GEORGE MASON UNIVERSITY
Graduate Council NEW Certificate, Concentration, Track or Degree Program
Coordination/Approval Form

(Please complete this form and attach any related materials. Forward it as an email attachment to the Secretary of the Graduate Council. A printed copy of the form with signatures should be brought to the Graduate Council Meeting. If no coordination with other units is requires, simply indicate “None” on the form.

Title of Program/Certificate: Remote Sensing and Image Processing

Level (Masters/Ph.D.): Graduate Certificate

Please Indicate: _____ Program _____ Certificate ____X____ Concentration _____ Track

Description of certificate, concentration or degree program:
Please attach a description of the new certificate or concentration. Attach Course Inventory Forms for each new or modified course included in the program. For new degree programs, please attach the SCHEV Program Proposal submission.

Please list the contact person for this new certificate, concentration, track or program for incoming students:

Peter A. Becker, Associate Dean for Graduate Studies, School of Computational Sciences

Approval from other units:

Please list those units outside of your own who may be affected by this new program. Each of these units must approve this change prior to its being submitted to the Graduate Council for approval.

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Submitted by: Peter A. Becker
Email: pbecker@gmu.edu

Graduate Council approval: ______________________________ Date: _____________

Graduate Council representative: ________________________ Date: _____________

Provost Office representative: ___________________________ Date: _____________
Graduate Certificate in Remote Sensing and Image Processing
(with differential/premium tuition rate)

Table of Contents

1. Executive Summary 4
2. Description of Proposed Graduate Certificate 4
   2.1. Mission and Objective 4
   2.2. Administrative Structure 5
   2.3. Admission Requirements 5
   2.4. Curriculum Requirements 5
   2.5. Relationship to Other GMU Programs 6
3. Justification for Proposed Graduate Certificate 7
   3.1. Student Demand 7
   3.2. Employer Demand for Graduates 8
   3.3. Comparison with Other Programs in the Region and Commonwealth 9
   3.4. Projected Enrollment 10
   3.5. Differential Tuition Rate 10
4. Resource Needs 11
   4.1. Faculty 11
   4.2. Equipment and Computing Environment 11

Appendix I: Catalog Descriptions of Existing Courses 13

Appendix II: Catalog Descriptions of New Courses 14
1. Executive Summary

Because of the enormous increase in the availability and utilization of remotely sensed data related to the Earth, the School of Computational Sciences (SCS) proposes this graduate certificate in Remote Sensing and Image Processing (RSIP) to meet the needs of prospective students, area employers, and society at large. The RSIP certificate requires students to complete a set of 15-credit hours of SCS graduate courses. Ideal candidates for this certificate are those who have a background in Earth and environmental sciences, and are either currently working in or intend to enter into the field of remote sensing, Earth observing, or image processing. We believe that the RSIP certificate will prove very attractive to students who are interested in advancing their career goals, but who may not have adequate time available to undertake a graduate degree program. The 15-credit certificate is based upon the set of core courses currently supporting the Earth Observing/Remote Sensing area of concentration within the Computational Sciences and Informatics (CSI) Ph.D. program, along with a set of elective courses. Students completing the RSIP certificate will receive the most up-to-date advanced remote sensing and Earth observing education available in the region. Completion of the certificate will enhance the careers of those students who are already working in this area, and can also serve as a useful intermediate step towards later enrollment in the Earth Systems Science (ESS) M.S. degree program, and/or the CSI doctoral program.

2. Description of Proposed Graduate Certificate

2.1 Mission and Objectives

The general area of remote sensing, Earth observing, and image processing is one of the most rapidly developing scientific disciplines, reflecting the fundamental need for a vastly improved human understanding of the complex, interconnected web of Earth cycles and processes, and the possible adverse effects caused by human intervention.

In recent years, this effort has greatly benefited from an enormous influx of resources dedicated to research, development, education, and implementation provided both by government agencies and the private sector. The government agency in the U.S. leading this effort is NASA, but NOAA plays an equally important role, and NRL is also a significant player. In the private sector, remote sensing is a booming industry, with many companies focusing exclusively on remote sensing (e.g., Orbital Science and EarthSat). Some relatively large technology companies have also established internal units dedicated to remote sensing, such as Boeing, SAIC, and Northrop Grumman. The quantity of remote sensing data archived and available for analysis and interpretation is increasing at an exponential rate, creating enormous demand for qualified scientists and data analysts. Further progress in the utilization of this valuable and expensive data to improve human understanding of Earth systems depends on the availability of these trained experts.

