The University Senate of Michigan Technological University

Proposal 13-10

(Voting Units: Academic)

"Doctor of Philosophy Degree Program in Geophysics"

1. General Description of the Program

The faculty of the Department of Geological and Mining Engineering and Sciences (GMES) at Michigan Technological University seek to establish a Doctor of Philosophy program in Geophysics. Graduates of the program will have broad training in geophysics and develop expertise in one or more of the following specialties: earthquake seismology, exploration seismology, geomagnetism, and volcano seismology.

2. Rationale

The GMES department recently hired two new faculty members who have specialties in geophysics, bringing the total number of geophysics faculty to six (Suzanne J. Beske-Diehl, Jimmy F. Diehl, Wayne D. Pennington, Aleksey V. Smirnov, Roger Turpening, and Gregory P. Waite). While the department currently graduates PhD students with specialties in geophysics, their degrees are awarded in geology or geological engineering. These graduates are geophysicists by training, but their degree titles do not accurately reflect their expertise. In some cases, the lack of a Geophysics PhD program has been a deterrent for applicants or would-be applicants to the department. Having a PhD degree in geophysics is particularly important for enabling our new assistant professors to attract high-quality PhD students.

The GMES department has long had an undergraduate program in Applied Geophysics, and a Master of Science program in Geophysics. Both programs have traditions of successfully placing graduates in other graduate programs, or with positions in the public and private sectors. The new PhD program in Geophysics builds on the strengths of the existing geophysics programs. In addition to the Applied Geophysics B.S. and Geophysics M.S., the GMES department awards B.S., M.S., and PhD degrees in both Geology and Geological Engineering. We also offer graduate degrees in Mining Engineering. Our new Geophysics PhD program will provide continuity across all graduate programs within the GMES department.

3. Related programs

3.1. Related Programs at Michigan Tech

The programs most closely related to the new Geophysics PhD program are the Geological Engineering and Geology PhD programs offered through the GMES department. These programs have outlined specific criteria that have been used to assess their success: 1) upon graduation, PhD students in geology and geological engineering have demonstrated the ability to carry out an advanced and original research project, including its written and oral communication; 2) their projects have synthesized knowledge from different scientific disciplines; and 3) PhD students gain experience as research proposal writers. The department requires presentation and defense of a research proposal and students are expected to participate in the preparation and writing of proposals for internal and external funding. There are no specific coursework requirements for the PhD; the advisory committees design a program of study tailored to each student's background and research interests. Additional courses may be added to the program of study based on the result of the comprehensive (qualifying) exam. Emphasis is placed on research and publication of research. The average student completes the PhD in 4-5 years.

3.2. Related Programs at Other Institutions

There are approximately 25 Geophysics PhD programs in the United States as of 2008 [1]. We conducted an informal survey of a subset of these programs in order to assure that our graduates will be competitive with those from other institutions. We found that many programs have requirements that are similar to those of our Geology and Geological Engineering programs. They generally require some combination of oral and/or written comprehensive examination, sometimes called a qualifying examination. Some programs (e.g., Caltech, Princeton) have specific coursework requirements with 45 or more credits, while other programs have no specific requirements. Instead, they allow their students' committees to design course schedules tailored to students' backgrounds and research interests. This flexibility is especially desirable for geophysics graduate programs. Most colleges and universities do not offer a B.S. degree in geophysics so geophysics graduate programs are likely to attract a large number of students with undergraduate degrees in physics, mathematics, or a related field, rather than geophysics.

3.3. Anticipated Enrollment

There are currently four PhD students who are being advised by geophysics faculty who would be affected by this new degree program. As the junior faculty members build their research programs, this number may increase to as many as 10.

4. Curriculum Design

Students entering geophysics graduate programs come from a variety of backgrounds. They are as likely to have bachelor degrees in physics or mathematics as geophysics or geology. Therefore it is up to the advisory committee to design curricula for students based on their experience and deficiencies.

As with the PhD programs in Geological Engineering, Mining Engineering, and Geology within the GMES department, no courses will be explicitly required for the PhD in Geophysics. Each student, in consultation with the thesis committee, will develop an appropriate program of study with courses that complement their research activities. A minimum of 30 semester credits beyond the master's degree or 60 semester credits past the bachelor's degree are required. Courses may be within the GMES department and in other departments. In addition, the committee may require additional courses following the comprehensive examination. There is no modern language requirement.

4.1. Course Offerings

The following is a list of existing courses within the GMES department that demonstrates the breadth of existing courses available to students.

GE 4050 -Advanced Structural Geology
How rocks deform on a microstructural to hand specimen scale. Topics include dislocations, work hardening and recovery processes, annealing and recrystallization, slip systems, preferred orientation mechanisms, and foliation development. Credits: 3.0; Lec-Rec-Lab: (3-0-0); Semesters Offered: On Demand; Pre-Requisite(s): GE 3050.

