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| 2. | Program action (Check one):  
  Spin-off proposal __X__  
  New program proposal  
| 3. | Title of proposed program: Ph.D. in Earth Systems and Geoinformation Sciences |
| 4. | CIP code: |
| 5. | Degree designation: Ph.D. |
| 6. | Term and year of initiation: Spring 2005 |
| 7. | Term and year of first graduates:  
  Spring 2007 |
| 8. | For community colleges: date approved by local board |
| 9. | Date approved by Board of Visitors: |
| 10. | For community colleges: date approved by State Board for Community Colleges |
| 11. | If collaborative or joint program, identify collaborating institution(s) and attach letter(s) of intent/support from corresponding chief academic officers(s): The degree is offered only by George Mason University. |
| 12. | Location of program within institution (complete for every level, as appropriate). If any organizational unit(s) will be new, identify unit(s) and attach a revised organizational chart and a letter requesting an organizational change (see Organizational changes--[hotlink]).  
  School(s) or college(s) of School of Computational Sciences  
  Campus (or off-campus site) Fairfax campus  
  Distance Delivery (web-based, satellite, etc.) |
| 13. | Name, title, telephone number, and e-mail address of person(s) other than the institution’s chief academic officer who may be contacted by or may be expected to contact Council staff regarding this program proposal:  
  Dr. David Wong, Associate Professor, School of Computational Sciences 703-993-1212  
  Dr. Peter A. Becker, Associate Professor, Associate Dean for Graduate Studies, School of Computational Sciences 703-993-3619 |
A Proposal for a Ph.D. in Earth Systems and GeoInformation Sciences

Presented by

The School of Computational Sciences
George Mason University

In Collaboration with

Department of Geography and
Department of Environmental Science and Policy
College of Arts and Sciences
George Mason University

And

School of Public Policy
George Mason University

April 5, 2004
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1. EXECUTIVE SUMMARY AND BACKGROUND

The School of Computational Sciences at George Mason University proposes an interdisciplinary Ph.D. in Earth Systems and Geoinformation Sciences. The proposed degree is a spin-off from the existing Earth Observing/Remote Sensing area of concentration within the Ph.D. program in Computational Sciences and Informatics. This new degree program will provide enhanced opportunities for students to pursue advanced studies in Geosciences, Geography, Remote Sensing, and Geographic Information Systems. These skills are in demand by private and government employers in the Washington, D.C. region, as well as nationally. Graduates from the proposed degree program will be qualified to serve as lead scientists in a wide range of activities involving geosciences, geography, geographic information systems, and remote sensing. The continual expansion of the NASA Earth observation satellite constellation, the development and expansion of the geospatial data infrastructure at USGS and other federal agencies, and the need to analyze these Earth-oriented data to achieve environmental and economic objectives will ensure a constant need for qualified scientists in these fields in the foreseeable future. Graduates will receive broad based training in the geosciences and geography as well as concentrated courses in computation and geoinformation sciences.

The proposed Ph.D. degree program represents a gateway to an academic career for some students, and for others it will facilitate career advancement in their current fields of employment, either in the public sector or private industry. Graduates will be equipped to participate in interdisciplinary research, which is the norm in today’s research arena. In addition, students will also receive training in teaching, thereby qualifying them to join academic units in more traditional disciplinary and instruction-oriented settings or in multidisciplinary programs.

The curriculum is organized into four concentrations: two Geosystems concentrations in Geosciences (GSC) and Geography (GEOG), and two Geoinformation Sciences concentrations in Remote Sensing (RS) and Geographic Information Systems (GIS). Students may choose one of these concentrations, or they may opt to develop a curriculum that combines elements from two or more concentrations, under the guidance of a faculty advisor.

2. DESCRIPTION OF THE PROPOSED DOCTORAL PROGRAM

2.1 Background

The advancement of science and technology experienced in the past several decades has been unprecedented historically, even surpassing the progress achieved during the industrial revolution. In the midst of all this technological innovation, no areas have experienced more rapid development than those focusing on developing a better understanding of the Earth. Advances in satellite, computer, and transmitter/receiver technology have fueled an explosion in the fields of Remote Sensing (RS) and Geographic Information Systems (GIS). While remote sensing focuses on capturing
environmental data and GIS focuses on handling, analyzing and displaying spatial data, both areas focus on data about the Earth, and therefore they each enhance and support the scientific queries that are vital to the fields of Geosciences and Geography.

About ten years ago, the School of Computational Sciences (formerly the Institute for Computational Sciences and Informatics) established the Earth Observing/Remote Sensing area of concentration within the doctoral program in Computational Sciences and Informatics (CSI). The area of concentration was built around the science supporting remote sensing technology with a significant focus on applying the relevant technologies to gain a better understanding of the Earth systems, including the atmosphere, lithosphere, hydrosphere, biosphere, anthrosphere, and the relationship among these systems. Since then, the number of Ph.D. students in that area has increased to the current size of about 50, with close to 30 full-time and more than 20 part-time. Between 2001 and 2002, three doctoral degrees in the Earth Observing/Remote Sensing area of concentration were granted. Between 2002 and 2003, 4 Ph.D.’s were granted, and we expect 3 more graduates in 2004.

The success of the Earth Observing/Remote Sensing area of concentration within the CSI doctoral program has led to some new challenges. The role of GIS has become more central to the program as remote sensing and GIS are inseparable tools in gathering and analyzing Earth data. The NASA-funded Virginia Access-Mid-Atlantic Geospatial Information Consortium project (VAccess-MAGIC, a consortium of several Virginia universities led by GMU), as well as a newly established GIS Center of Excellence at Mason, together provide a strong indication of the high level of expertise at GMU in remote sensing and GIS. The effort of integrating GIS and remote sensing will continue to be the central theme in the Geography, Earth Systems, Public Policy, and Earth Observing/Remote Sensing academic activities and in the research of the faculty involved.

The number of SCS faculty members with expertise in Earth Systems Science/ Geosciences, Geography, Remote Sensing and GIS has increased consistently over the years, and has already reached the “critical mass” required to maintain a thriving and self-sufficient group. This led to the establishment of the Earth Systems and Geoinformation Sciences (ESGS) Program within SCS. This Program administers the Earth Observing/Remote Sensing area of concentration within the CSI Ph.D. program. ESGS faculty members, all of whom are members of the Center for Earth Observing and Space Research (CEOSR), the largest research center at GMU, have generated more than $7 million of research funding in 2003. Thus ESGS together with CEOSR have a strong funding foundation to support the proposed degree, as well as a strong track record of producing highly qualified graduates.

SCS also offers a Ph.D. degree in Climate Dynamics with a focus on interseasonal variability, land-ocean-atmosphere interaction, and mesoscale modeling. The Ph.D. proposed here is complementary to the Climate Dynamics degree because the focus of the new degree is on geoinformation science, with a major emphasis on the atmosphere and hydrosphere, and the interactions among these components. The proposed degree
builds on the strength of the existing EOS and CLIM courses, and we expect that a significant number of students will take some elective courses under the CLIM designation.