The primary mission of the proposed graduate certificate in Remote Sensing and Image Processing is to equip students to meet the needs of society by working in the rapidly developing remote sensing industry. With this certificate, we intend to provide advanced and up-to-date training for students currently working in this field who would like to enhance their skills in this area and acquire the latest knowledge in remote sensing technology. Some of the potential students may be those who would like to enter this field of work, and may have some prior training, but do not yet have an in-depth educational background, training and skills. In other words, this certificate will help to “re-
train" the workforce to meet the new challenges in the area of Remote Sensing/Earth Observing, and to prepare the population for the job market in this area.

2.2 Administrative Structure

The Certificate will be administered by the Earth Systems and Geoinformation Sciences (ESGS) Program within SCS. Currently, faculty members in ESGS oversee the Earth observing area of concentration in the CSI Ph.D. program, as well as the Earth Systems Science M.S. program. For this certificate, a Certificate Coordinator, who will be an ESGS faculty member designated by the Program Chair, will direct the administration of the proposed certificate. The Coordinator will supervise the admission of students into the program, monitor student progress, advise the students, promote the certificate, and coordinate course offerings. The mechanics of the admission process (i.e., application processing, student record control, etc.) will be handled centrally by SCS. Thus, the Certificate Coordinator will work closely with SCS admissions staff and also with the Associate Dean for Graduate Studies on admission issues and processes.

2.3 Admission Requirements

Applicants to this graduate certificate program should hold a B.A. or B.S. degree in a discipline related to the science and applications of remote sensing from an accredited university, with a minimum GPA of 3.000. Applications will be processed by the SCS administrative office. Applicants must submit a completed GMU graduate application, along with official transcripts, resume, VA domicile classification form, and TOEFL scores if they are foreign nationals. GRE scores and letters of recommendation are not required. Applicants should have some priori education or training in remote sensing and/or image processing. Students with a background in one of the physical science areas (physics, chemistry, atmospheric science, hydrology, or geology), geography, or environmental science will be particularly well suited to undertake this certificate program. Applicants should have undergraduate backgrounds that include courses in differential and integral calculus, and they should possess working knowledge of a computer programming language. Depending on the background of the individual student, the Coordinator may recommend remedial or preparatory courses tailored to student’s needs. Students may not pursue this certificate concurrent with any other graduate degree programs or certificates offered by SCS (because this certificate will charge students a differential tuition rate). However, students enrolled in academic programs outside SCS may enroll in this certificate program concurrently. Students may transfer no more than 3 credit hours into the certificate program with the approval of the Certificate Coordinator or Program Chair.

2.4 Curriculum Requirements

The Remote Sensing and Image Processing certificate requires a total of 15 credit hours, or 5 courses. Students are required to take four core courses. The fifth one can be selected from the set of electives indicated below. Catalog descriptions of the existing and new courses are provided in Appendices I and II, respectively.

Required Core Courses:

   EOS 740 Hyperspectral Imaging Systems
EOS 753 Observations of the Earth and its Climate
EOS 757 Techniques and Algorithms in Earth Observing and Remote Sensing
EOS 758 Digital Processing of Remote Sensing Imagery (new course)

Elective Course (one of the following, or another course approved by Coordinator):

EOS 754 Earth Observing/Remote Sensing Data and Data Systems
EOS 756 Physical Principles of Remote Sensing (new course)
EOS 760 Remote Sensing Applications (new course)
EOS 840 Hyperspectral Imaging Applications

Upon completion of the RSIP certificate, students will be encouraged to continue their education by applying for admission into the ESS M.S. program or the CSI Ph.D. program.

2.5 Relationship to other GMU Programs

No comparable certificate program is currently being offered at GMU. The most similar existing certificate program is the Certificate in Signal Processing offered by the Department of Electrical and Computer Engineering. Although this existing certificate has a small amount of overlap with the proposed one in terms of a single topic (image processing), it is in fact quite different in terms of approach, emphasis, and content. The Certificate in Signal Processing is narrowly focused on image and signal processing, but it does not include any aspect of Earth observing or scientific data analysis. The approach adopted in that certificate is geared toward engineers rather than Earth or environmental scientists. Little time is spent on the interpretation of images related to the Earth’s surface or the physical or environmental phenomena and related issues. The proposed certificate is broader and more application-oriented in the sense that it focuses on the use of remote sensing technology to enhance our understanding of the Earth.

