also worked to leverage incentive funding from the UW Office of the Associate Vice Provost for Faculty Advancement and the Vice Provost for Research. We have been successful in only one of these requests, reflecting the very limited funding made available by the University and the fact that the incentives for faculty recruitment have been done on a "first-come, first-served" basis. Nevertheless, this funding was probably key in our attracting one of our new faculty members this year. We were also able to take advantage this year of the College of the Environment Dean's office offer for bridge funding, which enabled us to hire an additional faculty member from an underrepresented group.

- Faculty retention. ESS has had very low salaries compared with its peer institutions, as well as compared with peer Earth sciences departments in the College of the Environment: Oceanography and Atmospheric Sciences. We have been aggressive in negotiating faculty retention offers with the Dean's office, both for pre-emptive retentions and for competitive retentions. Additionally, the pay for incoming assistant professor salaries is now competitive (Fig. 6). There are no significant differences for either faculty of color or women, relative to men, for faculty at comparable stages of their career.
- Mentoring: Assistant professors meet annually with the Chair to discuss progress. Faculty are also encouraged to take advantage of the various university-level opportunities for training and mentorship, such as the Center for Teaching and Learning or UW ADVANCE program. However, mentoring within the department has been done historically on an *ad hoc* basis. Beginning this year, all new and recently hired faculty will be assigned faculty mentors who will be expected to provide independent guidance and assistance through the year in which materials are submitted for promotion. This plan borrows from the successful program that has been used in Atmospheric Sciences.

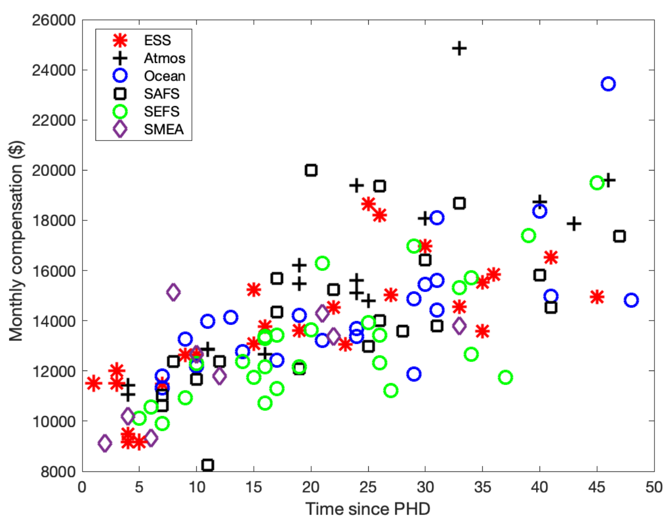

Figure 6. Tenure-track faculty salaries in the College of the Environment *vs*. time since PHD, as of December, 2021 (and including new faculty who begin in Fall 2023). (Some recent hires from departments other than ESS may be missing.)

1.3.2 Demographics

Our student demographics with respect to race and gender reflect the demographics of Earth and Space Sciences nationally. Here, we use the University of Washington's definition of "URM", which excludes all students of Asian descent other than those who are Native Hawaiian or Pacific Islander and also excludes international students. Women represent roughly 40% of the undergraduate majors (Fig. 7). We have seen a small steady increase in URM undergraduates. Recruitment and retention of women to the graduate program has steadily increased, and women now make up 50% or more of the graduate-student population (Fig. 6). The fraction of underrepresented minority URM students at the graduate level, however, remains small. MESSAGe has expanded access to the ESS graduate programs, broadening diversity in ways not represented by these graphs, including for veterans and first-generation college graduates.

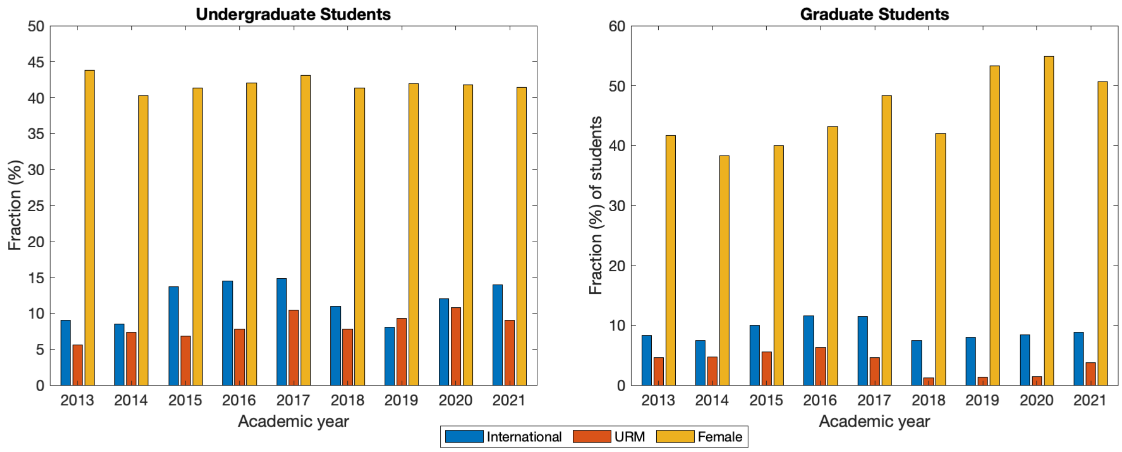

Figure 7. Proportions of international, URM, and female students among ESS undergraduate B.S. and B.A. students, and among graduate students (including MESSAGe).

At the faculty level, concrete changes to the rubrics used for faculty hiring have produced meaningful results: our most recent hiring efforts have led to the most diverse set of faculty hires in our history. As of 2019, there were only 3 women out of 20 tenure track faculty, and two persons of color; as of next year (including recent hires who will begin in Fall 2023), 7 out of 20 tenure-track faculty are women, and 4 are persons of color (2 are URM by the UW definition). Of the core department staff of 11, 5 identify as men, 5 as women, three as LGBQT+, one as non-binary, and five as people of color. We do not include research staff in individual faculty labs as part of these statistics.

Section II: Teaching and Learning

2.1 Student Learning Goals and Outcomes

2.1.1 Undergraduate degrees

ESS seeks to provide a rigorous interdisciplinary program in which student develop understanding of the fundamentals of Earth, space, and planetary science, and learn relevant skills for a variety of potential careers. Our goal is that students will acquire the skills and knowledge to be competitive for advanced degrees in science or for job placement in earth-sciences-related technical fields; that they will have the breadth and depth of knowledge of Earth processes to be able to use that knowledge as responsible citizens, who can help to address complex environmental and resources issues faced by society; and that they will have skills that transfer effectively to other areas.

Key learning goals for all our undergraduate degrees include:

- The ability to use quantitative approaches to critically evaluate scientific questions, particularly as they relate to the environment, resources, and geologic hazards, as well fundamental aspects of how the Earth system works, and how the Earth is affected by processes in the solar system.
- Competence in writing and oral presentations, to be able communicate effectively with audiences at all levels from the general public, to scientific peers, potential employers, and government agencies.
- Competence in key tools of the discipline, including basic to advanced scientific computing, laboratory techniques, and field methods.

- Experience in working in both in groups and individually in challenging settings such as the field or laboratory, and the ability to identify and solve problems as they arise.
- To have knowledge and skills in one or more specific Earth and space science-related field, that will allow them able further their education in graduate programs, if desired.

To achieve these goals, for the B.S. degrees, coursework and other experiences include:

- Core sciences including mathematics, chemistry and physics.
- General knowledge of broad areas of Earth science including solid earth geology, geophysics, geobiology, surface processes, environmental Earth science and climate, and the solar system.
- Deeper disciplinary knowledge in key areas, depending on the primary interests of the students, through completion of requirements in one of options: Geology, (geo- and paleo-)biology, (geo- and space-) physics, or geosciences. (Option areas are summarized in Appendix E.)
- Quantitative analysis of natural systems including interpretation and prediction of their behavior
- Communication skills, including the ability to read, understand, and use scientific literature.

The specific requirements of the Geology track ensures that students fulfill prerequisites for the Washington State Geologist Licensing Exam, which is required for work as a professional geologist in Washington (and similar to requirements in many other states). Maintaining our teaching and research expertise to be able to provide students with the course offerings that they need to be successful for this exam is a fundamental obligation for us as the flagship public university in Washington.

For the B.A. degree, quantitative requirements are reduced in favor of more flexibility in learning skills that may help the students pursue careers such as teaching, science journalism, and environmental law or policy. Such requirements are still intended to be sufficient to be foster the ability to think critically about scientific problems, and to be able to communicate, read, and use scientific literature at a highly competent level.

An important aspect of all B.S. and B.A. programs in ESS is that the students are immersed in hands-on experiential learning. Even students in non-science major classes participate in laboratory sessions and/or field trips. On any given weekend, the department will typically have more than 100 students in the field somewhere in Washington, with many hundreds more each week participating in laboratory sessions. In addition, the faculty provide at least 20 undergraduate research opportunities each year through the ESS Honors program, and many additional paid and informal research opportunities with faculty and graduate students. This full immersion in field and laboratory work is a significant undertaking by the department, but one which we value highly. Our effort to ensure experiential learning for all students is a significant factor in the successful recruitment of students to the department, and in the success of the students at the next stages of their careers.