For the proposed degree, this strong base of expertise in Computational Science and Geoinformatics will be augmented by geoscientists and geographers in the Departments of Geography and Environmental Science and Policy (ESP), and the School of Public Policy (SPP). Located in the College of Arts and Sciences, Geography and ESP are home to several faculty engaged in a variety of research areas that complement the SCS faculty expertise. Their research interests are in the areas of geosciences, geography, geographic information science, and remote sensing. Further expertise in geography, especially in human dimensions, will be contributed by faculty in the School of Public Policy.

It is clear that GMU has reached the point where it is appropriate for a new Ph.D. degree focusing on Earth Systems and Geoinformation Sciences. The proposed doctoral program utilizes an extensive base of existing EOS, CSI, and CLIM courses in SCS, and other courses in Geography, ESP, and SPP. Therefore only six new courses are proposed here (see Appendix II for complete catalog descriptions of the new courses). Consequently the spin-off category is appropriate for the proposed degree.

It is clear that GMU has reached the point where it is appropriate for a new Ph.D. degree focusing on Earth Systems and Geoinformation Sciences to spin off from the Earth Observing/Remote Sensing area of concentration within the CSI doctoral program. As a result of ongoing collaboration and cooperation between SCS and CAS, the ESGS Program within SCS has invited all GMU geographers in the Geography Department and the School of Public Policy to participate in the proposed interdisciplinary degree. The proposed doctoral program utilizes an extensive base of existing EOS, CSI, and CLIM courses, and therefore only five new courses are proposed here (see Appendix II for complete catalog descriptions of the new courses). Consequently the spin-off category is appropriate for the proposed degree.

2.2 Mission and Objectives

The proposed Ph.D. in Earth Systems and Geoinformation Sciences continues the well-established interdisciplinary education mission in SCS and the collaborating GMU units. Realizing that the treatment of any significant contemporary scientific problem now involves more than a single traditional discipline, the proposed degree fosters the integration of the two scientific disciplines in Geosystems, namely Geosciences and Geography, with the two slightly more technology-oriented scientific disciplines in Geoinformation Sciences, namely remote sensing and GIS. As in practically all fields of modern science, advancement in the Earth systems science is bolstered by the development of new and improved technology tools. When remote sensing and GIS are used to enhance our understanding of the Earth, they are regarded as tools. However, the continued development of the “tools” is itself a subject of intense scientific activity. It is noteworthy that the foundations of these technologies are structured sciences and elegant mathematical theories.
We believe that the proposed degree will prove attractive to graduates of several undergraduate and master’s programs at GMU as well as many other universities in the Commonwealth and in the region. At GMU, these programs include Civil, Environmental and Infrastructure Engineering (B.S. and M.S.), M.S. in Computational Science, Electrical and Computer Engineering (B.S. and M.S.), B.S. in Earth Science, M.S. in Earth Systems Sciences, M.S. in Environmental Science and Policy, Geography (both B.A. and B.S.), M.S. in Geographic and Cartographic Sciences, B.A. in Geology, B.S. in Information Technology, B.S. in Physics, and Public Policy (M.S.).

2.3 Program Structure

Administrative Structure

The Ph.D. degree program will be administered by the Earth Systems and Geoinformation Sciences (ESGS) Program and housed in SCS. The program will be administered by an Academic Coordinator who is appointed jointly by the Chair of the ESGS Program along with the SCS Dean. The SCS Associate Dean for Graduate Studies will provide additional oversight. An Executive Committee will be formed with members from the involved academic units, composed of three members from SCS, one member from the Geography Department, one member from Environmental Science & Policy, and one member from the School of Public Policy. This Committee will oversee all administrative issues related to the degree, such as program promotion, admission, curriculum development, and class scheduling. The Academic Coordinator will implement approved policy changes.

Admission Requirements

The program is intended for graduates with B.S. or B.A. degrees in atmospheric science, climatology, meteorology, Earth science, geology, environmental science, remote sensing/Earth observing, hydrology, oceanography, geography, or related fields, with a minimum GPA of 3.00. Applicants should have knowledge of calculus and working proficiency with a computer programming language. Knowledge of mathematics through ordinary differential equations is preferred. Students who do not satisfy these admission requirements may be asked to acquire such skills before they are fully admitted to the program. Interested applicants should contact the Academic Coordinator or the ESGS Chair for more specific advice. Applicants also need to obtain acceptable scores on the GRE-GEN exam and foreign applicants have to obtain acceptable scores on the TOEFL exam. Three letters of recommendation and a Goals Statement should be submitted with the graduate application. Depending on the background of the individuals, students with insufficient background may be accepted provisionally, and required to successfully complete selected courses tailored to the individual’s needs and background.

Curriculum Requirements
The proposed Ph.D. program in Earth Systems and Geoinformation Sciences is organized into the four concentrations listed below:

- Geosciences (GSC)
- Geography (GEOG)
- Remote Sensing/Earth Observing (RS)
- Geographic Information Systems Science (GIS)

All students in the program are required to take 48 credit hours of course work and 24 credit hours of dissertation research. Students entering the doctoral program with previous graduate work may be able to transfer up to 24 credit hours of related coursework. For students entering the doctoral program with a previous master’s degree, the 48 hours of course work may be reduced by a maximum of 30 credits. Students may select one of the four concentrations listed above, or they may choose not to have a specific concentration, in which case they will be assisted by their faculty advisor in the development of a cross-concentration curriculum plan, subject to approval by the Academic Coordinator.

All students are required to select courses from a set of three core areas (computational, geosciences-geography, and geoinformation). Additional coursework includes courses in an area of concentration, a single credit of seminar/colloquium, and electives relevant to the student’s focus. In recognition of the diverse interests of students in this scientific area, students are given considerable flexibility in constructing their specific curriculum under the guidance of a faculty advisor. To provide the desired level of flexibility and to encourage interdisciplinary education and research, the following seven program elements are required (further detail is provided below):

- 6 credit hours of Computational Core Courses
- 9 credit hours of Geosciences-Geography Core Courses
- 6 credit hours of GeoInformation Sciences Core Courses
- 6 credit hours of Concentration Courses
- 3 credit hours of Seminar/Colloquium (1 credit, taken three times)
- 18 credit hours of Electives
- 24 credit hours of dissertation research

The following discussion provides complete details regarding each of these requirements.