At GMU, several degree programs provide some formal training and course work related to remote sensing, Earth observing, and image processing currently, but no certificate program is designed specifically to meet the mission and objectives of the proposed certificate. In SCS, the Earth Observing/Remote Sensing area of concentration with the CSI Ph.D. program offers a series of remote sensing courses. These courses form the bases of the proposed graduate certificate. Students pursuing the Ph.D. in Computational Sciences in this track are required to take additional courses in Earth sciences and computational sciences.

The M.S. in Earth Systems Science (ESS), jointly managed by ESGS in SCS and ESP/GEOG in CAS, also requires students to take remote sensing related courses, but these courses are only a subset of the courses offered for the proposed certificate. The M.S. in ESS also requires students to take several core courses in Earth systems science. Both the Ph.D. in Computational Sciences and M.S. in ESS are formal graduate degree programs which require significant commitment from the students in terms of resources and time, and both include certain aspects of Earth sciences in addition to remote sensing.

The Department of Geography in CAS also offers some remote sensing courses, but the degrees offered are undergraduate degrees in Geography and M.S. in Geographic and Cartographic Sciences
(GECA). These degrees do not exclusively focused on remote sensing, and include significantly portions focused on other aspects of geography.

Students finishing the certificate proposed here may choose to pursue one of the remote sensing-related graduate degrees mentioned above. Courses completed for the certificate will be completely counted toward the CSI Ph.D. degree in the Earth Observing/Remote Sensing area of concentration and most of these courses will also be counted toward the M.S. in ESS. Some courses may also be apply toward the M.S. in GECA.

3. Justification for Proposed Graduate Certificate

3.1 Student Demand

Our research on student demand for this certificate is based upon our first-hand knowledge of the remote sensing industry and the related workforce in the Washington, D.C. metropolitan area, and also on the nation-wide development trend in remote sensing/Earth observing training, which will be addressed in more detailed in section 3.3. The Washington, D.C. region (including counties in Maryland and Virginia) probably has the highest concentration in the nation of remote sensing professionals and the highest demand in the nation for such professionals in both the government and private sectors.

The large number of employees at these organizations will provide a steady supply of students for enrollment in the proposed certificate program.

Below is a partial list of Federal government agencies and establishments with a large presence in the D.C. area either in terms of producing remote sensing data or heavily utilizing remote sensing data:

- NASA (headquarter in DC) and its Goddard Space Flight Center (in Greenbelt)
- NOAA (headquarter in Silver Spring) and several operations, including the National Ice Center within the DC metro area (Suitland, MD)
- Naval Research Laboratory (Washington, DC)
- NIMA (in Bethesda, MD and Navy Yard, DC)
- U.S. Army Topographic Engineering Center/U.S. Army Corps of Engineers
- USGS (Reston)
- CIA (Langley)
- U.S. EPA
- USDA/Forest Service

These government agencies currently employ a large number of remote sensing professionals and scientists. Some of these employees have been in the workforce for a significant period of time, and may greatly benefit from the re-training possibility offered by the proposed certificate. As the use of remote sensing in military and civilian applications will continue to grow, students who are not currently working in this field may wish to increase their chances of being hired by these agencies by completing our proposed certificate.
In the private sector, several companies that are major players in the remote sensing industry are located in this region. These include many large defense, IT, or environmental consulting companies. Below is a partial listing of these companies:

- Orbital Science (Dulles)
- EarthSat (Rockville)
- Northrop Grumman
- Raytheon
- SAIC
- Boeing
- Dewberry & Davis
- Michael Baker Corporation

The companies listed above, and many others, will likely send their employees to GMU to pursue advanced training in the science and technology/applications of remote sensing in order to support the growth of their businesses. The existence of this certificate will allow them to hire graduates with environmental or Earth science backgrounds, and then send them to GMU for advanced remote sensing training.

We have personal contacts with some of these companies via our faculty and alumni, and it is quite clear that these companies are eager to take advantage of such a locally provided certificate program to enhance the skills of their current employees, and to equip qualified remote sensing professionals and scientists to be employed by their companies.