2.1.2 Graduate degrees

The Masters in ESS – Applied Geosciences (MESSAGe) program is designed to educate students to become working professionals in Engineering and Environmental Geology. Key learning goals include proficiency in knowledge and skills that relate specifically to the work of a professional, practicing geologist. Completion of the MESSAGe program involves five required core courses, one or two additional electives, two year-long seminars and a 6 to 9-month capstone project. Core courses include Engineering Geology, Hillslope Geomorphology, Fluvial Geomorphology, Hydrogeology, and a course addressing GIS Remote Sensing or Geospatial Analysis. Students may choose electives from any 400- or 500-level course offerings in the College of the Environment or the Department of Civil & Environmental Engineering. MESSAGe seminars cover topics such as professional practice, writing technical reports, and career guidance. Students finish their degree with a capstone investigation defined in conjunction with an external stakeholder organization and advised by MESSAGe faculty. The investigation engages students in planning, data collection, analysis, and writing, and culminates in a technical report and an oral presentation open to the public.

MESSAGe has a track record of job placement for graduates of greater than 95%. Despite this clear track record of success, the program faces significant structural challenges going forward including both staffing and budget, and is not currently enrolling students.

The Research M.S. and Ph.D programs are for those students seeking professional employment and leadership roles in the Earth sciences in academia, government agencies, data science, or the private sector. Most students join the department with the intention of completing a Ph.D.

Admission as a graduate student in Earth and Space Sciences is competitive. We typically have 140-180 applicants, and accept an average of 15 new students each year. While graduate students arrive with diverse backgrounds spanning science and engineering disciplines, it is generally expected that students will have at least one year of calculus with analytical geometry, at least two quarters of calculus-based physics, and at least two quarters of general chemistry. Applicants who are admitted are guaranteed support in a combination of research assistantships (RAs) or teaching assistantships (TAs) during the nine-month academic year for five calendar years, assuming satisfactory progress. On average, students are funded with RAs about 75% of the time, though some students TA extensively. Summer funding is not guaranteed.

Students in the PhD Program are required to complete a minimum of 90 credits (a Masters degree from UW or another institution may substitute for 30 credits), including “Introduction to Research” in the first year and at least one course in data analysis. Ph.D. students must also TA at least one quarter and demonstrate experiential research in the field or laboratory. They must complete at least 18 credits of UW course work at the 500 level and above, with at least 18 numerically graded UW credits of approved 400 and 500 level courses. A minimum cumulative GPA (grade point average) of 3.00 is required. A minimum of 27 dissertation credits over a period of at least three quarters must be completed.

Learning goals for the research graduate program include:

- Disciplinary knowledge in Earth and space science: understand the current state of knowledge in their chosen field, as well as a broader understanding of ancillary fields.
- Ability to recognize outstanding scientific questions in their chosen field, and the ability to develop well-defined and tractable research approaches that can address those questions.
- Ability to locate, process, and interpret existing sources of information from the scientific literature, archived data sets, etc.
- Ability to use established methodologies and techniques common to the field, and ability to develop novel approaches that have the potential to lead to scientific advances.
- Ability to anticipate how the field will develop in the future, and to continually keep up with developing technical and theoretical developments.
- Ability to express their ideas in written reports and oral presentations to both specialists and to non-specialist audiences and defend these ideas under critical examination.

In addition to the above learning objectives, Ph.D. students are expected to develop original, independent research and to demonstrate thorough proficiency through field work, laboratory experiments, computational methods and/or data analysis. Students need to be able to collect, store, manipulate, analyze, and display data/information/theories for the purpose of problem solving and decision making in a research environment. Students must also be able to apply new theory, use and interpret existing theory, and use the existing literature to support their research and demonstrate its originality and relevance.

To achieve these learning goals, coursework and other experiences include:

- Advanced courses in the chosen discipline, as well as courses chosen to broaden knowledge beyond the chosen discipline.

- Experience giving presentations and lecture to other students, to faculty committees, at professional meetings and conferences.
- Writing papers intended for publication, usually in close collaboration with their advisor and/or other students and faculty. Publication of papers in the peer-reviewed literature in the course earning the graduate degree is not a strict requirement, but is generally expected that student will have completed thesis chapters that are suitable for publication with 1 paper typical for the research M.S., and 3 to 4 for the Ph.D.

Students in the research program are evaluated primarily through graduate examinations. The Preliminary Exam ("Prelim") is taken at the beginning of the second year and includes presentation of an original research problem (usually, their proposed graduate research). The General Exam, taken in the third year, should present detailed plans and show progress towards the Ph.D. The Final Exam (dissertation defense) is a presentation of the dissertation research. All three exams follow the same format: a written proposal, public presentation, and closed-door session with a faculty committee. The Prelim committees exclude the faculty advisor and include a graduate student observer. The General and Final exams include a Graduate School Representative, a UW faculty member outside the department and the student's research committee.

2.1.3 Non-Science Majors

The overall learning objective for our non-science-majors classes is literacy on issues related to the Earth and its environments, including its history, geological processes and hazards, surface process, and the solar system. The intent is that students taking our classes will gain sufficient background to become informed about processes that affect them, to be able to make knowledgeable decisions, educate others, and be good stewards of the planet. Our courses are also intended to inspire. The department provides a suite of these courses at primarily the 100 and 200 level. ESS 101 (Introduction to Geology and Societal Impacts) is offered during all four quarters each year, enrolls nearly 2000 students annually, and is among the most popular class at UW. ESS 102 (Space and Space Travel) engages 200-300 students each quarter of the academic year. Both of these courses emphasize hands-on learning, with weekly laboratories and (for ESS 101) required field trips. ESS reaches many hundreds of other students annually through courses such as Dinosaurs, Prehistoric Life, Natural Hazards and Disasters, and Living with Volcanoes.

2.2 Evaluation of Student Learning and Instructional Effectiveness

Student learning in large undergraduate courses is evaluated through regular problem sets, laboratory assignments, and exams. For our core classes for majors, there are frequent hands-on learning experiences in the classroom, involving group learning, peer-evaluation exercises, and laboratory and field reports, in addition to problem sets and exams. The majority of our undergraduate majors engage in a capstone experience, historically our ESS400/401 field course, which involves extensive mentoring in small groups. With rare exceptions, all of our classes are taught by tenure-track faculty or teaching faculty – i.e., we do not rely on temporary lecturers or graduate students for teaching. For large undergraduate classes and core majors classes with laboratory components or high enrollments, we make use of graduate teaching assistants, but responsibility for classes is always primarily that of the faculty.

All faculty are required to solicit feedback from students at the end of each quarter, in the form of written or online questionaries provided by the UW Office of Educational Assessment. Faculty are encouraged to add their own questions to solicit course-specific feedback. Faculty also have the option to use mid-quarter evaluations, though this is not required.

All faculty are evaluated by their peers, who visit their classroom to observe their teaching and to talk directly with students without the instructor present. Assistant professors are expected to obtain peer teaching evaluations at least once every year, associate and full professors every three years. This provides both a means of evaluation and a means for faculty to obtain advice and guidance from their colleagues. Peer teaching evaluations, as well as numerical feedback from the student-written evaluations, are used in the evaluation of faculty for re-appointment, promotion, and tenure.

Because TAs are an important component of our instructional staff, especially for large-enrollment non-majors courses, all TAs must enroll in the course, ESS 492, Education in Earth Sciences, which is taught by our Full Teaching Professor Terry Swanson, who teaches our ESS 101 and other large undergraduate classes. This course provides expert instruction on teaching methods in the laboratory, classroom, and field. TAs are also required to attend the Center for Teaching and Learning (CTL) workshops during graduate orientation and encouraged to attend the annual College of Environment TA seminar during a quarter they are teaching. The workshop uses interactive learning to prepare TAs with hands-on, evidence-based techniques for writing and grading assignments, leading discussions, and creating engaging and inclusive classrooms.

We note that ESS Teaching Professor Terry Swanson has won multiple teaching awards, including the highest-honor bestowed by the University of Washington for teaching: the UW Distinguished Teaching Award (2007). Several other faculty have also won the College of the Environment teaching awards, and the department rewards excellence in teaching through its own annual teaching award; recipients of the department awards must be supported by nominations from students.

Our faculty are encouraged to keep up to date on recommended practices for effective teaching, and many attend workshops run CTL or the College of the Environment Teaching support team. Our faculty both lead and take advantage of cross-College teaching programs and provide updates to their colleagues on what they have learned.