1) COMPUTATIONAL CORE: Two computational courses selected from the following list

   CSI 600 Quantitative Foundations for Computational Sciences
   CSI 700 Numerical Methods
CSI 701 Foundations of Computational Science  
CSI 702 High-Performance Computing  
CSI 703 Scientific and Statistical Visualization  
CSI 710 Scientific Databases

2) **GEOSCIENCES-GEOGRAPHY CORE**: Five areas of study have been identified as central to the study of Earth systems: Atmosphere, Hydrosphere, Lithosphere, Biosphere, and Anthrosphere. To ensure adequate breadth, students are required to take at least one course in three of the five areas:

- CSI 655 Introduction to Physics and Chemistry of the Atmosphere or GEOG 670 Applied Climatology  
- EOS 656/EVPP 652/GEOG 570 The Hydrosphere or EOS 725 Advanced Hydrosphere *(new course)*  
- GEOL 601/EOS 657/GEOG 671 The Lithosphere  
- EOS 721/EVPP 741 Biogeography  
- EOS 704 Spatial Analysis and Modeling of Population *(new course)*

3) **GEOINFORMATION SCIENCES CORE**: Two courses in GeoInformation sciences, one from each of the sub-categories of GIS and Remote Sensing

**GIS**
- GEOG 553 Geographic Information Science  
- GEOG 563 Advanced GIS  
- GEOG 653 Geographic Information Analysis  
- EOS 771 Algorithms and Modeling in GIS

**Remote Sensing**
- GEOG 579 Remote Sensing  
- GEOG 580 Digital Remote Sensing  
- EOS 753 Observations of the Earth and its Climate  
- EOS 756 Physical Principles of Remote Sensing  
- EOS 758 Digital Processing of Remote Sensing Imagery

4) **CONCENTRATION COURSES**: Two courses selected from those listed below for the desired concentration. Those students choosing not to select a specific concentration will be assisted by their faculty advisor in developing a curriculum plan by combining courses from more than one of the following areas. Their curriculum plan must be approved by the Academic Coordinator.

**Geosciences (GSC):**

- CSI 655 Introduction to Physics and Chemistry of the Atmosphere  
- GEOG 670 Applied Climatology  
- EOS 656/EVPP 652/GEOG 570 The Hydrosphere  
- GEOL 601/EOS 657/GEOG 671 The Lithosphere
EOS 721/EVPP 741 Biogeography  
EOS 725 Advanced Hydrosphere (new course)  
EVPP 663 CoastalGeomorphology  
CSI 755 Introduction to Atmospheric Dynamics  
EVPP 550 Waterscape Ecology and Management  
EVPP 546 Estuarine and Coastal Ecology  

**Geography (GEOG):**  

GEOG 503 Problems in Environmental Management  
GEOG 505 Transportation Geography  
GEOG 540 Medical Geography  
GEOG 531 Land Use Modeling Techniques and Applications  
GEOG 585/EOS 759 Quantitative Methods  
GEOG 575/EOS 759 Reconstructing Past Environment/Geoarchaeology  
GEOG 674 Environmental Impact Analysis  
GEOG 680 Seminar in Thought in Methodology  
GEOG 785 Geographic Field Work  
EOS 721/EVPP 741/GEOG xxx Biogeography  
PUBP 810 Theory and Methods in Regional Policy I  
PUBP 811 Theory and Methods in Regional Policy II  
EVPP 503 Field Mapping Techniques  
EVPP 741 Environment and Society  

**Geographic Information Systems (GIS):**  

GEOG 553 Introduction to GIS  
GEOG 563 Advanced GIS  
GEOG 590 GIS and Natural Resources  
GEOG 653 Geographic Information Analysis  
GEOG 664 Spatial Data Structures  
GEOG 661 Map Projections and Coordinate Systems  
EOS 771 Algorithms and Modeling in GIS  
EOS 772 Distributed GIS  
EOS 773 GIS Interoperability  

**Remote Sensing (RS):**  

GEOG 656 Terrain Mapping  
GEOG 562 Photogrammetry  
GEOG 579 Remote Sensing  
EOS 740 Hyperspectral Imaging Systems  
EOS 753 Observations of the Earth and its Climate  
EOS 754 Earth Observing/Remote Sensing Data and Data Systems  
EOS 756 Physical Principles of Remote Sensing  
EOS 757 Techniques and Algorithms in Earth Observing and Remote Sensing  
EOS 758 Digital Processing of Remote Sensing Imagery
5) SEMINAR/COLLOQUIUM COURSES: All students are required to take the 1 credit seminar/colloquium course

EOS 900 Colloquium in Earth Systems and Geoinformation Sciences (new course)

three times before they proceed to candidacy. These courses will provide students with exposure to current research in the interdisciplinary areas.

6) ELECTIVE COURSES: Students are required to take 21 hours of elective course work. The electives can be chosen from the core and concentration courses listed above as well as additional courses approved by their advisor. Some of the recommended elective courses are listed below:

CLIM 711 Introduction to Atmospheric Dynamics
CLIM 713 Atmospheric-Ocean Interaction
CLIM 715 Numerical Methods for Climate Modeling
CS 631 Object-Oriented Design Patterns
CS 652 Computer Graphics
EOS 700 Communication Skills for Scientists
EOS 722 Regional and Global Issues in the Earth Sciences
EOS 759 Radiative Transfer
EOS 760 Remote Sensing Applications
EOS 791 Advanced Spatial Statistics
EOS 840 Hyperspectral Imaging Applications
EOS 854 Introduction to Atmospheric Boundary Layer
EOS 855 Introduction to Mesoscale Atmospheric Modeling (new course)
EVPP 503 Field Mapping Techniques
EVPP 550 Waterscape Ecology and Management
EVPP 546 Estuarine and Coastal Ecology
EVPP 577: Biogeochemistry: A Global Perspective
EVPP 741 Environment and Society
GEOG 581 World Food and Population
GEOG 631 Spatial Agent-based Models of Human-environment Interaction
GEOG 670 Applied Climatology
INFS 614 Database Management
INFS 650 Object Oriented Applications for Information Systems
PUBP 601 Theory and Practice of Regional Economic Development
PUBP 602 Regional and Economic Development and Technology
PUBP 715 Introduction to Transportation Systems

For students in the GSC, GIS, and RS concentrations, courses offered by SCS, especially under the EOS and CLIM prefixes, and by the School of Information Technology and Engineering (IT&E), by CAS under GEOG, EVPP, and GEOG, and by SPP under PUBP can generally be selected as electives. For students in the GIS concentration, additional
courses in cartography (under Geography) and visualization (offered by SCS) are appropriate. For students concentrating in GEOG, courses offered by Geography and School of Public Policy can be selected as electives. Students should consult with their advisors and/or committees in selecting elective courses.

**Dissertation Committee and Candidacy Examination**

All students will be assigned a temporary academic advisor when they first enroll in the program. No later than the end of the second year, each student should identify a dissertation advisor to supervise his/her dissertation research. All tenure/tenure-track faculty from the participating units shall be eligible to serve as dissertation advisors and committee members. With input from the advisor, the student should also form a dissertation committee consisting of the dissertation advisor plus 3 or 4 appropriate faculty members. At least three committee members, including the dissertation advisor, must be tenure-line faculty. The committee membership must be approved by the Academic Coordinator. The ESGS Chair in consultation with the Dean of SCS may make exceptions to allow non-tenure-track line faculty to serve as the dissertation advisor and/or committee members. In consultation with their dissertation advisor each student will formulate a program of study mapping their coursework requirements by the end of their second year or soon thereafter. This program of study is subject to final approval by their dissertation committee.