### 3.2 Employer Demand for Graduates

The students interested in the certificate will likely have backgrounds in Earth science, such as geology, atmospheric science, oceanography, and hydrology. Some others may have a background in environmental science and geography. It is likely that a number of them may already have some formal training in Geographic Information Systems (GIS), cartography, and photogrammetry. We expect that our graduates from this certificate will be classified as Earth scientists or professionals in the mapping and surveying areas, as there is no formal category for remote sensing scientist in the labor market. But our graduates will have an edge over other Earth scientists or mapping professionals because they are also equipped with remote sensing, Earth observing, and image processing expertise. Therefore, in our assessment of employment demand, we focus on the categories of Earth scientists and mapping professionals.

According to the Bureau of Labor Statistics, “…employment of environmental scientists and hydrologists is expected to grow faster than the average for all occupations through 2010.” (http://www.bls.gov/oco/ocos050.htm#outlook). Furthermore, according to the results of a survey by the American Geological Institute published in the 2001 Report on the Status of Academic Geoscience Departments (http://www.earthscienceworld.org/careers/rsad2001.pdf), there is an anticipated increase in employment of Geoscience 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, BLM and USFS.
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, “…increasing 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, NIMA, BLM, FEMA, and USGS.

In short, we are very optimistic about the job prospect of graduates from the proposed certificate program given the development trends in the labor market for Earth scientists and mapping professionals with remote sensing, Earth observing, and image processing expertise.

3.3 Comparison with Other Programs in the Region and the Commonwealth

While the demand for remote sensing professionals in this region and nationwide is relatively high and on the rise, most professionals receive education and training through formal degree programs, which require significant commitment of one’s time and resources. Little is available in post-graduate training beyond the traditional degree programs. The proposed graduate certificate therefore serves a special niche in meeting the needs of remote sensing professionals in this geographic area, and potentially for the nation.

The only non-degree certification in the region that is somewhat related to the proposed certificate is the voluntary certification program for photogrammetrists overseen by the American Society for Photogrammetry and Remote Sensing. To qualify for this certification, photogrammetrists must meet work experience standards and pass an oral or written examination. Apparently, this is a professional certification, but not an education program. It is limited to photogrammetrists, but not broadly applicable to remote sensing professionals and scientists.

We performed a survey on the Internet to identify programs in the Washington, D.C. area similar to the one we propose here. The institutions included in this survey were Georgetown University (GU), George Washington University (GWU), Northern Virginia campus of Virginia Tech (VT), University of Maryland at College Park (UMCP), and University of Maryland Baltimore County (UMBC).

We found no existing programs in Georgetown University similar to the proposed one. In the VT Northern Virginia campus, the Civil and Environmental Engineering Department offers a set of certificates (http://www.nvge.vt.edu/engineering/CEECertificate1.htm), some of which include remote sensing and GIS courses. But all of them focus on specific civil and structural engineering issues and none of them focus on using remote sensing techniques for Earth observing. In the Computer Science/Electrical Engineering Department, VT offers an M.S. in Electrical Engineering in Communication and Signal Processing, which includes courses mainly in signal and image processing, with no emphasis on remote sensing and Earth observing (http://www.csee.umbc.edu/~graddir/CSEE/). In addition, they approach the image processing from an engineering perspective, which is quite different from the Earth science perspective.
In GWU, the Department of Civil and Environmental Engineering (www.cee.seas.gwu.edu) used to have a strong focus in remote sensing and GIS, but the program has been discontinued. The Department of Earth and Environmental Sciences is rather a traditional geological science department with little interest in remote sensing and related technology (http://www.gwu.edu/~geology/). The Department of Geography (http://www.gwu.edu/~geog) offers degrees in Geography, but remote sensing is not a focus and no certificate in related areas exists.

At UMCP, both the Department of Geography and Department of Meteorology have strong remote sensing-related programs. In addition to the M.S. and Ph.D. degrees, the Geography Department (http://www.geog.umd.edu/) also offers a Citation Program in Geographic Information Science, which is an undergraduate certificate program (http://www.geog.umd.edu/academic/undergrad/giscit.html). Similarly, the Department of Meteorology at UMCP offers formal graduate degree programs in meteorology with strong emphasis in remote sensing and Earth observing. The department also offers three citation programs, but all at the undergraduate level (http://www.atmos.umd.edu/education/citation.html). No certificate or citation program is offered at the graduate level.