Student feedback is important at the program level. All undergraduate majors meet at least once a year with our senior advising staff, who solicit feedback from the students and communicate that feedback to faculty (anonymously, unless the student wishes otherwise). Both graduate and undergraduate students are asked to participate in exit surveys upon graduation. Students are asked how well the program has prepared them for their chosen career paths, and whether there are any academic gaps or other impediments for students to reach their goals. In addition, the Chair regularly meets with elected student representatives. A specific example of how student feedback has influenced our program, is as follows:

A capstone field course is required for most of the ESS major tacks. We have modified this capstone experience several times, and currently, it is undergoing major re-design. The feedback that has led to these changes has come from course evaluations, conversations with graduate teaching assistants, undergraduate exit interviews, undergraduate participants in departmental committees (curriculum, diversity), and observations by instructors and our advising staff regarding student needs. The main capstone class was ESS 400, a traditional 6-week, residential geology field camp, based in Dillon MT. In the 2010s, due to enrollment pressures, ESS 401 was introduced (3-weeks field work in MT, 3-weeks GIS work in Seattle). During summer 2020 and 2021, pandemic restrictions required in wholly- or mostly on-line instruction. This break in tradition, as well as a change in staffing and financial pressures imposed on us (see Section I), motivated a further reevaluation and redesign.

What we have heard from students is that, while traditional field camp is a transformative experience, the time and the financial burden of a residential course is significant. Even though ESS has offered generous scholarships for tuition and fees, the ancillary cost of maintaining housing in Seattle and deferring employment for the duration of the class is significant. For some, the physical demands of field work were also a deterrent. For others, family obligations made it impossible.

We are now piloting two options to provide accessible and inclusive capstone experiences for our students:

- A new, Seattle-based capstone field course: In Summer 2022 we designed a six-week trip that included day trips and an expanded focus that included surficial geology, geologic hazards, and borehole and geophysical data along with bedrock geology. We envision continued evolution of this course that may eventually include options for short overnight trips. If the Summer Programs funding model remains prohibitive, we may design a course that can run in Autumn Quarter.

- A capstone series that can be completed during the academic year: The series includes a foundation course, an applications course, and a seminar focused on career preparation. For 2022-23, we are piloting two series: one in Engineering Geology, another in Environmental Geochemistry.

2.3 Teaching and Mentoring Outside the Classroom

Our faculty provide rich learning experiences outside the classroom, particularly in the lab and the field. Nearly all of our faculty employee undergrads in their labs or in their fieldwork, and there is a standing policy that the department will provide matching support for any such employment that also involves a mentored research project or other concrete academic learning experiences. Last year, our Diversity committee launched a new faculty-and-student panel event to provide information about how to connect with faculty for such learning and employment opportunities, and this will continue as an annual event. Additionally, the department's academic advising team participates in campus recruitment events both on and off campus and provides information about opportunities within ESS. At any given time, between 20 and 50 undergrads are participating in experiences of this nature.

ESS sponsors many extra-curricular activities that support learning and community engagement. Undergraduates are encouraged to join the Geoclub, which organizes additional geological and social activities with support of a dedicated Geoclub faculty advisor. Joint student/faculty activities led by GeoClub include an annual spring break field trip (commonly to Hawaii or the desert Southwest). The department hosts the ESS Research Gala each April, a three-day, student-run symposium with talks, posters by graduate and undergraduate students and awards for best presentations. The student-run outreach program Rock'in Out connects UW students to elementary and middle school classrooms and community events to present demonstrations on Earth, space, and planetary science topics.

One example of successful research mentoring outside the classroom is the "OGIVE" (Opportunities in Glacier InVEstigation) undergraduate program, run by members of the glaciology group and led by Research Assistant Professor TJ Fudge. (The name "ogive" refers to the light and dark bands of ice visible on some valley glaciers.) Six to eight students are paired with a faculty member and a graduate student or postdoc to work on individual research projects. OGIVE creates a community of undergraduate researchers during the summer, with two field outings. The OGIVE participants range from first year students with no research experience to rising seniors who have submitted scientific papers, allowing for peer mentoring opportunities. In addition to the goal of exceptional undergraduate research, OGIVE has the goal of training of graduate students and postdocs in devising research projects and mentoring students. Most of the undergraduate participants continue their research during the autumn quarter. The students are often part of partner programs, such as Washington Space Grant, CICOES (Cooperative Institute for Climate, Ocean, and Ecosystem Studies), or LSAMP (Louis Stokes Alliance for Minority Participation) and are paid a stipend of $5500 for the 9 week summer program, provided by a generous private donation. The OGIVE program is currently in its second year and expected to continue well into the future.

We help all students with career planning. We work with the College of the Environment, which hosts an annual career fair in Winter quarter, and offer career advising sessions through GeoClub. Our strong connections with private employers, particularly in Washington State through MESSAGe, provide many opportunities for mentoring and employment. For research graduate students, we rely on a combination of faculty mentorship and staff advising to help students navigate career alternatives after graduate school. Our track record in academia is particularly good: according to the 2018 American Geoscience Institute Report, "Status of the Geoscience Workforce", ESS ranks among the top 5 degree-granting institutions of U.S. for geoscience tenure-track and tenured faculty members,

Section III: Scholarly Impact

3.1 Overview of scholarly impact

3.1.1 Faculty

The Department of Earth and Space Science is a highlight ranked department in geology, geophysics, and related fields. According to the Shanghai Ranking's Global Ranking of Academic Subjects 2022, it ranks #9 in the US, and #13 in the world among geoscience departments. It is ranked #6 in the US according to the US News and World Report.

Our faculty publish successfully and are highly cited. For example, eight of our faculty have over 5000 citations, six have more than 7000; eleven have an H index of 30 or greater, and four have H indices over 50. A list of citation statistics for all current tenure-track and research faculty, by rank, is given in Appendix E.

The impact of our faculty is recognized by national and international awards, a partial list of which includes five elected Fellows of the Geological Society of America (GSA), and one each in the American Association for the Advancement of Science, the American Geophysical Union (AGU) and the Mineralogical Society of America (MSA). Early and mid-career faculty awards include the 2016 AGU Luna Leopold Award, 2012 GSA Donath Medal, and 2013 MSA award. Other major awards include a 2008 MacArthur "Genius" Fellow, 2006 GSA Kirk Bryan, 2016 Burwell, the 2021 AGU Bowen and the 2003 and 2014 James Shea Award from the National Association of Geoscience Teachers.

We have also been honored for our teaching and mentoring: Teaching Professor Terry Swanson has been recognized by at least three prominent teaching awards, including the University of Washington's, the Distinguished Teaching Award in 2007. Many of our faculty have been recognized by the College of the Environment for their excellence in teaching and research: David Montgomery, 2012; Roger Buick, 2013; Eric Steig, 2014; Juliet Crider, 2015; and David Catling, 2018. Fang-Zhen Teng (2013) and Gerard Roe (2019) have both received the College's award for Exceptional Mentoring of Undergraduates.

These lists include only our currently-active faculty, and do not include the numerous awards received by our emeritus faculty and affiliates, many of whom also remain active in the department; a near-complete list of all department awards and honors is available on our web site.

Below, we discuss key areas in which our scholarly impact is particularly noteworthy, and distinguished from other academic geoscience programs. We organize the discussion using six broad categories that reflect the subject areas we study. We highlight advances in the field, our responses to changing funding patterns, and contributions to new technologies. Much of this research is interdisciplinary and we work extensively with other programs at the University of Washington: Atmospheric Sciences, Oceanography, Biology, the Astrobiology Program, the Program on Climate Change, the Quaternary Research Center, the eSciences Institute, the School of Civil Engineering, the Applied Physics Lab, the School of Environmental and Forest Sciences, and the School of Aquatic and Fisheries Sciences are all key partners.

Subduction-zone processes: The department has long conducted research on subduction zone tectonic processes spanning and merging geophysical and geological approaches, and this focus has rapidly grown in recent years with a specific emphasis on tectonic geohazards. At least 8 of the academic faculty, as well as many other research faculty and affiliates, are engaged in subduction zone science,

- ESS's Pacific Northwest Seismological Network (PNSN) is the authoritative seismological facility for the region, and has been a leader in developing and implementing earthquake early warning for the entire west coast. PNSN has direct State of Washington support, leveraged 10-fold USGS and other federal funding. Harold Tobin took over PNSN directorship in 2018.
- We have attracted continuous NSF funding for major projects related to earthquake hazards over the last decade. Many of these projects are done in collaboration with USGS scientists who are housed in our department, many with departmental affiliate status. These include the *M9 Project*, funded by NSF under the Hazards SEES program, the *SZ4D Research Coordination Network*, a major

community effort led by Tobin to launch a new decadal NSF program in subduction zone science, and two awards from the NSF Coasts and People Hazards program, including *Cascadia Coastline Hazards Research Hub*, a new large center ($18M awarded to multiple institutions, 5 yr) focused on integrative and transdisciplinary research centered on the PNW. Alison Duvall and Harold Tobin are coPIs on this effort. Schmidt co-leads a major new NSF-supported effort to expand seafloor geodesy in Cascadia and Alaska; the nascent offshore geodetic network will be foundational to efforts to understand subduction zone processes on the shallow megathrust. Crider also works with the National Earthquake Hazard Reduction Program (NEHRP) to conduct geomorphological field research to identify evidence of past earthquakes that may not be detected from geophysical data. Alison Duvall was the first US scientist "on the scene" after the 2016 Kaikoura (NZ) earthquake, and leads an NSF project there. Duvall's combined work on surface processes and earthquake geophysics was honored with the Luna Leopold early-career award in 2016 from the AGU. Marine Denolle arrived in 2020 with an NSF CAREER award dedicated to study the dynamics processes of shallow subduction-zone earthquakes.