Upon the completion of all required courses, each student must take a Candidacy Examination administered by the dissertation committee. The candidacy examination will have written and oral components. The purpose of the exam is to determine whether the student has acquired adequate general knowledge in the selected subject area, as well as much more detailed knowledge of the specific research topic planned for the dissertation. To set the scope of the exam in the appropriate context, the student should provide the committee a summary (4-5 pages) of the dissertation proposal. The summary should provide an overview of the intended research topic. This dissertation proposal summary and the courses taken by the student will be used to define the scope of material to be covered on the candidacy examination. The oral exam is a follow-up of the written component, and offers the student the opportunity to clarify their written answers, if necessary, and to assure that the student can respond to other relevant questions. Both the written portion and the oral component can be retaken at most once each. If all of the committee members feel that the student’s performance on the written component is truly outstanding, then the oral component may be waived.

**Dissertation Proposal, Candidacy, and Defense**

Once the student has completed all required courses and passed the candidacy examination, the student may start taking research credits (EOS 998, Doctoral Dissertation Proposal) for a total of up to 12 credit hours in preparing the dissertation proposal. The student should work closely with the dissertation advisor and the other committee members on all aspects of the proposal and research. The appropriate research topic should potentially make a significant contribution to the relevant scientific
discipline. The committee will evaluate the proposal in terms of its viability, scientific integrity, intellectual merits, and anticipated scientific impact. Whenever appropriate, and with consultation with the dissertation advisor and/or committee members, students are encouraged to submit thesis proposals to funding organizations to seek financial support for the proposed work.

The dissertation proposal should be formally submitted to the dissertation committee for approval within 1 semester after the successful completion of the candidacy examination. A proposal defense will be held where the student presents the proposal to the committee and seeks their formal approval. After the dissertation proposal is approved and the candidacy examination is passed, the student is formally advanced to doctoral candidacy.

When the doctoral candidacy status is attained, the student can start taking EOS 999 (Doctoral Dissertation). The dissertation work should reflect high-quality original research, and it should make a significant contribution to the relevant field and be of quality suitable for publication in refereed journals. In consultation with the dissertation advisor and the committee members, the candidate should prepare to defend the dissertation at a time agreeable to all parties. The candidate is encouraged to hold a pre-defense session with the committee to assess their readiness for the final dissertation defense. The dissertation should be available to the committee at least two weeks prior to the defense date. The dissertation defense should be announced at least two weeks prior to its date and will be open to the public.

Sample Course Schedules

Selection of electives should be made in consultation and with the approval of the academic or dissertation advisor and/or the committee. Students may choose not to select a specific concentration. In this situation, the student chooses a set of courses from multiple concentration areas, subject to approval by the Academic Coordinator.

A sample curriculum for the Geosciences concentration is provided below

Geosciences (GSC)

Year 1: 16 credits/6 courses
  Semester 1:
  CSI 700 Numerical Methods
  CSI 655 Introduction to Physics and Chemistry of the Atmosphere
  EOS 900: Colloquium in Earth Systems and Geoinformation Sciences
  Semester 2:
  CSI 701 Foundations of Computational Science
  EOS 656 The Hydrosphere
  EOS 753 Observations of the Earth and its Climate

Year 2: 19 credits/7 courses
  Semester 1:
  CSI 755 Introduction to Atmospheric Dynamics
EOS 657 The Lithosphere
EOS 854 Introduction to Atmospheric Boundary Layer
EOS 900: Colloquium in Earth Systems and Geoinformation Sciences

**Semester 2:**
- EOS 855 Introduction to Mesoscale Atmospheric Modeling
- EOS 756 Physical Principles of Remote Sensing
- GEOG 563 Advanced GIS

**Year 3:** 13 credits/5 courses + 6 credits research

**Semester 1:**
- CLIM 711 Introduction to Atmospheric Dynamics
- EOS 740 Hyperspectral Imaging Systems
- EOS 757 Techniques and Algorithms in Earth Observing and Remote Sensing
- EOS 900: Colloquium in Earth Systems and Geoinformation Sciences

**Semester 2:**
- CLIM 715 Numerical Methods for Climate Modeling
- EOS 998 Dissertation Proposal (6 credits)

**Year 4:** 12 credits of research

**Semester 1:**
- Candidacy Exam
- EOS 998 Dissertation Proposal (6 credits)

**Semester 2:**
- Proposal Defense
- EOS 999 Dissertation (6 credits)

**Year 5:** 6 credits of research

**Semester 1:**
- EOS 999 Dissertation (6 credits)
- Dissertation Defense

### 2.4 Evaluation of Program Effectiveness

The University administers a standard Graduating Student Exit Survey through the Office of Institutional Assessment to gather feedback from graduate students. We will strongly urge our future graduates to complete that survey so that the resulting data can be used to assess the program. In addition to the standard university survey, the proposed degree program will also conduct its own evaluation. Upon the successful defense of the dissertation, and before graduation, the student will be asked to complete a program assessment survey. The assessment will comprise a set of standard questions and some open-ended questions related to the quality and effectiveness of education in the program received by the student. The Academic Chair will accumulate results from these surveys in a database to be used for internal program evaluation, which should be conducted at the end of the third year after the program is being offered. Data from these surveys will also be analyzed annually to identify program trends and check for possible problems.

Traditional Ph.D. programs generally use the job placement rate of their graduates as a metric to evaluate their degree program. For the proposed degree, which likely will
attract many part-time students who are already employed, this metric will still be useful, but it will not provide a complete picture. Therefore, a more qualitative approach should be used. The program will establish a very effective tracking system or alumni relationship effort to maintain future contacts with graduates. Two or three years after the student graduates, we will send him/her a questionnaire, inquiring how the Ph.D. training he/she received has enhanced the alumni’s work or career.

2.5 Relationship to Existing Ph.D. Programs at the University

Because of the interdisciplinary nature of the proposed program, it should complement several existing Ph.D. programs at GMU. These programs include the Ph.D. in CSI, from which the proposed program is a spin-off, the Ph.D. in Climate Dynamics in SCS, the Ph.D. in Environmental Science and Public Policy in CAS, and the Ph.D. in Public Policy in SPP. The Ph.D. in CSI has a focus on the application of computational techniques to the solution of problems in the physical sciences. While the new program has a significant computational orientation, especially in some aspects of Geosciences, GIS and remote sensing, the focus is more on applying various types of techniques, including computational techniques, to address issues related to Earth surface phenomena. The Ph.D. in Climate Dynamics (CLIM) emphasizes atmospheric dynamics, land surface processes, and oceanography. These emphases complement the proposed degree emphases on different components of the Geosystems, including the biosphere and lithosphere, and the interactions among these components. Due to the complementary relationship between the various degree programs, we expect that a significant number of students will take CSI and CLIM elective courses. The Ph.D. in Environmental Science and Public Policy focuses on the environmental aspects of the Earth sciences and includes a required policy component. The proposed degree focuses more on the physical principles and dynamics of the Geosystems, and environmental policy is not emphasized at all. The Ph.D. in Public Policy has an obvious policy orientation with a significant interest in the geographical dimension of socioeconomic systems. The Geography concentration in the proposed degree will focus more on the geographical dimension of the various phenomena, including diverse aspects of the physical systems. Therefore it is clear that the proposed Ph.D. degree will complement rather than compete with the existing programs, and it is expected that the availability of courses associated with the new degree program will add strength to the other programs.