GE 4250 -Fundamentals of Remote Sensing
This course focuses on the basic physics behind above-surface remote sensing and remote sensing systems. Topics covered include: properties of the atmosphere, absorption and scattering of electromagnetic radiation, instrument design, data acquisition and processing, validation, and basic applications. Credits: 3.0; Lec-Rec-Lab: (2-1-0); Semesters Offered: Spring; Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore; Pre-Requisite(s): PH 2200 and MA 2160.

GE 4450 - Advanced Environmental Geophysics
Covers the principles, design, and practice of geophysical site investigation utilizing electrical and electromagnetic techniques with emphasis on near surface application pertinent to the environmental

consulting industry. Credits: 3.0; Lec-Rec-Lab: (2-0-3); Semesters Offered: Fall; Pre-Requisite(s): GE 3040

GE 4500 - Plate Tectonics and Global Geophysics
Plate tectonics and the internal structure of the earth using information from seismology, geomagnetism, gravity, and heat flow. Credits: 3.0; Lec-Rec-Lab: (0-3-0); Semesters Offered: Fall, Spring; Pre-Requisite(s): MA 3160 and PH 2200 and GE 2000.

GE 4550 - Gravity and Magnetic Interpretation Methods
Interpretation of gravity and magnetic anomalies based on forward modeling techniques, including space filtering to enhance anomalies of importance. Emphasis will also be given to the design of the gravity/magnetic survey based on cost, implementation, and interpretation methods used. Credits: 3.0; Lec-Rec-Lab: (0-3-0); Semesters Offered: Fall, Spring -Offered alternate years beginning with the 2004-2005 academic year; PreRequisite(s): GE 3040.

GE 4560 - Earthquake Seismology
Physics of earthquakes and seismic energy propagation including stress and strain, elastic wave equation, body and surface waves, anelasticity, anisotropy, earthquake location, earthquake sources, passive seismic imaging. Homework will require computer skills in Matlab or similar. Credits: 3.0; Lec-Rec-Lab: (3-0-0); Semesters Offered: Fall; Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore; PreRequisite(s): GE 3050 and PH 2100 and MA 3160.

GE 4600 - Reflection Seismology
Principles of reflection seismic techniques, including theoretical background and application, and hands-on computer projects. Included are acquisition, data processing, and 2D/3D data interpretation. Students conduct projects using actual commercial-quality seismic data. Credits: 3.0; Lec-Rec-Lab: (2-1-0); Semesters Offered: Spring; PreRequisite(s): GE 3040.

GE 4610 - Formation Evaluation and Petroleum Engineering
Principles and practice of formation evaluation, primarily through analysis of well logs and the principles and practice of petroleum engineering. Emphasizes reservoir engineering and simulation. Students conduct projects using actual field data. A three-day field trip is required. Credits: 3.0; Lec-Rec-Lab: (2-1-0); Semesters Offered: Fall.

GE 5195 - Volcano Seismology
Will prepare students, including those with no seismology background, to interpret seismic and acoustic signals from volcanoes. Topics: basic seismology, monitoring techniques, tectonic and volcanic earthquakes, infrasound, deformation over a range of time scales. Credits: 3.0; Lec-Rec-Lab: (2-0-1); Semesters Offered: Spring; Pre-Requisite(s): (MA 1160 or MA 1161 or MA 1135) and GE 2000 and PH 2100.

GE 5250 - Advanced Computational Geosciences
Introduction to quantitative analysis and display of geologic data using Matlab and Excel, covering basic Matlab syntax and programming, and analysis of one-dimensional (e.g. time series) and two-dimensional datasets (e.g. spatial data). Techniques are applied to geological datasets. Credits: 3.0; Lec-Rec-Lab: (2-0-1); Semesters Offered: Spring; Restrictions: Must be enrolled in one of the following Level(s): Graduate.

GE 5400 - Global Geophysics and Geotectonics
Plate tectonics and the internal structure of the earth using information from seismology, geomagnetism gravity, and heat flow. A term project/report is required. Credits: 3.0; Lec-Rec-Lab: (0-3-0); Semesters Offered: On Demand; Restrictions: Must be enrolled in one of the following Level(s): Graduate; Pre-Requisite(s): MA 3160 and PH 2200 and GE 2000.

GE 5405 - Geophysics for Archaeology
Principles and practice of non-invasive archaeological geophysics (remote sensing) such as magnetometry, ground penetrating radar and resistivity. Data interpretation will involve basic computation, contouring, three-dimensional visualization programs, interpretation and archaeological significance. Activities include fieldwork, data analysis and presentation, and short reports. The mathematical content of the class will be minimal.