- ESS is engaged in study of the rock record to investigate the relationship between geochemical processes and geophysical processes at subduction zones in the field and laboratory, including the role of metamorphosed sediment in subduction fault strength, the evolution and controls of subduction thermal structure, and the rates of these processes. Cailey Condit, who arrived only in 2020, has already received two NSF grants to support this innovative work, with two more pending. Condit co-led the 2022 GeoPRISMS Synthesis Workshop which seeks to further integrated approaches. George Bergantz has done pioneering work on the transport of magma in the Earth's deep crust and mantle, as well as the life cycles of volcanic systems, for which he was recognized last year with the AGU Bowen medal.
- Finally, we recently launched two new initiatives. The UW *Photonic Sensing Facility*, with funding from the M.J. Murdock Charitable Trust, is led by two of our newest faculty, Brad Lipovsky and Marine Denolle. The facility is doing pioneering work using distributed acoustic sensing with optical fibers to monitor and explore surface motion, temperature, and other properties in diverse systems, with applications not only in the study of crustal deformation, but also hydrology, land surface processes, and glaciology. The newest development, the *Geohazards Initiative*, created with significant support from private donor Jerry Paros, will develop novel instrumentation for seafloor and terrestrial discovery of hazard processes from earthquakes, volcanoes, and landslides.

<u>Cryosphere and climate:</u> The "glaciology group" is widely recognized as one of the leading glaciology programs in the world, having produced dozens of PHD students that have gone on to faculty positions at top universities. While centered in ESS, glaciology at UW involves researchers from several other departments, including Applied Physic Lab, which is research center at UW that includes Ian Joughin, Ben Smith, and Dale Winebrenner, all of whom advise ESS graduate students. David Shean, a graduate of our program now in UW's Civil Engineering department also continues to work closely with ESS glaciology. Joughin's work on the remote-sensing of glacier motion using satellite synthetic aperture radar is particularly prominent; he was awarded the top Agassiz from EGU for this work in 2015. Other examples of prominent impact include:

- Ice-core programs in Greenland and Antarctica. We have led or co-led every major multi-institution ice-core project, in the last 30 years. TJ Fudge and Eric Steig co-led the recent drilling and analysis of a 1500-m ice core from the South Pole, and now lead the Hercules Dome project. Fudge is the current Chair of the Ice Core Working group for NSF Polar Programs; Steig is a member of the external advisory board. Steig's work using ice cores to assess climate variability in Antarctica, as well as his pioneering work on the communication of climate science, was cited in his election to the American Association for the Advancement of Science.
- Development and deployment of geophysical instruments for imaging the interior structures of ice sheets and glaciers. Knut Christianson leads radar-imaging programs in multiple projects in

Greenland, Antarctica, and alpine regions. This work is also an integral part of the ice more program, providing critical information on the selection of the best site for drilling. Koutnik, Fudge and Winebrenner lead the $5 UW portion of a $25M Science and Technology Center (STC) grant, Center for Oldest Ice Exploration (COLDEX), which will obtain paleoclimate records from Antarctica extending to 5 million years. Christianson plays a leading role in the international Thwaites Glacier collaboration, the flagship glaciology program for both the UK and the USA, and has deploy autonomous submarines to beneath the fringing ice shelves of Antarctica, important for understanding the processes causing the ice sheets to lose mass and contribute to sea level rise, with funding from the Paul G. Allen Foundation.

- Gerard Roe has done groundbreaking work in developing our understanding of Earth's climate sensitivity, as well as the sensitivity of glaciers to climate. The practical implications of Roe's work are notable: his demonstration that glacier retreat in Peru is unequivocally due to human influence is part of the evidence in a prominent climate lawsuit, the first of its kind, pitting a Peruvian farmer against a German energy utility over its role in contributing to global warming. Of the 21 graduate students Roe has advised, all are working as professional scientists; 12 have tenure track positions.

<u>Planetary and space sciences</u>: ESS has a long history of research in the near-space environment of Earth's upper atmosphere, currently led by research professor Mike McCarthy and emeritus professor Robert Holzworth, who leads the international Worldwide Lightning Location Network comprising an array of sensor in more than 40 countries. ESS also has a growing prominence in planetary sciences. The planetary sciences group, *sensu strictu* had only one tenure-track faculty member (David Catling) until the very recent (September 2022) hiring of Joshua Krissansen-Totton. Nevertheless, planetary sciences in ESS has secured the greatest per-capita funding and graduate student numbers, reflecting both the excellence of the faculty and the significant resources available, particularly through NASA. There is important involvement from soft-money-supported researchers, particularly Baptiste Journaux who works on high-pressure systems, including the structure and behavior of ice on other planets and moons. Faculty in the surface processes and cryosphere groups have done work on the Martian landscape and glaciers. Some highlights include:

- Direct involvement and leadership on planetary exploration missions: David Catling was a Science Team member on NASA's Mars Phoenix Lander Mission. Phoenix was the first spacecraft ever to land in the ice-rich high latitudes of Mars. Major discoveries included the first *in situ* identification of water ice on Mars, and the first direct measurements of the vertical structure of the Martian polar atmosphere. Catling is now a member of the Mars Perseverance Rover team (as are research faculty member Ron Sletten and emeritus professor Bernard Hallet.) Catling served on the 2017 New Frontiers Program science review panel, where he was one of two presenting reviewers for NASA's $1B Dragonfly mission to Titan, which ultimately was selected to fly in 2027. Baptiste Journaux is on the Dragonfly science team, working on planning methods and instrumentation for determining signatures of the interior structure and habitability of Titan.
- Pioneering theoretical and experimental research on the chemistry of planetary atmospheres and surfaces, and the potential for the detection of life. Catling also pioneered simulations of evaporite salt sequences on Mars which were then applied to real salts discovered in Martian meteorites. Since this time, the discovery of salts from possible dried-up water has been a key success of NASA's and ESA's Mars missions. Joshua Krissansen-Totton, then a student working with Catling and with Roger Buick, showed that atmospheric chemical disequilibrium could be used to detect extraterrestrial biospheres on exoplanets, and that this should be possible with NASA's James Webb Space Telescope. It is not at all unlikely that ESS scientists will be among the first to detect signs of life outside our solar system.

ESS is also part of the internationally recognized UW Astrobiology program, in which graduate students obtain dual degrees in ESS and Astrobiology, with 2 core faculty (Buick and Catling), 2 affiliate faculty (Gorman-Lewis and Teng) and 10 current graduate students.

Earth Surface Dynamics. Our ability to quantify processes and make theoretical advances specific to the near-surface environment is growing at an incredible pace through technology-enabled discovery, allowing us to reconstruct Earth's past, present, and future landscapes in increasing detail. The study of Earth surface dynamics is an integrative field, enabling collaborations with those who study volcanoes and earthquakes, soil processes, and geobiology. Additionally, there are strong applied-science aspects, ranging from the assessment of geologic hazards to the understanding of processes affecting fisheries, forestry and water resources. UW's prominence in this area is particularly strong. Examples include:

- David Montgomery influential papers on salmon and rivers, soil processes, agriculture and Quaternary geomorphology have been recognized with numerous awards, including the McArthur "Genius" award. His popular-science books have won the Washington State book award three times. Montgomery's two textbooks (*Key Concepts in Geomorphology* and *Environmental Science and Sustainability*) are used in undergraduate curriculum nationwide.
- Juliet Crider, as Director of the applied Master's (MESSAGe) program, with Teaching Professor Kathy Troost, has advised more than 100 M.S. students in applied geosciences, virtually all of whom who have gone on to successful careers in applied geosciences.
- Alison Duvall won the top AGU early-career prize for geomorphology, the Luna Leopold award, for contributions that have "fundamentally advanced understanding of landscapes across a range of scales—from the width of bedrock channels, to the uplift of Tibet, quantitative analysis of landforms across strike-slip faults, and landslides in the Pacific Northwest.
- John Stone's work on cosmogenic isotope production rates, and the development and application cosmogenic isotope measurements to the study of the Antarctic landscape and ice sheet evolution is considered pioneering in both geochemistry and glaciology.
- Katharine Huntington was appointed an GSA Fellow and awarded the Donath medal – the most prestigious early-career prize from GSA – for her work on tectonic processes and climate and her early contributions to the field of clumped-isotope geochemistry.