3. JUSTIFICATION FOR THE PROPOSED DOCTORAL PROGRAM

3.1 Student Demand

Based on the very strong enrollments in the current Earth Observing/Remote Sensing area of concentration within the CSI doctoral program, it is quite reasonable to expect heavy student demand for the new degree. A specific recent development further supports our claim that the proposed Ph.D. program will have high demand. Last year, a major programmatic change occurred at George Washington University affecting a group of students focusing on the applications of GIS and remote sensing. As a result of that development, a cadre of GW graduate students (eventually, the total number can be as
high as 15 to 20) has transferred or is in the process of transferring to GMU with, the expectation of switching over to the proposed Ph.D. degree when it becomes available.

We expect that the proposed degree will prove attractive to graduates of several GMU degree programs. Those existing programs include the M.S. in Computational Science, the B.A. and B.S. in Earth Science, the M.S. in Earth Systems Sciences, the M.S. in Environmental Science and Policy, the B.A. and B.S. in Geography, the M.S. in Geographic and Cartographic Sciences, the B.A. in Geology, the B.S. in Physics, and the M.S. in Public Policy.

We have also polled our current CSI Ph.D. students in the Earth Observing/Remote Sensing area of concentration to determine whether they would be interested in transferring into the proposed Ph.D. degree when it becomes available. So far, we have received responses from 11 current students, with all but one indicating that they would transfer into the new program. The one student who did not wish to transfer expects to graduate shortly and therefore the availability of the new program was not really relevant in that case. The students were also asked if they would apply to the proposed program if they were now applying to a graduate school. All except one indicated that they would. Also, we have received responses from three non-degree students indicating that they will apply to the proposed program when it becomes available. In addition, one student commented that his colleagues at work would be very interested in this program.

Our research on student demand for this new program comes from sources related to different concentrations encompassed in this program. However, because these concentrations are closely related, the student demand for one concentration subject may also reflect the demand for other concentrations. It is clear that in general, geosciences, geography, GIS and remote sensing have generated an unprecedented level of interest in the academic arena, partly due to the rapid advances in the Geoinformation sciences required to enhance our understanding of the Earth, and partly due to the synergy of the interdisciplinary approach necessary to address scientific issues related to the Earth. Thus, the four areas of concentration encompassed by the proposed degree program are expected to be of high demand among undergraduate students interested in the Earth and the many problems facing the future of the planet.

Recent changes in the government organizational structure also provide strong indications that our proposed program is on the right track. Last year, the National Image and Mapping Agency (NIMA) was renamed to National Geospatial-Intelligence Agency (NGA) to partially reflect the trend that the traditional “stovepipes” disciplinary structure for geospatial information cannot serve the organization, and interdisciplinary approach is warranted.

In addition, GMU has a location advantage related to the proposed program. Washington, DC metro areas (including counties in Maryland and Virginia) probably has the highest concentration of researchers and scientists in Geosciences, Remote Sensing professionals, GIS specialists and Geographers in the entire nation. The high demand for such professionals in this region is definitely attributable to the presence of various federal
government agencies (public sector) and the supporting companies (private sector) in the Washington, DC, northern Virginia and Maryland. Below is a partial list of Federal government agencies and establishments with a large presence in the DC metro area with employees who may seek Ph.D.-level education and training in Earth Systems and Geoinformation Sciences:

Bureau of the Census
Central Intelligence Agency - CIA (Langley, VA)
Defense Intelligence Agency (DIA)
Department of Housing and Urban Development (HUD)
Department of State
Smithsonian Institution
National Aeronautics and Space Administration - NASA (headquarters in DC) and its Goddard Space Flight Center (in Greenbelt, MD)
National Geospatial-Intelligence Agency – NGA, formally known as NIMA (in Bethesda, MD and Navy Yard, DC)
National Oceanic and Atmospheric Administration - NOAA (headquarters in Silver Spring) under the Department of Commerce, and several operations
NOAA/Navy National Ice Center (Suitland, MD)
National Park Service (NPS)
Naval Research Laboratory – NRL (Washington, DC)
U. S. Army Topographic Engineering Center/U.S. Army Corps of Engineers
U. S. Department of Agriculture (USDA) & Forest Service
U. S. Environmental Protection Agency (EPA)
U. S. Geological Survey – USGS (Reston, VA)

These government agencies currently employ a large number of scientists with background in Geosciences, Earth Systems Science, Geography, GIS and Remote Sensing. Many of these agencies/institutions have employed our graduates and current part-time students. In addition, all local and state governments in the region also have a significant proportion of their employees with backgrounds in the areas covered by the degree program. Another characteristic in the capital region is the large number of non-government organizations that have adopted or are starting to adopt remote sensing and GIS. Among these is the National Geographic Society, which highlights the use of imageries and maps, and the support of geographic-related research.

In the private sector, several companies that are major players in the remote sensing industry in providing data are in this region. In addition, many large defense or IT consulting companies have divisions dedicated to remote sensing and GIS, and they have a strong presence in this region too. Below is a partial listing of these companies:

Boeing
Booz-Allen & Hamilton
Earthsat
Lockheed Martin
Mitre and Mitretek
Northrop Grumman
Orbital Science
Raytheon
SAIC

In addition, several large environmental consulting companies heavily utilize remote sensing and GIS in their projects. They include, among others, Dewberry & Davis and Michael Baker Co. These companies will benefit from this program by sending their employees to GMU to pursue this advanced degree.

The large number of scientists in the area will generate a high demand for further education and training, and thus the proposed program will meet their needs. They are highly motivated to pursue advanced degrees and training that will enhance their job prospects both in terms of retention and advancement. We are therefore quite confident that the demand for the proposed Ph.D. will increase significantly over the years. We have had personal interactions with the scientists and management in some of these companies regarding the proposed Ph.D. program, and the feedback we have received from them has been uniformly positive and encouraging.

3.2 Employment Demand for Graduates

Our research results on employment demand for graduates of the proposed program are mainly based on the Occupational Outlook Handbook compiled by the Bureau of Labor Statistics of the U.S. Department of Labor [http://www.bls.gov/oco/].