Credits: 3.0; Lec-Rec-Lab: (2-0-1); Semesters Offered: Fall -Offered alternate years beginning with the 2003-2004 academic year.

GE 5450 - Potential Field Theory in Gravity and Magnetic Applications
The fundamentals of potential theory and the application to gravity and magnetic studies of the crust and lithosphere. Topics include Newtonian & magnetic potential, magnetization, regional gravity fields, the geomagnetic field, forward & inverse modeling. Fourier-domain modeling and transformations. Credits: 3.0; Lec-Rec-Lab: (0-3-0); Semesters Offered: On Demand; Restrictions: Must be enrolled in one of the following Level(s): Graduate; Pre-Requisite(s): MA 3160 and PH 2200 and GE 3040.

GE 5500 - Paleomagnetism and Environmental Magnetism
Origin and interpretation of the natural remanent magnetism in rocks and its use in deciphering the geologic past. Applications studied are plate tectonic movements, environmental change, stratigraphic correlation, and the earth's magnetic field. Credits: 3.0; Lec-Rec-Lab: (3-0-0); Semesters Offered: On Demand; Restrictions: Must be enrolled in one of the following Level(s): Graduate; Pre-Requisite(s): GE 2000.

GE 5600 - Advanced Reflection Seismology
Principles and application of reflection seismic techniques. Includes acquisition, data processing, and 2D/3D data interpretation. Project and report required. Credits: 3.0; Lec-Rec-Lab: (2-1-0) ; Semesters Offered: On Demand; Restrictions: Must be enrolled in one of the following Level(s): Graduate.

GE 5610 - Quantitative Reservoir Characterization
Develop and integrate several aspects of reservoir characterization using data from actual oil and gas fields. The various aspects include well logs, seismic data, production data, and geologic/outcrop inference. Geostatistical routines and integrated software suites. Credits: 3.0; Lec-Rec-Lab: (1-2-0); Semesters Offered: On Demand; Restrictions: Must be enrolled in one of the following Level(s): Graduate.

GE 5650 - Special Topics in Petroleum Geology
The study of current topics in petroleum geology. Research papers and reports are required. Credits: variable to 4.0; Repeatable to a Max of 8; Semesters Offered: Spring Restrictions: Must be enrolled in one of the following Level(s): Graduate.

GE 5785 - Seismic Petrophysics
Seismic petrophysics describes the use of rock physics information and logging data in the interpretation of reflection seismic data. The theories and empirical models relating seismic properties to other properties of rocks will be reviewed, and the logging techniques responsible for identifying those properties discussed. Various approaches to the quantitative interpretation of seismic data are covered. For varying course credit, projects with real data will be conducted by students. Credits: variable to 3.0; Semesters Offered: On Demand; Restrictions: Must be enrolled in one of the following Level(s): Graduate.

GE 5800 - Mathematical Modeling of Earth Systems
Introduction to numerical techniques for mathematical modeling of various earth-system phenomena, including groundwater flow, heat transfer, and atmospheric transport. Numerical techniques covered include finite-difference, finite-element, collocation, and characteristic methods. Students write their own mathematical models. Prerequisite: experience in programming computer languages such as FORTRAN. Credits: 3.0; Lec-Rec-Lab: (3-0-0); Semesters Offered: On Demand; Restrictions: Must be enrolled in one of the following Level(s): Graduate.

GE 5810 - Flow and Transport in Subsurface Systems
Analysis of fluid flow in geologic materials, including groundwater flow, solute and contaminant transport, heat flow, and petroleum movement. Develops fundamental transport equations and numerical methods for solving these equations. Credits: 3.0; Lec-Rec-Lab: (3-0-0); Semesters Offered: On Demand; Restrictions: Must be enrolled in one of the following Level(s): Graduate.

Students will be encouraged to enroll in relevant courses within other departments. The following list of courses is intended to provide examples of extradepartmental courses available to meet the interests

and eliminate deficiencies of individual students. The list is *not* intended to include all courses that could be used to meet degree requirements.

SU 4100 - Geodetic Positioning
Introduces the instruments and procedures used in surveying projects that require a high order of accuracy. Discusses some conventional instruments and techniques but the greater emphasis is on GPS techniques. Credits: 3.0; Lec-Rec-Lab: (0-2-3); Semesters Offered: Fall; Restrictions: Must be enrolled in one of the following Class(es): Junior, Senior; PreRequisite(s): SU 4060(C).