Earth and Life Through Time. ESS began to invest in what was then seen as the novel field of "geobiology" in the early 2000s, but retirements and loss of early career faculty have meant the area is now represented by just two faculty in ESS: geomicrobiologist Drew-Gorman-Lewis, and astrobiologist Roger Buick. ESS also has significant collaborations with paleontology faculty in Biology: Peter Ward (who has a ⅓ appointment in ESS), Caroline Strömberg, Christian Sidor and Greg Wilson (all of whom have adjunct appointments in ESS). Geobiology is fundamentally linked with stratigraphy (the temporal history of rock formation) and sedimentology (which connects modern surface processes to deep time and hence to tectonics, landscape evolution, and the evolution of life). This year, ESS hired two additional faculty members to deepen our expertise in these areas: Marjorie Cantine is a sedimentologist and isotope geochemist with a recent focus on sedimentary geochronology, and Akshay Mehra studies the quantitative physical attributes of sedimentary formations and the record of ancient life they contain. Highlights from the current faculty include:

- Gorman-Lewis's work focuses on understanding the chemistry of water-rock-microbe interactions. He combines interdisciplinary techniques from microbiology and low temperature aqueous geochemistry. By modeling these systems with chemical thermodynamics, his work quantitatively describes these Earth-life interactions and provides predictive power to understand these interactions through time and beyond our own planet: the essence of "geobiology".
- Roger Buick works on the early evolution of life at the intersection of geology, biology and chemistry, examining the oldest and best-preserved rocks available. He is particularly well known for his research in the use of geochemical methods to elucidate the origins of metabolisms and the mutual interactions of life and environments through time. Of particular note are his contributions to the evolution of the biological nitrogen cycle, and work that has significantly revised our understanding of the advent of oxygenic photosynthesis and origin of eukaryotes. Buick was elected a

GSA fellow in 2019, and his work has been honored with a best paper award from the Geochemical Society in 2018; two of his papers with his graduate students were awarded the "highly cited" distinction by Web of Science in 2021.
- Paleontologist Peter Ward is the world's leading authority on nautilus, and is a prominent popularizer of science: his books have won the 1992 best popular science book of the year award from the Paleontological Society and he won the Washington State Book Award in 2005.

Geochemistry. Many of the faculty in ESS use geochemistry in their work, and are especially well known for research in isotope geochemistry:
- Fang-Zhen Teng has done pioneering work on the development and application of techniques to measure "non-traditional" isotope systems, including lithium and magnesium. This work earned him the recognition of the Mineralogical Society of America award and Fellowship in 2008.
- John Stone's cosmogenic isotope lab is internationally known for its high precision and accuracy, and for highly-cited publications on *in situ* production rates in rocks, the recognition of the importance of muons as an additional source of production at depth, and the influence of air pressure changes.
- "IsoLab", a stable-isotope analytical laboratory, which Eric Steig and Roger Buick jointly launched in 2001, is a flagship institution within the College of the Environment, celebrated for its support for faculty and student research and its instrumental role in the recruitment and retention of faculty, including Becky Alexander (Atmospheric Sciences), Kate Huntington (ESS), and Gordon Holtgrieve (School of Aquatic and Fishery Sciences). Prominent IsoLab innovations include leading the development of clumped isotope carbonate research launching the international clumped isotope workshop, now in its 12th year, advancing laser spectroscopy techniques, and the measurement of ultra-low concentrations of organic nitrogen isotopes and reactive nitrogen and sulfur compounds in the atmosphere. Faculty in all College of the Environment units have relied on IsoLab in their research, as have faculty in several Engineering and Arts and Sciences departments. IsoLab has supported researchers from 23 U.S. states and 13 countries. IsoLab has been involved in at least 70 PHD theses and numerous research opportunities for undergraduates.

3.1.2 Undergraduate Students, Graduate Students, and Postdocs

Our program provides exceptional training for our students, discussed at greater length under our Teaching and Learning section. According to the 2018 report of the American Geosciences Institute, *Status of the Geoscience Workforce,* our undergraduates have received more NSF graduate fellowships (at least 13 since 2011) than those from any other earth science department, and we rank in the top 5 producers tenure-track faculty.

Our graduate students have won the Dean's medalist awards in five of the last 10 years (2011, 2013, 2014, 2016, 2017), and the undergraduate Dean's award in three. Our undergraduates have won 37 Mary Gates Scholarships – a competitive UW program based on research merit – since 2011. Three of our undergraduates have been Husky 100 Recipients (in 2016, 2017, and 2020). The "Husky 100" is the top honor for graduating seniors and graduate students at UW, awarded to less than 0.3% of the student population in any given year.

Postdoc and student lead-authorship is common and strongly encouraged. We do not separately provide examples of student papers and research contributions: these are an integral part of faculty scholarly output, and reflected on the faculty CVs included in the Appendices.

3.2 Promotion and Tenure Policies and Practices

ESS faculty are expected to demonstrate excellence in research and teaching, and to contribute to service at the department and national level. ESS does not currently have a written tenure and promotion policy; this is a priority for the 2021-2022 academic year. The general expectation is that faculty will

- Conduct original research, obtain funding to support that research, advise and support graduate students, and publish their research in peer-reviewed journals. Number of publications is an important consideration but there is no definitive publication target; an average of ~2-3 papers per year is generally considered acceptable. Publications on which a candidate's advisee is the lead author are viewed as having equal value to first-authored papers. Undergraduate research mentorship is also encouraged and valued.

- Teach three classes each year at a variety levels, from introductory undergraduate through advanced graduate. Teaching must be valuable to students, as evidenced by written and numerical student feedback and faculty peer review.
- Contribute to the functioning of the department through service on committees, undergraduate-supporting activities, and the like. Research faculty are not expected to do teaching, but this can be counted towards additional service to the department.
- Contribute to the broader research community through service, such as participating on national committees in scientific societies or funding agencies.
- Demonstrate a national reputation (and at the promotion to Full professor, international reputation) for scholarly output, impact, and teaching.

Additionally, service in the form of outreach activities, public speaking, etc., is encouraged. Contributions to diversity, equity and inclusion are encouraged, but formal demonstration of such contributions is not required at the individual level; this is considered an institutional responsibility.

Faculty meet with the Chair at least once per year and the Chair should provide them with a written summary of the discussion, and plans for the coming year, including an agreement on teaching and service responsibilities and general expectations for research. Faculty are expected to obtain peer-teaching evaluations at least once per year (3 times/year is encouraged for assistant professors). The peer teaching evaluation provides the most important formal opportunity for faculty to provide guidance on teaching practices.

We consider ourselves a collegial and supportive department. Nevertheless, faculty mentorship in ESS has generally been done on an *ad hoc* basis and we recognize that this should change. As of 2022, we are beginning a formal mentoring program modeled after that in the Atmospheric Sciences department, in which all junior faculty will be assigned faculty mentors upon appointment. The mentoring committee will be asked to meet with their mentee at least once a year when they are assistant professors and the year before an associate professor intends to be considered for promotion to full. The committee acts as advisor as well as evaluator at the time of promotion; they write a report and present it to the rest of the faculty, with a recommendation to the department. Faculty are free to request a change in committee membership at any time.

Section IV: Future Directions

4.1 Regional to Global Impact

As described in detail in Part A of this report, our department ranks highly both nationally and internationally, reflecting both our scholarly output and out contributions to teaching and learning. Our alumni populate geologic consulting firms across the region and are on the faculty of geoscience departments across the nation and internationally. Our faculty in surface processes, tectonics, petrology, volcanology, and seismology, along with our Pacific Northwest Seismological Network, serve a critical role for the State of Washington, and the nation, in improving our understanding of geologic hazards and ways to mitigate them. Our cryosphere and climate program is similarly world-reaching, delivering both fundamental science and science in the service of society through improved understanding of climate change and sea level rise. Our applied science Masters program provides training for professionals whose work contributes to the Washington State economy, critical resource and infrastructure management. Our planetary and space sciences and geobiology programs contribute to fundamental understanding of the Earth, its evolution, and its future.

4.2 Department Goals

Our goal in research is to remain at the forefront of areas of historical strength – seismology, climate and glaciology, surface processes, and solid-earth processes – while building new capacity and excellence in the growing fields of planetary sciences, data and computational Earth sciences, and in the further integration of geophysical and geochemical observations to understand subduction zone processes including earthquakes and volcanoes and other geologic hazards. We aspire to maintain and to further diversify our funding streams, maintaining disciplinary strength while capitalizing on both private and governmental funding sources, including large interdisciplinary initiatives.

Our goal in education is to provide challenging and supportive learning experiences for students at all levels. Our programs are intended to provide both strong preparation for graduate school – for those that are so inclined – as well as for scientific, technical, or other careers in private industry, government, or non-governmental organizations, consistent with our mission as a partially State-funded, public institution. We aspire to continue to be one of the most successful programs in the geosciences for job placement, as well as in the development of an educated populace with deep understanding of the role of science in a diverse and democratic civil society.

In the following, we consider the untapped opportunities and areas for growth in the categories of research and education.

4.2.1 Research

Our department's vision for the future reflects input from faculty and staff retreats over the last 10 years, as well as consultation with undergraduate and graduate students, postdoctoral fellows and alumni. It also reflects the scientific roadmaps, decadal surveys, and recommendations produced by agencies such as NSF and NASA, many of which incorporate significant contributions and leadership from our own faculty. Recent examples include the 2020 National Academies "Earth Through Time" report,[1], the NSF Office of Polar Program's report on Diversity and Inclusion[2], the National Academies Decadal Survey on planetary science and astrobiology[3], the US NSF/UK NERC's joint program in Antarctica,[4] and SZ4D: A New Initiative to Understand Subduction Zone Geohazards.[5]

We have been challenged by significant losses of expertise over the last decade. All research and educational areas have been significantly affected because our FTE (full time equivalent, tenure-track faculty) numbers have been reduced more than one third*, despite rising research revenues and significantly increased teaching contributions to the University.