According to the Bureau of Labor Statistics Occupational Outlook Handbook, “(e)mployment of atmospheric scientists is projected to increase about as fast as the average for all occupations through 2010.” In addition, “(t)here will continue to be demand for atmospheric scientists to analyze and monitor the dispersion of pollutants into the air to ensure compliance with Federal environmental regulations outlined in the Clean Air Act of 1990.” However, “(j)ob opportunities for atmospheric scientists in private industry are expected to be better than in the Federal Government over the 2000-10 period,” and “employment increases are expected.” [http://www.bls.gov/oco/ocos051.htm#outlook] On the other hand, “(e)mployment of environmental scientists and hydrologists is expected to grow faster than the average for all occupations through 2010, while employment of geoscientists is expected to grow about as fast as the average” [http://www.bls.gov/oco/ocos050.htm#outlook]. According to the results of a survey by the American Geological Institute (AGI) published in the 2001 Report on the Status of Academic Geosciences Departments [http://www.earthscienceworld.org/careers/rsad2001.pdf], there is an increase of employment of Geosciences graduates in K-12 education and federal and state government. Among federal agencies, many job opportunities for the above category of employment are mostly found in NASA, NOAA, EPA, USGS, the Bureau of Land Management (BLM) and USDA Forest Service.
The growth in employment related to the use of images for map production or analysis is also expected. According to the Bureau of Labor Statistics, “(o)verall employment of surveyors, cartographers, photogrammetrists, and surveying technicians is expected to grow about as fast as the average for all occupations through the year 2010. The widespread availability and use of advanced technologies, such as GPS, GIS, and remote sensing, are increasing both the accuracy and productivity of survey, photogrammetric, and mapping work.” (http://www.bls.gov/oco/ocos040.htm#outlook) Also, the BLS report states that “(i)ncreasing demand for geographic data, as opposed to traditional surveying services, will mean better opportunities for cartographers and photogrammetrists involved in the development and use of geographic and land information systems,” and “nontraditional areas such as urban planning and natural resource exploration and mapping also should provide areas of employment growth, particularly with regard to producing maps for management of natural emergencies and updating maps with the newly available technology.” Major federal government employers in this category of jobs include NOAA, NGA, BLM, Federal Emergency Management Agency (FEMA), Census, and USGS.

While some scientists and specialists in the fields of remote sensing and GIS have training in physical sciences and Earth sciences, many of them do have an academic background in geography. Therefore, the job outlooks described above also cover partially the field of geography. On the other hand, in the BLS job classification, geographers are lumped together with other social scientists (anthropologists, archaeologists, historians, political scientists, and sociologists), and BLS reported that the employment for these social scientists is expected to grow about as fast as the average for all occupations through 2010 (http://www.bls.gov/oco/ocos054.htm). Some geographers will also be involved in urban planning types of occupations, and employment for urban planners shares the same trend with geographers in general and other social scientists.

A recent article published in *Nature* (Vol. 427, Jan 22, 2004, pp. 376-377) is a clear indication that combining expertise from Earth sciences/geography with Geoinformation sciences has great prospect. In short, we are very optimistic about the job prospect of graduates from the proposed Ph.D. program given the employment outlooks provided by BLS for Earth scientists, GIS-related professionals, remote sensing experts, and geographers.

### 3.3 Comparison with Other Programs in the Region and State

The proposed degree builds upon the linkages between Geosciences, Geography, Remote Sensing and GIS. While there are quite a few institutions in the region offering graduate programs related to these areas, the majority of them offers only master’s degrees (George Washington University, Georgetown University, Northern Virginia campus of Virginia Tech, and University of Maryland Baltimore County). Given the interdisciplinary nature and structure of the proposed Ph. D. degree, there is no program identical to ours in the Mid-Atlantic region or in the entire country. Both the Earth System Science Center at Penn State (http://www.essc.psu.edu/) and the Earth System Science Interdisciplinary Center at the University of Maryland at College Park
are closest to ours in terms of research focus. Another is the Institute for Computational Earth System Science at the University of California at Santa Barbara. All these centers have research emphases in both Earth Systems Science and Geography, involve both Geoscientists and geographers, rely on remote sensing and GIS as the tools, but all these entities are research centers that do not offer academic degree programs. The types of Ph. D. degree programs most similar to the proposed one are likely in Geography and Earth Systems Sciences, and possibly Geosciences.

There is no Geography Ph.D. program in the Commonwealth of Virginia, and the institutions offering the Ph.D. in Geography closest to Northern Virginia include the University of Maryland at College Park and Johns Hopkins University in Baltimore. Going a bit further will includes West Virginia University in Morgantown, Penn State University, and Rutgers University. Most of these Ph.D. programs, as with many other Ph.D. programs in Geography nationwide include some aspects of the tools in remote sensing and GIS. Certain aspects of the Geosystems may also be covered. But none has clear emphases in these areas within the program. For instance, the one in West Virginia University can be regarded as a typical curriculum model for Geography. The one closest and most similar to ours in this region is in the University of Maryland. The Ph. D. in Geography at Maryland possesses the characteristics of a typical Geography Ph. D. program, but it has the additional strength of a remote sensing emphasis on land surface processes, the biosphere and environmental issues. The atmospheric component of Geosciences, however, resides in the Department of Meteorology instead, while the hydrosphere and lithosphere are less emphasized.

In terms of Ph.D. program in Geosciences or Earth Systems Sciences, there are hardly any institutions offering Ph.D. programs in ESS though there are many master’s level programs in ESS, including the one at GMU. The only Ph.D. Earth Systems Science program we can identify is the one at the University of California at Irvine. While this degree program focuses on the understanding of the Earth as a coupled system of atmosphere, ocean and land, it does not rely on the Geoinformation tools in remote sensing and GIS. There are many Geosciences Ph.D. programs nationwide, but the majority of them focus on geological science, and very few organize their curriculum structure like ours according to the NSF Geosciences divisions of atmospheric, Earth and ocean.

In short, the proposed degree does serve a niche in the region, and for the Commonwealth, especially for students who have the desire to pursue a Ph.D. degree in the general areas of Earth Systems and Geoinformation Sciences. As stated before, this is a unique emphasis not found in more traditional programs at the other universities in Commonwealth and in the region.

3.4 Projected Enrollment
With the expectation that the Ph. D. may be approved as early as late spring or early fall of 2004, the first batch of new students will not enroll until spring of 2005. As the major influx of new students occurs in the fall, we expect that the increase in fall 2005 applications will mark the first wave of new students. Given that we currently have close to 50 Ph.D. students in the Earth Observing/Remote Sensing area of concentration with about 30 full-time students, our projected enrollment starting in the Fall of 2005 will use these numbers as the base-line figures. We do expect the demand for full-time enrollment will increase tremendously, as we have already experienced a significant increase in the past several semesters, but unfortunately accepting full-time students has to be backed up by funding support, which is minimally provided by the Commonwealth/University. Therefore, we do not expect that we can accommodate the surging demand for full-time enrollment, and thus the slow-growth enrollment projection for full-time students below is based upon this financial constraint. Below are projected numbers of students enrolling in the proposed program based upon a variety of factors. Please note that the full-time student numbers are the numbers we can admit constrained by the financial support, while the actual numbers of applications will be much higher.

Projected Enrollment

<table>
<thead>
<tr>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Target Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRADS</td>
<td>GRADS</td>
<td>GRADS</td>
<td>GRADS</td>
<td>GRADS</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>HDCT</td>
<td>FTES</td>
<td>HDCT</td>
<td>FTES</td>
<td>HDCT</td>
</tr>
<tr>
<td>54*</td>
<td>38</td>
<td>60</td>
<td>41</td>
<td>68</td>
</tr>
</tbody>
</table>

**Definitions:** HDCT—fall headcount enrollment, FTES—annual full-time equated student enrollment, GRADS—annual number of graduates of the proposed program

Some additional detail on the breakdown between full- and part-time students is provided in the table below.