3.4 Projected Enrollment

With the expectation that the certificate will be approved and in place for Fall 2004, the enrollment in the initial year will likely be low, but the number will increase quickly when the news about the availability of the certificate spread throughout the local remote sensing community. Below are some projected figures for the number of students enrolling in the certificate program:

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<th>Fall 2005</th>
<th>Fall 2006</th>
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<td>3</td>
<td>8</td>
<td>13</td>
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In long run, we would like to keep the enrollment of the certificate between 15 and 18, approximately half the size of our Ph.D. student body. We expect that students enrolling in the certificate will be primarily part time students, and therefore they will take only one to two courses per semester. Consequently, on average, a student will complete the certificate program in about two years.

3.5 Differential Tuition Rate

We propose that the graduate certificate will charge students at a differential (premium) tuition rate, with an additional $100 per credit hour added to the standard GMU graduate tuition for students who enroll in this certificate program (regardless of in-state or out-of-state status). The additional $100 per credit hour (with $75 returned to SCS) will be used to support continuing improvements in the computational facilities described below, which will be heavily utilized by Certificate students. Based on standard GMU tuition for the AY 2003-2004, in-state graduate students in the certificate program will therefore pay $345/credit hour and out-state students will pay $723/credit hour. When our tuition is compared with private institutions in the area, our rates are quite competitive. For instance, graduate students at George Washington University (GWU) are charged $810 per credit hour, and in Georgetown University, the rate is $993 per credit hour.
Organizations and vendors offering remote sensing courses often charge premium tuition, in the format of a professional training course. For instance, Research System Inc. offers two image processing training courses using its software ENVI. Each of the 4-day training course costs $1,088. Another vendor, Leica Geosystems, provides trainings on ERDAS/IMAGINE in the Washington DC area at a rate of $700 for the two-day course and $1,050 for the three-day course. During the American Meteorological Society annual meeting, the AMS may charge as high as $325 for a one-day short course on Satellite Data Assimilation. Given the information collected above, we believe that the differential tuition rates we suggest are very competitive with various commercial programs. As stated above, the rationale for the differential tuition is that the portion returned to SCS will help to fund the continued improvement in the underlying computational facilities and related infrastructure required to support the certificate program.

4. Resource Needs

4.1 Faculty

The Earth Systems and Geoinformation Sciences (ESGS) Program in the School of Computational Sciences has a relatively large faculty body with 13 full-time faculty involved in instruction (although only six will be needed to teach courses supporting the proposed certificate). These primary faculty members supporting the certificate and their respective courses are:

Menas Kafatos (EOS 753)
Long Chiu (EOS 757)
Richard Gomez (EOS 740, 840)
Wenli Yang (EOS 758, 760)
Ruixin Yang (EOS 754)
John Qu (EOS 756)

In addition, we have several other faculty members and the Program Chair to serve potentially as the Coordinator of the certificate program. We do not expect that any additional faculty will be necessary to support the instructional and administration functions of this proposed certificate.

4.2 Equipment and Computing Environment

In addition to the general computing facilities provided by SCS and GMU, graduate students in the Earth Systems and Geoinformation Sciences Program in SCS also have access to Remote Sensing/GIS computational facilities located in the basement of David King Hall and other CEOR computer labs. In summary, CESOR has an SGI Origin 200 (2 IP27 processors, 240GB internal disk), a Sun E220 (2 UltraSPARC-II processors, 70GB internal disk), and over 20 desktops and PC-based servers running either the Linux or Windows operating systems. On the software side, CESOR has site licenses for the widely used image processing/data analysis software ENVI/IDL. In addition, we have a site license for Feature Analyst, a feature extraction package by Visual Learning System, and 10 licenses of Satellite Tool Kit (STK), a package for tracking satellites by Analytical Graphics. CESOR also has ACORN for atmospheric correction, ERDAS, most GIS products from ESRI and Intergraph, and other data analysis software such as Matlab, Splus, and the Oracle DBMS.
For remote sensing data transmission, CEOSR also has an HRPT antenna for receiving AVHRR data and other space-borne data such as SeaWiFS and the Chinese FengYun series. In addition, an Analytical Spectral Devices, Inc. field portable, lightweight, 512-channel, photodiode array spectroradiometer covering the 350 – 1050 nm region is available at CEOSR. These facilities as well as data derived from them will be available to students and for instructional use.
Appendix I: Catalog Descriptions of Existing Courses

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.

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.

754 Earth Observing/Remote Sensing Data and Data Systems (3:3:0). 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.

757 Techniques and Algorithms in Earth Observing and Remote Sensing (3:3:0). 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.

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 756 Physical Principles of Remote Sensing (3:3:0). 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.

EOS 758 Digital Processing of Remote Sensing Imagery (3:3:0). 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.