A short-term hiring plan was developed in 2019, which identified the need for a minimum of one new faculty member in each of the five broad areas of research excellence in our department. That plan addresses, at least in a minimal way, the most urgent needs to restore the areas in our department that were below critical mass, or at risk of being so. By "critical mass", we mean having a sufficient number of faculty to provide complementary breadth and depth of expertise, such that the loss of a single faculty member would not create an immediate crisis for research programs or core curricular needs.

The 2019 hiring plan is nearing completion, with the successful recruitment of four new faculty under the *subduction-zone processes* (two in seismology, two in petrology), two in *Earth and life* (one in geobiology and stratigraphy; the other in sedimentology and geochronology), and one in *planetary*

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[1] *A Vision for NSF Earth Sciences 2020-2030: Earth in Time*. Washington, DC: The National Academies Press. doi:10.17226/25761

[2] Under consideration at NSF.

[3] *Origins, Worlds, and Life: A Decadal Strategy for Planetary Science and Astrobiology 2023-2032*. Washington, DC: The National Academies Press. doi: 10.17226/26522.

[4] How much, how fast?: A science review and outlook for research on the instability of Antarctica's Thwaites Glacier in the 21st century, *Global and Planetary Change* 153: 16-34, doi: 10.1016/j.gloplacha.2017.04.008

[5]SZ4D Draft Implementation Plan: https://www.sz4d.org/

* There were $31^{1}/_{3}$ FTE in 2001. By the 2021-2022 academic year, this had been reduced to $17^{2}/_{3}$. Recent hires will increase the FTE to $20^{2}/_{3}$ as of September 2023.

sciences. *Earth surface dynamics* is our current priority for the 2022-2023 hiring cycle. Completion of those goals provides some freedom to consider building additional capacity in specific areas, while recognizing that budgetary constraints prevent us from investing equally in all.

The following describes our current aspirational plan for investment. By "investment", we mean not only faculty hiring, but also strategic changes to the educational program. Decisions about the details are likely to evolve in the coming few years as we add up to 6 new faculty between 2022 and by 2024.

Earth surface dynamics: To complete our 2019 hiring plan, we expect to hire two tenure-track faculty in Earth Surface Dynamics. One position will be oriented towards a geomorphologist with a field-oriented research program. Fluvial geomorphology in particular provides synergistic linkages with other units, including coastal processes in the School of Oceanography, forest health and resilience in the School of Environmental and Forest Sciences (SEFS) and ecosystem research in the School of Aquatic and Fishery Sciences (SAFS). The second would be much more open in scope and would encourage applicants with expertise in Earth and/or planetary surfaces processes, broadly defined. Areas of focus could include, for example, weathering and soil-forming processes, biogeochemical cycling, remote sensing, and landscape evolution on Earth or other planets. Someone with remote sensing expertise, in particular, would provide linkages across many aspects of our department, particularly glaciology and planetary sciences. Our aim with this dual advertisement is to simultaneously address the need for additional expertise in key areas, while advertising broadly enough to ensure a large and diverse applicant pool.

Planetary and Space Sciences: We aim to capitalize on the new energy and new investment made by NASA in planetary exploration, and the synergy with other programs across the department and the university. The rapidly expanding field of planetary sciences, and its highly interdisciplinary nature provides an opportunity for further growth in this area. We expect to hire one new research faculty in planetary sciences this year, with a focus on icy planets and ocean worlds. This is a well-funded area and therefore provides a realistic career path for research faculty; it is also highly synergistic with petrology (through the physics of materials at high pressure) as well as with glaciology and geo- and astrobiology. Our upcoming search in surface processes may also yield a new hire who can contribute to this area, either through their expertise in surface dynamics and/or remote sensing skills.

Subduction Zone processes. After more than a decade of significant losses of core faculty, ESS is now approaching critical mass in subduction zone processes and related areas. We have three tenure-track faculty in petrology, including a metamorphic petrologist hired in 2020 and an igneous petrologist who will join us in Fall 2023, as well as an analytical geochemist who focuses on crustal processes. Building on existing strengths in geodesy and fault processes, two new faculty with expertise in seismology and other geophysical techniques were hired in 2021, bringing with them significant expertise in machine learning and data science. In the short term, we expect to make at least one research faculty hire to provide greater capacity for taking advantage of the wealth of data generated through the PNSN. In the medium term, although this broad research area of our department is very robust, anticipated retirements over the next five years could rapidly reduce our expertise in solid earth processes; we expect it will be important to make an additional hire in this area. This would likely be in an area such as magma physics or geodynamics, to ensure that we continue to have expertise in geological transport processes and related numerical methods. Such a hire might also serve to better bridge disciplinary boundaries in the department, while also broadening training opportunities for students. Finally, there is need for significant investment in research infrastructure; this is happening already as part of the start-up packages for new hires, and will remain an area of emphasis for the department.

Earth and Life Through Time. This year, we hired two additional faculty members, one who is a sedimentologist and isotope geochemist who focuses on geochronology, and another who focuses on the quantitative physical attributes of sedimentary formation and the record of ancient life they contain, and also has data-science expertise. Together with faculty in Biology, as well as the participation of the faculty in planetary sciences who work in the realm of astrobiology, our department may now be considered to have (minimal) critical mass in this area. There is potential for new growth in a number of areas, which are likely to be most impactful if combined with planetary sciences, surface processes, or joint positions with other units. There is also strong potential synergy with the Burke Museum in the form of a fossil curator/paleontologist, and it is expected that this may be possible with anticipated retirements in the next five years. As is the case for the Subduction Zone processes, the success of our junior faculty in this research depends on significant investment in research infrastructure.

Cryosphere and climate. Considered narrowly (i.e., “physical glaciology”), glaciology in ESS currently consists of just one tenure-track faculty member and three research faculty. Considered more broadly it also includes three additional tenure-line faculty, one each in climate dynamics, paleoclimate and ice core research, and glacial geology and geochronology, and well as numerous collaborating faculty from other units. Nevertheless, having a sole faculty member largely responsible for the curriculum in physical glaciology – where we once had three – presents the risk that we will not maintain our core strength in this area. Given the continued reputation of ESS glaciology, and the continued prominence and funding opportunities in this field, a new hire should be considered within the next few years, particularly as the two currently-active emeritus faculty wind down their careers. There is also an important infrastructure-investment need: significant renovations of the cold rooms is critical.

4.2.2 Education

We briefly review the purpose and status of each of the areas that we consider our educational responsibility, and discuss the changes we plan to implement over the next few years, and the rationale for those changes.

General education: General science classes are essential to the finances of the College of the Environment. Our undergraduate general education program plays an important role for students across the university, serving more students any other unit in the College of the Environment, and we do not envision making many significant changes to this aspect of the curriculum. Our chief challenge is in keeping the two largest-enrollment classes, ESS 101 and ESS 102, financially viable. Both require many TAs – combined, we use 8 to 10 TAs for these classes each quarter. The ESS 101 & 102 program has been much larger than our pool of ESS graduate students, and we have hired many students from other departments. Teaching ESS 102 every quarter has relied on temporary faculty, without dedicated funding. To rectify both situations, we either need new funding to hire additional teaching faculty, or we will need to reduce enrollment to better align with the available funds.

Undergraduate majors: The five different majors’ tracks serve students’ varied interests while ensuring that there are clear pathways for those – the great majority – that will not continue in academia.
We face several challenges. First, the varied requirements of the different undergraduate tracks can be confusing, and the need to accommodate students with different needs and timelines (including transfer students who need to complete major requirements in two years), has put pressure on our ability to offer the classes students need, when they need them. This, coupled with a large number of faculty retirements has meant that many of our majors graduate with an eclectic potpourri of coursework, but without necessarily developing expertise or skills in particular area. Second, budgetary changes imposed by the university upper administration have made it impossible to continue to teach our conventional geology field camp. Third, our Physics option was originally developed to accommodate students interested in rocketry and space exploration. Because this part of our major attracted a different set of students – those with an engineering orientation – than our other tracks, it had been our fasted-growing track. With the necessary re-orientation from space towards planetary sciences, we face the challenge of accommodating (or losing) these students.

With ongoing turnover in faculty, we have the opportunity and necessity to revisit our major course offerings to ensure that these are both aligned with our expertise and serving our students well. Work to significantly revised the curriculum began in earnest only in 2022, and remains an ongoing project. Our current priorities include the following:

- Capstone, experiential-learning opportunities for all students in the major. Principally, students obtain such experiences by enrolling in ESS 400/401, the summer field geology courses. We are actively working to develop other capstone experiences, both during the academic year and in the summer. Although field geology is one important aspect of our discipline, pathways in laboratory science and data analysis offer an alternative, and for some students, a more relevant one.
- Communication, career readiness and writing opportunities. A decade ago, we developed a required 400-level writing class, in recognition of the observation that our students were not prepared for scientific writing and also unprepared for the geoscience workforce. While we all recognize the importance of the skills, it is a demanding class to teach, and, depending on the instructor, a disproportionate burden on the TAs for reading/revision. Two non-exclusive models for addressing these important soft skills include a) including more components of writing withing each core cores in the major, as the 200- and 300-level and b) developing capstone courses at the 400 level that require revised writing and presentation as well as content that includes professional skills. Both of these approaches are in early stages of implementation, including small reading/writing/presentation exercises in our 200-level sequence, and a pilot professional practice seminar at the 400 level, based on a similar class used successful for the last decade in MESSAGe.
- Modifying the B.S. tracks to simplify and upgrade our course offerings. Under consideration is reducing the separate tracks, modifying the Physics track to include more offerings in terrestrial geophysics and instrumentation, and inclusion of an advanced data science option. The latter builds on momentum already underway at the graduate level by faculty who have strong computational backgrounds and work in collaboration with UW's multi-department *e*Science Institute.