<table>
<thead>
<tr>
<th></th>
<th>Fall 05</th>
<th>Fall 06</th>
<th>Fall 07</th>
<th>Fall 08</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full-time</td>
<td>30*</td>
<td>32</td>
<td>34</td>
<td>34</td>
</tr>
<tr>
<td>Part-time</td>
<td>24</td>
<td>28</td>
<td>34</td>
<td>38</td>
</tr>
</tbody>
</table>

* The initial headcount of 30 represents 26 continuing CSI Ph.D. students currently in Earth Observing area + 4 new students.

The graduates in years 1, 2, and 3 represent students who are already enrolled in the CSI Ph.D. program in the Earth Observing/Remote Sensing area of concentration, with the
expectation that most of them will switch over to the new program when it becomes available.

In the long run, we would like to have a substantial number of part-time students. From the academic or intellectual perspective, it is desirable to have a higher proportion of full-time students. Also, without additional resources for student support and new faculty positions, the size of the program will be limited. As we proceed, we will need to identify the optimal numbers of students being admitted to the program given the size of the faculty body, the amount of student financial support, and the rate of graduation.

4. PROGRAM RESOURCE NEEDS

4.1 Available Resources

Faculty

The new Ph.D. program proposed here will be fully supported by the existing body of faculty currently teaching courses for students in the Earth Observing/Remote Sensing area of concentration in the CSI doctoral program. The Earth Systems and Geoinformation Sciences (ESGS) Program in the School of Computational Sciences has a large faculty body to support all concentrations in the proposed degree. All faculty members and most research scientists in ESGS will be involved in the instructional activities supporting the proposed program. In addition, some faculty members in Geography, Environmental Science and Policy, and School of Public Policy will also be involved in the instructional activities related to the new program. Their names and the concentration(s) they will support are listed below:

Earth Systems and Geoinformation Sciences (SCS):
Sheryl Beach (GSC, GEOG)
Zafer Boybeyi (GSC)
Long Chiu (GSC, RS)
Liping Di (GSC, GEOG, RS, GIS)
Richard Gomez (GSC, RS)
Yimin Ji (GSC, RS)
Menas Kafatos (GSC, RS)
John Qu (GSC, RS)
William Roper (GSC, RS, GIS)
Michael Summers (GSC)
George Taylor (GSC, GEOG)
David Wong (GEOG, GIS)
Kent Wood (GSC, RS)
Phil (Chaowei) Yang (RS, GIS)
Ruixin Yang (GSC, RS)
Wenli Yang (GSC, GEOG, RS)

Geography (CAS):
At the start, existing faculty across the campus will be adequate to support the proposed degree. As the number of students increases when the program develops, more faculty lines will be desirable, especially in filling the gaps in certain areas, such as the integration of atmospheric science with Geoinformatics.

### Equipment, Physical Space, and Other Resources

Graduate students in the proposed degree program will have accessed to a Remote Sensing/GIS lab located in the basement of D. King Hall. The lab is equipped with Window-based PCs with both GIS and Remote Sensing packages, including ENVI and IDL accessible from all machines, a limited number of ERDAS/IMAGINE licenses, and a lab license for the Virtual Learning Systems software package for image processing / feature extraction working within ArcGIS. The Center of Earth Observing and Space Research (CEOSR), a research center to which all ESGS faculty and students belong, also operates a HRPT antenna which can download several types of remote sensing data from satellites. These data will be available to students and for instruction use.

As most of the current students in the Earth Observing/Remote Sensing area of concentration are full-time Ph. D. students, and the above facilities are mainly to support
research activities, the current computing environment and equipment have been used to support the instructional needs of those students. Given the expectation that the number of part-time students will increase significantly a few years after the new program is established, the new program will require a dedicated GIS/RS lab to support the instructional needs of a large part-time student body in addition to full-time students.

4.2 Sources of Funds

The current resources in terms of faculty and computing facilities are adequate to start the proposed program. As the demand for enrollment increases, the program will be under pressure to accept more students even after raising the standard of admissions. Eventually, the program may have to turn away competitive students, both part-time and full-time, and may not fulfill the education mission of a public university in the Commonwealth. In order to avoid this possible undesirable situation, additional resources will be necessary in the medium and long term.

Graduate Research Assistantships

ESGS research activities have generated ample funding resources to support students. From July 1, 2002 to June 30, 2003, ESGS faculty members have brought in an additional of $7.8M of funding. Among this amount includes projects such as JIESIC, VAaccess, and research projects in Laboratory for Advanced Information Technology and Standards (LAITS) and Comprehensive Atmospheric Modeling Program (CAMP). With these research activities, we are currently supporting thirty (30) students in total, 25 of which are funded through research grants with a total stipend amount of approximately $125K, and 5 others funded through SCS-Index-9 account.

Given the above situation, the role of the Commonwealth in supporting students in the program is minimal. It is true that by increasing the capacity of funded research we can bring in more resources to support more full-time students. While ESGS has 9 faculty members holding tenure or tenure-track appointments, the Program has less than 6 FTEs supported by the State. Even though the already research-heavy ESGS faculty members may seek more external funding support to bring in more students, their research commitment will not allow them to increase their participations in instructional activities. Their increases in research commitment will also constrain the admission of part-time students who do not need funding support, but definitely need the instructional involvement of faculty. On the positive side, the additional faculty provided by the cooperating GMU units (ESP, GEOG, SPP) will increase the grant capacity above that which would be provided by SCS alone.

Given the above situation, additional state-funded fellowships or assistantships (research or teaching) are necessary to maintain the Program with faculty well-balanced in research and instruction. Currently, there are no fixed numbers of fellowships and assistantships allocated to ESGS from SCS. In the future, it is desirable that the Program will receive a fixed number of fellowships and assistantships to provide a stable stream of full-time student support in addition to the resources from research funding.
The current mix of faculty composition is adequate to support the proposed program with a reasonable balance among the concentrations. However, to increase more research funding to support students and to accommodate the expected large number of part-time students, it is necessary to increase the number of faculty positions, preferably in areas that can produce synergy among existing faculty. These areas include the intersection of Geosciences and Geoinformation, especially in merging the expertise in atmospheric science or biosphere with GIS and remote sensing.
APPENDIX I: Catalog Descriptions of Existing Courses

EOS 600 Communication Skills for Computational Scientists (1:2:0). Prerequisites: Graduate standing. This course helps students develop a basic set of essential skills for scientific communication and for the delivery of successful and informative oral presentations, with a focus on both scientific meetings and more general public presentations. The course also encourages students to develop and exercise scientific writing skills as applied to abstracts, manuscripts, and grants. The objectives of the course are met through a combination of activities, including practical writing assignments, training in composing grants for extramural competition, and advice in developing and delivering oral presentations.

EOS 721 Biogeography (3:3:0). Prerequisites: Courses in ecology, chemistry, and geology. Provides the student with a broad understanding of how physical geography and the environment influence the spatial and temporal distribution of plants and animals on the surface of the Earth.

EOS 722 Regional and Global Issues in the Earth Sciences (3:3:0). Prerequisites: Courses in ecology, chemistry, and physics. This course provides the student with a basis for evaluating existing and emerging issues in the Earth sciences at the regional and global scale, utilizing interdisciplinary scientific principles.