EE 4252 - Digital Signal Processing and its Applications
Digital signal processing techniques with emphasis on applications. Includes sampling, the Z-transform, digital filters and discrete Fourier transforms. Emphasizes techniques for design and analysis of digital filters. Special topics may include the FFT, windowing techniques, quantization effects, physical limitations, image processing basics, image enhancement, image restoration and image coding. Credits: 4.0; Lec-Rec-Lab: (0-3-2); Semesters Offered: Fall; Pre-Requisite(s): EE 2150 and EE 3160.

MA 4620 - Finite Difference Methods for PDEs
Derivation, analysis, and implementation of finite difference methods; applications to fluid mechanics, elasticity, heat conduction, acoustics, or electromagnetism. Difference equations, Taylor series, stability, and convergence. Finite difference methods for partial differential equations; alternate methods (spectral, finite element, or particle) for discretizing space. Credits: 3.0; Lec-Rec-Lab: (0-3-0); Semesters Offered: Fall; Pre-Requisite(s): (MA 3520 or MA 3521 or MA 3530 or MA 3560) and MA 3160.

PH 5110 - Classical Mechanics
Lagrangian methods, symmetries and conservation laws, variational formulation, small oscillations, Hamilton's equations, contact transformations, Poisson brackets, Hamilton-Jacobi theory, Lorentz-invariant formulation. Credits: 2.0; Lec-Rec-Lab: (2-0-0); Semesters Offered: Fall, Spring -Offered alternate years beginning with the 2002-2003 academic year; Restrictions: Must be enrolled in one of the following Level(s): Graduate.

4.2. Additional Requirements.

We plan to follow the model of the Geology and Geological Engineering PhD programs for the design of written comprehensive exams, public proposal presentation and defense, and final oral exam.

4.2.1. Comprehensive exam

The comprehensive exam will be a written examination of fundamental and advanced topics in geophysics. The thesis committee chair will be responsible for soliciting the committee members for content and judging the exam.

4.2.2. Research proposal

Following successful passage of the comprehensive exam, students will be required to present and defend a research proposal. The proposal is intended to provide focus for research. The presentation is open to the public. Following the presentation, the student has an opportunity to defend the plan before both a public audience and audience made up of only the advisory committee.

4.2.3. Written dissertation

The dissertation will be written and prepared under the supervision of the chair of the advisory committee according to the requirements of the Graduate School. Students are expected to produce at least three quality journal publications from their PhD research. The dissertation may be comprised in part by journal articles.

4.2.4. Final oral examination

The final requirement is a public oral presentation. As with the Research proposal (4.2.2), the presentation is public and followed by a public examination. Following the public examination, the

advisory committee may further question the student in order to better assess the validity of the methods and conclusions contained in the dissertation.

5. New Course Descriptions

No new courses are required specifically for this degree.

6. Computing Access Fee

Students enrolled in the Geophysics PhD program will be charged the same Computing Access Fee as other graduate students in the department. For the 2009-2010 academic year, the fee is $340.

7. Additional Resources Required

No new resources are required specifically for this degree.

8. Accreditation Requirements

There are no specific accreditation requirements.

9. Planned Implementation Date

We would like to make this degree available as soon as possible (Fall 2010). One student who is close to graduation would be affected in the short term.

10. Core Geophysics Faculty

The GMES department has six geophysics faculty members including one Research Professor (R. Turpening). The curricula vitae of these faculty members are available online as Appendix A: http://www.geo.mtu.edu/~gpwaite/GeophysicsPhD/AppendixA.pdf.

11. Affiliated Faculty

In addition to the six core geophysics faculty members, several other members of the GMES graduate faculty are likely to assist in educating the Geophysics PhD students. They are listed in the table below. The expertise of faculty members from other departments (e.g., Physics, Electrical Engineering, Mathematics, School of Technology) and other institutions will be sought as necessary on a case-by-case basis. In addition, the GMES department is conducting two faculty searches. We anticipate the new faculty members, who will have expertise in the related disciplines of Atmospheric Science and Geological Engineering, will provide additional assistance to train some of the Geophysics PhD students as well.

GMES faculty with research interests in fields closely related to geophysics.

Name	Position	Specialty
Carn, Simon	Assistant Professor	Remote sensing, volcanology
Gierke, John	Professor	Hydrology, near-surface geophysics
Mayer, Alex	Professor	Hydrology
Rose, William	Professor	Remote sensing, volcanology
Shannon, Jeremy	Lecturer	Remote sensing, volcanology
Shuchman, Robert	Adjunct Professor	Remote sensing
Viton, Stanley	Adjunct Associate Professor	Geomechanics

Watson, Matthew	Adjunct Assistant Professor	Remote sensing, volcanology
Wood, James	Professor	Remote sensing, subsurface visualization
Wu, Shiliang	Assistant Professor	Atmospheric chemistry

[1] http://www.gradschools.com accessed 30 January 2009

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