MESSAGe Program: An essential reason for the success of MESSAGe is the very hands-on nature of the advising, with all students doing an original capstone project. However, at present, just two faculty (only one of whom is tenure track) oversee the majority of these projects. In general, tenure-track faculty do not have any incentive to fully participate. Tuition is high, particularly for out of state students. Retirements and losses in the area of faculty in the area of surface processes have challenged our ability to offer the key courses the students need. New faculty in surface processes should help to address the limited course offerings but leaves other challenges unaddressed. The following are under consideration:

- Replacing MESSAGe with a 5-year BS/MS program, whereby ESS undergraduate majors apply in their junior year, and begin the MS requirements in their 4th year. The structure would include a sequence of capstone projects in a portfolio with a culminating presentation. This would leverage the capstone sequences already underdevelopment. There is also discussion about broadening the scope of the MS program to include Earth-data science as an option.
- Retiring the program. This would not present a financial risk to the department since it would also end our commitment to the non-tenure track faculty currently contributing to the program. It would, however, significantly affect our profile and our ability to serve our students and the State of Washington.

Graduate Program: Our chief challenge for the graduate research program is that there is no set curriculum. This presents the potential for students to be under-served by the breadth and depth of expertise available to them on the faculty: how rigorous an education students receive can depend very much on the individual advisor. Since early 2022, a group of faculty has been working on a set of expectations for graduate students who are oriented towards physics and/or computational approaches in their work. Implementing this will require careful consideration of available faculty time to avoid the risk of reducing their availability for undergraduate teaching.

Background on United-Defined Questions

In addition to the questions for the review committee posed by the UW Graduate school and addressed in the previous sections (Part A), the department posed additional “unit-defined” questions. Here, we briefly provide context to aid the committee.

Are the structures and content of our undergraduate and graduate programs appropriate? Looking to the next decade, how can the department best position itself to pursue emergent research and funding opportunities, given current expertise and reputation, but limited resources for new hires?

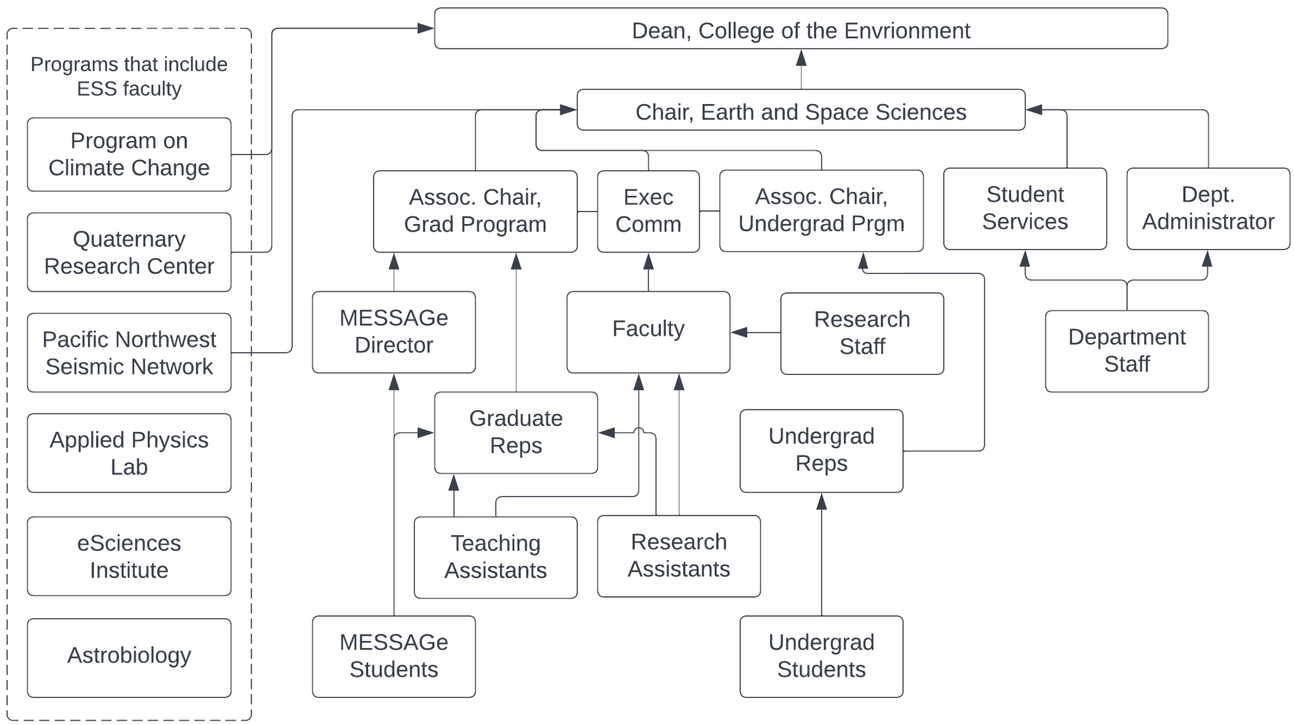
These questions reflect the tension between our mandate, as an R1 research university, to conduct cutting edge scientific work, and our desire to support undergraduate and graduate student, as well as postdocs, in pursuing a variety of career paths. An underlying issue is that our department has lost approximately 1/3 of its tenure-track faculty positions over the last 20 years.

Our program provides undergraduate training in the geosciences that is primarily oriented at fundamental rather than applied research: we teach the fundamentals. The traditionally most-relevant areas for non-academic jobs, economic and petroleum geology, are not well represented in our curriculum (or faculty expertise) and surface processes geomorphology and engineering geology have been bolstered recently by teaching faculty who have retired or will do so soon. Should we hire new faculty in these area, to ensure that we can deliver such programs? Should we instead emphasize “tech” sector skills, such as data science and GIS?

At the graduate level, the diverse nature of our subdisciplines, and the varied preparation of our students, has presented a challenge for the curriculum. We have few specifically-required courses (two “breadth” courses, any data analysis course, and a course or research requiring field or lab work). At least some of the faculty agree that we should devise a more concrete program or requirements for graduate students – or at least, clearer “recommended pathways”. Our applied M.S. program (MESSAGe) program has an enviable reputation for excellence in mentoring, with a ~95% successful job placement history. Yet, this success comes at the cost of significant time spent by a few of our faculty in advising, mentoring, and teaching, that is fundamentally in conflict with the budgetary model for the university. MESSAGe is in principle a “self sustaining” program, meant to support itself from tuition income; however only about a third of tuition paid by students is actually returned to the department. This income is about $180,000/year, which roughly covers salary for our non-tenure-track instructors (Troost, Collins (now retired) and Walters) but provides no support for the director (Crider) or other faculty (Duvall, Brown (now retired)) who are crucial to the program.

Without a revision to the program, in which we have more students getting less mentoring, it is unlikely to continue to be financially viable. Furthermore, the work that MESSAGe students produce does not typically lead to peer-reviewed publications. Given the expectations for promotion and recognition of the tenure-track faculty (prominent publications remain the overwhelmingly dominant criterion), there are strong disincentives for faculty to contribute to the program. Further discussion and evaluation of the benefits and losses to our program will be necessary before we can make a decision on the future of MESSAGe. The College of the Environment is currently considering launching other applied M.S. programs, and we look forward to the possibility of a comprehensive solution.

Appendix A: Organizational Chart



Appendix B: Budget Summary

Fiscal Year	Biennium General Operating Funds	Biennium Income from MESSAGe	Tenure-Track Faculty Salaries	Teaching-Faculty Salaries	Staff Salaries	TA salaries	RA salaries	Other	Benefits	Total Expenditures
2016	$10,526,585	$378,156	$2,829,052	$255,809	$535,995	$510,361	$22,045	$11,436	$1,025,983	$5,190,681
2017			$2,783,087	$258,807	$590,316	$503,698	$44,532	$17,412	$1,068,744	$5,266,596
2018	$10,284,933	$379,674	$2,824,800	$263,976	$572,339	$564,254	$54,745	$83,843	$1,120,748	$5,484,705
2019			$2,751,427	$269,274	$177,947	$518,427	$46,552	$69,506	$941,112	$4,774,245
2020	$10,164,839	$272,476	$2,900,099	$277,605	$452,404	$493,587	$13,134	$76,607	$1,034,864	$5,248,300
2021			$2,759,828	$277,605	$467,058	$356,637	$81,521	$10,201	$966,629	$4,919,479
2022	$8,866,934		$2,611,417	$283,846	$527,650	$472,682	$183,396	$207,820	$1,018,620	$5,305,431
2023		--	--	--	--	--	--	--	--	--

Table 1. Income and Expenditures for the general operating fund for the most recent fiscal year (FY 2022) and the previous three biennia (FY 2016 through FY 2021).
"Other" expenses refers to hourly student support (e.g. graders for classes) and for faculty re-hire after retirement.
Note that prior to 2021, the faculty re-hire costs were covered by the Dean's office but required a longer "parking" period before the position was returned to the department.