EOS 740 Hyperspectral Imaging Systems (3:3:0). Prerequisites: CSI 660 or equivalent, or permission of instructor. This course provides the requisite materials to understand hyperspectral imaging technology and its many civilian and military applications. The emphasis is on the scientific principles involved and the application of the technology to real-world imaging systems. Topics covered include hyperspectral concepts and system tradeoffs; data collection systems; calibration techniques; data processing techniques and software; classification methods; and case studies. The data processing techniques covered include N-dimensional space; scatterplots; spectral angle mapping; spectral mixture analysis; spectral matching; mixture tuned matched filtering; and other techniques. Ground, airborne, and spaceborne hyperspectral remote sensing systems are discussed.

EOS 753 Observations of the Earth and its Climate (3:3:0). Prerequisites: CSI 660 or an introductory remote sensing course; environmental science, space science, physics, or chemistry undergraduate background; or permission of instructor. Provides the requisite material to understand techniques of remote sensing and other observational methods as applicable to Earth science and global change. Surveys methodologies and their applications, including a systematic study of how each part of the electromagnetic spectrum is used to gather data about Earth. Describes limitations imposed by satellite engineering, sensor limitations on data gathering, and a survey of data reduction specific to remote sensing applications. Also covers current research issues, including examples pertaining to the atmosphere, land masses, and oceans. Includes discussions of current efforts by agencies such as NASA and NOAA to provide integrated data gathering and dissemination systems.
*Prerequisite: EOS 753 or permission of instructor.* Covers how to access and apply Earth observations/remote sensing data for Earth system science research and applications. Major topics are data formats, analysis and visualization tools, advanced data analysis methods, and data applications. The course also covers combining innovative information technology techniques and Earth science data to set up online data centers for web users to be able to access data through the web.

*Prerequisites: EOS 753 or permission of instructor.* This course emphasizes the fundamental physical and mathematical principles of remote sensing. It also provides an overview of the current Earth Observation System (EOS), as well as the National Polar-Orbiting Operational Environmental Satellite Systems (NPOESS), and the NPOESS Preparatory Project (NPP) missions.

*Prerequisite: EOS 753 or permission of instructor.* Covers retrieval, analysis, and application of geophysical parameters derived from remotely sensed data for Earth system research and applications. Includes theory of visible/infrared and microwave remote sensing, heritage sensors, sensor calibration, retrieval algorithms, validation, and error estimates.

*Prerequisites: EOS 753, GEOG 579, or permission of instructor.* This course introduces students to the fundamental concepts underlying the digital processing of remote sensing imagery. Topics of the course will include radiometric and geometric corrections, image enhancement, transformation, segmentation, and classification. Feature extraction may also be included.

EOS 760 Remote Sensing Applications (3:3:0). 
*Prerequisites: EOS 753 or GEOG 580.* This course focuses on the applications of remote sensing in various important areas of Earth systems science, such as analysis of the surface radiation budget, land cover, inland/coastal waterways, and soil moisture. Algorithms/techniques and examples are discussed in detail.

EOS 771 Algorithms and Modeling in GIS (3:3:0). 
*Prerequisites: Prior course or experience in GIS and computer programming experience.* This course examines several fundamental GIS algorithms based upon computational geometry and computer graphics. It will also discuss issues in modeling features of different dimensions and surfaces in GIS. Significant programming is expected.

EOS 772 Distributed Geographic Information Systems (3:3:0). 
*Prerequisites: An introductory course in GIS and some programming experience, or permission of instructor.* This course examines different aspects of science and technology in the context of distributed GIS. Issues included are general concepts, architecture, component
design, component development, and system integration as well as other advanced topics, such interoperability and agent-based GIS.

**EOS 773 Interoperability of Geographic Information Systems (3:3:0).** *Prerequisites: EOS 754 and GEOG 553 or a course in GIS.* This advanced course addresses theories, standards, and implementations of Web-based interoperable geographic information systems for on-line data and information services. International standards, including OGC, and associated tools for interoperability will be reviewed in detail.

**EOS 791 Advanced Spatial Statistics (3:3:0).** *Prerequisites GEOG 585 or STAT 535/554, or permission of instructor.* This advanced course focuses on analyzing georeferenced or spatial data represented as points or polygons. Higher moments, point pattern analyses, and interpolations of points to surfaces will be addressed. Spatial regression will also be included.

**EOS 840 Hyperspectral Imaging Applications (3:3:0).** *Prerequisites: CSI 660 or equivalent, or permission of instructor.* Introduces advanced hyperspectral imaging and multi-sensor concepts with emphasis on real-world civilian and military applications. Topics covered include advanced hyperspectral concepts, multi-system tradeoffs, data collection and processing systems, imaging radar systems, laser systems, calibration techniques, data fusion, quantitative remote sensing techniques, data compression techniques, case studies, and U.S national policy. Applications and case studies will include environmental, homeland security, medical, military, disaster mitigation, agricultural, and transportation.
APPENDIX II: Catalog Descriptions of New Courses

**EOS 704 Spatial Analysis and Modeling of Population (3:3:0).** *Prerequisites:* Courses in quantitative methods and GIS are preferred. An intermediate level population geography course discussing demographic concepts and spatial dimension of population. Various indices, measures and models commonly used in human geography will be the focus.

**EOS 725 Advanced Hydrosphere (3:3:0).** *Prerequisites:* Two semesters of calculus (partial differential equations recommended) or permission of instructor. This course uses mathematical and modeling approaches to present students with an in-depth study of the different components and transfer processes operative within the hydrosphere. Topics covered include the transfer processes relevant for oceans, lakes, rivers, snow, ice, glaciers, soil moisture, ground water, and atmospheric water vapor.

**EOS 855 Introduction to Mesoscale Atmospheric Modeling (3:3:0).** *Prerequisites:* permission of instructor. Introduction to the physical and numerical modeling issues involved in mesoscale atmospheric flows. These flows involve time and space scales associated with the diurnal cycle, the atmospheric inertial mode, thermal and mechanical forcing due to mesoscale terrain inhomogeneities, mesoscale precipitation systems, and downscale energy transfer from the synoptic scale to the mesoscale due to nonlinear flow interactions.

**EOS 900 Colloquium in Earth Systems and Geoinformation Sciences (1:1:0).** *Prerequisites:* graduate standing. Presentations in specific research areas of Earth Systems and Geoinformation Sciences by School of Computational Sciences faculty and staff members, GMU faculty in related programs, and professional visitors. May be repeated for credit; however, a maximum of three credits may be applied toward the Earth Systems and Geoinformation Sciences Ph.D.

**EOS 998 Doctoral Dissertation Proposal (1-12:0:0).** *Prerequisites:* permission of instructor. Covers development of a research proposal, which forms the basis for a doctoral dissertation, under the guidance of a dissertation director and the doctoral committee. May be repeated as needed; however, no more than 12 credits of EOS 998 may be applied toward satisfying doctoral degree requirements.

**EOS 999 Doctoral Dissertation (1-12:0:0).** *Prerequisites:* Admission to doctoral candidacy. Doctoral dissertation research under the direction of the dissertation advisor. May be repeated as needed; however, no more than a total of 24 credits in EOS 998 and 999 may be applied toward satisfying doctoral degree requirements.