Fiscal Year	Indirect Cost Returns	Salaries	Personal contractual	Other contractual	Travel	Supplies	Equipment	Grants & subsidies	Total Expenditures
2016	$505,580	$207,058	$0	$74,838	$24,178	$72,709	$35,686	$41,267	$454,237
2017	$599,131	$277,521	$0	$112,273	$24,805	$34,686	$27,295	$75,837	$556,203
2018	$651,199	$220,990	$0	$102,480	$44,913	$37,723	$0	$55,983	$466,777
2019	$678,092	$733,159	$0	$98,983	$16,839	$29,881	$0	$23,450	$917,081
2020	$811,563	$331,852	$2,920	$110,733	$23,511	$28,098	$0	$8,764	$507,121
2021	$589,687	$193,397	$9,175	$71,896	$4,486	$6,106	$57,655	$17,398	$361,312
2022	$591,744	$354,570	$10,466	$88,143	$35,311	$57,090	$0	$89,065	$570,197

Table 2. Income and Expenditures from indirect cost returns (ICR) from grants and awards, for the most recent fiscal year (FY 2022) and the previous three biennia (FY 2016 through FY 2021).
"Grants and subsidies" refers to relocation expenses for students and faculty. Personal contractual services is training sessions, and honoraria for speakers.
Note that prior to 2021, the faculty re-hire costs were covered by the Dean's office in exchange for a longer "parking" period before the position was returned to the department.
The large salary expense in 2019 was a reallocation to the ICR budget due to insufficient general operating funds to cover TA and faculty and staff salary.

Appendix C: Information About Faculty

Faculty CVs are available at the following URL:
https://www.ess.washington.edu/content/people/faculty_cvs/

Committee members should have access. If access is required, please request it from steig@uw.edu.

George Bergantz, Professor
Paul Bodin, Research Professor
Roger Buick, Professor; Participating Faculty, Astrobiology Program
David Catling, Professor; Adjunct Professor, Department of Atmospheric Sciences
Knut Christianson, Associate Professor
Cailey Condit, Assistant Professor
Juliet Crider, Associate Professor
Marine Denolle, Assistant Professor
Alison Duvall, Associate Professor
TJ Fudge, Assistant Research Professor
Drew Gorman-Lewis, Associate Professor
Katharine Huntington, College of the Environment Endowed Professor
Baptiste Journaux, Acting Assistant Professor
Michelle Koutnik, Research Associate Professor
Brad Lipovsky, Assistant Professor
Michael McCarthy, Research Associate Professor
David Montgomery, Professor
Mark Richards, Professor; Provost, University of Washington
Gerard Roe, Professor; Adjunct Professor, Department of Atmospheric Sciences
David Schmidt, Professor
Ron Sletten, Research Associate Professor
Eric Steig, Rabinowitz Endowed Professor; Chair; Adjunct Professor, Dept. of Atmospheric Sciences
John Stone, Associate Professor
Terry Swanson, Teaching Professor
Fang-Zhen Teng, Professor
Harold Tobin, Professor; Paros Endowed Chair; Director PNSN
Kathy Troost, Associate Teaching Professor
Steven Walters, Associate Teaching Professor
Peter Ward, Professor (1/3 appointment in ESS); Professor, Department of Biology
Dale Winebrenner, Research Professor; Applied Physics Laboratory and Electrical Engineering
Marcia Baker, Professor Emeritus
J. Michael Brown (retired spring 2022), Professor Emeritus
Joanne Bourgeois, Professor Emeritus
Ken Creager, Professor Emeritus
Darrell Cowan, Professor Emeritus
Howard Conway, Professor Emeritus
Bernard Hallet, Professor Emeritus
Robert Holzworth, Professor Emeritus
Bruce Nelson, Professor Emeritus
Charles Nittrouer, Professor Emeritus (1/3 appointment in ESS); Prof. Emeritus, School of Oceanography
Edwin Waddington, Professor Emeritus

Appendix D: Summary of Undergraduate B.S. Degree Options

	Interests That Might Lead a Student to Pursue this Option	Skills Available Through this Option	Possible Future Career Paths Related to this Option	Relevant Upper Division ESS Electives*
ESS Geology BS	Earth processes, rocks, plate tectonics, origin and evolution of the earth, mountain building	Fieldwork, quantitative and numerical analysis, scientific literacy and communication, GIS, geologic mapping, laboratory skills	licensed geologist, geologic mapping, consulting, mineral exploration, petroleum industry, graduate school, geospatial analyst, K-12 teaching	ESS 403; ESS 411; ESS 420; ESS 421; ESS 425; ESS 426; ESS 427; ESS 439; ESS 447; ESS 454; ESS 455; ESS 456; ESS 457; ESS 460; ESS 461; ESS 462; ESS 463; ESS 480
ESS Biology BS	Ecosystems, paleontology, fossils, life on earth, extinction, geomicrobiology, astrobiology	Fieldwork, quantitative and numerical analysis, scientific literacy and communication, GIS, laboratory skills	water remediation, museum curation, consulting, geomicrobiologist, graduate school, K-12 teaching	ESS 450; ESS 451; ESS 452; ESS 453; ESS 457; ESS 482; BIOL 421; BIOL 427; BIOL 430; BIOL 432; BIOL 437; BIOL 438; BIOL 439; BIOL 441; BIOL 443; BIOL 447; BIOL 448; BIOL 452; BIOL 453; BIOL 470; BIOL 471*
ESS Physics BS	Earthquakes, volcanoes, geomagnetism, space physics, quantitative processes, space and planets, fluids, glaciers and ice sheets	Data analysis, quantitative and numerical analysis, GIS, scientific literacy and communication, laboratory skills	NASA, government agencies, space industry, petroleum industry, geophysics exploration, graduate school, data science, K-12 teaching	ESS 403; ESS 410; ESS 411; ESS 412; ESS 414; ESS 415; ESS 421; ESS 431; ESS 454; ESS 467; ESS 471; ESS 472
ESS Geoscience BS	Landscapes, environment, climate, glaciers, groundwater	Fieldwork, quantitative and numerical analysis, GIS, scientific literacy and communication, geologic mapping, laboratory skills	consulting, graduate school, environmental planning, public land management, environmental policy, renewable resources, data science, K-12 teaching	ESS 420; ESS 421; ESS 425; ESS 426; ESS 427; ESS 433; ESS 447; ESS 454; ESS 455; ESS 456; ESS 457; ESS 460; ESS 461; ESS 480; ESS 482
ESS BA	Earth as a natural system, earth sciences-based interdisciplinary science	Laboratory and field skills, scientific literacy and communication, GIS	Applications of earth sciences to: education, business, science writing/journalism, environmental policy, renewable resources, data science, K-12 teaching	Flexible according to interests; ESS 307; ESS 345; ESS 408; ESS 418; ESS 420

*A complete list of classes by course number for reference is given in at https://www.washington.edu/students/crscat/ess.html.

Appendix E: Scholarly-impact statistics.

Number of publications, number of independent papers citing those publications (excluding self-citations), total number of citations, and H-index, for all currently tenure-track, tenured and research faculty in the Department of Earth and Space Sciences. The source of the data is the ISSI Web of Science, and numbers may differ from other sources.

Publications	Independent Citing Papers	Total Citations	H Index
Assistant Professors:			
10	90	107	6
18	219	279	10
21	506	689	12
33	948	1,160	15
45	1,097	1,647	20
Associate Professors			
20	606	627	11
20	844	1,314	13
41	791	1,069	15
34	809	1,004	15
74	1,411	1,804	21
62	861	1,438	22
61	2,546	2,830	30
86	4,133	7,481	39
Full Professors			
47	1,493	2,258	25
58	1,224	2,178	27
58	1,934	2,331	29
57	2,755	4,481	34
100	4,000	5,151	38
53	4,377	5,044	39
134	3,417	4,969	42
88	4,689	7,925	46
148	2,452	7,351	50
141	5,042	8,196	52
163	9,596	13,879	63
245	14,165	22,617	78

Addendum:

Answers to questions posed by the review committee prior to the site visit.

1) How many students are supported on TAs and GRAs?

There are currently 68 graduate students, all of whom are supported on TAs or RAs.
In a typical year, about 60 TA-quarters are used. Therefore, about 30% of the students at any given time are supported with a TA position, and about 70% with an RA position. Of the RA positions, about 80% are supported by individual grants to faculty, 10% by department endowment and gift funds, and 10 by fellowships obtained by the students (e.g. NSF graduate fellowships, NASA FINESST fellowships, etc.).

2) Of the ICR, how much does the University keep, the College, and finally the department?

Sixty-five percent (65 %) of overhead is retained by the University, 8.75 % by the College and 26.25 % by the Department.